Electronics World

JULY, 1965
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EXPERIMENTS IN SPACE
THE ART OF XEROGRAPHY

SPECIAL ISSUE: FIXED CAPACITORS

A ZIFF DAVIS PUBLICATION


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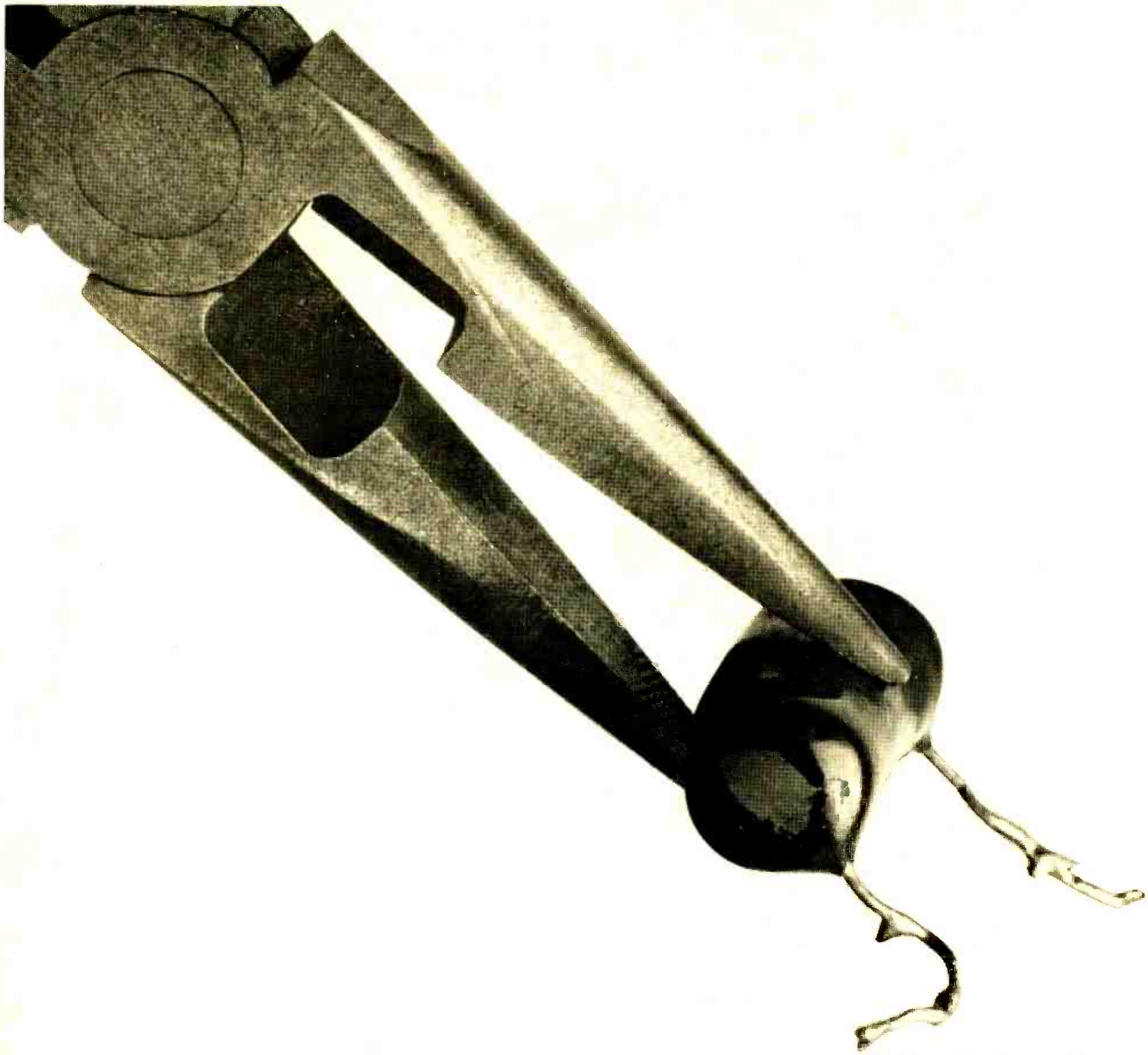

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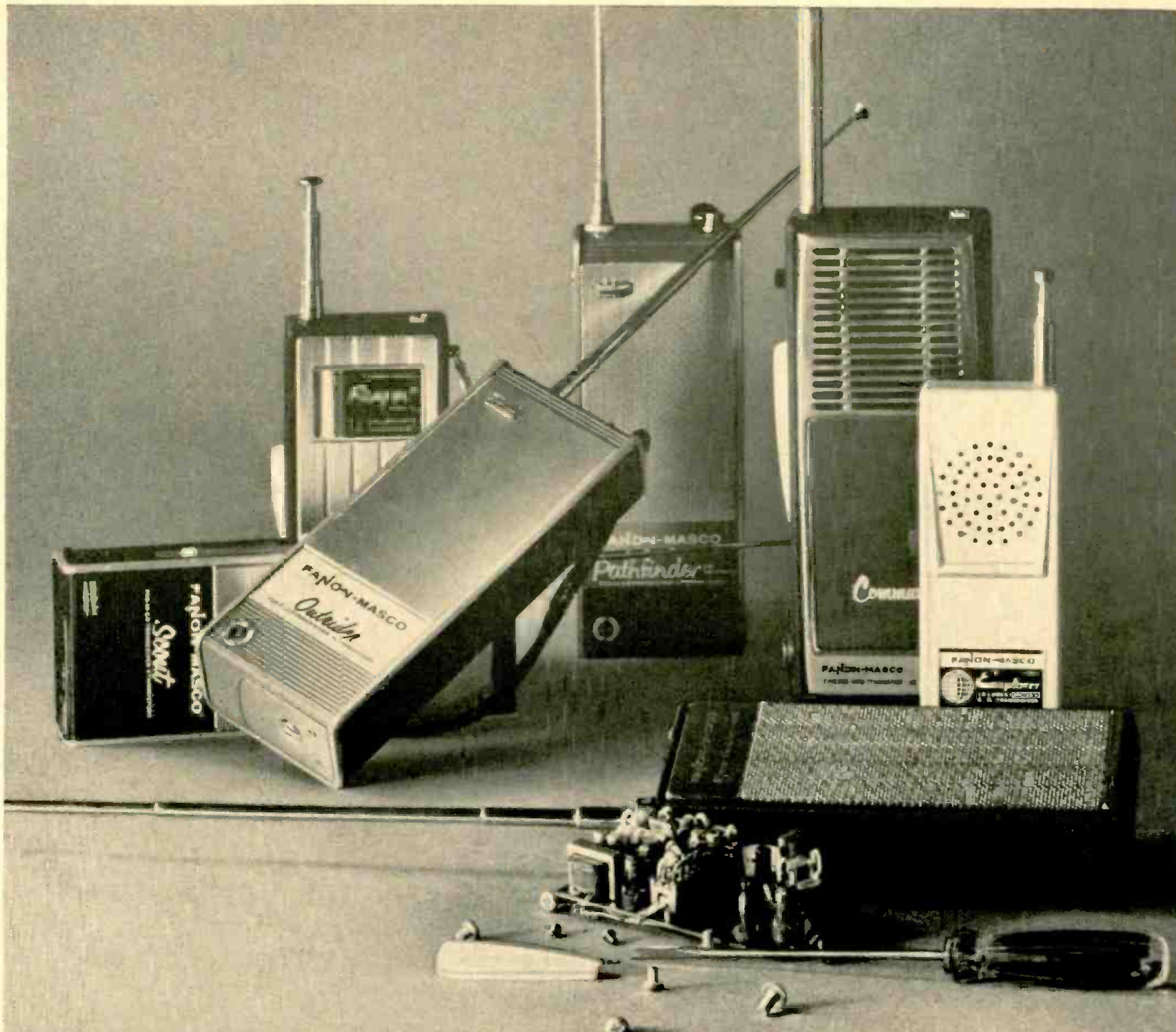

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Electronics World

CONTENTS

JULY 1965
VOL. 74, No. 1

THIS MONTH'S COVER illustrates some of the fixed capacitor styles presently available on the market. They range from a large electrolytic to a miniature plastic-potted unit. Three of these capacitors (the two red and the blue one) are specially designed for use with printed-circuit boards. The two electrolytics show the difference in size due to the development of newer dielectrics. The special articles on fixed capacitors in this issue describe the construction of the various classes of fixed capacitors and compares their electrical characteristics. The capacitors shown were supplied by Cornell-Dubilier and Sprague. ....(Photo: Bruce Pendleton, New York.)

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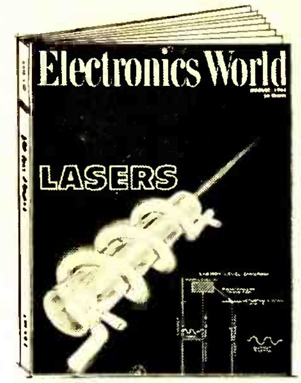

TELEVISION IN SPACE
Of the 35 TV cameras which have been hurled into space, some use slow-scan, some use digital techniques, and one uses a unique line-by-line scan from processed photographs. All of these are covered in this article.

MICROFILM AND ELECTRONICS
Widely used for record keeping, storage of documents and drawings, microfilm equipment is now employing electronic techniques for both creating and retrieving the desired information. How this is done is explained in this article by Daniel M. Costigan.

RADAR IMAGERY
New side-looking radars mounted in our military reconnaissance planes are providing near-photographic mapping coverage in clouds and darkness. J. L. Nelson of Motorola's Military Electronics Division describes the technique and provides some of the details on the equipment used.

LASERS
This is the first of a series of three articles designed to provide the reader with a clear and accurate understanding of laser operation. Warren Groner of Sperry Gyroscope's Electro-Optics Group discusses the operation of solid and gaseous lasers and the significance of such effects as coherence, population inversion, photon amplification, and stimulated emission.

RECEIVER NOISE
The sensitivity of a radio receiver is governed by the amount of internally generated noise. Joseph Tartas tells how this noise originates, how it is measured, and how it can be reduced.

SELECTING THE PROPER FUSE
Important factors to consider include physical size, amperage, voltage, type, ambient temperature, and special characteristics. Rules for proper fusing are included by Arthur J. Steele of Littelfuse, Inc. in a comprehensive treatment of this important component.

"LONG-HAND" PRINTED CIRCUITS
Whether you are designing a single prototype or a "master" for a production run, the simple technique described in this article should be a useful addition to your store of technical "know-how."

AMPLIFIER GAIN NOMOGRAM
An easy way to find power and voltage gain for amplifiers with equal input and output impedances.

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

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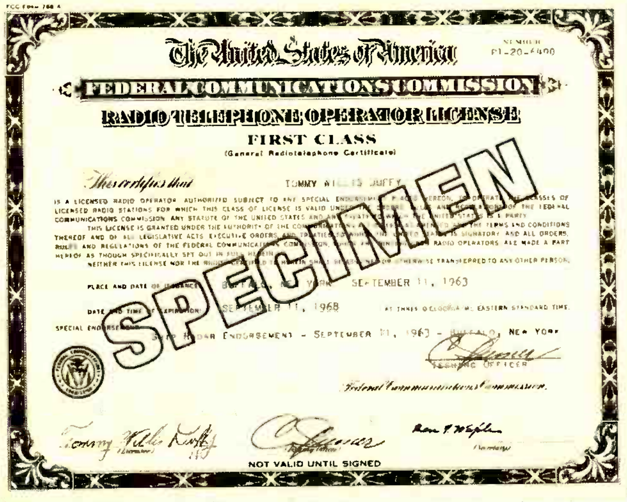

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Glenn Horning, Local Equipment Supervisor, Western Reserve Telephone Company.

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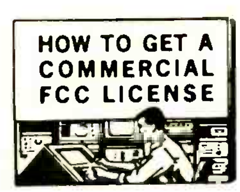

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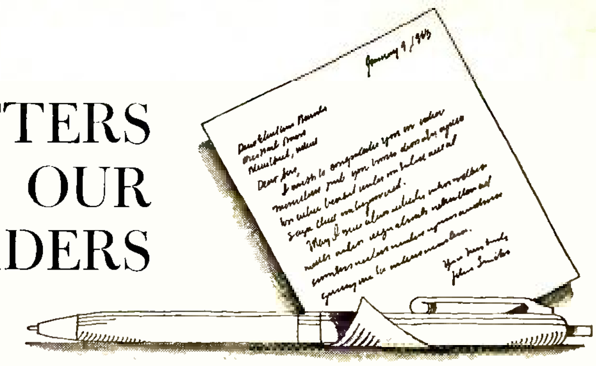

RECHARGING DRY CELLS

To the Editors:

I have always thought that zinc-carbon dry cells were primary cells whose chemical reaction could not be reversed. In other words, such cells should not be rechargeable. Yet I have seen advertisements for small, in-home battery chargers where a claim is made that such chargers will restore dry cells many times. Do these chargers really work?

MARC SMITH
Floral Park, N.Y.

Although the chemical reaction in a dry cell may not be reversible, such a cell can be recharged for a limited number of cycles under certain conditions. Even in a completely discharged cell, the active materials are far from being completely consumed. By passing a reverse current, during charging, through a cell, changes occur in the electrolyte and in the depolarizing agent used that give the cell additional life. Such cells cannot be completely restored, however, and every time they are recharged their useful life is reduced. We would recommend a charging current of about 30 ma. for an overnight recharge. (See p. 64 of our May issue.)

The National Bureau of Standards Letter Circular LC-965 lists the following conditions under which recharging may be done:

1. The operating voltage on discharge should not be below 1.0 volt per cell when battery is removed from service for charging.

2. The battery should be placed on charge very soon after removal from service.

3. The ampere-hours of recharge should be 120% to 180% of the discharge.

4. Charging rate should be low enough to distribute recharge over 12 to 16 hours.

5. Cells must be put into service soon after charging as the recharged cells have poor shelf life.—Editors.

* * *

SPECIAL RESISTOR ISSUE

To the Editors:

I am a military technical electronics instructor currently serving with the 307A Field Training Detachment at Shaw AFB, South Carolina.

I have been a subscriber to your fine magazine for over ten years and find it invaluable in keeping abreast of the many changes in our field. I often incorporate such information into my lesson plans.

The series of articles on fixed resistors in your April issue was marvelous and *will* be used as a reference attachment with my lesson plans.

May we look forward to similar articles on capacitors, including factors and problems relating to ceramics?

TSGT HAROLD L. STEPHENS
Shaw AFB, S. C.

To the Editors:

I have received the April issue of ELECTRONICS WORLD, and I would like to give you my handshake and hats off. It is one of your best issues.

I would like to see similar coverage on test instruments.

T. GRABOWSKI, Chicago, Ill.

We've received quite a few compliments on our special resistor issue. Every one of the articles has been reprinted by the manufacturers that prepared the stories for us. Also, we have been contacted by a number of technical institutes for permission to use this special section in their courses.

Readers Stephens and Grabowski will be interested in the similar coverage on capacitors that appears in this issue and in the coverage on test equipment that will appear shortly.—Editors.

* * *

200-WATT AMPLIFIER

To the Editors:

Many of the readers of our article "A 200-Watt Solid-State Stereo Amplifier" in the March issue are determined to try to construct the amplifier in spite of our recommendations to the contrary.

The driver transformer used has a turns ratio of 3:1 and is pentafilar wound. The novelty of our circuit lies not in this transformer but in the latching diodes being used to eliminate crossover distortion in conjunction with a low-output impedance driver circuit.

If a ready-made driver transformer is not available, this is how one can be wound. On a nylon bobbin with a ⅝" square hole, wind simultaneously five

(*Continued on page 12*)

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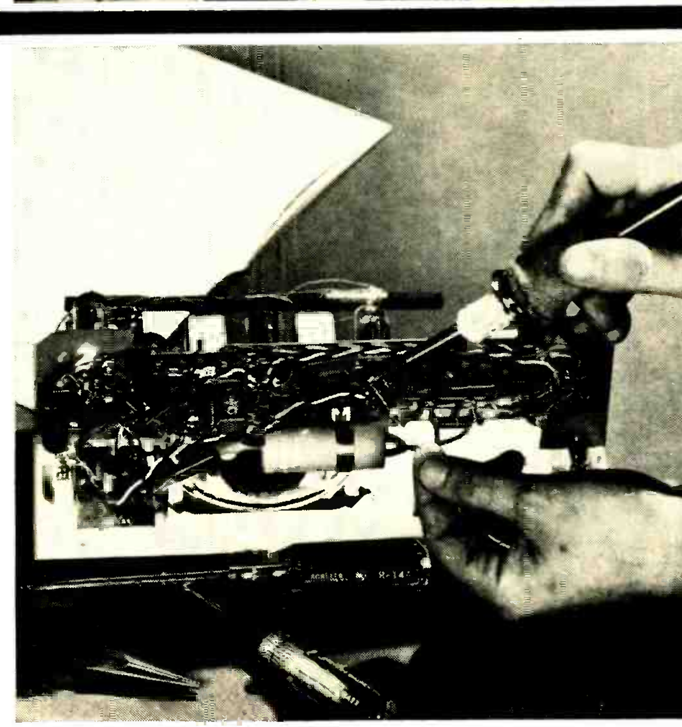

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(*Continued from page 6*)

wires, 26-gauge enamel. About 100 or 110 turns would do. Join three of the windings in series and call it the primary. The other two windings will be the secondaries. Use 50-mil grain-oriented steel EX1 cores for a ⅝" lamination stack.

Since this amplifier is a high-powered one and a lot of feedback has been used in order to linearize it, ground loops are very critical. This is one of the primary reasons why we do not recommend home construction. If readers are willing to spend time in order to eliminate ground loops by trial and error, they may be able to build this amplifier.

Many different modifications are possible. This amplifier works without the latching diodes, but the output is low and a resistor has to be inserted in series with the driver transformer.

MADAN SHARMA
Mattes Electronics, Inc.
4937 W. Fullerton Ave.
Chicago, Ill. 60639

° ° °

ELECTRONICS INDUSTRY REPORT

To the Editors:

This is in reference to the article "A Special Report on the Electronics Industry: Products, People, and Prospects" which appeared in your April issue. In the first paragraph under the subtitle "New York Area" (p. 82), you have attributed certain statements to me and have indicated that you were not aware of my sources.

Enclosed you will find a copy of my recent article entitled "Engineering Unemployment—Whose Responsibility?" If you would read through this article and the bibliography at the end, I am sure that you will obtain complete information as to my sources.

R. P. LOOMBA
Assoc. Prof., Elec. Eng.
San Jose State College
San Jose, Calif.

Thanks to Prof. Loomba for sending us a copy of his article along with the 18-item bibliography. His sources include published articles and books, government reports, speeches, and his own survey.—Editors.

° ° °

PRECISION RESISTANCE BRIDGE

To the Editors:

In the April, 1965 issue of your magazine on page 46 there is an article on "Precision Wirewound Resistors." In this article you state that one resistance bridge, *General Radio* Model 6003, measures in the microvolt region. This instrument should be referred to as the *General Resistance* Model 6003 bridge.

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The old familiar twin-lead antenna line, that worked pretty well for black-and-white TV, is hopelessly inadequate for color reception. When your pictures smear, ghost, or change color, it's usually because the signal is being garbled between the antenna and your TV set.

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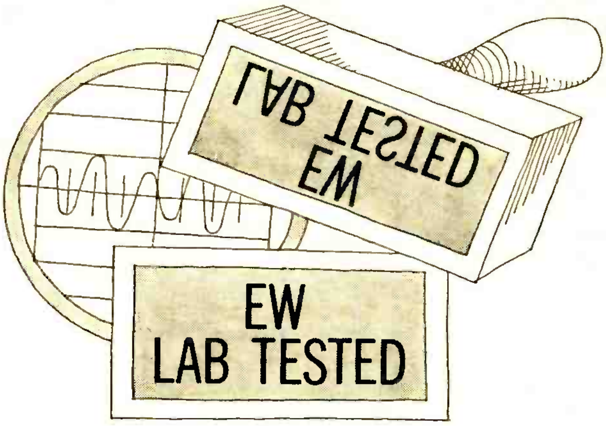


HI-FI PRODUCT REPORT

TESTED BY HIRSCH-HOUCK LABS

KLH Model 16 Stereo Amplifier
Garrard Lab 80 Automatic Turntable

KLH Model 16 Stereo Amplifier

For copy of manufacturer's brochure, circle No. 32 on Reader Service Card.

THE *KLH* Model 16 is a compact, solid-state integrated stereo amplifier, rated at 70 watts r.m.s. total output. Although it is one of the most powerful integrated amplifiers on the market, it measures only 11¾" wide, 10½" deep, and 4½" high. It is simply, yet attractively, styled, with aluminum knobs on a satin-finished aluminum panel.

The amplifier has inputs for magnetic phono cartridge, tuner, and two other high-level sources. A three-position slide switch on the rear of the amplifier adjusts the sensitivity of one "Aux." input in order to obtain the most effective use of the loudness compensation. The tuner level must be adjusted at the tuner. A two-position slide switch similarly adjusts the sensitivity of the phono input.

There is no input for a magnetic tape playback head, but inputs and outputs are provided for connection to the amplifiers of a tape recorder. A slide switch on the front panel replaces the normal program with the output of the tape playback amplifier for monitoring while recording, or simply for listening to recorded tapes.

Other front-panel knob-operated controls include volume, balance, and bass and treble tone controls. The latter operate simultaneously on both channels. A row of slide switches control loudness compensation ("Off," plus two degrees of compensation), stereo/mono, high-frequency filter, power, and speakers on/off. A front-panel stereo headphone jack allows private listening with the speakers switched off.

The semiconductor complement includes 24 transistors and 8 diodes. Each channel has four output transistors of the germanium drift-field type.

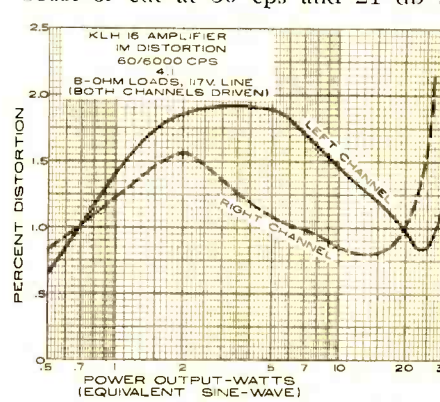
KLH rates the Model 16 at 70 watts, +0, −1 db from 25 to 20,000 cps, with both channels driven simultaneously into 8-ohm loads. The total music power output is over 100 watts. Into 16-ohm loads, the output is reduced by about 2 db, or 37%. The output circuits are electronically protected against short-circuit or open-circuit damage. The worst result of overdriving the amplifier, even into a short circuit, is to blow the line fuse.

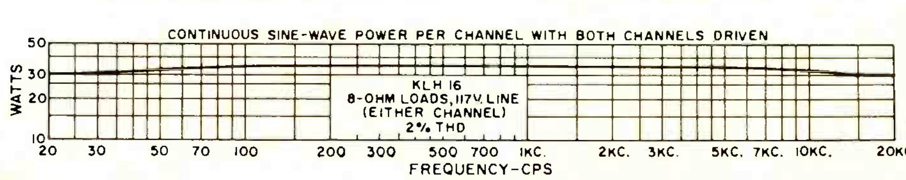
A warning notice attached to the amplifier cautions against connecting the negative speaker output terminals to each other, or to ground. Similarly, neither phono jack sleeve may be grounded, or connected to a negative speaker lead. These precautions are necessary to keep the two channels isolated. The unit is guaranteed (parts and labor) for two years against failure in normal usage.

The basic frequency response was measured at ±0.5 db from 20 to 20,000 cps. The high-cut filter was unusually mild, having an appreciable effect only at frequencies above 10,000 cps. It is useful in reducing background hiss in stereo broadcasts, but will not quiet old or noisy records. The RIAA phono equalization was within ±1 db from 80 to 15,000 cps, falling at lower frequencies to −5.5 db at 30 cps. The loudness compensation, which affects only the low frequencies, is very pleasing, causing no boominess or tubby sound, yet adding body to low-level programs.

The measured IM distortion was about 0.75% at low levels, and was between 1% and 2% for power outputs between 0.7 watt and 20 watts. It was not possible to measure IM distortion at over 35 watts because the fuse blew before readings could be made. The amplifier would readily handle short-term music peaks at higher power output levels. The output at 2% total harmonic distortion was 35 watts per channel over a wide range of middle frequencies. Power output fell slightly to 29.3 watts at 20 cps and to 30.7 watts at 20,000 cps. At 0.5% distortion, the mid-range power output was about 25 watts per channel.

The tone controls had an unusually wide range, providing about 19 db of boost or cut at 50 cps and 21 db at





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10,000 cps. Although there is not a distinct "flat" position of the controls, setting the knobs to the indicated dot produced a very flat response.

The hum and noise were very low, measuring about −70 db on high-level inputs and −58 on phono inputs, referred to 10 watts output. This appeared to be all hiss (and very little of that); no hum whatever could be heard.

We tried shorting the amplifier outputs with high-level driving signals, with no effect on its performance. We were careful not to ground the critical points mentioned earlier. There were absolutely no audible transients when switching inputs. This is an important consideration with a powerful amplifier, to avoid damaging speakers, and most amplifiers have such switching transients to some degree.

The sound of the *KLH* 16 was all that it should have been—very clean, smooth, uncolored, and with the solidity which bespeaks a tremendous power reserve. It is capable of driving almost any speaker system, and can do justice to the finest music system. The installation instructions caution against installing the amplifier in an unventilated location, and a noticeable amount of heat can be felt on the cover above the power-supply section. Of course, it runs much cooler than any tube amplifier, even one of much lower power rating.

The *KLH* 16 sells for $249.95. A walnut cabinet is available for $19.95. ▲

Garrard Lab 80 Automatic Turntable

For copy of manufacturer's brochure, circle No. 33 on Reader Service Card.

The name "automatic turntable" was coined by *Garrard* several years ago when they introduced the Model "A." Although never precisely defined, an automatic turntable is generally considered to be a high-quality record player, with sufficiently low rumble, wow, and flutter to qualify for the most exacting home high-fidelity applications, yet with the facility for automatic record changing.

The new *Garrard* Lab 80 is another step in the development of the automatic turntable. To the eye, it looks like a high-quality turntable with a separate, full-sized wooden tonearm. Unlike other automatic turntables and record changers, it is a two-speed machine (33⅓ and 45 rpm). This is a clear indication that it is designed for playing modern records, either stereo or mono.

The unit has a heavy, full-sized, 12-inch aluminum platter, driven on its inner rim by a four-pole induction motor through a stepped shaft and rubber idler wheel. One of the four control levers at the right front of the motor board changes the speed. The others control manual or automatic operation and record indexing for 7-, 10-, or 12-inch records. A short spindle is inserted in the turntable center hole for manual playing. Another longer spindle is used for automatic operation. All changing functions are contained within the spindle, which supports the records on three fingers.

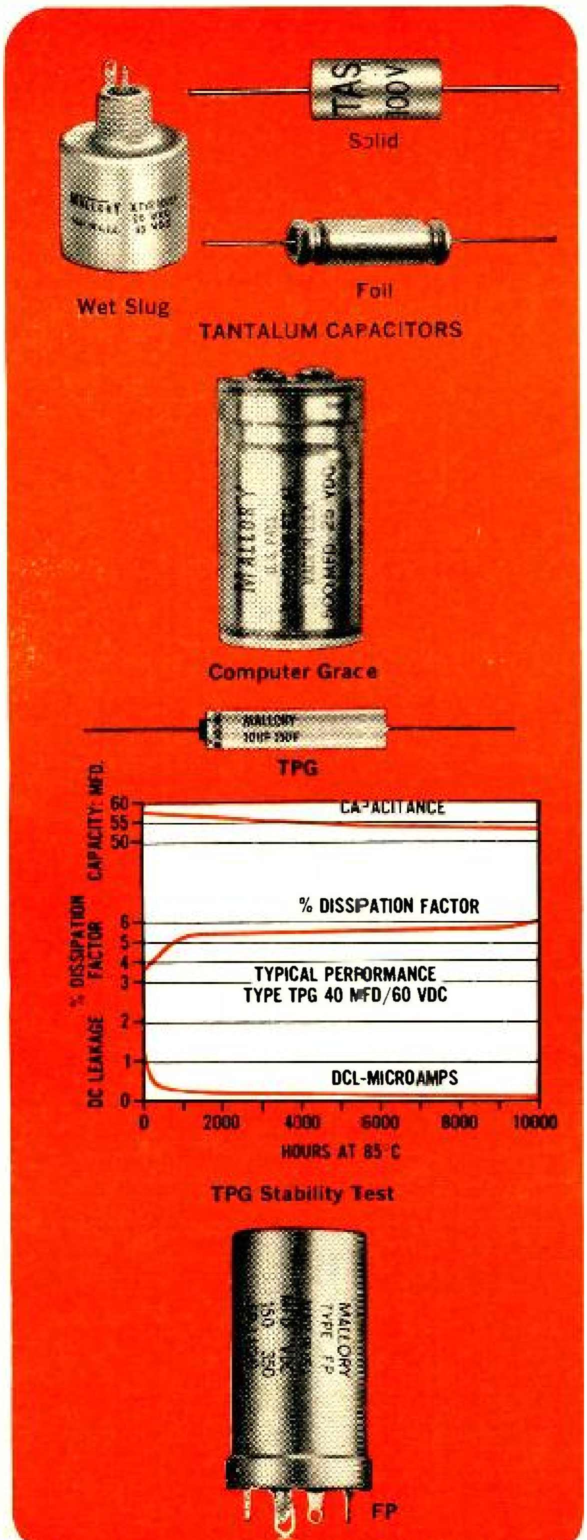
The arm of the player is made of an attractive wood, resembling teak. This material minimizes arm resonances, which can occur in tubular or hollow metal arms. The plug-in cartridge shell is a lightweight plastic type, cut away to reveal most of the cartridge. In addition to reducing arm mass, this simplifies cueing, since the stylus is visible on many types of cartridges when mounted in the arm. An adjustable counterweight balances the arm, after which a spring applies the desired tracking force. A scale on the side of the arm is calibrated from 0 to 5 grams. The adjusting screw under the arm has click stops, with each click corresponding to a change of ¼ gram in tracking force.

An unusual, and very effective, feature is the bias compensator. Inherent in any tonearm with an offset head (and all arms have offset heads to minimize tracking error) is a frictional drag which tends to move the arm toward the center of the turntable. The stylus thus exerts less force on the outer groove wall than on the inner wall. Since the effective tracking force is less for one channel than for the other, the channel having the lower force will tend to distort at high recorded velocities. The Lab 80 has an adjustable weight which acts through a lever arm to press the arm outward. When set correctly, it equalizes the tracking force for the two channels and minimizes distortion on the other groove program.

The arm of the unit may be lifted from the record at any point by pressing the "Manual" lever. It is raised automatically and smoothly and remains at that point until the dropping lever on the arm-rest housing is pressed. It then lowers slowly and gently to the point from which it was raised, and playing continues. The bias compensator may tend to move the stylus outward by one or two grooves as it is lowered but the effect is slight. At the end of a record, whether it is played manually or auto-

MALLORY — Tips for Technicians

About reliability in electrolytic capacitors



Reliability has become a big, important word in electronics today. Makers of military equipment demand it—and get it—because today's intricate weapons and warning systems can't risk failure of even the smallest component. But a lot of other electronic manufacturers are setting requirements for reliability that often come close to the military.

When it comes to electrolytic capacitors, you can have just about any level of reliability you want—and are willing to pay for. Highest reliability usually means highest price, because it takes a lot of costly testing to verify reliability. We make 'em all, so we can be unbiased.

The highest reliability comes in tantalum capacitors—wet slug, foil and solid electrolyte. The best of these have a "mean time between failure" in the tens of thousands of hours. Or putting it another way, their failure rate level is around 0.01% per 1000 hours. Although they are used mostly in military gear, tantalum capacitors have become increasingly popular for industrial circuits where you need maximum assurance against failure. And they give you an unbeatably high amount of capacity in small size.

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matically, the arm returns to its rest and the turntable shuts off. The trip mechanism is unique in having no direct mechanical contact between the arm striker and the trip. The repulsive force between two magnets operates the trip when the pickup reaches a radius of 2⅞ inches from the record center. This virtually eliminates any side thrust on the arm near the end of the record, and allows automatic operation with cartridges tracking at less than 1 gram.

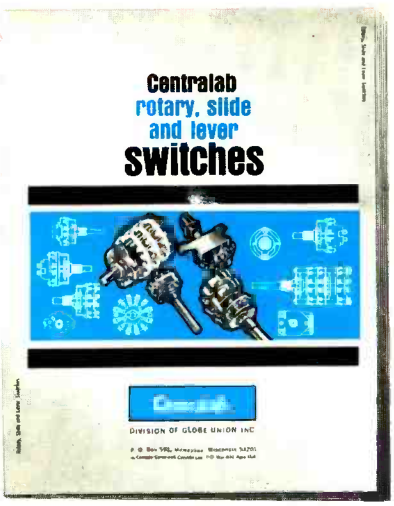
We measured the rumble of the turntable as -32 db, including the vertical and lateral components, and -39 db in the lateral plane only. These figures are in terms of the NAB standards for turntable rumble measurement. This rumble is very low indeed, being better than most manual turntables. The lowest rumble was measured with the turntable clamped down on its board as for shipment. With it floating free on its springs, the rumble was about 5 db higher, although still low enough to be completely inaudible.

The wow and flutter were negligible, 0.8% and 0.05% at 33⅓ rpm and 0.06% and 0.03% at 45 rpm. The operating speeds were about 1% fast, and did not vary with line voltage variations of 90 to 135 volts.

The arm had a tracking error of less than 0.5 degree per inch of record radius, which is typical of a well-designed arm. These figures might vary somewhat with different cartridges, due to a lack of standardization in the distance from the stylus to the mounting holes. There is no provision for sliding the cartridge in the head to minimize tracking error. However, as stated previously, the tracking error is negligible. The stylus force indication was very accurate and no external gage is needed. The bias compensator worked well, producing a visible reduction in high-level signals, as viewed on an oscilloscope.

Although the turntable will handle stacks of up to 8 records, the change in angle of the arm from bottom to top of the stack may cause some cartridges to strike the record surface on the seventh or eighth record. This should be checked before selecting a cartridge if automatic operation is contemplated. If a bulky cartridge is selected the unit will still stack 6 records, which is over 2 hours of continuous play. The stylus force remains essentially constant over the entire stack of records.

Operation was very smooth and free from clicks and other noises which plague most automatic record changers. In addition to being one of the most attractive record players we have seen, it meets the highest performance standards for home high-fidelity equipment. The Lab 80 sells for $99.50, and an attractive walnut base is available for $6.50. ▲



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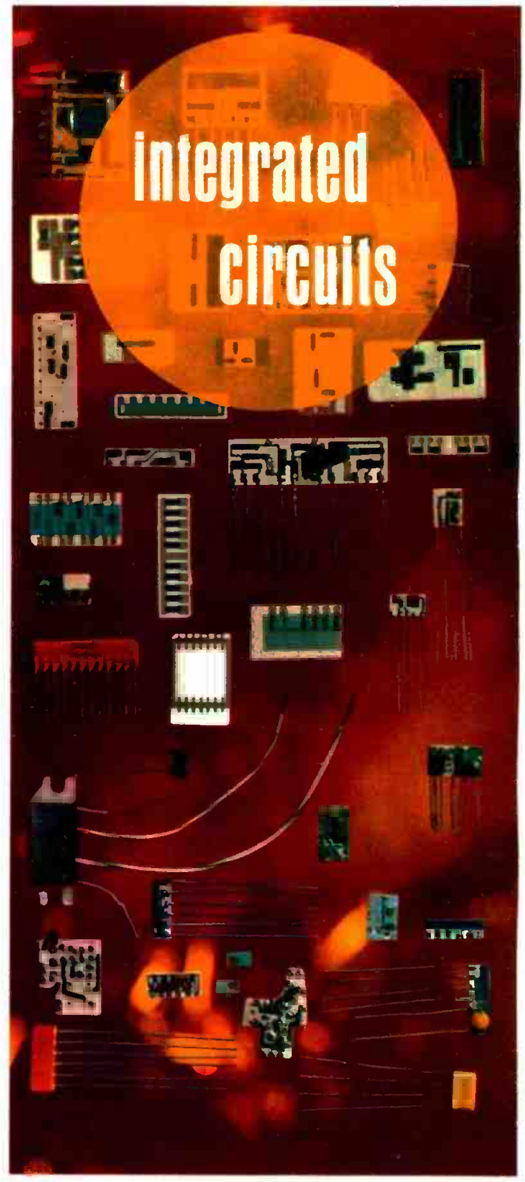

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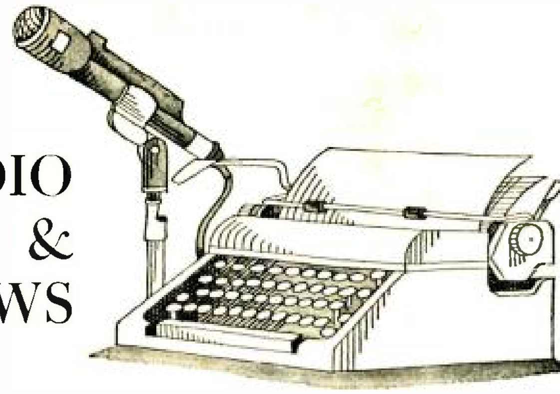
RADIO & TV NEWS



THE prospect of considerably reducing servicing problems on major electrical appliances has been improved as electrical manufacturers turn their attention to the use of relatively trouble-free, solid-state devices to replace or to work in conjunction with conventional functional controls.

The growing semiconductor family for appliance applications was introduced at the annual meeting of the Consumer Products Division of the National Electrical Manufacturers Association by the Association's Power Semiconductor Component section.

The members of the semiconductor family of most interest were the switching types, such as power transistors and SCR's. Other semiconductor devices capable of detecting humidity, temperature, variations of light, weight, and strain were also under consideration.

While suited for variable torque loads such as furnace blowers, pumps, and air-conditioner fans, a system combining solid-state and conventional motor-control principles can also work successfully with more difficult loads such as the home laundry. Not only can speeds be made infinitely variable, but the system can be automatically controlled from a very low-level electrical signal. Thus, if it were desired that an electrical clothes dryer automatically vary speed with a combination of inputs such as water content, weight of load, temperature or other parameters, each could be sensed by an appropriate sensor and integrated into a decision regarding the proper speed for drying.

Inexpensive remote controls are getting wide attention after their success in the TV market. For house-wide control, carrier-current principles are most likely, using signals superimposed on the house wiring for such functions as remote-control thermostats, control of various major appliances, or notification of the housewife in any part of the house of the cooking progress of the roast.

Solid-state sensing and control devices such as the thermistor, cadmium-sulphide photocell, humidity sensor, and the silicon strain gage, plus the appropriate amplifier, now offer the design engineer a flexibility not previously attainable within the electromechanical arts.

RBI Flip-Flop

Well, it had to happen sooner or later. The *Columbia Broadcasting System* has now added a digital computer to its baseball broadcasting staff to calculate "pressure factor" on a batter.

As the game gets under way, the computer is made aware of the situation on the field and calculates, from an estimated 52,800 possible situations based on the present score, inning, bases occupied, and the number of outs, the pressure factor facing the next batter.

There is a different pressure factor for each situation. If a batter comes up in the seventh inning with the score tied, no one on base and two outs, the pressure factor is 34%. If he were to single, the pressure factor on the next batter would rise to 52%. If this batter were to walk putting men on both first and second base, the pressure factor on the next batter would be 72%. With a bases-loaded, no-outs situation in the late innings, a batter would face a 100% pressure factor. Should that man clear the bases with a home run, the next batter would face only a 6% pressure factor due to the fact that his team is four runs ahead.

Although the computer hasn't had a base hit yet, we understand that part of the ASCII code it sent back to the ballpark read: 1000111 1001111 1000111 1001111 1001101 1000101 1010100 1010011. (See July, 1964, page 28.)

Police Computer

Speaking of computers, the one used by the city of Flint, Michigan to handle that city's payroll, income tax, property tax, water billing, and voter registration is now being adapted so that the city's Police Dept. can query the computer to discover if any particular suspicious person has a previous record or is currently wanted for investigation. Such information can help the arresting officer decide whether or not the person should be brought in for further questioning or for booking, thus saving the Police Dept. time, inconvenience, and possible legal entanglements due to unwarranted arrests. ▲

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Fallacy: *"Doesn't Perform As Well As Factory-Built Models".*

FACT: The first Heathkit design consideration is performance. Our special staff of kit engineers use the latest, most sophisticated techniques in the "state of the art". And much effort is devoted to developing new design. For example, Heath introduced the first successful all-transistor stereo components. Only after rigid performance tests are passed, does kit assembly enter the picture. But don't take our word for it. Compare the specifications . . . read the Heathkit reviews by respected authors and editors . . . or ask any Heathkit owner!

Fallacy: *"Kits Use Inferior Parts".*

FACT: Heath's reputation for top quality has always been respected by kit builders and non-kitbuliders alike. In fact, we're noted for our conservative ratings. Actually our engineers "over-specify" parts to insure that extra margin for best performance and long, dependable life. As you build your kit, you'll recognize famous names like GE, Sylvania, RCA, Weston, Tung-Sol, etc., on the parts you use.

Fallacy: *"Because Of Its Low Price, It Just Can't Be As Good".*

FACT: Because you build it yourself, you save the labor cost of factory-built models. Even more significant, buying direct from the Heath factory eliminates high dealer markups. With Heath, your money goes where it should . . . in parts quality, not product distribution.

Fallacy: *"Takes Special Test Gear To Align It".*

FACT: A prerequisite to every Heathkit design is that they meet specifications after assembly *without* instrument alignment. All critical circuits are completely wired and prealigned at the Heath factory. All other alignment steps are accomplished with the simple "Alignment Without Instruments" instructions in each Heathkit manual.

Fallacy: *"If Something Goes Wrong, I Can't Get It Repaired".*

FACT: The Heath Company's most vital concern is your satisfaction, and every effort is made towards this end. If you do encounter problems, first check the "In Case Of Difficulty" section, and "Trouble-Shooting" chart in each manual. Because of the intimate knowledge gained through kit assembly, most kit builders make repairs themselves, thus saving service charges. Heath also maintains a staff of consultants to help & advise you . . . just drop them a note. And you can always take advantage of factory service facilities, as well as local authorized Heathkit service centers.

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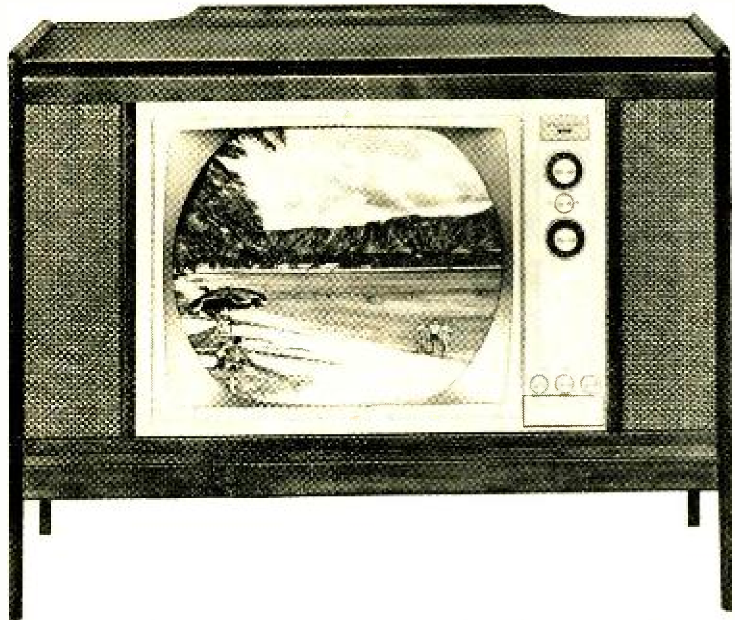

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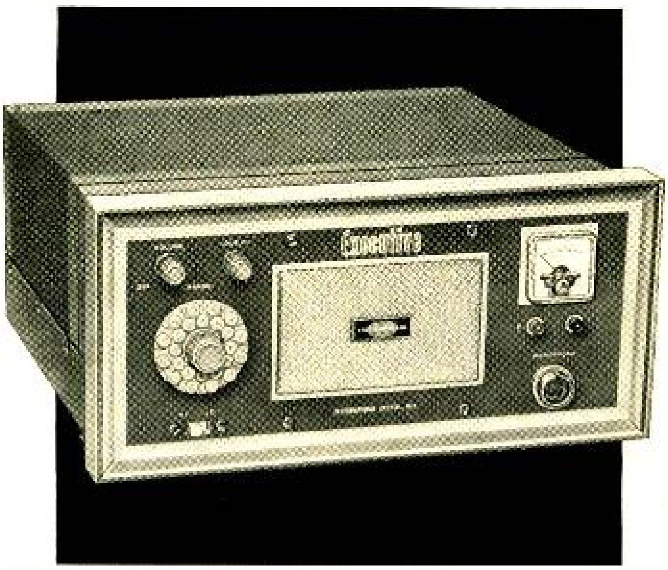

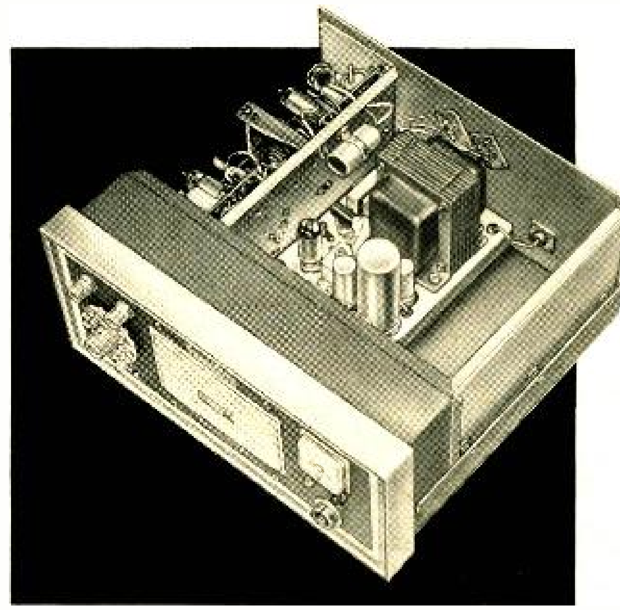

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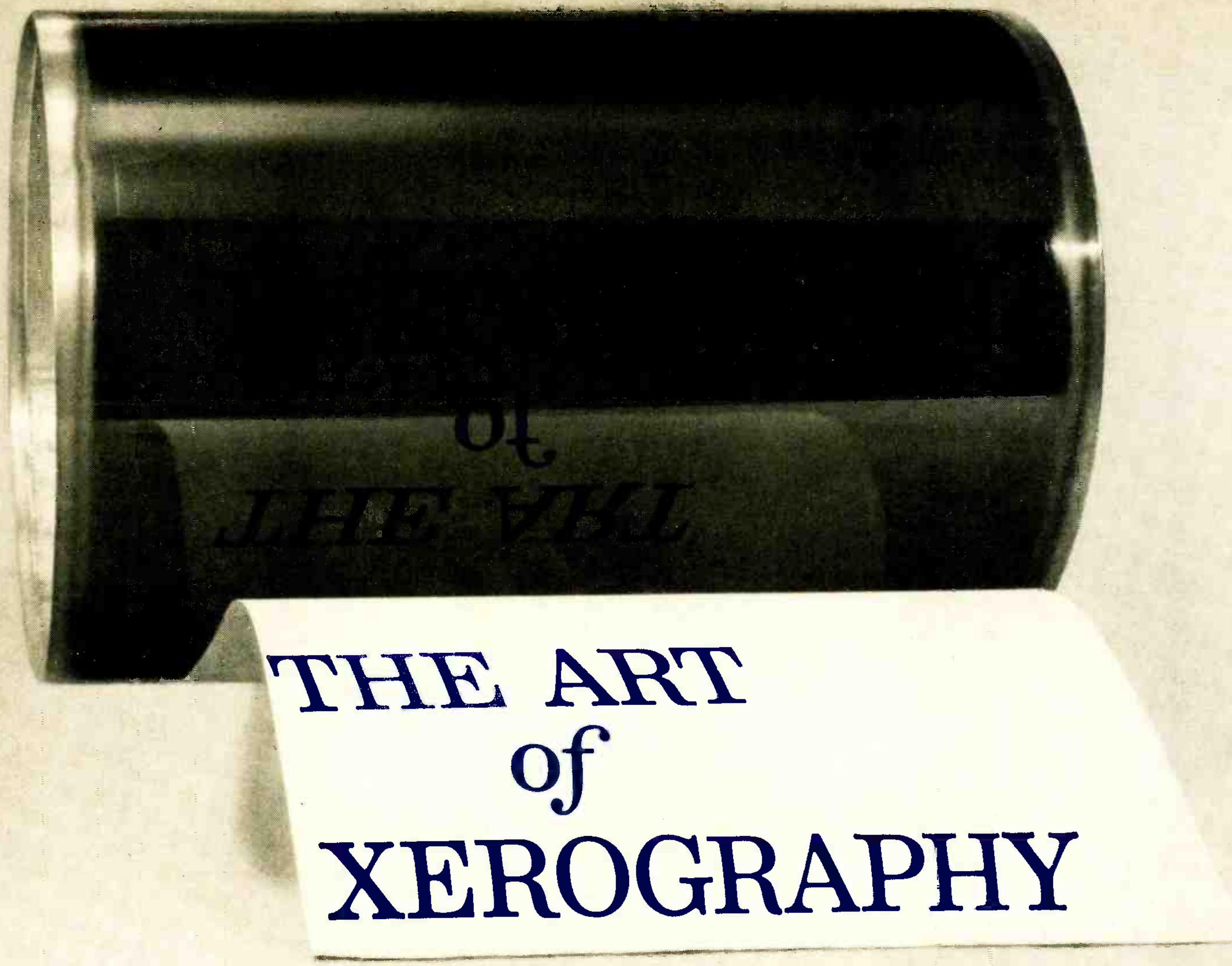


THE ART of XEROGRAPHY

Xerography, the laboratory curiosity reported by Electronics World (then Radio News) in 1944, has been instrumental in creating a giant new industry with sales in the hundreds of millions of dollars. The primary growth has been in office copiers, but xerographic principles and processes are finding new and broader electronic applications. This article up-dates the original.

By CHRISTOPHER M. CELENT / Research & Engineering, Xerox Corporation

ON October 22, 1938, a young physicist and patent attorney, Chester F. Carlson, wrote "10,-22,-38 Astoria" on a piece of glass. Then, working in a darkened room with another physicist as a laboratory assistant, they rubbed a sulfur-coated metal plate with a handkerchief and quickly exposed the plate to light transmitted through the glass. Next, they sprinkled the plate with dyed lycopodium powder, blew lightly over it, and pressed a sheet of waxed paper to the paper surface. When the paper was pulled free of the plate, the date and location were reproduced, and xerography (Carlson called it "electrophotography") was born.

Carlson patented his invention and then set out to find some company to refine and develop it. He knocked on the doors of some 20 to 30 companies without success. But he persisted, and in 1944 succeeded in interesting scientists at Battelle Memorial Institute. Battelle, a research organization located in Columbus, Ohio, agreed to study the process.

In July, 1944, Radio News magazine (now Electronics World) heard about the invention and published a technical analysis. A year later, Dr. John H. Dessauer, the research director of a small company in Rochester, N.Y., read an abstract of the article, then obtained and read the original article. Intrigued, he arranged for the president of his company, Joseph C. Wilson, to visit Battelle.

Photomicrograph of xerographic image being formed. The large positively charged carrier beads transport negatively charged toner particles to the positively charged selenium-coated plate. The carrier beads are 100-200 times larger than toner particles. (The dry developer powder is a special formulation of small glass or sand carrier beads plus particles of black heat-fusible carbon.)

Wilson was the president of *The Haloid Company*, then a small, moderately successful sensitizer of photographic and photocopy paper and manufacturer of photocopying machines. Wilson saw promise in the new idea and sponsored further research both at Battelle and within his own company. In 1947, *Haloid* obtained partial rights to the process and launched an intensive development program.

Thus the seeds of invention were sown, germinated, and nurtured. They were to bloom in little more than a decade into a revolution in business office practices and to catapult the little *Haloid Company*—renamed *Haloid-Xerox*, later *Xerox Corporation*—into the ranks of the five hundred largest corporations in the United States.

Why Xerography?

Chester Carlson's invention of xerography was no sudden flash of genius nor was it an accidental discovery. When he "discovered" it he was seeking the solution to a specific problem. Mr. Carlson in 1935 was working in the patent department of *P. R. Mallory and Company* (and going to law school at night) and never seemed to have enough carbon copies of patent specifications.

He could have found a copying machine in 1935, of course. There were, for example, the Rectigraph machine (made, incidentally, by *Haloid*), blue-printing machines, machines using the photographic processes, and others. But there were serious deficiencies in the copies made by these machines and in the way these copies were produced.

The time it took to get a copy is a good example of the problems he faced. It took about 30 minutes for each copy made and the machines of that day were so complicated that it took special training to operate them as well as special locations for the machines.

The process most likely involved handling "messy" chemicals which gave off offensive odors. Other objections were that the copy was often faint, hard-to-read, and not very permanent, or printed on hard-to-handle or flimsy paper. Other machines required specially prepared masters.

There were other reasons why copy was unsatisfactory. For example, some machines would not copy certain colors. When the ball-point pen came into general use, it was discovered that many of the machines would not copy it. Or, the copy came out as white-on-black, white-on-blue, or in some other-than-usual color combination. Then, too, only single sheets could be copied—often at some risk that the original would be destroyed.

It is interesting to note that some of these faults were not really objectionable back in 1935. As a matter of fact, most people then would have been satisfied with almost any kinds of copies that would last, were legible, and could be made quickly and cheaply. But the requirements of the customer became refined and he demanded better copiers.

How Does It Work?

Xerography is an electrostatic copying process. It makes use of the basic principle of static electricity; objects having opposite electrical charges (positive and negative) attract and objects having the same charge (both positive or negative) repel.

There are two commonly used xerographic copying techniques employing electrostatic principles. One technique uses a re-usable plate or drum coated with a photoconductor, usually selenium. The second technique uses paper specially coated with a photoconductor such as a zinc oxide mixture. Such precoated papers are not re-usable.

Laboratory test method to determine charge of individual toner particles in xerographic developer. Powdered developer is placed in particle generator at bottom. A loudspeaker vibrates the mix, randomly freeing charged particles. Some of the particles are eventually drawn in a flow system through a capillary and a drift-tube detector. The detector picks up a voltage proportional to the particle charge. This voltage, indicating charge and velocity, is amplified and displayed on oscilloscope.

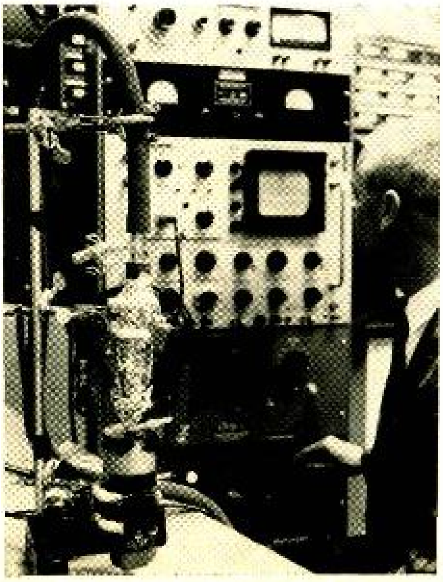
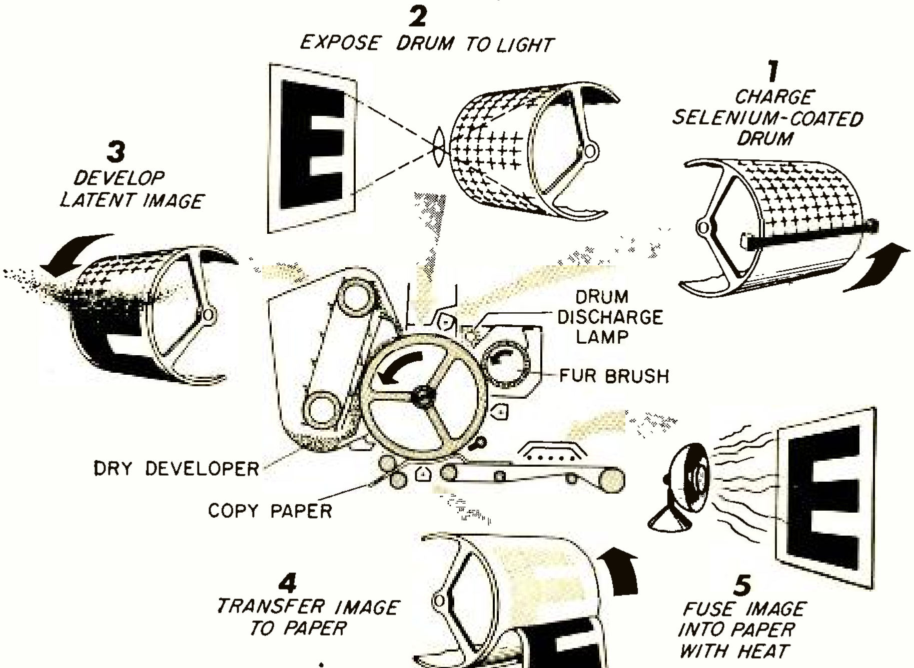


Fig. 1. The five basic steps in the xerographic process are illustrated here.



Each of these xerographic techniques has been used successfully in document-copying machines. Systems based on re-usable drums employ the "transfer electrostatic process." The precoated paper systems use the "direct electrostatic process." References to xerography in the remainder of this article pertain mainly to the "transfer electrostatic process."

The heart of the selenium-based systems is an aluminum plate, or substrate, coated with a thin film of amorphous selenium. In automatic systems, the plate is in the shape of a cylinder, or drum. The extremely thin layer of selenium is a photoconductor, that is, its electrical conductivity changes

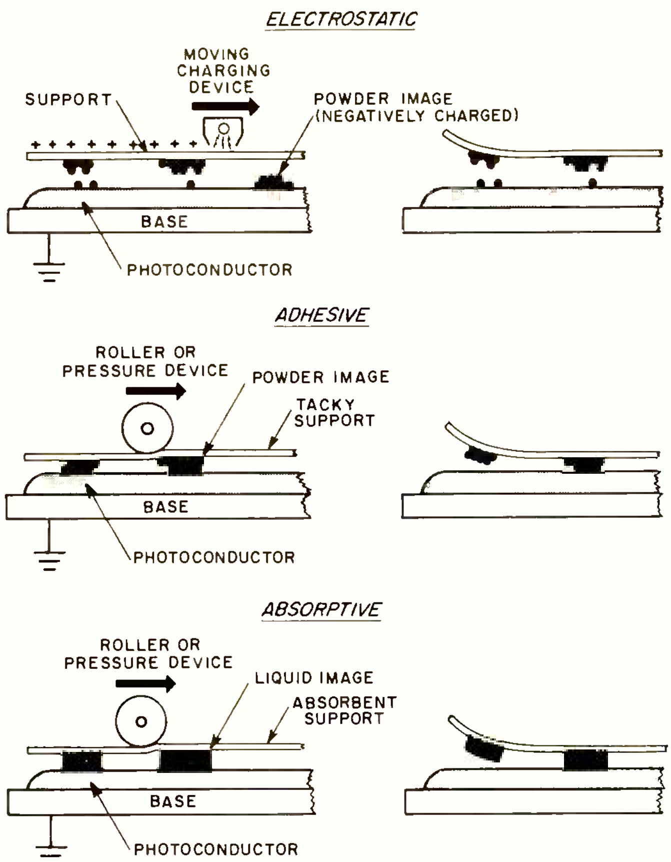


Fig. 2. Image-transfer techniques. For electrostatic transfer, the paper is given a charge opposite in polarity to that of the toner which makes the image on the photoconductor. The image is thus attracted or transferred to the copy paper. In the adhesive method, the paper to which the image is to be transferred is coated with a sticky substance to which the toner adheres. In the absorptive technique, the image on the photoconductor is liquid and when contacted by the paper, the liquid will then be absorbed directly into the copy paper.

when it is subjected to light. The glass-like selenium layer also accepts an electrostatic charge. If kept in darkness, the layer retains that charge long enough to be put to use. However, if exposed to light, the charge dissipates (leaks through the selenium layer to the aluminum substrate) quite rapidly. If only a portion of the selenium is exposed to light, the charge dissipates only in that area and the unexposed part retains the charge, in other words, the amount of lateral dispersion of the charge is entirely insignificant.

The Five Basic Steps

There are five basic steps in the xerographic process. The plates are *charged*, *exposed*, and *developed*. At the end of the developing step there is a powder image on the plate. This image is then *transferred* to paper and *fused*. As a final measure the plate is cleaned. Let us examine each step in turn (Fig. 1).

The selenium is *charged* by passing a wire held at high potential over its surface. If the surface is a drum, as in automatic machines, the cylinder is rotated under the wire.

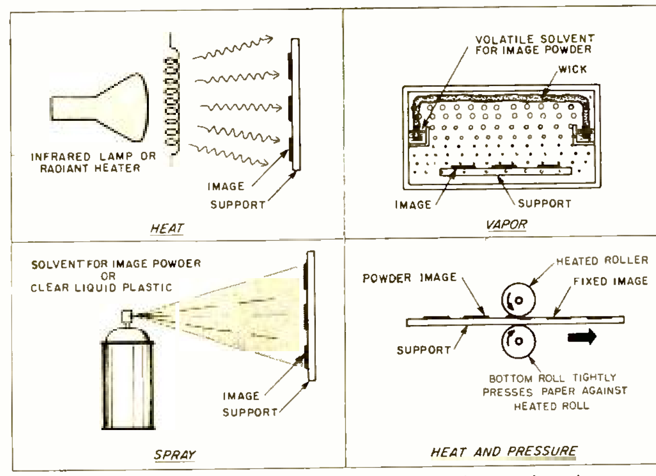


Fig. 3. The various techniques that may be employed to fix the image onto the copy paper. Refer to the text.

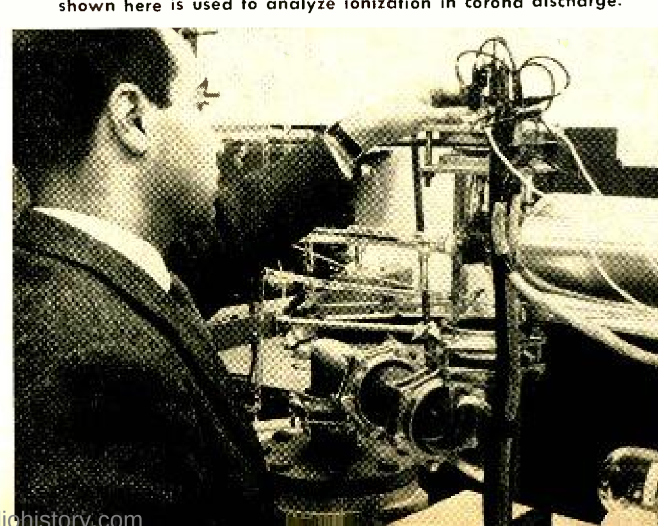
The electrical potential on the wire is held high enough so that a corona (glow discharge) is produced and maintained. The plate is literally sprayed with positive or negative ions —the choice of charge depends on the type of document (a negative or a positive) to be copied. In advanced xerographic machines, a system of wires and grids is used to insure that the surface of the selenium receives a uniform charge. Charging must be carried out in darkness.

In the second step, *exposing*, the image to be copied is projected optically to the sensitized plate. When light from the image strikes the sensitized selenium surface, it affects the uniformly distributed charge. Suppose, for example, the original is an ordinary business letter. Those areas of the charged surface which are struck by light rays reflected from the white areas of the document lose most or all of their electrical charge. Light is not reflected from the black areas (the type on the letter) so those areas of the selenium retain their charge. The result is a pattern of electrical charges on the selenium plate which corresponds exactly to the image being exposed. This pattern is called the "latent electrostatic image." A strong electrostatic field is established between the charged and uncharged areas of the selenium plate.

The third step in the process is to *develop* the electrostatic image. This is done by pouring (cascading) a developer over the plate surface. The developer is a granular material made up of two components: small glass or sand beads called "carrier" and a black powder called "toner." It is in the developer that the basic principles of static electricity are employed.

The materials for the developer are selected for their triboelectric properties, that is, their ability to induce opposite charges of static electricity in each other when they are rubbed together. Having opposite charges, the carrier

The xerographic process relies upon the deposition of electric charges on a selenium surface. These charges are generated by a corona discharge in air. The quadrupole mass spectrometer shown here is used to analyze ionization in corona discharge.



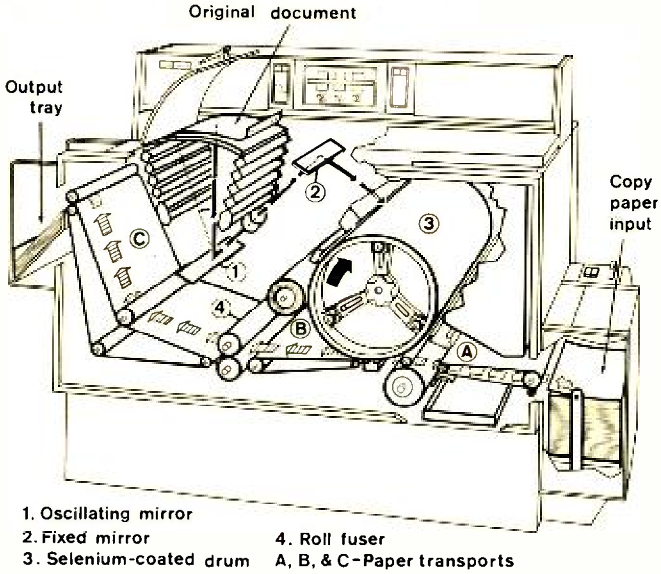


Fig. 4. The operating principles of the 2400.

beads and toner adhere to each other. The charge on the toner is opposite to that which forms the latent electrostatic image on the plate.

As the developer cascades over the selenium plate containing the latent electrostatic image, some of the toner is dislodged from the carrier beads by a combination of mechanical and electrical forces. It is captured by the electrostatic field between charged and uncharged areas, and collects on the charged portions of the image area. This black toner forms a visible, but reverse-reading, image on the plate.

The next step in the copying process consists of *transferring* this toner image from the surface of the plate to a piece of paper (or to almost any other material). This is done by placing the paper over the image area, then charging the back of the paper with an electrical charge and bringing it in contact with the selenium surface. The toner is thus attracted and transferred from the plate surface to the paper.

We now have a right-reading image on paper, but the process is not yet complete. The toner is only lightly attracted to the paper and can be brushed off easily. It must be fixed. This can be done by *fusing*, that is, heating the paper and toner so that the toner particles melt and bond to the paper. The image is now permanent.

Finally, the last procedure, cleaning, is not a part of the xerographic copying process but is necessary so that the selenium plate can be used again to make more copies. There is a faint residue of toner called a *residual image* left on the selenium surface after the transfer step and it must be removed, usually by wiping with a soft brush, before the selenium can be re-used.

A new transistorized circuit for a data display simulator is shown here being checked out in the company's laboratories.

We have described a basic xerographic process, but there are many variations on each step of the process. For example, a corona discharge is not the only way to sensitize a plate. It can be charged by a radioactive source or by a conductive rubber roller. The plate can be exposed by contact, by reflection, by projection—or even by x-ray. The latent image can be developed by aerosols or by powder clouds, by liquid sprays or by immersion in a liquid. The image can be transferred electrostatically, as described, or by using an adhesive or absorptive transferring system (Fig. 2). Finally, the images can be fused chemically, by heat, by high-pressure rollers, or a thin plastic coat can be sprayed over the image area (Fig. 3). In the zinc oxide and similar systems, the two steps of transferring and cleaning up are unnecessary; the image is fixed directly on the photosensitive paper.

The Early Machines

After *Xerox* acquired the patent rights to xerography, the company set out to develop an office copier. The first commercial machine was announced in 1950. It was a manually operated machine consisting of several pieces. It had a corona device for charging a flat selenium-covered plate, a contact box with an optical system for exposing the plate to the image to be copied, a tray for cascade development, and an oven for heat-fixing the image. Each step was carried out separately and a good operator could make a copy in about two or three minutes. The company soon saw that it would have to speed up the process, automate it, and reduce the size of the equipment.

The process was automated and the speed increased by replacing the flat plate with a drum. The several process steps (charging, exposing, etc.) were arranged at locations about the periphery of the drum so that each process step could be carried out sequentially, but on different parts of the copy simultaneously. For example, while one part of the drum is being exposed, another part is being developed, the image is being transferred from another part, and the drum is being cleaned in still another part.

Reducing the size of the equipment was another matter. The first automatic machines were rather large and heavy—certainly not desk-top copiers.

In 1956, the company was firmly convinced that size was not the major consideration. What was important was the performance of the equipment, the ease and speed of obtaining copies, and copy quality. Hence, instead of concentrating on a small copier that could be built at a cost competitive with other desk-top copiers, it built versatility and long-run economy into a larger machine and concentrated on selling a copy service. This machine, developed and introduced in 1960, was called the 914 Copier (because the maximum copy size that the machine could handle was 9" x 14").

A Desk-Top Copier

Attention was next turned to the design of a true desk-top copier. The engineering plan called for a miniaturized version of 914. At first, the problems involved in shrinking the mechanisms of the 914 to about 1/7th of the size seemed almost insurmountable.

For example, over 1200 parts (not including nuts and bolts) had to be shrunk. The diameter of the drum had to be reduced from 8 inches to about 4¾ inches. The size and design of the drum cleaning system presented a problem in shrinking it down to size. An entirely new cleaning system using a new, soft, non-woven fabric was designed. Internal heat also became a design problem. The moving parts had to be much closer to the heating unit which fuses the toner. This meant that a new air-circulating system had to be designed to remove the heat, a system which would allow uniform fusing but would not disturb loose paper near the machine or make objectionable noise. These particular problems along with a good many others were solved (*Continued on page* 72)

RC TIME-CONSTANT NOMOGRAM

By MAX H. APPLEBAUM / Warwick Electronics Inc., Pacific Mercury Div.

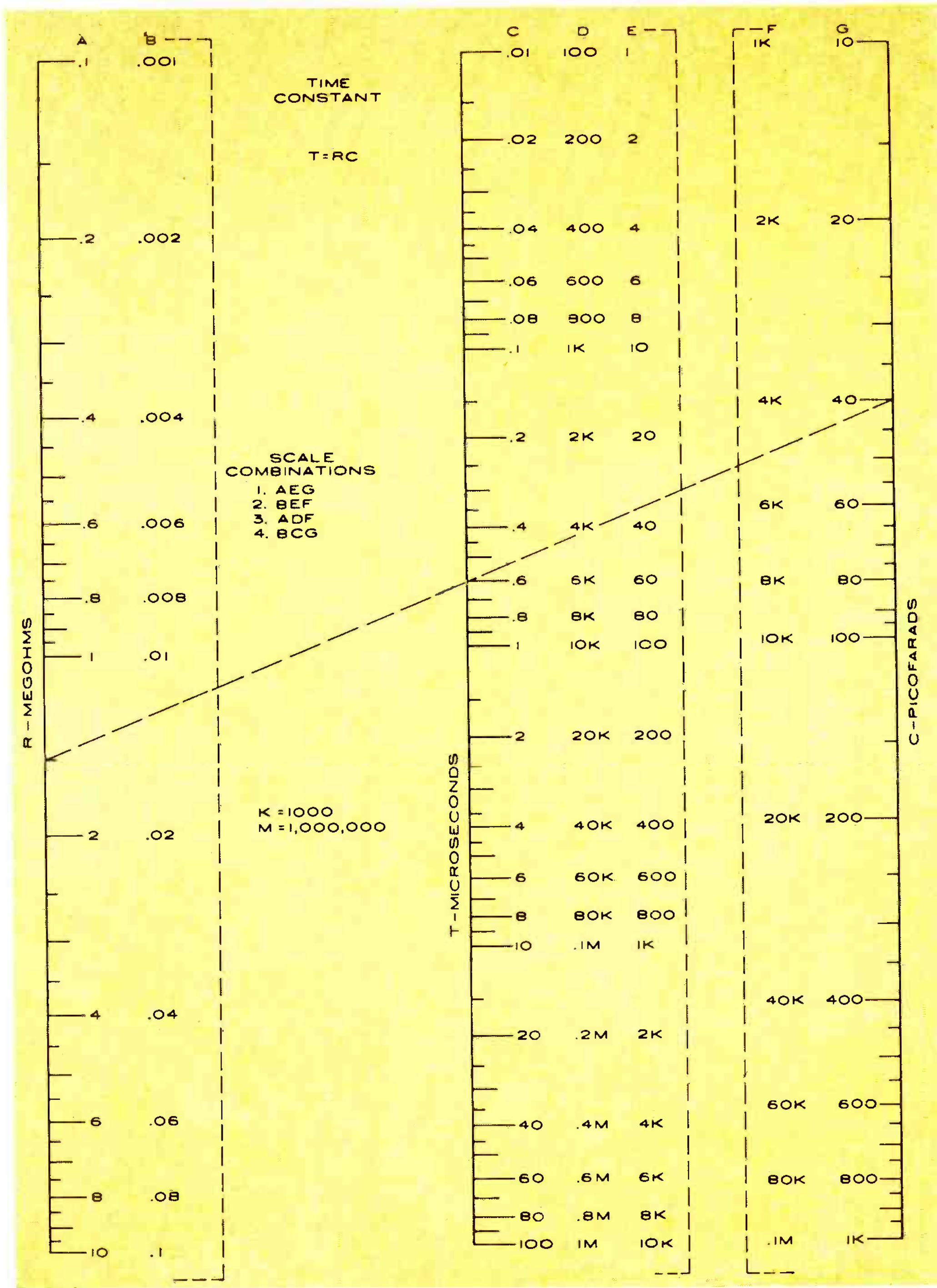
Chart permits quick method of finding combinations of resistance and capacitance to produce the required time-constant combination.

THE purpose of this nomogram is to simplify the calculations of *RC* time constants. Although the operation is fairly simple it can become cumbersome with powers of 10.

More useful, however, is the ability—with this nomogram—to find combinations of *R* and *C* which will give the desired time constant. Various scales are given so that wide ranges of *T*, *R*, and *C* can be found without any calculations. The various possible scale combinations are shown on the nomogram.

Example: Find the time constant of an *RC* network which has a 1.5-megohm resistor and a 40-pf. capacitor.

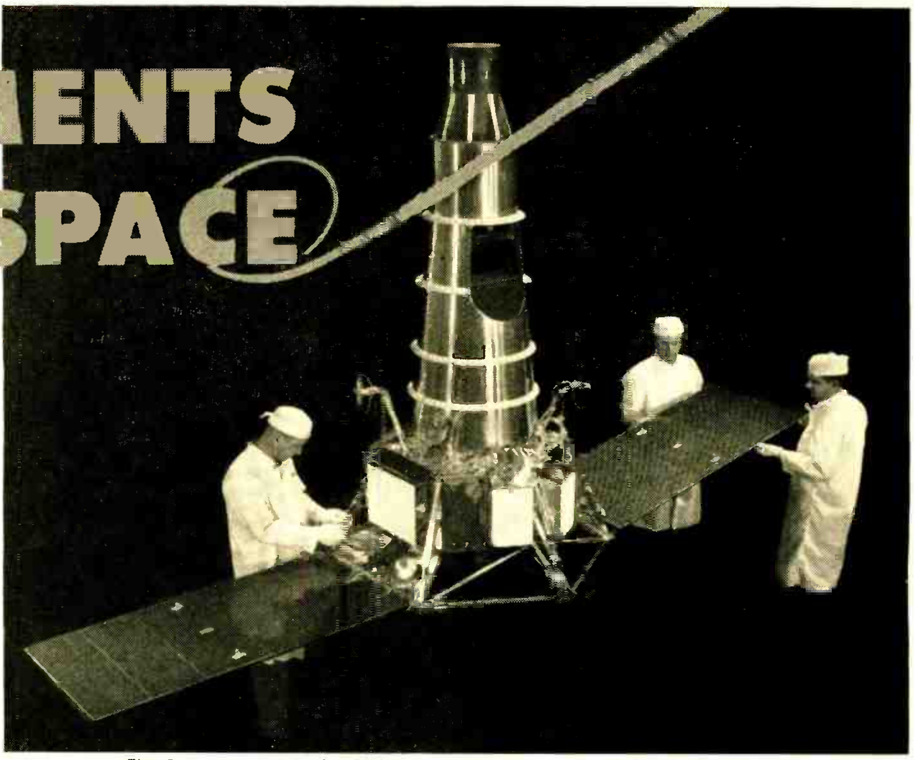
Solution: Using the *AEG* scale combination, draw a straight line from 1.5 on the *A* scale to 40 on the *G* scale. The answer, 60 microseconds, is found on the *E* scale where the drawn line crosses the time scale. ▲



EXPERIMENTS IN SPACE

By JOSEPH H. WUJEK, JR.

New knowledge, new processes and techniques, new materials, and new designs have all come out of our scientific program for the exploration of space. Article describes sounding rockets, scientific satellites, and deep-space probes.



The Ranger moon probe which recently photographed the moon surface.

Editor's Note: The following article is the first in a group of stories that will cover details on our scientific experiments in space. This article covers the subject from a general point of view. Subsequent stories will go into far more detail on each of the many experiments that are now being conducted. Such items as the purpose of the various experiments, how each one operates, the special transducers used, and how the information is transmitted back to earth will be included.

WITH the technological advances in rocketry during the past twenty years, new regions for exploration were opened to Man. No longer would scientists and engineers be satisfied to study only the phenomena of our earth and its atmosphere, or view that small fraction of the universe visible through telescopes. With rockets probing several hundred miles above the earth, more information could be gathered about our globe and its surroundings than was heretofore possible.

In 1957 the USSR launched the first artificial earth satellite. Since that time, payload capabilities of launch vehicles have steadily increased, so that now we find a variety of instrumented packages in space. We are no longer limited to several hundred miles altitude, or to an earth orbit. The United States has successfully launched space probes to the Moon and Venus (Rangers 7, 8, 9, and Mariner 2, respectively) and at the time this was written another Mariner probe (Mariner 4) is enroute to Mars, some 35 million miles away. (Mariner will, in fact, cover over 100 million miles enroute to Mars, but the intercept with the distant planet will be made at the 35-million-mile distance.)

Why Space Experiments?

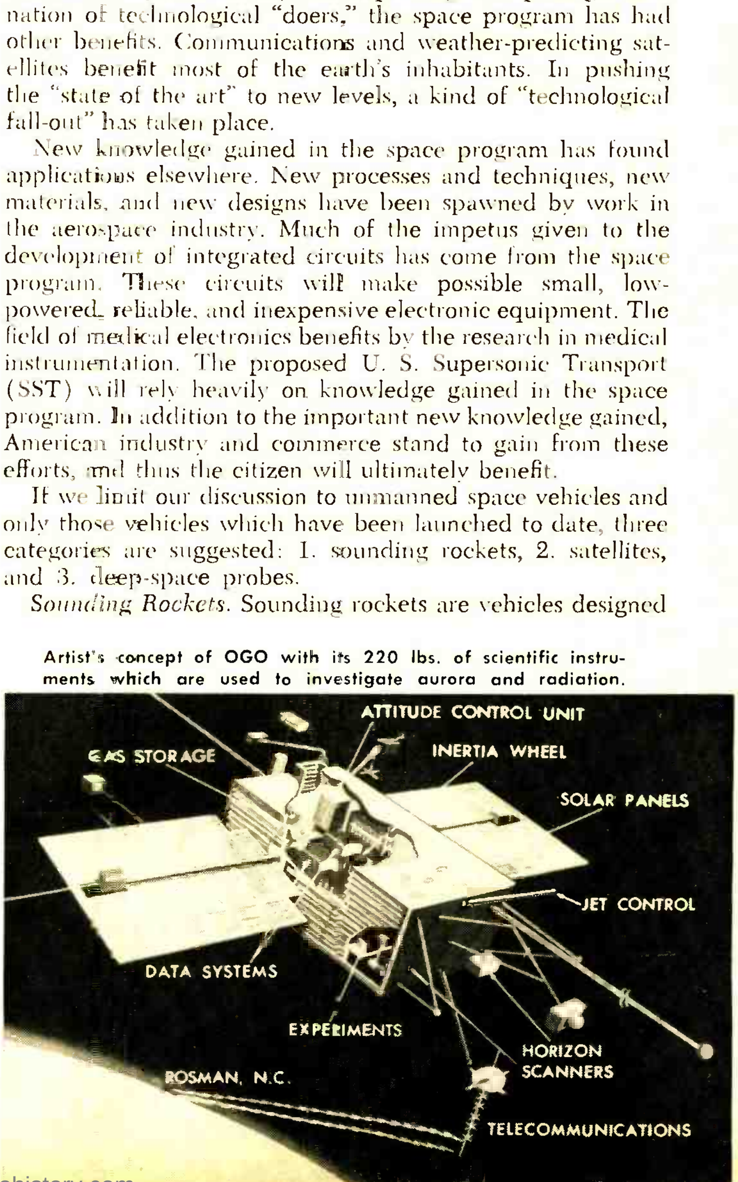
In any undertaking as expensive as the U.S. space program, and it *is* expensive, a citizen might reasonably ask, "Why?" The classic answer of Sir Edmund Hillary, who, when asked why he led an expedition in scaling Mount Everest, replied, "Because it was there," is probably an unsatisfactory answer to many critics of the program. They argue with some justification that these funds might be better spent on cancer research, or education, or a host of other worthwhile pursuits. Beyond improving our prestige as a nation of technological "doers," the space program has had other benefits. Communications and weather-predicting satellites benefit most of the earth's inhabitants. In pushing the "state of the art" to new levels, a kind of "technological fall-out" has taken place.

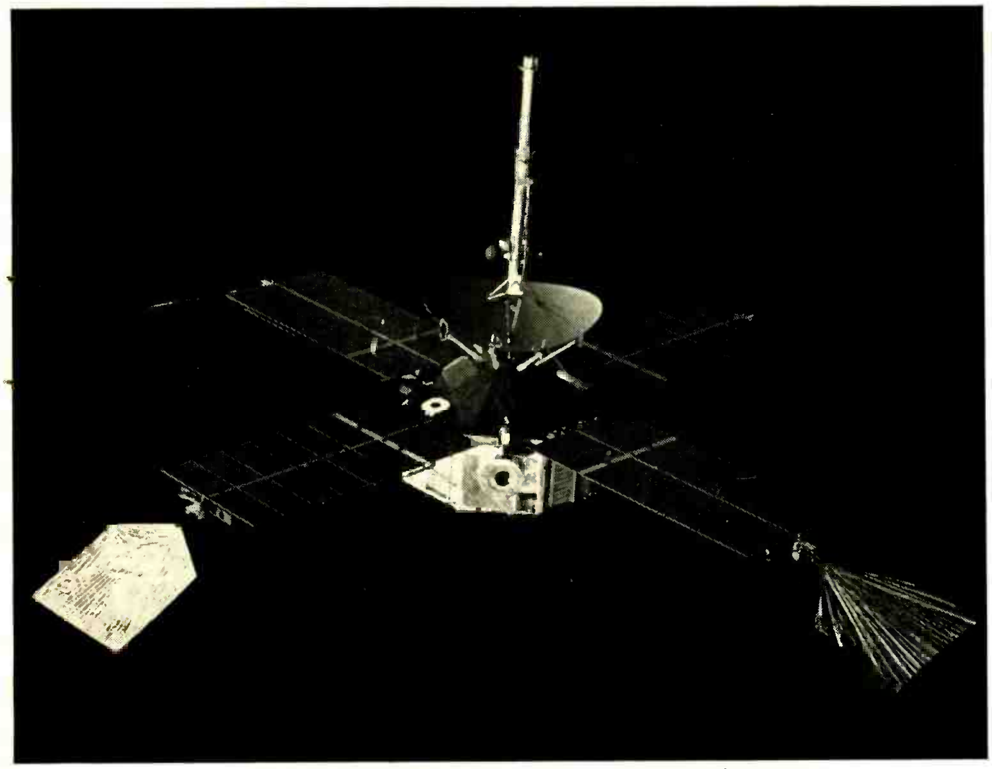
New knowledge gained in the space program has found applications elsewhere. New processes and techniques, new materials, and new designs have been spawned by work in the aerospace industry. Much of the impetus given to the development of integrated circuits has come from the space program. These circuits will make possible small, low-powered, reliable, and inexpensive electronic equipment. The field of medical electronics benefits by the research in medical instrumentation. The proposed U. S. Supersonic Transport (SST) will rely heavily on knowledge gained in the space program. In addition to the important new knowledge gained, American industry and commerce stand to gain from these efforts, and thus the citizen will ultimately benefit.

If we limit our discussion to unmanned space vehicles and only those vehicles which have been launched to date, three categories are suggested: 1. sounding rockets, 2. satellites, and 3. deep-space probes.

Sounding Rockets. Sounding rockets are vehicles designed

Artist's concept of OGO with its 220 lbs. of scientific instruments which are used to investigate aurora and radiation.



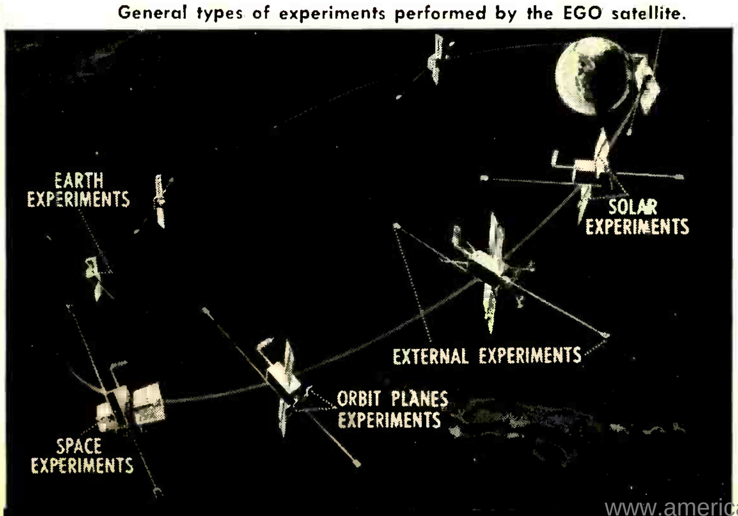

The Mariner satellite, which is now on its way to planet Mars.

to pass through the region of up to several hundred miles above the earth. These rockets are usually smaller vehicles, up to 50 feet in length. The lifetime of these probes is on the order of several minutes. Information is relayed *via* telemetry (TM) channels, and/or a recovery of the instrument package may be effected by parachute and floatation bag if the re-entry is over water. These experiments are *relatively* inexpensive since older, obsolescent rockets may be used, and the ground support requirements are minimal. The launch vehicle may be one or several stages of rocket, with the experiment mounted in a detachable nose cone.

Satellites. Satellites are vehicles which are designed to orbit a planet and, in particular, the Earth. Schemes for orbiting other planets have been described, but we limit our discussion to earth satellites.

The Orbiting Geophysical Observatories (OGO) are an example of the new generation of satellites. The eccentric-orbiting version (EGO), will be launched by the two-stage Atlas-Agena B to an orbit of 68,000 miles maximum (*apogee*), to 175 miles minimum (*perigee*). The polar-orbiting version of the satellite (POGO) will have *apogee* and *perigee* of about 570 and 150 miles, respectively. POGO will be launched by Thor-Agena. At this writing, one EGO satellite is in orbit.

General types of experiments performed by the EGO satellite.



Many other earth satellites have been launched or are in the development stage. Some of these are for scientific measurements. Others, such as the Syncom, Telstar, and Echo are primarily communications satellites. So-called *active* satellites contain receiver/transmitter equipment to receive, amplify, and re-transmit high-frequency r.f. over the horizon. *Passive* satellites such as Echo, merely act as reflectors for r.f. transmission.

Yet another class of satellites is the Tiros (*T*elevision *I*nfrared *O*bservation *S*atellite) type, used to gather data for weather prediction.

Deep-Space Probes. This class of vehicle ordinarily contains equipment similar to that of sounding rockets and earth satellites, but has a mission in deep-space. The Mariner 2 vehicle which passed Venus in mid-December 1962 was of this category, as were the Ranger Moon probes.

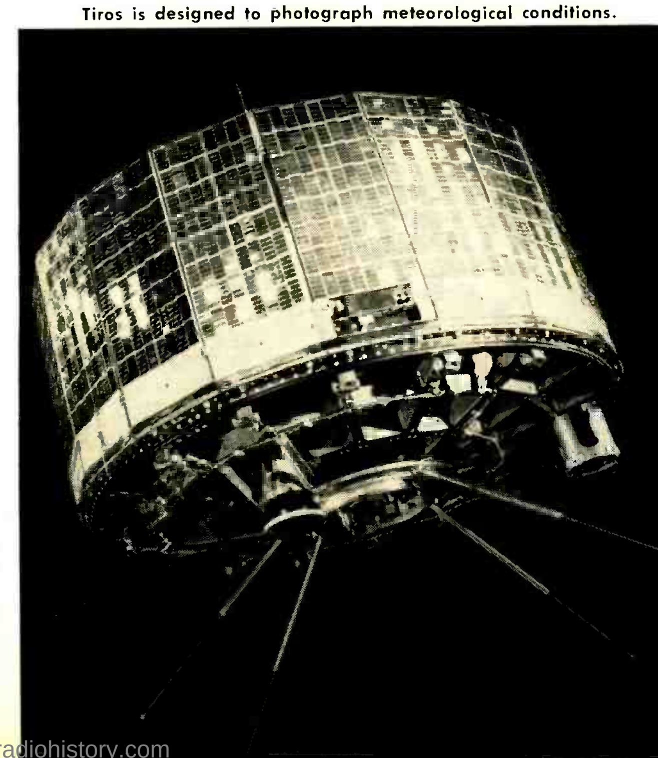
Experiments in Space

While a wide variety of approaches to instrumentation exists for each particular experiment, most experiments may be classified as one of six general types: 1. micrometeoroid measurements, 2. magnetic measurements, 3. solar-plasma measurements, 4. radiation measurements, 5. wave-propagation measurements, and 6. astronomical observations.

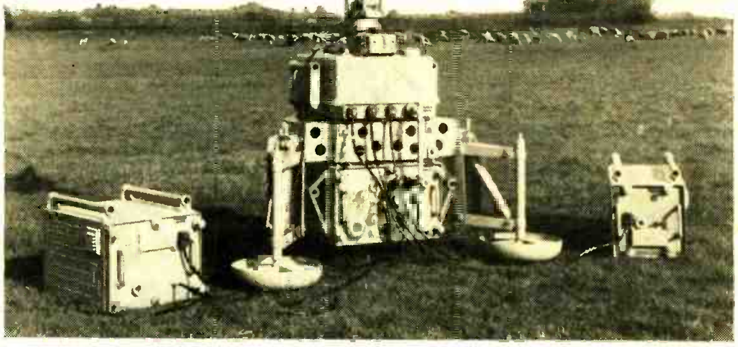
Micrometeoroid Measurements. The far reaches of space abound in cosmic debris. We are familiar with meteors and meteorites, which are seen burning in the earth's atmosphere or occasionally find their way to a collision with the earth's surface. These particles may be seen either by optical means or radar.

But many smaller parts, too small to be seen by radar, exist above the earth's atmosphere. Particles of less than 1 millimeter diameter (about 4/100th of an inch) are called *micrometeoroids*. These particles may be traveling at speeds of up to 100,000 feet per second (more than 68,000 miles per hour), and hence could prove haz- (*Continued on page 82*)

Tiros is designed to photograph meteorological conditions.



Early Bird Communications Satellite. (Above) The world's first commercial communications satellite was launched successfully into a synchronous orbit at the beginning of April. The satellite, called "Early Bird," is shown here being prepared for space-simulation tests at Hughes Aircraft Co, which built the spacecraft for COMSAT. The satellite provides 240 two-way telephone channels between Europe and North America, or two-way television between the continents. It can also handle teletypewriter and facsimile along with phone conversations. Some 6000 solar cells power the electronic equipment in the new satellite.



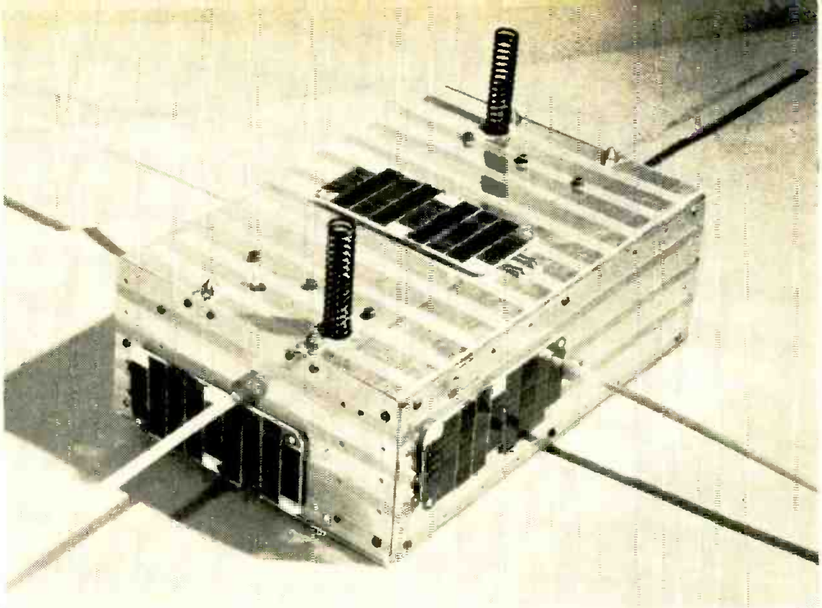
Battlefield Radar. (Above) A battlefield radar system so sensitive that it will spot a moving person 9 miles away and a moving vehicle at 22 miles has been developed by a French subsidiary of ITT. The radar is a pulse system using Doppler effect for canceling stationary targets. Accuracy is within a quarter degree in azimuth and 65 feet in range. Equipment can be transported by a helicopter.

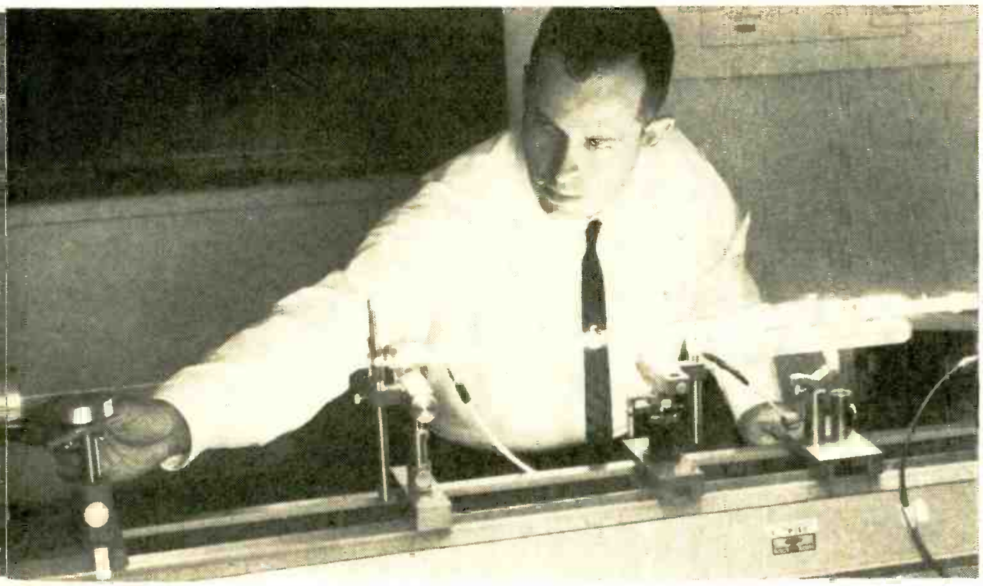
RECENT DEVELOPMENTS in ELECTRONICS

Laser Altimeter. (Below) The first terrain profiler using a laser has been successfully flight tested. The system consists of a c. w. gas laser altimeter, a high-resolution barometer sensor, and a strip or aerial mapping camera. Distance to the ground is measured continuously by comparing the difference in phase between the transmitted and received laser beams. The barometric sensor provides a reference to the aircraft's pressure altitude within one foot. By using the sensor, any recorded change in elevation represents changes in terrain rather than a change in aircraft altitude. At an altitude of 1000 feet, the profiler has an accuracy better than 1 foot; at 10,000 feet accuracy is within 2 feet. The new system has been designed and built by Litton Industries.

Integrated-Circuit Radar Transponder. (Above) The small unit being held is the integrated-circuit PRADOR (Prf RAnging DOppler Radar), a feasibility model of a miniature space rendezvous radar transponder. The larger unit beneath is a transponder which is part of the all-solid-state radar system developed by Westinghouse in 1963. The integrated-circuit version is much smaller and has better ratings and performance. The miniature transponder was built to demonstrate the feasibility of using integrated electronic circuitry to achieve a huge reduction in size, weight, and complexity but with an increase in reliability. The unit uses 23 monolithic blocks, 13 multichip integrated circuits, 12 transistors, and 12 diodes. The system range is 500 nautical miles; it operates on X band.

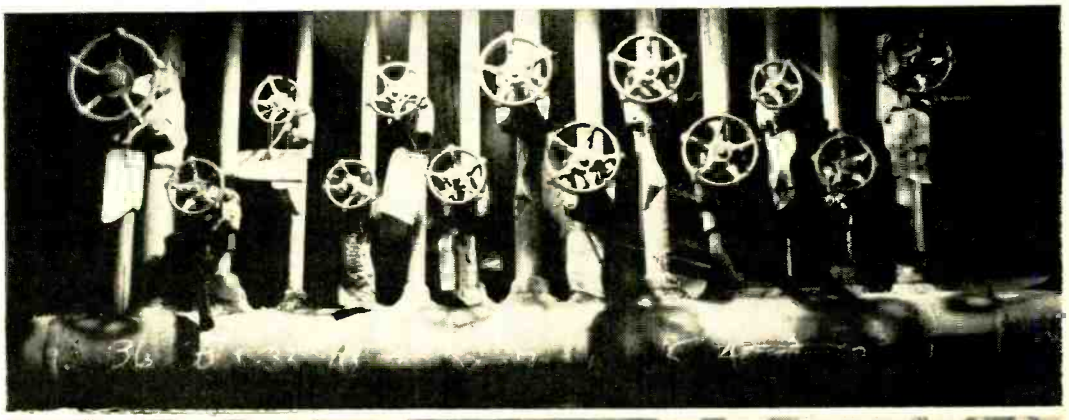
Radio Amateur Satellite. (Right) Launched into orbit on March 9, this home-made radio amateur satellite was put into a 502-mile high, 103-minute orbit about the earth. The satellite, called "Oscar III," was designed to receive amateur 2-meter signals and to rebroadcast them on the same band. Record-shattering ham contacts have been made via the satellite across the Atlantic Ocean, between California and Argentina, between California and Hawaii, and between Alaska and the West Coast. Contacts have also been established with European hams in Switzerland, Germany, England, Czechoslovakia, and Sweden. The satellite was constructed by San Francisco Peninsula radio amateurs, directed by William I. Orr, W6SAI. The satellite was carried as a passenger into space aboard a research and development vehicle of the United States Air Force.





High-Power Single-Frequency Laser. (Left) Two new techniques which produce a high-power, single-frequency laser beam capable of transmitting light signals efficiently have been developed by Sylvania scientists. The techniques, called the frequency-modulated laser and the supermode laser, result in concentrating all of the energy of a high-power, multi-mode laser into a single discrete frequency instead of multiple frequencies that are close together. Briefly, the technique consists of phase-modulating a conventional laser beam by applying an electric field to a special crystalline optical modulator. The result is a signal that takes on the appearance of a frequency-modulated signal. This is then passed through a second optical phase modulator driven 180° out of phase with the first one. The result is complete elimination of all modes except one.

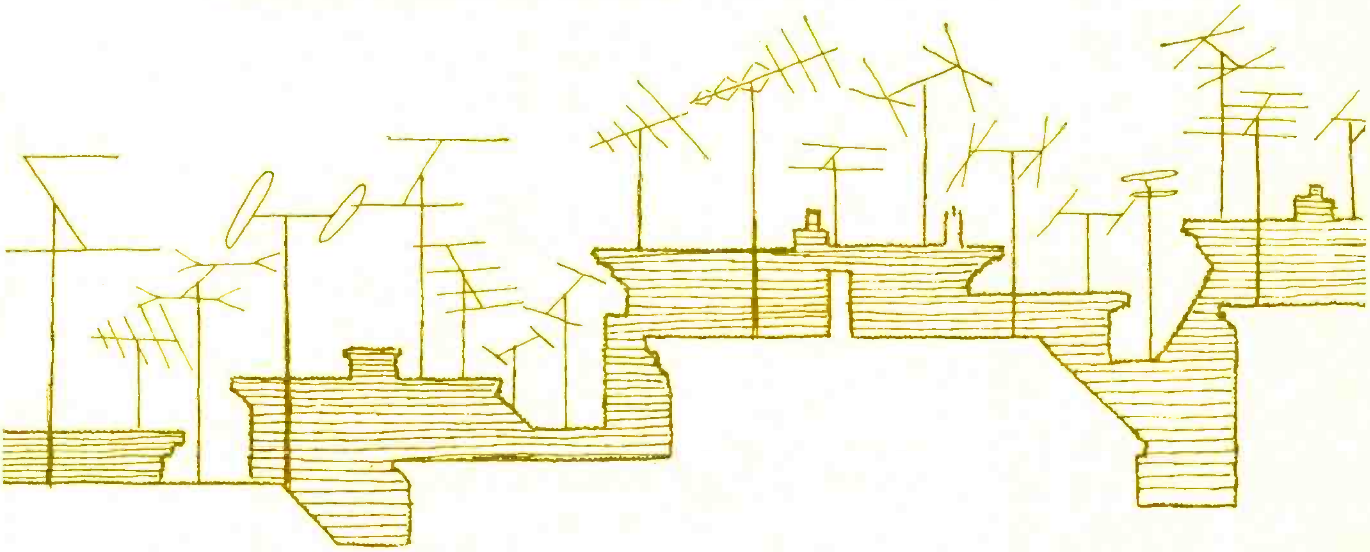
Infrared Camera. (Right) The top photo shows a number of valves, piping, and a tank manifold as they would appear to the eye. With an infrared camera focused on the same scene, the lower photo is obtained. This photo is a thermal map of the system in which the colder objects are darker and the hotter objects are lighter. Note the cold valve handles and tags, the warm pipes and manifold, and the white hot spot at the very bottom of the manifold. The infrared camera employed, developed by Barnes Engineering Co., offers potential as a non-destructive testing and troubleshooting tool. The camera uses a scanning infrared detector whose output is converted to electrical signals. These are amplified and fed into a tiny gas tube whose brightness is proportional to the infrared energy being received from a small part of the target being viewed. A second scanning system converts this light into a complete image on a piece of film.



COAX vs TWINLEAD

By LON CANTOR / Jerrold Electronics Corp.

For monochrome TV reception, conventional twinlead presents no serious problems. It is low in cost and can cause less loss than coax. However, for color-TV where color adjustments become quite critical, problems do exist and many technicians are finding coax transmission lines more suitable.



TRANSMISSION line is the necessary link between an antenna and a TV receiver. Although TV engineers have always preferred coaxial cable, twinlead has been used almost universally. Recently, however, many technicians began to use coax, especially for color-TV and FM-stereo.

If twinlead was all right for monochrome TV, why should coax be required for color? Let's make a close comparison between the two transmission lines and find out.

Fig. 1 shows an antenna picking up a TV signal. Because the TV carrier frequencies are high, the wavelength is short. At channel 2, the distance between a positive-going wavefront and the succeeding one is about 17 feet. At channel 13, the wavelength is about 4½ feet.

As these signal wavefronts cut the antenna, they induce current to flow. At first glance, it would appear that current induced in the antenna could go down one conductor of the twinlead, into the TV receiver, and back up the other twinlead conductor.

However, things are not quite that simple. The problem is that the signal current simply doesn't have the time to complete the trip. Notice from Fig. 1 that between each positive-going wavefront is a negative-going wavefront. This negative wavefront is only half a wavelength (for channel 2, about 8½ feet) behind the positive one. The negative-going wavefront induces a current in the antenna that goes in a direction opposite to that of the current induced by the positive wavefront. The r.f. signal is traveling toward the antenna with the speed of light, about 980 feet per microsecond.

Nothing can exceed the velocity of light. In fact, the transmission line slows the signal down a little. Therefore, by the time the signal has traveled about eight feet down the twinlead, the negative wavefront is cutting the antenna and the signal must reverse itself.

Obviously, TV signals can't travel through transmission line like battery current. Instead, they must get to the TV set in the manner illustrated in Fig. 2.

The alternator symbols in Fig. 2 represent the antenna. Fig. 2A shows the flow of current and the magnetic-field distribution during the first quarter cycle. Polarity is indicated by the arrow enclosed in the sine wave. Fig. 2B shows the entire first half cycle, at the end of which the current has traveled about eight feet down the twinlead.

This brings us to the critical part of the process. As the alternator current falls to zero, the magnetic fields around the twinlead collapse. In so doing, they cut the twinlead conductors, inducing current in the original direction of current flow. It is the induced voltage that pushes the current beyond the eight feet of twinlead traversed by the original current.

This process is repeated continuously along the length of the twinlead. Current builds up a magnetic field and the collapse of the magnetic field induces another current. The entire package of energy, comprising the current and the magnetic field, is called an incident wave. The leading edge of each incident wave is built up by the collapsing field of the trailing edge.

Note that once the incident wave leaves the antenna, it is on its own. It cannot be affected by anything happening behind it. The incident wave travels down the twinlead at about 80% of the speed of light.

Fig. 2C shows the second half cycle. This produces a similar incident wave, except that current direction and magnetic-field polarity are reversed. In other words, electron movement is opposite to that in the portion of the line just ahead.

How is it possible for electrons to move in two different directions in the same conductor simultaneously? Actually, electrons travel within the conductor on the order of millionths of an inch—a mere "twitch" of electrons. In other words, electrons in the section of twinlead under the leading wavefront twitch forward, while electrons under the succeeding wavefront twitch backward, as indicated by the arrows.

Standing Waves

The alternator (antenna) does not "see" its final load. It sees only the half wavelength of wire into which it feeds its currents. The load at the other end of the line cannot affect the generator directly because there are points of zero potential between the generator and the load.

For this reason, the law which says that source impedance must equal load impedance for maximum energy transfer does not precisely apply here. There is an in-between step. For high frequencies such as TV signals, where the line is more than a half wavelength long, the source (antenna) impedance must match the transmission-line impedance, and the transmission-line impedance must match the load (TV receiver) impedance.

It is because 300-ohm twinlead is so widely used that almost all TV sets and antennas are matched to 300 ohms (nominally).

What makes twinlead have an impedance of 300 ohms? First of all, because every conductor shows inductive and capacitive reactances, we can come up with a representation such as the basic network (shown untinted) in Fig. 3.

This figure is just a schematic representation of twinlead, but an artificial transmission line can actually be built of coils and capacitors and it will act exactly like a long 300-ohm line. As a matter of fact, artificial "delay" lines are used to time pulses in radar equipment.

Not every parallel pair of conductors has an impedance of 300 ohms. (In fact, not all TV twinlead on the market has the correct impedance.) Actual impedance depends upon three factors: the size of the conductors, the spacing between the conductors, and the dielectric material used between the conductors.

We've already watched a signal as it traveled down a transmission line. But what happens when it gets to the end? Suppose the end of the line is an open circuit. The TV signal will start down the twinlead. All it "sees" is a half wavelength at a time. When it gets to the end of the line a peculiar thing happens. The signal energy has no place to go. It can't just disappear. Therefore, it just starts back up the wire again, reversing its direction.

While part of the signal has bounced back from the circuit end of the twinlead, more signal is coming down the line. This is illustrated in Fig. 4A. The solid line represents the signal going down the line and the dashed line represents the signal bouncing up (reflected wave).

Once again, it appears that we have current simultaneously going in two ways in a conductor. Actually, you can't have two opposite currents in the same portion of the same wire at the same time, but you can have two opposite fields in the same space. That's what is happening here. What's more, these fields are passing through each other.

At certain points along the transmission line, the polarity of these fields is such that they add, increasing the current conduction at these points. At other points, the fields cancel and no current flows in the conductor at these points.

While the signals going up the line are moving, and the signals going down the line are moving, they always cross each other for a given polarity at the same point. Thus, the points of addition and cancellation are always the same. As shown in Fig. 4B, the resultant wave pattern does not move. Because it remains stationary, we call these waves "standing waves."

So far we've discussed only open-ended twinlead. What happens if the end is shorted? Pretty much the same thing. The signal still bounces back up the line, but it is reversed in phase. While unterminated line will show a voltage maximum and current minimum, a shorted line shows current maximum and voltage minimum at the end.

How can reflected signal and resulting standing waves be eliminated? We must either make the transmission line endless, or make it appear endless. Obviously, the second method is the more practical. To an alternator, an endless 300-ohm

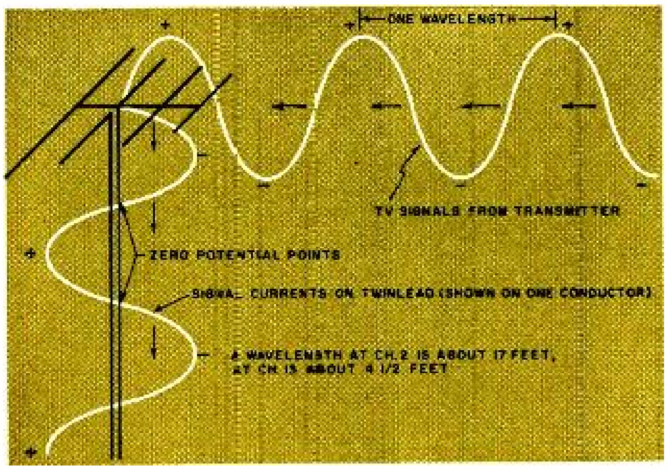


Fig. 1. Field pattern of a typical TV or FM antenna pickup.

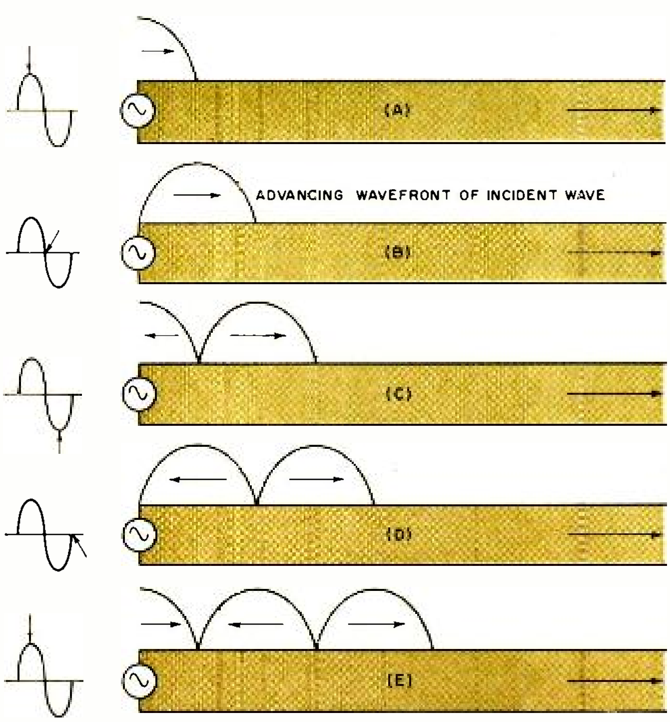
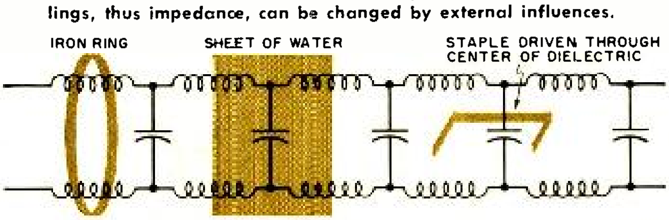


Fig. 2. How a wavefront gets down antenna transmission line.

Fig. 3. Schematic representation of transmission line shows it to be a network of inductors and capacitors. Mutual couplings, thus impedance, can be changed by external influences.



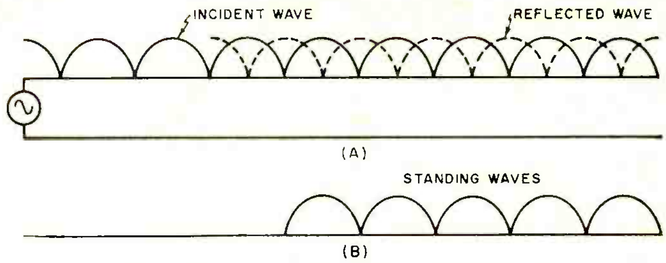


Fig. 4. When both ends of a transmission line are not terminated in the correct impedance, standing waves are set up.

transmission line looks just like a 300-ohm load. Therefore, we can fool the alternator into thinking it sees an endless line by terminating the line with a 300-ohm load. This could be a 300-ohm resistor placed across the end of the line, but in most cases the TV-tuner input acts as the 300-ohm load.

To recap, we started with a 300-ohm antenna, went through 300-ohm twinlead, and terminated the line with a 300-ohm TV set. Theoretically, the installation works just fine.

The trouble is that twinlead maintains 300-ohm impedance only in free space. Fig. 3 shows what happens to twinlead under normal installation conditions. Standoffs and insulators, represented by the iron ring, couple into the magnetic fields around the twinlead. This increases both inductance and capacitance, causes an increase in losses, and greatly reduces the impedance. In fact, if the ring is crimped closed, the transmission line behaves almost as though it were shorted at that point.

Similarly, a sheet of water or ice acts like a large capacitor across the line. Staples used to run twinlead along baseboards can be the worst offenders.

Proximity to metal, with the resulting change in impedance also causes standing waves in twinlead.

If standing waves are unavoidable, how have TV technicians been able to use twinlead all these years? Do standing waves actually make any difference in the TV picture? Standing waves cause both ghosts and signal attenuation. However, these problems have not been particularly severe for monochrome TV. Let's consider the "ghosts" first. When the signal sees an impedance change—or a "jump" in the line—it bounces back up the line. However, a portion of that signal eventually does reach the receiver. Because the average installation uses a number of standoffs and staples, there are multiple reflections, each arriving at the screen at a different time.

The reason that we are willing to put up with these multiple-line ghosts is because they are so closely spaced. The horizontal sweep trace moves across the TV screen in 53 microseconds. Therefore, the reflected signals would have to travel over half a mile extra up and down the twinlead to cause a one-inch displacement on a 17-inch TV screen. Since the reflected signal actually doesn't travel very far, the ghosts are closely spaced, appearing more as smears. These close-spaced ghosts are not too greatly disturbing for black-and-white TV, but they can destroy a color picture.

Remember, the color carrier is demodulated by a phase-sensitive detector. Thus, a change in phase causes a change in color. The reflected signals not only cause ghosts, but the ghosts are the wrong color—a very annoying situation.

What about signal cancellation? As an experiment, connect a piece of twinlead about six feet long to the TV-tuner input terminals—in parallel with the antenna lead-in. Tune to an operating channel and then start snipping the end of the twinlead off, about a quarter of an inch at a time. Soon you'll arrive at a length of twinlead that severely attenuates the signal strength of the channel being watched, and the picture will get snowy or lose sync. What has been done is to make the line length such that the null point (see Fig. 4) of the standing wave is right at the TV-set input. This illustrates how standing waves can reduce signals. Strategically placed standoff insulators can have the same effect.

Reflected signals can also ruin FM-stereo reception by attenuating the signals, causing the typical buzzes and squawks that are characteristic of weak signal reception.

Fig. 5 shows a cross-section of coaxial cable compared with a cross-section of twinlead. Note that the magnetic and electrostatic fields around the twinlead conductors extend out into the space around the twinlead. This is why twinlead is susceptible to impedance changes caused by surrounding objects.

Look closely at the coaxial cable representation. Like twinlead, coax depends upon the build-up and collapse of magnetic and electrostatic fields in order to conduct. The difference is in the contours of these fields. By definition, both inner and outer conductors of coax have the same center. Therefore, the magnetic fields around these conductors also have the same center. However, current always travels through the outer conductor in a direction opposite to that of the inner conductor. In other words, these magnetic fields occupy the same place at the same time, but they are opposite in polarity. Since they are also equal, *they cancel each other out.*

The electrostatic lines of force appear only between the inner and outer conductors. They do not cancel out but are confined within the cable shield. Since no part of the coaxial cable fields appears outside the cable, it is completely unaware of its surroundings. It maintains its impedance regardless of proximity to metal or water.

A commercial, weatherproof matching transformer can be used to match a 300-ohm antenna to 75-ohm coax. The transformers should be mounted as close to the antenna as possible. The coax can be taped to the mast or tied with nylon cord.

At the TV set, another matching transformer is required. The coax can be secured in place with round staples, such as *Arrow* #T-25, or ordinary fence staples. Be careful not to crush the coax, however. The one thing that can change coax impedance is a change in spacing between the center conductor and the shield.

There are five good reasons why coaxial cable should be used for all color-TV and FM-stereo antenna installations:

1. Coax is impervious to its surroundings. You can run it underground, through pipes, alongside a.c. wires, or under water, and it won't change impedance.

2. Coax won't pick up direct TV signals. This is another cause of ghosting in twinlead installations.

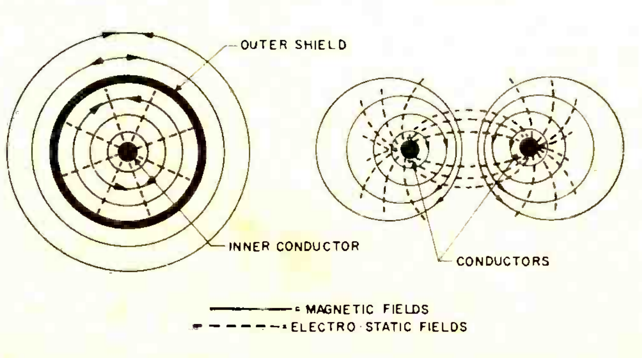
3. Coax is very durable. It will last about ten times as long as twinlead.

4. Coax is easy to install. There is no need to worry about avoiding metal or other wires.

5. Coax won't pick up auto or appliance interference. ▲

(Editor's Note: It should be understood that all twinlead referred to above is the conventional flat type. Many of the comparisons made do not apply to such special all-weather twinlead as Belden 8285 *and* Amphenol 214-103.*)*

Fig. 5. Coaxial cables are not influenced by external fields as much as twinlead. Impedance remains relatively constant.



The Fixed-Capacitor Industry

N. WAYNE ETTER

N. WAYNE ETTER has been President and General Manager of the Mallory Capacitor Co., Division of P. R. Mallory & Co., Inc. since 1963. He is also chairman of the EIA Fixed Capacitor Subdivision of the Parts Division. From 1960 to 1963 he served as President of Mallory Timers Co. and prior to that was Works Manager of Mallory Metallurgical Co.

Guest Editorial

WITH the exception of resistors, fixed capacitors are undoubtedly the most widely produced and used component in the electronics industry today. The capacitor industry is a prime portion of the electronics manufacturing field and its future is inextricably dependent upon the growth of the over-all industry, which is presently expanding at the rate of 5-8% a year. Expectations are that this growth will continue at an ever-increasing rate. Disregarding for the moment the possible effect of integrated circuits, it is safe to assume that the fixed-capacitor industry will grow at a like rate.

Since certain aspects of the market, and some capacitors themselves, fluctuate from model year to model year, it is impossible to predict with any accuracy the number of units of any specific type to be made in a given year. There are approximately 150 manufacturers of fixed capacitors in the United States. Competition is keen, and it is a buyer's market. This condition has existed within the electronics industry ever since the late 1940's and 1950's, due, of course, to the initial television boom—which was a seller's market.

In reviewing 1964, we find that there were 2,305,000,000 fixed capacitors produced, valued at $343,835,000. At first glance, especially to an outsider not familiar with our industry, these figures might seem to indicate that fixed capacitors are low-priced components and that the capacitor industry is a highly standardized product market with highly automated volume production facilities. This is not the case.

Of some 20 general lines of capacitors, only a few are standardized enough to permit automated production methods. Disc ceramics, paper and film dielectric tubulars, glass dielectrics, and possibly solid tantalums are the only items which at present enjoy some degree of mechanized production.

A look at the aluminum and tantalum electrolytic market offers a good example of one of the major problems which besets our industry today. Our company, which is no different from many in our industry, has 14 major aluminum types and 10 major tantalum types. But when individual ratings are examined, it will be found that a file of over 14,000 exists. Within any 90-day period, our company involves itself with 4000 distinct and different items, and this is in the field of electrolytics alone. One can well imagine the total number of distinct units when the entire fixed capacitor industry is taken into account. One manufacturer recently reported that his company would produce upwards of 40,000 different products in the course of a year. This diversity and customized line of products eventually costs the user a good deal of money.

The trend—at least on the part of the manufacturer—is to encourage a gradual design standardization in the years ahead. The industry also hopes that the engineer/technician consumer can be shown the desirability of standard components. Savings would accrue to both not only in terms of dollars and cents, but in delivery time, inventories, interchangeability, and replacement stocks as well.

The use of automated assembly equipment for the insertion of parts into printed-circuit boards is becoming very common now and this forces mechanical standardization of fixed capacitors. Most hi-fi and stereo equipment is already transistorized and it now appears that all TV, except color, will be transistorized by 1967. This trend to transistorized circuits creates a demand for more and smaller fixed capacitors and a large-scale change of this nature presents an opportunity for manufacturers to retool. Naturally, most of them are going to reduce cost by automating where possible. It is almost an inflexible principle that automation forces standardization of component parts and this fact may resolve the biggest problem of the fixed-capacitor industry.

A long-term projection would also have to take into account the effect of integrated and thin-film circuits. Here, again, an extremely complex technology is involved which is best accomplished by highly automated processes and manufacturing techniques. It follows that discrete fixed capacitors used with these devices will also need to be highly standardized ▲

Ceramic Capacitors

By ENGINEERING DEPT. / Capacitor Products, Centralab
The Electronics Div., Globe-Union, Inc.

Varying composition of the ceramic dielectric can produce a broad range of temperature-compensating, high-dielectric-constant capacitors.

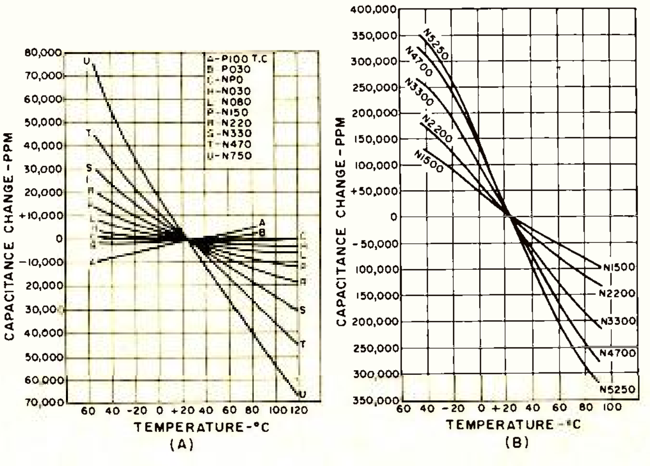
CERAMIC dielectrics are among the most outstanding and versatile of all capacitor dielectric materials. They can duplicate, and in many instances far surpass, the characteristics of other dielectrics. Their wide range of dielectric constants (*K*) gives them a notable advantage in microminiaturization. The *K* advantage which ceramics possess is only one of the inherent superiorities of this dielectric. The ability to operate over wide frequency ranges, to be functional over large temperature excursions, and to possess either linear or non-linear characteristics gives a heretofore simple capacitor giant capabilities. The ability to mold ceramic materials into numerous shapes, sizes, and thicknesses gives them both mechanical and electrical design possibilities beyond those of any other dielectric material.

The development of ceramic capacitors can be traced to the German discovery in the 1870's of Rutile (titanium dioxide). Experiments with this material enabled production of ceramic capacitors with *K*'s less than 25 in the early 1920's, but these efforts were scarcely more than a laboratory curiosity until the advent of higher dielectric constant materials.

In 1936, *Centralab* commercially produced the first ceramic capacitor in a tubular configuration, having a dielectric constant of 100. World War II gave tremendous impetus to the development of higher *K* ceramic dielectric materials and implemention of the use of the disc configuration. Capacitor usage in disc form grew by leaps and bounds until the mid-50's when their usage far surpassed that of any other dielectric material.

Virtually all of the ceramic used for the dielectric in ceramic capacitors can be divided into two broad categories: temperature-compensating (or low *K*) and high dielectric constant (high *K*). This latter category can be expanded into a conventional ceramic dielectric type and into a semiconductor type, represented by such trade names as "Ultra-Kap," "Hypercon," "Magnacap," and "Transcap."

Fig. 1. As the proportions of the capacitor material are altered, the slope of the temperature curves are changed.



Since glass and porcelain capacitors possess electrical characteristics similar to temperature-compensating ceramic, these materials will also be included in the following discussion on capacitor types.

Temperature Compensating

Ceramics possessing this characteristic have a predictable capacitance change *vs* temperature. This change is called temperature coefficient (TC) of capacitance and is expressed in parts per million per degree C (PPM/°C). It indicates the number of picofarads of capacitance change per degree change in temperature (centigrade).

These ceramics are available with a TC from P120 (or +120) to N5250 (or −5250) and with dielectric constants from 5 to 570, generally increasing as TC becomes more negative. Standard coefficients and tolerances are available as specified in EIA Specification RS-198, and Military Specification MIL-C-20D should be consulted when required.

Temperature compensation for commercial applications is specified from +25° to +85°C. MIL Specs require measurements from −55° to +85°C, or in some cases to +125°C, or to the maximum operating temperature.

Magnesium and calcium titanates are two of the compounds used for the temperature-compensating types. The various *K* levels are achieved by mixing magnesium titanate (exhibiting positive TC) with calcium titanate (having negative TC). The material proportions alter the slope of the temperature curves (see Fig. 1).

These titanate materials and other compositional additive types provide a *K* range from 5 to 110, with temperature coefficients from positive 120 to negative 750 PPM/°C, while the extended TC series have *K* ranges from 100 to 570 with temperature coefficients from N1000 to N5250.

The temperature-compensating ceramics possess little or no voltage-coefficient characteristics, that is, a change of capacitance or dissipation factor with applied voltage. The effect of frequency on these materials indicates that change of capacitance and dissipation factor over the frequency range of 60 cps to 1 mc. is minimal.

Glass and porcelain capacitors exhibit general characteristics similar to the temperature-compensating ceramic and also possess high insulation resistance, excellent stability, and high "*Q*". They are limited to temperature coefficients in the NPO to P140 range and are not available in a large variety of configurations as are TC ceramics. They are also widely used in applications involving adverse environments and where cost is not a large consideration.

High Dielectric Constants

Ceramics in this class are characterized by a dielectric constant ranging from 600 to 10,000, a dissipation factor less than 2.5%, and insulation resistance greater than 20,000 megohms. They do not have the stability and high "*Q*" of the TC type.

The high-*K* ceramic dielectrics generally are barium titanate modified with alkaline earth titanates, zirconates, and stannates. Barium-titanate dielectric material has a peak (Curie point) K of approximately 6000 at 120°C. The addition of small amounts of barium stannate shifts the peak to a lower temperature, and increasing percentages raise the K level. A barium-zirconate modification exhibits a similar but less marked effect. Magnesium-titanate additions produce a stabilizing effect, and although these additions reduce K level, a more linear curve is thereby produced.

Typical capacitor bodies are combinations of these materials and exhibit K *vs* temperature characteristics whose peak or Curie point occurs at about room temperature (25°C), with K falling off on either side of this peak. Generally, the magnitude of this change will be greater for materials with higher dielectric constants. It is obvious that this change in dielectric constant *vs* temperature will cause the capacitors to exhibit capacitance changes which directly follow these curves. Capacitors are available such that their capacitance *vs* temperature change characteristics fall within established limits.

In addition, these materials will exhibit capacitance changes with respect to time (aging), frequency, and voltage. Fig. 2 shows the variation of capacitance and dissipation factor *vs* frequency, indicating a decrease in capacitance as frequency increases. The effects of applied a.c. and d.c. voltage on capacitance are shown in Fig. 3 and on dissipation factor in Fig. 4.

Capacitors using these high-K ceramics will decrease logarithmically in capacitance over a period of time. Most reputable manufacturers take these small changes in capacitance into account, and units are produced to remain within tolerance (at room temperature) for one year. It is also well to note that whenever the unit is heated it will tend to be restored to original capacitance. Therefore, aging is generally not a problem.

Semiconductor Types

A recent discovery utilizing advanced techniques for processing high-K ceramics led to the development of the semiconductor-type ceramic capacitor. The "Ultra-Kap," first introduced by *Centralab* in 1955, uses this principle. These capacitors provide capacitance values as much as 100 times greater than those attainable through the use of conventional ceramic dielectrics, achieving levels heretofore available only with electrolytics and film-type capacitors. The economy and compact size of these semiconductor units resulted in their widespread usage in transistor circuits for bypass and coupling applications. They are most suitable for operation in the audio-frequency range, and the voltage ratings of these devices are from 3 to 25 volts.

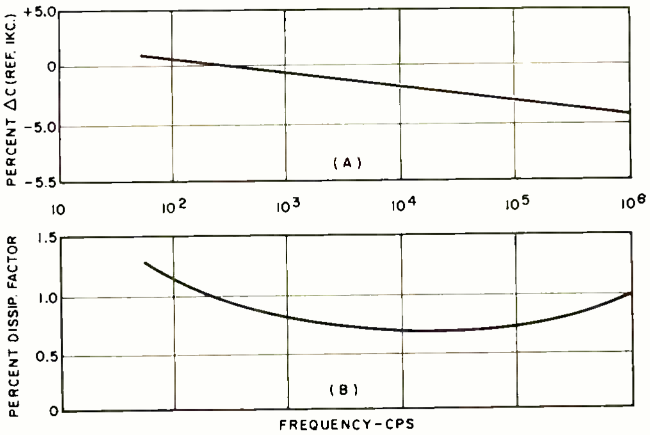


Fig. 2. Curves show the variation in capacitance and dissipation factor with frequency, for high-K type dielectric.

All capacitors of this type will exhibit lower insulation resistance than standard ceramic types, with insulation resistance decreasing with applied voltage. They are therefore best suited for use in low-impedance circuits where this low resistance will not cause loading problems. Fig. 5 illustrates the minimum leakage resistance of this particular type of capacitor rated at 25 volts.

Application Considerations

The TC type of ceramic dielectric capacitor is essentially linear and therefore ideal for use in tuned circuits to compensate for inherent impedance changes. In a receiver, this compensation can be added to the oscillator circuit to effect drift compensation throughout that portion of the receiver which is dependent on the oscillator frequency. The i.f. amplifier drift can be controlled indirectly in this same manner.

The linearity and tolerance of the temperature coefficient are slightly influenced by the physical configuration and may be noticeably influenced by the metallic mass in contact with the ceramic.

For this reason, even though the ceramic can be fabricated in a variety of shapes, the disc or tubular style is most suitable for use in critical temperature-compensating applications. Standard compensating disc capacitors are available in sizes ranging from 3/16" to 1" in diameter with voltage ratings up to 6 kv. d.c. Tubular capacitors are generally available in 1 kv. d.c. or less.

In addition to temperature compensation, the stability, high "Q," and high insulation resistance (low leakage) associated with this ceramic make it an ideal general-purpose, high-quality capacitor for use in tuned circuits, oscillators, high-frequency filters, r. f. power applications, or any

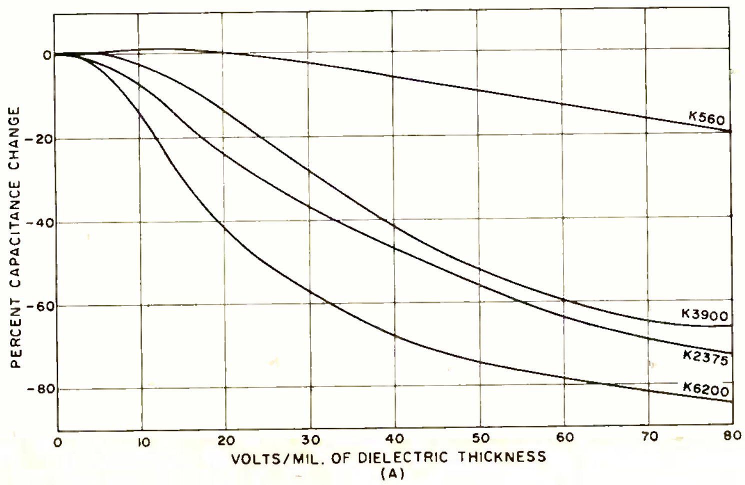
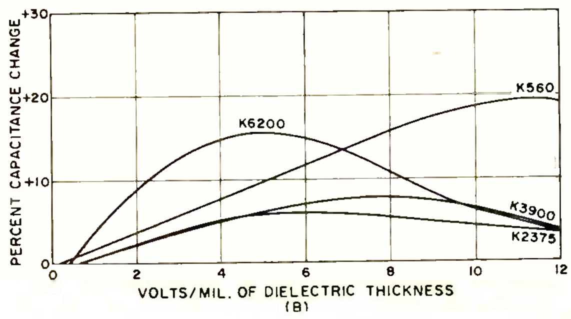


Fig. 3. (A) The d.c. voltage coefficient of capacitance at 25°C and 1 kc. (B) The a.c. voltage coefficient.



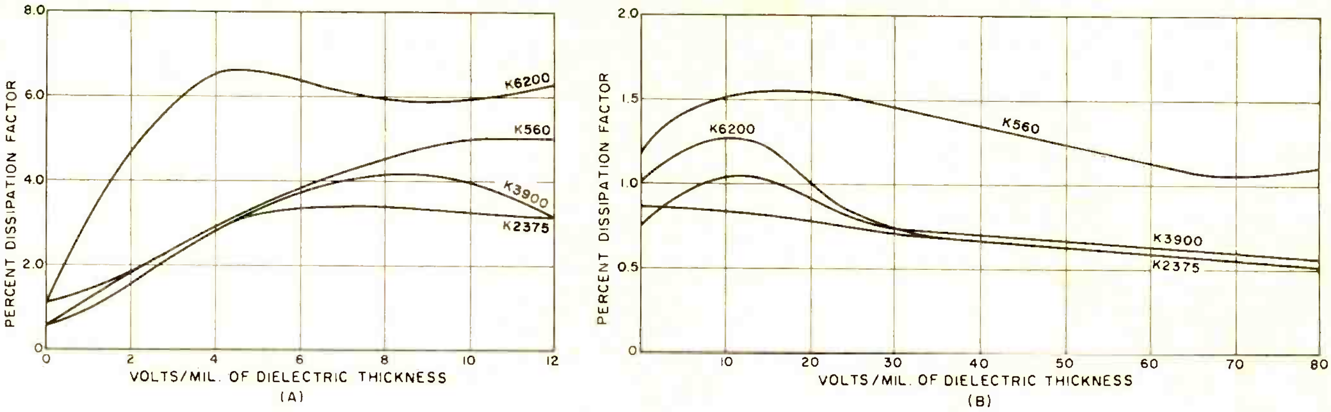


Fig. 4. The a.c. voltage coefficient of dissipation factor at 25°C and 1 kc. (B) The d.c. voltage coefficient.

other electronic circuit requiring high "*Q*" stability.

Feedthrough capacitors are a combination of bypass and feedthrough that enables the designer to run leads through the chassis and simultaneously bypass. Both TC and high-*K* materials are used in the fabrication of these units to provide very low or very high capacitance as required. They are produced in physical sizes ranging from 1/8" in length to over 8" in length and voltage ratings ranging from 50 volts to 60 kv. d.c. Conductor current-carrying capabilities can be as high as those required for broadcast transmitters.

Feedthrough capacitors are available in either tubular or discoidal forms. These latter types are considerably more expensive than the tubular configurations. Discoidal types tend to exhibit more linear attenuation characteristics in the 500- to 1000-mc. frequency range.

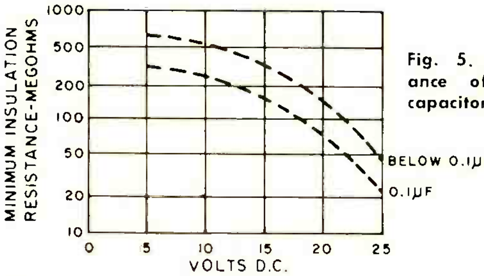


Fig. 5. Leakage resistance of semiconductor capacitor rated at 25 v.

Standoff capacitors are available in disc or tubular configurations. Tubular standoffs are used in such low-frequency applications as tie points and chassis bypass. Disc standoffs find use in high-frequency applications where lead inductance must be minimized.

Special high-voltage capacitors for induction heaters, x-ray, diathermy, and r.f. applications where high-frequency and high r.f. currents are encountered, such as plate, coupling, tank, and bypass functions, utilize the desirable characteristics of TC ceramics.

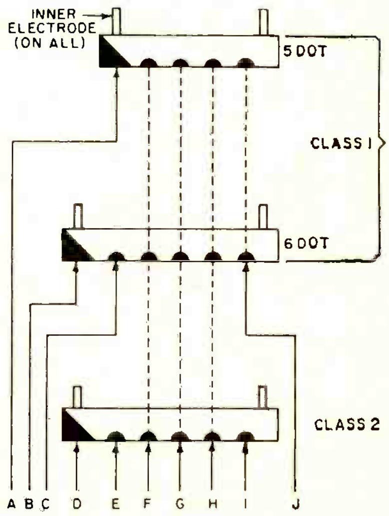
High-*K* materials can also be used in those applications where no specific temperature coefficient is required and where dielectric losses are inconsequential. These devices are designed for specific applications but in most cases utilize variations of four basic shapes, which are cup, double cup, slug, and cylinder. Voltage, current, frequency, and mechanical considerations are some of the factors which influence the final capacitor design that is to be employed in a given circuit.

Capacitors of either TC or high-*K* dielectric (as listed by *UL*) can be used as a.c. line bypass or for antenna isolation applications in commercial receivers. ▲

Ceramic-Capacitor Color Code

Color	A Temperature Coefficient (PPM/°C)	B Temperature Coefficient (Sig. Figure)	C Temperature Coefficient Multiplier	D Temperature Range (°C)	E Capacitance Change over Temp. Range	F G 1st 2nd Significant Figure	H Decimal Multiplier	I Capacitance Tolerance	J Tolerance of Capacitance <10 pf.	J Tolerance of Capacitance >10 pf.
Black	0	0.0	−1	—	±2.2%	0	1	±20%	±2 pf.	±20%
Brown	−33	—	−10	+10 to +85	±3.3%	1	10	—	±.1 pf.	±1%
Red	−75	1.0	−100	—	±4.7%	2	100	—	—	±2%
Orange	−150	1.5	−1000	—	±7.5%	3	1000	—	—	±3%
Yellow	−220	2.2	−10000	—	±10%	4	10,000	+100, −0%	—	—
Green	−330	3.3	+1	—	±15%	5	—	±5%	±.5 pf.	±5%
Blue	−470	4.7	+10	—	±22%	6	—	—	—	—
Violet	−750	7.5	+100	—	+22, −33%	7	—	—	—	—
Gray	+150 to −1500	−1000 to −5200*	+1000	—	+22, −56%	8	.01	+80, −20%	±.25 pf.	—
White	+100 to −750	—	+10,000	—	+22, −82%	9	.1	±10%	±1 pf.	±10%
Gold	—	—	—	−55 to +85	±1%	—	—	—	—	—
Silver	—	—	—	−30 to +85	±1.5%	—	—	—	—	—

*Multiplier dot is black.



NOTE

Color-code bands used on axial units.
Color-code dots used on radial units

CERAMIC-CAPACITOR SUMMARY CHART

CAPACITOR TYPE	USE	OUTSTANDING CHARACTERISTIC	D.C. WORKING VOLTAGE	SPECIFICATIONS		TYPE OF CERAMIC	INSULATION RESISTANCE (MINIMUM)	DISSIPATION FACTOR (MAXIMUM)	OPERATING TEMPERATURE
				COMMERCIAL	MIL				
DISC									
TEMPERATURE COMPENSATING	Compensate for drift in tuned circuits	High-Q & stable capacitance characteristics	Up to 500 v.	RS198 Class 1	MIL-C-20	NPO-N750	50,000 meg.	.1% @ 1 mc.*	—55°C to 125°C
			1 kv. to 6 kv.	RS165 Class 1	—				
EXTENDED RANGE TEMP. COMPENSATING	Circuits requiring high-Q & stability	High-Q & stable capacitance characteristics	Up to 500 v.	RS198 Class 1	—			.6% @ 1 mc.*	—55°C to 85°C
			1 kv. to 6 kv.	RS168 Class 1	—	N1000 N5250	50,000 meg.		
HI-K CERAMIC DIELECTRIC	Bypass & coupling	High capacitance in small package	Up to 500 v.	RS198 Class 2	MIL-C-11015	Hi-K	20,000 meg.	1.5% @ 1 kc.	—55°C to 200°C
			1 kv. to 6 kv.	RS165 Class 2	MIL-C-11015 Some				
A.C. RATED	Line bypass & antenna isolation	High capacitance in small package	150 v.r.m.s.	UL 492	—	NPO-N750	50,000 meg.	.2% @ 1 mc.*	—55°C to 85°C
						N1000-N5250	50,000 meg.	.6% @ 1 mc.	
						Hi-K	20,000 meg.	.15% @ 1 kc.	
LOW VOLTAGE (ULTRA-KAP)	Low voltage circuits	Very high capacitance in small package	3 v.d.c. to 25 v.d.c.	—	—	Special	2000 ohm to 10 meg.	5% to 15% @ 1 kc. depending on voltage	—55°C to 85°C
TUBULAR									
TEMPERATURE COMPENSATING	Compensate for drift in tuned circuits	High-Q & stable capacitance characteristics	Up to 1 kv.	RS198 Class 2	MIL-C-20	NPO-N750	50,000 meg.	.1% @ 1 mc.*	—55°C to 125°C
EXTENDED RANGE TEMP. COMPENSATING	Circuits requiring high-Q & stability	High-Q & stable capacitance characteristics	Up to 1 kv.	RS198 Class 1	—	N1000-N5250	50,000 meg.	.6% @ 1 mc.	—55°C to 85°C
HI-K CERAMIC DIELECTRIC	Bypass & coupling	High capacitance in small package	Up to 1 kv.	RS198 Class 2	—	Hi-K	20,000 meg.	1.5% @ 1 mc.	—55°C to 85°C
FEEDTHRU	Tuner & other feed-thru applications	Dual function low cost	Up to 60 kv.	—	—	NPO-N750	10,000 meg.	.2% @ 1 mc.*	—55°C to 125°C
						N1000-N5250	10,000 meg.	.6% @ 1 mc.*	—55°C to 85°C
						Hi-K	10,000 meg.	2.5% @ 1 kc.	—55°C to 125°C
SPECIAL									
TRANSMITTING	Transmitters induction heaters, electronic welding, x-ray, diathermy	High-Q & stable capacitance characteristics	Up to 60 kv.	—	—	NPO-N750	10,000 meg.	.1% @ 1 mc.*	—55°C to 85°C
						N1000-N5250	10,000 meg.	.2% @ 1 mc.*	—55°C to 85°C
						Hi-K	10,000 meg.	1.5% @ 1 kc.	—55°C to 125°C
MISC.									
GLASS DIELECTRIC CAPACITORS	Circuits requiring high-Q & stability	High-Q & stable capacitance characteristics	Up to 500 v.	—	MIL-C-11272	P140	100,000 meg.	.1% @ 1 kc.	—55°C to 125°C
PORCELAIN DIELECTRIC CAPACITORS	Tuned circuits, high-freq. circuits		500 v.	—	MIL-C-11272	P105	100,000 meg.	.1% @ 1 kc.	—55°C to 125°C
MULTI-LAYER CERAMIC	These capacitors are extensions of the std. disc capacitor. Very high capacitance is obtained thru the use of multiple plates.		25 v. to 200 v.	—	MIL-C-11015	TC	100,000 meg.	.2% @ 1 mc.	—55°C to 150°C
						Hi-K		1.5% @ 1 kc.	

*Limits are for capacitance values above 30 pf. See RS198 or MIL-C-20 for limits below 30 pf.

Plastic-Film Capacitors

By WALTER C. LAMPHIER / Senior Product Specialist, Sprague Electric Co.

Advances in plastic chemistry have produced an open-ended list of capacitor dielectrics whose electrical characteristics can be tailored to suit almost any particular circuit need.

AMONG the plastic-film dielectrics presently used in capacitors are polystyrene, polypropylene, polytetrafluoroethylene, polyester, polycarbonate, cellulose tri-acetate, polypyromellitimide, and polyparaxylene. The basic construction of capacitors using these materials is quite similar. They may be considered as parallel-plate capacitors which have been rolled into a coil. For the most part, the conducting plates extend from opposite ends of the coil and have leads attached. The capacitor roll is protected from the external environment by a metal case, a plastic housing, or a plastic encapsulation. Fig. 1 shows the basic construction of a typical capacitor which might use any of the these dielectrics.

The photograph (next page) shows a number of capacitors which demonstrate the numerous variety of external housings and terminal arrangements in which plastic-film dielectric capacitors are furnished.

The dielectric materials mentioned may be used to produce extremely thin sheets which are employed as the separators in plastic-film capacitors. Each material is used in capacitors because some particular characteristic or combination of characteristics of the resulting capacitors is unique and most advantageous for specific circuit applications. Table 1 covers some of the more important physical and electrical properties of these materials.

Polystyrene

Polystyrene is a polymer of the aromatic styrene monomer and possesses outstanding electrical characteristics. Using this material, capacitors may be made to capacitive tolerances as close as 0.1%. They will retain this precise value almost indefinitely, even following moderate temperature changes. The high resistivity and small negative, but linear, temperature coefficient of capacitance make them very useful in analog computers. The two chief limitations to the use of polystyrene capacitors are the 85°C maximum operating temperature and their relatively large size.

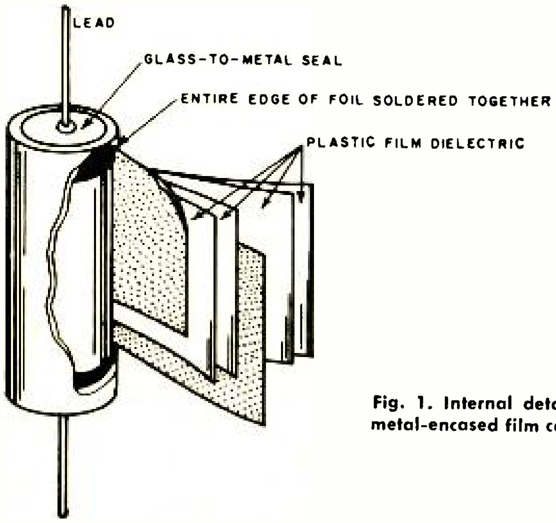


Fig. 1. Internal details of a metal-encased film capacitor.

Polypropylene

Polypropylene is an aliphatic polymer of the propylene monomer and possesses outstanding electrical characteristics similar to polystyrene. It is available from high-volume production equipment and hence has the lowest price per pound of any of the organic materials mentioned. Unfortunately, it has some serious limitations because of its physical properties. It has low tensile strength and thus is limited to a minimum thickness of 1.0 mil (0.001") at the present time. Its lack of physical stability prevents it from having the outstanding electrical stability that is characteristic of properly made polystyrene capacitors.

Polytetrafluoroethylene

Polytetrafluoroethylene (PTFE) is an aliphatic polymer of the fluorinated carbon atom. Its intrinsic insulating properties are the best of all plastic materials presently used. The highly symmetrical fluorinated carbon atom, as well as a lack of impurities in the material as manufactured, result in the highest resistivity and lowest loss factor of all organic dielectric materials used in capacitors. It also has a small linear negative temperature coefficient of capacitance. PTFE does not melt but may be sintered above 300°C, indicating high bond strength which may be capitalized upon to produce capacitors rated for reliable operation at 200°C. The two most striking drawbacks of TFE-fluorocarbon capacitors are their large size and high cost. The size is greater than that of polystyrene capacitors and the cost is five times as great. Because of these limitations, PTFE capacitors are used as a last resort when the highest insulation resistance possible, a linear temperature coefficient above 85°C, or an operating temperature above 150°C are key parameters. The material is available from several sources here and abroad under such names as Teflon-TFE, Fluon, Halon, and other trademarks. It also has widespread uses in such applications as coating for chemical ware and cooking utensils because it is inert to most chemicals and materials do not adhere to it.

Polyester

Polyester capacitors are presently the most widely used of all plastic-film capacitors. The most common polyester which is employed is a product of the reaction of terephthalic acid and ethylene glycol. The latter may be familiar as the standard non-boiling automotive antifreeze material. Polyethylene terephthalate was originally developed abroad and its electrical characteristics were first published in 1949. It is not only used as a capacitor dielectric but it is also one of the most widely used synthetic materials for making fibers for weaving cloth. *Imperial Chemical Industries*, which originated PETP (to use the common abbreviation), markets its capacitor film under the trademark Melinex and its fiber as Terylene. *E. I. DuPont de Nemours*, which introduced the material into the U. S., calls it Mylar or Dacron for the corresponding applications. A heavier gauge film for photographic purposes is

	Polyester	Polystyrene	Polycarbonate	Polypropylene	Polytetra-fluoroethylene	Cellulose-tri-acetate	Polypyro-mellitimide	Polypara-xylene
Diel. Const. (1kc.)	3.1	2.55	3.0	2.2	2.1	4.5	3.1	2.7
D.F. (1kc.)	.004	.0002	.0009	.0006	.0001	.022	.001	.0002
Volume Res. (ohm-cm.)	10^{18}	$>10^{18}$	$>10^{17}$	10^{17}	$>10^{18}$	10^{12}	10^{18}	10^{18}
Gauge	15-100	25-100	8-100+	40-100	25-100	100* / <10**	50-100	<10**
Temp. Range (°C)	T_o+150	T_o+85	T_o+125	T_o+105	T_o+200	T_o+125	T_o+200+	(air)+70 (inert)+200
T.C. (PPM/°C)	+333(85°C)	−120	−75(+75)***	−200	−200	+500	+60	−50
Available as Metallized	yes	no	yes	no	yes	yes	development	development
Outstanding Characteristic	tensile strength, dielectric strength	linear T.C. low D.F. high resis.	low D.F.	light low D.F. inexpensive	low D.F. high resis. high temp. linear T.C.	high dielectric constant	high temp. low D.F. good T.C.	T.C. low D.F. high I.R.

* Unsupported film ** Supported film *** Depends on construction

Table 1. Characteristics of the various dielectrics which are used in the manufacture of plastic capacitors.

sold under the trademark Cronar by *DuPont*. Other vendors have recently come on the market with PETP as well, selling it simply as an XX-brand polyester or under other trademarks, such as Celanar, etc. A somewhat similar polyester material with slightly different qualities, polycyclohexylene dimethylene terephthalate (abbreviated as PCHMTP or PMPT), is sold by *Eastman Kodak* under the trademark Kodar.

Polyester, as made by *DuPont*, was the first dielectric film to effectively challenge the use of kraft paper in an important segment of the capacitor field. The material is physically very tough. Moreover, it may be obtained in near-perfect sheets as thin as 0.15 mil (15 gauge), 1/20 the thickness of a typical brunette hair. It exhibits a much greater tolerance toward atmospheric contamination, such as from moisture, than does kraft paper. For this reason, non-hermetically sealed polyester-film capacitors have substantially replaced the conventional "paper tubular." Polyester capacitors must be operated below the corona, or flash-over voltage of air, since voids are always present. As a consequence, alternating voltages above 250 volts r.m.s. and direct voltages above 2500 volts are frequently detrimental to dry-wound polyester capacitors. A further limitation in PETP film is the second-order transistion in the material which may occur between 85° and 125°C. Indications are a substantial increase in capacitance, a peak in the loss factor, and a pronounced increase in failure rate under d.c. operation.

A combination dual dielectric of polyester film and kraft paper with various impregnants, either "solid" or liquid, overcomes some of these problems and increases reliability. These dual dielectric capacitors are very widely employed.

Polycarbonate

Polycarbonate, while also a polyester, is usually referred to by this generic name. It is formed by reacting bisphenol-A and phosgene. The latter may be remembered as a poisonous gas used in World War I.

The KG-polycarbonate material offered by the German firm *Farbenfabriken Bayer A. G.* has proven to be superior to polycarbonates from other sources when used as a capacitor dielectric. The thickness gauges are approximately the same as those of Mylar-brand PETP. Its handling properties are quite similar; however, polycarbonate does not exhibit the second-order transition characteristic of PETP and retains its excellent electrical qualities at temperatures as high as 140°C. Both the resistivity and loss factor approach the values for polystyrene. The capacitance of polycarbonate units will change about 1% from room temperature over the operating temperature range. The curve or capacitance change with temperature is crescent-shaped with its maximum at about room temperature. Capacitance stability with time is very good but not quite as excellent as that exhibited by polystyrene capacitors. At this time, the two factors that have prevented its use in a major section of the capacitor field are the physical condition of the sheet and the cost of the film, which is more expensive than either paper of PETP-polyester.

It should be noted that dual-dielectric capacitors, which balance the characteristics of PETP and polystyrene to achieve an essentially zero temperature coefficient of capacitance over a wide temperature range, in many cases may be replaced by polycarbonate units.

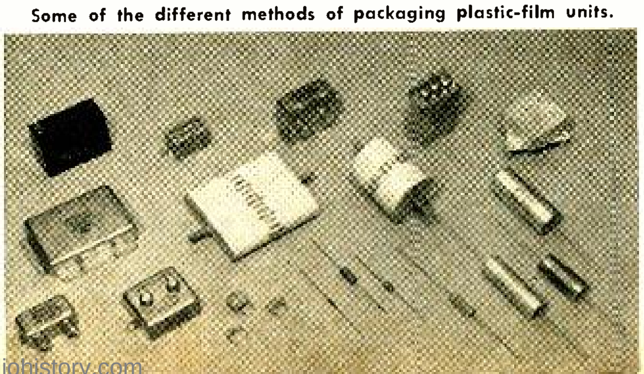
Cellulose Tri-Acetate

Cellulose tri-acetate (CTA), which is a nearly completely acetylated cellulose, has been well known for many years. Straight cellulose acetate and cellulose acetate butyrate have also been used as capacitor dielectrics but have been sustantially replaced by polyester. Cellulose tri-acetate, however, may be manufactured in film as thin as 4 gauge or 0.00004". The smallest capacitor which can be manufactured from CTA film is ⅓ the volume of the smallest equivalent PETP capacitor. Electrical properties of the cellulose tri-acetate capacitors are adequate for most requirements at temperatures up to 85°C but are a limitation on their use at higher temperatures.

Polypyromellitimide

Polypyromellitimide film is made from a resin resulting from the condensation reaction of pyromellitic dianhydride and an aromatic diamine. This unique organic polymer, sold by *DuPont* under the trademark Kapton-H polyimide,

Some of the different methods of packaging plastic-film units.



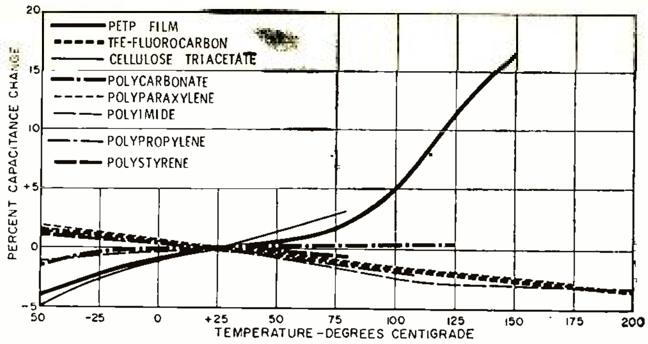


Fig. 2. Capacitance change vs temperature for various plastics.

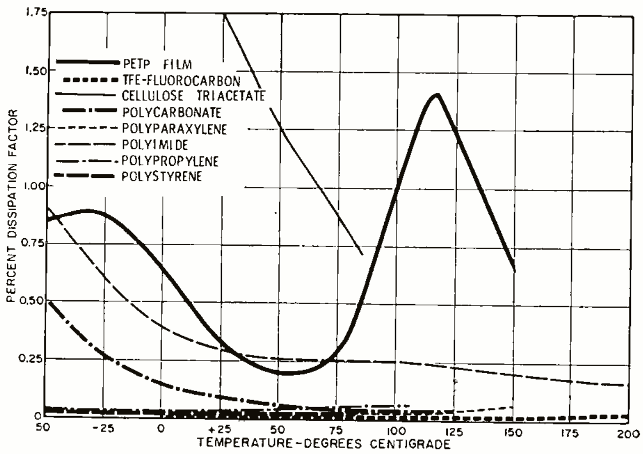
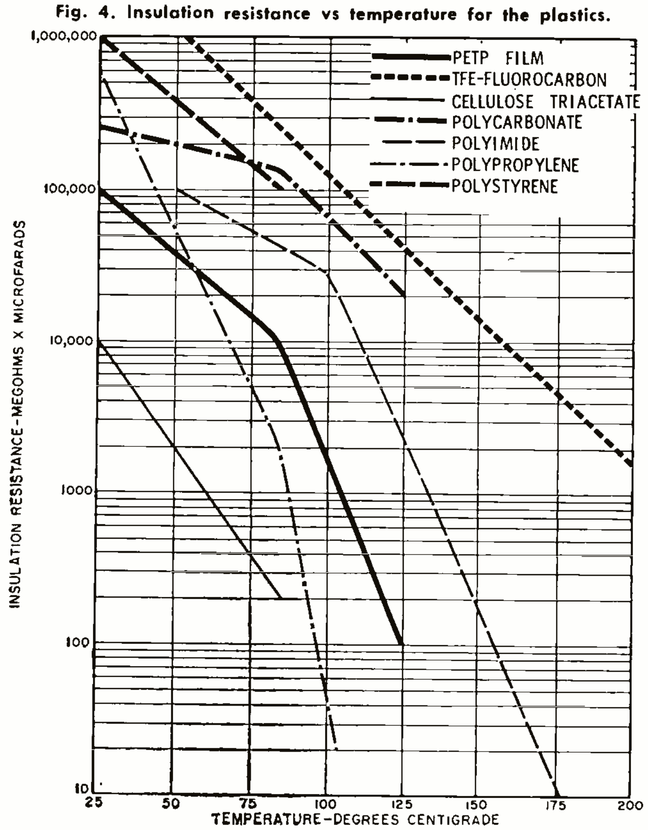


Fig. 3. Dissipation factor vs temperature for various plastics.

is capable of being used over a very wide temperature range and is highly stable. Its electrical characteristics approach those of TFE-fluorocarbon except that the temperature coefficient of capacitance is positive and not precisely linear. The material presents a number of exciting possibilities to the capacitor designer and user; but its ultimate value will best be determined after some history in capacitor production when it has passed the pilot-plant stage, production problems have been solved, and prices have been firmed. This should not be too far in the future.

Fig. 4. Insulation resistance vs temperature for the plastics.



Polyparaxylene

Polyparaxylene polymer may be deposited on electrodes in extremely thin films. It is consistent with the other highly priced plastics mentioned previously in yielding a dielectric strength of several thousand volts per mil. Capacitor data to this time is quite limited because the material is still in the final stages of development for this application. Available information does hold out the prospect of a substantial reduction in capacitor sizes for uses above 125°C.

Because this film can be vapor deposited directly onto the metal electrodes as a pure uniform polymer in thicknesses one-third that of free film dielectrics, stable devices having less than one-fifth the size of polystyrene capacitors of equivalent electrical rating can be produced.

Comparisons

Capacitors produced from these materials are compared in a number of ways when selecting the proper type to best meet circuit needs. The curves given in Figs. 2, 3, and 4, showing variation in capacitance, dissipation factor, and insulation resistance to temperature, illustrate the type of data used for this purpose.

In addition to these fundamentals, two other features of organic-film capacitors must be taken into consideration. Of the eight materials mentioned, polystyrene has not been extensively available or used in the metallized form. Thin sheets of polystyrene must have very low voltage ratings, and the basic size problem which exists with capacitors made from this material becomes amplified. Both TFE-fluorocarbon and polyparaxylene can be deposited on electrodes by vacuum techniques which permit film thicknesses of less than 1000 Angstrom units. These techniques are still in the embryonic stages but do present the possibility of low-voltage film capacitors in the future being minified to approach the sizes, in some cases, of aluminum electrolytic capacitors. As previously mentioned, two different films may be used together in a capacitor winding, either in series or in parallel within the same roll. The resultant compromise in electrical characteristics can be forecast from curves of Figs. 2, 3, and 4. The PS/PETP combination, which has substantially zero capacitance change from 0°C to 80°C, is the best in this respect of any known capacitor, including the so-called NPO ceramics.

MIL Spec

One measure of the acceptance of a new type of capacitor in industry is found in the status of its Military Specification. MIL Specs are written only after a capacitor has had some usage by suppliers of military electronic equipment. A rule of thumb might be that a MIL Spec is generated after two to three years of significant and successful usage. Keeping this in mind, Table 2 may be of interest, setting forth as it does the present specification status in the Department of Defense of capacitors which are currently manufactured from the organic plastic materials discussed in this article. ▲

Table 2. MIL-Specs covering some of the plastic dielectrics.

Type Capacitor Dielectric	MIL Type No. or Characteristic	MIL Spec. No.
Polystyrene	Char. P	MIL-C-19978
Polytetra-fluoroethylene	Char. T	MIL-C-19978
Polyester	Char. M CTM	MIL-C-19978 MIL-C-27287 (USAF)
Metallized-Polyester	Char. R	MIL-C-39022

Paper Capacitors

By WILLIAM M. ROBINSON / Chief Engineer, Cornell-Dubilier Electronics Div., Federal Pacific Electric Co., New Bedford, Mass.

One of the most widely used types of capacitor, the paper type has characteristics mostly dependent on the type of impregnant used.

PROBABLY the least exotic member of the capacitor family is the paper-dielectric capacitor. It is well known that mica types have much better over-all electrical characteristics, film dielectrics have lower losses and better resistance to humidity, and electrolytics and ceramics are smaller in size and lower in cost. Yet, after seventy years of commercial application, paper capacitors are still the most widely used capacitive component.

Paper capacitors range in physical size from the subminiature to huge complex banks—in ratings from a few volts to hundreds of thousands of volts. Paper capacitors are well suited for a.c. or d.c. service, pulse and energy-storage applications, and for use in simple electronic devices or the most complex computers.

Basic Construction

Basic materials for all paper-capacitor elements are kraft paper, aluminum foil, and a liquid wax or resin impregnant. The type of paper and impregnant, as well as vital design factors, determine the rating and establish the over-all performance characteristics of the finished capacitor. Packaging in a metal or insulated housing, together with the type of terminals used, limits or extends the capacitor's capability with respect to environmental performance.

Dielectric Structure

A paper capacitor receives its name from its basic dielectric material, kraft paper. This material is not just a porous separator as found in electrolytic capacitors but is a vital part of the dielectric structure.

Kraft capacitor tissue is manufactured from specially selected unbleached sulfate pulp made from certain species of soft woods. These pulps are chosen for their uniformly long fibers and high degree of purity. The pulps are made to rigid specifications to insure that the fiber length, chemical composition, and purity of each lot will meet exacting requirements.

There are many types and grades of kraft for use as a dielectric. Some of these perform better on a.c., others on d.c., depending upon the dielectric strength and dissipation factor.

Aluminum foil used for paper capacitors ranges from .00017 to .0005 inch in thickness and has a purity of at least 99.8%. The surfaces must be free from all traces of rolling lubricants and other sources of contamination. Although tin-lead alloy foil is occasionally used on very small capacitor elements, aluminum is preferred because of its resistance to corrosion and electrochemical action, both of which are apt to severely degrade the capacitor electrical characteristics under certain operating conditions.

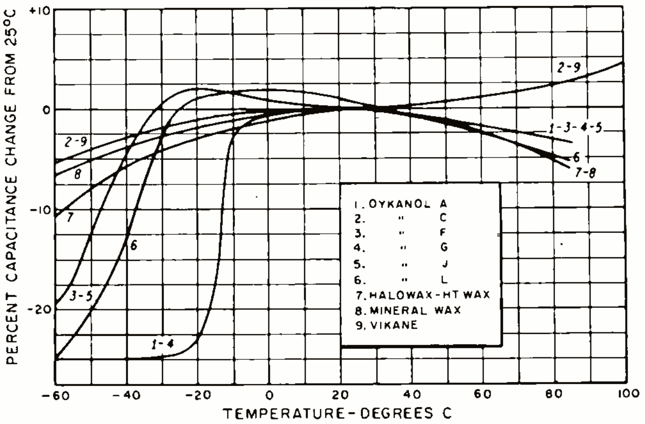
Use of impregnants for kraft paper improves the dielectric strength greatly and increases the dielectric constant, consequently reducing both the size and cost for any given capacitor rating. The impregnant also establishes the temperature-capacitance characteristics as shown in Fig. 1 and is an important factor contributing to the insulation resistance and dissipation factor of the finished capacitor. Some impregnants are used exclusively in capacitors for d.c. service, others for a.c. capacitors, depending upon the dissipation factor and dielectric strength they impart.

Design Factors

The voltage rating is established by the selection of the type, thickness, and number of layers of kraft paper, together with the characteristics of the impregnant used. Insulation spacing between metal parts of the element is directly related to the voltage rating. Capacitance is proportional to the area of the aluminum-foil electrodes and inversely proportional to the distance between the electrodes. Design factors determining capacitance are $C = (.225\ A\ K)/(T \times 10^3)$ where A is the active electrode area in square inches, K is the dielectric constant of material, T is the dielectric thickness in mils, and C is the capacitance in microfarads.

Winding of the capacitor element is accomplished with automatic or semi-automatic machines to minimize hand contact and to assure uniformity of the product. Fig. 4A shows a wound roll of kraft and aluminum foil together with inserted tinned-copper contact strips. The extended-

Fig. 1. Capacitance change with temperature for kraft paper dielectric material showing effects of various impregnants.



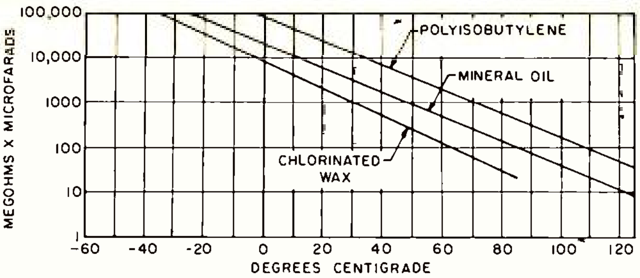


Fig. 2. Insulation resistance characteristics of paper capacitors showing effects of the various types of impregnants.

foil type of winding, shown in Fig. 4B, has the foil protruding so connections may be made externally. Inserted-tab construction is generally used for d.c. or low-frequency a.c. capacitors, the extended foil being used for the smaller sizes, those used at higher frequencies, or where high-current pulses or discharges are required in operation.

Paper capacitors are usually made with two aluminum foils separated by two or more layers of kraft. Higher voltage windings often employ twelve or more papers with as many as six foils.

Many of the smaller, lower-cost paper capacitors for the entertainment field are impregnated at this stage. Assembly in non-metallic molded, tubular, or dipped enclosures follows the operation of attaching lead wires. This is the wet-assembly method of manufacture.

Most military and industrial capacitors, including all those for a.c. and higher voltage ratings, are made by the dry-assembly process. This consists of assembling the windings in metal containers and, after seaming, conducting the impregnation process through a small hole in the case. The hole is then sealed.

Dry-assembly processed capacitors are made in almost an infinite variety of shapes and sizes using squeezed-seam, rolled-seam, and welded-seam containers.

Terminal connections and insulators range from the subminiature to extremely large sizes. The capacitor element and internal circuit connections are generally heavily insulated from the case with thick sheets of kraft paper made to the same requirements as for the dielectric paper.

Impregnation

Capacitors are loaded into the impregnation tanks where they are subjected to extended heat and vacuum cycles to remove all traces of moisture and air. This process is conducted at temperatures well below the critical level, which would be harmful to the kraft paper, by extending the time and monitoring the temperature and vacuum frequently. Force-drying the elements at excessively high temperatures to reduce process time is generally detrimental to reliable operation.

After the internal parts of the capacitor element have been thoroughly evacuated and dried, the tanks are flooded with the impregnant. Alternate vacuum and pressure cycles are applied so that every fiber of the paper is thoroughly impregnated and all voids are removed.

Finishing and QC

At the end of the impregnation cycle, the capacitors are removed from the tanks, drained, sealed, and cleaned, and markings are applied over plain, painted, or plated finishes. The QC (quality-control) program includes 100% tests of capacitance, dielectric strength, seal, and mechanical inspection, as well as statistical checks of insulation resistance and dissipation factor.

Test facilities are used to conduct life tests to determine quality-level and service-life capabilities to verify design standards and to accumulate data for reliability studies. These facilities consist essentially of high-temperature ovens with adjustable a.c. or d.c. power supplies and controls to maintain specified test conditions. Before any new design standard or material is used in a paper capacitor, it is thoroughly evaluated under accelerated life conditions.

Special Constructions

The capacitors previously described are of conventional foil-paper construction. Other types are made using series-wound elements with high-voltage ratings and low-inductance conductors for energy-storage and pulse applications. Such capacitors often are required to deliver discharges of tens of thousands of amperes in intervals as short as a few microseconds.

Plastic films are also used in conjunction with paper for a dielectric having special characteristics of capacitance change with temperature and an extremely high insulation resistance. The mixed dielectric combines the best properties of both materials, frequently resulting in a more reliable product, although at a higher cost.

Metallized paper capacitors with vapor-deposited metal electrodes are available where space will not accommodate standard capacitors. The smaller size is obtained by use of electrodes less than one micron thick and reduced dielectric for a given rating. This type of unit has limited self-healing properties upon voltage breakdown, as the electrode material will fuse and clear by electrical discharge. Metallized capacitors are used in ratings up to 600 v.d.c. They should not be employed in circuits where high insulation resistance is a necessary critical requirement.

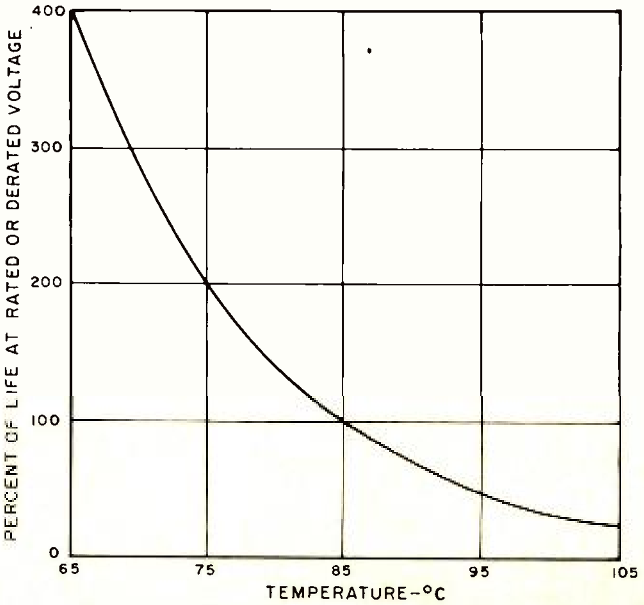
Power Losses

Even though paper capacitors normally perform to more than 99.5% efficiency, there are internal power losses that must be considered for units operating in a.c. or pulse circuits. The methods of calculating power loss for a.c. operation is Watts Loss = D.F. (E^2/X_c) where D.F. is the dissipation factor of the capacitor, E is the applied r.m.s. sine-wave voltage, and X_c is the capacitive reactance of the device involved.

The method of calculating power loss for pulse operation is Watts Loss = D.F. ($C\,E_1^2\,N$) where C is the capacitance in farads, E_1 is the applied peak voltage, D.F. is the dissipation factor of the capacitor, and N is pulses per second.

Approximately .06 watt per square inch of case surface area will result in a 10°C rise above the ambient tempera-

Fig. 3. How temperature affects life of a paper capacitor.



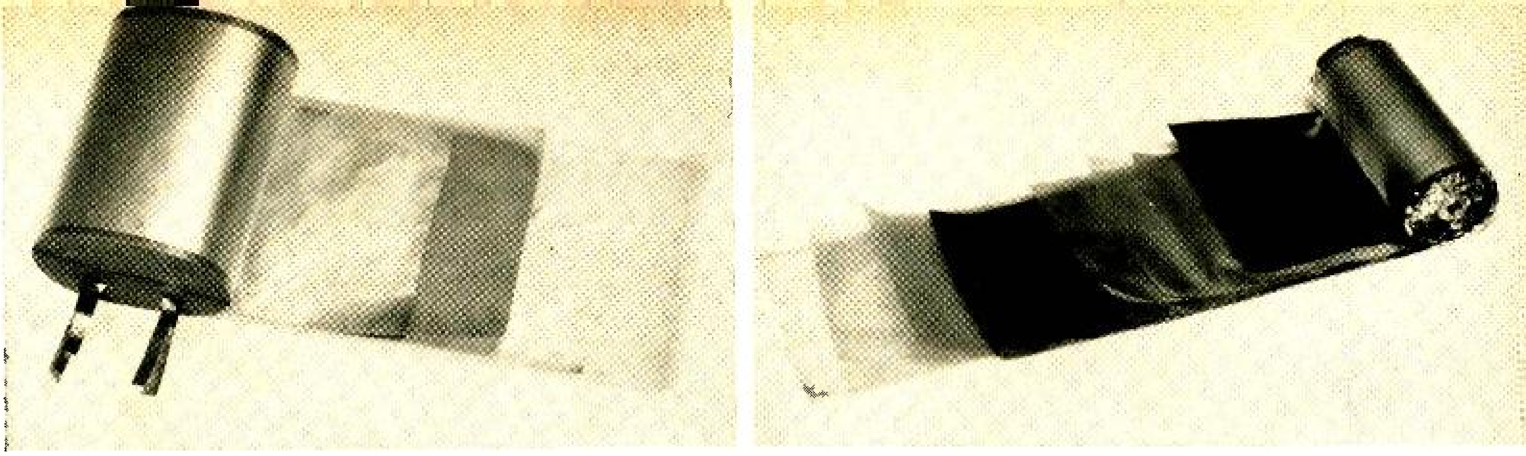


Fig. 4. (A) Paper capacitor element made with inserted contact tabs. (B) Paper capacitor element extended foil construction.

ture, assuming the capacitor is operating in still air. This temperature rise has a marked effect on capacitor life, as will be described.

When making the calculations for power loss, the dissipation factor may be assumed to range from .0025 to .005, depending upon the type of impregnant used. The actual temperature rise may, of course, be measured by testing the capacitor under the given conditions.

Effects of Temperature

Paper dielectric capacitors are designed to operate at ambient temperatures of 55°C, 70°C, 85°C, or 125°C, depending upon the design standards and impregnants used. Chlorinated or mineral waxes and oils are generally limited to 85°C. Silicone-fluid, certain resins, and polyisobutylene-impregnated capacitors may be used to 125°C. Higher temperatures result in gradual decomposition of the cellulose fibers of the paper, as well as chemical changes in the impregnants, causing degradation of electrical characteristics of paper capacitors.

Effects of temperature and capacitance are shown in Fig. 1. The large loss in capacitance for some impregnants is due to change in the dielectric constant of these materials. Such capacitors recover full capacitance when returned to room temperature. Units operating in a.c. or pulse circuits frequently generate sufficient heat through internal losses to recover full capacitance after less than one hour of operation, even though they are exposed to very low ambient temperatures.

Designers must also consider insulation-resistance changes with temperature. Shunt leakages are often 100 times greater at high ambient temperatures than at 25°C, as shown in Fig. 2. Insulation resistance of capacitors may also decrease with life due to the effects of moisture on units made in non-metallic cases and chemical changes in those made in hermetically sealed construction. Circuits should be designed to accommodate ten times the leakage current specified for a given capacitor with an additional adequate allowance for operation at high temperatures.

Dissipation-factor changes with temperature are not significant except for capacitors operating in a.c. or pulse circuits.

Life performance of paper capacitors is related to ambient temperature. A 10°C increase may reduce life as much as 50%, as shown in Fig. 3. Use of capacitors at temperatures below maximum rating is recommended to extend life and lower failure rates. This may also be accomplished by using capacitors at less than rated voltage where higher ambient temperatures cannot be avoided. When designing a mechanical layout for equipment, capacitors should be located as far as possible, or thermally insulated from, sources of damaging heat such as tubes, transformers, and power dissipating resistors.

Voltage Effects

A well-designed paper capacitor generally is rated for

CAPACITOR PRECAUTIONS

1. Keep all large capacitors, high-voltage or high-capacitance types, fully discharged with a low-resistance or shorting wire connected across the terminals. Many persons have been seriously injured by touching capacitors long after they had been removed from a source of voltage.

2. Install capacitors away from sources of heat such as tubes, transformers, or power resistors.

3. Do not exceed the temperature or voltage ratings unless such service is approved by the manufacturer.

4. Do not discharge a capacitor with a direct short circuit unless the capacitor is rated for this type of service. Direct discharge may result in an exceedingly high current flow from the capacitor or set up an oscillatory discharge which may be harmful to the capacitor. Limit the discharge current to one ampere unless the capacitor is designed for higher current service.

5. Keep non-metallic cased capacitors in a dry storage area, not exposed to a humid atmosphere.

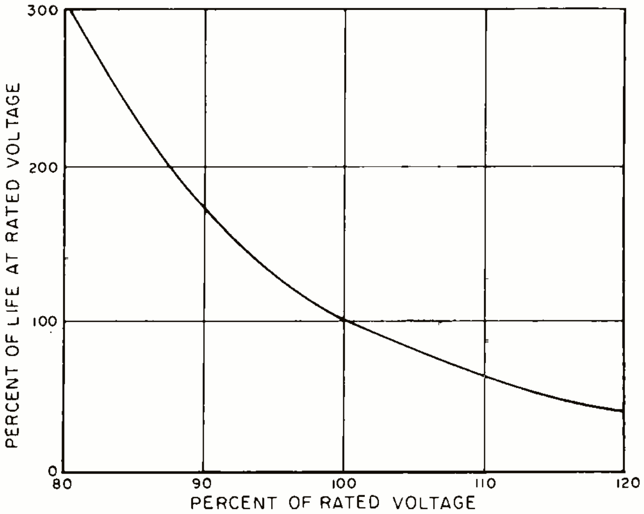
6. Solder connections to capacitors in a manner which will not damage the seal. On wire-lead types, soldering should be done at least ¼" away from capacitor body.

7. Use a torque wrench when tightening nuts to avoid damage to capacitor seal.

8. Do not subject capacitors to any unusual environmental conditions of vibration, shock, pressure, or immersion without first checking with the manufacturer.

9. Allow a maximum of ventilation for a.c. or pulse capacitors operating at high ambient conditions.

Fig. 5. How voltage affects the life of a paper capacitor.



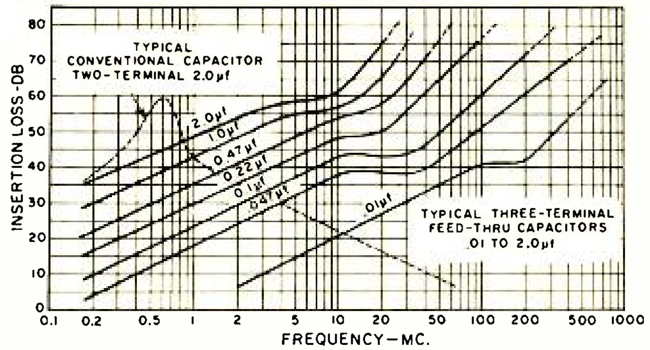


Fig. 6. Attenuation characteristics of conventional and feedthrough capacitors as measured in a 50-ohm circuit.

a life capability of more than 50,000 hours. However, service conditions may shorten or extend this time. In addition to the temperature effects, the applied voltage also has a considerable bearing on the successful performance of a capacitor.

Both industry and the military have accepted in their specifications the use of the fifth-power rule relating to the voltage life of paper capacitors for d. c. operation. The following equation shows the relationship between the applied voltage and operating life: $L_2 = L_1(V_1/V_2)^5$ where L_1 is the life at rated voltage V_1, L_2 is the life at voltage V_2, V_1 is the rated voltage, and V_2 is the intended operating voltage.

Fig. 5 shows that operation for 20% under rated voltage will result in almost a 300% increase in capacitor life. This factor applies mainly to hermetically sealed paper capacitors, but it may also be applied to non-metallic cased types if desired circuit operation is not critical with respect to the capacitor insulation resistance.

Frequency Effects

Electrical characteristics of capacitance and dissipation factor remain fairly stable at increased frequencies. There may be a 5% to 10% loss of capacitance at frequencies above 1 mc. as compared with 60-cycle or 100-cycle values. Dissipation factors will also be somewhat higher.

Since all capacitors contain some degree of series inductance as well as shunt resistance, the effect of these on impedance must be considered in circuit design. Inductance is caused by circuit connections to the capacitor element. Series resistance is also contributed by these connections and the foil electrodes. Shunt resistance results from normal dielectric leakage.

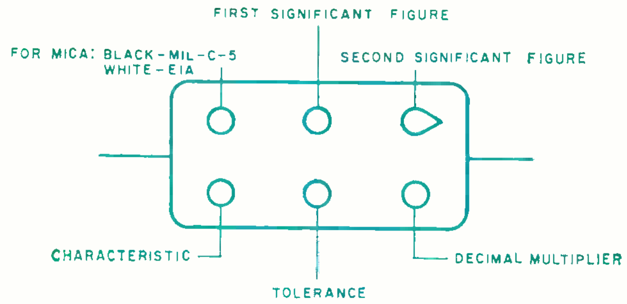
At the higher frequencies, conventional paper capacitors can be expected to perform as shown in Fig. 6 with exact characteristics dependent upon capacitance value and type of circuit connections to the element. Feedthrough capacitors of coaxial construction have much better frequency characteristics although they employ paper dielectrics.

When using d.c. paper capacitors in audio- or radio-frequency circuits, precautions must be observed to limit voltage to prevent overheating and greatly reduced life. At 60 cycles, the maximum voltage applied should be less than 20% of rating; at 1000 cycles, 6%; and at 10,000 cycles and higher, only 1%. These values may be exceeded only if a specific capacitor is evaluated under the intended conditions of operation and is found to stabilize within its maximum ambient temperature rating. ▲

MICA-CAPACITOR COLOR CODE

The electrical value of a mica capacitor can be determined from an examination of the six-dot color code imprinted on the body of the capacitor.

When the capacitor is being read, the direction indicator (an arrow on the body in some form) should point to the right of the reader. The dots are read from left to right across the top row and from right to left across the bottom row, in that order.



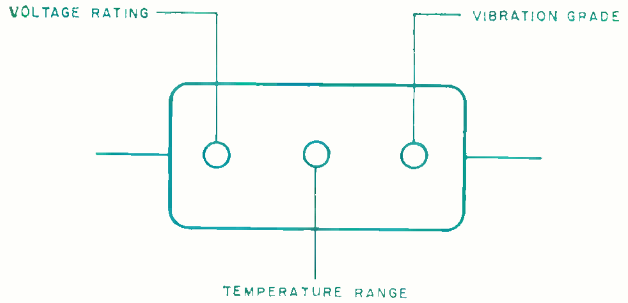
Color	First and second significant figure	Decimal Multiplier	Tolerance	Characteristic
black	0	1	±20%	—
brown	1	10	±1%	B
red	2	100	±2%	C
orange	3	1000	±3%	D
yellow	4	—	—	E
green	5	—	±5%	F
blue	6	—	—	—
purple	7	—	—	—
gray	8	—	—	—
white	9	—	—	—
gold	—	.1	±5%	—
silver	—	.01	±10%	—

The only exception which may be made occurs when three significant figures are to be found in the characteristic. In this case the upper three dots represent the three significant figures and the identification color is eliminated.

Characteristic Code

Letter	Temperature Coefficient (PPM/°C)	Capacitance Drift
B	MIL—not specified EIA—±500	MIL—not specified EIA—±(3% + 1 pf.)
C	−200 to +200	MIL—±(.5% + .1 pf.) EIA—±(.5% + .5 pf.)
D	−100 to +100	±(.3% + .1 pf.)
E	−20 to +100	±(.1% + .1 pf.)
F	0 to +70	±(.05% + .1 pf.)

If the color code is to be used to identify a MIL molded or dipped mica capacitor, a nine-dot sequence is used. The six dots on one face of the capacitor remain and have the same identification as the six-dot code previously discussed. There are three additional dots on the reverse side of the capacitor and these are identified as follows:



MIL 9-Dot Code

Color	Voltage Rating	Temp. Range	Vibration Grade
black	—	−55 to 70°C	10 to 55 cps
brown	—	—	—
red	—	−55 to 85°C	—
orange	300 v.d.c.	—	—
yellow	—	−55 to 125°C	10 to 2000 cps
green	500 v.d.c.	—	—
blue	—	−55 to 150°C	—

Mica Capacitors

By E. M. ROTHENSTEIN
Executive Vice President, Arco Electronics

Mica capacitors are widely used because of their high stability and good reliability. This article covers the foil, silvered, reconstituted, molded, and dipped types.

MICA is one of a very few natural materials directly adaptable for use as a capacitor dielectric. Its physical and electrical properties, plus its rare characteristic of perfect cleavage, elevate mica to a position of the very best natural capacitor dielectric known today. Its position is further strengthened in comparison with organic synthetics, such as plastic films, and multiple-composition dielectrics, such as ceramics, by reason of its inherent stability. Mica, being a natural mineral and adapted to use without physical or chemical alteration, is completely inert both dimensionally and electrically. As a dielectric, it will not exhibit aging or deterioration nor subtle variants in electrical properties.

The property of perfect cleavage enables mica fabricators to split blocks of mica into sheets as thin as .0001 inch. The surfaces of the split sheets are parallel, and the splitting along natural crystalline structure lines can be accomplished with relative ease and uniformity.

The best of several varieties of mica is muscovite, a particularly clear form with the best electrical performance. It is found primarily in South America and the Orient, with the latter being the principal source. In listing the properties of muscovite mica which pertain to its use as a capacitor dielectric, examination of the figures will provide an immediate explanation of its popularity:

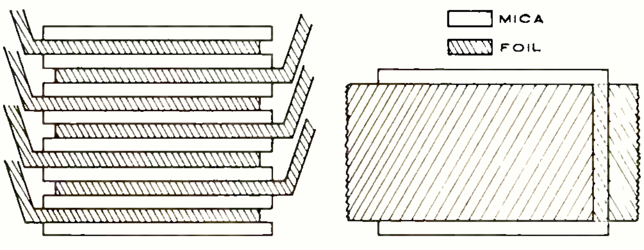
Dielectric strength—3000 to 6000 volts per .001 inch.
Volume resistivity—greater than 2 x 10^{13} ohm centimeters.
Dielectric constant—6.5 to 8.7.
Dissipation factor—about .0001 at radio frequency to about .001 at 60 cycles.
Operating temperature—approaching 500°C.

Mica, being a natural product, exhibits a non-uniformity of chemical composition and purity. Gross variants are screened out, but variability is still present, as evidenced by the figures just mentioned. Some synthetics have inherently uniform characteristics which will sometimes prove to be a design advantage.

Structure

The use of mica sheets in capacitors is accomplished by the classic technique of interleaving alternate layers of insulating and conducting material, as shown in Fig. 1. Each "sandwich" of insulation between two conductors creates the capacitor, with capacitance being a function of area and spacing of the plates, and dielectric constant of the insulation. Each sandwich of capacitance is paralleled by using tin-lead foil conductors extending alternately from opposite edges of the mica stack. All foils from one side are shorted together and connected to one capacitor termination. The other foils, also interconnected, form the second electrode. Parallel capacitors are additive in capacitance.

Fig. 1. Mica capacitors are made in "sandwich" fashion.



The conducting foil does not reach to the limits of area of the mica sheet, except on the edge over which the foil extends for electroding. This area between the edge of conductor and insulator is commonly called the "margin." This margin is a safety area to prevent conduction from one plate to another around the edge of the mica insulation. There is danger of a current path through impurities on the surface of the mica or of flashover in air or gaseous material which may exist within the capacitor structure. This is eliminated through provision for adequate areas of non-conducting margin.

The earliest mica capacitors in common usage were of a foil structure as described. There were two primary classes, identified as receiving and transmitting. Both these basic styles are still widely used today. The receiving mica is a smaller device for low-power, low-voltage circuits with electrodes clamped to pigtail wire leads. Molded-foil mica capacitors are limited to the order of .01 μf., a voltage rating of 2500 v.d.c., and current-carrying capacity measured in milliamperes. The later development of a silvering technique for capacitor plates has expanded these limits.

The transmitting mica capacitor, as its name implies, is used in higher power circuits—voltages as high as 30,000 v.a.c. and currents in excess of 100 amperes at radio frequency. To allow mica capacitors to withstand such electrical extremes, it is necessary to increase the mica thickness to gain sufficient resistance to voltage breakdown, increase the margin area, pot the capacitor in insulating material to eliminate gaseous elements, reducing the possibility of "flashover" around the edges of the mica and corona, and increase the thickness of the conducting foil to accommodate heavy current. Ribbons of foil are used to connect each plate to the capacitor terminals.

When electrical stress levels are too great for the simple parallel capacitor structure illustrated (as in the case of excessive voltage for a single sheet of mica, or an excessive current requirement despite the low dissipation factor of mica as a dielectric material, whose current-carrying capability is limited mainly by the heat generated within the capacitor due to I^2R losses), the capacitor sections are connected in series. This provides a voltage-dividing effect, easing the dielectric burden on the individual mica films. Since series connection of capacitors provides a divisive capacitance effect, greater plate area is required per unit of capacitance, and the volume of the capacitor per unit of capacitance is greatly increased. Heat generation within the capacitor is diminished, and the larger surface area of the capacitor enclosure affords faster dissipation of heat to the surrounding environment.

For purposes of physical comparison with each other and with other types of capacitors, the molded receiving-type capacitors vary in volume from well under 0.1 cubic inch to somewhat less than a cubic inch. The potted transmitting styles vary from 3 to more than 500 cubic inches in volume.

Although some paper and plastic-film dielectric capacitors have made inroads into the mica transmitting field, the latter style of capacitor is still pre-eminent in its area. However, the foil-electrode, molded receiving-type mica capacitor has been largely supplanted by silvered mica capacitors and ceramic dielectric units. The foil mica structure had excellent and unmatched stability by early standards, and there was no suitable substitute for low-capacitance values until the advent of ceramic capacitors. The ceramics eventually replaced foil mica to a large extent in general-purpose, broad-tolerance use where capacitance change with temperature was not a design factor. For the burgeoning market of precise frequency-selective and timing circuits, foil mica did not fill the bill and was superseded by silvered mica and temperature-compensated ceramics. So the original foil mica capacitor today has a very small share of the capacitor market.

The silvered mica differs from the foil in that the conductive capacitor plate is a thin layer of silver which is screened and fired onto the surface of the mica. The following advantages are obtained:

1. The exact screening process provides an area on the surface of the mica which is predictable in size and position to a degree not possible in a foil construction.

2. Since the plate is physically bonded to the dielectric, no relative motion occurs in the presence of physical, electrical, or environmental stresses, making the capacitor extremely stable and its variation with temperature closely repeatable.

3. The direct contact of plate and dielectric eliminates the potential presence of air or other foreign matter in the active dielectric area of the capacitor. This preserves the dielectric characteristics of the mica and eliminates instability created by expansion and contraction of air pockets in foil mica capacitors.

4. The obvious instability created by warping or wrinkling of foil during fabrication is eliminated.

Slips of conducting foil are still used to provide an electrical path from the silvered plates to the terminals of the capacitor. As in the case of pure foil capacitor construction, the foils are brought out alternately at opposite edges of the stack, folded to the top of the stack, and clinched together with the clamp-lead assembly. Fig. 2 shows a silvered mica capacitor before it is encased in its protective enclosure. In this case, the capacitor is a dip-coated unit.

Although mica capacitors are enclosed by means of a wide variety of methods, there are four principal styles. Low-power receiving types are usually molded or dipped; high-power transmitting types are potted in molded plastic cases or in large ceramic tubes with metal terminations.

Molded Types

The molded-style receiving mica capacitors retained practical exclusivity in the marketplace for some 30 years. The dipped style is a relatively recent innovation. For some time, the mold material was a phenolic resin, and it remains as the case material in a large percentage of molded micas made today. The phenolic resin has excellent electrical properties, good moisture resistance, is hard, and will not flow extensively during molding to contaminate the active capacitance field. However, its high-temperature performance leaves much to be desired, and it is necessary to use an impregnant (usually wax) to obtain a good moisture seal. The phenolic will not bond to the pigtail lead when molding takes place, so a possible moisture path exists at the interface of wire lead and mold material. This must be filled by an impregnant to serve as a moisture barrier.

In recent years, softer plastics with greater ease of flow, even at substantially lower molding temperatures and pressures, and better high-temperature characteristics have been used as mold materials. A bond of sorts is made between the material and lead, prompting some manufacturers to eliminate the impregnating process. However, the electrical characteristics of the softer resins are not as good as those of the phenolic, principally affecting dissipation factor, and resin moisture resistance is not as good. Investigation into newly developed plastics for use as enclosure materials continues today, and it is likely that markedly improved mold materials for mica capacitors will appear in the near future.

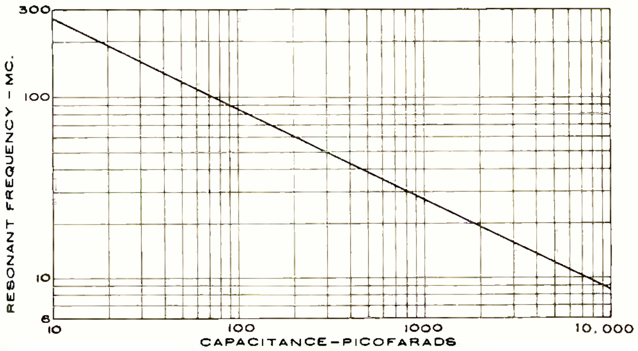
Another facet of molding effects on the capacitor is the tendency toward reduction of the life expectancy and increase in the failure rate of the mica section. The heat and pressure of molding apparently produce a fatigue effect which influences the reliability of the capacitor. This effect is noticeable in phenolic-molded units and manifests itself to a lesser degree in mica capacitors molded in the softer resins. Much higher reliability is obtained in capacitors which have been dip-coated instead of molded.

Dipped Types

The improvement in reliability, change in lead configuration to increase its adaptability to printed circuitry, reduction of fabrication cost, and some saving in size are all factors in development and rapid industry acceptance of the dipped unit. The reduction in stresses related to enclosure also tends to decrease capacitance change during the finishing process and makes for a more stable capacitor in operation.

The dip is usually a combination of resins applied in a series of coats to build up necessary dielectric insulation and a moisture barrier. An excellent bond can be obtained between case material and wire lead, completing the moisture seal. A proper blend of resins will exhibit excellent moisture resistance, electrical properties, and satisfactory performance at a temperature of 150°C.

If the dipping is performed at less than atmospheric pressure, a near monolithic structure is obtained, giving



As the frequency of the current passing through the capacitor increases, a self-resonant condition is approached. The capacitive reactance, dominant at normal operating frequencies, decreases, while inherent inductive reactance increases with a rise in frequency. The inductance of the mica capacitor is found in its leads, lead assembly, and the metallic internal structure of the active capacitive section. Actual tests confirm the inverse relationship between resonant frequency and square root of the capacitance value. The inductance of the capacitor remains relatively constant for a given lead length. It is also very nearly the same for all case-size configurations. Shortening the wire leads will effect a modest increase in resonant frequency. As self-resonance is approached, dissipation factor rapidly increases as the resistance of the capacitor becomes a greater percentage of the total impedance. At resonance, capacitor is purely resistive.

the capacitor great strength and physical stability and excluding corona-producing air and other impurities. A minor disadvantage of this technique is the introduction of the case material into the dielectric field of the capacitor. Since the electrical properties of the dip material do not approach those of mica, higher dissipation factor and temperature coefficient is the result. However, the increase in these characteristics is slight, not enough to change the relative merit of the mica capacitor when compared with other dielectric materials. The dipped mica capacitor is still capable of far exceeding minimum published standards in all respects. Incidentally, these published standards are MIL-C-5C for military applications and the Electronic Industries Association Standard RS-153-A.

Other Types

The higher power potted transmitting types are enclosed in molded plastic cases specifically designed for the purpose or in large ceramic tubes. The mica capacitor stack is clamped under pressure for retention of physical integrity and minimum spacing between plates. The capacitor is inserted in the case with proper electrical connections made to screw terminals, and the structure is potted. In the case of the large tubular styles, the large metal end caps also serve as terminals, and a compressive force during closure adds to the assembly's strength and rigidity.

It might be well to point out that some mica capacitors have been made in tubular forms, using the rolling technique normally associated with paper and plastic-film capacitors. Even the thinnest natural mica sheets are not flexible enough to withstand rolling; but in this case, the rolls of dielectric are not mica in natural form but *reconstituted* mica. Reconstituted mica is made by flaking the mica into very small pieces and then reorienting the flakes into paper-like thin sheets, usually incorporating a small percentage of organic binder material. The binder material has an appreciable effect on electrical characteristics. However, in one instance, a firing process has enabled reconstitution of the mica flakes into sheets without the use of binders so that most of the basic properties are retained. The use of reconstituted mica capacitors is limited to certain applications for which they are particularly adaptable.

Operating Characteristics

Whether for receiving or transmitting applications, the principal characteristics of mica manifest themselves in the ultimate decision as to the type of capacitor to be employed. In the case of a high-power application, the decisive factors are the fundamental security inherent in use of this natural material, coupled with electrical excellence when the dictates of application clearly demand mica. A properly designed high-power mica capacitor will operate year after year, withstanding high dielectric stresses and passing heavy a.c. current without noticeable deterioration. During this period, the capacitor may be expected to maintain its original capacitance value within narrow limits, and the effect of changing temperatures is minimal. When we consider low-power applications, again the inherent stability of the dielectric and its relative insensitivity to electrical or environmental variants is decisive. A silvered mica capacitor may be manufactured to extremely close tolerances; but more important, it can be expected to retain the original setting throughout operating life. To verify this fact, it is well to call attention to the fact that when size limitations eliminate the use of air-dielectric capacitors as standards, mica dielectric is used for the fabrication of primary capacitance measurement standards.

After establishing the key points of stability and reliability (there is more actual documentation on verified reliability of micas than any other), certain comparisons can be made with other dielectrics. These may demonstrate a narrow superiority of other materials within limited spheres of performance, but for all-around use, mica still plays a most important role.

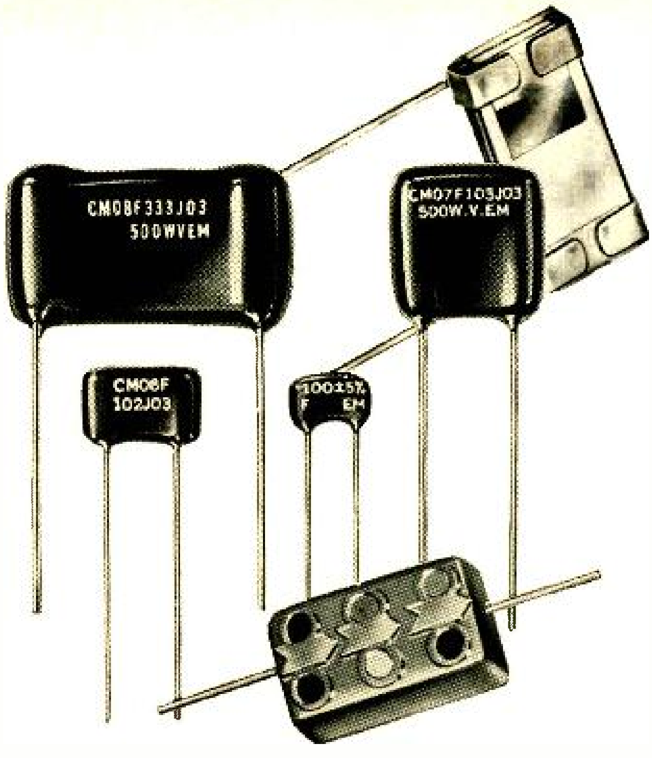


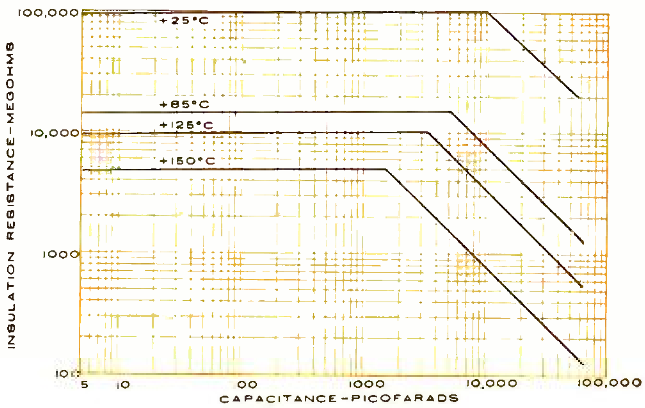
Fig. 2. An assortment of mica capacitors. Silvered mica capacitor (upper right) is shown before application of coating.

1. Temperature-compensating ceramic capacitors (specifically NPO zero-temperature coefficient) may have temperature coefficients closely controlled to a point where capacitance variation with temperature may be less than that for a silvered mica capacitor, but the mica will have better long-term aging characteristics, a much lower dissipation factor, less sensitivity to frequency variation, less sensitivity to voltage variation, and smaller size in high-capacitance values.

2. Polystyrene dielectric capacitors may have lower dissipation factor and dielectric absorption, but again, mica will have superior long-term stability, will operate reliably at much higher temperatures, have a much lower temperature coefficient (percentage change in capacitance value per unit change in temperature), and physically be a more rugged dielectric material.

3. Polyester dielectric capacitors may rival mica in reliability (with conservative design), and they may be physically rugged and provide greater capacitance per unit volume. But in all other respects, from a standpoint of electrical and environmental performance, mica remains superior. ▲

Mica capacitance insulation resistance varies with the environmental temperature present during its operation.



Fixed-Capacitor Sources

AVAILABILITY A Parts distributor B Industrial distributor C Direct D Custom-made only E Not sold as discrete item

Company	Address	Items
Aerovox Corporation (A,B,C)	740 Belleville Ave., New Bedford, Mass.	1,2,4,6,7,8,9,10,11,12,15,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36
Airborne Accessories Corp. (B,C,D)	1414 Chestnut Ave., Hillside, N.J.	2,5,7,9,36
Allen-Bradley Co. (C)	136 W. Greenfield Ave., Milwaukee, Wis.	21,22,23,27[a]
Alpha Microelectronics, Inc. (C,D)	2414 Reedie Dr., Wheaton, Md.	11[b]
Amark Corp. (C)	92 North Ave., New Rochelle, N.Y.	29
American Elite, Inc. (C)	48-50 34th St., Long Island City, N.Y.	1,12,18,21,22,23
American Lava Corp. (C,D)	Cherokee & Mfrs. Rd., Chattanooga 5, Tenn.	21,22,23
Amp Incorporated (C)	Harrisburg, Pa.	2,28,30,31,37[c]
Amperex Electronic Corp. (C)	230 Duffy Ave., Hicksville, N.Y.	2,4,7,8,12
Arco Electronics, Inc. (A,B,C)	Community Dr., Great Neck, N.Y.	1,2,4,5,6,12,22,23,27,33,35
Astron (A,C,)	255 Grant Ave., East Newark, N.J.	1,4,5,7,8,12,14,18,22,23,24,25,27,28,29,30,31,32
Axel Electronics Inc. (C,D)	134-20 Jamaica Ave., Jamaica 18, N.Y.	5,28,30,31
Balco Capacitors Div. (B,C)	49-53 Edison Pl., Newark 2, N.J.	1,2,4,5,6,7,8,9
Barco, Inc. (A,B,C)	Box 1222, Milwaukee, Wis.	12
Bel Fuse, Inc. (C,D)	204 Van Vorst St., Jersey City 2, N.J.	19,20,21,22,23
Bourns Inc., Trimpot Div. (C)	1200 Columbia Ave., Riverside, Cal.	21,22,23,24,25,26,27[d]
Brand Electronic Components, Inc. (C)	220 Ferris Ave., White Plains, N.Y.	1,2,7,10,12,28,29
Callins Industries (C,D)[f]	Greenfield, Tenn.	7,12,18
Cambridge Thermionic Corp. (B,C)	445 Concord Ave., Cambridge 38, Mass.	19,21,22,23,24,27
Capco Capacitors (B,C)	1410 Pioneer Drive, Irving, Tex.	2,5,7,8,9
Capon, Inc. (C)	61 Stanton St., New York 2, N.Y.	1,2,3,4,5,6,7,8,9,10,11
Centralab Electronics (A,B,C)	998 E. Keefe Ave., Milwaukee 1, Wis.	1,21,22,23,24,25,26,27
Chicago Condenser Corp. (C,D)	3255 W. Armitage, Chicago 47, Ill.	1,2,7,28,29,30,31,32
Components, Inc. (C)	Smith St., Biddeford, Me.	15
Component Research Co., Inc. (C)	3019 S. Orange Dr., Los Angeles 16, Cal.	1,2,4,5,6,7,8,9,11
Components Specialties, Inc. (C)	101 Buffalo Ave., Freeport, L.I., N.Y.	4,12[d],21
Condenser Products Co. (A,B,C)	Box 1046, Brooksville, Fla.	1,2,5,6,28,30,31
Connolly & Co., Inc. (C)	914 Rengstorff Ave., Mountain View, Cal.	1
Cornell-Dubilier Electronics (A,B)	50 Ave. L, Newark, N.J. 07101	1,2,4,6,7,8,11,12,13,14,15,16,18,28,29,30,31,32,33,34,35,36,37
Corning Glass Works (A,C)	Corning, New York	19
Corson Electric Mfg. Corp. (C,D)	Watrous St., East Hampton, Conn.	5,30,31,34,36,37
CTS Corp. (C,D)	1142 W. Beardsley Ave., Elkhart, Ind.	e
Dearborn Electronic Labs, Inc. (C)	Box 3431, Orlando, Fla.	1,2,3,4,5,6,7,8,9,11,28,29,30,31,32
Dickson Electronics Corp. (B)	248 S. Wells Fargo Ave., Scottsdale, Ariz.	14,18
Dietz Design Inc. (C,D)	100 Electronics Parkway, Belton, Mo.	1
Dilectron Div. (C,D)	2669 S. Myrtle Ave., Monrovia, Cal.	21,22,23,24,25,26,27
Dolinko & Wilkens, Inc. (C)	1907 Summit Ave., Union City, N.J.	g
Eitel-McCullough, Inc. (C)	301 Industrial Way, San Carlos, Cal.	g
Electra Mfg. Co. (E)	800 N. 21st St., Independence, Kans.	11
Electrical Utilities Co. (C)	2427 St. Vincent Ave., La Salle, Ill.	2,4,7,8,28,29,30,31,32
Electro Cube Inc. (A,C)	805 Fairview Ave., South Pasadena, Cal.	1,2,4,6,7,8,29,30,32
Electro-Mec (C)	E. Orchard St., Terryville, Conn. 06786	12,18
Electro Motive Mfg. Co. (A,C)	S. Park & Johns Sts., Willimantic, Conn.	2,28,31,33,35,36
Electro Scientific Industries, Inc. (C)	13900 N.W. Science Park Dr., Portland 29, Ore.	h
Electron Products (B,C)	1960 Walker Ave., Monrovia, Cal.	[i]1,4,5,6,7,8,24,27,28,29,30,31,32
Electronic Associates, Inc. (C)	West Long Branch, N.J.	1,2,4,5,6,7,8,9,24,25,26,27,31
Erie Technological Products, Inc. (C)	644 W. 12th St., Erie, Pa.	2,14,21,22,23,24,25,27,35
Fansteel Metallurgical Corp. (A,B,C)	Rectifier-Capacitor Div., No. One Tantalum Pl., North Chicago, Ill.	14,15,16
Film Capacitors, Inc. (B,C)	100 8th St., Passaic, N.J.	1,2,3,4,5,6,7,8,9,28,29,30,32
Filmohm Corp. (D)	48 W. 25th St., New York 10, N.Y.	34
Filtron Co., Inc., (C,D)	131-15 Fowler Ave., Flushing 55, N.Y.	1,2,3,5,6,7,9,28,29,30,31,32
General Electric Co., Capacitor Dept. (B,C)	P.O. Box 158, Irmo, S.C. 29063	1,2,3,4,5,6,7,8,11,28,29,30,31,32
General Instrument Corp., Capacitor Div. (B,C)	65 Gouverneur St., Newark 4, N.J.	1,2,5,7,12,14,15,16,17,18,28,29,30,31,32,33,35
General Laboratory Assoc. Inc. (D)	17 E. Railroad St., Norwich, N.Y.	37
General Products Corp. (C)	Union Springs, N.Y.	1,2,4,7,28
General Radio Co. (C)	22 Baker Ave., West Concord, Mass.	1,35,36
Genistron, Inc. (C,D)	6320 W. Arizona Circle, Los Angeles 45, Cal.	1,2,4,5,6,7,8,28,30,32
Glenco Corp. (A,B,C)	212 Durham Ave., Metuchen, N.J.	21,22,23,24,25,27
GLP Electronics (B,C)	350 Riverside Ave., Bristol, Conn.	14,17,18
Good All Capacitors (TRW) (B,C)	112 W. First St., Ogallala, Neb.	1,2,4,6,7,8,14,18,28,30,31

a. also printed circuit discs; b. also silicon oxide; c. also polymide; d. microminiature; e. cermet; f. OEM only; g. vacuum type; h. air dielectric standard; i. air

LEGEND

FILM	ELECTROLYTIC	GLASS & CERAMIC	PAPER & PAPER FILM	MICA
1 polystyrene	12 aluminum	19 glass	28 paper	33 receiving
2 polyester	13 tantalum foil	20 porcelain	29 metallized paper	34 transmitting
3 polypropylene	14 tantalum solid	21 L.V. ceramic	30 oil impregnated	35 silvered
4 polycarbonate	15 tantalum slug dry	22 G.P. ceramic	31 paper polyester	36 foil
5 TFE fluorocarbon	16 tantalum slug wet	23 T.C. ceramic	32 metallized paper polyester	37 reconstituted
6 polystyrene polyester	17 tantalum wire	24 high capacitance		
7 metallized polyester	18 non-polarized	25 high voltage		
8 metallized polycarbonate		26 a.c. operation		
9 metallized fluorocarbon		27 temperature stable		
10 lacquered dielectric				
11 deposited dielectric				

Manufacturer	Address	Types
Gudeman Co. (B,C)	340 W. Huron St., Chicago, Ill. 60610	1,2,4,5,6,7,8,9,28,29,30,31,32
Gudeman Co. of Calif. Inc. (B,C)	7473 Ave. 304, Visalia, Cal. 93278	1,5,7,25,29
High Energy, Inc. (C,D)	9 Cricket Terr., Ardmore, Pa.	1,2,5,6,25,26,28,30,31,33,34,36,37
Hopkins Engineering Co. (C)	12900 Foothill Blvd., San Fernando, Cal.	2,4,5,7,8,9,28,29,30,31,32
Hunter-Stanley Electronics, Inc. (C)	208 Russell St., Nashville, Tenn.	13,16
Illinois Condenser Co. (C)	1616 N. Throop St., Chicago 22, Ill.	12,18
Industrial Condenser Corp. (C)	3245 N. California Ave., Chicago 18, Ill.	1,2,4,7,8,12,18,28,30
International Electronic Industries (B,C)	Box 9036 Melrose, Nashville, Tenn.	12,13,15,16,18
International Electronics Corp. (C)	316 S. Service Rd., Melville, L.I., N.Y.	1,2,4,7,8,12,13,14,21,22,28
Ionetics Corp. (C,D)[f]	86 Leonard St., New York, N.Y. 10013	2,4,6,7,8,10,12,21,22,23,25,27
ITT Capacitor Dept. (B,C)	815 San Antonio Rd., Palo Alto, Cal.	14,15,16,18
Jennings Radio Mfg. Corp. (C)	970 McLaughlin Ave., San Jose, Cal. 95108	g
JFD Electronics Corp. (B,C)	15th Ave. at 62nd St. Brooklyn 19, N.Y.	21,22,23,24,25,26,27
La Pointe Industries (C)	155 W. Main St., Rockville, Conn.	i
Lapp Insulator Co., Inc. (C)	31 Gilbert St., Le Roy, N.Y.	j
Leeds & Northrup Co. (C)	4970 Stenton Ave., Philadelphia 44, Pa.	35
Line Material Industries (C)	700 W. Michigan St., Milwaukee 1, Wis.	30
Luther Electronic Mfg. Co. (D)	5728 W. Washington Blvd., Los Angeles 16, Cal.	2,5,25,28,30
Maida Development (C,D)	214 Academy St., Hampton, Va.	21,22,23,25,27
Mallory, P.R. & Co., Inc. (A,B,C)	3029 E. Washington St., Indianapolis, Ind.	12,13,14,15,16,18,20,21,22,23,24, 25,26,27,28,29,30,31,32
Measurements (C,D)	Box 180, Boonton, N.J.	33
M.E.C. Inc. (C)	796 Berry Rd., Nashville, Tenn.	12
Midwest Sales Co. (B.C)	601 S. Jason St., Denver 23, Colo.	1,2,4,5,6,7,8
Mucon Corp. (C)	9 St. Francis St., Newark, N.J. 07105	21,22,23,24,26,27
Muter Co. (D)	1255 S. Michigan Ave., Chicago 5, Ill.	22,23,25
Nytronics, Inc. (C)	550 Springfield Ave., Berkeley Hgts., N.J.	21,22,23,24,25,26,27
Ohmite Mfg. Co. (A,B,C)	3601 Howard St., Skokie, Ill.	13,16,17
Paktron (C)	1321 Leslie Ave., Alexandria, Va.	2,4
Plastic Capacitors, Inc. (B,C)	2620 N. Clybourn Ave., Chicago 14, Ill.	1,4,7,10,28,29,30,31,32
Presin Co. Inc. (C)	226 Cherry St., Bridgeport 5, Conn.	1,12,29,32
Priester Corp. (C)	Box 267, Scarsdale, N.Y.	2,4,7,12,21,25,35,36
Products Research Co. (B,C)	2919 Empire Ave., Burbank, Cal.	21,22
Quality Components, Inc. (C)	St. Marys, Pa.	k
Reid Hill Electronics (C,D)	150 Church St., Amsterdam, N.Y.	30,37
RF Interonics, Inc. (C,D)	15 Neil Ct., Oceanside, N.Y.	2,5,7,28,29,30,31,32
STM (Safe-T-Mike) Corp. (C,D)	2904 Chapman St., Oakland, Cal.	12,18
San Fernando Electric Mfg. Co. (B)	1509 First St., San Fernando, Cal.	1,2,3,4,5,6,7,8,9,21,22,23,28,29,31,32
Sangamo Electric Co. (B,C)	1201 N. 11th St., Springfield, Ill.	12,18,28,29,30,32,33,34,35,36,37
Scintilla	Sidney, N.Y.	2[E],28[E],29[E],31[E],37[D]
Solar Mfg. Corp. (C)	4553 Seville Ave., Los Angeles 58, Cal.	21,22,23,24,25,26,27
Southern Electronics Corp. (B,C)	150 W. Cypress Ave., Burbank, Cal.	1,2,3,4,5,6,7,8,9,22,23,27,30,31,37
Sprague Electric Co. (A,B,C)	North Adams, Mass.	1,2,3,4,5,6,7,8,9,10,12,13,14,15,16,17,18, 21,22,23,24,25,26,27,28,29,30,31,32,34,35,36,37[l]
Stackpole Carbon Co. (C)	201 Stackpole St., St. Marys, Pa.	m
Standard Condenser Corp. (C,D)	3749 Clark St., Chicago 13, Ill.	1,2,4,5,6,7,8,28,30,31
Sun Capacitors (C,D)	2554 W. Lawrence Ave., Chicago 25, Ill.	1,2,4,26,27,28,30,31
Syncro Corp., Electronics Div. (D)	Hicksville, Ohio	12
Tansistor Electronics, Inc. (B,C)	West Rd., Bennington, Vt.	13,14,15,16,17,18
Texas Capacitor Co. (A,B,C)	4310 Langley Rd., Houston 16, Tex.	1,2,4,5,7,8
Texas Instruments Inc. (B,C)	Box 5012, Dallas 22, Tex.	14
Ti-Tal, Inc. (C)	2001 Main St., Santa Monica, Cal.	14,16,18
Union Carbide Corp., Kemet Dept. (B,C)	11901 Madison Ave., Cleveland 1, Ohio	11,14,18[n]
United Electronic Mfg. Corp. (A,C)	542 39th St., Union City, N.J.	12,18
United Mineral & Chemical Corp. (A,B,C)	16 Hudson St., New York 13, N.Y.	21,22,23,24,25,26,27
U.S. Semcor (A,B,C)	3540 W. Osborn Rd., Phoenix, Ariz.	14,15,16,17,18
Vitramon, Inc. (A,C)	Box 544, Bridgeport 1, Conn.	20,21,22,23,24,25,27
Wayne-Kerr Corp. (C,D)	22 Frink St., Montclair, N.J. 07042	i
Wesco Electrical Co., Inc. (C)	27 Olive St., Greenfield, Mass.	1,2,4,6,7,8,28,29,30,31,32,33,34,36,37
West-Cap Arizona (B)	2201 E. Elvira Rd., Tuscon, Ariz.	1,2,3,4,5,6,7,8,9,21,22,23,28,29,31,32

dielectric; j. gas filled; k. composition capacitor; l. also Bentonite (Amplifilm) and metallized triacetate; m. low-capacitance "gimmick"; n. also polyparaxlyene.

Glass-Dielectric Capacitors

By ARCHER N. MARTIN / Corning Glass Works

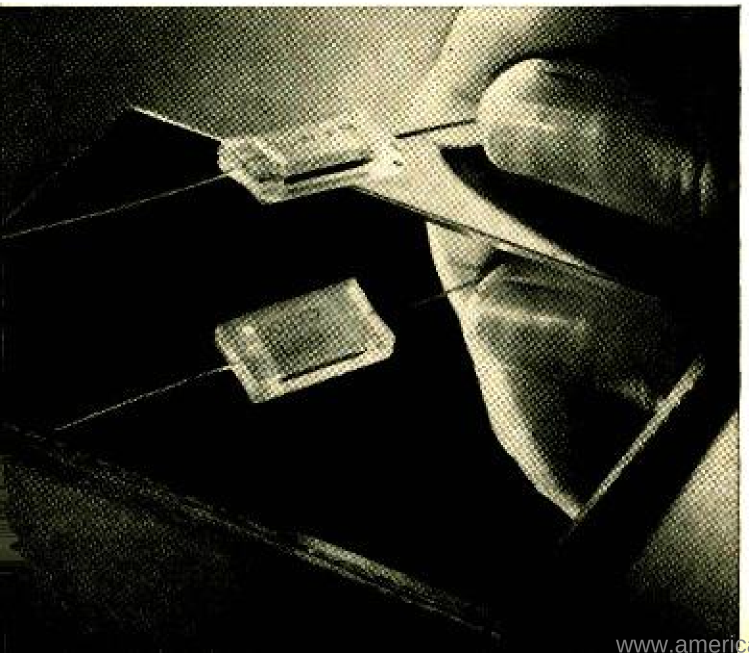
Known best for its aerospace applications, this capacitor is now being used in other high-quality circuitry. Various types of glass capacitors, with their characteristics, are described.

THE history of the glass capacitor began in World War II, when the sources of natural mica were threatened. Because glass is electrically and physically stable and chemically inert, the Signal Corps and Bureau of Ships suggested that *Corning Glass Works* begin development of a glass dielectric to replace capacitor mica. An optical-grade, lead-potash composition was produced with electrical properties equal to and in some cases better than those of mica. A process was then developed to form the glass in an extremely thin ribbon of practical width. With this dielectric, the company introduced a commercial glass capacitor in 1951 that was a direct substitute for the mica capacitor.

The capacitors are made by stacking alternate layers of aluminum foil and glass ribbon until the desired capacitance is obtained, then fusing the assembly into a monolithic block as shown in Fig. 1. The same glass composition is used for both the case and dielectric, insuring that the electrical properties of the capacitor are entirely those of the dielectric. Leads are welded to the electrodes to form a glass-to-metal seal where they enter the case, creating a truly hermetic capacitor.

Military specification MIL-C-11272 was written to describe only glass capacitors but has been broadened in recent years to include other types.

A typical glass capacitor such as those discussed in the text.



Because of interest generated by the exotic aura of aerospace missions, the glass capacitor is known mostly for its application in missiles and spacecraft. With the glass capacitor, *Corning* was the first company to meet the Minuteman component-reliability research and development goals of the *Autonetics Division* of *North American Aviation.* This singular success helped make the glass capacitor famous, but it also may have tended to obscure its usefulness in fields aside from the specialized one of reliability. A creditable market exists for the component in such equipment as high-quality test sets, measurement instrumentation and process controls, in such functions as high-"*Q*" filtering, reliable bypassing in r.f. circuits, and peripheral computer applications, and in other systems where circuit parameters cannot be allowed to wander.

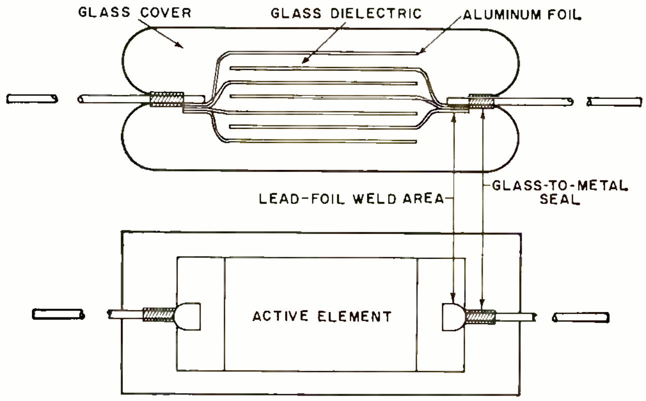


Fig. 1. Basic construction of the glass-dielectric unit.

The singular advantage of glass-dielectric capacitors is the way they help circuit designers predict the operation of their circuits. There are few components possessing as sturdy and consistent a history of stability and reliability. The manufacturer states, for example, that any two of its units, regardless of capacitance value or size, exhibit temperature coefficients within 10 PPM/°C of each other.

For a designer, this means that his circuits containing many capacitors will track accurately and predictably during temperature variations. In addition, retrace of the TC of glass capacitors is essentially absolute, assuring negligible hysteresis. Capacitance drift with load life is less than 0.5%. Voltage coefficient is stated as zero, so capacitance can be expected to remain the same despite voltage levels or surges.

Other specs that characterize the glass capacitor are extremely low losses and high "Q", even at elevated temperatures and high frequencies. With such low losses, designers can realize higher "Q" and the resultant narrower bandwidths in filters and tuned circuitry.

Characteristics

Most glass capacitors range in capacitance from .5 to 10,000 pf. (.01 μf.) but can come as high as 150,000 pf. (.15 μf.). The capacitance range below 10,000 pf. makes

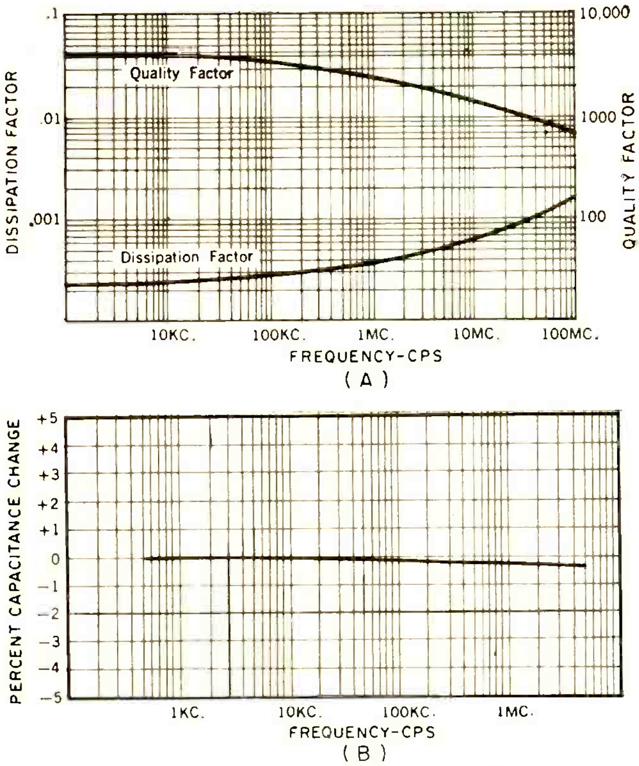


Fig. 2. (A) Quality and dissipation factor and (B) percent capacitance change with frequency for glass dielectrics.

up about 15 to 20% of the total capacitor dollar. Tolerances for glass capacitors range from 1% to 20%, d. c. working voltage is generally between 300 and 500 volts but can be made as high as 6000 volts, and operating temperature range is from −55 to +125°C.

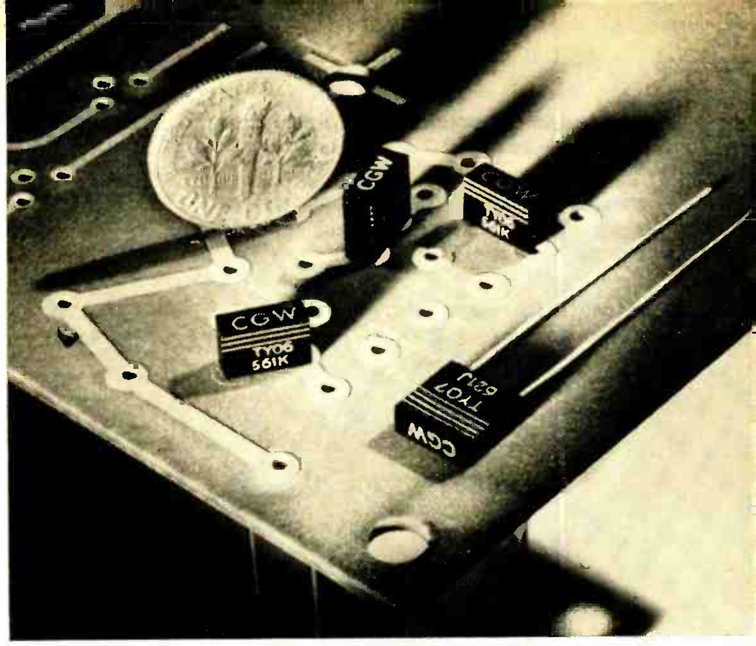
Fig. 2A shows the range of quality factor ("Q") and dissipation factor with frequency, while Fig. 2B demonstrates the percent capacitance change with frequency. Fig. 3A shows the insulation resistance with temperature curve for glass capacitors, while Fig. 3B illustrates the capacitance change with temperature.

Temperature coefficient (TC) of these capacitors is +140 ±25 PPM/°C at 100 kc. with essentially absolute retrace. At any given temperature, the TC will not deviate from the curve by more than 5 PPM.

Load life is less than .5% capacitance change after 2000 hours at 125°C with 150% of rated voltage applied. The change in resistance with moisture is negligible with the hermetically sealed units, and the plastic-potted types show an insulation resistance in excess of 10^{10} ohms after standard military tests.

Radiation resistance, except for the plastic-potted units, shows no significant change in capacitance from exposure to levels of 10^{18} NVT^{th}.

The plastic-potted unit (Type TYO) was developed to provide a glass capacitor at prices comparable to those of ceramic units. Potted in a plastic shell, this device has parallel radial leads spaced symmetrically with the square-cornered case on .1-inch grids. This unit lends itself to fast,



Plastic-potted glass capacitors are made for printed boards.

high-density, upright installation on printed-circuit boards.

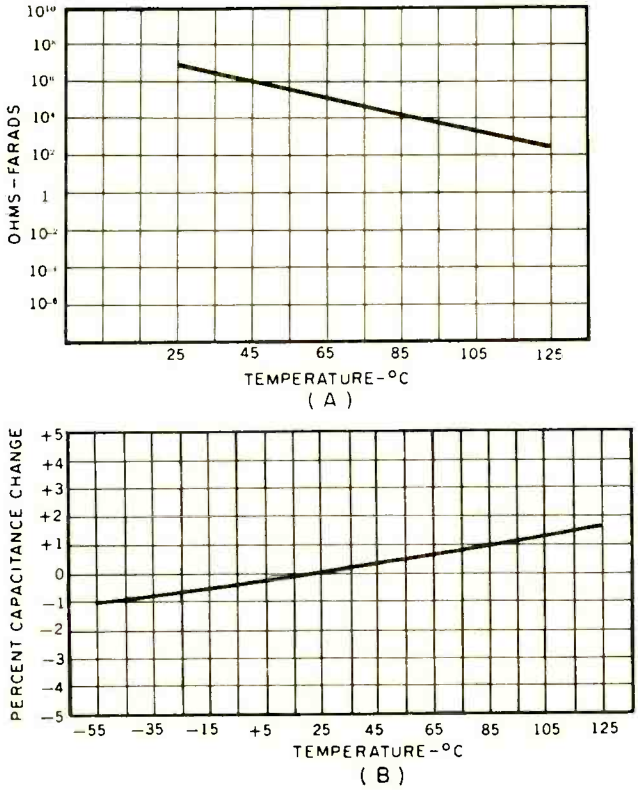
Two other types of glass capacitors are designated CYFR and CYFM styles by the company. Both are fusion-sealed, thus making them virtually impervious to environment.

The CYFR capacitors have an established reliability figure, proven under Minuteman stress conditions, of 99.-9996% per thousand hours at a 60% confidence level and at full-rated voltage at 125°C. Stated another way, this figure means that no more than four failures (deviation from specified performance) will occur in a *billion* part-hours of operation.

The CYFM style is electrically and environmentally interchangeable with the CYFR. However, the former units provide cost savings up to 60%, since they do not undergo the expense of extensive reliability testing and documentation.

Another type of glass capacitor is represented by me-

Fig. 3. (A) Insulation resistance and (B) capacitance change with frequency for glass-dielectric capacitors.



dium-power transmitting units, designated CY60 and CY70 rated at 1 kva. and 7.5 kva., respectively.

Power ratings significantly higher than listed can be easily obtained merely by making sure that the operating temperature of the capacitor remains below 125°C. This can be done with terminal and/or body heat sinks. Terminal heat sinks are very efficient because of the many layers of solid aluminum that extend into the capacitor.

The CY60 and CY70 capacitors are used for r.f. applications such as power amplifiers, low-power transmitters, and many electronic devices in grid, plate, coupling, tank, and bypass functions. Their relatively small size and low weight make them suitable for airborne equipment and mobile transmitter applications.

Performance of the glass capacitor is a direct function of its dielectric. The composition is closely controlled by the manufacturer from day to day, month to month, and year to year, and unlike mined dielectrics does not have to be graded or culled. During more than a decade of commercial experience, this control is what has given the glass capacitor its reputation for stability, reliability, and performance predictability. ▲

Standard Capacitors

A PROPERLY designed air capacitor approaches the ideal standard reactance in that it has very low loss and very small changes with time, frequency, and environment. Capacitance changes with atmospheric pressure and relative humidity can be eliminated by hermetic sealing. Changes with temperature can be eliminated by the use of low temperature coefficient materials in the capacitor.

For values above 1000 pf., solid dielectrics are used. The preferred dielectric is high-quality mica because of its dimensional stability, low loss, and high dielectric strength. At d.c. or extremely low frequencies, the mica dielectric has the disadvantage of relatively large change of capacitance with frequency as a result of dielectric absorption caused by interfacial polarization in the dielectric. Polystyrene, on the other hand, has a dielectric constant and dissipation factor very nearly constant with frequency, so that capacitance change from d.c. to 1 kc. is a small fraction of a percent instead of the 3% drop at 1 kc. typical of mica. However, the temperature coefficient of a polystyrene capacitor is on the order of −140 PPM/°C.

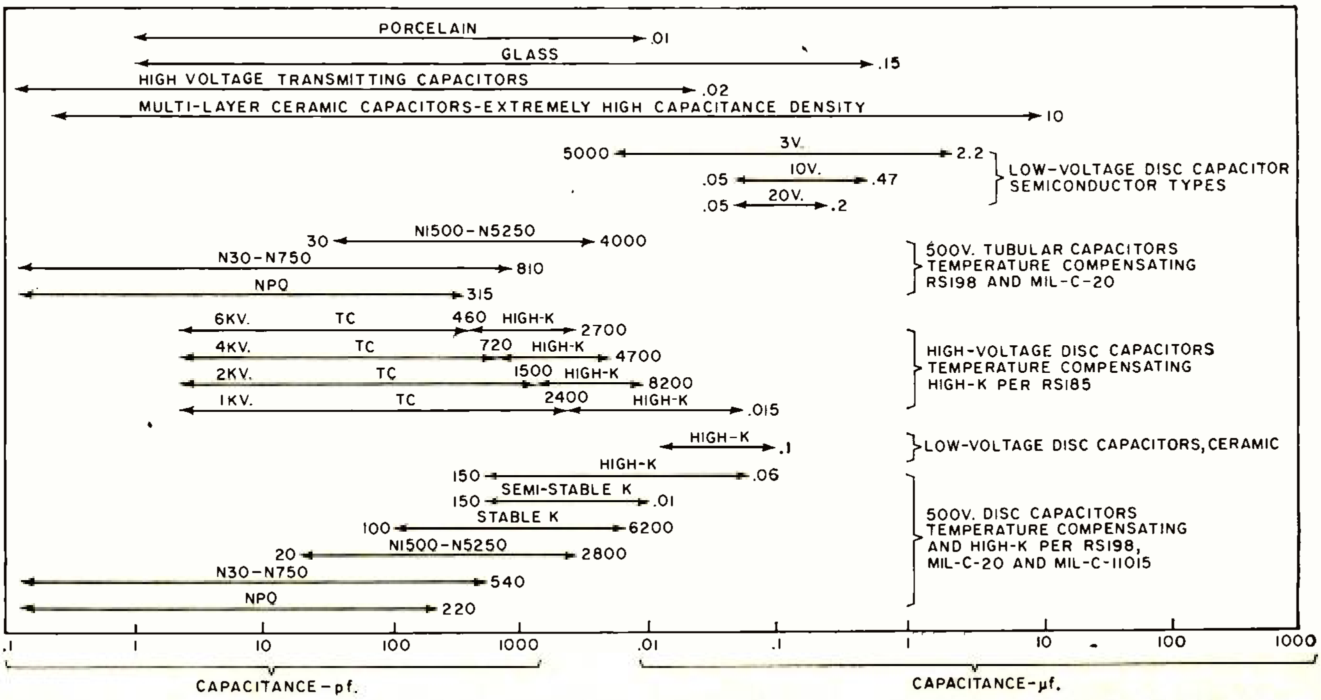
Uncertainties in the calibrated value of a two-terminal capacitor can be on the order of tenths of a pf. if the geometry, not only of the capacitor plates, but also of the environment and of the connections is not defined and specified with sufficient precision. For capacitors of 100 pf. and more, the capacitance is usually adequately defined for an accuracy of a few hundredths percent if the terminals and method of connection are specified. For smaller capacitances, or higher accuracy, a two-terminal is seldom practical and a three-terminal unit is preferred.

A three-terminal capacitor has a shield that completely surrounds at least one of its terminals, its connecting wires, and its plates, except for the area that produces the desired direct capacitance to the other terminals. Changes in the environment and connections can vary the terminal capacitance but the direct capacitance is determined only by the internal geometry.

The direct capacitance can be made as small as desired since the shield between the terminals can be complete except for a suitably small aperture. The losses in the direct capacitance can also be made very low because the dielectric losses in the insulating materials can be made a part of the terminal impedances. When a three-terminal capacitor is connected as a two-terminal device, the two-terminal capacitance will exceed the calibrated three-terminal value by at least the terminal capacitance.

Although the characteristics of the high-quality capacitors used as standards closely approach those of the ideal capacitor, any deviations from ideal performance must be evaluated to obtain the necessary high accuracy. ▲

Ceramic Capacitor Value Ranges



Electrolytic Capacitors

By H. NIEDERS / Mallory Capacitor Co.
Div. of P.R. Mallory & Co., Inc.

Widely used where large capacitance and small size are required, electrolytics are among our most important capacitor types. Aluminum and tantalum units are covered.

IN 1964 some 2,305,000,000 units of all types of capacitors were produced and sold. Of this total, electrolytic capacitors accounted for 249,000,000 units. In terms of dollars, this amounted to about $344,000,000 for all capacitors and $127,000,000 for electrolytic types. These figures would seem to indicate that electrolytic capacitors are expensive—but this is not true.

Electrolytic capacitors actually save money, space, and weight when used properly within their limitations and the limitations of the circuitry employed. The "why" of electrolytic capacitors is economy; the "when" is a matter of application.

Generally, electrolytic capacitors can be divided into two basic types by the nature of the base-oxidizable metal used. This is usually either aluminum or tantalum. There are other usable metals, but these two yield relatively large capacitance per unit of volume at an economical price. A tantalum capacitor costs more money but saves more space and weight than an aluminum unit. There are other technical differences, but the two types are more easily understood when reviewed separately.

Aluminum Electrolytics

Fig. 1 is a simplified representation of an aluminum electrolytic capacitor. Both polarized and non-polarized types are shown. Normally a piece of aluminum foil is etched to increase its surface area, then it is treated electro-chemically to form aluminum oxide on its surface. The oxide is the dielectric of the capacitor—the thickness of this oxide determines the voltage rating. Since this oxide film is so thin and the surface area of the electrodes is so great, the capacitance produced is very large.

Paper spacers are applied next to the aluminum oxide surface. These spacers prevent direct shorts between anode and cathode foils. Thus, for higher voltages, more and thicker spacers are used. The spacers also absorb the electrolyte, allowing it to be retained in the correct place and providing intimate contact with the surfaces of the anode and cathode foils as required for proper operation.

The cathode foil serves only as an electrical connection to the electrolyte. The electrolyte is the true cathode and it has the ability to oxidize any imperfections in the aluminum oxide dielectric.

Non-polarized capacitors use two anodes and have one-half the capacitance of an equal-size polarized unit of the same voltage rating.

When electrolytic capacitors are used as energy-storage devices where the load resistance is small compared to load inductance, current reversals may occur for a short time. Accordingly, the voltage will reverse for the same time, making the use of a non-polarized unit mandatory. Electrolytics for a.c. motor starting and for audio cross-over networks should be non-polarized types. It is also wise to consider using a non-polarized unit where large pulse signals are encountered. For most applications, however, electrolytics are used across a d.c. voltage so that the ordinary polarized units are employed. The designer must avoid voltage reversals on polarized units.

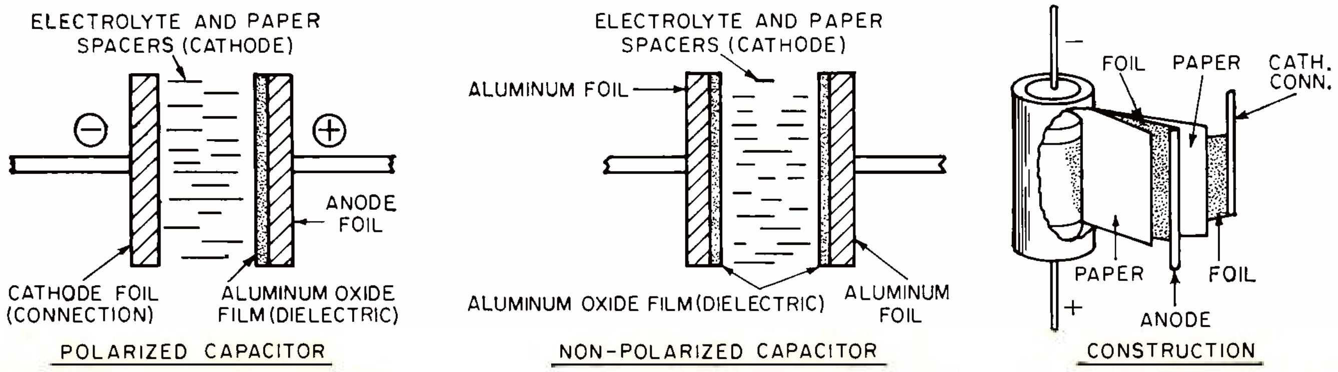
Leakage Current and ESR

All electrolytic capacitors allow a small amount of d.c. leakage current to pass through when rated polarized d.c. voltage is applied. This current will go up with rising temperature and voltage. In general, the amount of leakage current is indicative of the immediate quality of an electrolytic capacitor—the lower the better. Long shelf life or storage will cause the leakage current to go up. Leakage can also be detected by the time it takes to charge the unit to rated d.c. voltage.

ESR (equivalent series resistance) is a measure of the internal resistance of a capacitor. This resistance is responsible for the heating effects associated with a capacitor. The ESR of an electrolytic varies inversely with temperature. It is also related to capacitance and frequency.

The dissipation factor (D.F.) of a capacitor is the ratio of the ESR to the capacitive reactance. The power factor

Fig. 1. Cross-section of (A) polarized and (B) non-polarized aluminum electrolytics. (C) shows the construction details.



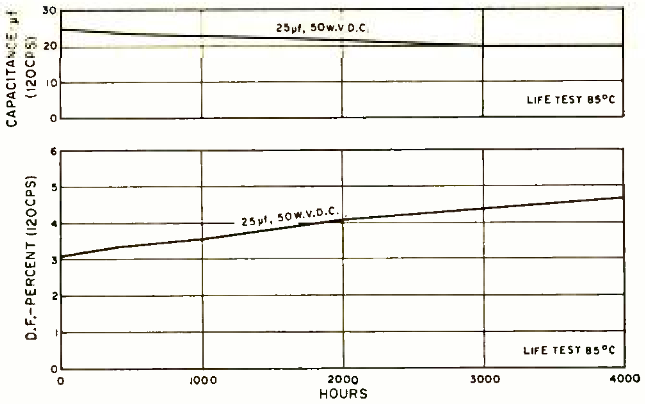


Fig. 2. A typical life test for one specific type of industrial-grade can-type aluminum electrolytic with axial leads.

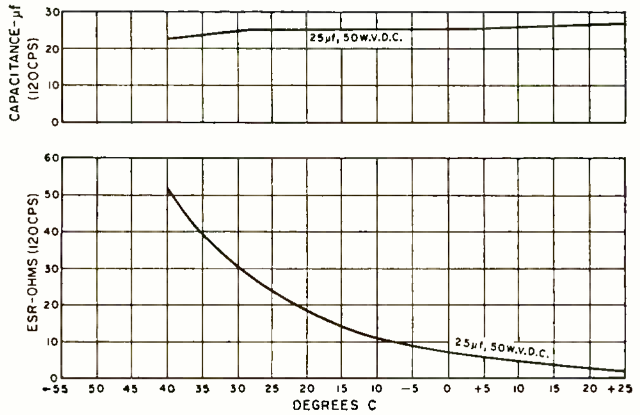


Fig. 3. Typical stability of electrical characteristics vs temperature for same type of industrial-grade capacitor.

(P.F.) is the ratio of the ESR to the total impedance of the capacitor. For low losses, power factor is equal to dissipation factor up to 12%. Beyond this, dissipation factor increases without limit as losses go up. Naturally, as the capacitor deteriorates, the ESR increases. If all these factors are taken together, it can be concluded that ESR is a most important factor when judging a capacitor for its use and end-life characteristics.

ESR also has an effect on the ripple-current rating of an electrolytic capacitor. The a.c. ripple current combined with the ESR causes internal heating which must be dissipated. A small additional loss caused by the d.c. leakage current is also present, but is usually negligible.

A rule-of-thumb for determining maximum permissible ripple current conditions is that the capacitor case temperature shall not exceed +10°C above the maximum rated temperature for the capacitor. It is also common to allow a 5°C increase in case temperature rise for each 10°C decrease in ambient operating temperature.

Variations and Types

The capacitor designer can vary the cost, life, electrical parameters, temperature range, and mechanical factors by changes in anode foil, cathode foil, paper spacers, electrolytes, terminations, and packaging.

For example, using an anode with a high ratio of formation voltage to rated capacitor voltage in combination with heavy paper separators and a conservatively activated electrolyte (close to neutral *ph*), will result in a capacitor having long life, −20 to +65°C temperature range, and medium changes in electrical parameters. The choice of packaging can affect even this conservatively designed unit. Generally the package can be judged by its ability to keep the electrolyte from escaping, leaking, or diffusing from the container. The better the package is sealed, the better the capacitor will retain its initial characteristics.

Capacitors are made and sold by intended end use in three grades: (1) commercial, (2) industrial/instrument, and (3) premium. The commercial generally offers the most capacitor for the lowest price. The industrial/instrument is a conservatively designed capacitance section in the lowest priced package. The premium grade is the finest capacitance section and best package for optimum electrical performance in all respects.

Within each of these three categories, the manufacturer offers a very large variety of sub-types that differ from each other in certain characteristics and applications. Table 1 generalizes the importance of the various characteristics and ranks them for the three main grades of capacitor. In addition, Figs. 2, 3, 4, and 5 show some of the important characteristics of two specific types of aluminum electrolytics, one in the industrial/instrumentation grade and one in the premium grade.

Tantalum Electrolytics

Tantalum is the second most popular oxidizable-base metal for use in electrolytics. Tantalum oxide has almost twice the dielectric constant of aluminum oxide and is exceptionally stable with temperature. It is also very inert to chemical attack and this property allows the use of highly ionized acid electrolytes not possible with aluminum. Tantalum is available in a high-purity form both as a foil and a powder, thus more diverse physical arrangements are possible than with aluminum.

All these properties of tantalum make it possible to produce tantalum capacitors with these advantages: higher μf./volt per unit volume, wider operating temperature range, better temperature stability characteristics, longer life, more rugged construction features, better electrical parameters, and excellent shelf life. The main drawbacks

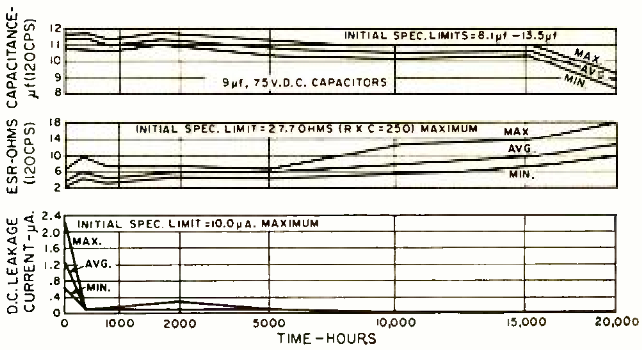
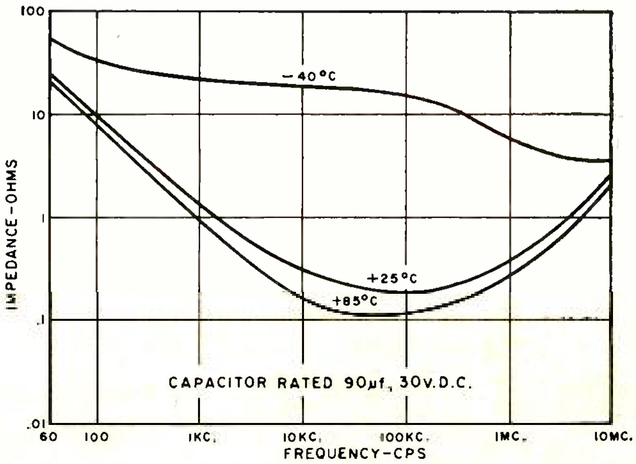


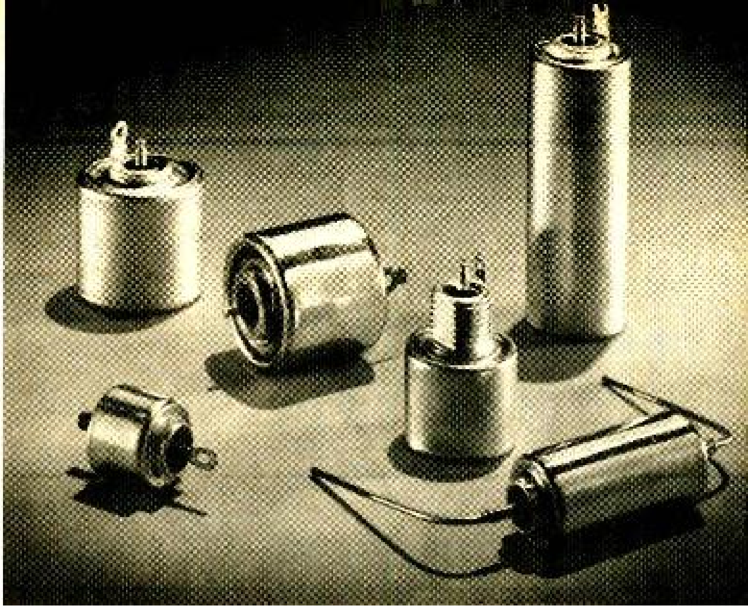
Fig. 4. Typical life test for one particular type of premium-grade can-type aluminum electrolytic unit with axial leads.

Fig. 5. Typical impedance vs frequency at various temperatures for same type of premium-grade can-type aluminum electrolytic.



Characteristic	Commercial Grade	Industrial/ Instrument	Premium Grade
D.C. Leakage Current	3	2	1 (lowest)
ESR, Diss. Factor	3	2	1
Impedance	3	2	1
Parameter Changes vs Temp.	3	1	2
Parameter Changes vs Life	3	2	1
A.C. Ripple Current	3	1	2
D.C. Surge Voltage	3	2	1 (highest)
Polar or Non-Polar	Either type for all grades		
Mode of Failure	Gradual degradation for all grades		
Normal Life	3-5 years	5-10 yrs.	15-20 yrs.
Cost	3	2	1 (highest)

Table 1. Ranking of some of the more important characteristics of the three major types of aluminum electrolytic capacitors.



Grouping of special radiation-resistant tantalum electrolytics.

are the greater cost and the lower operating voltages of the tantalum types.

Of all the plus features, the stable shelf life at temperatures of 30-40°C for periods of time up to 5 and even 10 years without harmful parameter changes is the most outstanding. This factor alone makes it possible to use electrolytics widely in military gear. Thus, the expense of this rare metal was justified and has led to the almost explosive development and use of several types of tantalum electrolytics in the past ten years. In 1964, for example, 64,000,000 units, worth $51,000,000, were sold.

Three major categories of tantalum electrolytics are being made and used in quantity. They are the solid electrolyte types, foil types, and wet anode types with solids outselling the other two by a ratio of 5 to 1 or more.

The tantalum foil types are similar in construction to the aluminum electrolytics. The oxide on the anode foil is the dielectric, the electrolyte is the cathode, and the cathode foil is primarily a connector. They are cased in aluminum with various end seals made of rubber or Teflon. Generally, the package construction is more critical because of the emphasis on long life and stable electrical parameters for high reliability end use.

Wet-anode styles are made by pressing tantalum powder and a binder, in a mold or die, to a given shape, usually cylindrical. These pellets are then sintered under high vacuum and temperature to remove the binder and impurities, leaving a rugged, porous metal pellet which is then electro-chemically treated to form a layer of tantalum oxide. These anodes are then assembled in silver outer cases, filled with an electrolyte, and sealed. Again, a rubber or Teflon end seal or a combination of both are used to achieve a nearly hermetically sealed container.

Solid-electrolyte units are made by using a sintered anode which has an oxide formed on it the same as that used for wet-anode types. The porous anode is then im-

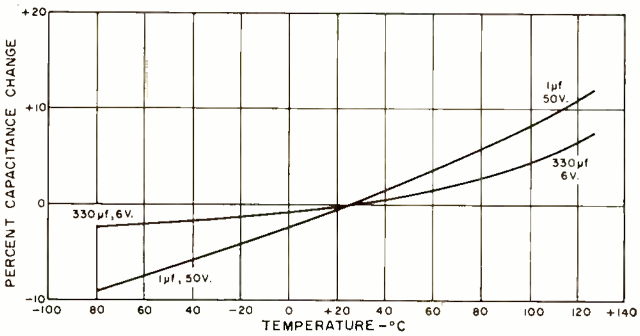


Fig. 6. Typical capacitance change with temperature for one specific type of solid-electrolyte tantalum electrolytic.

Fig. 7. Impedance change vs frequency measured at 25°C for the same type of solid-electrolyte tantalum capacitor unit.

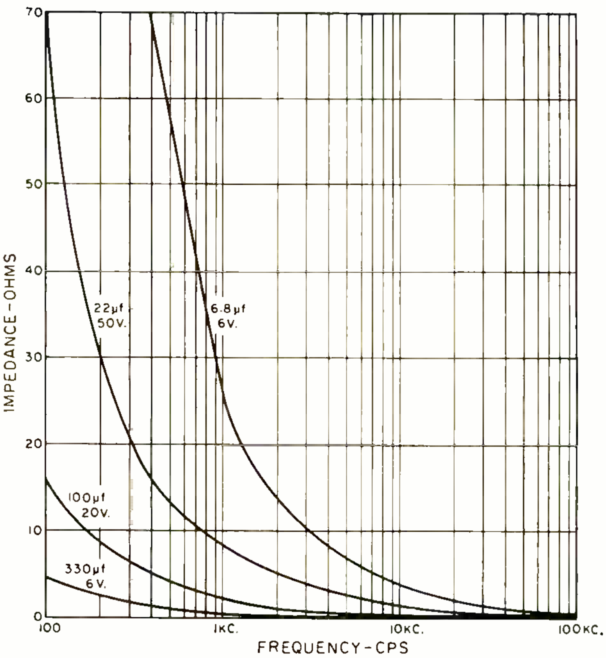
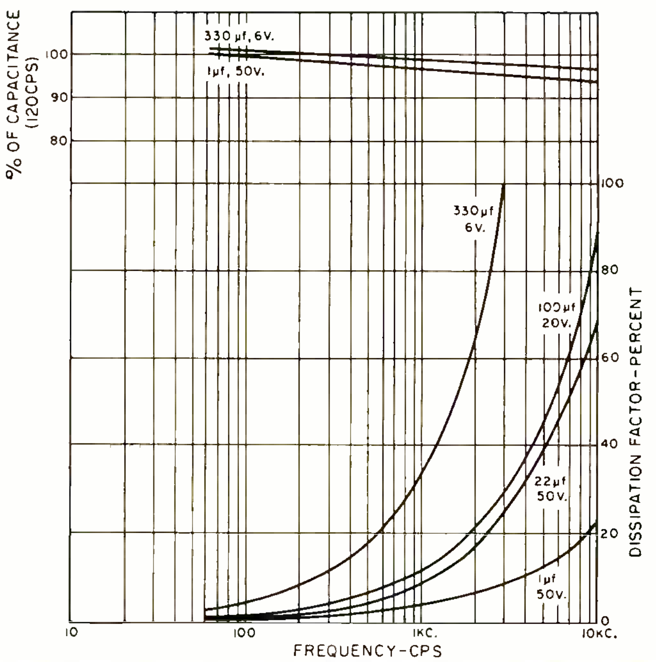


Fig. 8. Typical capacitance and dissipation factor changes with frequency at 25°C for same type of tantalum capacitor.



Characteristic	Solid Electrolyte	Wet Anode	Foil Type
Max. Working Voltage	100 v.d.c.	125 v.d.c.	300 v.d.c.
Max. Temperature	125-200°C	125-200°C	125°C
Capacitance Efficiency (μf./volts/volume)	2	3	1 (lowest)
D.C. Leakage Current	3	1 (lowest)	2
Reverse Voltage Potential	5% w.v.d.c.	0	3 v. max.
Param. Changes vs Temp.	1	2	3 (lowest)
Failure Mode	Catastrophic	degradation	Degradation
Life, Reliability	1 (highest)	2	3
MIL-Spec.	MIL-C-26655	MIL-C-3965	MIL-C-3965

Table 2. Ranking of some of the more important characteristics of the three types of tantalum electrolytic capacitors.

pregnated with a liquid solution of manganous nitrate which is then fired in an oven and converted to manganese dioxide. This semiconductor material is the solid electrolyte and true cathode of the capacitor. A layer of carbon followed by a layer of silver paint completes the cathode connection. This complete capacitor is then soldered in a tinned metal container and a glass-to-metal seal affixed to the positive end. Thus we have a rugged, hermetically sealed package with no liquids to leak out.

A brief comparison of these three types of capacitors is given in Table 2. The characteristics are ranked numerically for brevity and ease of interpretation.

A thorough and detailed description of all three styles, along with a quality-control plan and much information on test techniques is available in the MIL-C Specs listed in the table. These MIL-Specs are widely used as industry standards and many suppliers are qualified to furnish products which meet these specifications. All major manufacturers also have special designs and lines in addition to the Military types.

The graphs shown in Figs. 6, 7, and 8 illustrate typical characteristics of a solid-electrolyte tantalum electrolytic capacitor. ▲

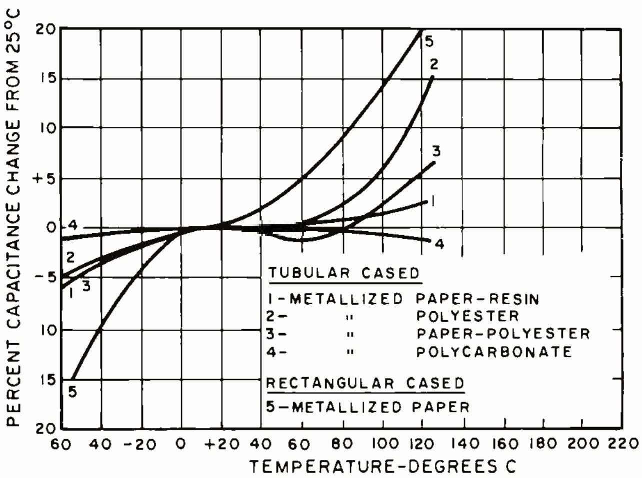
Metallized-Dielectric Capacitors

THE use of metallized paper, film, and dual dielectrics normally results in a capacitor much smaller than foil-type capacitors of comparable rating. In some cases, a volume savings of up to 75% may be realized by the selection of a metallized dielectric capacitor. The small size and self-healing properties of metallized dielectric capacitors make them an ideal choice in many applications.

The advantages of metallized capacitors, however, cannot be utilized in all situations. Metallized capacitors are not recommended for coupling applications, logic circuits, or other applications where occasional momentary breakdowns and periods of low insulation resistance (sparking and subsequent self-healing) cannot be tolerated. The maximum value of the a.c. component that may be applied to the capacitor is limited by both the test voltage rating and by the limited heat conductivity of the thin metallized surfaces. Instantaneous surge voltages must not exceed the maximum, or sparking, voltage rating of the capacitor.

Metallized capacitors are widely used in power-supply filter circuits, bypass applications, and decoupling and smoothing applications where low impedance is required.

The graph illustrates the capacitance-temperature characteristics of paper, polyester, polycarbonate, and paper-polyester metallized dielectrics and metallized dielectric combinations. ▲



MICA CAPACITOR CHARACTERISTICS

	Mica Receiving	Mica Transmitting	Mica Reconstituted
Capacitance Range (μf.)	.000001 — .1	.00001 — 1	.01 — 4
Tolerance (%)	to ±.25	to ±1	to ±5
D. C. Operating Volts	50 to 5000	200 to 50,000	200 to 15,000
A.C. Operating Volts	seldom used	r.f. voltage varies with current and frequency	100 — 7500v. (60 cps)
Dissipation Factor (% at 60 cps)	.001 to .01	seldom used	seldom used
Dissipation Factor (% at 1 kc.)	.02 to .5	.04 to .07	.5
Dissipation Factor (% at 1 mc.)	.01 to .1	.03 to .06	.7 to .9
Insulation Resistance (meg./μf. at 25°C)	100,000 meg. or 1000 meg./μf.	15,000	10,000
Insulation Resistance (at 85°C compared with 25°C)	1:5	1:7	1:8
Temperature Range (°C)	−55 to +150	−55 to +70	−55 to +315
Temperature Coefficient (PPM/°C)	+50 to +200 (depends on cap.)	−20 to +100	−350 to +500
Stability (ΔC with temperature aging)	very small	very small	good

JOHN FRYE

These special transformers, as opposed to conventional transformers, operate on the ferroresonant principle.

VOLTAGE-REGULATING TRANSFORMERS

BARNEY came bustling into the service department with a heavy object cradled in his arms. "There's something I've wanted a long time," he announced, depositing a husky transformer from which dangled a metal-encased capacitor on the service bench.

"What do you need with a voltage-regulating transformer?" Mac, his employer, asked.

"My single-sideband ham receiver drifts a few cycles on 15 and 20 meters when the line voltage changes. Plate voltage of the receiver v.f.o. is regulated with a VR tube, and since the frequency change is a slow affair I'm sure it's the result of oscillator filament voltage change. Even a few cycles of drift is annoying on sideband; but after I plug my receiver into this little gem—which a friend just gave me—the line voltage can horse up and down all it wants without making me retune. I'm told this transformer, in some mysterious way, will hold output voltage within 1% while the line voltage is changing as much as 15%. Just for kicks, I thought I'd check it out on our variable-voltage transformer."

Grinning expectantly, Mac watched Barney connect a 75-watt lamp to the output of the transformer and attach leads from the v.o.m. to the lamp terminals. Confidently the youth plugged the line cord of the voltage-regulating transformer into the output receptacle of the service bench variable-voltage transformer, but he hastily jerked out the plug when he noticed the v.o.m. reading. Gingerly he replaced the plug and rotated the voltage-selecting knob of the bench transformer. Next he substituted test leads from the v.t.v.m. for those of the v.o.m. Finally he connected leads from both meters to the a.c. line and compared readings.

"Man, I don't get that!" he exclaimed. "This transformer is supposed to put out 118 volts, but the v.o.m. reads 133 volts, no matter if the input voltage is anywhere from 105 to 130 volts. The v.t.v.m., on the other hand, reads a little under 100 volts for the same range of input voltage. Yet both meters read exactly 118 volts when connected to the line. This July heat must be getting to me."

"Maybe not," Mac said soothingly. "Think a little. The a.c. meter of the v.o.m. is a rectifying type that deflects according to the average value of a sine-wave voltage but has a scale calibrated in r.m.s. units. The v.t.v.m. is deflected in accordance with peak-to-peak values, but the scale indicates r.m.s. voltage of a sine wave—"

"A non-sinusoidal waveshape!" Barney interrupted, switching on the scope. Sure enough, cycles of the voltage-regulating transformer output looked like slightly domed square waves.

"Your transformer is of the type called *normal harmonic*," Mac commented. "Output voltage of such a transformer contains from around 14% to more than 20% harmonic content, depending on the manufacturer, loading, etc. From the looks of that wave, I'd guess this one is close to 20%. Voltage from these transformers is set with a dynamometer type of voltmeter, and readings from any other type of voltmeter will not be the same. Remember, multiplying peak voltage by .707 to get r.m.s. voltage and by .637 to get average voltage only holds true for a sine wave. Actually, in a square wave the peak, r.m.s., and average values are all the same. Let's see what will happen if you feed your receiver from this transformer."

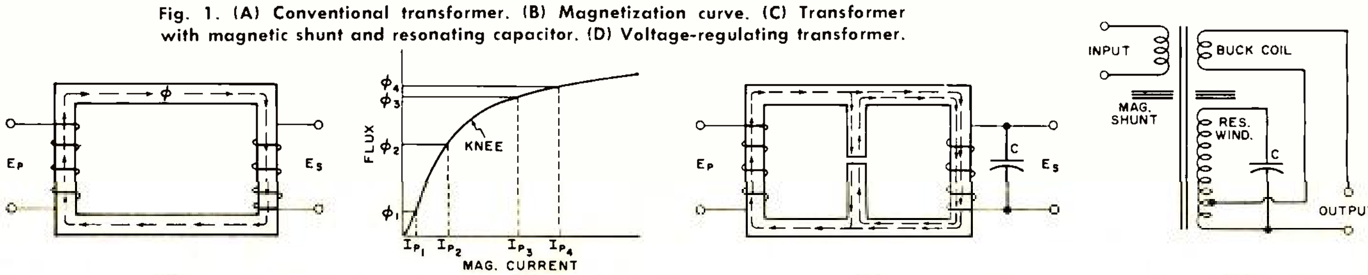
Mac connected a full-wave bridge instrument-rectifier across the 10-volt secondary of a bell transformer and placed a 40-μf. filter capacitor across the rectified output. A 14-volt lamp was connected across the secondary.

"Voltage across the filter capacitor will represent d.c. voltages in your receiver," he said. "The lamp bulb will represent filaments, and the reading of this lightmeter beside the bulb will indicate any change in filament temperature. When the primary is connected straight to the 118-volt line, I see we have 13 volts d.c. across the filter capacitor, and both the v.o.m. and the v.t.v.m. read 10.5 volts a.c. across the secondary.

"Now we switch the primary to the output of the voltage-regulating transformer. The lamp gets a little brighter—I'd guess about 5% according to the lightmeter—but our d.c. voltage has dropped to 11 volts! Secondary voltage has gone *up* to 11.6 volts measured with the v.o.m., and *down* to 8.8 volts measured with the v.t.v.m. Besides demonstrating the futility of trying to measure non-sinusoidal voltages with conventional meters, this experiment leads us to expect d.c. voltages will be down by about 15% in your receiver while the filaments burn a little brighter.

"Normal-harmonic-type voltage-regulating transformers are not recommended for use where a high harmonic content may lead to difficulty or where the output is to be rectified. Such is not the case when the output is used for heating or to operate relays and solenoids. In your case, why not use a separate filament transformer working off this gift horse of yours for heating critical filaments in your receiver? You could arrange it so these filaments burn all the time and keep heat-sensitive circuitry warmed up. That will make your receiver

Fig. 1. (A) Conventional transformer. (B) Magnetization curve. (C) Transformer with magnetic shunt and resonating capacitor. (D) Voltage-regulating transformer.



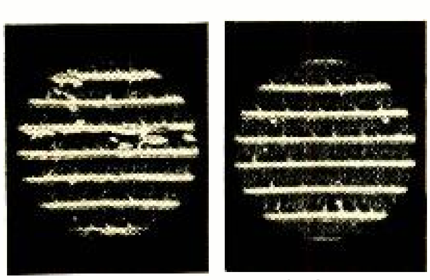
Some plain talk from Kodak about tape:

Slitting accuracy and skew angle

Tape is made in wide rolls which are slit to width — ¼″ for most audio tapes. There are three main considerations in this process: cleanliness, dimensional accuracy and trueness of cut. Cleanliness cannot be given too much consideration. When the tape is slit, particles of the oxide and the base can flake off. This condition arises from poor oxide adhesion and poor quality-control standards on slitters. Slitting dirt is virtually nonexistent in Kodak tapes because of our "R-type" binder and our unique slitting techniques.

Tape dirt clogs the recording gap and prevents the tape from making intimate contact with the head, thus causing dropouts and high-frequency losses. Oxide dirt can also cause a phenomenon known as re-deposit. During a normal tape transport operation, gummy oxide dirt can actually re-deposit on the magnetic layer and fuse in position. Just imagine Main Street strewn with giant boulders. Well, that's the way re-deposits appear to your recorder heads. Pleasant thought, isn't it?

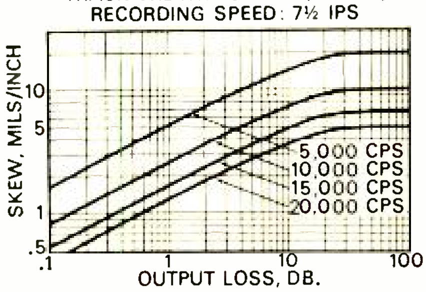
To get some idea about how Kodak tape slitting compares to ordinary slitting, take a look at these two photomicrographs. The dirt you see between the turns on the left is oxide dirt. Compare it to the virtually spotless edges of KODAK Sound Recording Tape on the right.



It's like splitting hairs, only more critical

From our 42-inch-wide master web, we have to cut 160 quarter-inch ribbons of tape — each almost two miles long. That's a lot of total mileage, especially when you think how straight and true those edges must be to assure optimum tracking on your recorder. In terms of slitting accuracy, the standard specs call for a tolerance on width of ±.0020 inches. We decided that that was just about double what it really should be, so we hold ours to ±.0010 inches.

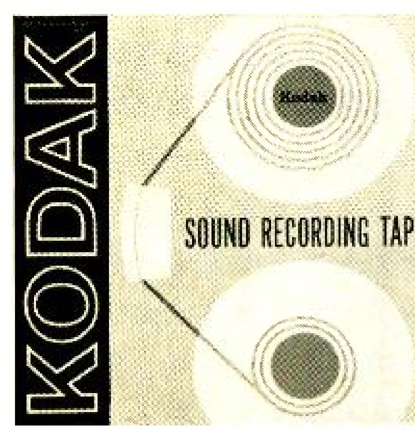
But the really critical part of slitting is a bad guy known as weave. When a tape weaves, it passes the head at a continuously changing skew angle. Look at the graph.



Note how losses pile up as skew angle increases. And as you would guess, the losses are in proportion to the frequency. Higher frequencies, higher losses. Same principle, really, as an azimuth loss.

The patterns of tension set up within the roll when the tape is wound are quite interesting. Normally, the tension at the outside of the roll will decrease until it reaches a point of zero tension about ⅓ of the way from the core. Beyond this point the tension increases, but the direction of that force is reversed. Near the core the tape is in a state of compression. It's just the opposite with the outer layers. They're clocksprínged.

Proper tape tension is also important if you want to prevent "stepping." Stepping usually takes place at the point of zero tension. You can visualize it as a lateral shearing of a roadway during an earthquake. Shades of old San Francisco. This sets up stresses which cause fluted edges and prevent proper head contact. From winding billions of feet of motion picture film, Kodak has developed some pretty specialized tension-control techniques. The end result, of course, is that when you get Kodak tape on a roll, you know it's wound properly: not too loose, not too tight. Just right. Our Thread-Easy Reel is part of the story, too. Because it is dynamically balanced, we get a good wind right off the bat, and you get a good rewind, too, when you run it on your tape deck.



KODAK Sound Recording Tape in a complete variety of lengths and types is available at most tape outlets: electronic supply stores, specialty shops, department stores, camera stores . . . everywhere.

FREE! New comprehensive booklet covers the entire field of tape technology. Entitled "Some Plain Talk from Kodak about Sound Recording Tape," it's yours on request when you write Department 8, Eastman Kodak Company, Rochester, N.Y. 14650.

EASTMAN KODAK COMPANY, Rochester, N.Y.

even more stable than it is right now."

"You know, you're not so dumb for an older man," Barney said. "I'll do it. Now can you tell me how voltage-regulating transformers work?"

"I'll try, but it's not easy," Mac warned. "Not much has been published on the subject in popular magazines. Most of what I know I've learned from literature furnished by the *Sola Electric Company,* a pioneer in the field and a major manufacturer of these transformers.

"Let's start by reviewing conventional transformer action," Mac said while he drew some sketches on the blackboard at the end of the bench. "Fig. 1A here is such a transformer; Fig. 1B is the magnetization curve of the core material. A voltage E_{p1} across the primary causes a current I_{p1} to flow through the primary, producing magnetization flux Φ_1. This flux links the secondary and, in accordance with Faraday's Law, produces a voltage E_s across the secondary proportional to the primary/secondary turns ratio. Secondary current flowing through a load produces a secondary flux that tends to cancel primary flux so that primary current must increase to maintain the original flux level.

"The conventional transformer is a linear device operating on the linear portion of the magnetization curve. Increasing primary voltage to E_{p2} produces current I_{p2}, causing a flux increase to Φ_2 resulting in an increase in secondary voltage directly proportional to the increase in primary voltage. But if the transformer is operated to the right of the knee of the magnetization curve, it ceases to be a linear device. Now a similar change in primary voltage causing an I_{p3} to I_{p4} increase in primary current results in a much smaller increase in flux and, consequently, in secondary voltage. Such a *saturated* transformer provides a degree of voltage regulation, but it is not practical for any considerable amount of power because primary current approaches short-circuit value as the core saturates. What we need is a transformer in which secondary flux could be saturated without materially affecting primary flux.

"This is accomplished in Fig. 1C by what is called a *magnetic shunt* or bypass built into the core. Here, as you can see, only part of the primary flux links the secondary, and *vice versa.* Next, to increase secondary flux saturation, we connect a large value of capacitance across the secondary and establish a condition called *ferroresonance.* A ferroresonant circuit cannot be exactly the same thing as an ordinary resonant circuit because the inductance in the ferroresonant circuit is non-linear; yet the two circuits have many common properties.

"For example, the resonant tank circuit of your amateur transmitter develops very high voltages across it because of heavy circulating tank currents. So long as the excitation voltage is maintained above a certain minimum value, changes in the level of that exciting voltage have little effect on voltage across the tank circuit.

"High voltage across the ferroresonant circuit is also chiefly due to heavy circulating currents through the capacitor. This voltage is much higher than would be expected from the primary/secondary turns ratio. You will find around 600 volts across that capacitor. And voltage across the ferroresonant secondary is little affected by changes in the primary voltage. Isolation of primary and secondary magnetic fluxes allows the heavy saturating secondary current to be produced without heavy primary current.

"But there is always some increase in secondary voltage with an increase in primary voltage, and this leads to the circuitry of Fig. 1D. Here we see a portion of the voltage developed across the resonant circuit fed to the load in series with a bucking winding wound over the primary. An increase in primary voltage leading to a slight increase in voltage across the tapped portion of the resonant winding also produces a slight increase in voltage across the bucking coil. Since the bucking-coil voltage opposes the voltage of the resonant winding, the two voltage increases cancel each other.

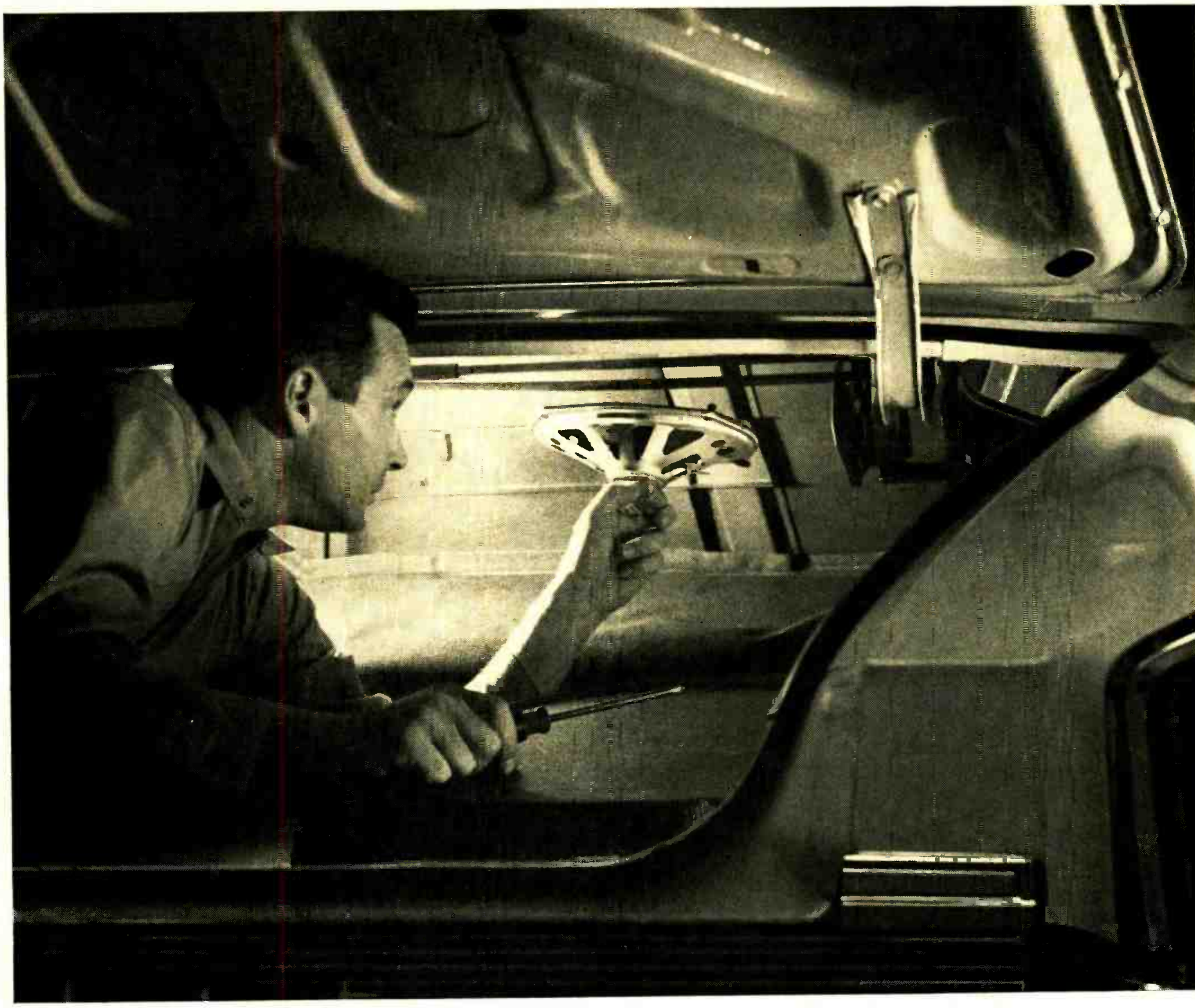
"Those are the highlights of the regulating transformer story, but there's much, much more. For example, if one of these transformers is overloaded, the magnetic field collapses and output voltage falls to zero without primary current increasing enough to do any damage. When the overload is removed, normal operation is automatically restored. And there is another type of regulating transformer, costing slightly more, called the *sinusoidal* that uses additional 'neutralizer' windings to reduce the harmonic content of the output to less than 3%. It can be used for those applications where the normal-harmonic type is not recommended since it has the same excellent voltage-regulating characteristics. Other voltage-regulating transformers are designed to furnish various filament voltages, or combined plate and filament voltages, and for 400-cycle use."

"Is *Sola* the only manufacturer of these transformers?"

"No. Other companies that manufacture or have manufactured voltage-regulating transformers include *Stancor, Triad, Acme Transformer, General Electric,* and *Raytheon.*"

"Well, thanks for all the information—I think," Barney said. "I feel a little like the fellow who asked for a slice of bread and got a bakery. But you just let me mull over what you've told me for an hour or so, and I'll bet I can come up with some questions."

"No bet!" Mac answered quickly. ▲



How to make some sound money

Talk up rear-seat speakers! Here's a good profit item you can sell to your car-owning customers. And spring is the time when everyone wants one. If he doesn't have a rear-seat speaker now he's probably already half sold, just waiting for someone to ask him to buy.

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CIRCLE NO. 123 ON READER SERVICE CARD

THERMISTOR BRIDGE DESIGN MADE EASY

Once a particular thermistor is chosen, the bridge circuit can be designed so that it not only covers the range of interest, but also has a linear scale.

THERMISTORS have a negative temperature coefficient of resistance: *i.e.*, as the temperature goes up, the thermistor resistance goes down. Many circuits using the thermistor as a temperature-sensing device have been published, however, most of these circuits have been designed for one temperature span and, quite often, that is not the range you are interested in. Also, the type of thermistor you have is not quite the same one that the author used. Following is a method suggested by *Fenwal Electronics* for designing a thermistor bridge for a particular application.

Problem

A thermistor bridge is needed to measure air temperature between 0 and 50°C (32 and 122°F), at a precision of .2°C, using a meter as the readout. The meter scale should be linear as possible.

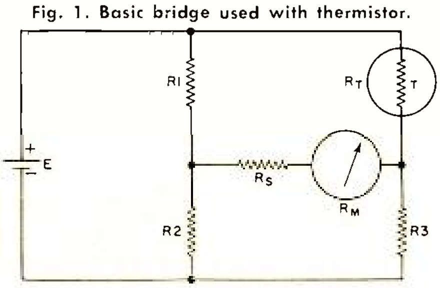
Thermistor

For this particular application, a *Fenwal* 4K "Iso-Curve" thermistor was chosen. According to the catalogue, this device has a resistance of 11,400 ohms at 0°C, 4002 ohms at 25°C, and 1619 ohms at 50°C.

Bridge

The bridge shown in Fig 1 will be used. For a linear output scale, legs $R2$ and $R3$ must be equal to each other and approximately equal to the resistance of the thermistor at the mid-range temperature. Therefore, $R2=R3=4000$ ohms. To get zero current through the meter when the thermistor is at 0°C, leg $R1$ must equal the thermistor resistance at 0°C (11,400 ohms).

Fig. 1. Basic bridge used with thermistor.



Because current flowing through the thermistor produces self-heating, and thus false temperature indications, such self heat must be kept as small as possible, and the still air dissipation must not be exceeded. From the manufacturer's specification, this is 1.9 milliwatt per degree C. Maximum power will be dissipated in the thermistor when the thermistor is the same resistance as the resistor in series with it. ($R3=4000$ ohms). Because the self-heat effect of the thermistor must not exceed the .2°C precision originally specified, a reasonable amount of dissipation would be 50% or .1°C. The maximum amount of power dissipated then becomes $.1\times1.9$ or .19 milliwatt in the thermistor.

Voltage across the thermistor is determined by $E^2=PR$, where P is the allowable power (.19 mw.), and R is the thermistor resistance (4000 ohms). In this case voltage is .872 v. Because the thermistor is in series with $R3$, up to 1.744 ($2\times.872$) volts can be used across the bridge. (A 1.5-v. cell can be used.)

For good results, the meter circuit resistance should be equal to approximately ten times thermistor resistance at highest temperature (1619 ohms at 50°C). Total meter leg is then 16,000 ohms. With 1.5 v. across the bridge and no meter, voltage across the meter circuit ($E1$) at 50°C will be $(1.5\ RT)/(RT+R3)$. This equals .4323 v. Voltage ($E2$) across $R1$ will be $(1.5\ R1)/(R1+R2)$ equals 1.1104 v. $E2-E1=.6781$ volt across the meter circuit. Current flow is equal to E/R where E is .6781 v. and R is 16,000 ohms. The 43-μa. result indicates the use of a 50-μa. full-scale meter. The series resistor Rs can be juggled to make this even out at 50 μa.

Calibration

Various points on the meter scale can be calibrated by substituting resistance values for the thermistor resistance at various temperatures determined from the thermistor operation curve. The bridge may also be calibrated against a known thermometer at various temperatures. ▲

Finco's Color Ve-Log challenges all competition on color or black and white reception and stands behind this challenge with a "Guarantee of Supremacy". The swept element design assures the finest in brilliant color and sharply defined black and white television reception – as well as superb FM monaural and stereo quality. FINCO precision-engineered features make these advanced-design antennas indispensable to good home sight-and-sound systems. And, of course, they carry the famous unconditional guarantee from the leading manufacturer in the field – FINCO. Promote the Color Ve-Log Antennas with pride, sell them with confidence, and profit handsomely.

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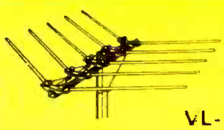

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5 driven elements
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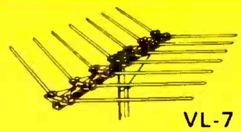

VL-7
7 element VHF-FM
7 driven elements
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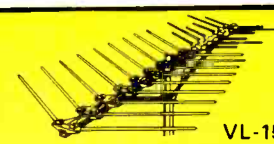

VL-15
15 element VHF-FM
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6 parasitic elements
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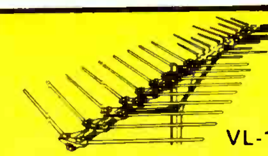

VL-18
18 element VHF-FM
9 driven elements
9 parasitic elements
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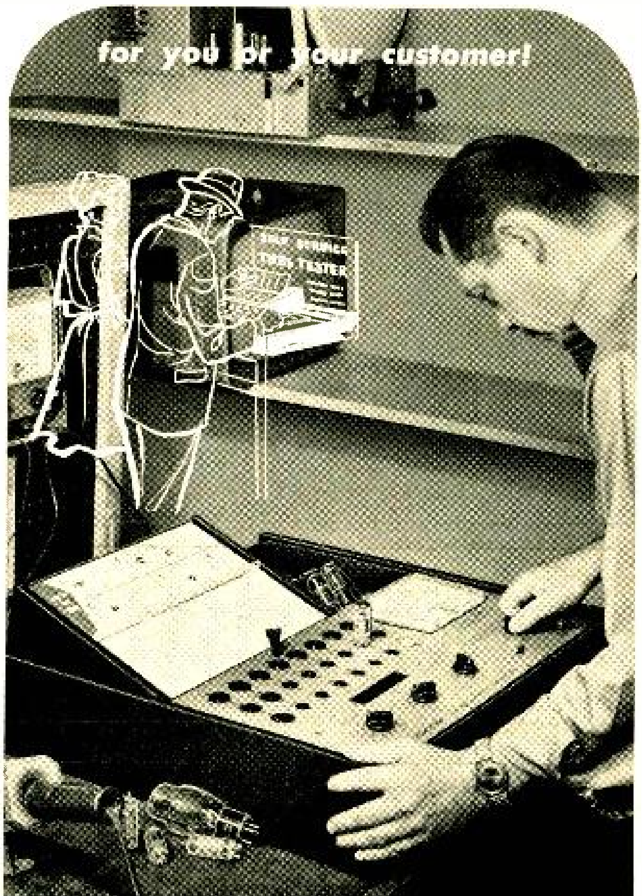


RESISTANCE SOLDERING

By D. A. REID

Electrical circuit replaces soldering iron for fine work and elimination of cold-solder joints.

ELECTRONICS technicians who service equipment on aircraft, ships, or other outdoor installations often have to solder connections in awkward, exposed places, in many cases with some degree of wind blowing. They have to make a choice between a soldering tool that will physically fit the job or one that is big enough to hold the heat required. All too often, they have to settle for the awkward-sized iron that will hold the heat.

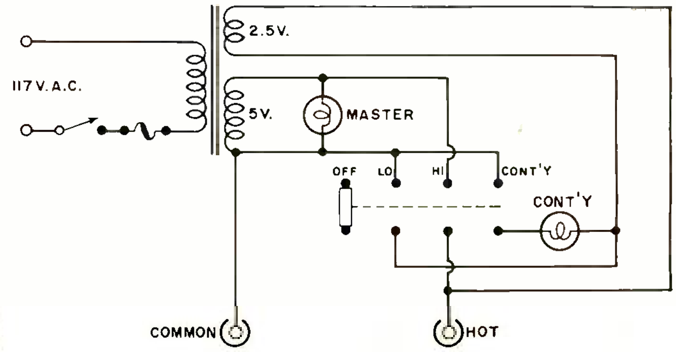
It was for this reason that resistance soldering was developed. Using this technique, enough heat to melt the applied solder is created only when both sides of a power source are applied across a conducting medium. Anyone who has felt a resistor getting hot under excess current flow, or who has had a piece of screwdriver chewed away while it was acting as an accidental short across a power source, has had a practical demonstration of resistance heating.

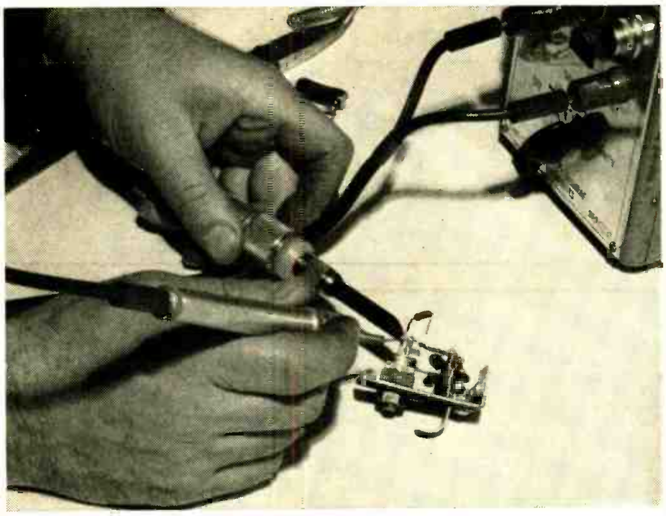
Resistance soldering can be used where components are closely packed without the danger of burning components close to the working point. Heat control for different types of work can be obtained by changing the applied voltage. Doubling the voltage (or current) will double the amount of heat, since the heat generated is proportional to the square of the current flow.

Fig. 1 shows the circuit of a resistance-soldering unit. This particular one is called the Conductance Soldering Kit SU-1C and is used by the RCAF. A carbon bit is connected to the "Common" terminal, and the tool or device used to complete the circuit is connected to the "Hot" terminal. With the selector switch in the "Lo" position, the no-load voltage across the terminals is 2.5 volts; with the switch in the "Hi" position, it is 5 volts. The "Cont'y" position provides a means of checking both the circuit of the soldering tool and the continuity of the completed joint. The "Cont'y" lamp in the circuit reduces current flow sufficiently to prevent the circuit from becoming unsoldered.

As shown in the photographs, there are two ways to use the

Fig. 1. Circuit of the resistance-soldering unit. The fuse size is determined by the current required during soldering.





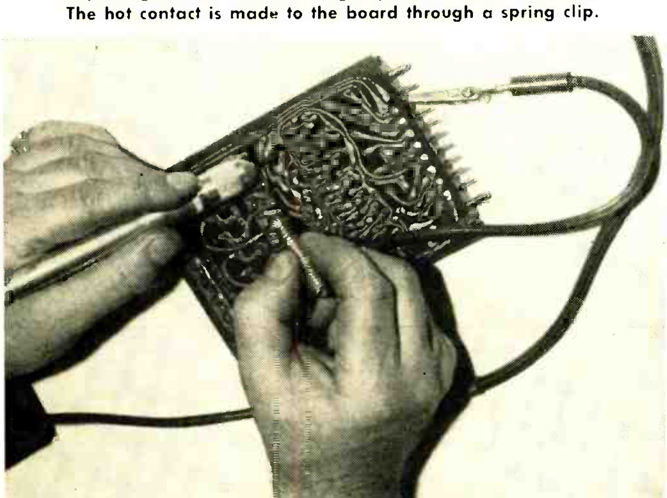
A solder dispenser can be used as one contact when desired. The circuit is completed with either a carbon or metal tip.

resistance-soldering device. One way is to apply both terminals directly across the point to be heated, and the other is to use a spring clip to connect the common terminal of the resistance-soldering unit to a common terminal on the work. The hot terminal is then touched to the working point by a probe-like tool to create the heat. As will be noted in the photograph, one terminal can be a carbon rod. This rod, made from industrial carbon, can be shaped for a particular need by a sanding disc or file. In the probe method, the collet end piece of the probe mounts a slender carbon rod that is used as the electrical contact. A further heat control for working on delicate circuits can be obtained by using a pencil lead in the collet. Soft leads (3B, 2B, B, and HB) will produce more heat than hard leads of the H series, and the smaller diameter of the pencil lead restricts the area of the generated heat.

As with any new technique, some practice is needed to become familiar with resistance soldering. The bit does not become hot instantly, but the contacted point does. Consequently, cold-soldered joints are almost impossible since the solder cannot melt on the bit and then flow to the work. When soldering, an arc may be produced upon contact or upon release of the tool from the work. This arc quenches very rapidly and is a minor optical annoyance.

For unsoldering and disconnecting, a steel hook similar to a dental probe can be fitted into the collet. The carbon rod is brought to one side of the connection and the steel hook is inserted between the component lead and the solder point. As the solder softens, the hook can be slightly rocked to facilitate wire removal. ▲

Repairing a circuit board using a pencil lead in the collet. The hot contact is made to the board through a spring clip.



THE ELECTRONIC DRAFTSMAN

By WAYNE R. WISE

If all alphanumeric and electronic symbols are given a digital code, it then becomes possible to program a digital computer to create finished schematic diagrams.

BETWEEN the scrawled circuit diagram of Fig. 1 and the final schematic of Fig. 2 lies not the hand of a skilled draftsman but the work of a clerk with only 40 hours of special training and a new device called the Automatic Drafting Machine (ADMA).

ADMA is a system of automated design and drafting developed by *Hughes Aircraft Company* that uses a computer and a unique digital-to-analog *x-y* plotter to create finished drawings from rough sketches. For the last two years, two shifts a day, it has been turning out schematics and PERT networks on a production basis.

The heart of the new system is the plotter, which consists of a 30" x 30" table with two symmetrical arms, one moving on the *x*-axis and the other on the *y*-axis. A carriage at the crossing of the two arms holds four drawing pens and a lightweight alphanumeric printer developed specifically for ADMA. The arms of the plotter are driven by a.c. servos with a positioning accuracy of .005%—so accurate that if one line is drawn over another with the same coordinates, the eye cannot detect any difference.

The printer operates at a speed of 200 characters per minute. The characters, available in three sizes, include Greek letters and punctuation symbols as well as the standard alphabet and digits.

The characters are individually mounted on spring-loaded typebars located around the circumference of a three-inch wheel which rotates in the same plane as the table. The wheel is driven by a high-speed stepping motor, one step per character. A binary encoder is driven from the same shaft and relays the position of the desired character to the computer. The printer can print both horizontally and vertically. The small size and light weight make it possible to move rapidly and print in the corners of the table.

ADMA needs only one computer command to draw any line of any length. This is accomplished through the use of six algebraic equations that define the location of the line, the shape (straight, curved, elliptical, or arced), and the length of the line. This feature is unusual, since digital and incremental plotters require a completely separate command for each segment of a line.

Encoding

The creation of a drawing starts when the engineer's sketch is given to an encoder who prepares the paperwork for the computer. First, all of the elements, terminals, and junctions are given numbers as shown in Fig. 3. These numbers are then connected in rows and columns to define their positions, horizontally and vertically. This information, as well as the code for each component, is punched into cards and fed into the computer.

The computer determines the total drawing area required, striking a balance between compactness and visibility, se-

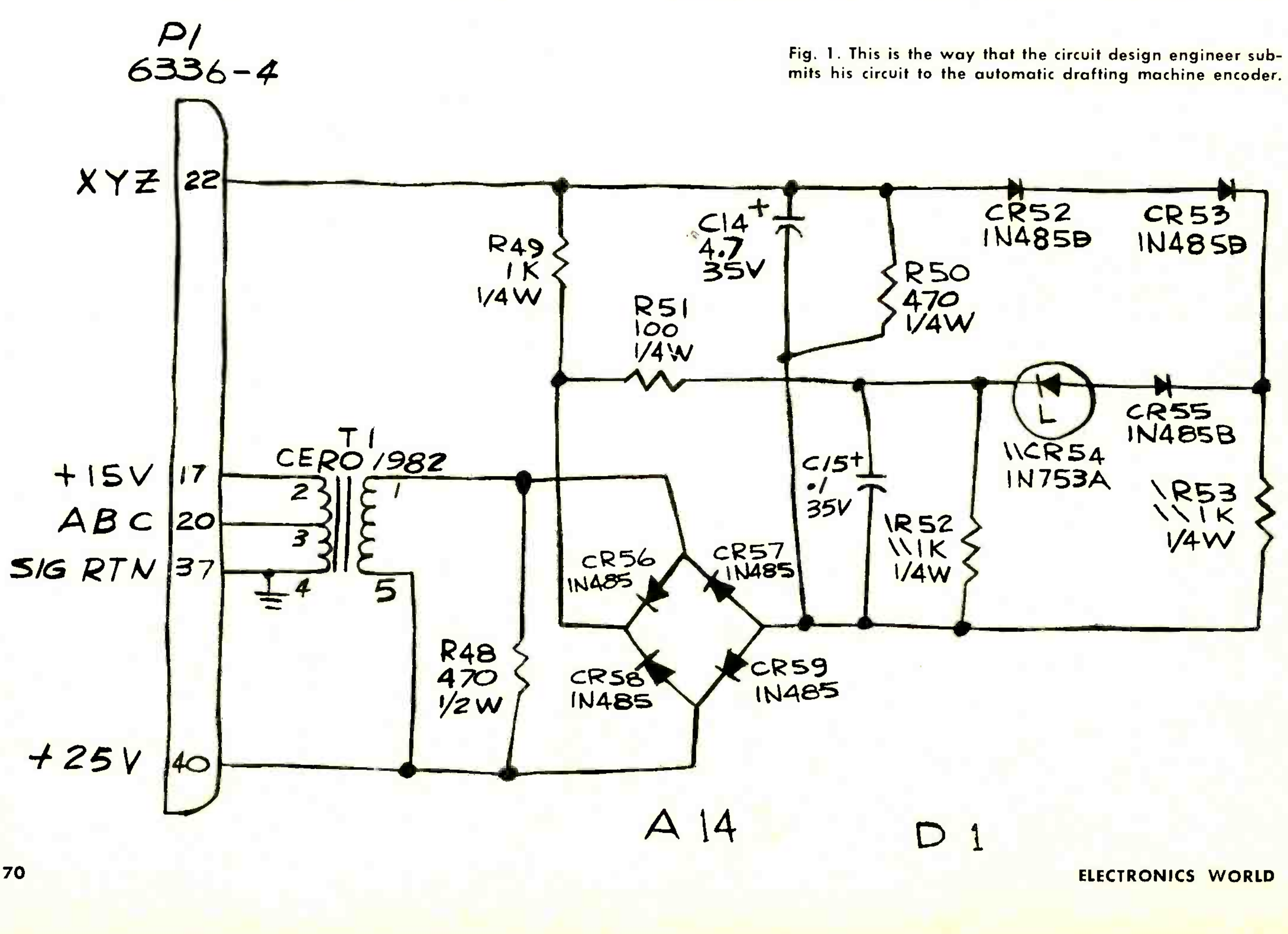


Fig. 1. This is the way that the circuit design engineer submits his circuit to the automatic drafting machine encoder.

The automatic drafting machine couples a magnetic memory with a servo-controlled x-y plotter to produce sketches.

lects the reference point within this area for each element, letter and line, and fixes the coordinates of each terminal, junction, and lead. It then prepares the tape for ADMA, adding the address of each standard symbol and component in the permanent library.

The permanent library consists of about 250 standard symbols recorded on magnetic tape. This eliminates redesigning a symbol each time it is used, since it is only necessary to call out the address in the memory and the computer does the rest. This idea can be extended so that a whole section of a drawing can be reproduced by the use of a single address for that particular section.

Changing a drawing is a relatively simple process. The affected punched cards are changed and a new tape is made with all of the corrections incorporated within a matter of minutes.

The high degree of accuracy and the ability of the system to make drawings in any of six reduced sizes makes it ideal for producing printed circuit masters. Usually these masters are drawn up many times full size and then photographically reduced. The only change required on ADMA is replacing the pen with a heated embossing stylus.

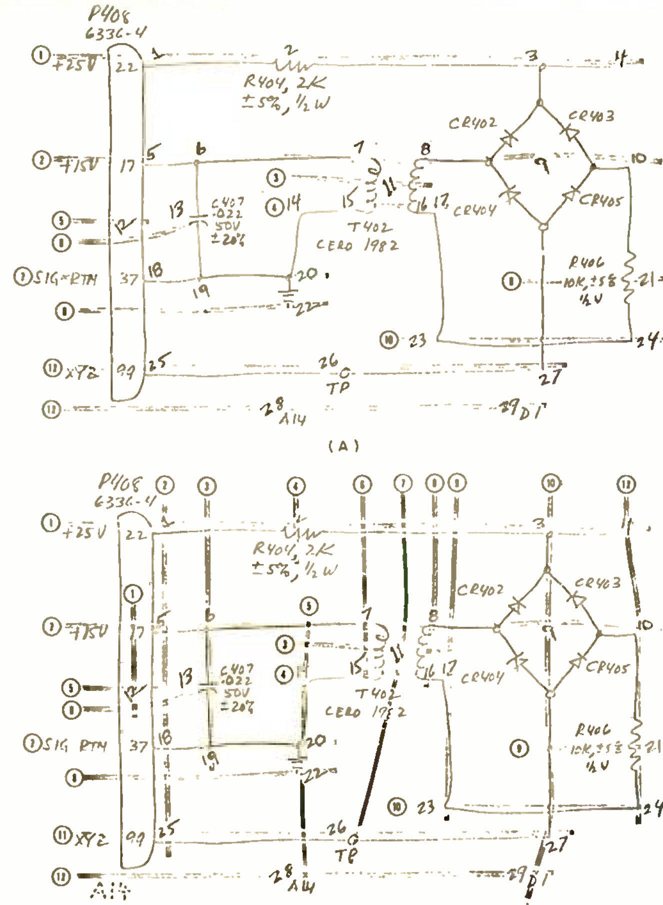


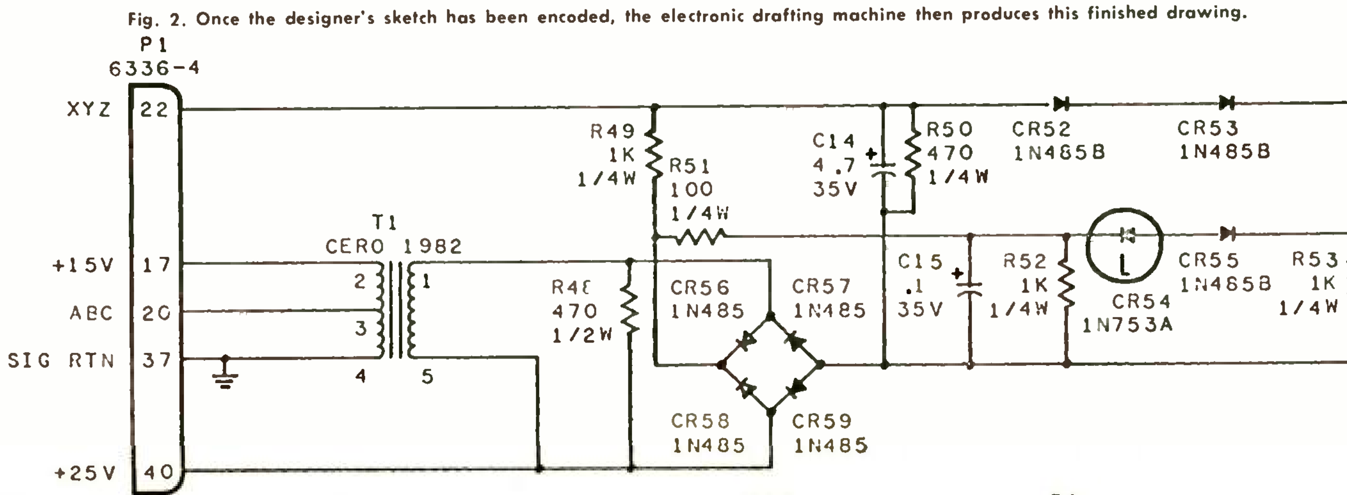
Fig. 3. The encoder takes the designer's sketch and identifies each circuit element as to row (A) and column (B) position.

The program that produced ADMA was started four years ago when a study of the costs in developing engineering products showed that as much as 70% of the total expense was in design and drafting.

Schematics drawn by the machine cost 75% as much as hand-drawn schematics, and PERT networks only 25% as much. In terms of time, the savings are even greater: 75% less time is required for the schematics and 90% less for PERT charts.

Other applications for ADMA that are presently being developed include map-making, drawing logic charts, and making highway and weather maps. The company also hopes that with the aid of another computer, ADMA will soon be able to do routine design work, such as designing gear trains, component layout, and other simple mechanical designs. ▲

Fig. 2. Once the designer's sketch has been encoded, the electronic drafting machine then produces this finished drawing.



Art of Xerography
(Continued from page 28)

and the 813 Copier was put on the market near the end of 1963.

High-Speed Reproductive System

The distinction between office copying and duplicating has always been that the duplicating process requires the preparation of an intermediate copy or master and copiers do not. For long runs, the cost per copy with duplicators is generally less than with copiers. In practice, duplicators are sometimes used to produce 5 or 6 copies (a costly operation) and office copiers are often used to run off copies by the hundreds.

The gap between copiers and duplicators was bridged last fall with the introduction of the *Xerox* 2400. Copies are made with this unit at the rate of 2,400 per hour directly from the original document.

The original document is put on a curved glass platen and illuminated from below by a bank of specially developed fluorescent lights (Fig. 4). The document is then scanned by an optical system using a newly developed oscillating mirror. The image is reflected through a lens to a fixed mirror which, in turn, reflects each image onto a selenium-coated drum. The xerographic image is developed and transferred to the paper. It is then fixed permanently on the paper by a new method called "heated roll fusing."

To achieve speed, new developments were necessary in the optical, developing, and fusing systems. In addition, drum speed had to be increased. The document image is placed sideways on each third of the drum instead of the single image lengthwise on the whole drum. In the new fast-fusing process, the paper is squeezed between two rolls, one heated.

A small analog computer is used by engineer to simulate a control system for a copying machine under development. The mathematical model shortens test time and increases confidence in the design of the control system.

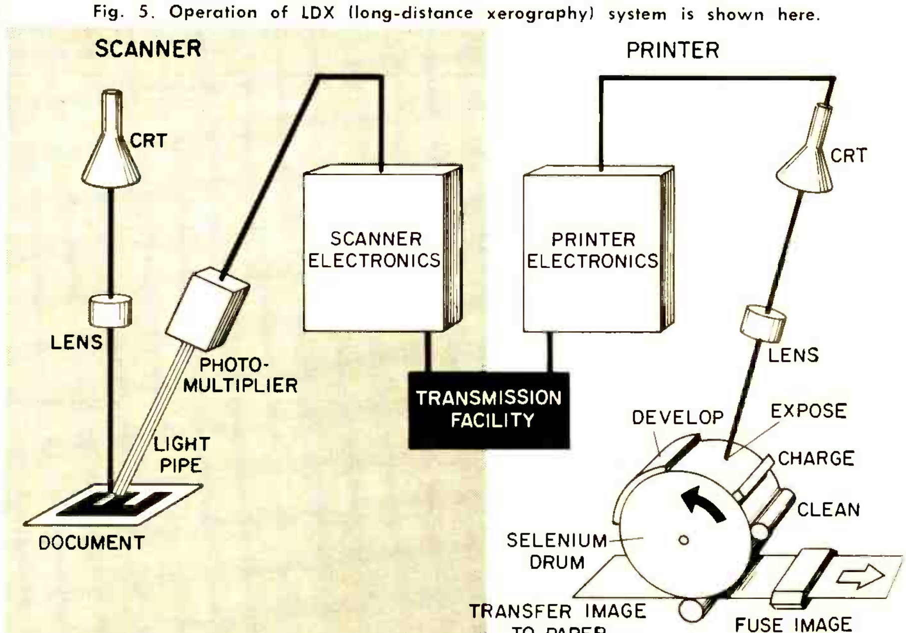
Search for New Products

Xerography can be used with just about any electronic system where the electrical signal can be converted to light. It has, as a matter of fact, been used to produce documents from the outputs of radar, digital computers, and seismic detectors.

As far back as 1950, there existed the capability to apply the principles of xerography in a system utilizing a cathode-ray tube display to produce an image. However, existing transmission facilities were so limited that further development and applications to a long-range facsimile system were not practical.

In 1961 development began on a system that would overcome the shortcomings of earlier facsimile techniques. A primary objective was to produce a

Fig. 5. Operation of LDX (long-distance xerography) system is shown here.



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system that would rapidly provide high-quality copies on ordinary paper.

In 1964 the first commercial long-distance xerographic (LDX) facsimile system was installed. This system, using a scanner and electronics, converts the image to be transmitted into two-level video signals for transmission over broadband facilities, such as microwave, special telephone lines, or cable (Fig. 5). On the receiving end, the signals are sent to a cathode-ray tube that projects them optically onto a xerographic drum. Then, they are reproduced by standard xerographic techniques.

Still in the research laboratory is an imaging method which is based on the deformation (selective wrinkling) of a thin film of plastic. Called "frost," the new method is inherently a continuous-tone process. A photoconductor is used to control the formation of an electrostatic image and the selective deformation of a heat-softened film. A light-scattering image is formed which can then be displayed by reflection or transmission optics.

One final application of the principles of xerography should round out our discussion. Xerographic toners are inert to most inorganic and to some organic etching solutions and, therefore, can be used as a chemical resist in the preparation of printed circuits. The technique can also be used to produce microminiature circuits.

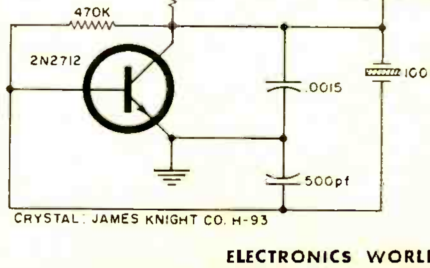
These are but a few of the directions the research program has taken. The company intends to continue this emphasis on "directed research and development" and to push forward into new areas of graphic communications. ▲

CRYSTAL CALIBRATOR

The simple 100-kc. crystal calibrator shown in the diagram, suggested by G-E, can be used to place harmonics of the 100-kc. signal along the frequency spectrum.

Receiver coupling can be either direct to the receiver antenna terminal, or via a small plug-in antenna.

The transistor is used in a common-emitter configuration with collector-to-base feedback. Two capacitors are connected across the crystal to form a voltage divider with the center tap grounded. Sufficient voltage is developed across the lower capacitor to cause oscillation. ▲



CRYSTAL: JAMES KNIGHT CO. H-93

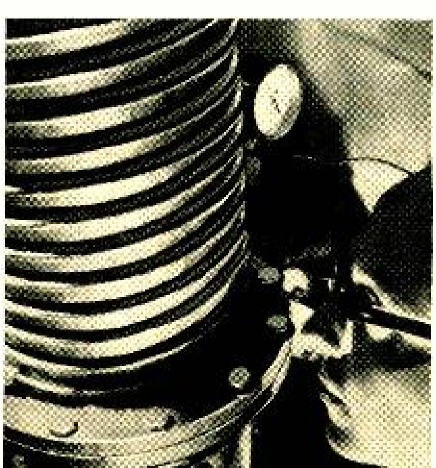
696,000 TECHNICIANS NEEDED BY 1970!

Government Report* Points Out Rapidly Growing Job Opportunities: Need for Trained Electronics Technicians An Important Factor

By Bill Gordon, RCA Institutes, Inc.

President Johnson Emphasizes Need. In his 1964 annual manpower report, President Johnson indicated that the demands for manpower are expanding most in, among other fields, service and technical (including technician) occupations. This expansion is the result of a handful of causes underlying today's big changes in the occupational picture: (1) increasing complexity of modern technology, (2) trend toward automation of industrial processes, (3) growth of new areas of work, such as in the field of atomic energy, earth satellites and other space programs, and (4) data systems analysis and data processing. Indicative also of the growing importance of the use of technicians is a recent revision of the "List of Critical Occupations" published by the U.S. Department of Labor in which technicians are listed for the first time by the U.S. Government.

Salary Levels for Trained Technicians Rising Fast. Beginning salaries for graduates of top level technician education programs have continued to go up during the past five years, at a faster rate than salaries of similar types of jobs. In fact, a U.S. Labor Department projection based on the figures shows that by 1970, technician salaries will average an all-time high.

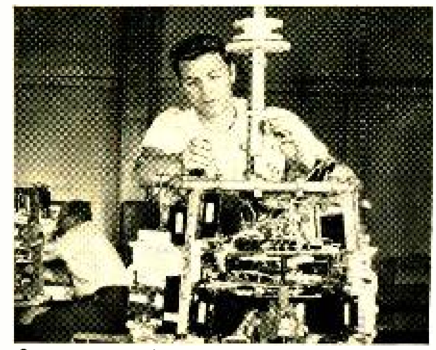


Nuclear Instrumentation

Technical Education is One of Today's Best Investments. Today, a person interested in becoming a technician can choose Home Training or Classroom Training to begin building his career. One of the nation's largest schools devoted to training electronics technicians, RCA Institutes, offers a wide variety of courses in both categories. In addition, the RCA "AUTOTEXT" Programmed Instruction Method is helping people learn faster and easier so they can get started on their careers in the shortest possible time. Dramatic proof comes from the success stories of countless graduates who find profitable positions in government, industry, or in their own businesses.

Of the total 696,000 technicians needed by 1970, it can be estimated that electronics technicians at all levels will form a vital core in today's major job picture.

*"Scientists, Engineers, and Technicians in the 1960's" U.S. Department of Labor, Bureau of Labor Statistics.



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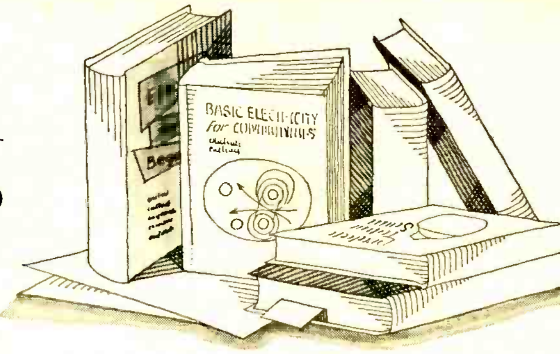
BOOK REVIEWS



"UNDERSTANDING LASERS AND MASERS" by Stanley Leinwoll. Published by *John F. Rider Publisher, Inc.*, New York. 87 pages. Price $1.95. Soft cover.

This is a basic handbook suitable for students, laymen, and technicians. In clear, no-nonsense style the author covers the various types of masers, the ruby and other lasers, applications, laser communications, and laser products commercially available in various forms.

The text material is well illustrated with line drawings, block diagrams, and photographs of commercial equipment. It would be useful if the reader had some scientific background since the author has omitted any discussion of basic electrical and electronic theory.

° ° °

"ELECTRONICS—CIRCUITS AND DEVICES" by R. R. Wright & H. R. Skutt. Published by *The Ronald Press Company*, New York. 428 pages. Price $9.50.

The authors, professor and associate professor of electrical engineering at Virginia Polytechnic Institute respectively, have designed this volume as a textbook for a basic course in electronics for students of engineering—whether or not they plan to continue an electronic engineering curriculum. For this reason the treatment is fairly broad although theory is presented in sufficient depth to be of use to those continuing in electronics.

The text material covers both vacuum-tube and semiconductor circuitry and principles, with all electronic devices discussed before specific circuit applications are covered. The first nine chapters cover the theory while the remaining seven chapters deal with specific circuit applications.

Problems and reference material for additional study are appended to each chapter. There has been no attempt to avoid mathematical treatment where necessary or suitable, so those planning to use this volume as a self-instruction text should govern themselves accordingly. Incidentally, answers to the problems are not included in the text.

° ° °

"PHOTOCELL APPLICATIONS" by Rufus P. Turner. Published and distributed by *Lafayette Radio Electronics Corporation*, Syosset, N.Y. 80 pages. Price $1.50.

This handy little compilation contains over 46 circuits utilizing photocells from which the experimenter, ham, or technician can build a wide variety of useful devices or gadgets.

Included are test instruments, signal generators, photoelectric relays, control devices of various types, communications devices, and miscellaneous and experimental units. Complete schematics and parts lists are included with all of the parts specified readily available and standard.

° ° °

"THE TRANSISTOR" by Joachim Dosse. Published by *D. Van Nostrand Company, Inc.*, Princeton, N. J. 279 pages. Price $8.75.

This is a fourth revised and enlarged edition of a German text, translated from the fourth German edition by Michel Pradervand, a member of the Technical Staff at *RCA*. The proven popularity of this book is easy to understand since the presentation is clear, precise, and comprehensive.

Like the earlier editions, the text has been revised to include the newest developments in transistor technology, both from production and application angles. MADT, planar, post-alloy-diffused types are included along with new applications for improved versions of the older and more familiar transistor types.

This self-contained reference manual includes tables of symbols, schematic diagrams and circuit matrices, plus a complete and up-to-date bibliography listing some 300 pertinent references.

The author has provided over 170 diagrams, some in color, as well as seven pages of full-color photographs. College-level mathematics and a good background in physics are prerequisite.

° ° °

"BASIC THEORY OF SPACE COMMUNICATIONS" by Frederick J. Tischer. Published by *D. Van Nostrand Company, Inc.*, Princeton, N. J. 458 pages. Price $11.75.

Since individual space shots are so incredibly expensive, there is no room for "cut-and-try" experimentation with circuits in the rocket, satellite, or spacecraft. Equipment must be designed, debugged, and built in a non-space environment yet perform flawlessly in space.

This is a unified presentation of the

many subtopics in the field of space communications. Fundamental theoretical topics from four major subject areas—electromagnetics and antennas, plasma dynamics, wave propagation, and communications theory—are covered. The treatment is rigorous, theoretical, and mathematical. Bibliographies are appended to each chapter for further investigation of other source material. The author calls for a baccalaureate in physics or electrical engineering with the appropriate mathematical training as prerequisite.

° ° °

"HI-FI TROUBLES" by Herman Burstein. Published by *Gernsback Library, Inc.*, New York. 159 pages. Price $3.95. Soft cover.

This book is subtitled "How *you* can avoid them, how *you* can cure them," and sets the tone for the treatment of the subject matter. This volume is addresed to the layman/owner of various types of audio equipment—including tuners, amplifiers, speakers, and even equipment constructed from kits.

In eleven chapters the author covers the minimum tools the audiophile will require to work on his equipment, preventive maintenance, noise and hum problems, trouble in bass and treble circuits, distortion, stereo problems, and problems which might arise in constructing a kit.

Cartoon-type illustrations, photographs, block diagrams, response curves, and line drawings are used extensively to amplify the text material which is written in an easy-to-take, informal, conversational style.

° ° °

"THE ELECTRONICS OF MATERIALS" by Samuel Ruben. Published by *The Bobbs-Merrill Company, Inc.* and **"THE ELEMENTS"** by Samuel Ruben. Published by *Howard W. Sams & Co., Inc.*, Indianapolis. $4.25 and $1.95, respectively.

The first volume is based on the author's circular chart in which the periodic relation of the elements is indicated in terms of the valence electron potential in electron volts. Using this chart, as instructed, it is possible to select and determine the components of materials which would be preferable and logical for electronically or ionically dependent applications, such as junctions in solid-state conductors. This volume is addressed to both students and industrial engineers.

The second volume is a convenient and expanded version of the Periodic Table outlining atomic structure in sufficient detail to serve as a reference manual for advanced research projects. The 103 elements are arranged in alphabetical order with one page devoted to each element. There is also a Periodic Table of elements arranged according to atomic number. ▲

Experiments in Space

(*Continued from page* 31)

ardous to a manned space vehicle. This cosmic dust, moving at high velocities, has a "sandblasting" effect on materials. Solar batteries used for power aboard satellites may have their efficiency impaired by the eroding effect of the "sandblast." By measuring the size, velocity, and abundance of these particles, scientists and engineers hope to be able to determine the level of hazard these particles represent. The recently orbited Pegasus satellite is being used to take such measurements.

Magnetic Measurements. Of itself, the earth's magnetic field is of interest. A detailed measurement and mapping of the earth's field will aid in understanding related phenomena. Trapped radiation, the aurora, radio propagation through space, and magnetic storms are believed related in some measure to the magnetic field of the earth.

The presence and strength, or absence, of magnetic fields in the vicinity of a planet or our moon give some indication of that body's composition. Hence we find that magnetic field measurements are of interest in virtually every satellite or deep-space mission.

Solar Plasma. Solar plasma, or solar winds, are tremendous hydrogen clouds which emanate from the Sun. These clouds move at several hundred miles per second and contain α particles (helium ions with +2 electron charge), protons, and electrons as well as hydrogen. Measurements to date indicate that the solar plasma is always present but is subject to broad fluctuations in composition and energy. Moreover, the times of increased solar activity, as with solar flares, have a marked effect on the plasma. Radio communication is greatly affected during solar flares, and extraterrestrial radio noise increases.

The origin and mechanism of solar plasma is not well understood at this time. It is hoped that further experimentation will assist in a better understanding of the nature of this phenomenon.

Radiation Measurements. With the discovery by Van Allen of the radiation belts which bear his name, much interest was aroused in space radiation measurements. In addition to these natural belts of radiation, U.S. and Soviet high-altitude nuclear explosions have added charged particles to these regions, altering the Van Allen belts' composition and shape. While the Van Allen belts are believed to be primarily high-speed electrons and protons, more measurements are needed to better chart these regions. Clearly, these radiation regions could prove hazardous to space travelers.

In addition to electron/proton radiation, other radiations are found in space. Gamma rays (γ rays, similar to high-energy x-rays), cosmic rays, and particles emitted from the sun are also of interest. Also, since our atmosphere filters much of the radiation from the sun, measurements of solar radiation made above the atmosphere will yield more information about the sun. With such an abundance and mixture of particles and waves, more experimental work is in order.

Wave-Propagation Measurements. Since we rely heavily upon the properties of the ionosphere for much of our radio communication, it behooves us to seek a better understanding of this region.

The radio propagation properties of the ionosphere are subject to variation from day to evening, and with the seasons. Solar activity, particularly the eleven-year sunspot cycle, produces severe changes in the ionosphere.

In addition to radio propagation measurements, noise measurements are also of interest.

Astronomical Measurements. Since the earth's atmosphere greatly reduces the resolving power of terrestrial telescopes, we find it desirable to make observations from above this region. Hence telescopes and/or TV cameras aboard satellites and probes can give improved resolution to astronomical observations. This fact was dramatically illustrated when the TV camera aboard Ranger 7 showed the Moon's surface with a resolution of 1½ feet, some 1000 times better than any earth telescope.

Related to this type of experiment are the meteorological satellites, which look toward, rather than away from, the earth. By relaying photographs of cloud formations and earth heat radiation patterns, meteorologists have added information at their disposal for predicting the weather. The Tiros satellite in 1961 warned of the approach of hurricane Esther two days before conventional systems detected its buildup.

In addition to the kinds of measurements we have discussed, most space vehicles carry so-called "housekeeping" instruments. These devices monitor and transmit information having to do with the spacecraft itself. Temperatures, pressures, power bus voltages, attitude (orientation of spacecraft), vibration, acceleration, shock, velocity, time from launch, etc. are of interest during launch and over extended periods of the vehicle's mission.

Housekeeping data is usually transmitted by the telemetry equipment at a slower rate than experimental data since usually housekeeping data is changing at a slower rate. During launch it may be that only housekeeping data is transmitted, and experiments might not be turned on until the region of interest is reached. ▲

CALL ALERT FOR TWO-WAY RADIO

By GAILAND CHILDS
Sr. Development Eng., E. F. Johnson Co.

Simple and economical neon lamp memory tells when unattended two-way radio has been called.

IN the development of a device which would permit selective calling of two-way radio units, it was determined that a system based on a resonant-reed relay would permit operation of many receivers on the same frequency and also eliminate the annoyance of listening to irrelevant transmissions. Such a device could allow operation of the receiver on standby 100% of the time, yet remain silent until called individually.

In a conventional selective calling system, there is usually no way to tell that a call has been received if the operator was not present at the receiver when the call came in.

The call alert device is connected to the audio output of the receiver. When the particular calling tone is received, the resonant-reed relay operates to produce a signalling-tone output while at the same time it activates the call alert circuit to turn on an indicator lamp signifying that a call has been received.

The unit, designed by *E. F. Johnson Co.*, uses one of 37 available reed-relay frequencies thus permitting 37 different systems to operate on the same channel without standby annoyance.

The resonant reeds are of the plug-in type and may be changed easily if two systems in the same locality find they are using the same calling tone and are on the same r.f. channel. The tone generator in the transmitter consists of a resonant-reed controlled transistor oscillator.

The selective calling tone unit in the receiver consists of a vacuum-tube driver, operating with a resonant-reed relay, neon lamp memory, and a reset switch, as shown in Fig. 1.

In operation, the resonant-reed relay is activated when a tone of the correct frequency is received, causing the relay contacts to make intermittent contact. This intermittent contact converts the d.c. current into pulsating d.c. at the signalling frequency. The tone is passed into the audio amplifier and is heard in the receiver's speaker, signifying that this station is being called.

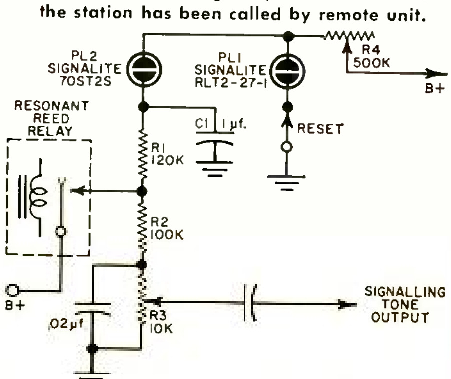
In addition to the audible tone, it was decided that a memory device should be incorporated so that the operator would know his station had been called if he left the unit unattended. For this, the simple and economical "latched-light" circuit shown in Fig. 1 was included.

Two conventional neon glow lamps whose characteristics allow reliable operation over a ± 15% variation of line voltage are used. *PL2* has a starting potential of 100 to 120 volts and it breaks down and ignites as soon as the unit is turned on. The second neon lamp *PL1* (which ignites when the station is being called), has a starting potential of 155 to 210 volts. Because *PL2* has the lower breakdown potential, it always ignites first. Since the sum of its maintaining voltage plus the drop across the three associated resistors is less than the starting potential of the second lamp, *PL1* will not ignite.

When the station is called, the resonant-reed relay causes a voltage to be applied to *PL2* which is nearly equal to the voltage applied to the other side of the lamp. This drops the potential across *PL2* below its maintaining voltage and it goes out. The total circuit voltage is then applied to the second glow lamp (*PL1*), the "call" indicator, which breaks down and ignites. Since the maintaining voltage of *PL1* is lower than the breakdown voltage of *PL2*, the circuit is locked, or latched, until the operator, noting the call signal, resets the circuit by switching the unit to "operate". This returns the circuit to its original condition, and the call indicator light *PL1* goes out.

Neon glow lamps lend themselves well to this type of application as they are economical, rugged, reliable, and have very long operating life. Lamps with different starting potentials are readily available, and the characteristic difference between breakdown and maintaining voltage provides a simple "latched-light" switch and indicator. ▲

Fig. 1. When PL1 glows, it indicates that the station has been called by remote unit.



SELECTIVE AUDIO AMPLIFIERS

By JIM KYLE

Design trends in special amplifiers used to separate signals of different audio frequencies. Circuits are used in high-reliability communications systems, for telemetry data reduction, in research, and for special audio-frequency amplifier design and measurement.

TELEMETRY data reduction, various types of research, audio-frequency amplifier design and measurement, and high-reliability communications systems all make wide use of selective amplifiers to separate signals of different frequencies.

The radio-frequency selective amplifier offers little challenge; it is more commonly known as a communications receiver. However, all the above-mentioned applications are for *audio*-frequency selective amplifiers, which involve many design considerations dissimilar to those for r.f.

The simplest a.f. selective amplifier (on paper, at least) is merely a t.r.f. tuner moved down to operate in the audio range, that is, it consists of a number of resonant circuits tuned to the desired frequency, separated by amplifier stages to both isolate the tuned circuits from each other and provide amplification. This approach is shown in Fig. 1.

The Early Approach

Until recently, this "simple" approach was the one most usually employed. Unfortunately, in practice it provides rather stiff design problems. A number of new techniques sidestep these problems and widen the scope of applications

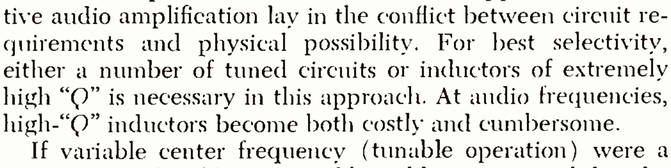


Fig. 1. Audio resonant circuits are used in selective amplifiers.

for a.f. selective amplifiers by reducing cost, complexity, and component count.

The major problem inherent in the older approach to selective audio amplification lay in the conflict between circuit requirements and physical possibility. For best selectivity, either a number of tuned circuits or inductors of extremely high "Q" is necessary in this approach. At audio frequencies, high-"Q" inductors become both costly and cumbersome.

If variable center frequency (tunable operation) were a requirement, the older approach's problems increased sharply. To resonate at audio frequencies, both capacitance and inductance of the tuned circuits must be large. High-value variable capacitors are not readily available—especially when multi-gang units become necessary.

Designers have gone to extremes to overcome these problems, including such approaches as electronic variation of inductance value (Increductors) and use of low-"Q" circuits with high-impedance tuning. However, all these techniques add to the cost and complexity of the instrument; the newer approaches avoid the problems by operating in a completely different manner.

The tuned amplifier of Fig. 1 obtains its selectivity through the flywheel effect of resonant circuits. However, resonant circuits are not the only arrangements of components which offer a flywheel effect and resulting selectivity.

Consider the feedback amplifier diagrammed in Fig. 2. If open-loop gain (a) of the amplifier itself is 99, and the negative feedback network, indicated merely as a block, is a purely resistive affair with a "gain" of 1/10 ($\beta = -.1$), then the total gain of the amplifier will be 9.08. Should open-loop gain increase to 999, total gain would go up to only 9.9. These gain figures would be the same at all frequencies within the passband of the amplifier, and for a considerable extent on either side of the open-loop passband.

However, if the feedback network were something other than a purely resistive "all-pass" arrangement, the result would be somewhat different. Assume that the feedback network has the property of passing all frequencies with a "gain" of 1 ($\beta = -1$) *except* that of 1 kc., and that a 1-kc. signal is totally rejected.

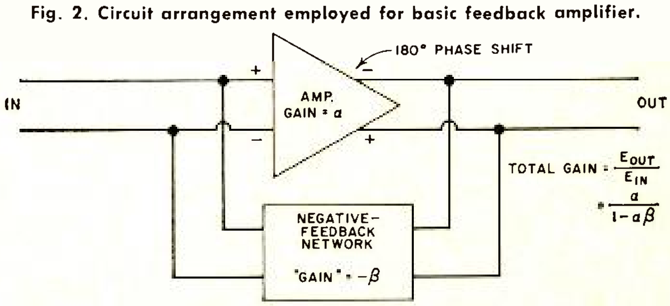
Now, with an amplifier open-loop gain of 99, the total gain will be 0.99 at all frequencies except 1 kc. At 1 kc., though, the gain is 99, since this frequency cannot get through the network and thus the total gain is the same as the open-loop gain. If open-loop gain rises to 999, then total gain at frequencies other than 1 kc. will be 0.999, while that at 1 kc. will be 999, for an approximately 60-db voltage difference.

Unfortunately, the feedback network assumed for this example is not possible. However, several types of *RC* networks do exist which approximate this performance.

Twin-T Networks

One of the most commonly used is the parallel-T or twin-T, as shown in Fig. 3. The transfer characteristic of this network appears in Fig. 4 (values are determined by relationships among the various resistors and capacitors; the transfer char-

Fig. 2. Circuit arrangement employed for basic feedback amplifier.



acteristic shown is valid only for the relationships indicated in Fig. 3, although many other ratios also perform in the same manner).

Note that it *does* have the total-rejection feature of the assumed ideal network, but falls short of perfection in that frequencies near the design center are also attenuated as well as shifted in phase.

To achieve the transfer characteristic shown in Fig. 4, the network must be driven from a zero-impedance source and must not be loaded at its output. In practice, these conditions are met by driving from a cathode-follower or emitter-follower, and by using another cathode-follower or emitter-follower to isolate the network from the amplifier stage providing the gain.

When these conditions are met, the composite unit has an over-all response curve as shown in Fig. 5. Note that higher amplifier gain has two major effects; it narrows the passband and increases the output signal level. At frequencies far from the "tuned" spot, gain will be unity. The increased output signal level has the same over-all effect as reducing the out-of-passband gain, providing better rejection of unwanted signals.

The parallel-T rejection amplifier here described is shown in block diagram form in Fig. 6. It was one of the first of the newer types to gain widespread industry acceptance.

For variable tuning, the values of either the resistors or the capacitors in the parallel-T network can be changed. It is us-

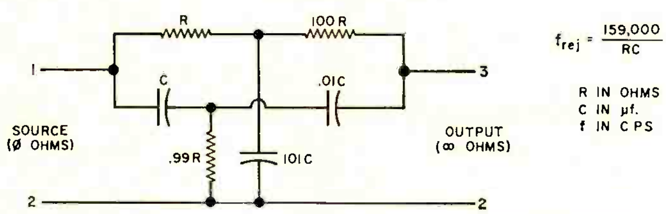


Fig. 3. The circuit constants that are used in parallel-T network.

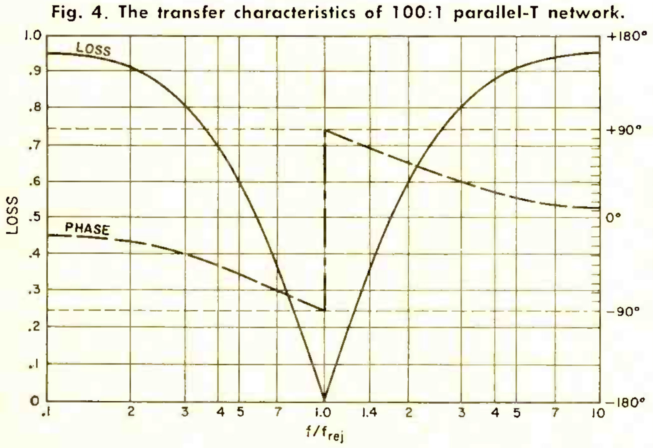
ually more convenient to vary the resistors, since multiple-gang potentiometers are readily available.

However, when this is done the impedance of the network will vary with tuning, and, at the extremes, either selectivity or gain may suffer. Designers have found it more practical to vary the capacitors for decade steps, and vary the resistors over a 10-to-1 range for continuous tuning within each decade.

For laboratory use, switched precision resistors are sometimes employed instead of potentiometers. This permits trimming to exact balance for best selectivity; potentiometers rarely track with sufficient accuracy to maintain peak performance over the full range.

While the parallel-T arrangement offers escape from the bulky and costly high-"Q" inductors required by the tuned-filter approach, it fails to equal the performance of the older techniques throughout its range. An effective "Q" of about 10 was the most attainable with the arrangement discussed thus

Fig. 4. The transfer characteristics of 100:1 parallel-T network.



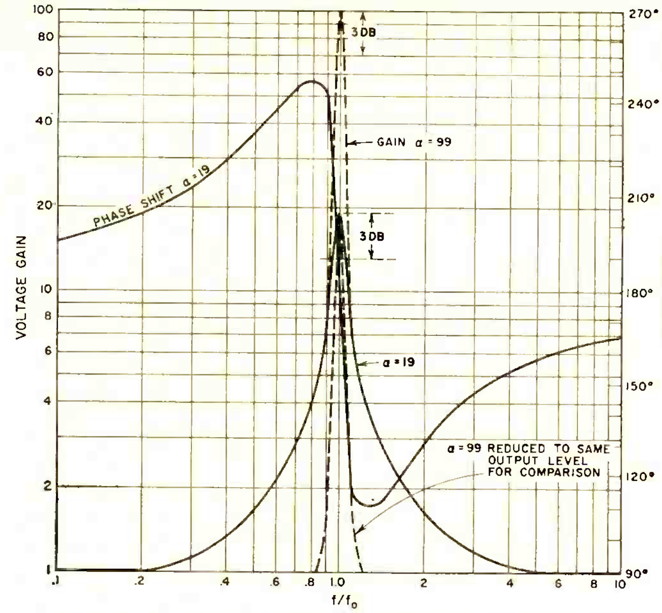


Fig. 5. Gain and phase shift of amplifier discussed in the text.

far. This provides a 10-cycle passband at 100 cps, but at the upper end of the audio range (20 kc.) the passband widens out to 2000 cps. For many applications, this is inadequate.

Remembering that increased amplifier gain resulted in increased selectivity and better out-of-passband rejection, and that one way to increase gain was to add *controlled* positive feedback (regeneration), the designer's next step was to add regeneration to the circuit of Fig. 6.

This required two outputs from the amplifier within the circuit. One must be 180 degrees out of phase with the input signal, and the other in phase. A convenient way of obtaining both outputs as well as providing a low impedance to drive

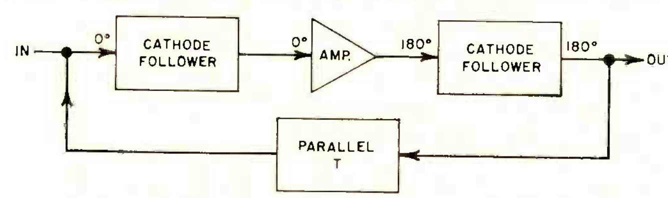


Fig. 6. Parallel-T selective audio amplifier circuit arrangement.

the feedback network is to substitute a phase splitter (Fig. 7) for the output cathode-follower of Fig. 6.

The in-phase output is returned to the input through a variable-loss resistive network which need be no more complicated than a simple variable resistor. The out-of-phase output returns, as before, through the feedback filtering network, a parallel-T. Fig. 8 shows the arrangement.

Adjustment of the amount of positive feedback will vary the gain of the amplifier, but will have no *direct* effect upon events in the negative-feedback portion of the circuit. As gain increases, however, the passband narrows and center-frequency output rises rapidly.

If positive feedback is increased too far, it will overcome the effects of the negative feedback and the circuit will oscillate. Greatest selectivity and best performance is found just before oscillation sets in. Since this point will vary both with frequency and with strength of the input signal, the regeneration control is invariably brought out as an operating front-panel adjustment.

The extra gain provided by regeneration allows effective "Q" of a single-stage selective amplifier to reach at least 80. This is equivalent to a 250-cycle passband at 20 kc., and to a passband just greater than 1 cps at 100 cps. If greater selectivity is needed, two or more such stages may be cascaded.

The regenerative *RC* selective amplifier of Fig. 8 gives performance equivalent to the circuit of Fig. 1, with far fewer

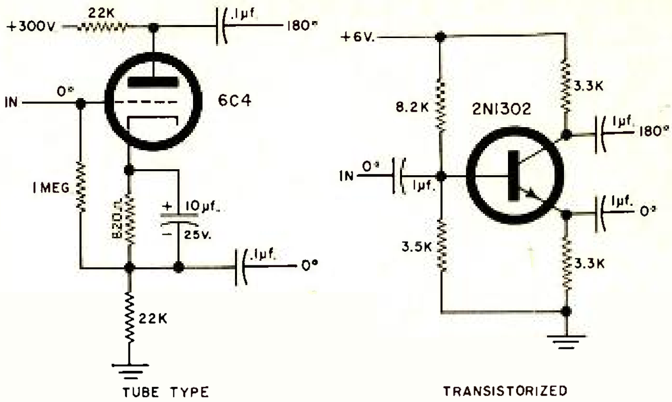


Fig. 7. Tube type and transistorized phase-splitter circuits.

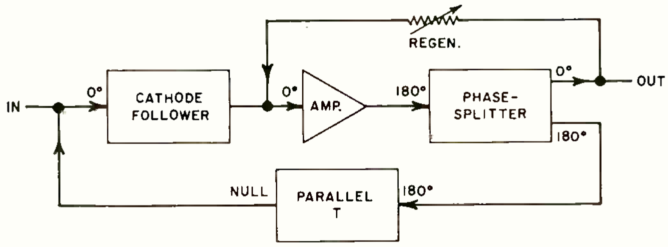


Fig. 8. Selective audio amplifier with controlled regeneration.

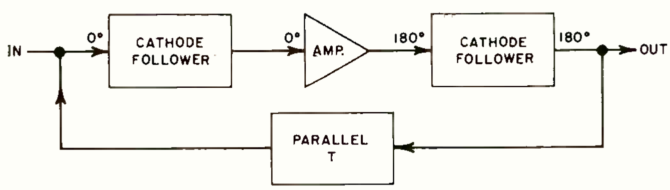


Fig. 9. Single-loop regenerative selective audio amplifier.

components and much less bulk. However, the designers didn't stop at this point.

The selective amplifiers shown in Figs. 6 and 8 both depend on *null* networks in the negative-feedback path. To attain desirable effective-"Q" figures, positive feedback must be added. And isolating stages before and after the null network are necessary for proper operation.

Controlled Phase Shift

Once regeneration was accepted as a useful tool in these circuits, the necessity for blocking the desired frequency from the negative-feedback path with a null network disappeared. Instead, any arrangement which would provide a controlled phase shift through the feedback network could be used.

With controlled phase shift, the shift in the network could be made to vary with frequency. Then the shift would be 180 degrees at only *one* frequency. By controlling amplifier gain, oscillation could be prevented, and the result would be a regenerative amplifier with *one* feedback loop instead of two.

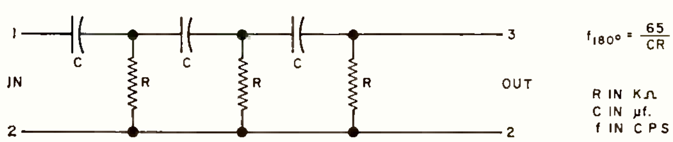


Fig. 10. Circuit of a three-section RC phasing network and formula.

Fig. 11. Voltage gain may be obtained from passive phasing network.

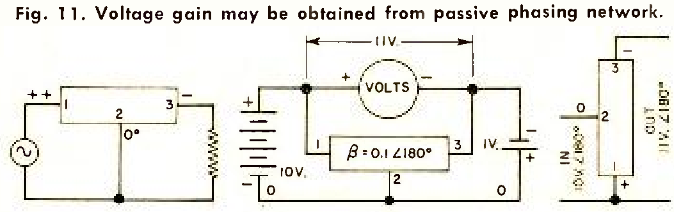


Fig. 9 is a block diagram of an amplifier using this arrangement, with a 3-section *RC* phase-shift network. This circuit provides performance comparable to the more complex hookup of Fig. 8, with much simpler adaptation to variable tuning. The phase-shift network is shown in Fig. 10, together with design equations. With vacuum tubes, the only factors to watch are to be sure enough gain is available in the amplifier so that oscillation *can* be obtained, and that enough control of gain is provided so that regeneration can be smoothly controlled. Transistors require lower impedances, and may require an emitter-follower stage to isolate the phase-shift network output and prevent loading.

However, the relatively low input impedance of the transistor can be used as the output resistor of the phase-shift network if desired. Frequencies can no longer be calculated if this is done, but in practice this is of little consequence.

It might appear that this circuit offers the ultimate in simplicity as compared to the arrangement shown in Fig. 1, but the designers didn't stop here either.

Gain from Passive Network

It has been noted that any three-terminal network capable of producing 180-degree phase shift is also capable of producing voltage or current gain without any active components. While it seems incredible, a glance at Fig. 11 will show how this comes about.

In Fig. 11A, the network is hooked into the circuit in the conventional manner and is being examined at the instantaneous positive peak of the input signal. The output signal is both attenuated and reversed in phase and is thus at its negative peak.

At Fig. 11B, these instantaneous peak voltages have been replaced by batteries of the same value. In addition, a meter has been connected from input to output to measure the voltage.

This meter will measure the sum of the input and output voltages, since the two batteries are connected in series. If

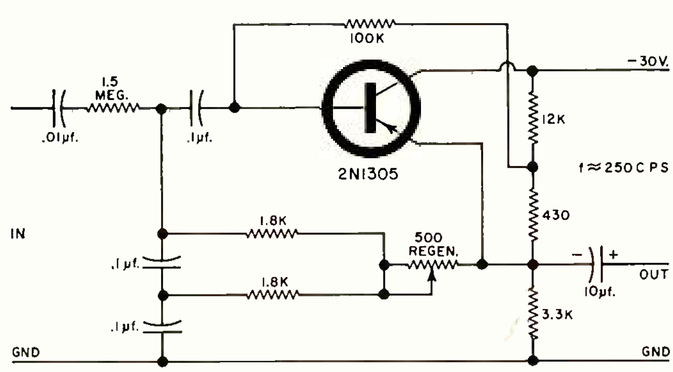


Fig. 12. Single-stage transistorized regenerative selective amplifier.

the input voltage is 10 and the attenuation of the network is 1/10, the output voltage will be −1 and the meter will read 11 volts.

Now, in Fig. 11C, the input is moved from terminal 1 to terminal 2, and the common leads are moved from terminal 2 to terminal 1. The 11-volt potential still exists between terminals 1 and 3 when a 10-volt potential appears between 1 and 2—which is a voltage gain.

Note that transposition of input leads (input and common) amounts to another 180-degree phase shift so that phase shift from input to output is now 0° at the frequency which shows the voltage gain.

Next, consider what happens in adding a cathode-follower to the output and connecting it back to the input. Gain of the cathode-follower is slightly less than unity (about 0.98) and that of the network is slightly greater than unity (about 1.03 maximum in practice). The total loop gain is then 0.98×1.03, or 1.0094. Being over 1, the circuit therefore oscillates.

If cathode-follower gain is decreased to 0.97, the loop gain drops to 0.9991. Oscillation is impossible but selectivity is high.

As before, transistors may be employed by using their low input impedance as the final resistor in the phase-shift network. A working circuit for a single-transistor selective amplifier using this arrangement appears in Fig. 12.

Greater selectivity and more control is possible by using compound-connected transistors as shown in Fig. 13. This circuit has been tested with the parts values indicated and resonates at a frequency of 250 cps. Exact center frequency is affected somewhat by the regeneration control; at maximum selectivity the center frequency is 259 cps and the bandpass extends from 257 cps to 260 cps, equivalent to a tuned circuit with a "Q" of just over 85.

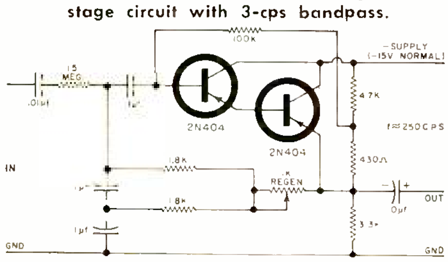
During the course of extended experimentation with this circuit, several modifications were made. More successful was the use of 600-ohm headphones in place of the 3300-ohm emitter resistor and omission of the regeneration control. Regeneration was controlled by adjusting supply voltage. It was this arrangement which provided effective "Q" of 85, although the circuit shown was also capable of doing so. Supply voltage was approximately −6v. It was adjusted by first running the circuit into oscillation, then reducing voltage until oscillations barely ceased.

Requiring only seven resistors, five capacitors, one transistor, and a potentiometer, the circuit of Fig. 12 represents the latest in selective amplifiers and active filters. It operates over an extended frequency range, going as high as 20 kc. with ease. No lower limit has been found; it has been used as an oscillator at 0.0125 cycle per second, and produced a perfect sine wave as traced with a pen recorder. For this frequency, the 1800-ohm resistors were replaced by 47,000-ohm units, and the three 0.1-μf. capacitors with 100-μf. tantalum electrolytics. Supply voltage was −30v.

Comb Filters

With so few parts, selective amplifiers of this type lend themselves readily to construction of "comb filters" for communications use. The response curve of a comb filter for voice communications is shown in Fig. 14. It has been found

Fig. 13. A more selective single-stage circuit with 3-cps bandpass.



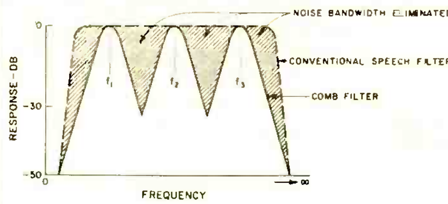


Fig. 14. Frequency-response curve of a typical comb filter network. The network passes voice signals in a manner quite similar to that of a conventional flat-top filter except that noise reduction is obtained.

that a filter having this response will pass voice components in a manner hardly distinguishable from that of the conventional 300-3000-cps speech filter. However, its "comb" curve allows far less noise to pass through. Thus, signal-to-noise ratio of the signal is increased significantly.

To construct such a comb filter, the block diagram of Fig. 15 would be fol-

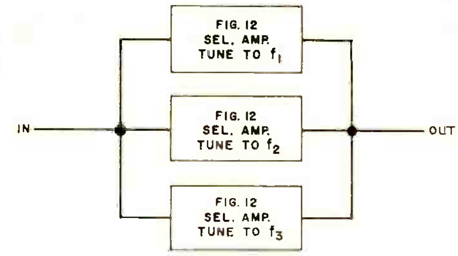


Fig. 15. Block diagram of comb filter using selective amplifiers.

lowed. Center frequencies for the three selective amplifiers would be determined by experiment; starting points would be approximately 700, 1700, and 2700 cps. ▲

C. J. LeBEL, AES FOUNDER, DIES SUDDENLY

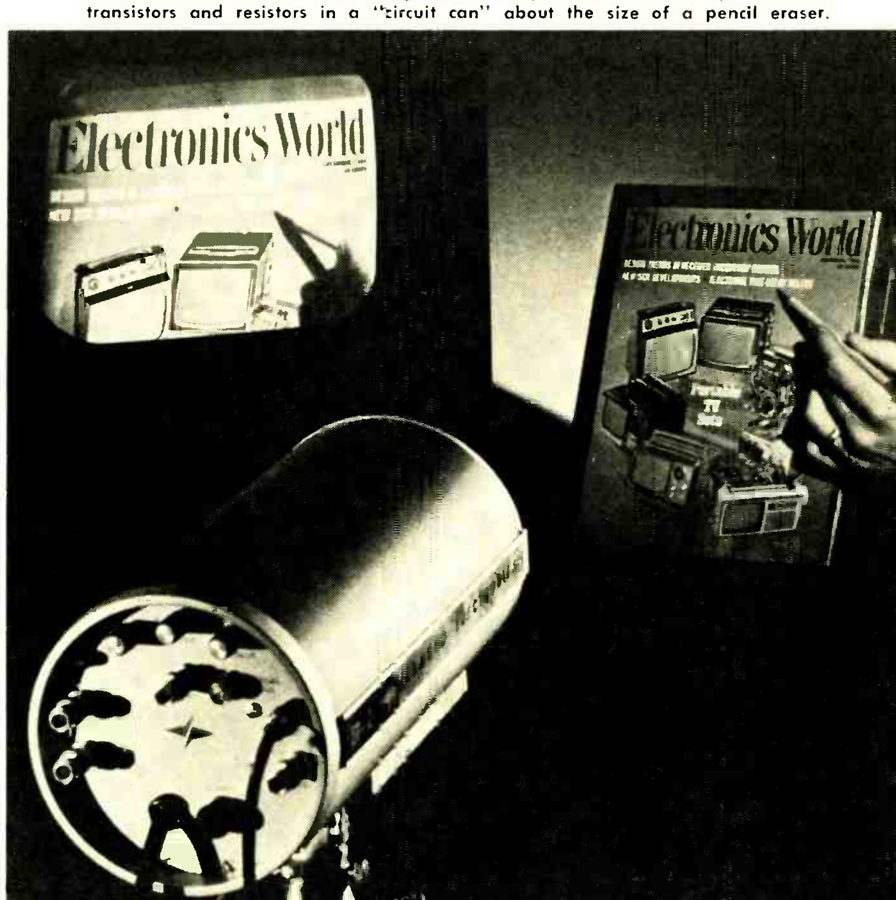
THE audio fraternity was shocked by the untimely death, in New York, of C. J. LeBel, founder and first president of the Audio Engineering Society.

A leading specialist in the field of audio, Mr. LeBel held a number of basic patents covering a wide variety of products in the electrical and audio fields.

A native of New York City, he received his Master's in Electrical Engineering from MIT in 1927. He helped to found Audio Devices in 1937, a firm with whom he was associated as vice-president at his death.

He had served as permanent secretary of the AES for fourteen years at the time of his death. He was also affiliated with the IEEE, Acoustical Society of America, and the Society of Motion Picture and Television Engineers. ▲

The quality of the monitor image produced by a new closed circuit TV camera is demonstrated in this photo of our December cover and the monitor reproduction. The camera, developed by Diamond Electronics, has a resolution of 800 lines with a video bandwidth of 12 mc. It is a companion unit to the world's first all-silicon solid-state camera introduced by the company late last year. Another unique feature is the use of integrated circuitry, which takes the place of 28 transistors and resistors in a "circuit can" about the size of a pencil eraser.



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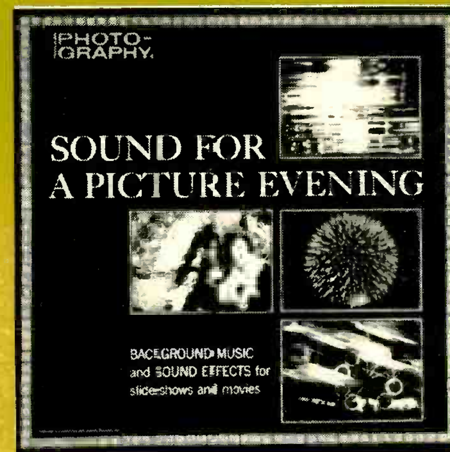

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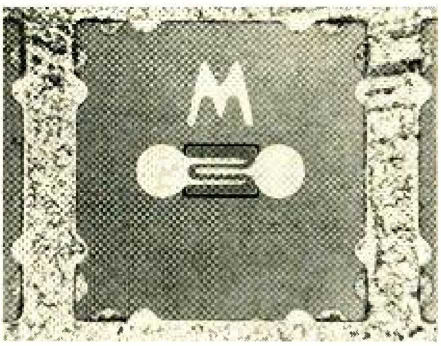
NEW PRODUCTS & LITERATURE

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 coupon on the Reader Service Card.

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

H.F. GERMANIUM ANNULAR TRANSISTOR

Motorola Semiconductor Products Inc. has introduced a transistor where the high-frequency performance capability of germanium is combined with a passivated, annular structure in a new germanium annular transistor. Outstanding features of the new device, the MM2503, include a guaranteed minimum f_T of 1000 mc., a maxi-



mum noise figure of 3 db at 200 mc., and a breakdown voltage of 30 volts.

All junctions as well as the transistor surface are passivated with silicon dioxide. Advanced microconnection techniques are used to make connection to the extremely small bonding areas of the high-frequency structure. The "p-n-p" epitaxial device is housed in a 4-lead TO-18 case.

Circle No. 126 on Reader Service Card

ENGINE TUNE-UP INSTRUMENTS

Rite Autotronics Corp. has added three new hand-held engine test instruments to its line of equipment designed primarily for the do-it-yourselfer. The units, an idle tachometer, a cam dwell tester, and a dual-range voltmeter, are smaller than conventional size testers and have a new easy-to-read black on yellow dial. A metal clip is incorporated for convenient hanging to user's pocket or belt.

The tach provides accurate low rpm readings on all 4-, 6-, and 8-cylinder engines while the dual-range voltmeter is designed for either 6- or 12-volt automotive electrical systems.

Circle No. 1 on Reader Service Card

BATTERY-OPERATED IRON

Parker Trading Company is handling the distribution of the "Miniscope" instant-soldering iron which is designed specifically for both miniature and medium-sized soldering jobs. Current is switched on or off by means of a feather-touch control lever. The tip can remain cold until it touches the soldering point. This eliminates burning of adjacent wires, terminals, or insulation in cramped or crowded chassis.

Although normally used with a transformer for production-line applications, the iron can be battery-operated for electrical repairs on cars, boats, or airplanes. The unit weighs 1¾ ounces and operates at 2 volts.

A comprehensive spec sheet on this iron is available from the distributor.

Circle No. 2 on Reader Service Card

MODULAR INDICATOR LIGHTS

Dialight Corporation has recently introduced a new system which makes possible the construction of light indicators from basic components to meet individual requirements for indication and readout.

By standardizing the various components which go into an indicator light unit the company offers designers new flexibility in specifying. The various cartridges are designed to fit various holders with an assortment of lenses available to fit the assembly. Both neon and incandescent type lamps are included in this new interchangeable line.

The company has complete details on the various lamps plus samples for design engineers.

Circle No. 127 on Reader Service Card

CONTROLLED RECTIFIER KIT

International Rectifier Corporation is marketing a controlled rectifier kit which has been especially designed for R&D laboratories, experimental work, and instructional purposes.

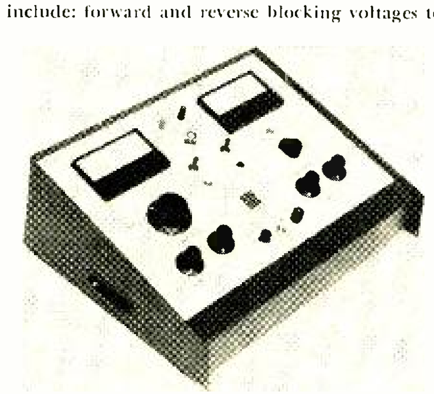
The kit contains five silicon controlled rectifiers providing voltage ranges from 50 to 200 v. at current ratings from 1.5 to 9 amperes r.m.s. In addition, the kit includes an 18-page booklet containing instructions for a dozen projects and experiments. It is available locally through the company's more than 900 distributors.

Circle No. 3 on Reader Service Card

SCR TESTER

Sensory Systems, Inc. is now marketing the Model MP-122 SCR tester which is designed for use in engineering, production, quality control, and reliability organizations. The unit will evaluate all significant parameters of silicon controlled rectifiers and switches, gate turn-off SCR's, photo switching devices, unijunction transistors, and conventional rectifiers and diodes.

Parameters which can be tested on the unit include: forward and reverse blocking voltages to



1000 volts; leakage current with sensitivity to 1 μa., gate firing current and voltage to 100 ma. and 5 volts; forward saturation voltages to 1 amp d.c. and 100 amps pulse; holding current to 1 amp; gate turn-off current to 300 ma.; d.v./d.t. to 500 volts/μsec.; d.i./d.t. to 50 amps/μsec.; and unijunction stand-off ratio and valley storage.

Circle No. 128 on Reader Service Card

TV/FM ANTENNAS

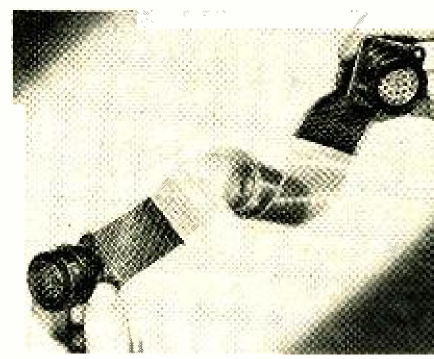
JFD Electronics Corporation is in production on a new series of "Log Periodic" TV/FM antennas which will be marketed as the LPV-TV line. The seven models in the line feature extremely narrow beamwidth across channels 2 to 13 and capacitor-coupled dipoles and directors which enhance third-harmonic mode performance for improved gain and directivity.

The seven models include antennas with 19, 16, 11, 10, 7, 4 and 3 active cells all with director cap-electronic element systems. All antennas feature the use of twin-boom feeder with improved impedance match between low-impedance line and linear dipoles. A unique open-wire transformer brings the impedance up to 300 ohms. Gold alodized aluminum construction is employed.

Circle No. 4 on Reader Service Card

MULTI-CONDUCTOR FLEXIBLE WIRING

Methode Electronics, Inc. has combined its flat, multi-conductor flexible wiring "Plyo-Duct" with cylindrical connector end terminations to provide a "Plycon" harness. The specially designed pin and socket contacts permit interconnection with existing military (MIL-C-26500 and MIL-C-26482) and industrial connectors in the



field for easy circuit modification and weight savings.

All cylindrical connector shell sizes up to 1½ inches in diameter and 61 size 20 contacts can be utilized in the flexible design. The "Plyo-Duct" can also be made in shielded form for the exclusion of stray signal interference in electronic circuitry.

The new harness can be provided in various designs to meet the customer's requirements as to number of insulation layers, conductors and contacts, shell sizes, etc.

Circle No. 129 on Reader Service Card

LOW-LEAKAGE RECTIFIERS

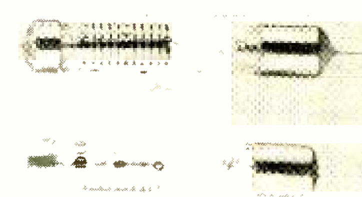
Semicon, Inc. has available a new line of miniature flangeless rectifiers for applications requiring low inverse leakage currents. According to the company, these premium quality rectifiers provide extremely high reliability for such applications as medical, space, military, and special industrial uses. The maximum d.c. reverse current at p.i.v. @ 25°C is 10 nanoamps. Where circuit conditions warrant, selections to one nanoamp are available. The units weigh one gram and can be used in any mounting position.

A bulletin on this new line is available on request.

Circle No. 130 on Reader Service Card

ELAPSED-TIME INDICATOR

Sela Electronics Company has introduced an electrolytic elapsed-time indicator which is being marketed as the "Minichron." This subminiature



time totalizer is offered in either pigtail or 3AG fuse configuration. Time increments of 100, 500, 1000, 5000, and 10,000 hours can be measured. The indicator will operate from 6, 12, or 115 volts a.c. or d.c.

The cartridge measures 1.250" x 0.250" in diameter and weighs 5.6 grams. The entire circuit is encapsulated in a protective seal. The company's data sheet on this indicator includes specifications and application data.

Circle No. 5 on Reader Service Card

TRANSISTORIZED INVERTER

Electro Products Laboratories, Inc. is in production on the Model TI-100, a compact transistorized inverter which provides enough power to operate portable TV sets, radios, lights, and other small household appliances.

The inverter, which plugs into an auto lighter socket, has an output of 117 volts, 60 cycles and a capacity of 125 watts. A unique charge-indicator light glows while the unit is operating and shows condition of the car battery. The cords total 12 feet in length and include the cigarette lighter attachment for simple plug-in operation.

Over-all size of the unit is 3½" high x 6¼" wide x 6¼" deep. It weighs 6¾ pounds. Bulletin TI-265 covering the inverter is available without charge on request.

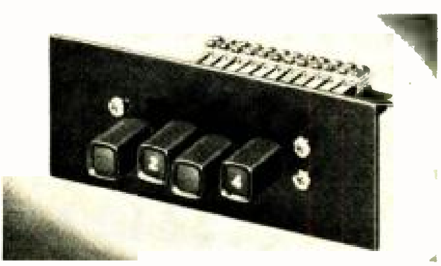
Circle No. 6 on Reader Service Card

BUTTON ILLUMINATION

Switchcraft, Inc. has introduced a new type of button which looks and functions like an illuminated button but which requires no bulb or electrical power.

The button has a translucent front screen upon which a desired legend is marked in an opaque color. The opaque color provides the background for the legend, while the legend itself remains clear. An internal fluorescent illuminator is carried on a pusher which has two legs extending out from the rear.

When the station is actuated the rear legs of the pusher bring the orange-red fluorescent il-



luminator flush with the screen and the legend lights up due to the reflected ambient light.

A limited variety of the new "Glo-Buttons" is currently available in various sizes and configurations. The company will supply complete specifications on request.

Circle No. 131 on Reader Service Card

ULTRAVIOLET EXPERIMENTAL KIT

Raytech Equipment Co. has developed a "broad spectrum science set" designed especially for demonstrations and experiments with fluorescence and ultraviolet rays. The kit is designed around a newly developed lamp that emits both longwave and shortwave ultraviolet. A clearly written booklet is included in the kit and suggests a number of projects that may be used to study atomic structure, quanta, and energy levels.

The set includes the lamp, instruction booklet, four different mineral specimens, fluorescent tracing powder, invisible ink, visible and invisible crayons, and a fluorescent tagged stamp as used for automatic mail sorting.

Circle No. 7 on Reader Service Card

DIFFUSED EPITAXIAL TRANSISTORS

National Semiconductor Corporation has replaced its entire line of silicon alloy junction transistors with a new family of diffused epitaxial transistors which has been designated DET.

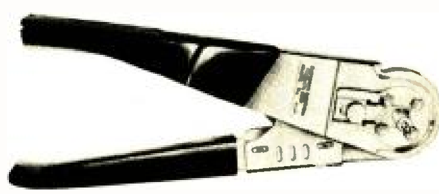
The new line is available in all standard packaging including ceramic micro, TO-46, TO-18, and TO-5. Because of a power dissipation increase of 50%, the new passivated devices reduce leakage current by at least one order of magnitude. According to the company, the DET line has demonstrated extremely low and stable leakage currents and flat forward current transfer ratios over a range from 10 μa. to 500 ma., indicating its suitability for small-signal and medium-power amplifier applications.

Data sheets on this new line are available from the company on request.

Circle No. 132 on Reader Service Card

MINIATURE CRIMPING TOOL

Buchanan Electrical Products Corporation has developed a cycle-controlled miniature crimping tool which has been especially designed for handling miniature pin and socket contacts in a multi-



tude of sizes and designs. The tool is approximately 6¾" long and weighs only 10 ounces.

Because of its light weight and the low crimping pressure required, operator fatigue is reduced. According to the company, one of these tools and inexpensive positioners can crimp almost any proprietary or MIL-Spec contact #20 and smaller, accommodating wire sizes #20 through #30. The specially designed positioners facilitate the handling of miniature contacts when required.

Information on the various types of units in the line and features of each type is available from the manufacturer.

Circle No. 133 on Reader Service Card

HEAVY-DUTY ENGRAVING TOOL

Meredith Separator Co. is marketing a heavy-duty, compact engraving tool which provides a fast, permanent method of engraving names or identification numbers on steel, copper, brass, silver, aluminum, glass, plastic, ceramic, wood, stone—virtually any solid material.

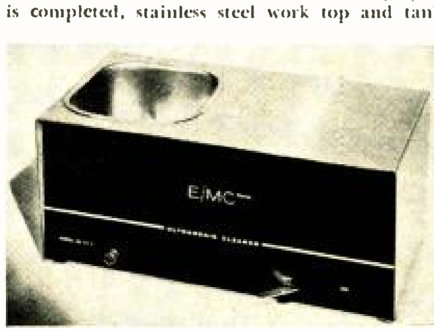
A high-speed reciprocating motor with high-impact nylon housing powers a solid carbide point that is practically wearproof. It delivers 7200 strokes per minute. Another feature of this "Porcupine" engraver is a calibrated stroke adjustment which regulates the depth of engraving. It is adjustable to five positions.

A data sheet giving full details on this tool plus a direct-mail order form is available on request.

Circle No. 8 on Reader Service Card

SOLID-STATE ULTRASONIC CLEANER

Artronics Company, Inc. is distributing a low-cost ultrasonic cleaner, the Model LP-1. The unit operates on 50-60 cycles, 115 volts. Operating frequency is 90 kc. nominal with power input of 30 watts. It includes an automatic time switch which turns the unit off when the cleaning cycle is completed, stainless steel work top and tank



which cannot be marred or harmed by any normal cleaning agent or solvent, and automatic self-tuning operation.

The one-pint-capacity tank can be used for all small parts to remove grease, tar, dirt, grime, stains, wax, chemical residue, organic deposits, etc. Over-all size is 9½" x 5" x 4⅝". The tank measures 3½" x 3½" x 2½".

Circle No. 9 on Reader Service Card

LARGE-SIZED NUMERICAL READOUT

National Electronics, Inc. is now offering a new, larger size numerical readout tube designed specifically for the instrumentation field.

The NL-7037 is a long-life, cold-cathode, neon-glow tube displaying 2" high numbers from 0 to 9. It has an ionization voltage of 250 volts d.c., requiring a minimum supply voltage of 250 volts d.c. It can be used at higher anode voltages with the proper anode resistor. Anode current ranges from 6 to 10 ma. d.c. with a typical value of 8 ma. d.c.

A data sheet with complete electrical and mechanical specifications is available on request.

Circle No. 134 on Reader Service Card

HI-FI AUDIO PRODUCTS

COMPACT SPEAKER SYSTEM

Altec Lansing Corporation is now marketing the 845A Verde which combines compactness with quality sound reproduction in an enclosure measuring 11¼" high x 23" wide x 11¼" deep.

The speaker system employs a new design involving the use of an extremely low-resonance bass reproducer mounted in a heavily damped "air-spring" ported reflex cabinet. According to the company, frequencies down to 45 cps are reproduced with maximum efficiency. The enclo-

sure has an annular port distributed around the high-frequency speaker cone. The high-frequency section of the speaker system employs the company's 2000B speaker using a gap-suspended radiator that reproduces with maximum efficiency up to 18,000 cps. A built-in network crosses over at 2000 cps. Frequency range is 45-18,000 cps. The impedance is 8 ohms and the system will handle 20 watts.

Circle No. 10 on Reader Service Card

TWO-SPEED TAPE DECK

Martel Electronics has announced the addition of the "Uher 9000" tape deck to its line of recording equipment.

The circuit features computer-designed modules with separate plug-in panels for record, playback, equalizer, power pack, and push-pull r.f. bias oscillator circuits. Each module is tested separately and then combined. Other features of the new deck include a playback equalization curve that provides either CCIR or NAB standard playback, hysteresis synchronous motor, four-tracks, separate erase, record, and playback heads as well as separate level controls for each channel, sound-on-sound switch, vu meter, and a vernier adjustment of playback for exact azimuth alignment for every type of tape.

Frequency range is 20-20,000 cps at 7½ ips and 20-15,000 cps at 3¾ ips. The unit, which weighs approximately 24 pounds, measures 15.3" x 6.8" x 13".

Circle No. 11 on Reader Service Card

4-TRACK STEREO RECORDER

Roberts Electronics has added the Model 721 4-track stereo tape recorder to its line. It features full stereo and mono record and play, has separate channel vu meters, sound-with-sound, channel transfer of recorded sound, and 17,000-cps response.

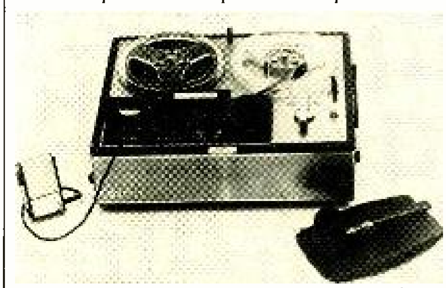
The unit also features a rotary track selector, 3¾ and 7½ ips with 15 ips available with an optional accessory, vertical or horizontal operation, and two extended-range speakers.

The instrument will handle 7", 5", and 3" reels. It has standard NAB playback equalization. The unit measures 20½" high x 13¾" wide x 11" deep and weighs 49 pounds.

Circle No. 12 on Reader Service Card

BATTERY-OPERATED RECORDER

Craig Panorama, Inc. has developed a new 5" two-speed, all-transistor tape recorder which will provide up to 4 hours of recording time. The TR-520 capstan-drive tape recorder operates at 1⅞



and 3¾ ips on standard flashlight batteries or a.c. power lines when an external a.c. adapter is used. There is a single lever control for play, record, rewind, and stop; inputs for remote microphone or telephone pickup and for radio recording; plus outputs for earphones or speaker.

The TR-520 comes equipped with a vu meter, safety recording lock, and fast-forward control. The unit measures 11½" wide x 9½" deep x 4½" high. It weighs 10 pounds with tape and batteries. The unit is delivered with remote-control microphone, earphone, batteries, a reel of tape, and an empty reel.

Circle No. 13 on Reader Service Card

ANTI-FEEDBACK SYSTEM

Boom Sound Engineering, Inc. has been licensed as agents for a new equalization system which may be incorporated in any properly engineered public-address installation.

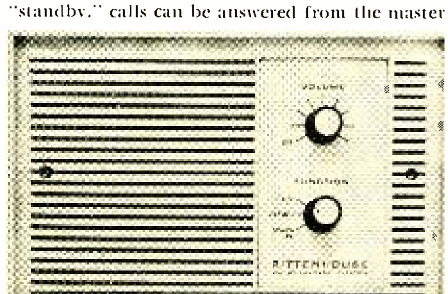
The new system successfully filters out certain sound frequencies that produce acoustical feedback. Narrow-band filters are employed, after feedback frequencies are indentified by means of precision test equipment. As a result, additional amplification can be employed for improved intelligibility.

Circle No. 135 on Reader Service Card

RADIO/INTERCOM SYSTEM

Emerson Electric Co.'s Builder Products Division is now marketing a new solid-state radio/intercom home sound system which is being offered in two versions: the RM-20 (AM) and RM-22 (AM-FM).

Special "do not disturb" switching permits regular intercom calls between the master station and remote stations throughout the house, without disturbing any remote station switched to "standby." Complete privacy can be obtained by merely switching any of the remote stations to "listen." In this mode intercom calls can be received and the radio or recorded music continued without the danger of conversations being overheard. With the remote station switched to "standby," calls can be answered from the master



station without touching a switch. Coverage of the front door from any room in the house is also provided.

A colorful brochure listing all features of these intercom systems will be supplied by the manufacturer on request.

Circle No. 14 on Reader Service Card

TAPE-CARTRIDGE DICTATING MACHINE

StenOtape Division, American Geloso Electronics, Inc. claims to have eliminated the problem of threading magnetic tape dictating and transcribing machines with the introduction of its "Cartromatic 915." An enclosed magnetic tape cartridge is just dropped into position. Fingers do not touch the tape at all.

In addition to the instant, automatic loading feature, the machine provides adjustments for tone (more or less treble or bass) as well as volume for transcribing. The unit starts without warm-up time because of its solid-state circuitry. It includes two speakers—one in the microphone for quick playback and one in the machine for greater volume and conference use.

For dictating convenience, controls for recording as well as review are on the microphone. Sensitivity of the microphone is adjustable. There is provision for "fast erase" but accidental erasure is virtually impossible.

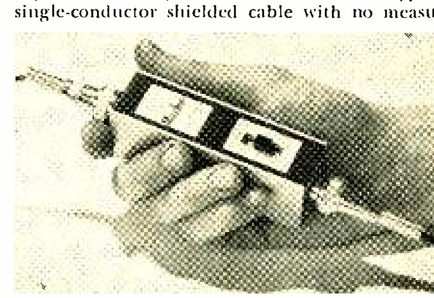
The machine comes complete with accessories for either dictating or transcribing—all of which are covered in the company's descriptive literature.

Circle No. 15 on Reader Service Card

MICROPHONE PREAMPLIFIER

Marlboro Engineering Company has announced the availability of a microphone preamplifier, the "MikeAmp," which is designed to permit the use of long cable runs between microphone and tape recorder.

This transistorized, battery-operated circuit is capable of driving as much at 2000 feet of typical single-conductor shielded cable with no measur-



able losses or hum pickup, according to the company. The low-noise, high-input-impedance circuit provides either 0 db or 20 db voltage gain, each at an impedance level of less than 200 ohms.

The amplifier is located near the microphone, which may be either a crystal (ceramic) or dynamic type. The low-impedance output connects via the long cable directly to the normal high-impedance input of the recorder or p.a. amplifier. The unit is housed in a case of extruded aluminum trimmed in anodized black.

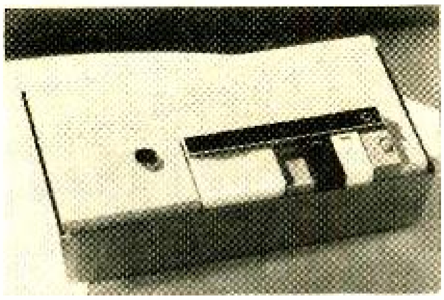
Circle No. 16 on Reader Service Card

ELECTRONIC "MESSAGE CENTER"

Westinghouse Electric Corporation is marketing a new electronic "Message Center", a continuous tape recording unit designed for household use. The unit, which weighs less than 5 pounds, is designed so that it can be operated by children. A signal light, which automatically goes on when a message is recorded, indicates to the person seeing it that he should push the play button to receive the recorded instructions or information.

Three minutes of messages may be recorded on the continuous tape. At the conclusion of a message, the tape automatically advances to the beginning so that no rewinding is necessary when the play button is pushed. Messages are recorded by pushing the record button and can be stored, played over and over, or cleared off by recording a new message.

The "Message Center" operates on standard



power line current, measures 2⅞" high by 10" wide, and 5½" deep.

Circle No. 17 on Reader Service Card

ECONOMY TAPE DECK

Rheem Califone Division is now marketing a low-cost playback tape deck, the "Corsaire 1," Model 3519.

Among the features offered in this new deck are four-track stereo plus mono playback, three tape speeds (1⅞, 3¾, and 7½ ips), digital tape index counter, fast-forward and rewind controls, and jack connections for plugging into stereo equipment. The deck will accept 3", 5", and 7" reels.

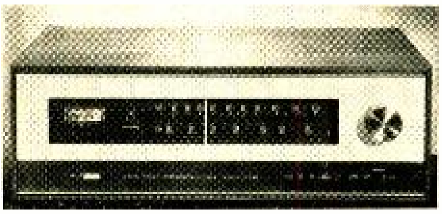
Dimensions are 12¼" wide x 8⅜" long x 5⅝" deep. It is in a fawn and gold housing with a walnut-colored base.

Circle No. 18 on Reader Service Card

SOLID-STATE AM-FM STEREO TUNER

Harman-Kardon, Inc. has added the Model ST-2000 AM-FM stereo tuner to its line of all-transistor audio equipment. Sensitivity of the new tuner is rated at 2.9 μv. IHF for FM and 50 μv./meter for AM. The i.f. rejection is 55 db. with image rejection better than 45 db and spurious response rejection exceeding 60 db, according to the company.

The tuner features flywheel tuning with a d'Arsonval tuning indicator and tuning meter.



Three front-panel switches provide the AM/FM stereo/mono, and on/off functions. There is also a stereo indicator light and a convenience outlet.

The instrument measures 13¼" wide x 4⅜" high x 10½" deep. Shipping weight is 9 pounds.

Circle No. 19 on Reader Service Card

CB-HAM-COMMUNICATIONS

ROTATABLE DUO-BEAM ANTENNAS

Hy-Gain Electronics Corporation is in production on two new rotatable duo-beam base-station antennas for CB. Both models employ horizontally stacked twin-driven beams, each with its own director. One model, the 114DB uses 2-element beams and multiplies the e.r.p. of an efficient 5-watt CB transceiver to 42 watts.

The second model, the 116DB, uses 3-element beams which raises the e.r.p. of a 5-watt CB transceiver to 93 watts. Both units are designed for mechanical rotation: the 114DB with a standard TV rotator and the 116DB with a heavy-duty TV rotator.

Technical data/comparison reports on the new antennas will be supplied by the manufacturer on request.

Circle No. 20 on Reader Service Card

FM TWO-WAY RADIO

Singer Products Company, Inc. is handling the overseas distribution of the **Aerotron** "Tracer," a new personal portable radio that operates in the 134-174 mc. range and has a power output of one watt. It features a completely transistorized solid-state circuit with epoxy-sealed solid plug-in modules for easy servicing.

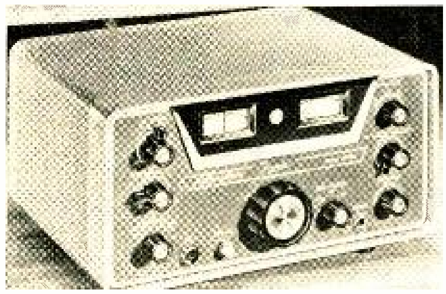
The unit is locked firmly into optimum operating condition by back-up circuits provided with the transmitter and receiver. Two-frequency operation, leather carrying case, rechargeable nickel-cadmium batteries, and external earpiece which mutes the speaker for silent operation are optional features of the "Tracer."

Circle No. 21 on Reader Service Card

500-WATT P.E.P. HAM MOBILE

The Hallicrafters Co. has announced the SR-500 "Tornado" transceiver which has been specifically designed to provide hams with high-performance SSB and c.w. operation on 80, 40, and 20 meters. Lower sideband is used on 80 and 40 meters and upper sideband on 20 meters. The 500-watt p.e.p. unit weighs only 13¼ pounds and measures 13" w. x 6⅜" h. x 11" d.

The transceiver incorporates the firm's amplified automatic level control which prevents splatter often caused by final amplifier flat-topping. The receiver section contains the company's receiver incremental tuning control which allows the operator to tune the receiver up to 3 kc. on either side of the transmitter frequency. All jacks and switching for linear amplifier operation are



included as well as a combination "S" meter/r.f. output indicator.

Full specifications and information on operating accessories are available from the manufacturer.

Circle No. 22 on Reader Service Card

PORTABLE CB TRANSCEIVER

Pace Communications Corporation has developed a new portable 5-watt CB transceiver which weighs less than seven pounds. It incorporates the firm's Model 5000 transceiver which is equipped with a 48-inch flexible steel whip antenna and powered by rechargeable nickel-cadmium batteries. The unit uses all silicon transistors and features modular PC construction.

The plug-in battery pack provides 48 hours of continuous operation in normal field use. Batteries can be brought up to full capacity with an overnight charge. Range of the instrument is up to 20 miles under normal conditions, according to the company. The set is designed to function in temperatures from −20° F to +300 F. Provision is made for up to six crystal-controlled channels.

The transceiver can be carried in a fitted leather case which measures 7" wide x 9" high x 2" deep. Straps are provided for hand or shoulder carry.

Circle No. 23 on Reader Service Card

NOISE-CANCELING MIKE

Roanwell Corporation has put a new lightweight, noise-canceling carbon microphone on the market as the RM-515. Designed for all mobile operations, frequency range of the instrument is 300 to 3500 cps and sensitivity is −17 db ref. 10 dynes/cm². Noise cancellation averages 18 db and impedance is 50 ohms. Recommended operating current is 50 to 100 ma. with a maximum intermittent current of 250 milliamperes.

The unit is switched by means of a soft-action, press-to-talk d.p.s.t., 125-v.a.c., 5-amp switch. The microphone is equipped with a four-conductor retractile cord. The microphone measures 2 7/16" w. x 3⅞" h. x 1 11/32" d. It weighs 5 ounces without the cord set. A brochure giving complete specs and features on the RM-515 is available on request.

Circle No. 24 on Reader Service Card

INDUSTRIAL/BUSINESS RADIO

Pearce-Simpson, Inc. has added a 30-watt AM (25-54 mc.) industrial/business-band two-way radio to its line as the IBC 301.

The new single-frequency radio can be installed as a complete unit or the self-contained

remote-control head may be slipped out of the main unit and installed independently with its own mounting cradle. The remote-control head weighs less than 2½ pounds and is only 6½" w. x 2½" h. x 7½" d. Frequencies are individually allocated by the FCC for business/industrial use.

The unit also features an all-transistor receiver for low power drain (0.6 amp), a solid-state power supply, illuminated function indicators, adjustable squelch and pre-set noise limiter, muting switch, and a corrosion-resistance housing.

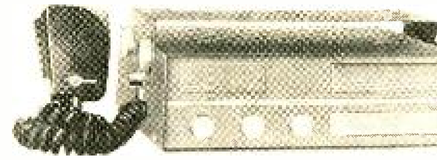
Over-all dimensions are 11" wide x 3½" high x 8½" deep. Weight is 7½ pounds. It comes complete with noise-canceling push-to-talk microphone, crystals, and a universal, all-angle mounting bracket on a slide rail. Full details are available from the company.

Circle No. 25 on Reader Service Card

TWO-WAY MOBILE FOR "HELP"

United Scientific Laboratories has introduced a popularly priced, two-way radio with a fixed channel for monitoring by emergency aid offices as suggested by the Automobile Manufacturers Association as "HELP."

The new unit, called "Contact Help," has been designed for easy car installation and simple op-



eration. The radio is 10½" wide x 3¼" high x 8" deep and weighs less than 5 pounds. Accessories include a featherweight hand microphone with push-to-talk button, 12-volt cord for cigar-lighter plug-in, and a special theft-proof mounting bracket.

Circle No. 26 on Reader Service Card

MANUFACTURERS' LITERATURE

STANDARDS CATALOGUE

American Standards Association has published a comprehensive, updated checklist of more than 2500 documents which cover existing standards in such fields as acoustics, chemicals, construction, symbols and abbreviations, electronics, and photography. In addition to ASA definitions, the new 80-page catalogue lists recommendations of the International Organization for Standardization (ISO) and the International Electrotechnical Commission (IEC).

An organizational cross-index covers those

American Standards which have been accepted by some 10 national trade, technical, and professional societies, including the American Society of Mechanical Engineers, the EIA, and the IEEE.

Circle No. 27 on Reader Service Card

ZENER DIODES

Transitron Electronic Corporation has made available a convenient wall chart which provides detailed information on military and commercial zener diodes, voltage references, multi-current reference diodes, ultra-stable certified references, and industrial zeners.

Over 300 different devices are covered by this compact chart, which contains ranges and representative specifications for each unit listed.

Circle No. 136 on Reader Service Card

LASER DATA

Maser Optics, Inc. has released a comprehensive chart containing helpful laser formulas, data, constants, and conversion factors. Information is included on laser radar range formulas, optical formulas, standard spectral line data, wavelength and energy interconversion tables, and a simple system for the alignment of optical components or lasers.

Circle No. 137 on Reader Service Card

SOLDERING IRONS

General Electric Company's Industrial Heating Department has recently issued a 12-page, fully illustrated catalogue describing the firm's complete line of industrial soldering irons, soldering tips, and renewal parts.

Catalogue GEC-1545B lists nine basic soldering-iron models, including the new "Mighty Midget," a 12-volt, 100-watt unit for medium-duty, repetitive-production soldering where up to 200 watts are normally required.

Circle No. 138 on Reader Service Card

MICROWAVE HEATING

Atherton Division of Litton Industries has recently published a 14-page booklet describing the use of microwave energy for cooking, industrial processing, agriculture, and medicine.

Briefly outlined are six advantages of microwave heating, a wide range of typical applications, and a technical discussion of the microwave-heating process. In addition, the application of microwave heating to the problem of solvent removal in magnetic-tape production is covered in some detail.

Circle No. 139 on Reader Service Card

LONG-LIFE LAMPS

Hudson Lamp Company is currently offering a new catalogue sheet (Form #103) describing its line of microminiature and subminiature lamps. Ideal for instrument illumination on all types of aircraft and for pilot lights and readout units of various kinds, the microminiature lamps come in lengths as short as 3/32" and have approximate lives of 100,000 hours. Featured are the company's axial-lead microminiature lamps, originally developed for imbedding in thin wall panels where the use of conventional lamps is difficult or impossible.

The subminiature lamps are approximately 5/8" long and include the exclusive "Tu-Pin" units which have bases that are color-coded to electrical characteristics. Both types of lamps are available in a wide choice of voltages, and complete specifications and diagrams are provided for all devices listed.

Circle No. 140 on Reader Service Card

BATTERY ACCESSORIES

Omi Plastics Mfg. Co., Ltd., a Japan-based concern, is now making available an 8-page catalogue covering its line of plastic products for portable radio batteries. The fully illustrated brochure contains information on battery cases (available with lead wire), battery snaps, and battery terminal boards.

In addition to these plastic products, the company also markets battery chargers for transistor radios and magnetic earphones. All items are moderately priced and are available in bulk to manufacturers in the United States.

Circle No. 141 on Reader Service Card

COMPONENT CATALOGUE

J. W. Miller Company has recently released a 60-page general catalogue (No. 65) covering the firm's line of adjustable r.f. coils, FM coils, i.f. transformers, loop antennas, and r.f. chokes. Over 100 new items have been added to the company's stock since the last catalogue was issued.

A 6-page index and price list is conveniently placed at the front of the illustrated booklet, and a special industrial cross-reference guide to the part numbers of ten major coil manufacturers is provided.

Circle No. 28 on Reader Service Card

SCHOOL SOUND SYSTEMS

Rauland-Borg Corporation is now offering a 4-page illustrated brochure describing its new "Deluxe" line of solid-state, all-transistorized school intercom systems. A wide selection of basic systems is offered in console, desk-top, and rack-mounted styles, with hundreds of flexible variations to meet every conceivable need for intercom and program distribution.

Folder No. 1265 also notes that the company provides a complete line of matching system accessories, including speakers, speaker housings, microphones, and call-in switches.

Circle No. 29 on Reader Service Card

POWER RECTIFIERS

International Rectifier Corporation has recently published a compilation of technical articles and application data studies on controlled and power rectifiers. Entitled "Specific Data File—Rectifiers" and containing more than 70 pages, the compilation discusses such topics as series and parallel operation of SCR's, turn-on time of controlled rectifiers, and recommended customer test methods for power rectifiers.

Circle No. 142 on Reader Service Card

TEST ACCESSORIES

Pomona Electronics Co., Inc. has issued a 27-page illustrated catalogue (No. 10-65) listing the company's complete stock of molded electronic test accessories.

Intended primarily for those engaged in testing or designing electronic equipment, the brochure includes patch cords, cable assemblies, connecting leads, test socket adapters, and molded test plugs. Over 40 of the more than 200 items covered are new, and complete specifications are supplied for all products described.

Circle No. 143 on Reader Service Card

LINE-VOLTAGE REGULATORS

Sola Electric Company is now offering a new 2-color, 8-page buyers' guide to its "Solatron" line-voltage regulators. These units combine the advantages of fast response, tight voltage regulation, no moving parts, adjustable output, and high kva. capacity.

Included in the illustrated catalogue (VR-200) are tables giving the specifications and physical dimensions of the more than 100 regulators in the series, a chart listing the effects of voltage fluctuations, and operating data on the "Solatron."

Circle No. 144 on Reader Service Card

PHOTOMULTIPLIER TUBES

Gencom Division of Whittaker Corporation is now distributing copies of a new condensed catalogue which covers the complete line of photomultiplier tubes manufactured by EMI Electronics Ltd. Included in the booklet (PM-2) are tables and curves providing detailed information on construction, dimensions, types, operating conditions, and characteristics.

Circle No. 145 on Reader Service Card

ETV RECEIVERS

Sylvania Electric Products Inc., Commercial Electronics Division, is now making available a brochure which discusses in detail two of its new TV sets designed especially for educational TV.

Each unit provides sensitive reception of both v.h.f. and u.h.f. broadcast channels, as well as closed-circuit channels, and each receiver comes with a 23-inch "Bonded Shield" picture tube which gives a viewing area of 282 square inches. Use of this particular tube results in a distinct improvement in picture quality, an advantage in group viewing.

Circle No. 146 on Reader Service Card

ELECTRON TUBES

Amperex Electronic Corporation has published a revised edition of its condensed electron-tube catalogue, which is intended to be a quick reference guide to the company's line of power tubes, thyratrons, and entertainment and audio tubes, as well as a variety of other types.

All material is arranged in tabular form with complete device descriptions and electrical characteristics, and a 2-page index is conveniently provided. Included in the 26-page catalogue for the first time are new cathode-ray and vidicon-tube lines.

Circle No. 147 on Reader Service Card

ELECTRONICS COURSE

Association Instructional Materials is offering information on how to obtain a multi-media introductory course in basic electronics. The core of the course is a series of 90, half-hour, 16-mm. films designed primarily for use in industrial training, adult education, and technical or vocational high-school classes. In addition, supplementary study guides, exercise manuals, and teaching guides are available. All materials of the course, entitled "Electronics at Work," are offered for sale and rental.

The course is organized into six units of 15 lessons each and employs as a unifying theme the development of increasingly advanced communication systems. Topics treated include oscillators, amplifiers, resonant circuits, meters, and power supplies.

Circle No. 30 on Reader Service Card

SEMICONDUCTOR PHONO CARTRIDGE

Euphonics Corp. has just issued an 8-page king-size 4-color brochure covering a technical analysis of all major characteristics involved in phonograph recording and playback. Some 36 different topics covering such things as constant velocity, constant amplitude, RIAA equalization, causes of ringing, square-wave response, the stereo groove, etc. are analyzed technically.

The brochure also includes complete details on the company's line of high-fidelity semiconductor phono cartridges and accessories.

Circle No. 31 on Reader Service Card

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ELECTRONIC Kits wired and tested. Electronics Fabrication, 1717 N. Ft. Harrison, Clearwater, Fla.

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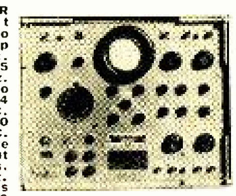

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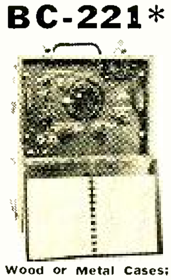

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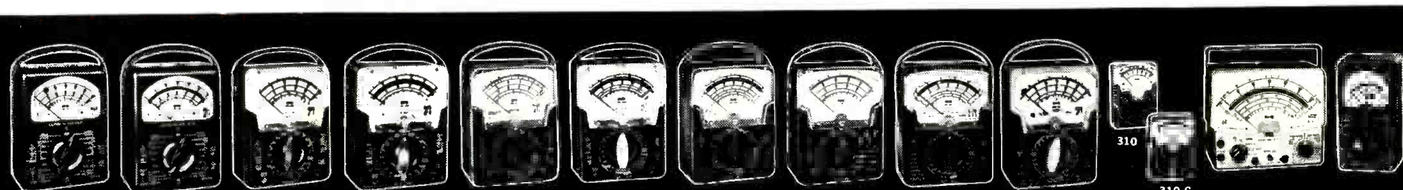

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