Electronics World

APRIL, 1966
60 CENTS

SPECIAL WEST COAST REPORT

THE ELECTRONICS INDUSTRY:
*ITS PRODUCTS, PEOPLE,
AND EMPLOYMENT PROSPECTS*

REVERBERANT ROOMS:
THEIR DESIGN & USE

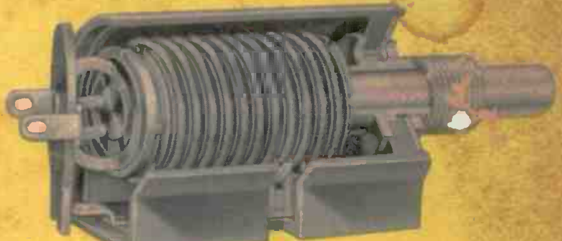
PHONO EQUALIZER USES FET'S

SPECIAL ISSUE:
VARIABLE RESISTORS

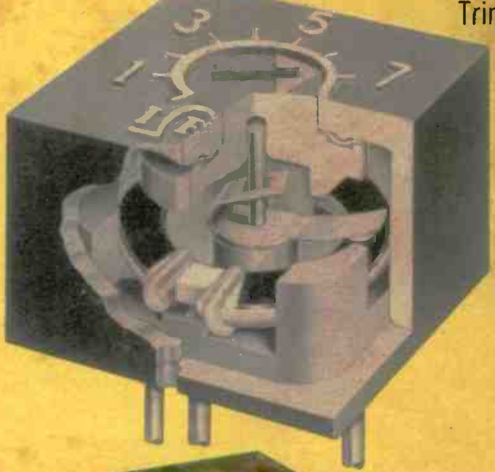
■ POTENTIOMETERS ■
TRIMMERS ■ RHEOSTATS

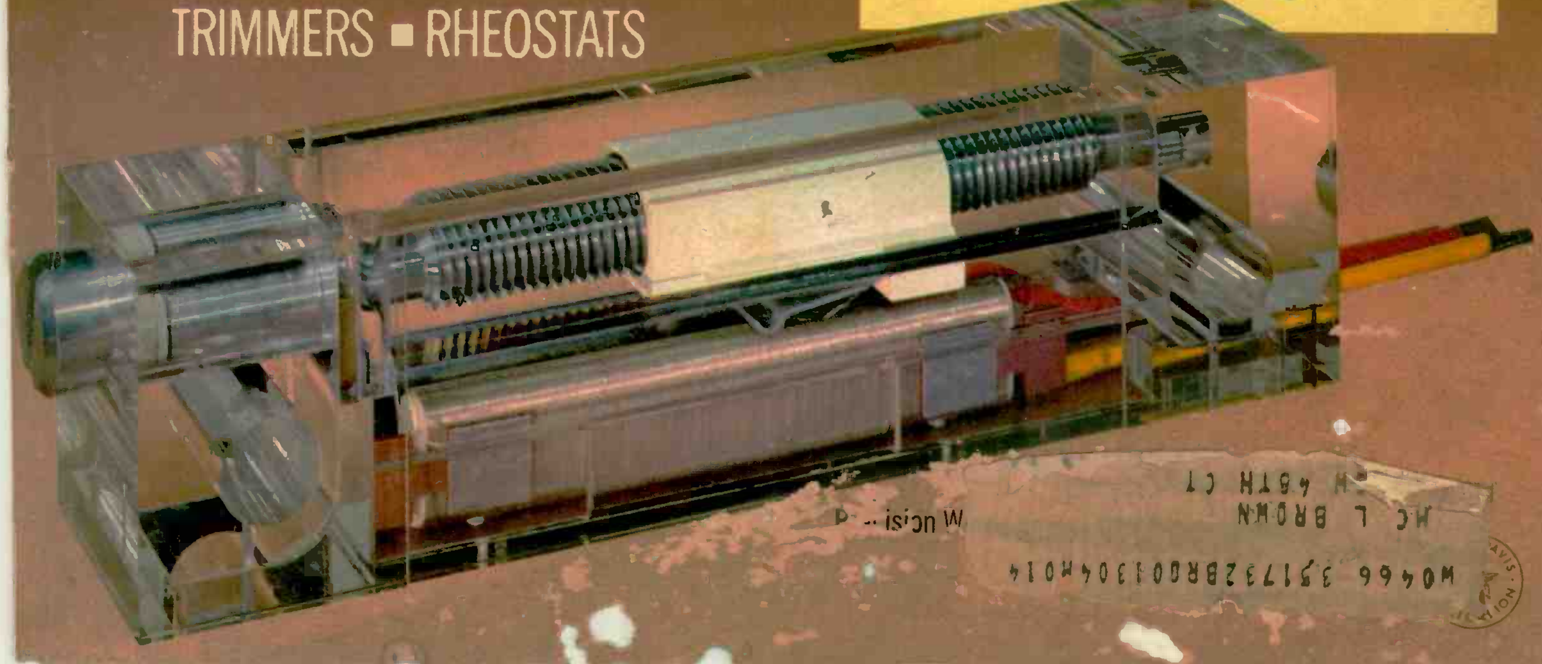
Precision Non-Wirewound Pote tiometer

Precision Wirewound Potentiometer



Precision Non-Wirewound
Trimmer





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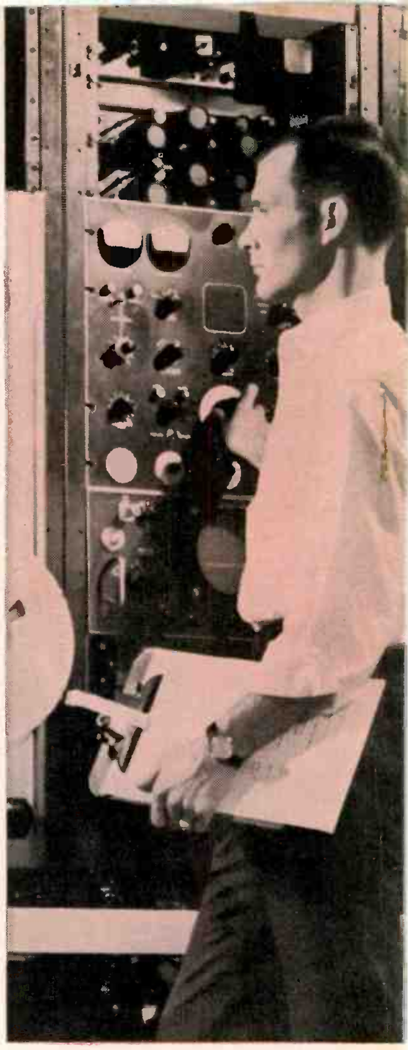

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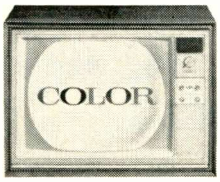

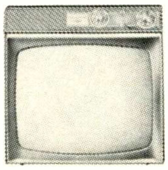

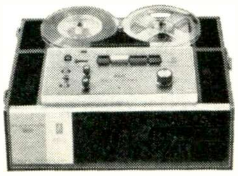

Electronics World

APRIL 1966 VOL. 75, No. 4

THIS MONTH'S COVER ties in with our special 24-page section on potentiometers, trimmers, and rheostats. The large illustration near the bottom is a photo of a special model of a precision wirewound adjustment potentiometer from Bourns' Trimpot Div. The grouping of photographs at the right are precision multi-turn potentiometers from Computer Instruments Corp. (top) and Clarostat (center), along with a single-turn wirewound trimmer from IRC. Articles on these as well as general-purpose potentiometers, trimmers, and rheostats will be found in our special section this month.

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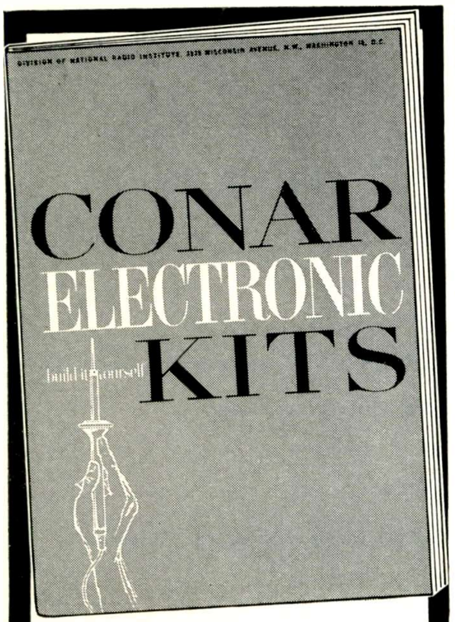
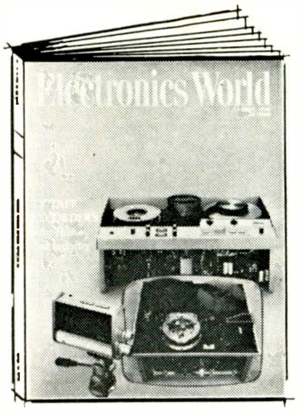


COMING NEXT MONTH



Special Feature Articles:

Our May issue will carry three important and authoritative articles on video tape recording. In the article "Sony Home Video Recorder," C. H. Fields and Saburou Oniki provide a technical description of this $1000, two-rotary-head machine for home and industrial applications. The Ampex VR-6000 video recorder, a machine for home or commercial use, is analyzed by Joseph Roizen. Leon Wortman of Ampex discusses and compares performance characteristics of longitudinal and helical methods of video tape recording for home applications.

HOME TV VIA SATELLITE

Can we use space satellites to broadcast TV directly to individual homes? What are the problems and can they be solved in the immediate future? Bradford B. Underhill of Arthur D. Little, Inc. delves deeply into this fascinating subject, and comes up with some authoritative answers.

ULTRASONICS IN MEDICINE

This survey of the increasing use of "silent sound" waves for physiotherapy, as a diagnostic tool, and to destroy malignant or unwanted tissue is important to electronics personnel as well as those in the medical field. Abe Kagan describes some of the equipment and techniques currently in use.

RESISTIVE ATTENUATORS & PADS

Circuitry, design, and selection of these devices which vary signal levels without disturbing the impedance, frequency response, or other system characteristics are discussed in depth by Chester F. Scott, Section Head, Engineering of the Daven Division of McGraw-Edison Co.

CHROMA DEMODULATION IN COLOR SETS: RCA

This is the first of a series of articles covering modern color-TV circuit design. Walter Buchsbaum analyzes the band-pass amplifier, chroma demodulation, and matrixing sections of RCA models.

HOW TO SELECT R.F. CHOKES

There is more to an r.f. choke than a wire wound about a form. When all characteristics are known, it can prove useful as a tuned circuit, transformer, low- or high-pass filter, and an r.f. isolator. This article covers various choke applications.

All these and many more interesting and informative articles will be yours in the MAY issue of ELECTRONICS WORLD . . . on sale April 19th.

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How the FET works:

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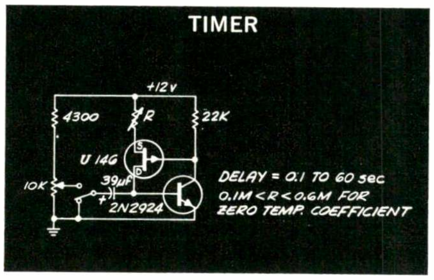
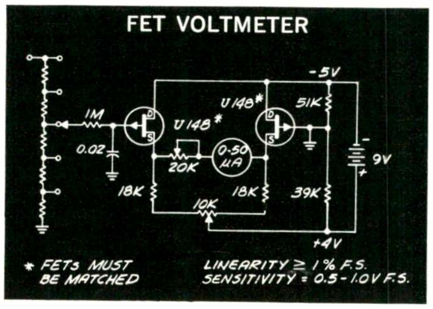
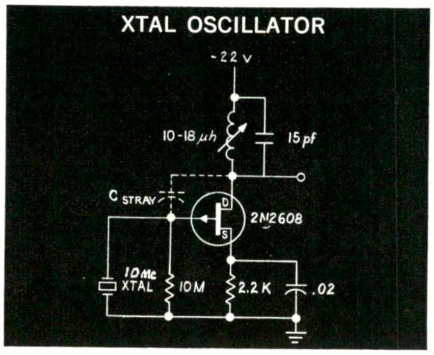
6 practical circuits you can build:


TIMER

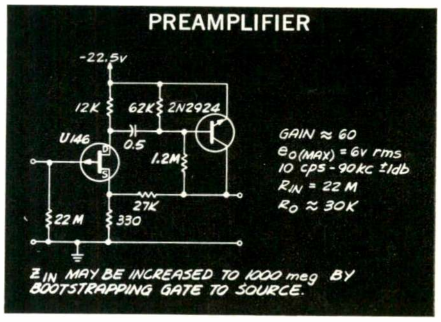
This basic circuit can be used for an enlarger timer, metronome, or other timing device.


FET VOLTMETER

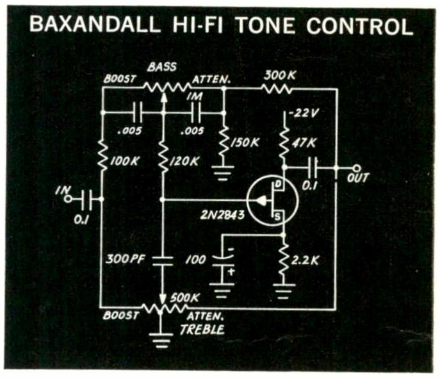
Here is a DC voltmeter with an input impedance that competes with any good VTVM, full scale sensitivity of 0.5 volts max. Add a diode and recalibrate for AC.

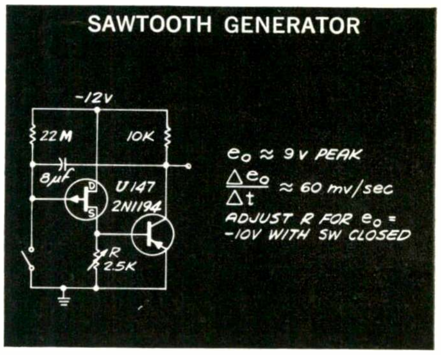

XTAL OSCILLATOR

The high impedance of a crystal works hand-in-hand with the high-Z FET.


PREAMPLIFIER

This mike preamp could be built into the mike's case, complete with battery operated by the PTT switch. A FET source-follower stage would provide a low-Z output to long mike lines.


BAXANDALL HI-FI TONE CONTROL


SAWTOOTH GENERATOR

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GET TO WORK WITH FETs FOR AS LITTLE AS $1.00!

Here are the principal parameters (and their tube equivalents) of the two low-priced FETs available from Siliconix.

FET Parameter	I_{DSS}	V_P	BV_{GDS}	g_{fs} (Min.)
Tube Equivalent Parameter	Zero Bias Plate Current	Grid Cutoff Voltage	Max. Plate Voltage	Minimum Transconductance
U110	0.1–1.0 ma	1–6 V	20 V	110 μmho
U112	0.9–9.0 ma	1–6 V	20 V	1000 μmho

Offer #1—$1.00 A Siliconix U-110 field-effect transistor, data sheet with complete specification, applications notes, and a detailed discussion of FET operations. $1.

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For the record

WM. A. STOCKLIN, EDITOR

NEW IHF STANDARD ON AMPLIFIERS

AFTER almost a year of meetings, long hours, and hard work, a panel of the best qualified engineers in the hi-fi industry (at the request of the Institute of High Fidelity) has completed work on a new standard* on the measurement and proper evaluation of audio amplifiers. It is an impressive document of some 8000 words with diagrams of test circuits to be used, and is the first standard of measurement ever published that involves stereo amplifiers. This new standard is so complex that even for the simplest power amplifier a total of 30 different graphs of performance and some 25 different meter readings are required to obtain complete performance characteristics.

It was interesting to note that the panel gave equal weight to the use of continuous sine-wave and dynamic power power measurements. It seemed over the past few years that the trend was away from continuous sine-wave figures and we are pleased to note this change.

One of the most important additions to this new standard is in regard to dynamic (or music) output. Previously, only the constant supply method was used. The panel has added another method of measurement, referred to as the transient-distortion method. For this test, the input signal is supplied to the amplifier from a novel type of modulator. It is quite an involved test arrangement and, to date, not much experience has been had in its application. We do hope, however, to have an article on this subject in ELECTRONICS WORLD shortly. Basically, the method involves the use of a combination light source and photocell device, similar to *Raytheon's* CK-1122. The built-in light is used to actuate the photocell which operates simply as an "on" and "off" switch. The thermal delay of the light source in the circuit specified does, however, provide a rise time equivalent to that of music and the resulting distortion measurements are made from an oscilloscope pattern.

In summing up, all manufacturers are asked to list four or five specific characteristics in rating their units. For single-channel amplifiers, these are:

Dynamic output and distortion
Continuous output and distortion
Power bandwidth
Sensitivity (highest and lowest gain inputs)
Hum and noise, "C" weighting (highest and lowest gain inputs)

For multi-channel designs, these are:

Dynamic and continuous output at mid-frequency (all channels driven)
Power bandwidth (all channels driven)
Sensitivity (highest and lowest gain inputs)
Hum and noise, "C" weighting (highest and lowest gain inputs)

For complete specifications, ten specific characteristics are required for single-channel performance and twelve for multi-channel units.

Obviously, not only is the entire industry involved, but this also affects our publication since our hi-fi EW Lab Tested Reports, in essence, evaluate products. Like everyone else, we are obligated to conform to industry standards and we therefore plan to make a few changes in our Lab Reports.

Hereafter, all measurements will be made using a 120-volt a.c. power source instead of 117 volts.

Our power bandwidth curves, although the results will be the same, will appear differently. The distortion *vs* frequency, with fixed output powers, will be plotted on a log-log scale, where formerly we showed the power curve as power *vs* frequency for a fixed distortion.

Both our harmonic and IM distortion curves will now be shown on a log-log scale instead of semi-log. As in the past,

(*Continued on page* 64)

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In Memoriam

The high-fidelity industry mourns the untimely passing of one of its best-known executives, Ben L. Arons, executive vice-president of Fisher Radio Corporation.

Mr. Arons, who was 50 years old, died suddenly while vacationing in Florida.

Associated with Fisher Radio since 1946, he was active in the affairs of the Institute of High Fidelity, Inc., serving as a member of its Board of Directors.

Before joining Fisher, he was with the Reconstruction Finance Corporation. A Navy lieutenant during World War II, Mr. Arons is survived by his wife and two children.

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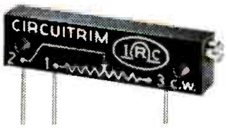
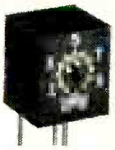


Sealed, shockproof rectangular type 450. ½ watt @ 70°C, 100 ohms to 1 meg. 10 and 20% tolerances. 2 pin arrangements, or leads.

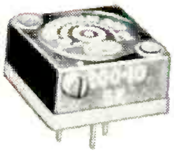
½" square type 251 has anti-backlash drive. ¾ watt @ 70°C, 100 ohms to 1 meg. 5, 10 and 20% tolerances. Available in 144 models.

Economical ½" round unit offers speedy adjustment. ¾ watt @ 70°C, 100 ohms to 1 meg. 5, 10 and 20% tolerances. Type 150 in 24 different models.



5⁄16" cube trimmer saves space. .30 watt @ 70°C, 50 ohms to 0.5 meg. 10 and 20% tolerances. Top and side adjustment or panel mount. Type 350.

WIREWOUND PRECISION TRIMMERS



½" square type in MIL-R-27208 or commercial styles. Shock-resistant. 1 watt @ 60°C, 10 ohms to 50K, 5% tolerance. Type 201 in 144 models.

Popular ½" round trimmer with positive stops for fast response. 1 watt @ 50°C, 10 ohms to 50K, 5% tolerance. Type 100 in 24 termination and adjustment variations.

Microminiature 5⁄16" cube trimmer, TO-5 size, is ideal for miniaturization. .60 watt @ 60°C, 50 ohms to 20K. Top and side adjustment or panel mount. Type 300.

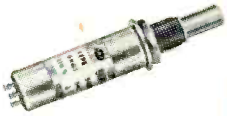
Precision rotary trimmers in ½", ¾" and 1½" dia., 2 to 3½ watts @ 40°C. 10 ohms to 100K, ±5% tolerance. Meets environmental requirements of MIL-R-27208A.

PRECISION MULTI-TURN POTENTIOMETERS

HERMETICALLY SEALED TYPE

¾" dia., 5 and 10 turns. Dry nitrogen filled. 2 and 3 watts @ 40°C, 25 ohms to 250K. 5% tolerance, 0.5% linearity. Series HS-750.

METAL CASE TYPES



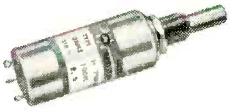
½" dia., 5 and 10 turns. Shock and moisture-resistant. 1 and 1.5 watts @ 40°C, 15 ohms to 150K. 0.1% stability. Series 5000.

¾" dia., 5 and 10 turn models. 2 and 3 watts @ 40°C, 25 ohms to 250K. 5% tolerance, 0.5% linearity. Series 7500.

1" dia., 5 and 10 turns. From 1.5 to 4 watts @ 40°C, 50 ohms to 500K. 5% tolerance, 0.5% linearity. Series 1000.

1" dia., 15 and 20 turns. 4 and 5 watts @ 40°C, 750 ohms to 600K. 5% tolerance, 0.2% linearity. Series 1220.

MOISTURE SEALED TYPES



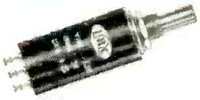
¾" and 1" dia., 5 and 10 turns. 2 to 4 watts @ 40°C, 25 ohms to 500K. 5% tolerance, 0.5% linearity. Also with O-ring panel seal. Series H-750MS.

PLASTIC CASE TYPES

Popular ⅞" dia., 10-turn unit is ruggedly built. 3 watts @ 40°C, 25 ohms to 250K. 3% tolerance, 0.2% linearity. ¼" or ⅛" dia., shaft. Series 8000.

1½" dia., 3, 5 and 10 turns. Designed for heavy-duty industrial use. 500 ohms to 600K. 3% tolerance, 0.25% or 0.1% linearity. Series HD-150.

LOW COST COMMERCIAL TYPE



¾" dia., 10-turn unit also saves space. Rated at 2 watts @ 40°C, 100 ohms to 100K, 5% tolerance. Screwdriver slotted shaft. Series 7300.

All IRC precision potentiometers are application-proved in the field over years of rugged use. They are continually tested for compliance to specifications. Current, documented test data is available on request. For complete technical specifications, prices and samples, write: IRC, Inc., 401 North Broad St., Phila., Pa. 19108.

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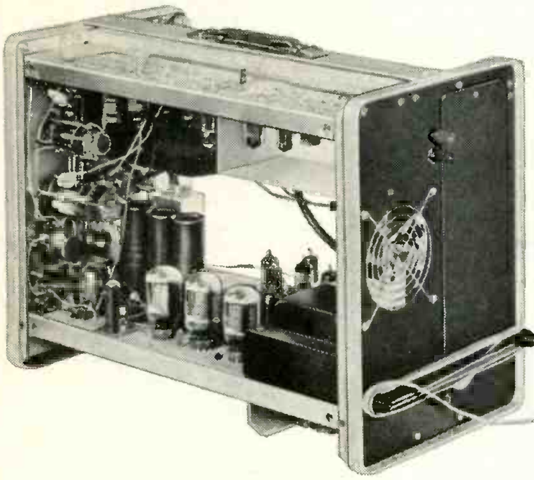

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Here Is A Truly Sophisticated Instrument . . . designed with modern circuitry, engineered with high quality, precision-tolerance components, and capable of satisfying the most critical demands for performance. The IO-14 features precision delay-line circuitry to allow the horizontal sweep to trigger "ahead" of the incoming vertical signal. This allows the leading edge of the signal waveform to be accurately displayed after the sweep is initiated.

The IO-14 Provides Features You Expect Only In High Priced Oscilloscopes. For example, switches are quality, ball-detent type; all major control potentiometers are precision, high-quality sealed components; all critical resistors are 1% precision; and circuit boards are low-loss fiber glass laminate. The IO-14's cabinet is heavy gauge aluminum. Its CR tube is shielded against stray magnetic fields, and forced air ventilation allows the IO-14 to be operated under the continuous demands of industrial and laboratory use.

Kit IO-14, 45 lbs.................................$299.00
Assembled IOW-14, 45 lbs.........................$399.00

IO-14 SPECIFICATIONS—(Vertical) Sensitivity: 0.05 v/cm AC or DC. **Frequency response:** DC to 5 mc, —1 db or less; DC to 8 mc, —3 db or less. **Rise time:** 40 nsec (0.04 microseconds) or less. **Input impedance:** 1 megohm shunted by 15 uuf. **Signal delay:** 0.25 microsecond. **Attenuator:** 9-position, compensated, calibrated in 1, 2, 5 sequence from 0.05 v/cm. **Accuracy:** ±3% on each step with continuously variable control (uncalibrated) between each step. **Maximum input voltage:** 600 volts peak-to-peak; 120 volts provides full 6 cm pattern in least sensitive position. **(Horizontal) Time base:** Triggered with 18 calibrated rates in 1, 2, 5 sequence from 0.5 sec/cm to 1 microsecond/cm with ±3% accuracy or continuously variable control position (uncalibrated). **Sweep magnifier:** X5, so that fastest sweep rate becomes 0.2 microseconds/cm with magnifier on. (Overall time base accuracy ±5% when magnifier is on.) **Triggering capability:** Internal, external, or line signals may be switch selected. Switch selection of + or — slope. Variable control on slope level. Either AC or DC coupling. "Auto" position. **Triggering requirements:** Internal; ½ cm to 6 cm display. **External:** 0.5 volts to 120 volts peak-to-peak. **Horizontal input:** 1.0 v/cm sensitivity (uncalibrated) continuous gain control. Bandwidth: DC to 200 kc ±3 db. **General** 5ADP31 or 5ADP2 Flat Face C.R.T. interchangeable with any 5AD or 5AB series tube for different phosphor characteristics. 4250 V. accelerating potential. 6 x 10 cm edge lighted graticule with 1 cm major divisions & 2 mm minor divisions. **Power supply:** All voltages electronically regulated over range of 105-125 VAC or 210-250 VAC 50/60 cycle input. (Z Axis) Input provided. DC coupled CRT unblanking for complete retrace suppression. **Power requirements:** 285 watts. 115 or 230 VAC 50-60 cps. **Cabinet dimensions:** 15" H x 10½" W x 22" D includes clearance for handle and knobs. **Net weight:** 40 lbs.

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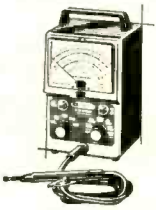
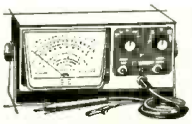


VTVM...Kit IM-11, $24.95; Assemb. IMW-11, $39.95



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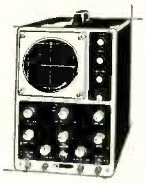

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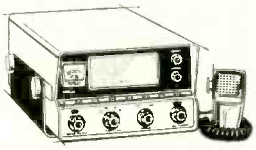

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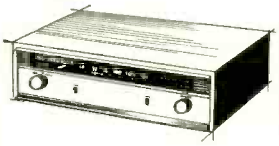

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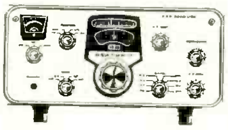

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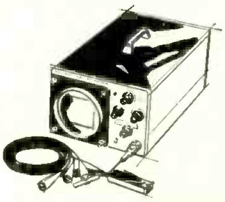

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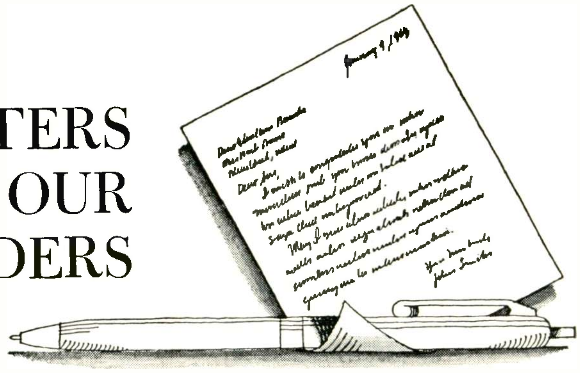
CIRCLE NO. 108 ON READER SERVICE CARD

LETTERS FROM OUR READERS



LASER ARTICLES

To the Editors:

I wish to express my sincere thanks to you for assistance rendered to me recently. The articles on the laser are extremely well done, and they form the backbone of my information concerning laser operation.

Murray Thomas
Selkirk, Manitoba

Thanks to Reader Thomas as well as to others who have complimented us on the three laser stories that appeared in our August, September, and November, 1965 issues.—Editors

* * *

SHIELDED TWIN-LEAD

To the Editors:

With regard to Reader Yetman's letter in your January, 1966 "Letters from Our Readers," shielded twin-lead is available from *ITT* as stock No. K-111. *Burstein-Applebee Co.* or *ITT Distributor Products Div.*, Lodi, New Jersey can supply this cable.

Carl M. Schentes
Senior Field Engineer
ITT Field Service
Ellsworth, Me.

By now we assume that the new Belden *shielded twin-lead should be available at the manufacturer's local distributors. We also note that shielded twin-lead is available from* Lafayette Radio, Allied Radio, Olson, *and others at prices ranging from 7 to 12 cents a foot in 100-foot lengths.—Editors*

* * *

WWV FORECASTS

To the Editors:

When WWV gives its station identification, it also transmits a letter and a number which I understand to be a radio propagation forecast. What is the meaning of the various letters and numbers transmitted?

Paul Johnson
Boston, Mass.

The WWV propagation forecasts give the condition of the ionosphere in the North Atlantic area, at the time of last issue, and radio quality expected in the subsequent 6-hour period. The forecasts are issued at 0500, 1200–1100 in summer—1700, and 2300 UT (Universal Time). The letter portion identifies radio quality at the time of the forecast and the numbered portion is the forecast of expected quality on the typical North Atlantic path during the 6-hour period following the forecast, according to the following scale:

Disturbed grades (W)
1. useless
2. very poor
3. poor
4. poor to fair

Unsettled grade (U)
5. fair

Normal grades (N)
6. fair to good
7. good
8. very good
9. excellent

—Editors

* * *

PROVEN TRANSISTOR IGNITION

To the Editors:

In answer to many readers' inquiries on my article "A Proven Transistor Ignition System" (January issue), there is indeed an error in the schematic at the bottom right on p. 47. The wire coming from terminal 2 of *SO1* should have been connected either to the "Start" terminal of the ignition switch or to the positive side of the starter-relay coil, as it is connected in my own particular vehicle.

The whole idea of the quick-start circuit is to connect it in parallel with the starter relay so that both are energized when, and *only* when, the key is turned to "Start." You would not want *RL1* to remain closed when running as it would short out the ballast probably causing coil damage.

Charles C. Morris
San Diego, Calif.

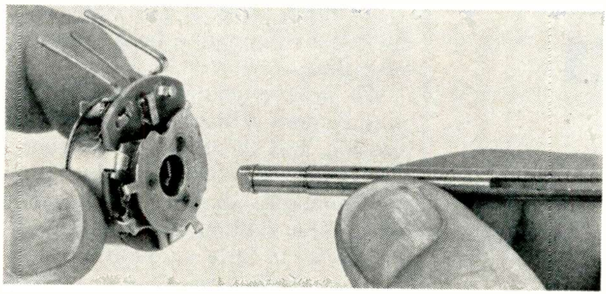
To the Editors:

"A Proven Transistor Ignition System" (January, 1966 issue) reminds us of the first time this circuit appeared in Electronics World (August, 1962) in an article by Boghos N. Saatjian. We built four units on standard heat sinks which proved very satisfactory. Later we made a pattern for the heat sink and built up eleven more units.

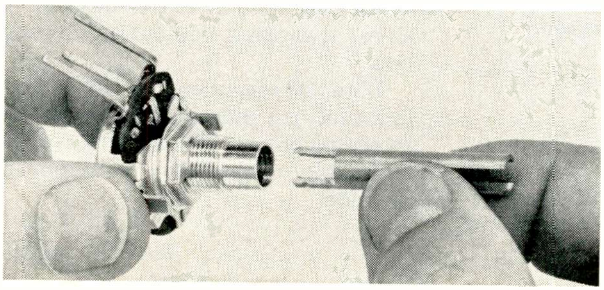
These have been used on *Chevrolet, Corvair, Ford, Oldsmobile, Peugeot,*

MALLORY **Tips for Technicians**

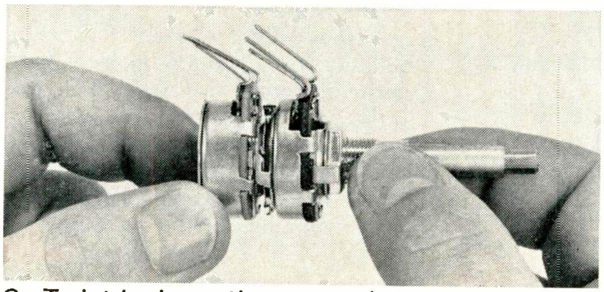
Short-cuts in custom-building controls



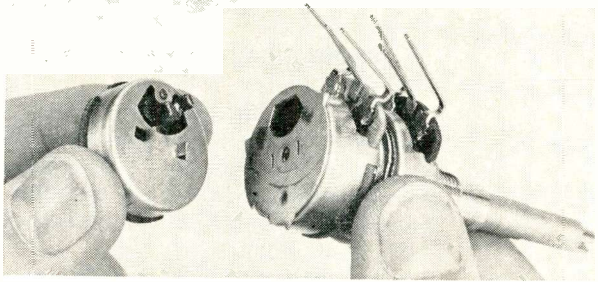
1. Snap shaft into rear section



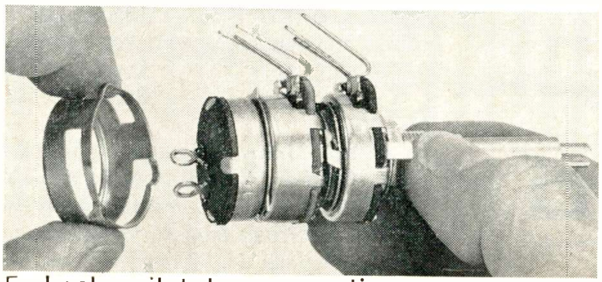
2. Snap shaft into front section



3. Twist-lock sections together



4. Insert switch



5. Lock switch to rear section

Sometimes it seems as though there's some sort of conspiracy to keep you from getting the exact control you need. For example, some of the new television and auto radio sets have really *wild* combinations of control elements, shafts and switches. And, every once in a while one of these fancy dudes just up and quits.

What do you do now? Hunt all over the town for the exact replacement? Or, maybe you'd like to convince the customer's kids to just stare at that blank tube for a few weeks while you try to order the control from the factory. Well, cheer up. There's a better way!

Just zip down to your Mallory Distributor and explain your problem. He'll turn to his STA-LOC® Control Center and come up with your particular control in three minutes flat. No foolin'! He's got the parts to make any of nearly *FIVE BILLION* different controls. How about *that*, control fans!

But if you think STA-LOC is just for replacement controls, you are wrong. Matter of fact, with just a little imagination, you can dream up a control that would make a graduate engineer turn green with envy. All you do is turn to pages 30, 31 & 32 in the 1966 Mallory General Catalog. You'll find carbon front sections from 100 ohms to 10 megs. You can couple these to all sorts of rear sections. And then add a switch. And then . . . WOW! . . . get a load of all those wild shafts! Maybe you'd like to make a "clutch" control so that both front and rear turn together except for balancing. It's a *snap* with STA-LOC.

STA-LOC controls snap together and *stay* together. Even the shafts just plug in. Everything fits and works smoothly. There's even a special single control series called the "UA" . . . a real timesaver.

If you have really exotic tastes, you can take any rear section and make it into a single control by just snapping on an adapter bushing. Then, you plug in a shaft or, maybe add a switch.

Before you get the idea that STA-LOC is absolutely perfect, we'd like to set the record straight. Every once in a while a set manufacturer comes up with a design problem that can only be solved by an all-in-one-chunk control. Some of these weird designs just *can't* be made up from STA-LOC parts. So, after Mallory has made a few thousand of these "far-out" dudes, we stock some. Then, we can shoot 'em to your Mallory Distributor if and when you ever need one. The whole point of this statement is to let you know that your Mallory Distributor *has*, (or can get), just about any doggone control you'll ever need.

Next time you're talking to your Mallory Distributor, ask him about a STA-LOC Technician Kit. With one of these kits you can make replacements *on the spot*, or experiment to your heart's content. For the name of the distributor nearest *you*, write to Mallory Distributor Products Company, a division of P. R. Mallory & Co. Inc., Box 1558, Indianapolis, Indiana 46206.

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Renault, *Buick*, and *Volkswagen* automobiles.

The only casualty on these units so far has been a F12-T (250:1 turns ratio) coil, the case of which cracked vertically and horizontally after about two years service in a *Corvair*. The coil still operated but we were afraid moisture might be a problem and replaced it with a 400:1 turns ratio coil. We understand the F12-T ignition coil is no longer available.

We think some of the statements in this latest exhumation bear further consideration.

We believe you will find that plug wear is more a function of engine compression and combustion chamber design. Points do not burn but the constant pounding shows even after 10,000 miles. The rubbing block requires attention at as little as 5000 miles. Furthermore, unless you do your own tune-ups, these will be changed automatically by service personnel at as little as 3000 miles, apparently without any examination.

Without exception, all users report increased gas mileage (5% to 12%) and increased power. This is, of course, more noticeable on the lower powered automobiles.

J. M. Binding
Port Huron, Mich.

* * *

HOME VIDEO RECORDER

To the Editors:

A few fellow workers have started building the "longitudinal" video recorder for home use which I described in the February, 1966 issue. To simplify the electronic part, we have made copies of the printed-circuit boards which I would like to make available to prospective builders of the recorder.

Eugene Leman
Memorex Corp.
1180 Shulman Ave.
Santa Clara, Calif. 95052

* * *

SHORT-CIRCUITED EMERSON TV

To the Editors:

On p. 40 of the February, 1966 Electronics World ("Line-Operated Transistor TV Sets: Emerson"), Fig. 3, there seems to be a dead short designed in across the 47-ohm, 2-watt resistor and the diode. Right?

Just in passing, let me tell you how much I appreciate the articles on new developments. I am a biochemist but find your magazine very worthwhile.

Jay D. Mann
Riverside, Calif.

Reader Mann is of course right in spotting the short circuit. Remove the short by removing the lead from the resistor in the −35 volt lead to the junction of the secondary of T1, the 47-ohm resistor, and the diode anode.—Editors ▲

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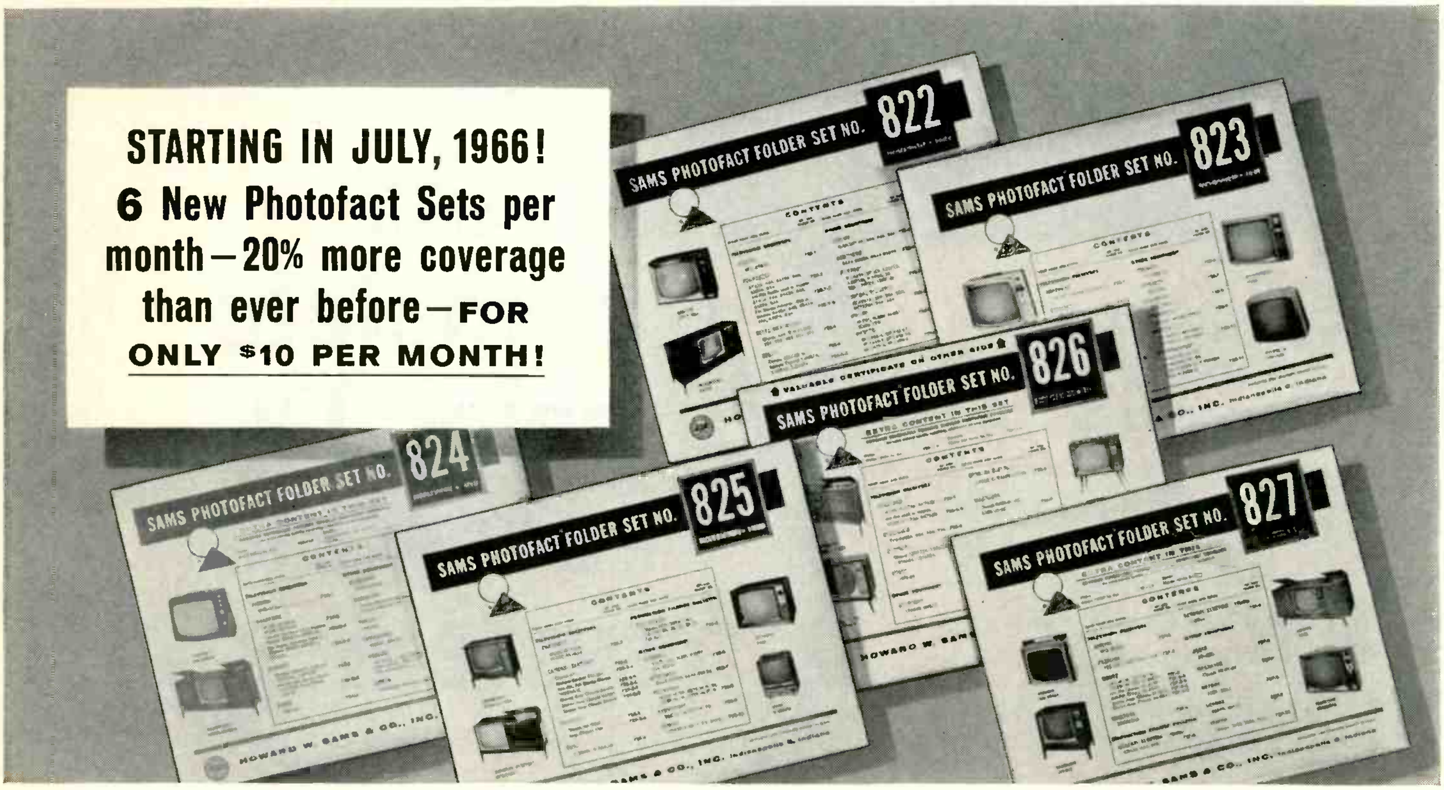

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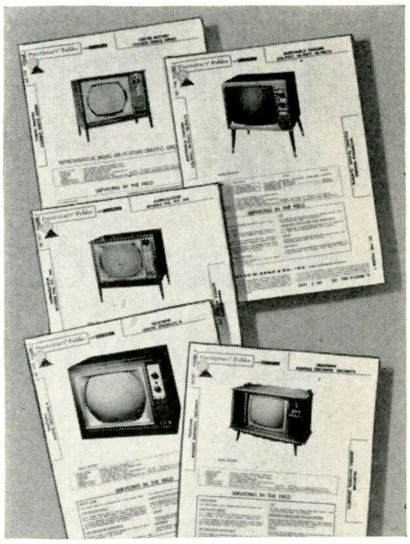

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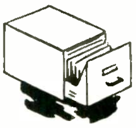

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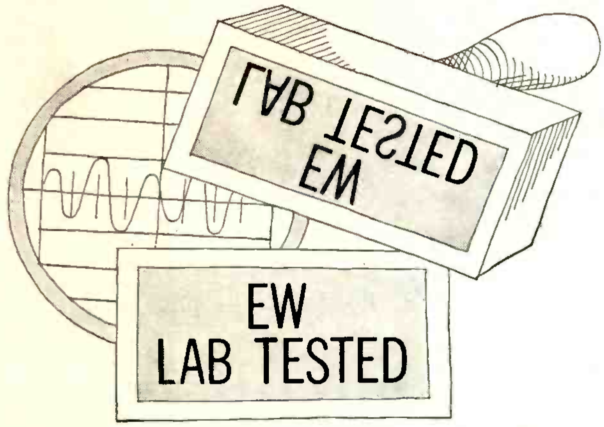

HI-FI PRODUCT REPORT

TESTED BY HIRSCH-HOUCK LABS

Dual 1019 Automatic Turntable
Grado Model "B" Phono Cartridge

Dual 1019 Automatic Turntable

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

THE designers of the *Dual* 1009 automatic turntable (see March, 1964 issue of ELECTRONICS WORLD) did not choose to rest on their laurels and have now introduced the Model 1019. This turntable is identical to the 1009, but with three noteworthy additions: an adjustable anti-skating-force compensation, a viscous-damped cueing control, and a single-play spindle that rotates with the turntable. In addition to satisfying those audio purists who object to any possible wear of the center hole of the record by friction against a stationary spindle, *Dual* claims this feature improves the unit's noise level and allows more precise spindle centering.

The new unit is a four-speed mechanism, with an over-all 6 percent speed adjustment about each nominal setting. The 7½-pound, nonferrous turntable rotates on low-friction bearings. The tonearm is balanced by means of an easily adjusted, damped counterweight. Tracking force is set by, and read directly on, a dial calibrated in a continuous range from 0 to 5 grams. A flat spiral spring in the base of the arm applies the tracking force directly at the vertical pivots. The balance of the arm is such that leveling of the turntable is unnecessary, no matter what the tracking force is.

For single play (with the short spindle inserted), the pickup is placed on the desired portion of the record and the turntable started by moving the control lever to "Manual." The turntable platter comes up to full speed in less than one revolution. If desired, the control lever can be set to "Auto" and the arm will then set down at the beginning of the record without being handled. A separate lever can be set for 7-, 10-, or 12-inch records. At the end of the play, the arm returns to its rest and the turntable shuts off.

For automatic operation as a changer, a tall spindle is inserted. Up to ten records can be accommodated on this spindle. The change cycle, which requires about 13 seconds, begins with the stack of records being raised to remove the weight from the bottom record, which drops gently to the turntable where it is supported by its edges on the ribbed mat. The remaining discs are then lowered to the three supporting prongs to await the next change cycle.

In the 1019, the cueing lever arm on the right side of the motorboard raises the pickup from the record by a distance adjustable over a ⅜-inch range. This does not otherwise interrupt or affect the operation of either the "Auto" or "Manual" modes. Flipping the cueing lever to its "Down" position lets the pickup descend slowly (by means of silicone damping) to the record surface. With or without the anti-skating compensation, the pickup returns precisely to the same groove that it left. Over-all, the mechanism is impressively precise and functions smoothly.

The cartridge shell of the 1019 is removed simply by pushing the tonearm fingerlift back through 45 degrees and letting the plastic cartridge insert drop out. The cartridge mounting position in the shell is adjustable so that its stylus coincides with a mark on the locating jig, thus insuring minimum tracking error with any cartridge.

The anti-skating adjustment is to compensate for forces that act on any cartridge in any tonearm with an offset head (this includes all conventional arms). This force tends to push the arm toward the center of the record, increasing stylus pressure on the inner groove wall and decreasing it on the outer wall. This causes a measurable increase in distortion on the stereo channel corresponding to the outer groove wall as well as an increase in wear of the inner wall.

The *Dual* anti-skating system uses a coil spring in an ingenious mechanism that maintains constant corrective action over the playing area of the record. It operates at the horizontal pivot and is set by a dial which is calibrated to correspond to the tracking-force dial. Normally, the two are set to the same value, but the owner's manual includes information on the correct settings for styli of various radii.

This anti-skating force adjustment, when set according to the instructions, was quite accurate and resulted in a substantial reduction in the measured distortion of the outer-groove wall channel at very high velocities. With normal program material, no audible improvement was noted when using the anti-skating compensation, but it does permit some reduction of the tracking force needed with any given cartridge.

Tracking error was measured as less than 0.5 degree per inch of radius. Near the center of the record, where low tracking error is most important to minimize distortion, it was approximately

(Continued on page 74)

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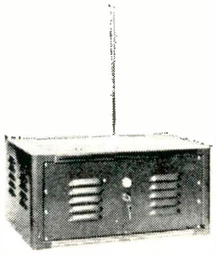

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UNIQUE FEATURES OF HiFi/STEREO REVIEW'S MODEL 211 STEREO TEST RECORD

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- White-noise signals to allow the stereo channels to be matched in level and in tonal characteristics.
- Four specially designed tests to check distortion in stereo cartridges.
- Open-air recording of moving snare drums to minimize reverberation when checking stereo spread.

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Although there are many stereo test records on the market today, most critical checks on existing test records have to be made with expensive test equipment.

Realizing this, HiFi STEREO REVIEW decided to produce a record that allows you to check your stereo rig, accurately and completely, **just by listening!** A record that would be precise enough for technicians to use in the laboratory—and versatile enough for you to use in your home.

The result: the HiFi STEREO REVIEW Model 211 Stereo Test Record!

Stereo Checks That Can Be Made With the Model 211

- ✓ **Frequency response—a direct check of eighteen sections of the frequency spectrum, from 20 to 20,000 cps.**
- ✓ **Pickup tracking—the most sensitive tests ever available to the amateur for checking cartridge, stylus, and tone arm.**
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- ✓ **Flutter—a test to check whether your turntable's flutter is low, moderate, or high.**
- ✓ **Channel balance — two white-noise signals that allow you to match your system's stereo channels for level and tonal characteristics.**
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ALSO: ✓
Stereo Spread
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PLUS SUPER FIDELITY MUSIC!

The non-test side of this record consists of music recorded directly on the master disc, without going through the usual tape process. It's a superb demonstration of flawless recording technique. A demonstration that will amaze and entertain you and your friends.

All Tests Can Be Made By Ear

HiFi/STEREO REVIEW's Model 211 Stereo Test Record will give you immediate answers to all of the questions you have about your stereo system. It's the **most complete test record** of its kind—contains the widest range of check-points ever included on **one** test disc! And you need no expensive test equipment. **All checks can be made by ear!**

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The Model 211 Stereo Test Record is a disc that has set the new standard for stereo test recording. There is an overwhelming demand for this record and orders will be filled by HiFi/STEREO REVIEW promptly upon receipt. At the low price of $4.98, this is a value you won't want to miss. Make sure you fill in and mail the coupon together with your check ($4.98 per record) today.

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EW-46

WEST COAST ELECTRONICS INDUSTRY:

A SPECIAL EW REPORT

By LAWRENCE ZEITSOFF
Vice Pres. & General Manager
Consultants and Designers, Inc.

An almost incredible turnabout that began in the spring of 1965 has resulted in a vibrant, rapidly growing segment of a national industry that is still continuing to expand.

LESS than two years ago, the western electronics industry was in a critical condition. Its heavy dependence on the region's defense and aircraft business made it more vulnerable to defense cutbacks than any other geographic section of the industry. When McNamara's axe fell, the region suffered badly.

Electronics firms in Los Angeles, San Francisco, Salt Lake City, Denver, and Seattle were particularly hard hit. Thousands of layoffs in defense-related electronics plants choked the unemployment rolls. Engineers, production workers, and technicians eyed job opportunities in Florida, Georgia, and other growth areas. Many moved away altogether.

Strong Comeback

Today, many electronics firms are trying to lure them back. For the western electronics industry has undergone a nearly miraculous turnabout that began in the spring of 1965. Today, it is among the most vibrant, rapidly growing segments of a national industry whose phenomenal growth continues to confound the analysts.

The west's rapid recovery certainly was helped by the new look in defense procurement brought on by increasing activity in Vietnam. Moreover, three additional government-related developments will power even greater expansion over the next four or five years: (1) the Air Force's Manned Orbiting Laboratory contract that *Douglas Aircraft* snared last fall; (2) rapid growth of the multi-billion-dollar spaceport around Vandenberg Air Force Base; and (3) *North American Aviation's* mounting backlog of rocket engine contracts from the National Aeronautics and Space Administration (over $200-million at year end).

The most encouraging aspect of the western electronics comeback, however, is that so much of the new production has been in consumer and industrial markets and only marginally in government work. And even in aerospace, there is more volume in private contracts today than there has ever been before. Both *Douglas* and *Boeing* enjoy huge backlogs for many types of civilian aircraft.

Big Business

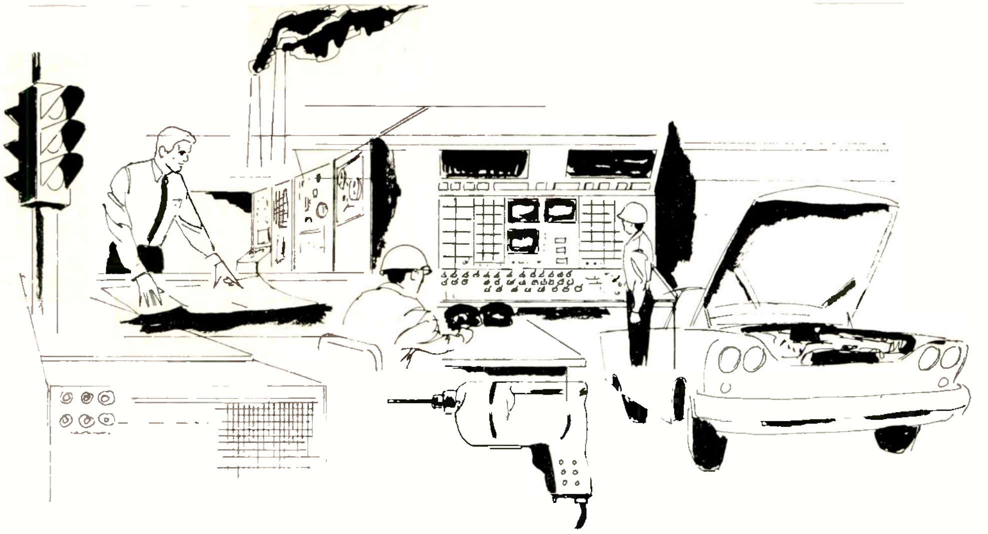
Government, to be sure, still dominates western electronics, as it dominates electronics everywhere. Nationally, government accounts for more than half of the $17 billion electronic industry's sales this year, as it has since the Korean War. And, according to Electronic Industries Association forecasts, government will still be taking more than half of the industry's output by 1970 when sales are conservatively expected to approach $24-billion.

The west—including the Pacific Coast and Mountain States—produces about 25% of the industry's output with about 22% of the nation's electronics plants and close to 30% of its electronics engineers.

As recently as fiscal 1963, eleven western states drew more than 33% of total prime military contracts, totaling more than

Our author heads the Technical Services Div. of his company. After receiving his ME degree in 1938, he was an engineer with Fairchild Aircraft and Consolidated Aircraft. He then joined Vultee Aircraft and later became asst. chief engr. with American Central Mfg. Corp. Later he joined the Eastern Aircraft Div. of GM where he helped convert that facility from autos to aircraft production. He joined Consultants and Designers in 1951 and helped develop it to its present strength of 2300 personnel.

He knows the West Coast area, having lived and traveled there extensively. He is a member of the American Institute of Aeronautics and Astronautics.



MOST PROMISING CIVILIAN MARKETS FOR ELECTRONICS IN NEXT TEN YEARS

Controls for major household appliances: Potential is in the hundreds of millions of dollars, most of which is now monopolized by mechanical devices. A few major appliance manufacturers are already experimenting with various types of electronic controls.

The automotive market: Solid-state ignition systems and air conditioning, in particular, are expected to take a large volume of electronic products.

Traffic control systems, vending machines, voting machines, and other equipment used to provide services to large numbers of people. The problems of a growing population have multiplied pressures for improvement in current equipment design. For example, traffic congestion has greatly increased demand for electronic switching in traffic control devices; spread of self-service selling has created need for better vending machines.

Automated equipment for small plants: Electronic controls for machine tools and industrial ovens will be especially important; many present controls are only semi-automatic and sometimes awkward to use.

Heavy industrial plants controlled by computers either in part or completely.

Large computer installations: Big companies will continue to dominate the main market, but smaller companies will have opportunities in peripheral gear.

Universal motor controls as used in hand tools and portable appliances.

Hobby applications such as Citizens Band communications systems.

Toys: Electronics is one of the fastest growth areas in this multi-million-dollar business.

Source: Survey of marketing executives of major electronic firms by Research Institute of America.

$8-billion. By the end of fiscal 1965, however, these states' share had dwindled to little more than 28%, or $6.5-billion.

Federal research and development contracts awarded to profit organizations in western states during fiscal 1964 totaled over $4.6-billion, or nearly half of the total $9.4-billion such contracts awarded nationally that year. All but $59-million of the west's share was from three federal agencies most likely to involve electronics in a major way—NASA, Defense, and the Atomic Energy Commission.

R&D, of course, is one of the fastest growing segments of government spending. Since the beginning of World War II, federal expenditures for this purpose soared from $74-million in 1940 to an estimated $20-billion in fiscal 1966. Federal R&D accounts for around 19% of government expenditures, and about two-thirds of total national outlays for R&D.

NASA is second only to Defense in the R&D business; it puts up more than a third of the total. Here, too, the west plays a dominant role. Nearly half of the prime contracts awarded by NASA in fiscal 1964 went to western states, mostly to California. In fact, some 27 of the top business firms awarded NASA contracts were in California.

Leading State

California, of course, leads western electronics as it does national electronics. This dominance, like so many things in this rapidly changing industry, is a fairly recent phenomenon. Only nine years ago, the Business and Defense Services Administration reported that little more than 11% of total electronics shipments originated in California. At that time it ranked third among the states, outstripped by New York's 20% and Illinois' 13%.

It wasn't long, however, before all that changed. By December, 1962, California was out in front, and its electronics employment was approaching 232,000. When McNamara lowered the boom, the layoffs started and, by the end of 1964, electronics employment was down to 190,000. Now, however, it is well along the comeback trail.

New Companies

Internal developments within *Hughes Aircraft Co.*—one of the patriarchs of the western electronics industry—spawned the great proliferation of electronics firms in California and thrust that particular state into the forefront of the entire industry.

Hughes led western electronics from 1947 to late 1953, when some of its leading personnel left and set up several other important companies.

Among them were: Charles B. "Tex" Thorton, founder of amazingly successful *Litton Industries, Inc.*; scientists Simon Ramo and Dean E. Woolridge, who started the firm now known as *Thompson Ramo Woolridge, Inc.*; and Henry E. Singleton and George Kometsky, whose young, but rapidly expanding *Teledyne, Inc.*, was formed by the duo in 1960 after both left vice presidencies at *Litton*.

California's dynamic home-grown electronics industry—spearheaded by *Hughes, Litton, Teledyne, Scientific Data Systems, Inc., Electronic Specialty Co., Lear-Siegler, Inc.*, and a clutch of aggressive, though smaller firms—mushroomed faster than the industry as a whole. Moreover, the sweet smell of success—plus the scientific elite that grew up around the state's vast aerospace-electronics-R&D complex—began to attract satellite plants from many large midwest and eastern electronics firms—*General Electric, International Business Machines, Raytheon, Fairchild*, and others.

General Electric's California plants employ over 9100, with about 20% in electronics. *Fairchild Camera* located its solid-state R&D lab in Palo Alto three years ago because of the area's proximity to Stanford University. Today, *Fairchild's* semiconductor complex employs over 3000 in the Bay area, and its prospects have brightened considerably since it cracked the commercial-consumer market for integrated circuits.

But it's the home-grown companies that have given the state most of its growth in electronics. *Litton* is the most spectacular, although not necessarily atypical among California companies. In 1957, this Beverly Hills firm employed only 2700 persons and shipped $28-million worth of goods. Today, only nine years later, it is one of the giants of American industry, with nearly 70,000 employees and a sales rate in excess of $1-billion annually.

Not all these jobs or sales originate in California, or even in electronics. Through innovation, acquisition, and merger, *Litton's* aegis now spreads across 142 plants in 21 states and 15 foreign countries, and through a plethora of industries ranging from typewriters to shipbuilding. The company's roots and reputation, however, are firmly planted in electronics and in California.

Today *Litton* operates 14 plants in California and employs about 12,000 in the state. Elsewhere in the west, it operates plants in Salt Lake City and Ogden, Utah, and Colorado Springs, Colorado, which employ a combined total of 2100.

Another fledgling California firm, *Teledyne*, seems to be taking off at *Litton*-like pace. In its third year of existence, the new firm rang up $30-million in sales and beat out such giants as *IBM*, *North American Aviation*, *Bendix*, *Burroughs*, and *Honeywell* to become one of three finalists in a competition to build an integrated helicopter avionics system.

Teledyne's aim—to become a thoroughly integrated electronics capability that one day, it fondly hopes, will rival *General Electric*—led it to acquire more than two dozen smaller firms that fit into its blueprint for self-sufficiency. More acquisitions are reported under consideration.

Today, *Teledyne's* network includes 20 plants in five states, employs more than 3500 persons, and is expected to generate sales of more than $80-million this year.

Unlike *Litton* and *Teledyne*, which are building their strength and diversity as much through acquisition as through innovation, another growing California electronics firm, *Electronic Specialty Co.* of Los Angeles, is concentrating on retrenchment and consolidation in order to build muscle for future expansion.

In the past three years, *Electronic Specialty* has boiled down 32 plants into nine (five of them new). Costs of the consolidation ran high in both profits and effects on manpower. The company's sales continued to grow, and went over $79-million in 1964. Net income reached a high of $2.7-million in 1962. In 1964 a deficit of $600,000 was reported. Profits began to move up early in 1965, however, totaling $566,233 in the first half of 1965.

Today, the company employs nearly 5000 workers in nine states. Western operations center in California and Oregon.

Rapid Growth in the Northwest

Oregon's electronics industry, miniscule by comparison with California's, nevertheless is generating a lot of excitement among industry observers, along with the Pacific Northwest as a region. In fact, data compiled by Western Electronics Manufacturers Assn. revealed that in recent years electronics growth in the Pacific Northwest has been faster than for the west as a whole.

According to WEMA, electronics employment and sales in the Pacific Northwest has more than doubled in the past four years—a rate of growth more than twice as fast as the total west; and most of this growth centers in Oregon.

Northwest states' employment departments count around 9000 workers in electronics, and at least two-thirds of these are in Oregon. WEMA, however, estimates electronics employment in these states at closer to 12,000. (The confusion stems from the inadequacy of Standard Industrial Classifications used by the states; these lump electronics under "electrical machinery" and overlook electronics firms classified under ordnance or instruments.) By WEMA's measure, Oregon electronics employment probably is over 8000. In a thinly populated state like Oregon, where total manufacturing employment is only 167,000 (Los Angeles employs more than twice that number in aerospace alone), that amount of highly paid electronics jobs weighs heavily on the economic scale.

The 1963 Census of Manufacturers counted 69 establishments in Oregon's electronics-dominated electrical machinery industry. Only two years ago, these firms accounted for little more than $57-million in value added by manufacture. But Oregon's electronics industry is led by *Tektronix, Inc.*, an oscilloscope manufacturer outside Portland.

Tektronix grew from a small basement industry formed after World War II to one that employs more than 5000 workers and generated sales of $81-million in the year ending May 29, 1965.

Medical electronics is an important part of *Tektronix'* product line. This in fact, is a growing segment of Oregon's electronics industry, as it is in electronics nationally. Moreover, with the big investment now going into hospital construction, and the huge wave being generated by new federal appropriations for hospital and medical school construction, medical electronics promises to be one of the real growth elements of the industry in the years ahead.

Prime Military Contract Awards
(Net value of military procurement awards × $000)

State	fiscal 1963	fiscal 1964	fiscal 1965
Arizona	$ 285,751	$ 173,825	$ 176,857
California	5,835,670	5,100,650	5,153,635
Colorado	444,196	389,511	249,547
Idaho	8,634	7,804	11,724
Montana	79,349	16,422	69,375
Nevada	13,143	6,361	19,142
New Mexico	61,642	71,486	84,137
Oregon	41,777	29,104	39,624
Utah	408,127	340,040	191,173
Washington	1,041,581	1,085,696	545,607
Wyoming	125,081	49,408	7,867
Total, western states	**$ 8,344,951**	**$ 7,270,307**	**$ 6,548,688**
Total, U.S.	**25,233,240**	**24,417,107**	**23,268,057**
West % of U.S.	**33.1**	**29.8**	**28.1**

Source: Dept. of Defense

Other Oregon electronics firms prominent in the medical field include: *Field Emission Corp.*, a world leader in radiology and x-ray equipment, and developer of a revolutionary, lightweight, portable clinical x-ray unit; *Electro Scientific Industries, Inc.*; and *Electro Glass Laboratories, Inc.*

A few years ago, Oregon's Department of Planning and Development forecast that the state's electronics industry would employ over 15,000 by 1970. At that time, economists at *Pacific Power and Light Co.* thought that estimate too conservative and boosted it to 20,000; that goal seems easily within reach.

The neighboring state of Washington has a much smaller, but also fast-growing electronics industry. Most of the state's electronics firms cluster around the Seattle area, and there are no giants. Most are young and small. Of the 45 firms listed by the Seattle Area Industrial Council, only 23 were there ten years ago, and only eight employ more than 100 workers.

Largest of Seattle's electronics firms is, naturally, the *Aero-Space Division* of *The Boeing Co.*, which employs a little over 1100. The parent company is, of course, one of the nation's largest airframe manufacturers and, with around 61,000 on its payroll, also is the state's largest employer.

Boeing probably is the reason why *United Control Corp.*, producer of aerospace control systems and avionics, started in the Seattle area in 1958. The firm now employs around 550 persons.

John Fluke Manufacturing Co., Inc., moved to Seattle from

Federal Research and Development Allocations to Profit Organizations, Fiscal 1964 (×$000)

State	Total	Defense	AEC	NASA
Arizona	$ 40,733	$ 32,863	$ 65	$ 7,739
California	3,726,577	1,963,323	94,259	1,664,766
Colorado	217,858	209,556	360	7,428
Idaho	22,351	406	21,632	313
Montana	3,162	3,162	—	—
Nevada	154,350	10	153,396	942
New Mexico	172,823	23,934	148,514	—
Oregon	950	463	—	467
Utah	35,420	35,245	—	175
Washington	231,151	198,715	29,459	2,840
Wyoming	26,210	26,210	—	—
Total, western states	**$4,631,595**	**$2,439,887**	**$447,685**	**$1,684,670**
Total, U.S.	**$9,414,900**	**$5,157,218**	**$768,310**	**$3,430,739**
West % of U.S.	**49.2**	**48.4**	**58.3**	**49.1**

Source: National Science Foundation

Major Defense Contractors with Western Plants

Company	Total contracts fiscal 1964 (× $000)	Amount allocated to western plants
North American Aviation, Inc.	$568,163	$557,477
General Dynamics Corp.	432,855	242,819
Lockheed Aircraft Corp.	324,022	315,933
Western Electric Co.	318,264	34,554
Boeing Co.	313,473	238,612
Martin Marietta Corp.	281,391	223,366
General Electric Co.	216,263	8,980
Aerojet General Corp.	215,916	201,799
United Aircraft Corp.	201,924	109,468
Pan American World Airways, Inc.	136,275	10,505
Hughes Aircraft Co.	109,662	109,425
Sylvania Electric Products Inc.	107,444	46,536
Westinghouse Electric Corp.	97,953	19,522
Douglas Aircraft Co.	89,631	78,065
Philco Corp.	[illegible]5,588	81,401
Ling Temco Vought, Inc.	77,912	885
Radio Corp. of America	72,948	2,029
Sperry Rand Corp.	72,689	1,642
General Motors Corp.	68,453	1,927
Thiokol Chemical Corp.	55,686	29,375
Raytheon Co.	54,073	2,236
Space Technology Labs, Inc.	52,802	52,802
Bendix Corp.	46,745	1,178
Hercules Powder Co.	44,608	22,140
General Precision, Inc.	35,826	3,707

Source. Dept. of Defense

Number of Western Scientists in Electronics-Related Fields, 1964

State	Meteorology	Physics	Mathematics	Statistics
Arizona	88	197	178	18
California	630	4,536	3,167	297
Colorado	156	424	221	35
Idaho	24	70	34	1
Montana	44	19	41	8
Nevada	40	46	21	1
New Mexico	92	530	206	24
Oregon	55	131	121	10
Utah	64	113	107	27
Washington	125	427	297	42
Wyoming	8	13	20	3
Total, western states	**1,326**	**6,508**	**4,413**	**466**
Total, U.S.	5,510	26,698	17,411	2,843
West % of U.S.	**24.1**	**24.4**	**25.3**	**16.4**

Source: National Register of Scientific and Technical Personnel, 1964, National Science Foundation, Washington, D.C.

There are fewer electrical engineers on tap . . .

	Number of active applicants registered in public employment offices		
Area	May 1965	November 1964	May 1964
Denver	25	82	30
Los Angeles-Long Beach	432	638	477
Portland, Ore.	6	3	7
San Francisco-Oakland	85	117	99
Seattle	9	16	47
Total, 30 major labor areas	1,368	1,862	2,073

. . . to fill available jobs.

	Number of unfilled openings		
Denver	1	0	3
Los Angeles-Long Beach	128	168	106
Portland, Ore.	1	5	1
San Francisco-Oakland	21	34	13
Seattle	62	74	0
Total, 30 major labor areas	696	650	429

Source: U.S. Dept. of Labo

Connecticut in 1949, recently reported 400 on its payroll. Other major electronics firms in the area include: *Honeywell, Inc.*, which employs 247 in its Seattle Development Laboratory; *Electro Development Corp.*, with 250; *Tally Corp.*, with 160; and a few others with less than 150 each.

One area of increasing potential in Washington is the atomic research complex now growing up around the Atomic Energy Commission's huge facility in Hanford. Recently, six different contractors, led by *Batelle Memorial Institute*, were selected to operate the facilities from which *General Electric* is withdrawing. One of the contractors is *Computer Sciences Corp.*, which will provide computer and data processing services under a $7½-million government contract.

The new complex is expected to attract many satellites, and with the existence of a strong medical school already in the state, could spawn an important center for medical research in the atomic-electronics sphere. In addition, Hanford is a strong contender for the huge $275-million proton particle accelerator that the AEC will soon announce.

Mushrooming Arizona

Of all the western states, however, the one with the most spectacular growth in electronics is Arizona. Unlike Pacific Coast states, however, very little of Arizona's electronics industry is home-grown.

The first major electronics firm to establish a beachhead in Arizona was *Motorola Inc.*, which located a research center for its Military Electronics Division there in 1948. Since then, the company has brought to Phoenix its Control Systems Division and its Semiconductor Products subsidiary, the latter being the second largest semiconductor plant in the U.S.

Today, *Motorola* employs more than 12,000 in Arizona, and is the state's largest private employer. How rapidly this leadership development may be measured by the fact that in 1965 alone *Motorola* hired 5000 new workers in its semiconductor operations. By the end of 1966, that division's general manager, C. Lester Hogan says his plant alone will employ 11,000 to 12,000 workers. Moreover, Hogan estimates that his division will have 15,000 on its payroll by 1970.

A similar history of rapid growth characterizes most of the other large firms that came to Phoenix. Seven years ago, *General Electric* brought its computer department to the area; today, it employs nearly 5000 and is still growing. Last summer, it announced its fourth expansion, a $4-million addition to the computer plant.

Some other examples: *AiResearch Manufacturing Co. of Arizona*, a division of *Garrett Corp.*, opened 12 years ago with 170 employees. By 1965, its payroll had gone over 3500. And a comparative newcomer to Arizona, the *Sperry Phoenix Co.*, division of *Sperry Rand Corp.*, now employs more than 1600 and is the parent firm's principal center for aeronautical equipment.

Goodyear Aerospace Corp. came to Phoenix early in World War II and saw its employment go up as high as 8000 during the war years. Today, with close to 2000 workers, *Goodyear's* diversified activities range from airframe production to advanced radar systems. It is an important *Boeing* contractor.

Actually, only a handful of new electronics plants of 100 or more employees have located in the west in recent years. Most of the growth has emerged from consolidation, streamlining, and innovation in existing firms; from a hard look at the area's overdependence on government work and the problems it brought; and from a new determination to seek fresh markets and develop new products that would make it less vulnerable to procurement whims of the Defense Department.

Today, there is a broad cushion of jobs in semiconductor diodes and transistors, consumer electronics, microwave equipment, controls, testing and measuring gear, microelectronics, optics, as well as such esoteric developments as the maser and the laser.

(*Continued on page* 92)

V.H.F. RADIO CONFERENCE at BOAT SHOW

By RICHARD HUMPHREY

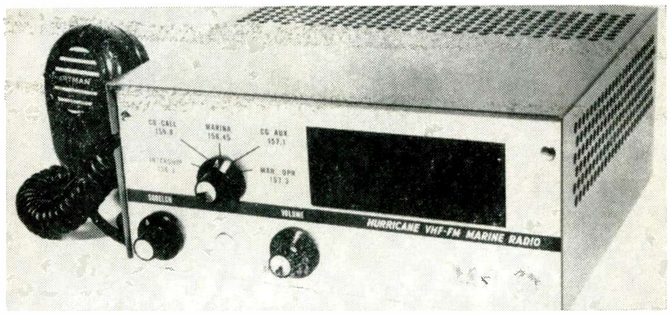
Manufacturers, FCC, and Coast Guard officials meet to promote pleasure-boat interest in new marine band.

THE Marine Communications Companies' V.H.F. Conference during the recent New York Boat Show gave clear evidence that the new v.h.f./FM Maritime Service has come to life with startling swiftness. A brief six months prior to the Show, there were only three v.h.f./FM marine transceivers on the market which could—from the point of view of price—be described as aimed at the recreational boater.

As the 40 participants in the MCC v.h.f. meeting were discussing ways and means of bringing home to the average boat owner the many advantages of the v.h.f./FM service, out in the Coliseum's lofty exhibition hall no less than nine companies new to the v.h.f./FM marine field were showing equipment in various stages of development from mock-up to immediate-delivery status.

All told, thirteen (or more) v.h.f./FM marine two-way radios will be making their appearance during the coming months of 1966; all are pleasure-boat oriented as to price, output, and number of channels.

New v.h.f. transceiver, for which early delivery is promised, is Konigsberg's "Konel" with 10 channels and 50 watts output.



Already being sold, the Hartman "Hurricane" with 5 channels and 15 watts output, has units in service in New York area.

Such familiar names as *Bendix, Sonar, Raytheon, Ray Jefferson, Hartman, Konigsberg,* and *Pearce-Simpson* will be joining *Kaar Electronics* (*Canadian Marconi*) which has two models, and *Aerotron.* Still others include *Walco* and *Simpson.*

Representatives of most of these companies and others, as well as U.S. Coast Guard communications officers and Federal Communications Commission officials assembled one afternoon during the Show with one idea in mind: how to bring home to the recreational boater the fact that the new v.h.f./FM marine band has too many advantages for him to ignore.

Limited Public Correspondence Coverage

Prominent in the discussion was v.h.f. marine's one remaining—and possibly most important—weakness. This is the limited Public Correspondence (marine operator) coverage on the new band.

"There will *not* be a shift by the pleasure-boater to the v.h.f. band until we have the necessary telephone facilities," bluntly asserted Mr. A. Dee, *Hartman's* chief engineer.

Mr. Dee's statement certainly touched the sore spot in the v.h.f./FM marine framework. Authorized in these new marine v.h.f. frequencies are five Public Correspondence channels. Yet only *two* are being used by the various telephone companies and common-carrier organizations throughout the country. What is worse, this curtailed service is limited to the few major port areas. Once a pleasure-boater (or commercial shipper, for that matter) leaves these port waters, he is absolutely without ship-to-shore telephone service on the v.h.f. frequencies.

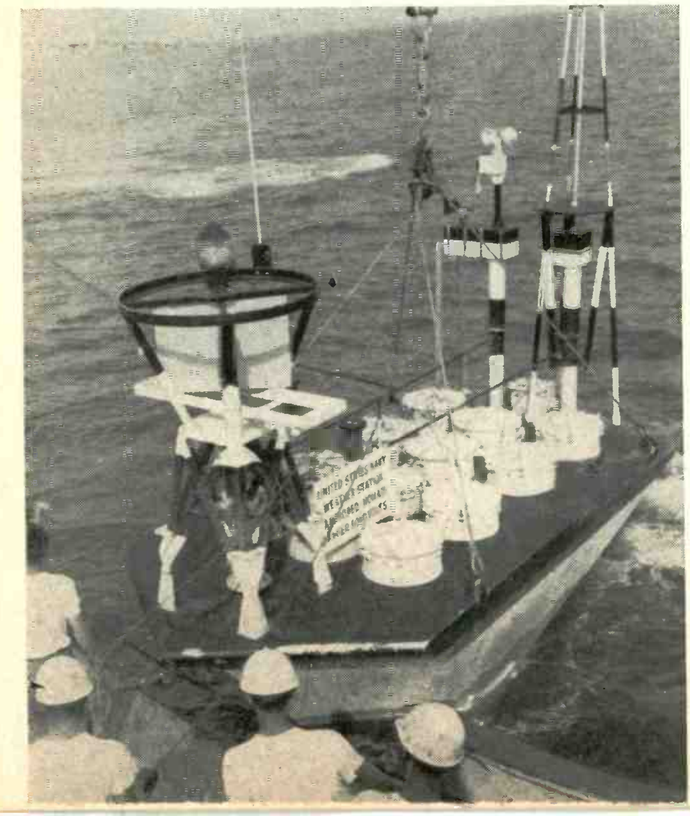
"I really hope," said George Stiles (*Canadian Marconi*) in his address to the Conference on Canadian v.h.f. methods, "that the telephone companies (in the U.S.) get into v.h.f. for they have the background, the facilities, the know-how. They," he pointed out, "are communications minded."

The "communications-minded" telephone companies are presently refusing boats telephone service in the Land Mobile classification (firmly established in some 200 areas). This was a compromise practice which, like Topsy, just "grew" in an effort for v.h.f./FM marine band users (mostly commercial) to get better telephone service. But this is definitely out as far as the *Bell System* is concerned.

"It is our feeling that the vessels should use the marine v.h.f. facilities available to them," Mr. E. F. Mattern of the N.Y. *Telephone Company* told me when I contacted him by phone, "and not add to the burden on the overcrowded land-mobile service."

But the telephone companies are not expanding either by (1) making use of the three

(*Continued on page 84*)



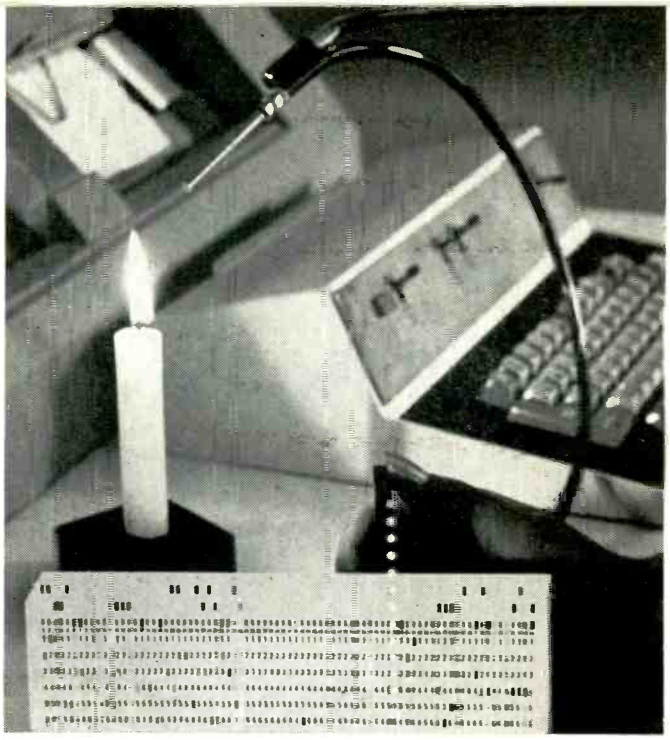
RECENT DEVELOPMENTS IN ELECTRONICS

Air-Turbulence Detector Laser. (Top left) Clear air turbulence has been detected by a ruby laser mounted on an Army aircraft. The laser transmitter and the optical receiver were installed on opposite ends of a four-foot aluminum tube which extended through the fuselage so the laser beam was transmitted from one side of the aircraft and the return signals were received on the opposite side. The transmitter and receiver are in fairings at each side of the fuselage just aft of the pilot's compartment. University of Michigan physicists reported more than 1300 in-flight experiments during a year of flying into areas of severe turbulence. The laser transmitter operates at an output power of 3 megawatts with a repetition rate of four pulses per minute. A high-gain photomultiplier with a 4-in diameter telescope detects the return radiation and feeds its output directly to an oscilloscope in an A-scan display. Very distinct and sizable optical radar echoes were produced by particles in the turbulent wakes of approaching and cruising aircraft. The entire equipment package was designed and manufactured by Lear Siegler, Inc.

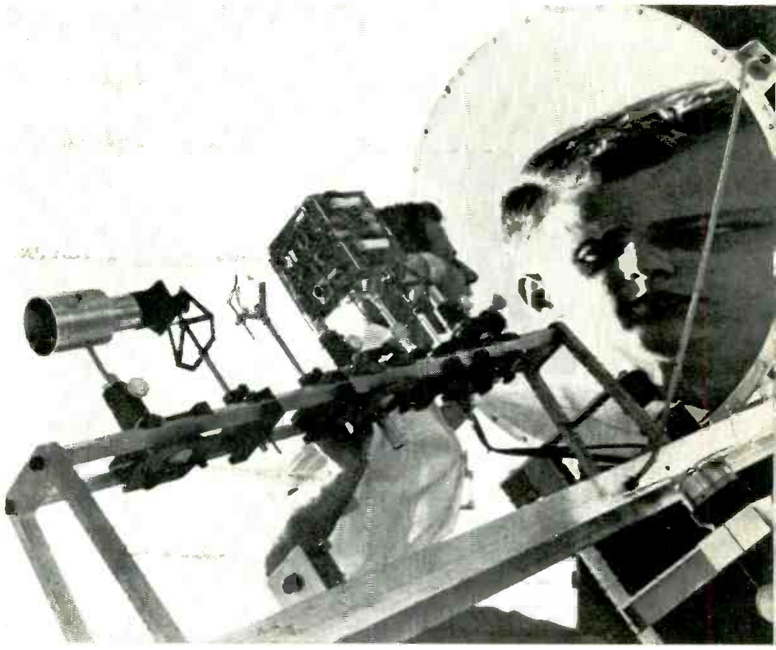
Lunar TV Camera. (Center) An engineering model of the Apollo lunar television camera developed by Westinghouse for NASA is shown here. The final version of the camera will be used in the first manned moon exploration mission. Integrated circuits were used to make the camera compact, lightweight, and reliable. The low light level capability of the unit is the result of a special image tube, called the secondary electron conduction image tube, being used. The camera will produce TV pictures that will be relayed to earth and distributed to the world's TV networks. The quality of the pictures produced will be virtually as good as those usually seen on home receivers. The camera's primary scanning rate is 10 frames per second with 320 scan lines. It has a second mode of operation in which the scanning rate is 0.625 frame per second to permit more detailed observation of the moon's features by scientists on the earth.

Nuclear-Powered Weather Buoy. (Bottom left) A nuclear-powered model of the Nomad weather buoy is now broadcasting weather information at regular intervals from the Gulf of Mexico to monitoring stations ashore. Operating completely unattended, the floating station, developed by the National Bureau of Standards for the Navy, transmits both general weather data and advance warning of hurricanes. The buoy is powered by nickel-cadmium batteries that are kept charged by a Snap-7D nuclear generator. This generator is a thermoelectric device operated by heat from the nuclear source. The buoy broadcasts in continental code the station identification, water and air temperatures, barometric pressure, wind speed and direction, and integrated wind force. Each transmission takes about 2⅓ minutes and can be programmed to occur at intervals of 1, 3, 6, or 12 hours. The buoy's transmitter operates on a frequency of 5340 kHz with a power of 4 kW. Signals are reliably received over 800 miles.

Fiber-Optic Card Reader. (Top right) This tube of glass fibers is sensitive enough to take light from a candle, curve it around a corner, and use it to "read" documents. Such a technique is now incorporated in two different IBM data processing machines. These computers use fiber-optic bundles to transmit light from a central source around internal assemblies to scanning stations. Each bundle contains hundreds of extremely fine glass fibers, several feet long but far thinner than a human hair. Acting as tiny light pipes, the fibers carry beams of light which activate photosensitive elements and register data on punched cards.

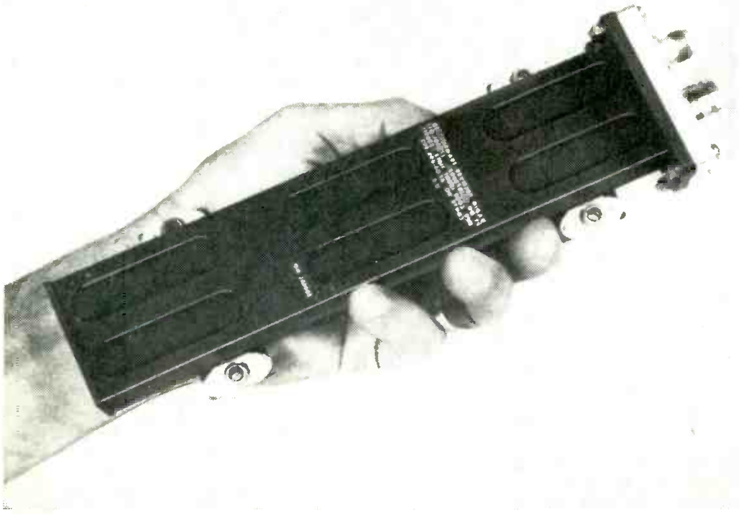


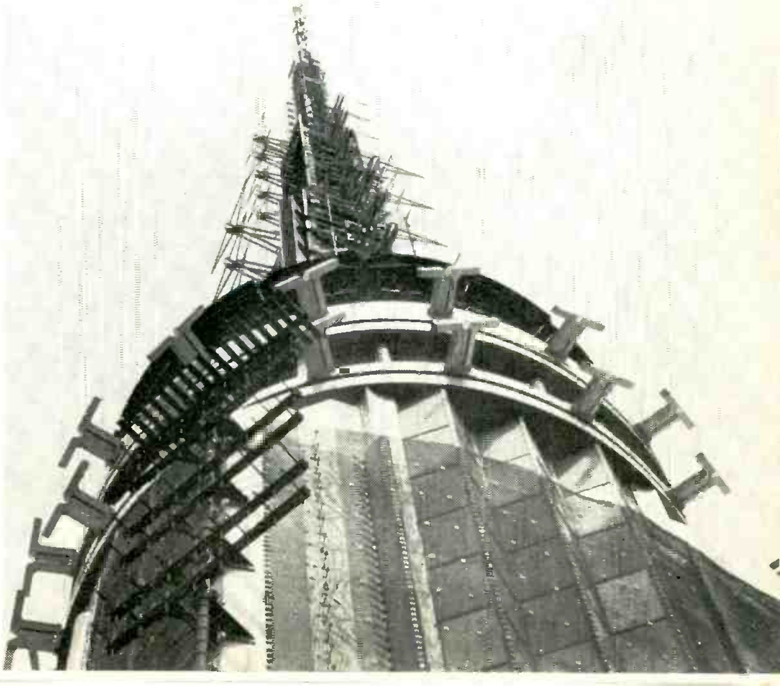
Sun-Pumped Laser. (Center) Deep-space communications is the purpose of this experimental laser device that is powered by the sun's rays collected in the parabolic mirror. The device, developed by RCA, is the first step in a 50-million-mile communications link between spacecraft near Mars and the earth. The laser has already been used to transmit a television picture over the narrow light beam in the laboratory. The laser employs an yttrium aluminum garnet crystal which is optically pumped by sunlight and water-cooled because of the intense heat. The continuous laser beam has an output power of one-half to one watt. Modulation is accomplished by a gallium arsenide electro-optic crystal.

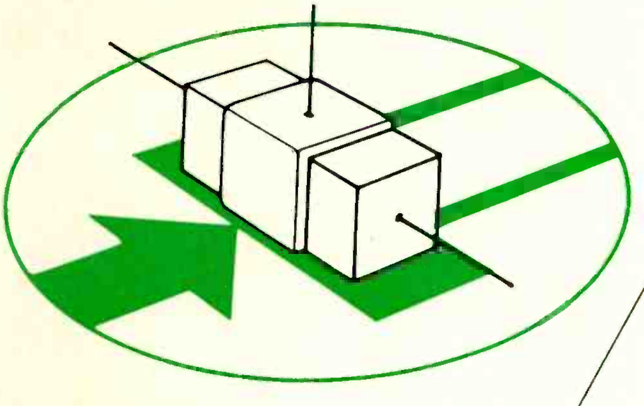


Transceiver for Gemini. (Below left) This compact radio transceiver is expected to be used for the first time on the Gemini 9 mission. The two-way radio enables an astronaut walking in space to talk with his companion in the orbiting spacecraft. The transceiver measures only 1 by 1.8 by 8.6 inches and weighs 15 ounces. The solid-state circuitry is of welded cordwood construction. The transceiver, produced by ITT, is designed to permit high-quality AM voice communications at 296.8 MHz.

Master FM Antenna. (Below right) Thirty-two dipoles have been installed above and below the observation windows on the 102nd floor of New York City's Empire State Building to serve as the nation's first FM master transmitting antenna. When fully installed and wired, the antenna will be able to transmit the signals of 17 different FM stations simultaneously. The 1250-foot height will eliminate interference from surrounding skyscrapers enabling greater coverage. To date, WQXR-FM, the first FM station to go on the air in New York City in 1939, is the only station using the new antenna. The antenna, designed by Alford Mfg. Co., consists of two circular rows of dipoles, 16 above and 16 below the observation windows. The array is omnidirectional, and because of the angle at which the elements are oriented, it produces a signal with both vertical and horizontal polarization. This should benefit listeners with FM receivers in their cars and those having table radios with short, vertical antennas.







Field-effect transistors (FET's) behave just like low-distortion solid-state pentodes and, when properly used, far exceed the performance obtainable with either tubes or transistors.

Phono Equalizer Uses FET's

By W. A. RHEINFELDER / Applications Consultant, Dickson Electronics Corp.

A PHONO equalizer is a vital and usually critical part of any high-quality audio system. Its function is amplification of the weak audio signals produced by the phono cartridge as well as correction of the pre-equalization that was necessary when the phonograph records were cut. This playback equalization, known as RIAA characteristic, consists mainly of a well-defined low-frequency boost together with a controlled high-frequency roll-off (two turnover points). While passive equalization, that is, equalization by interstage networks and the like, has been used for some time, the most popular approach uses feedback over two active stages. This concept results in reduced distortion and noise as well as reduced drift of parameters with tube aging, power-supply changes, etc.

The problems associated with the design of a phono equalizer concern mainly noise and hum, correct input and output matching circuits, equalization, gain, and overload characteristics.

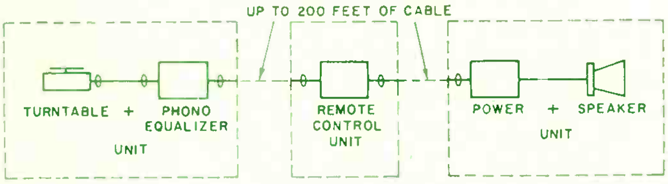
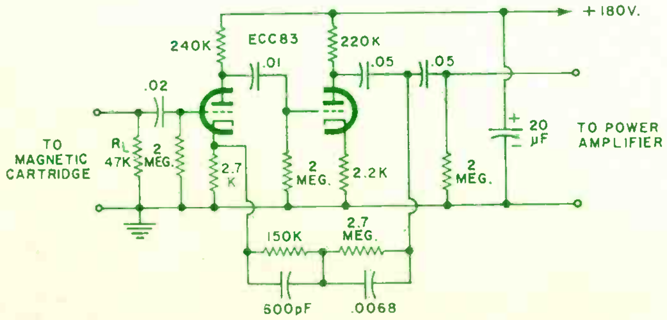


Fig. 1. Interconnection between blocks of a high-quality music system. Only one channel of stereo system is shown.

Fig. 2. A typical low-noise, vacuum-tube phono preamplifier.



Due to the equalization used, low-frequency noise and hum are particularly troublesome. The input stage must be designed for low noise using the latest state-of-the-art techniques. In tube circuits, the filaments are balanced and connected to some positive bias from 0 to 15 volts. This technique, together with careful layout and shielding, leads to the elimination of hum as effectively as the use of direct current on the filaments. Other techniques are used in addition, together with the selection of special-purpose tubes, if necessary, to reduce noise other than hum.

The input impedance of a phono equalizer must be chosen with the cartridge in mind. Typical magnetic cartridges have an inductance of 0.5 H which together with a capacitance of 130 pF produces a resonance at 20 kHz. Depending on the "Q" of the cartridge, and the exact resonance frequency, a damping resistor is needed to avoid the high-frequency peak and to achieve a flat over-all frequency response. This resistance generally runs between 22,000 and 120,000 ohms and is best chosen by measuring the high-frequency response with a test record. A resonance below about 15 kHz is undesirable for high-quality audio systems. This puts an upper limit on the total input capacitance at 220 pF. Allowing for 3 feet of coaxial cable at 30pF/ft, the amplifier input capacitance including Miller effect must then be less than 130 pF. The total input impedance of the phono equalizer must then be 22,000 to 120,000 ohms in parallel with less than 130 pF.

To drive long coaxial cable lines, the output impedance should be low. One hundred feet of cable (or 3000 pF) requires a source resistance of less than 1300 ohms for less than 1 dB loss at 20 kHz. Such a low source impedance is easily obtained with a follower-type circuit, or heavy voltage feedback effective at the high-frequency end, as is automatically achieved in a feedback equalizer.

Overload is mainly a matter of correct load and bias re-

	Tube	Transistor	FET
Circuit	Fig. 2	Fig. 3	Fig. 4
Device, 1st stage	ECC83	2N1192	DNN-1.8-A
Device, 2nd stage	ECC83	2N1193	DNL-1.8-A
Gain	40	40	40 dB
Min. Output Noise, wideband	−66	−72	−73 dBV
Min. Input Noise, at 1 kHz	−106	−112	−113 dBV
Max. Output Level, 1% Dist.	+26	+13	+31 dBV
Distortion at 30-V Output	in heavy overload		0.06%
Overload-to-Noise Ratio	92	85	104 dB
Supply Voltage	180	15	120 V
Current Drain	1	5	2 mA

Note: All measurements with identical equalization and gain as shown in Fig. 5. For increased low-frequency response (dashed in Fig. 5), noise increases 4.5 dB in all cases.

Table 1. Characteristics of tube, transistor, and FET units.

sistors and depends very much on the device used. A typical gain might be 40 dB, producing a 1-volt output signal with a 10-mV input signal. Since it has been shown that the peaks of certain types of music read 30 dB above the average level, an overload of 30 volts would be desirable for such a cartridge. If this cannot be achieved, reduced gain (more feedback) should be used for the most critical applications.

Such a phono equalizer is typically part of a preamplifier or amplifier circuit. For stereo, two such circuits are needed. The concept of a remote-control amplifier, however, is not used in high-quality systems because the lead length from cartridge to phono equalizer often becomes excessive and no adjustment of the tone controls and volume is then possible from the normal listening position. In installations of the highest quality, a concept as shown in Fig. 1 is used. The phono equalizer is built right into the turntable as it does not have to be accessible, draws negligible current, and is wired right to the turntable switch. Shielded cable up to 200 feet may be run from the equalizer to the control unit. The control unit contains all operating controls and is made small and lightweight so that it is easily moved to the preferred listening position. From the control unit, a long cable may be run to the power amplifier and the loudspeaker since no adjustments are needed.

Phono Equalizer Performance

Fig. 2 shows a typical high-quality tube circuit. Feedback is supplied from the last plate into the first cathode. The feedback network itself was trimmed to obtain exact RIAA equalization. All hum was removed and low-noise resistors as well as selected tubes were used in the critical locations. The performance of this circuit is given in Table 1. Note the good overload-to-noise ratio.

Attempts to achieve similar results with transistors were more or less successful, and a typical circuit is shown in Fig. 3. Germanium alloy transistors were consistently less noisy than other types. The high input impedance required is readily achieved by feedback, as well as the low output impedance. The major shortcomings of conventional transistors are their high distortion level and thermal instability. While the latter can be handled to a certain extent by special design techniques, the higher distortion is inherent in transistors (base-emitter non-linearity) and may be reduced only by feedback. The actual overload level is far inferior to tubes (see Table 1) and is caused by breakdown and supply limitations of normal transistors used for this purpose.

FET Phono Equalizer

Modern field-effect transistors (FET's) behave in every respect like excellent low-distortion pentodes with the omission of the filament, screen, and suppressor grids and operate at a considerably lower current drain and noise level. All capacitances are very much like those of triodes. The excellent characteristics of FET's are only obtained if the proper biasing conditions are observed and attention is paid to the specialized design of FET voltage amplifiers. When properly operated, FET's far exceed the performance obtainable with vacuum tubes or conventional transistors. As a matter of fact, they are the best amplifying devices available today for most linear applications and are likely to replace tubes and transistors in the future.

An FET phono equalizer of excellent quality is shown in Fig. 4 and its frequency

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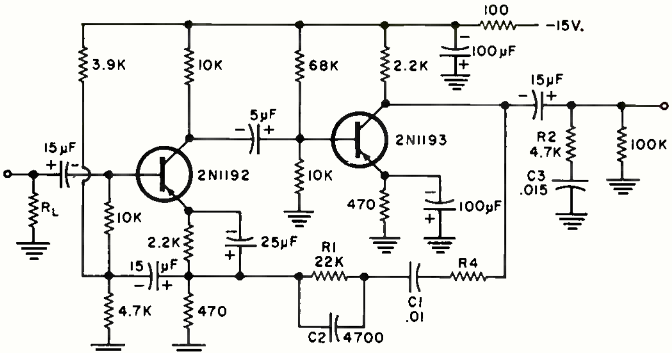


Fig. 3. Typical low-noise, transistorized phono preamplifier.

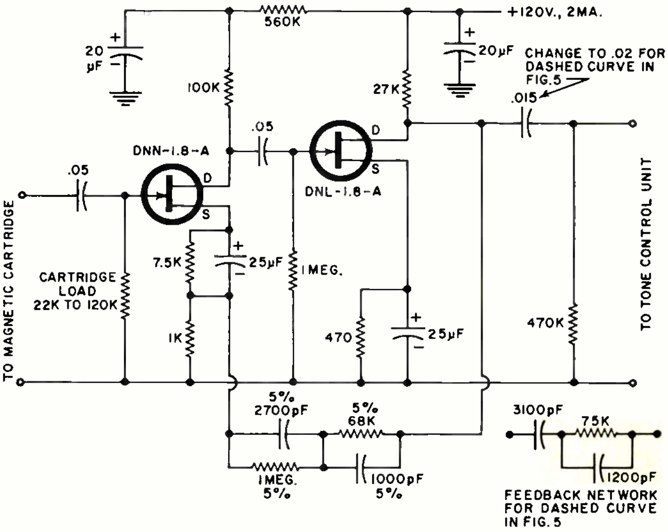


Fig. 4. High-quality FET phono equalizer and preamplifier.

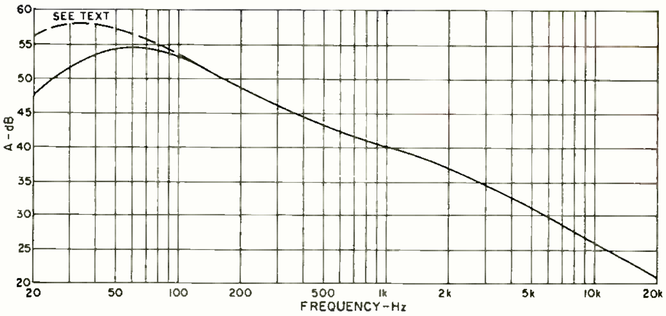
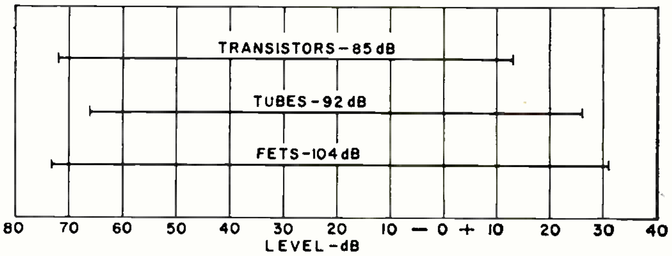


Fig. 5. Frequency response curve of the FET preamplifier.

Fig. 6. Dynamic ranges of the three types of preamplifiers.



REVERBERANT ROOMS
their design and use

By ARTHUR OPPENHEIM / Research Engineer
and SEYMOUR WASSERMAN / Chief Engineer
Industrial Acoustics Co.

Loudspeaker and microphone evaluations, transmission loss of materials, acoustic absorption, subjective listening tests, noise measurements, and fatigue tests are some applications.

THE reverberant room is one of the most practical acoustic test facilities in terms of measurement techniques and physical characteristics and is, therefore, widely used as a tool for product design and quality control. Because of its reflective walls and characteristic diffuse field, the sound-pressure level in a reverberant room is dependent only upon the sound power radiated by the noise source within it. This property, which allows it to be calibrated prior to use, facilitates rapid set-up and test which, in turn, permits production-line testing. Quality-control tests can be set up to indicate malfunctioning products. Sound-power levels produced by an assembly known to be in good condition can be measured, then that unit can be used as a standard for comparison with other assemblies on the production line in order to check for faulty bearings, defects in stator or rotor assemblies, or other operational defects. In addition, when the total radiated sound-power level of a device is known, it is possible to predict the noise that will be produced by the device within many different environments.

Reverberant-room surfaces are highly sound-reflective so that sound energy reflects from wall to wall, much the same as light rays will do from one mirror to another, until it reaches a steady-state condition, with sound level higher than would exist in an open field or in any area where there are openings such as doors, windows, air ducts, or other sound-absorbing surfaces. The more reflective the interior surfaces, the longer is the reverberation time or time for a noise to "decay." The reverberation time of a room is usually specified for a particular frequency or frequency ranges called "octave bands." Reverberation time is determined by generating a steady sound of short duration and measuring the time it takes for the noise to decay 60 decibels. The 60-decibel (dB) decay represents a decrease of the sound energy to one-millionth of its initial value, and is usually measured in seconds. Sound levels are measured by an instrument which responds to the pressure fluctuations of the sound source and indicates the sound-pressure level (SPL) in decibels (dB) of that sound source.

Calibration of Reverberant Rooms

When the dimensions of the reverberant room are sufficiently large, sound throughout the room (excluding locations close to the room's boundaries) arrives at a particular point almost equally from all directions. Furthermore, the variation of sound-pressure levels throughout the room is extremely small, within each frequency range or octave band, dependent upon the narrowness of the frequency range and/or the amount of air trapped within the room. Large air volumes absorb certain frequencies; therefore, they require special treatment.

By carefully selecting the room size, tedious positioning of the microphone and/or machine can be avoided. Further, since the volume, reverberation time, area, and absorption of the room's surfaces remain constant, the sound-power level

Fig. 1. Plan and section views of typical skewed-wall reverberant room.

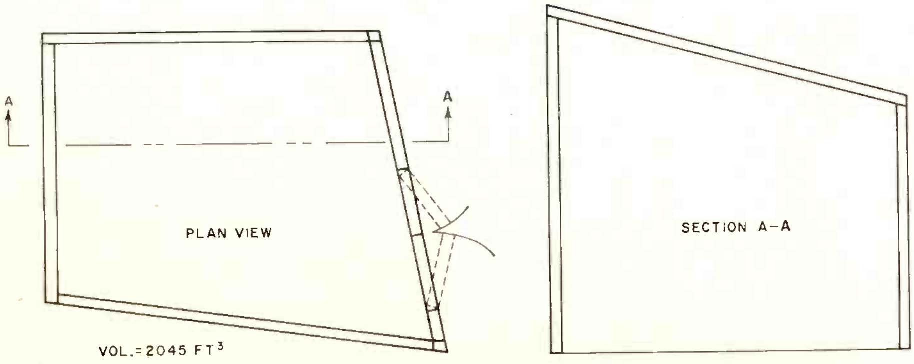
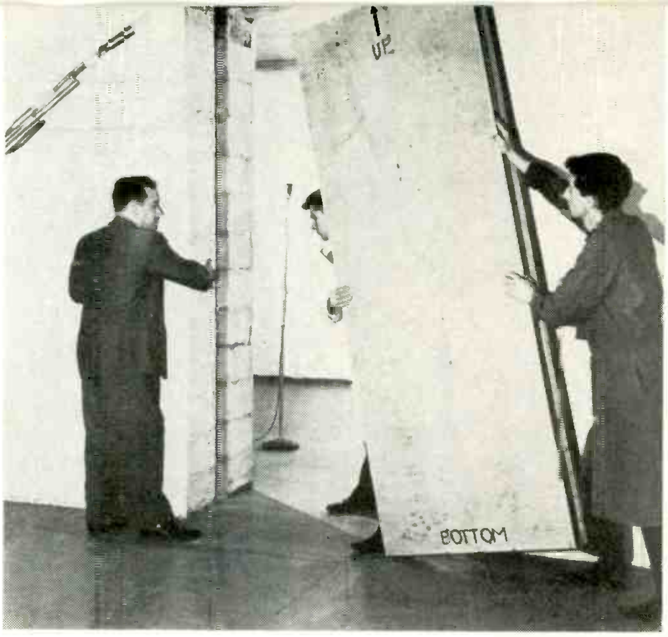


Table 1. Absorption coefficients of skewed-wall reverberant room.

OCTAVE BAND (freq. in Hz [cps])	MEASURED ABSORPT. COEFF.
37.5— 75	0.075
75— 150	0.056
150— 300	0.056
300— 600	0.040
600—1200	0.031
1200—2400	0.029
2400—4800	0.040
4800—9600	0.045

Co-author Wasserman is seen setting up a quality-control test in a reverberant room. Sound-pressure levels produced by an assembly known to be in good condition are being measured. When used in production-line testing, this standard will be used as a comparator against which other similar assemblies will be checked to reject those with faulty bearings, stator or rotor assemblies, or other defects revealed by their sound spectra.



Adjacent reverberant rooms facilitate architectural research. Shown here are two adjacent reverberant rooms. The acoustic transmission loss from one side of the modular wall panel to the other is measured by sealing it into the space between the two rooms. Noise measurements are then made in each room. Loudspeakers will be placed in the foreground room to generate a noise level of about 110 to 120 decibels throughout room.

(PWL) can be determined from a single sound-pressure-level (SPL) measurement, as evidenced by the following formula: $PWL = SPL + 10\ log_{10}V - 10\ log_{10}\ T - 19\ dB$ . . . . $re\ 10^{-13}$ watts where: PWL = sound-power level (in dB); V = total room volume (ft^3); SPL = sound-pressure level (dB re 0.0002 dyne/sq cm); T = reverberation time of room (sec), measured with a high-speed level recorder or estimated from the following formula: $T = 0.049\ V/Sa$ (sec), where S is the area of the bounding surfaces (ft^2) and a is the average absorption coefficient of the room's surface.

Hence, since V and T are essentially constant for any given room, for any frequency or frequency band, the sound-power level (PWL) can be obtained directly from a single set of sound-pressure-level (SPL) measurements once the room has been calibrated.

The use of the reverberant room as a production-line measurement station for quality control, as outlined at the beginning of this article, is quite evident since the single measurement can be readily made as the particular unit (s) pass through the reverberant room.

Uses of Reverberant Rooms

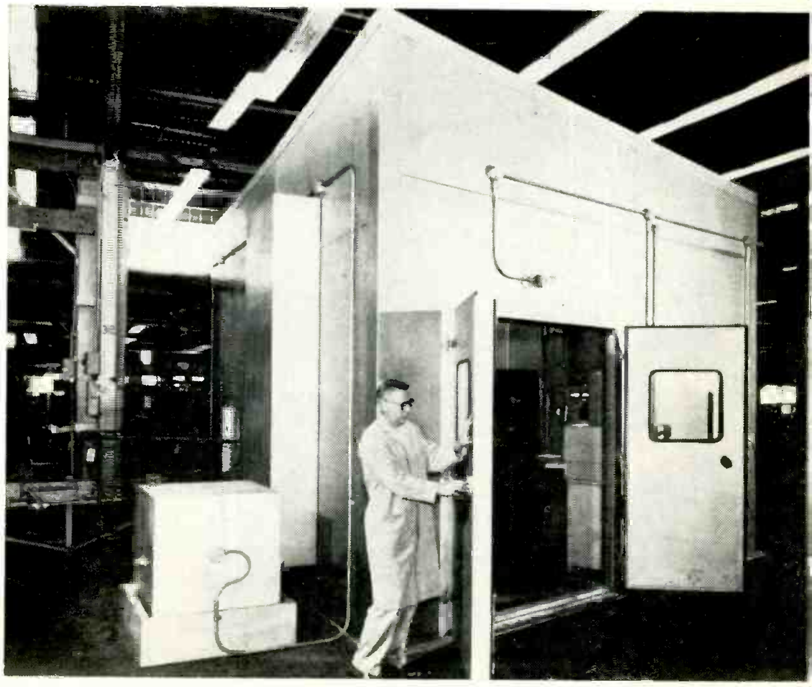
Loudspeaker Evaluations: The frequency response of loudspeakers can be measured out of doors, in anechoic chambers (which simulate the non-reflectivity of an outdoor "open-field" condition), and in reverberant rooms. Each area will produce a different response curve. Some authorities feel that the response curve measured in a reverberant room is the closest controlled measurement of performance for speakers intended for normal home or studio use.

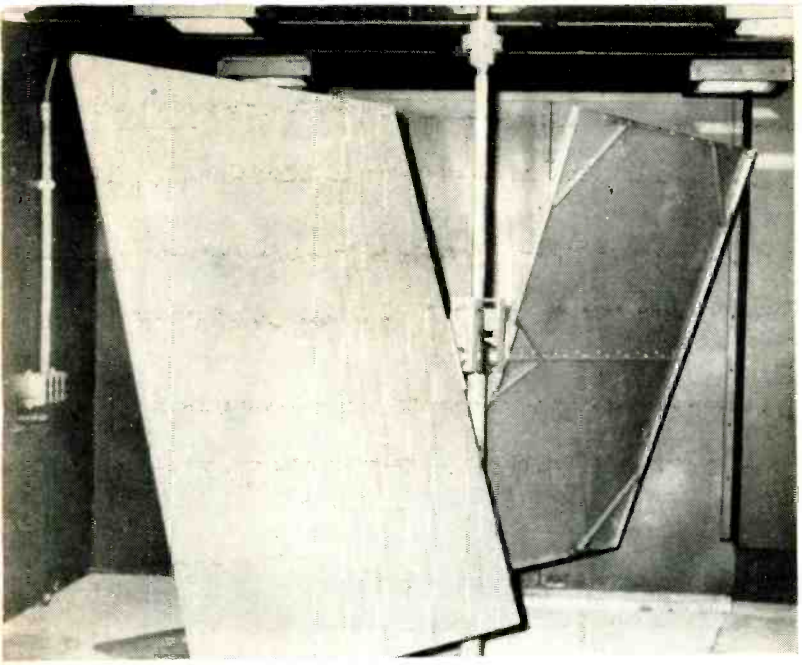
There are other characteristics of loudspeakers which can best be measured with a reverberant room. These are: speaker efficiency, distortion, power handling, transient responses, and even subjective "listening" tests. Each of these measurements depends upon an acoustic power level (PWL) and/or the emphasis of peaks in the frequency response curves.

Microphone Evaluations: The frequency response of a microphone placed in a diffuse sound field is a very important microphone characteristic for the user to know, especially for the omnidirectional type of microphone. This is a measure of the microphone's ability to reproduce the sound energy from the complete area. A diffuse field is one where the probability exists that sound arriving at the microphone from each direction is the same for all directions; it is also a sound field in which sound waves from all directions have essentially the same magnitude and will arrive at the microphone in a random phase relationship. The reverberant room is the only type of room in which a diffuse field can be maintained.

Acoustic Absorption of Materials: Once having measured the room's reverberation time during its calibration, the average absorption (a) is determined and will remain constant for a given frequency unless an acoustically absorbent material is introduced. When the reverberation time of the room is remeasured with this new material in it, the reverberation time will be shortened; the difference between the

A typical prefabricated skewed-wall reverberant room with accessories. This type of reverberant room is particularly helpful in conducting subjective listening tests where care must be taken in the placement of noise sources (speakers, motors).





Rotating vanes break up standing waves in reverberant rooms.

two reverberation times will be entirely due to the acoustic absorption of the added material.

It is because of this change that people should not be allowed inside the reverberant room while an experiment is being conducted. The only exception to this rule would be for a "listening" type of experiment, such as described later.

Other items to be considered when making absorption tests are size of a sample and method of mounting the sample. A sample size of 72 square feet is most commonly used. There are also eight commonly used mounting arrangements. This is not to say that any size or arrangement cannot be used by a manufacturer to develop his own product.

Transmission Loss of Materials: Another important property of materials used in noise abatement programs and/or in the construction of enclosures around machines, transformers, etc. is sound-transmission loss (TL). This property of a material is measured by the installation of a test specimen in an opening between two adjacent reverberant rooms. A diffuse or uniform sound field is generated on one side of the test specimen while measurements are made of the sound-pressure levels on each side of the specimen. The transmission loss can then be determined from the following formula: $TL = SPL_1 - SPL_2 + 10\ log_{10}\ P/(S \times a)$, where TL=sound transmission loss (in decibels); SPL_1=average sound pressure level in room with the noise source (in decibels); SPL_2=average sound pressure level in receiving room (in decibels); P= the surface area of test panel (ft^2); S=total surface area of receiving room (ft^2); and a=total absorption of receiving room (from room calibration measurements).

"Soft-hard" room typifies flexibility obtainable from combination steel-paneled rooms. It is shown here in its reverberant state. It can easily be converted to a "soft" room which is not very reflective, with the built-in handles seen on walls. The use of the highly absorptive configuration enables the designer to determine directivity pattern of the generated noise.

Here, again, it is seen that once the room has been calibrated, the last term in the equation becomes a constant correction factor for a given frequency which can be applied whenever a test is made, without the necessity of remeasuring the room's characteristics; provided, of course, that the area of the test specimens is not varied.

Subjective Listening Tests: Because a reverberant room has the property of producing the same sound throughout the room, it follows that with a little care in the placement of noise sources (such as loudspeakers, mufflers, motors, etc.) several variations of the same product can be "listened to," one at a time and a choice made based upon the subjective effect of the sound upon the listener. The "care" involved consists mainly of not placing items in the exact center of the room or near any of its surfaces. The use of turning vanes and skewed-walled rooms has also proved helpful in obtaining reliable data within this type of room.

Fatigue Tests: By generating a loud white (random) noise within a reverberant room, constantly varying modes of vibration can be induced in a test specimen. Subjecting the specimen to this type of environment for a specified time can cause it to fail by brittle fracture or even by opening electrical connectors or mechanical fasteners. Thus, the reverberant room can be an excellent quality-control instrument.

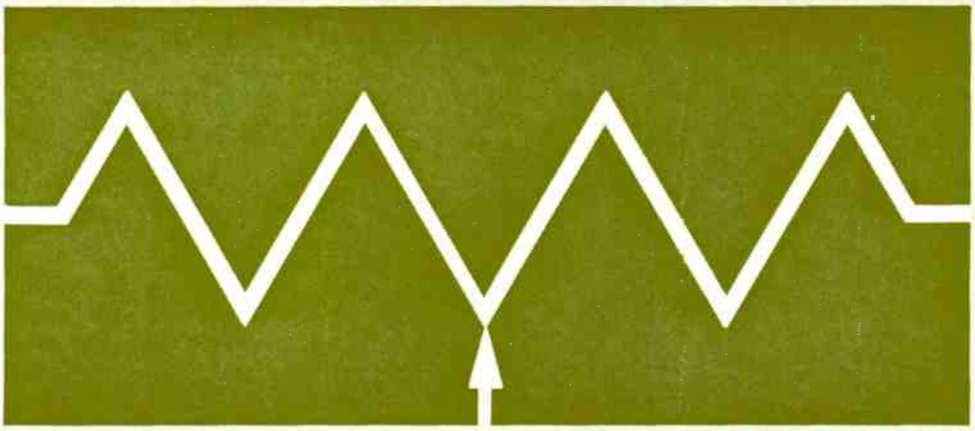
Since the surfaces of the room must have low sound absorption (ranging from 7½ to 5 percent in the 125-Hz (cps) to 4000-Hz (cps) frequency region, the surfaces can be made of prefabricated sheet metal panels, which are properly stiffened to obtain the desired absorption-reflection characteristics. Materials such as Transite or other hard nonferrous materials may be used, provided they meet the above and following criteria. It is important that the walls also provide a good degree of sound isolation from unwanted noise which may exist outside the room.

Basic construction for prefabricated reflective panels involves an outer face, an acoustical filler material, and a heavy gauge sheet metal interior face. The finer points of panel design will vary among manufacturers depending on their own development studies, practical field experience, and manufacturing capabilities.

It is possible to obtain an optimum acoustic attenuation or reduction of the outside environment's noise for an allowable weight per square foot of treatment. Once this basic wall design is determined, however, precautions must be taken in order to preserve this noise reduction when combining panels to form a complete room. Practical field experience and laboratory testing are big factors in the design and selection of these various components. Aside from the panels themselves, the basic components which go into the construction of the complete reverberant room are: panel joiners, floors, room vibration-isolation systems, doors, windows, pipe and electrical penetrations, and ventilation systems.

The many applications of reverberant rooms to production-line and laboratory-type work, as well as the construction considerations have only been briefly touched upon. For more specific applications, the manufacturers of acoustic materials and acoustic enclosures should be contacted so that the most economical reverberant rooms can be selected to meet individual requirements. ▲

SPECIAL SECTION



VARIABLE RESISTORS

PRECISION

Non-wirewound Trimmers

By JAMES R. TAYLOR / Manufacturing Engineer, IRC, Inc.

Recent advances in resistive material for these devices have generated much interest in performance and applications.

NON-wirewound trimmers are miniature, resistance-adjustment potentiometers whose function in a circuit is usually a one-time compensation, *i.e.*, "set and forget." Adjustable in various ways, by means of lead screws, worm gears, or fingertips, they are available in a variety of shapes.

The major resistance elements that are employed in today's non-wirewound trimmers are carbon composition, metal film, and metal glaze.

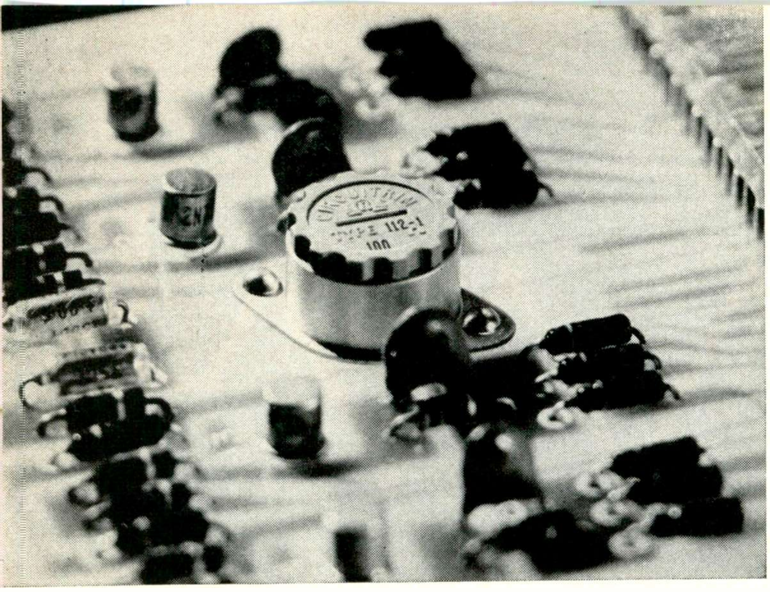
Types of Elements

Carbon Composition. Carbon composition pre-dates the other materials by several years. It was initially received with wide acceptance but, following World War II, the demands for new and superior trimmer characteristics—greater stability, improved accuracy, higher operating temperatures—made several of its characteristics unacceptable for universal use.

The major objections to carbon composition were its poor load and moisture stability and its high temperature coefficient of resistance. Another problem was its size. Compared with newer materials, it required about twice the size for the same power rating.

Metal Film. Metal film, the first of the more sophisticated materials to appear, was being employed in fixed resistor applications because of its superior characteristics. For a while, following its introduction in trimmer elements, it enjoyed considerable popularity, but the demand for a superior product at lower cost continued to grow.

Metal film elements, because they require expensive manufacturing techniques, including vacuum processes, first encountered opposition due to their high cost. A



A typical application of a fingertip-operated non-wirewound trimmer is shown here. The unit is on computer circuit board.

contributing factor to their fall from favored acceptance was range limitation; but noise and sensitivity to arcing (*i.e.,* a sudden surge could cause arcing through the element) and poor rotational life also helped dislodge them.

The development of high-speed digital computers, now in widespread airborne use, brought demands for unusually stable trimmers possessing both low reactance and high temperature capability.

Metal Glaze. In 1963, a new metal glaze material was introduced for trimmer elements. This material has become the most promising to date for use in the manufacture of precision, low-reactance, high-temperature trimmers.

Metal glaze type materials on ceramic substrates are, by far, the most popular type of element construction that is used in non-wirewound elements today.

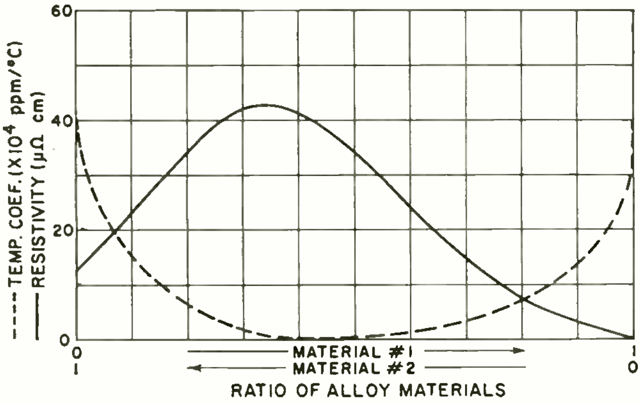
Characteristics

A metal glaze resistance element consists of a ceramic substrate and the glaze coating. The latter is a mixture of glass and metal powder in a ratio which is controlled to yield optimum electrical and mechanical characteristics for the particular resistivity desired (see Figs. 1 and 2).

One of the most important features of non-wirewound trimmers is their high resolution. As the wiper passes from turn to turn over a wirewound element, the output of the device is readily seen to be a step function. Consequently, it is sometimes impossible to obtain the exact output value desired.

Non-wirewound units, because the resistance element is continuous, provide a continuous output, that is, infinite resolution. The advantage of such a continuous track goes beyond resolution. The construction eliminates the problems of the loose turn, the metal particle lodged between turns, the sudden break of wire that produces a catastrophic failure, and the minute arc that volatizes metal as the wiper shorts turns in passage.

Fig. 1. Depending on the ratio of the materials that make up the metal glaze, a wide range of temperature coefficients and resistivities can be produced in a variable resistance trimmer. Note how these two parameters change as more of material No. 1 is added to the alloy mixture while reducing material No. 2.



Reliable wirewound trimmers, in the ½" variety, have a resistance range from a few ohms to 50k. With metal glaze, reliable elements of the same size and shape, range from a few ohms to several megohms, with standard tolerance of ±10%. (See Fig. 3.) For comparable sizes, power ratings of the two types are similar.

One advantage that wirewound units have over metal glaze elements is in the area of temperature coefficient of resistance. The former may have maximum values of ±70 ppm/°C while the latter will have ±250 ppm/°C.

Noise is sometimes a problem in non-wirewound trimmers. We do not mean current noise, but rather dynamic noise which is primarily determined by contact resistance variations. As the wiper moves across the resistance element, momentary open circuits due to oxide spots, dirt, or wear, cause a variable voltage or noise to develop in the wiper arm circuit. However, the output voltage fluctuation developed is a function of the load current which may be less than 1/50th of the element current.

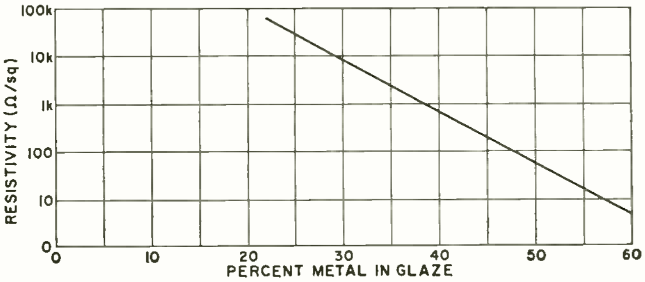
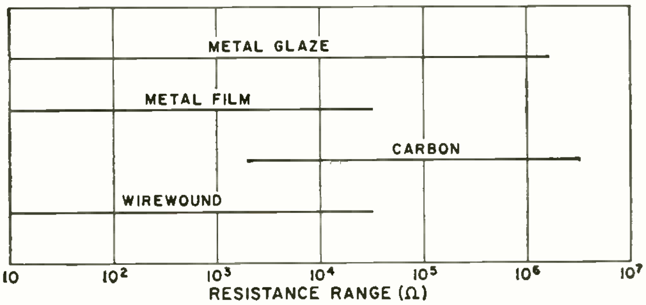


Fig. 2. The resistivity of the material used on the element of metal glaze trimmer goes down as more metal is employed.

Fig. 3. Approximate ranges of resistances that are currently available in various types of non-wirewound trimmers.



Another attractive feature of non-wirewound trimmers is their low reactive component.

Element Construction

Metal Glaze Elements. Here is how a metal glaze resistance element is made. First, the ends of the ceramic substrate are metallized with a platinum glaze which is fired into the ceramic to provide positive termination points.

Next, the substrate is passed through a screening process using a masked fine mesh stainless steel screen to apply the slurry of organic vehicle, glass, and metal powders. In this way, precise control is maintained over film thickness and coverage.

The coated substrate is then passed through a belt kiln containing a closely controlled programmed temperature schedule where it is subjected to temperatures between

700°C and 900°C. During this firing cycle the glass melts, the organic vehicle burns off, and the dispersed metal powder is fixed in position. Thus, the resistive element "wets" a portion of the platinum termination and provides a positive contact.

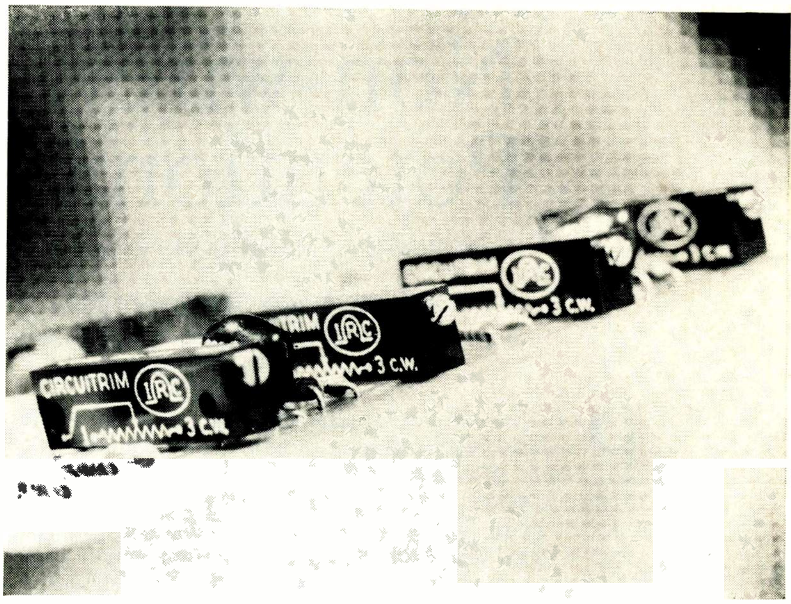
Carbon Composition Elements. Depending on the end results desired of a carbon composition element, the carbon may be brushed on, sprayed on, applied with a transfer wheel, dipped, or even screened onto the supporting surface in some cases. For thinner films of resistance elements, carbon may be pyrolytically applied. This method, while yielding an excellent fixed resistive element, results in a film that is usually too thin for trimmer applications.

Because of the many methods of applying carbon, only the spray method will be discussed here. The resistance element card or backing, usually a ceramic base or a phenolic or epoxy sheet material cut to the desired shape, is mounted appropriately in a spray booth. The carbon, suspended in a suitable vehicle, is applied with a paint spray gun which is swept back and forth automatically. The speed of sweep and time of spraying are controlled to yield the desired value of resistivity.

Next, the resistance elements are transferred to an oven where the vehicle, usually a varnish or other adhesive material, is dried. During this part of the cycle, a major change in the resistance of the element occurs and care must be taken to integrate it into the over-all process so that the desired resistance value will result.

Metal Film Elements. The metal film resistance element is prepared by depositing a thick film of special metal alloys on a substrate. Due to its small size and construction, metal film elements are particularly low in reactive impedance, the housing and other packaging materials determining the parallel capacitance much more so than the element.

After deposition, a very important part of the element preparation is the stabilizing treatment given the film. It is through precise control of this stage of manufacture that the complex strains inside the films are controlled.



These trimmers are adjusted by means of a slotted lead screw.

Typically, the next step in making a square non-wirewound trimmer is attaching leads to the element terminations. Then, the element is cemented in a molded element-cup and the wiper assembly attached: this subassembly is cemented into a housing. The last step is closing and sealing the housing.

Research continues for new and better resistance materials as well as for ways to improve those that are already in use.

Production improvements are expected to yield a more stable metal glaze resistive material and to considerably narrow its temperature coefficient variation. ▲

POTENTIOMETER TERMS AND DEFINITIONS

The following definitions deal principally with wirewound, single-turn rotary-type potentiometers; however, most of these terms may be applied to precision wirwound types in general.

Direction of Shaft Travel is defined as clockwise (CW) or counterclockwise (CCW) for rotary potentiometers when viewed from the specified mounting end of the potentiometer.

Total Mechanical Travel is the total travel of the shaft between integral stops. Unless otherwise specified, mechanical travel is assumed to be continuous (See diagram).

Electrical Continuity Travel is the total travel of the shaft over which electrical continuity is maintained between the wiper and the resistance element.

Actual Electrical Travel is the shaft travel over which the theoretical function characteristic extends, as determined from the index point.

Electrical Overtravel is the shaft travel over which there is continuity between the wiper terminal and the resistance element beyond each end of the actual electrical travel. In cases where absolute linearity or absolute conformity is specified, theoretical electrical travel shall be substituted for actual electrical travel in this definition.

End Resistance is the resistance measured between the wiper terminal and an end terminal with the shaft positioned at the corresponding end point.

Total Resistance is the actual resistance recorded in ohms when measured between the two end (or input) terminals with the wiper positioned to give a maximum value.

Resolution is a measure of linear wirewound potentiometer sensitivity or the degree of accuracy to which the output ratio of the potentiometer may be set. Either of two methods of measurement (voltage and travel resolution) are commonly used.

Linearity and Conformity. Two of the more common terms used in defining these limits are independent linearity and absolute conformity.

Independent Linearity is maximum deviation of the actual function characteristic from a straight reference line with its slope and position chosen to minimize deviations over the actual electrical travel or any specified portion thereof.

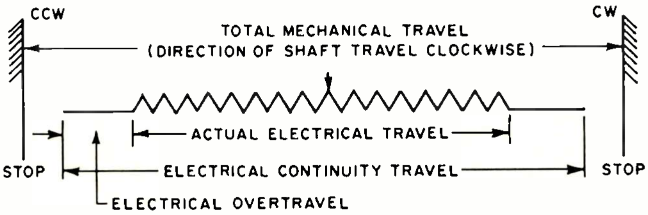
Absolute Conformity is maximum deviation of the actual function characteristic from a theoretical function characteristic extending between the specified output ratios which are operated by the theoretical electrical travel. An index point on the actual output is required. The index point serves as a point of reference, fixing the relationship between a specified shaft position and the output ratio. It is used to establish a shaft reference.

Temperature Coefficient of a wirewound potentiometer is normally interpreted to mean the temperature coefficient of the resistance wire itself. It is defined as the unit change in resistance per degree centigrade change from a reference temperature and is expressed in parts per million per degree centigrade (ppm/°C).

Power Rating can be defined as the amount of excitation power in terms of watts that can be dissipated at a given temperature. This wattage rating is normally derated linearly to zero power at a temperature coincident to the maximum ambient temperature of the surrounding atmosphere at which the potentiometer will perform within its intended specifications throughout the specified life of the unit.

Noise. Wirewound potentiometer noise, as defined by MIL-R-12934, is any spurious variations in the electrical output not present in the input, defined quantitively in terms of an equivalent parasitic transient resistance in ohms, appearing between the contact and the resistance element when the shaft is rotated or translated. The equivalent noise resistance is defined independently of the resolution, the functional characteristics, and the total travel. The magnitude of the equivalent noise resistance is the maximum departure from a specified reference line. The wiper of the potentiometer is required to be excited by a specified current and moved at a specified speed.

For a complete listing of potentiometer terms and definitions, refer to The Precision Potentiometer Manufacturers Association's booklet entitled: "Industry Standard for Precision Potentiometer Terms and Definitions" (3525 Peterson Road, Chicago, Illinois).



PRECISION

Non-wirewound Potentiometers

By HOWARD A. MORRISON / Computer Instruments Corp.

Providing essentially infinite resolution and very long life though at a somewhat higher cost, these pots are widely employed in military and industrial applications.

PRECISION potentiometers with non-wirewound resistive elements have been available commercially from at least two suppliers for more than 15 years. In recent years, they have largely displaced wirewound types in many military and industrial high-performance servo systems and computers due to certain unique characteristics discussed below. In other applications, such as rheostat control of current or handset volume controls, the wirewound types still dominate.

Non-wirewound precision potentiometers excel in providing essentially infinite resolution, accuracy in generation of linear and non-linear functional outputs, and very long life. These are the major requirements in reliable precision feedback systems where the potentiometers are used as voltage dividers, feeding relatively high load impedance, typically in servo amplifiers or balanced bridge circuits.

Table 1. General characteristics of non-wirewound pots.

1. Output smoothness: The largest continuous peak-to-peak excursion voltage, expressed as a percentage of the excitation, is 0.01% to 2%, depending on the grade of potentiometer.
2. Contact resistance variation: (See Fig. 1) A random variable up to 1% of terminal resistance in magnitude, depending mainly on uniformity and composition of resistance element, wiper contact pressure, and number of wipers. Typical maximum effect of 1% contact resistance variation on output voltage is .0015% (10 kΩ potentiometer resistance, 1 megohm wiper load).
3. End resistance: 2Ω or 0.1% of terminal resistance, whichever is greater.
4. Rotational life: 5 million to 50 million movements of the wipers past any point or line on the resistance element. This is equivalent to 5 million to 50 million shaft revolutions on a single-turn potentiometer or ten times this number of shaft revolutions on a ten-turn potentiometer.
5. Dither life: 5 to 25 hours of wiper oscillation @ 60 cycles/sec over a 1° excursion with a superimposed sinusoidal precession of 4 cycles/hour over 10°.
6. Temperature coefficient of resistance: 250 parts per million per °C.
7. Operating temperature range: −55°C to +150°C; with special substrate materials, −150°C to +250°C.

Table 2. Typical characteristics of rotary potentiometers.

	SINGLE					TEN-TURN		
Case dia. (in)	⅞	1 1/16	1 7/16	2	3	⅞	1 7/16	2
Res. (Ω ±10%, ±5% is best)	500 to 500k	500 to 750k	500 to 1M	500 to 1.5M	500 to 2M	500 to 1M	2 k to 4M	5 k to 3M
Best independent linearity	0.2%	0.1%	0.075%	0.05%	0.025%	0.05%	0.025%	0.01%
Best sine, cosine conformity	—	0.25%	0.25%	0.15%	0.1%	—	—	—
Electrical function angle (degrees)	320	350	350	350	350	3600	3600	3600
Starting torque (inch/ounces)	0.5	0.5	0.75	0.1	1.5	1	1.5	1.5
Power (watts @ 70 degrees C)	1	1.5	1.5	2	3	2	3	4

The performance characteristics of non-wirewound potentiometers are the consequence of using a highly uniform, homogeneous resistance element which presents to the wiper a continuous smooth surface. However, since the resistance element is non-metallic, its temperature and humidity coefficient of resistance and the contact resistance between wiper and element tend to be greater than wirewound types. Consequently, the wirewound type is better suited for use as a rheostat.

Noise in potentiometers, in the broad sense, refers to any unwanted signal which is not present in the input and is not a function of the static position of the wiper. It is a dynamic phenomenon. In non-wirewound types, the extremely smooth surface over which the wiper rides minimizes wiper bounce and related mechanical effects. Although all mechanical problems increase as wiper speeds rise, non-wirewound types, however, may operate continuously for millions of revolutions at 1000 rpm.

The continuous nature of the non-wirewound resistance element makes it the effective equivalent in an electric field of a single turn of wire; the typical wirewound element may contain thousands of closely spaced turns of wire. The relative inductance and capacitance of the non-wirewound types are thus extremely low, making possible their practical use in the presence of high-frequency fields or with high-frequency excitation voltages. Non-wirewound precision potentiometers have operated even when excited directly with radar-frequency voltages, whereas the wirewound types may experience some changes in their effective electrical characteristics in the presence of even 400-Hz electrical fields.

Available Types

There are three important non-wirewound precision potentiometer types available from a number of suppliers today. These include conductive film, bulk conductive plastic, and metal-glass film. Although each of these three basic materials has distinct characteristics, the general characteristics are sufficiently alike so that it is appropriate to describe them as a class of non-wirewound potentiometer without discussing the differences.

In the non-wirewound potentiometers, the resistive

Table 3. Typical characteristics of rectilinear potentiometers.

Case dimensions (inches)	¼ x 5/16 x 1¾	½ o.d.	¾ o.d.	1 x1 x stroke plus 1⅛	2½ o.d.
Res. (Ω ±10%)	500/in to 250 k/in	500/in to 250 k/in	500/in to 250 k/in	250/in to 200 k/in	500/in to 200 k/in
Maximum electrical stroke (inches)	1	4	10	28	60
Best independent linearity	0.2% ÷ stroke	0.2% ÷ stroke	0.2% ÷ stroke	0.2% ÷ stroke or 0.01%	0.2% ÷ stroke or 0.01%
Starting force (ounces @ 25°C)	4	8	8	8	16
Power (watts @ 70 degrees C)	¼/in	½/in	1/in	1/in	2/in

track is many times wider than it is thick and the thickness is invariably a few mils or greater. The end terminals and taps are connected to the resistive track with wire embedded along the end or a band of silver bonded across the track next to the insulating slot. Thus, the current is distributed through a wide and relatively deep band from one excitation terminal to the other.

Most manufacturers take advantage of the element width and supply multiple-fingered wiper contacts to the resistive track. The advantages of multiple fingered wipers are: less effect on output due to wear at any given point in the potentiometer element, and the ability to provide each wiper finger with a different characteristic natural frequency so that one or more wipers will always be in contact with the resistance element under environmental conditions of shock or vibration. Inadvertent shorting of the wiper terminal may cause local burning of the resistance element surface, but it rarely results in catastrophic failure.

It is also characteristic of the resistive track in non-wirewound precision potentiometers that the surface is smooth and hard. This property makes it possible to traverse the wipers over any point or points on the resistive track 5 million to 50 million times before sufficient wear occurs to cause noisy or non-linear performance. In forming the resistive track, high-temperature processes are employed so that the finished potentiometer is inherently capable of high-temperature operation, frequently up to temperatures as high as 350°F, and even higher for shorter periods of time.

The output-voltage ratio at any point along the resistive track can be altered by simply "manicuring" the edge of the resistive track so as to alter the slope of the local voltage ratio at the wiper pick-off point. This process is usually performed automatically or semi-automatically on a continuous basis. Thus, non-wirewound potentiometers can readily be "trimmed" or altered to bring them into required linearity or made to provide non-linear output functions of a wide variety without the use of shunts so that the output voltage ratio with the load connected will faithfully provide the required curve (Fig. 2).

Keeping in mind the greater resistance change with environmental conditions and the requirement for relatively high load impedance, non-wirewound potentiometers can generally be used in any potentiometer (not rheostat) application. The specific advantages of non-wirewound potentiometers are best utilized in the following situations and applications: (*a*) millions of shaft revolutions or actuations, (*b*) high-performance servo feedback control loops where infinite resolution (and good output smoothness) prevent servo instability and hunting, (*c*) high-frequency dithers, (*d*) complex mathematical output voltage functions, (*e*) ganged pots with linear and non-linear functions and/or commutation, (*f*) close conformity with specified load, (*g*) high shaft speeds where the absence of "wiper bounce" assures long life and noise-free performance, (*h*) high-frequency excitation in which low capacitance and inductance minimize or eliminate quadrature and phase-shift problems, (*i*) high terminal resistance, and (*j*) low terminal resistance without sacrificing resolution.

The minimum of information required to properly specify non-wirewound potentiometers includes: (*a*) case size; (*b*) number of turns and stops, if any; (*c*) electrical stroke (rectilinear); (*d*) terminal resistance; (*e*) linearity and whether independent, absolute, etc.; (*f*) conformity and equation or tabulated data for non-linear functions: (*g*) load and where it is connected, *e.g.*, wiper to clockwise terminal, wiper to center tap, etc.; (*h*) taps, if any, including tap width, current capacity, and maximum resistance between wiper and tap with wiper opposite tap. ▲

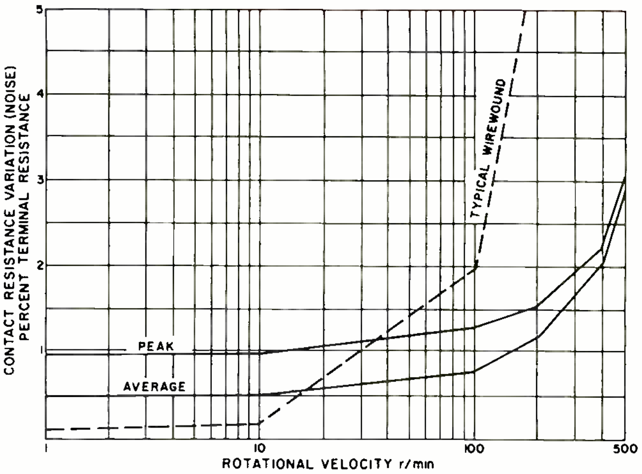
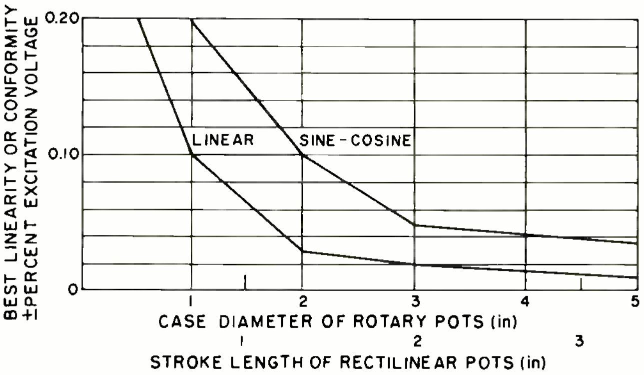


Fig. 1. Contact-resistance variation (noise) of a typical 2" non-wirewound potentiometer compared to wirewound type.

Fig. 2. Best linearity or conformity of non-wirewound pots.



UNIQUE VARIABLE RESISTORS

The variable resistors covered in this special section are all mechanically adjustable. However, there are a number of other variable resistors whose resistance value is a function of temperature, light, current flow, applied voltage, magnetic field, and ferroelectricity. Among these are the following:

Thermistors: These temperature-sensitive resistors usually decrease their resistance non-linearly with an increase in temperature, although some positive TC components are available. Devices having linear resistance/temperature change are due on the market soon.

Optical Link: This variable resistor is essentially a light source closely optically coupled to a photoresistor within a light-tight enclosure. There is total isolation between the elements.

Photoresistors: These high-impedance components generally display an increase in conductivity with applied illumination.

Magnetoresistor: This two-terminal device changes its resistance with the strength of the applied magnetic field. Unlike a Hall generator, it is a magnetic-sensitive resistor rather than a voltage generator.

Ferroelectric Resistor: Although still a laboratory phenomena, this effect is produced when a thin metal film, deposited on a ferroelectric material, changes its resistance with the polarity of the ferroelectric material being used.

Negistor: This solid-state, two-terminal component consists of a pair of transistor-like devices directly coupled and provided with heavy regenerative feedback. It exhibits a linear change in resistance as a function of the applied voltage. ▲

Directory of

K E Y
G-P: general-purpose
Prec.: precision
a: special-purpose trimmers
b: special-purpose pots
c: special-purpose rheostats
d: parameter-sensitive resistors
e: special-purpose attenuators
f: special packaging
g: special pickoffs

Potentiometers				Trimmers						
G-P Wirewound	G-P Non-wirewound	Prec. Wirewound	Prec. Non-wirewound	G-P	Prec. Wirewound	Prec. Non-wirewound	G-P Rheostats	Attenuators/Pads	Other	
●		●	●		●					**Ace Electronic Associates**, 99 Dover St., Somerville, Mass. 02144
				●	●					**Aero Electronics Corp.**, 1745 W. 134th St., Gardena, Calif.
		●						●		**Aerovox Corp., Hi-Q Div.**, Burbank Plant, 1100 Chestnut St., Burbank, Calif. 91503
	●			●			●	●		**Allen-Bradley Co.**, 1201 S. Second St., Milwaukee, Wis. 53204
●		●	●	●	●	●				**Amphenol Controls Div., Amphenol Corp.**, 120 S. Main St., Janesville, Wis. 53545
●		●							b	**Astro Electronics, Inc.**, 1160 E. Ash Ave., Fullerton, Calif.
				●	●					**Atohm Electronics**, 3030 Empire Ave., Burbank, Calif.
●	●	●	●	●	●	●			b	**Beckman Instr., Inc., Helipot Div.**, 2500 Harbor Blvd., Fullerton, Calif. 92634
●		●					●			**Biddle Co.**, Twp. Line & Jolly Rds., Plymouth Meeting, Pa. 19462
●	●	●	●							**Bliss-Gamewell Div., E. W. Bliss Co.**, 1238 Chestnut St., Newton, Mass. 02164
●	●	●	●	●	●	●				**Bourns Inc., Trimpot Div.**, 1200 Columbus Ave., Riverside, Calif.
●	●	●	●	●	●	●		●	g	**Brys Instrument Corp.**, 7026 Sixth Ave., Brooklyn, N.Y. 11209
		●								**California General Inc., Mektron Div.**, 798 F St., Chula Vista, Calif.
●	●	●	●	●	●	●	●			**Carter Mfg. Corp.**, 23 Washington St., Hudson, Mass. 01749
●		●		●	●		●	●	f	**Carter Precision Electric**, 7447 West Wilson Ave., Chicago, Ill.
●	●			●			●	●	f	**Centralab Div., Globe-Union, Inc.**, Box 591, Milwaukee, Wis. 53201
●	●				●					**Chicago Telephone of Calif. Inc.**, 1010 Sycamore Ave., South Pasadena, Calif. 91030
●	●	●		●	●	●	●	●	b	**Clarostat Mfg. Co. Inc.**, Washington St., Dover, N.H.
	●		●						g	**Computer Instruments Corp. (CIC)**, 98 Madison Ave., Hempstead, N.Y.
				●	●	●				**Conelco Components**, 465 W. 5th St., San Bernardino, Calif.
●				●			●	●		**Continental-Wirt Electronics**, 26 W. Queens Lane, Philadelphia, Pa. 19144
●	●			●	●	●		●		**CTS Corp.**, 1142 W. Beardsley Ave., Elkhart, Ind. 46514
●		●		●	●					**Dale Electronics, Inc.**, Box 609, Columbus, Neb. 68601
●	●	●	●					●	e	**Daven Div., McGraw-Edison Co.**, Manchester Airport, Manchester, N.H. 03103
		●	●		●					**Duncan Electronics Inc.**, 2865 Fairview Rd., Costa Mesa, Calif.
		●							b	**Electro-Mec Instrument Corp.**, 183 Commercial St., Watertown, Conn. 06795
									b c	**Electro Scientific Ind.**, 13900 N.W. Science Park Dr., Portland, Oreg.
●		●	●		●	●				**Electro Techniques**, 11301 E. Ocean Ave., La Habra, Calif.
		●	●		●	●				**Fairchild Controls, Div. Fairchild Camera & Inst.**, 225 Park Ave., Hicksville, N.Y.
		●								**Fluke, John, Mfg. Co. Inc.**, Box 7428, Seattle, Wash.
								●	d	**General Electric Co.**, Electronic Components Sales Operation, 1 River Rd., Schenectady, N.Y.
									d	**General Electric Co.**, Magnetic Materials Section, Edmore, Mich. 48829
●		●					●	●		**General Radio Co.**, 22 Baker Ave., West Concord, Mass.
●		●			●					**General Scientific Corp.**, 1535 First St., San Fernando, Calif. 91341
		●							g	**Giannini Controls Corp.**, 1600 S. Mountain Ave., Duarte, Calif.
								●	b	**Gotham Audio Corp.**, 2 W. 46th St., New York, N.Y. 10036
		●			●					**Guidance Controls Div., Vogue Instr. Corp.**, 31 Commercial St., Plainview, N.Y. 11803
		●							b	**Humphrey Inc.**, 2805 Canon St., San Diego, Calif.
●		●					●			**Industrial Winding Machinery Corp.**, Box 744, Church St. Station, New York, N.Y. 10008

POTENTIOMETER SPECIFICATIONS

By JOHN G. WOODS

Senior Development Engineer, Research & Development
IRC, Inc.

TO specify a potentiometer for a given application, the equipment designer must determine the particular characteristics required and describe them adequately so the manufacturer can supply the best unit for the purpose.

Often, a design or components engineer can select a military or industrial specification which lists some of the requirements applicable to his particular case. Although this may be the easiest way to specify a component, frequently it is not the best or most economical. Use of these specifications does not assure good performance in all applications; in fact, some of the specified requirements may be useless and expensive.

Here's an example of specification misuse. A typical military potentiometer specification may call for operation over a temperature range of −55°C to +150°C. This range is necessary for several military and space applications; but, most industrial computers, control systems, and other equipment operate in the +25°C to +100°C range. Specifying a needlessly wide temperature range may involve expensive materials and elaborate manufacturing processes. Often, design compromises may even be necessary to meet the various requirements.

As an example of design compromise, consider temperature coefficient of resistance (TC). Specifying a blanket TC requirement of ±250 ppm/°C between −55°C and +25°C and between +25°C and +150°C (as does characteristic C of MIL-R-22097B—lead screw actuated, variable, non-wirewound, resistors) for all resistance values, is an instance where compromises might be required in the basic resistive element.

For metal glaze resistance materials often called cermet (ceramic/metal), the formulation and kiln firing conditions would have to be carefully varied and adjusted to achieve a TC for all resistance values within the ±250 ppm/°C requirement over the entire temperature span. It would be simpler and more practical to produce many resistance values with TC's as close as ±100 ppm/°C in the commonly used span of +25°C to +100°C, or even to +150°C; but at −55°C, the TC for these same values would exceed the 250 ppm requirement, and hence would not meet the MIL Spec.

The same approach applies to thin metal films and to wirewound resistance elements, where formulation and processing parameters are carefully controlled to obtain a given TC under all circumstances.

Variable Resistor Sources

	Potentiometers				Trimmers					
	G-P Wirewound	G-P Non-wirewound	Prec. Wirewound	Prec. Non-wirewound	G-P	Prec. Wirewound	Prec. Non-wirewound	G-P Rheostats	Attenuators/Pads	Other
IRC Inc., 401 N. Broad St., Philadelphia, Pa. 19108			●			●	●			f
Javex Electronics, 9509 Oak Glen Rd., Cherry Valley, Calif.	●								●	
Keltron Corp., 223 Crescent St., Waltham, Mass.				●						
Kendick Mfg. Co. Inc., 616 S. Lafayette, Fort Wayne, Ind. 46802			●							
Lebo Electronics Corp., 80 Carleton Ave., East Islip, New York			●							g
Logan Electronics Corp., 44 Breed St., East Boston, Mass. 02128	●		●		●	●				
Mallory Controls Co., Box 231 Frankfort, Ind. 46041	●	●			●			●	●	
Markite Corp., 155 Waverly Place, New York, N.Y. 10014				●						
Maurey Instrument Corp., 4555 W. 60th St., Chicago, Ill. 60629	●		●		●	●		●	●	b
Mel-Rain Corp., 3100 Roosevelt Ave., Indianapolis, Ind.	●							●		
MEMCOR, Inc., Components Div., 1320 Flaxmill Rd., Huntington, Ind. 46750	●		●					●		
Micro-Lectric Inc., 15 Burke Lane, Syosset, N.Y.			●	●						
Miniature Electronic Components Corp., 600 South St., Holbrook, Mass.	●				●			●		
New England Instrument Co., Kendall Lane, Natick, Mass. 01761	●	●	●	●		●	●			
Nucleonics Products Co., 3133 E. 12th St., Los Angeles 23, Calif.				●						
Nytronics, Inc., 550 Springfield Ave., Berkeley Heights, N.J. 07922									●	a
Ohmite Mfg. Co., 3601 Howard St., Skokie, Ill. 60076	●				●			●	●	c
Peerless Instrument Co., Inc., 90-15 Corona Ave., Elmhurst, N.Y. 11373	●		●							
Polytronics Co., 582 Bathurst St., Toronto 4, Ont., Canada			●							
Precision Line, Inc., 63 Main St., Maynard, Mass.			●	●		●	●			b
Priester Corp., Box 267, Scarsdale, N.Y. 10583	●	●			●				●	
Reon Resistor Corp., 155 Saw Mill River Rd., Yonkers, N.Y. 10701		●							●	
Rex Rheostat Co., 149 Babylon Turnpike, Roosevelt, N.Y. 11575	●							●		c
Rolara Corp., 61 Brightside Ave., East Northport, N.Y. 11731	●	●	●	●						
Samarius, Inc., 300 Seymour Ave., Derby, Conn.	●		●		●	●		●	●	b
San Fernando Electric Mfg. Co., 1509 First St., San Fernando, Calif.	●		●		●	●				
Servonic Instr. Inc., Sub. Gulton Ind. Inc. 1644 Whittier Ave., Costa Mesa, Calif.			●							
Servo Systems Co., 14 Carmer Ave., Belleville, N.J.			●	●						
Shallcross Mfg. Co., Preston St., Selma, N.C.									●	
Spectrol Electronics Corp., 17070 E. Gale Ave., City of Industry, Calif. 91745	●		●		●	●	●			
Subminiature Instruments Corp., 3236 Kansas Ave., Riverside, Calif.	●		●		●	●				g
Superior Electric Co., 383 Middle St., Bristol, Conn. 06012	●							●		
Tech Laboratories Inc., Bergen & Edsall Blvds., Palisades Park, N.J.	●	●	●	●				●	●	e
Techno-Components Corp., 7803 Lemona Ave., Van Nuys, Calif. 91405					●	●				
TIC of Calif., Sub. Bowmar Instr. Corp., 850 Lawrence Dr., Newbury Park, Calif. 91320			●			●				e
Voak Engineering Co. Inc., A St., Upland, Calif.				●						
Waters Mfg. Co. Inc., Boston Post Rd., Wayland, Mass.	●	●	●	●	●	●				
Weston-Archbald, Archbald, Pa. 18403	●	●	●	●	●	●	●			b
Winslow Tele-Tronics Inc., 1005 First Ave., Asbury Park, N.J.			●						●	b

Thus, compromises are required to meet a specification which may not provide the best TC available under any particular condition.

There are many other compromises which must be made in the design and manufacture of potentiometers. For instance, the unit which performs well under high humidity conditions may not be the best performer in a high-temperature-exposure or load-life test. The potentiometer having the lowest contact noise—equivalent noise resistance (ENR)—may do so at the expense of rotational life.

Such environmental requirements as just described were designed to simulate a wide variety of conditions which might be imposed on a type of potentiometer. Sometimes, requirements having little to do with performance are written into specifications—as in the previously mentioned MIL-R-22097B and its wirewound equivalent, MIL-R-27208A, where an immersion test is required.

This immersion test requires that the unit be suspended in water at 85°C for one minute and observed for visual evidence of continuous bubbling from any part of the potentiometer. If such bubbles occur in the qualification test, the lot fails. The test is designed, ostensibly, to check the adequacy of the potentiometer sealing. In reality, it merely tests the assembly's ability to retain gaseous materials at 85°C for one minute, and not its ability to keep gases out.

Sealing a potentiometer to pass the immersion test may actually cause it to perform less well in the moisture resistance test of the same specification. The latter test requires 10 cycles of combined load, elevated temperature, and humidity conditions, which may cause water vapor to enter the unit and to be trapped inside. When moisture is sealed inside, it can attack the resistance element and cause a change in resistance. This is one of the dangers in requiring that a potentiometer be sealed to prevent escape of gas or vapor.

But, specifications established by industry and the military are useful. They provide standards of classifying and specifying performance requirements. This helps to eliminate wasteful inventory and duplication; gives assurance of performance levels; and provides more likelihood of interchangeability among units from various manufacturers.

For industrial and commercial applications which involve relatively benign environments, blind use of a MIL specification, for example, may be uneconomical and may result in calling for a potentiometer which does not best meet the requirements. When writing a specification for a particular application, the equipment designer should examine all of the performance and size requirements then specify what is needed. In this way, the potentiometer manufacturer can supply the unit best suited to the need, at the lowest cost.

Much progress has been made, and will be made, through having standard potentiometers which meet known specifications, but they should be used with an understanding of their limitations. The best equipment performance and lowest cost will not always be obtained unless the individual application is carefully analyzed and appropriate potentiometer specifications are written. ▲

GENERAL-PURPOSE

Trimmer Resistors

By GEORGE RAEBURN & DON ZUNKER/Centralab, Div. of Globe-Union, Inc.

These "set and forget" variable resistors are employed either for rarely changed service adjustments or rear-panel controls.

A TRIMMER resistor can be broadly described as a "set and forget" variable resistor or an adjustable fixed resistor. These devices can be divided into two basic groups. The first group consists of those that are set initially by the manufacturer of the device in which they are used and are either never changed again or only rarely changed as a service adjustment. These trimmers are generally small in size and may have a very limited rotational life. The second group involves those used as rear-panel or service adjustments, but not as front-panel controls. These trimmers are usually larger in size than the first group and have a rotational life of about 250 to 1000 cycles.

In most cases, trimmer resistors are employed in order to utilize a supplier's entire production run of a device, such as a transistor or photocell. If the user of the transistor or photocell can purchase an entire run with a normal distribution of characteristics, the piece price is greatly reduced as compared to the cost of a selected portion of the total production run. By buying the entire run, the user gets the lower cost of the device but is faced with the problem of standardizing his circuit to compensate for device variation. He must, for example, adjust an amplifier gain, a transistor operating point, or photocell output.

The user can do this by one of the following methods:

1. He can sort the purchased devices into many small groups of a similar critical parameter and assemble each group with the appropriate value of resistor. These resistors are either precision units or resistors carefully sorted into groups from a job lot.

2. He can assemble his circuits using the entire run of the devices but leave out the critical resistors. He can institute an intermediate test on the line to determine the required resistor values for each circuit. Proper value resistors are then inserted into the circuit. These resistors, again, would be either precision units or else resistors that were especially handpicked from a particular bulk order.

3. He can assemble the circuit using the entire run of the purchased devices with a trimmer resistor instead of the critical fixed resistors. By doing this, he can assemble all of his circuits in exactly the same way and then adjust the trimmers to standardize the circuit at final test. In addition, these trimmers can be readjusted if the circuit is returned for service.

Many manufacturers choose method 3 because they can build all circuits alike; they don't need to sort resistors; and they have only one trimmer to purchase and inventory instead of many resistors. In addition, service problems are reduced using trimmers. If the technician replaces a transistor or photocell, the replacement will probably have a different *beta* or voltage output. With the trimmer he can easily readjust for proper performance. With fixed resistors, he must remove the resistors, determine the required new value by temporarily substituting a variable resistor, adjust the variable, then remove it, read the value, and finally find a resistor of exact value for installation.

Since a trimmer resistor is generally used in place of fixed resistors, you must consider the same factors that would apply in selecting a fixed resistor. (See Special Issue, Fixed Resistors, ELECTRONICS WORLD, April 1965.)

There are, however, a few additional points which must be examined before making a final choice.

1. Price is probably paramount and we will leave this to the discretion of the buyer because of the wide price spread, quantity discounts, etc.

2. Size must be considered as trimmers come in various sizes and shapes. Fixed resistors are available in a number of *standard* sizes but trimmers are available in many forms and sizes. The user must keep in mind the space available and the mounting technique involved in order to establish which will meet his specific requirements.

3. Mounting position must be considered. After determining that the trimmer is adaptable to the mounting method desired, the user must also see to it that the mounting position will allow the trimmer to be adjusted from the desired direction and that, in this position, it will fit into the available space.

4. Wattage must be within the manufacturer's specification. As long as the part is derated according to the manufacturer's derating curve for the ambient temperatures the trimmer will encounter, the user is in the clear. For example, using the derating curve of Fig. 1, consider a trimmer rated at 0.25 watt at 70°C (158°F) in still air

Fig. 1. Power derating data for typical trimmer resistors.

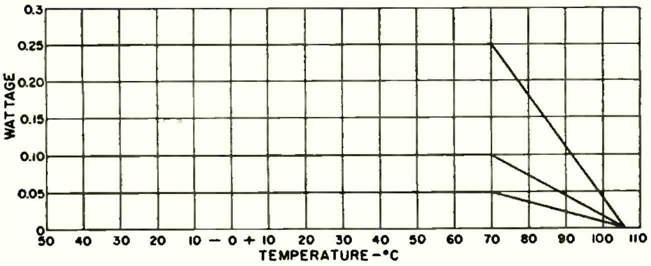


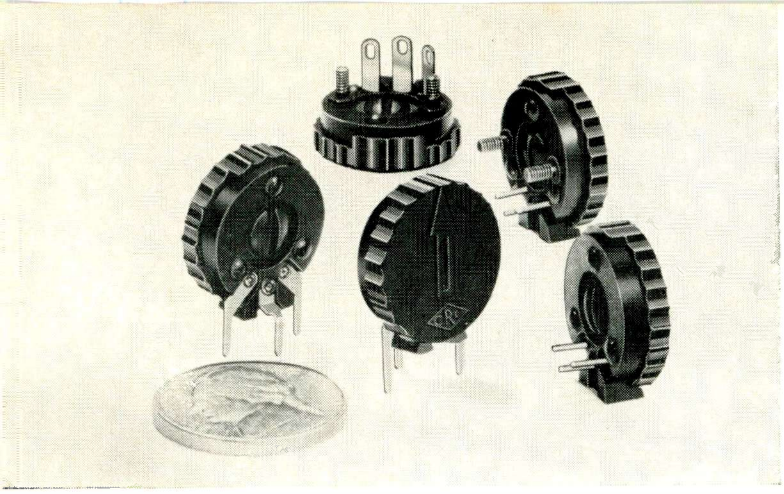
Table 1. (facing page) Listing of non-wirewound and wirewound general-purpose trimmer resistors available from several sources.

NOMINAL SIZE (in.)	LEADS & MOUNTING	SECTIONS	ELEMENT CONSTRUCTION	ADJUST TOOL	RESISTANCE RANGE	INSULATION SHAFT-KNOB	PER SECTION RATINGS			TEMPERATURE FOR DERATE TO ZERO WATTS	FIXED RESISTORS				ROTATION LIFE CYCLES	MFG.'s TYPE	MFG.
							Watts	Temp.	Volts		Ratings	W.	Temp.	Volts			
.25 x .25 x .1	Wire	1	Exposed	Special	100 Ω to 10M	No	.05	70°C	200	105°C	Individual Circumstance				50	620-1	CRL
.25 x .25 x .145	Wire	1	Exposed	Screw-driver	100 Ω to 10M	No	.05	70°C	200	105°C	Individual Circumstance				50	621-1	CRL
.438 x .406 x .120	Wire	1	Exposed	Special	100 Ω to 10M	No	.1	70°C	250	105°C	Individual Circumstance				150	600-1	CRL
.438 x .406 x .120	Wire	1	Exposed	Screw-driver	100 Ω to 10M	No	.1	70°C	250	105°C	Individual Circumstance				150	601-1	CRL
.900 x .450 x .120	Wire	2	Exposed	Special	100 Ω to 10M	No	.1	70°C	250	105°C	Individual Circumstance				150	603-2	CRL
1.350 x .450 x .120	Wire	3	Exposed	Special	100 Ω to 10M	No	.1	70°C	250	105°C	Individual Circumstance				150	603-3	CRL
.346 Dia. x .106	PC Board	1	Insul. & Covered	Knob	100 Ω to 10M	Yes	.1	40°C	—	85°C	———				—	M250	CTS
.347 Dia. x .111	PC Board	1	"	Knob	500 Ω to 10M	Yes	.1	40°C	—	85°C	———				25000	Model 8	CRL
.438 x .5 x .312	PC Board	1	"	Knob	250 Ω to 2.5M	Yes	.125	55°C	350	85°C	———				—	220	CTS
.480 x .5 x .430	Wire	1	"	Knob-Screw-driver	125 Ω to 10M	Yes	.15	70°C	250	105°C					1000	69	CRL
.592 Dia. x .179	PC Board	1	Metal Covered Uninsul.	Screw-driver	100 Ω to 10M	No	.250	55°C	—	100°C	Available (Contact manufacturer)				—	MTC	Mallory
.594 Dia. x .196	PC Board	1	Covered	—	100 Ω to 5k	Yes	.2	55°C	—	85°C	Available (Contact manufacturer)				—	201	CTS
					5K to 5M	—	.25	55°C		100°C	Available (Contact manufacturer)				—	201	CTS
					Up to 2M				350								
					2M to 5M				500								
.696 Dia. x .253	Stud/Par. PC/Par. PC/Per.	1	Insul. Covered	Knob-Screw-driver	100 Ω to 10M	Yes	.2	40°C	250	85°C	———				25000	Model 9	CRL
$2\tfrac{1}{64}$ x $1\tfrac{7}{64}$ x .350	PC Board Par./Per.	2	Insul. Covered	Finger & Screw-driver	250 Ω to 1000	Yes	.33	55°C	—	85°C	Available (Contact manufacturer)				—	X52 U52	CTS CTS
			"		1000 to 25k	—	.25	55°C	—	85°C	———						
			"		25k to 250k	—	.20	55°C	500	85°C							
			"		250k to 10M	—	.165	55°C	500								
$2\tfrac{29}{32}$ x $1\tfrac{7}{64}$ x .350	PC Board Par./Per.	3	Insul. Covered	Finger & Screw-driver	250 Ω to 1000	Yes	.33	55°C	—	85°C	Available (Contact manufacturer)					X53 U53	CTS CTS
			"		1000 to 25k	—	.25	55°C	—	85°C							
			"		25k to 250k	—	.20	55°C	500	85°C							
			"		250k to 10M	—	.165	55°C	500								
.702 x .750 x .430	PC/Per. PC/Par. Wire	1	Insul. Cover.	.100 Inside Hex./.218 Outside Hex. Screwdriver	125 Ω to 10M	Yes	.25	70°C	350	105°C	100 Ω to 10M	.25	70°C	200	1000	70-1 71-1 73-1	CRL CRL CRL
1.218 x .750 x .430	"	2	Insul. Cover.	or Screwdriver Only	125 Ω to 10M	Yes	.25	70°C	350	105°C	100 Ω to 10M	.25	70°C	200	1000	70-2 71-2 73-2	CRL CRL CRL
1.734 x .750 x .430	"	3	Insul. Cover.	"	125 Ω to 10M	Yes	.25	70°C	350	105°C	100 Ω to 10M	.25	70°C	200	1000	70-3 71-3 73-3	CRL CRL CRL
2.250 x .750 x .430	"	4	Insul. Cover.	"	125 Ω to 10M	Yes	.25	70°C	350	105°C	100 Ω to 10M	.25	70°C	200	1000	70-4 71-4 73-4	CRL CRL CRL
1.734 x .881 x .430	Wire Wrap	3	Insul. Cover.	"	125 Ω to 10M	Yes	.25	70°C	350	105°C	100 Ω to 10M	.25	70°C	250	1000	74-3	CRL
	PC/Per.	"	"	"	"	"	"	"	"	"	"	"	"	"	"	75-3	CRL
	PC/Par.	"	"	"	"	"	"	"	"	"	"	"	"	"	"	76-3	CRL
	Solder Lug	"	"	"	"	"	"	"	"	"	"	"	"	"	"	77-3	CRL
	Solder Lug & Wire Wrap	"	"	"	"	"	"	"	"	"	"	"	"	"	"	78-3	CRL
2.250 x .881 x .430	PC/Per.	4	Insul. Cover.	"	125 Ω to 10M	Yes	.25	70°C	350	105°C	100 Ω to 10M	.25	70°C	250	1000	79-4	CRL
	Wire Wrap	"	"	"	"	"	"	"	"	"	"	"	"	"	"	80-4 81-4	CRL
	PC/Par.	"	"	"	"	"	"	"	"	"	"	"	"	"	"	82-4 83-4	CRL
	Wire	"	"	"	"	"	"	"	"	"	"	"	"	"	"	84-4	CRL
WIREWOUND																	
.564 Dia. x .335	PC Par.	1	Closed	Screwdriver or Knob	50 Ω to 20k	Yes	1	55°C	—	125°C	———				—	350	CTS
.785 Dia. x $\tfrac{27}{64}$	PC	1	Open	Screw-driver or Knob	.5 Ω to 10k	No	1.5	55°C	—	105°C	Available (Contact manufacturer)				—	110	CTS
							2.0	55°C	—								
							(Depends on heat sink)										
							3	special 85°C		185°C							
.785 Dia. x $\tfrac{25}{64}$	PC	1	Closed	Screw-driver	.5 Ω to 10k	Yes	2	55°C	Std.	105°C	Available (Contact manufacturer)				—	115	CTS
							3	85°C	Special								

Insul. = Insulated
PC = Printed Circuit

Par. = Parallel
Per. = Perpendicular

CRL = Centralab
CTS = Chicago Telephone Supply



A group of one type of general-purpose trimmer resistors.

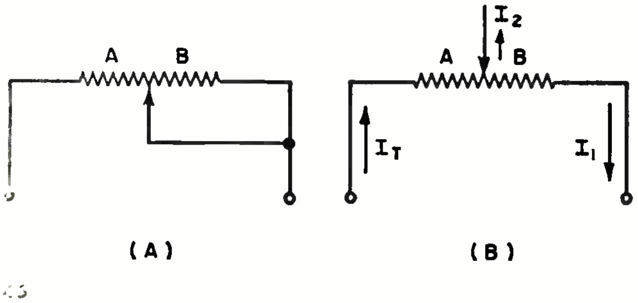
and derated to 0 watts at 105°C (221°F). If the ambient temperature will be 77°C in still air, it can be determined from the curve that the wattage will be 80% of the 70°C rating or 0.2 watt at 77°C. If the trimmer is used as a rheostat (Fig. 2A) the device must be derated additionally by the approximate percent of the resistive element being used (Section A in the schematic). To continue with this example, if the contact will be at approximately 50% of the rotation, we must further derate the wattage to 50%, or to 0.1 watt. This would be a safe operating wattage. However, if the application requires somewhat more than 0.1 watt but not more than 0.2 watt, the manufacturer may sanction a deviation because the unused half of the trimmer acts as a heat sink and helps to dissipate power. This amount of additional dissipation will vary considerably among units and the particular application should be discussed with the manufacturer. When calculating actual dissipation, percent of resistance and percent rotation will be different on non-linear trimmers.

If the trimmer is used as a potentiometer (Fig. 2B), then current flow must be considered. The user can feel safe if the total current, I_T, does not exceed the current that the entire resistor would carry if it were run at rated load. The formula used is: $I = \sqrt{W/R}$, where I is rated current at ambient temperature, W is the rated wattage at ambient temperature, and R is the resistance value of the trimmer. In addition, if $(I_T)^2 \times$ the resistance of Section A plus $(I_1)^2 \times$ the resistance of Section B does not exceed the rated wattage, the manufacturer may approve having Section A operated above the normal allowable wattage of that section (determined by percent of rotation) since Section B would then be running below the allowable wattage. Under most circumstances, the trimmer should not be run above the maximum allowable voltage without the manufacturer's approval. In many instances the wattage at maximum rated voltage may be lower than all calculated wattages and, therefore, voltage dictates the maximum rating.

5. The probable number of rotations (cycles) must be estimated to make sure that the number does not exceed that guaranteed by the supplier.

6. Would a non-linear pot be better than a linear unit? In this article the authors have assumed that linear trimmers will usually be used. Table 1 reflects this assumption.

Fig. 2. Trimmers used as (A) rheostat and (B) potentiometer.



However, many trimmers can be obtained with tapered elements.

7. You should also consider whether fixed resistors included within the trimmer would offer any space, cost, or electrical advantages. Some trimmers can be supplied with a mechanical stop which reduces the number of degrees of mechanical rotation and effectively inserts a fixed resistor in series with one end of the trimmer. The resolution of such trimmers may be somewhat inferior. This type is convenient when a minimum resistance is desired, especially when, by turning a trimmer to one end, another component could be damaged or destroyed. Others can be supplied with fixed resistors in all legs of the trimmer and, depending on the circuit, between other points on the unit. If multiple units are purchased, custom-made circuits can be supplied. In all cases the wattage dissipation of these fixed resistors must be included in all total wattage calculations.

8. One must consider the advantages that accrue by using multiple units. Many of the trimmers can be obtained with two, three, or four trimmer sections in various combinations of resistance values, fixed resistors, and tapers. In some instances, an overload condition can be tolerated on one section if the other sections are operating below rated load. Also, only one mechanical mounting is required instead of one for each of the single units that would have been required.

9. If the user employs more than one single unit or a multiple unit, some can be purchased with variously colored knobs or shafts for easy identification of circuit function.

10. Fixed resistors usually have wire leads but some trimmers, including certain models of *Centralab* or *CTS* ceramic base trimmers, can be obtained with wire-wrap terminals.

11. Resolution should also be considered. How precisely and rapidly must the trimmers be set? When using carbon trimmers, resolution is seldom a problem. For sensitive circuits, keeping the adjustment range low will improve the resolution and speed of adjustment. This can be done conveniently by adding a fixed resistor on each end of the trimmer resistor. Where large range and exceptionally precise setting are required, two trimmers may be used, one a larger value for range setting and the other a lower value vernier for precise settings that may be required in a circuit.

In some cases, tapered trimmer resistors may give more precise settings in the critical low-value region, where a large range is also required. The wirewound trimmers present greater resolution problems because the resistive element consists of a definite number of turns of wire and there are finite steps in the resistance setting as the contact spring moves from wire to wire. These steps can be determined by taking the total resistance and dividing by the number of turns. The percent change can be obtained by dividing 100 by the number of turns. This percent figure decreases as values increase due to the use of smaller wire and more turns.

12. Minimum resistance can, in some applications, be a problem. If it is required that the trimmer will sometimes be set at what is, theoretically, zero resistance, then the user must obtain minimum resistance values from the manufacturer. Special "low-minimum" units are available from some companies.

Table 1 can be of great assistance in helping the user to select the best trimmer for his particular application. Three U.S. suppliers of trimmers have been listed. These are *Centralab (CRL), Chicago Telephone Supply (CTS),* and *Mallory*. Almost all of the units listed are available in OEM quantities. Some of them are also available through parts distributors. ▲

GENERAL-PURPOSE

Rheostats

By HERBERT LEVY/ Senior Development Engineer, Ohmite Manufacturing Co.

Power-handling devices used mainly as 2-terminal current controls capable of dissipating from 7.5 to 1000 watts.

GENERAL-purpose rheostats, as covered in this article, include those which are used primarily for power handling from 7.5 to 1000 watts. A variety of control uses is encompassed by rheostats and includes both stock designs which can be used wherever the resistance and current ratings permit, and special variations for optimum performance in given applications.

Rheostats are used for control of generator fields, motor speed, filament voltage of transmitting tubes, lamp dimming, x-ray and other electronic tube voltages, heaters or ovens, setting of over-voltage relays, rectifier voltage, electroplating equipment, faders, circuit balancing, welders, magnetic clutches and brakes, servo and position devices, and for control of many other devices. Designers frequently specify general-purpose rheostats to be connected as potentiometers (3-terminal devices) for low-wattage use, instead of precision potentiometers, for reasons of economy.

Such applications should be carefully considered because of the differences in service requirements. Circuit considerations, repeatability of settings, close resolution, low TC (temperature coefficient), electrical noise, dust protection, and thermal effects may require special attention.

The usual rheostat built for inclusion in electronic apparatus is generally disc-shaped in over-all outline and controlled by rotating a shaft, generally with a knob but sometimes with a screwdriver. Tubular, slide-type rheostats are commonly laboratory items, although there are some exceptions, and are not included here.

Construction Features

The resistance winding, made of special resistance alloy wire, is wound on an open ring of ceramic and is welded at each end to a terminal band having extensions for circuit connection. The wound core is covered, except for an exposed contact track, with vitreous enamel (an inorganic glass-like material) which has been fired on at red-heat and holds the wires rigid to prevent shifting. The enamel also bonds the core to a ceramic insulating base. A bushing, fastened to the base, supports a metal shaft which is equipped with a ceramic hub to insulate the moving contact assembly from ground.

The contact brush, carried by a contact arm, is generally a powdered-metal compact of copper-graphite or silver-graphite. On some small units, the end of the contact arm itself may be the contact brush. On many types of rheostats, the contact is connected by a flexible stranded shunt to a slip-ring, which rubs under coil-spring pressure against a center lead supported by the base. The contact is held against the winding track by pressure from the spring material of the contact arm itself or, in some designs, by means of a separate torsion spring.

In some designs, the current is carried through the contact arm (or an attached lamination). Still other designs use a longer metal-graphite contact which bridges from the winding track to a center-lead ring.

Silicone-ceramic coating is sometimes used instead of vitreous enamel, especially for very fine wire rheostats. Mica strip, or insulated aluminum strip, embedded in cement is sometimes used in place of a ceramic ring, in sizes up to 50 watts.

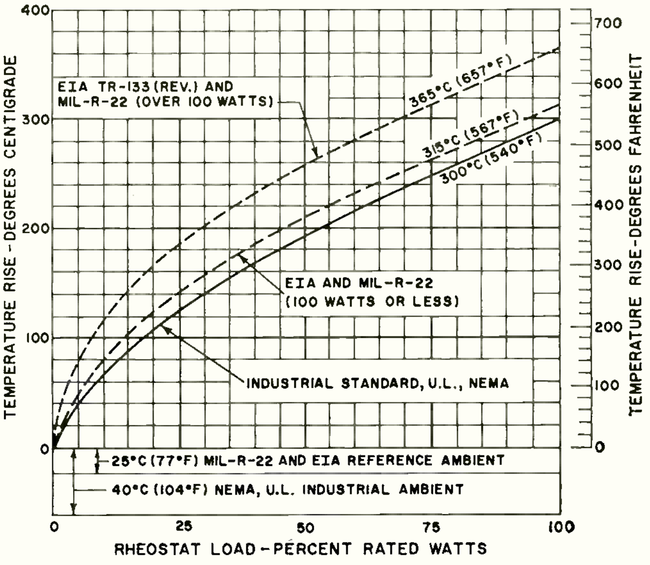
The self-lubricating nature of the contact brush, due to the graphite content, permits relatively high contact pressure for good electrical conductivity without excessive wear on the resistance winding. Copper-graphite, or brass-graphite, is used for medium to high resistance, and silver-graphite is preferred for high-current, low-resistance use.

Characteristics

The nominal dimensions given in Table 1 are commercial and military standards. The wattage ratings are based on a maximum attained temperature of 340°C measured at the hottest spot on the embedding material. NEMA and UL standards use 40°C as the reference ambient, while the MIL and EIA specifications use 25°C. Recently revised EIA specifications and MIL-R-22 permit 390°C to be attained for rheostats over 100 watts.

The curves of Fig. 1 show how the hot-spot temperature varies with the percent load (with the entire winding in use). Fig. 2 shows the hot-spot temperature for constant maximum rated current as the percentage of the rheostat winding in use is varied.

Fig. 1. Hot-spot temperature rise for various specifications.



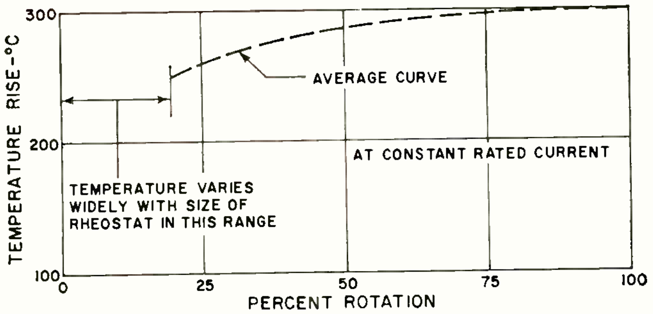


Fig. 2. Rheostat temperature rise at constant rated current.

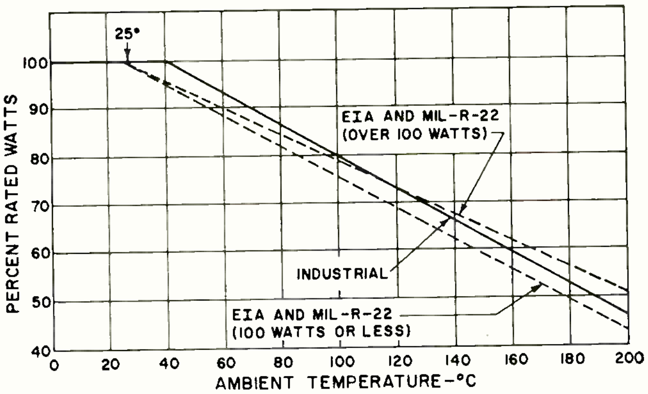


Fig. 3. The derating of rheostat for high ambient temperature.

When the ambient temperature is higher than rated, it is necessary to operate at decreased wattage to reduce the temperature rise in order to avoid exceeding the hot-spot limit. Fig. 3 is a conventional derating curve for ambient temperature.

A quotation taken from EIA Standard RS-322 (TR-133 revision) reads: "Additional Derating. When rheostats are mounted in restricted enclosures which limit ventilation, or when mounted on a non-metallic panel, the input wattage should be reduced still further so that the maximum operating temperature will not be exceeded. In the absence of specific measurements of operating temperature, a reduction of input power to 50% of the nominal rated wattage is customarily followed in good engineering practice."

Most rheostat applications require only the specification of the resistance and the current to be carried by the device. Sometimes other parameters are specified, after the fashion of precision pots, and more parameters are included in the EIA and military specifications.

Table 2 is representative of present-day rheostat characteristics and will serve as a guide when specifying.

Tapered Windings

Rheostats are frequently wound with 2 to 5 (or more) sections of diminishing wire size. This produces different resistance-per-degree-of-rotation in each section. The purpose of a tapered winding for any given application would be to (1) make possible the use of a smaller rheostat than the linear wound rheostat of the same total resistance, (2) provide more nearly linear control, or (3) provide a special curve of control.

Table 1. Listing of readily available rheostat sizes.

RHEOSTAT DIMENSIONS & MOUNTING METHODS

Wattage Size	Dia. (in)	Depth Behind Panel (in)	Shaft Dia. (in)	Mounting Method
7.5	1/2*	7/8	1/8	1/4-32 bushing
12.5	7/8	11/16	1/8	"
25	1 9/16	1 3/8	1/4	3/8-32 bushing
50	2 5/16	1 3/8	1/4	"
75	2 3/4	1 3/4	1/4	"
100	3 1/8	1 3/4	1/4	"
150	4	2	1/4	" and/or 2 screws
225	5	2 1/8	3/8	2 screws
300	6	2 3/8	3/8	"
500	8	2 1/8	3/8	"
750	10	3	3/8	"
1000	12	3	3/8	"

*Metal Case

The tapered windings for audio volume controls and T-, L-, or H-pad speaker controls are examples of reasons (2) and (3). Field-control rheostats are examples of (1) and (2).

How the physical size of rheostats can be minimized by a tapered winding can be explained by considering the effect of the variation of current from zero to maximum resistance. The total power rating is $I_{max} \times I_{min} \times R$.

When the moving contact of a rheostat is on the first turn of wire or ribbon, this turn must carry the maximum current. But as more resistance is put into the circuit, the succeeding turns never have to carry more than a certain fraction of the maximum current because the current tapers off from the maximum to some minimum value.

Hence, in a uniform or linear winding, the latter portions of the winding operate at lower wattages (I^2R) per square inch than the rated values. The tapered winding, using smaller size wire for each section in proportion to the current to be carried, increases the ohms per inch of winding in successive sections. This makes the watts dissipated per square inch of winding section more nearly approach the rated wattage value. As the core area required for a given wattage dissipation is less when operated at higher watts per square inch than for lower watts per square inch, the total core size of the rheostat is reduced.

Variations

The basic design and methods of manufacture make many variations in resistance and configuration possible at reasonable cost. While there are extensive lists of standard resistance values in the EIA (latest revision) and MIL specifications, there are many other resistance values and physical configurations carried in stock by leading manufacturers and distributors.

Additional features commonly used are: tandem assemblies (ganged), auxiliary switches, concentric control tandems, 360° winding, enclosures (ventilated, dust-proof, and explosion-proof), motor drives, locking devices, special stops, and off-positions.

Standardized modules for motor drive provide for remote control of rheostats, both large and small. When supplied ganged with sensitive switches and adjustable operating cams, such assemblies become convenient automation units.

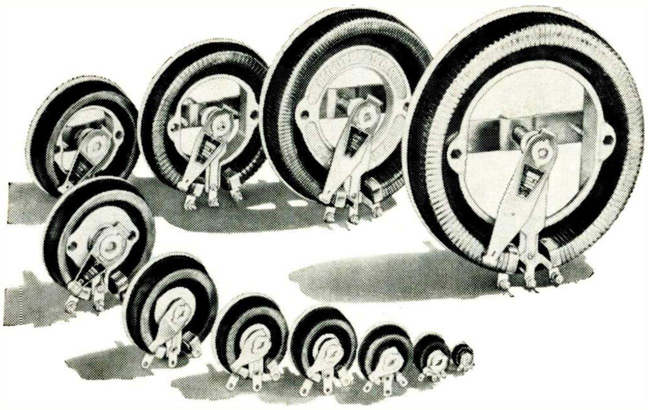
Rheostats are frequently made with an off-position located at one extreme of rotation. Such off-positions are suitable only for moderate currents and voltages in substantially resistive (non-arcing) circuits. Toggle or sensitive switches can be mounted on rheostats to operate as off-position switches or in auxiliary circuits.

Tandem assemblies of rheostats generally rotate all rheostats together, may have separate shafts concentrically located to rotate both main and vernier rheostats individually, or may have sequence-coupling that provides a two-turn assembly with many possible applications. Rheostat manufacturers can provide almost any variation in mechanical arrangements.

Commercial & Military Specifications

The great majority of general-purpose rheostats, like many other components, are purchased without detailed customer specifications. The exceptions are purchases by the military, aerospace companies, and the larger manufacturing and communications corporations.

As the principal military specification has become the basis for commercial specifications, the MIL Spec will be



Group of rheostats ranging from 12.5 watts to 1000 watts.

described briefly. MIL-R-22B, "Resistors, Variable (Wirewound Power Type), General Specifications For," provides standards for the eleven open-style sizes from 12.5 to 1000 watts listed in Table 1, plus enclosed versions of the 12.5-, 25-, and 50-watt sizes (derated 50% because of enclosure). The rheostats are identified by a coded type designation such as RPO62SB252KK. The RPO6 tells style (12.5-watt size); 2 is for electrical off-position; SB is shaft and type of mounting; 252 is resistance in a coded format (2500 ohms); and KK is resistance tolerance (+10%).

Most of the items listed in Table 2 (plus others) are detailed in the specification. Qualifications and periodic tests are called for. Tables of standard resistance values and part numbers are provided.

The recently revised version of the Electrical Industries Association's "EIA Standard RS-322—Wirewound Power-Type Rheostats" has been made to parallel the MIL Spec, even to the extent of using recognizably similar style numbers (RRP10 for RP10, etc.). The EIA standard includes the 7.5-watt size not yet appearing in the MIL Spec, and the RRP11 is rated 18 watts while the RP11 is 12.5 watts. Qualification testing, etc. is not covered by the EIA standard.

Neither specification provides standards for tapered windings, ganged assemblies, or other variations. Some special-purpose military aircraft rheostats are purchased under another specification, MIL-R-6749. ▲

Table 2. A listing of the most important ranges of characteristics available for general-purpose rheostats.

Power rating: (see Note 1)	7.5 to 1000 watts.
Resistance range:	0.5 to 50,000 ohms.
Initial tolerance:	±10% is standard although 5% is possible.
Resolution:	varies greatly with resistance and rheostat size; defined as (1/number of turns) times 100.
Linearity:	±2% of total resistance (usually the best possible).
Temperature range:	from −65 to +125°C ambient.
Temperature coefficient:	varies with resistance and size; resistances near one ohm generally wound with copper-nickel wire yielding temperature coefficient (TC) of ±20 to ±80 ppm; medium to high resistances use nickel-chromium-iron wire for TC of +140 −30 to +80 ppm; low TC nickel-chromium-aluminum wire (0 ±20 to ±80 ppm) can be ordered.
Noise:	not usually specified.
End resistance:	0.2 ohm or 2% of total resistance, whichever is larger.
Contact resistance variations:	not specified except as included under effects of vibration.
Mechanical rotation: (see Note 2)	one turn, 275° to 340°.
Electrical rotation:	less than mechanical rotation by an amount depending on the size and design.
Insulation resistance:	not usually specified.
Dielectric strength: (see Note 3)	500 Vrms, one minute for 7.5- and 12.5-watt size; 1000 Vrms for larger sizes.
Torque:	varies with size and resistance from 0.5 to 6 ounce-inches to 4 to 10.5 pound-inches.
Vibration:	MIL-R-22 requires no evidence of intermittent contact; total resistance change less than 5%; contact arm movement less than 2° when vibrated through the range of 10 to 55 cycles per second for two hours in each of three mutually perpendicular planes; excursion of 0.03 inch. High-frequency test of 10 to 2000 cycles per second for 12 hours with maximum resistance change of 5% maximum is specified for 12.5-watt rheostats.
Rotation life:	MIL-R-22 requires 5000 cycles at 20 cycles per minute with less than 5% change.
Load life:	5% maximum resistance change at 1000 hours total consisting of cycles of 1½ hours on and ½ hour off at full load.

Note 1: High-resistance rheostats are also voltage limited.

Note 2: Mechanical and electrical rotation of a part of one turn can be made to order. Wattage, resistance, and resolution are proportionally reduced.

Note 3: UL tests, where applicable, call for twice maximum rated voltage to ground plus 1000 V r.m.s. EIA and MIL Specs also specify 550 volts at reduced atmospheric pressure of 3.4 inches of mercury to simulate high-altitude use.

PHOTORESISTORS

THESE passive, high-impedance devices are composed of thin, single crystal or polycrystalline films of compound semiconductor materials. Since no *p-n* junctions are used, these are non-polarized devices and it makes no difference which side is positive or negative when a d.c. voltage is applied.

When the sensitive surface is illuminated, conductivity generally increases linearly with light intensity on a logarithmic plot.

Although many materials have been used for these cells (cadmium sulfide, cadmium selenide, cadmium sulfoselenide, germanium, indium antimonide, lead sulfide, and lead selenide), only cadmium sulfide and cadmium selenide are being used extensively. The sulfide cell has high sensitivity, low dark current at room temperature, peaks near the same point as the human eye (5300-6300 Å), has a high breakdown voltage, and good temperature characteristic. However, it has a slow response time.

The selenide cell has a very high sensitivity, has high dark current at room temperature, peaks about the near infrared (6800-7400 Å), and has fast response time. The light-to-dark resistance ratio is highest for selenide.

The bulk of available photoresistors have maximum power dissipations between 50 and 2000 mW. However, cadmium sulfide units have been produced that would dissipate 25 watts on a heat sink.

Most photoresistors exhibit illumination fatigue effects; *i.e.*, their resistance may increase with time under steady illumination.

Of two other types, cadmium telluride peaks about 8000 Å, while zinc sulfide peaks about 4000 Å, extending photoresistor response into the ultraviolet region. ▲

GENERAL-PURPOSE

Composition Potentiometers

By WILLIAM A. MURPHY and ROBERT D. HOSTETLER / CTS Corporation

The most popular potentiometer type, these non-wirewound general purpose devices are used in such wide-ranging applications as inexpensive radios to highly sophisticated military systems.

GENERAL-purpose composition potentiometers are used in applications ranging from inexpensive portable radios to highly sophisticated military electronics equipment. Power ratings range from one-tenth watt through several watts, while resistances from 20 ohms through 10 megohms are available.

Composition potentiometers can be broken down into three major categories by the type of resistance element used: carbon film, carbon ceramic and molded carbon, and cermet (metal glaze). These three categories roughly indicate the three major potentiometer markets—commercial, industrial, and military equipment.

Carbon Film

The resistance element is made by flowing, spraying, screening, or otherwise applying a carbon resistance compound onto the surface of an insulative material, usually a laminated plastic. This element has characteristics that are similar to those of carbon-film fixed resistors. The carbon-film pot is usually the designer's first choice for an economical way to vary resistance in an electronic circuit, particularly in commercial applications where specifications are less exacting and cost is a major factor. A substantial portion of the recent growth in sales of carbon-film pots can be attributed to increased color-TV sales: a color set uses sixteen to eighteen carbon-film pots as compared with seven or eight for a black-and-white set. Carbon-film pots with high-quality elements and special construction techniques are also used in industrial and military equipment.

Carbon Ceramic & Molded Carbon

These potentiometers have very dissimilar resistance elements but have roughly the same "black-box" characteristics. Carbon-ceramic elements are made by screening a carbonaceous compound onto a ceramic substrate. Molded-carbon pots are manufactured by molding together, at the same time, the previously formed carbon resistance element and other parts of the pot. The resistance element is entirely comparable to the carbon-pellet-type fixed resistors.

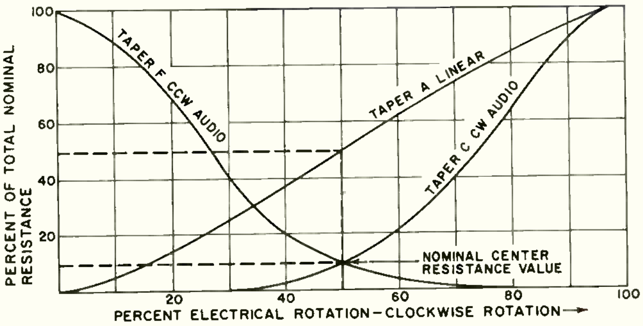


Fig. 1. Three resistance tapers covered by MIL-R-94B.

These two types of potentiometers are used in a wide range of industrial and military gear. They usually meet MIL-R-94B, without special elements or constructions.

Cermet

These potentiometers use a resistance element that is made by screening an inorganic resistive composition onto a ceramic substrate and firing at temperatures above 600°C. The resulting element is very stable under extreme environmental conditions, has high overload capabilities, and the characteristics shown in Table 1.

Specifying the Composition

Assuming that a decision to use a composition pot has already been made (perhaps requirements dictated infinite resolution or very high resistance characteristics difficult to achieve with wirewound pots), the designer must still decide upon the type of element to be used.

Table 1 lists approximate specifications for the three types of composition pots. Although the values in the table depend on the manufacturer, the quality of the element, and other considerations, they are generally descriptive of the specifications of the three categories.

Table 1. Average specifications of composition pots.

	Standard Commercial Carbon Film	Carbon Ceramic and Molded Carbon	Cermet
Power rating ½" to ⅝" diam.	¼ watt at 55°C	½ watt at 70°C	¾ watt at 85°C
Power rating 15⁄16" diam.	½ watt at 55°C	2 watts at 70°C	2 watts at 85°C
Derated to zero at	85°C	120°C to 150°C	175°C
Resistance range	100 ohms to 10 meg.	50 ohms to 5 meg.	20 ohms to 5 meg.
Tolerance	±20% to ±30%	±10% to ± 20%	±5% to ±10%
TC (max.)	500 to 2500 ppm	±500 ppm	±250 ppm
Rotational life	±15% to ±25% change after 10,000 cycles	±8% max. change after 25,000 cycles	±7% max. change after 25,000 cycles
Humidity	±20% to ±30% 100 hrs. 40°C, 95° R.H.	±5% 100 hrs. 40°C, 95% R.H.	±4% Method 106 MIL-STD-202

Although much standardization has been achieved by the use of military specs, EIA standards, and the evolution of "accepted industry standards," it is advisable for a designer to use the electrical and mechanical standards of his supplier rather than a list of standards arrived at arbitrarily or specifications from another source. The potentiometer manufacturer can realize many cost advantages by producing high volumes of standard controls. This has become especially important to companies introducing highly automated production equipment.

Many factors must be taken into consideration in selecting a particular set of specifications. A discussion of several of the most important characteristics follows.

Resistance, Taper, and Tolerance

Composition potentiometers are available in resistance ranges from 20 ohms to 10 megohms with other values sometimes available at extra cost.

Although efforts have been made by the EIA to standardize total resistance into nine values, most manufacturers offer at least ten in distributor programs and will produce pots to any specified nominal resistance value, within their capabilities, for the OEM market.

Resistance taper is the curve of resistance measured between one end of the element and the movable arm, in percent of total resistance *versus* the percent of effective rotation of the movable arm of the potentiometer. Three resistance tapers have been established as standard by military specifications and by industry usage. These three standard tapers—linear, clockwise audio, and counterclockwise audio—are shown in Fig. 1. Again, however, most manufacturers list many other standard resistance tapers and produce special tapers on request.

Standard tolerances on full resistances range from ±40% for high-resistance commercial carbon-film potentiometers to ±5% for high-quality cermet pots. For the non-precision units being discussed in this article, the tolerance within which the resistance taper must conform to the nominal taper is usually expressed only in terms of the resistance at 50% of full electrical rotation. Military specifications require that the resistance taper "shall conform in general shape to the nominal curves" and that the resistance value at 50% (±3%), of electrical rotation, shall be within ±20% (10% for cermet). For commercial controls, this particular specification figure can be as high as ±40% tolerance at 50% electrical rotation.

Wattage Rating

The three types of composition potentiometers are available in a wide range of wattage ratings (Table 1). Although the necessary wattage rating for a potentiometer is primarily determined by an application of Ohm's Law to the current expected through the pot and its resistance, many other factors enter into the choice of an ideal wattage rating for a particular application.

The power rating is determined by the application of a load-life test with the potentiometer adjusted to its full resistance position. This test specifies that the potentiometer must operate at rated ambient temperature through a specified number of cycles during which the test load is applied for part of the cycle and no load is applied for the rest of the cycle. If the resistance change after this test is within a specified tolerance, then the pot can be rated at the tested power.

Two factors affecting the power-dissipation capacity of a potentiometer are the ambient temperature and the method of mounting. Industry practice is to use 55°C as the ambient temperature for rating commercial controls, while military specifications dictate 85°C for cermet pots and 70°C for all others. Although military specifications call for mounting potentiometers on a 4-inch-square, 16-gauge steel panel, many applications will not provide a heat sink this large, especially when the pot is mounted on a nonmetallic board. The proximity of other heat-producing components must also be taken into consideration. Derating is particularly important when potentiometer sections are ganged on the same shaft; derating curves are available for these situations.

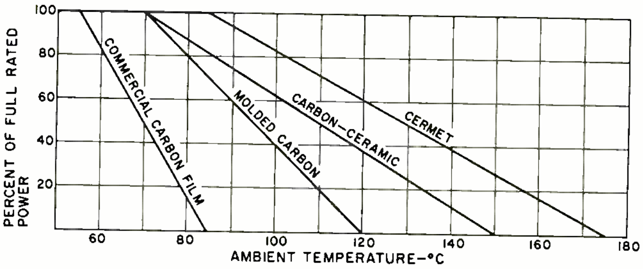


Fig. 2. Derating curves for composition potentiometers.

Since the breakdown of a composition potentiometer is mainly due to heat build-up, most pots can withstand *impulses* of several times rated wattage. This characteristic is especially outstanding in cermet pots, with molded carbon and carbon ceramic, and carbon film being less effective in that order. However, it has been found that repeated impulses of several times rated wattage may cause a breakdown of the composition element, seemingly without prohibitive heat build-up. If it is planned that repeated impulses of this nature are to be applied to a potentiometer, the designer should consult with the supplier to insure that a particular pot will not fail under these conditions.

The power-dissipation capability of a potentiometer as the shaft is rotated away from maximum resistance is not linear with either angle of rotation or resistance value. For instance, on linear-taper potentiometers the designer can expect 60% to 70% of full rated power capacity at 50% rotation.

For high nominal resistance values, the maximum voltage rating across the end terminals of the potentiometer becomes an important factor. At a resistance defined as the critical value, the potentiometer is operating at maximum voltage and maximum power at the same time. For resistances above this value, the voltage rating becomes the limiting factor and the potentiometer can no longer be operated at its maximum rated power. For instance, the critical value of resistance for a one-watt, 500-volt potentiometer is 250,000 ohms. For resistance values above this figure, the potentiometer, for all practical purposes, is no longer a one-watt potentiometer.

Finally, some authorities recommend that designers play it safe by purchasing pots with a power rating of twice the maximum expected power dissipation. This policy provides an adequate margin of safety for small ambient temperature changes and the lack of a sufficient heat sink. Furthermore, if a pot is to be adjusted often and operated at sustained power levels, the usable life can be substantially extended by operation at one-half the rated power. However, some manufacturers

(*Continued on page* 60)

Table 2. Comparison between MIL-R-94B and MIL-R-23285.

	MIL-R-94B Characteristic Y	MIL-R-23285
Rated at	70°C	125°C
Derated to zero at	120°C	175°C
Moisture test (max. change in resistance)	±10%	±5%
Thermal cycling (max. change in resistance)	±6%	±3%
Rotation* (max. change in resistance)	±10%	±7.5%

*Much more severe test under MIL-R-23285

GENERAL-PURPOSE

Wirewound Potentiometers

By ROBERT FREY & JAMES FRED/Development Engineers, Mallory Controls Co., Div. of P.R. Mallory & Co., Inc.

Bridging the gap between low-power composition controls and high-power rheostats, these potentiometers are widely used where d.c. powers of 1.5 to 12.5 watts are required.

GENERAL-PURPOSE potentiometers come in several different wattage ratings, types of construction, resistance ratings, and physical sizes. They are used as fader controls in auto radios, as speaker controls in hi-fi systems, in electronic test equipment; but they are probably found more often in government electronic equipment. MIL-R-19 includes three types of general-purpose potentiometers.

Basic Construction

All of these controls feature the same general construction. The wire is wound on a "card," a flat strip which varies from 0.020- to 0.061-inch thick and from 0.250 to 0.500 inch in width. Several different materials are used as winding cards. General-purpose phenolic is used for low-temperature applications, glass-filled laminates for high-temperature controls, as well as filled plastic material that is molded or extruded.

The cup is usually made of metal or general-purpose phenolic. Bushings and shafts are standard with all manufacturers. Shafts are plastic, steel, aluminum, and brass. Some are plain round, some are flatted, and some are hollow, knurled, and slotted. Bushings are brass, diecast, and plastic. They come both plain and slotted for locking of the shaft with a locknut.

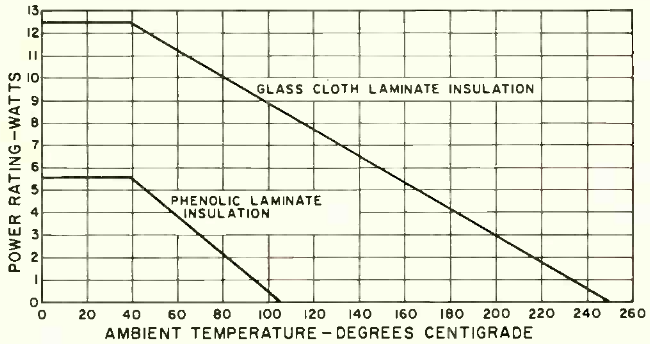


Fig. 1. Derating curves for conventional wirewound pots.

The heart of the wirewound potentiometer is, of course, the resistance wire used for winding the resistance element. The selection of the wire determines many of the characteristics of the potentiometer. The higher resistance values will normally be wound with nickel-chromium alloy wire. These alloys not only provide high resistivity, but they offer sufficient hardness to provide good wear qualities even in the very fine sizes. Lower resistance values are normally wound with copper nickel alloy wire. Because of their lower resistivity, these alloys enable the use of smaller diameter wire for improved resolution. It is usually possible to select more than one type of wire for a given resistance value. If the selection is left to the manufacturer without limitations on temperature coefficient, resolution, etc., he will select the wire to provide the most economical unit while providing the best over-all performance characteristics required by the end-user.

Mechanical Characteristics

Mechanical rotation is normally from 280° to 307°. The larger physical sizes have the longer rotation. Rotational torque will vary from 0.5 to 6 inch-ounces on catalogue items. Higher torque units can usually be had on special order.

Some unusual features to be obtained on OEM units are a.c. switches attached to rear of controls, twist-tab mountings, flange mountings, two to ten controls tandem mounted and driven from one shaft, concentric-mounted controls with separate shafts, and even controls without any sort of protruding shafts have been built. (The latter may be referred to as trimmers.)

Electrical Characteristics

One of the most important considerations in a general-

Fig. 2. Effect on resistance of a linear and multiple-section winding.

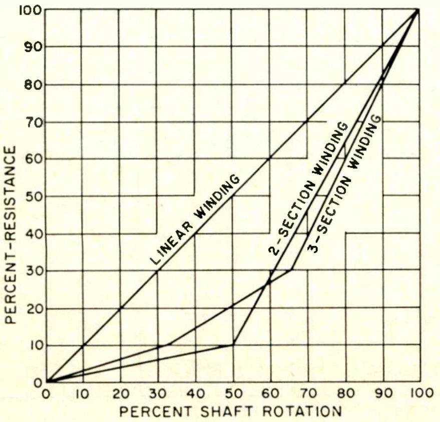


Fig. 3. Angular resolution and voltage resolution in a wirewound pot.

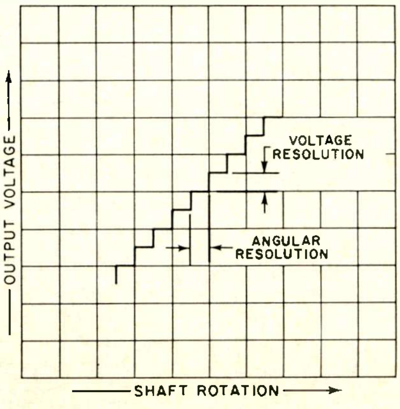
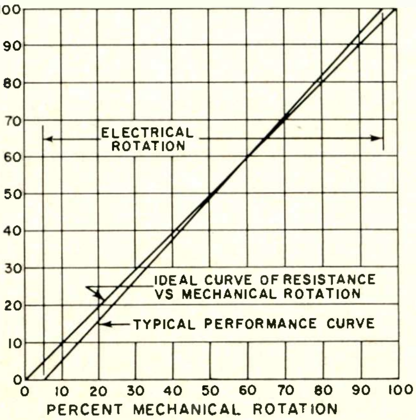


Fig. 4. Plot of typical potentiometer performance compared to ideal curve.



purpose control is its power rating. The primary limitation is the maximum allowable temperature rating of the insulating materials. For controls using conventional laminated phenolic insulating materials, the power rating is based on a maximum hot-spot temperature of 105° C.

In recent years the use of higher temperature insulating materials such as filled plastics and glass-cloth laminates has made power ratings at temperatures as high at 250° C possible.

Fig. 1 shows derating curves comparing potentiometers using laminated phenolic and glass-cloth laminate insulation. It will be noted that the power rating is more than doubled by the allowable increase in operating temperature.

There are, of course, many characteristics closely related to the operating temperature such as temperature coefficient, life, oxidation, noise level, etc. These must all be considered in the selection of a potentiometer for a given application. An additional factor is the ambient temperature and the nature of the other components surrounding the control.

The resistance range of linear-wound controls is from 0.5 to 150,000 ohms. The resistance of taper-wound controls is approximately half this amount. The smaller physical sizes are limited in their over-all resistance. To get the higher resistance values it is necessary to buy the larger physical sizes. Since these controls are not precision types, the resistance tolerances of catalogue items are ±5% and ±10%. Most companies can furnish closer tolerances on special order.

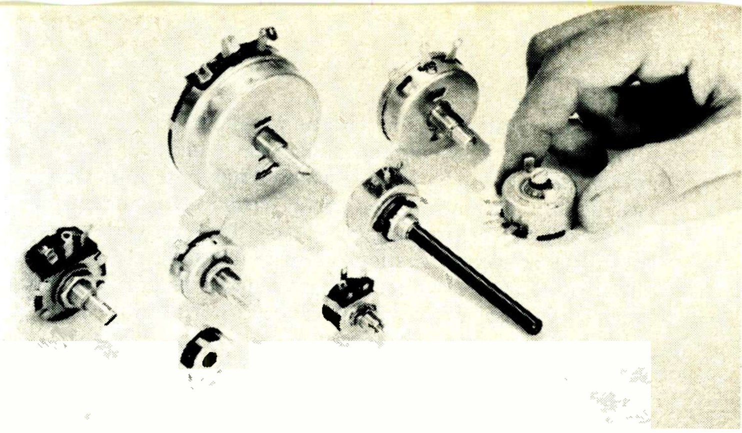
Most "off-the-shelf" or stock potentiometers have linear resistance windings, but most manufacturers do supply tapered resistance windings where the resistance change is not constant throughout the total shaft rotation. Some suppliers stock the more commonly used tapers, such as the so-called audio taper which provides 10% resistance at 50% rotation. There are various methods of obtaining tapered resistance windings; the usual method is to change wire size or wire type at preselected points on the winding card. The different wire sections are then joined by soldering or welding. Fig. 2 is a plot of typical linear and multiple-section windings.

One of the lesser known, but very important, properties is resolution. With a wirewound potentiometer the resistance change, as the slider moves from one extreme of rotation to the other, does not occur as a straight line. Instead, it occurs as a steplike progression as the slider moves from one turn of wire to the next. Resolution is actually a measure of sensitivity of the potentiometer output. It may be expressed as angular resolution or voltage resolution.

Angular resolution (degree of shaft rotation required to progress from one turn of wire to the next) is given as θ/n where θ is the total rotation angle and n is the total turns of the resistance element.

The more common expression of resolution is voltage resolution (percent of total applied voltage represented by each incremental step) which is given as a percentage by $1/n \times 100$, where n is the total turns of the resistance element. Fig. 3 shows the relationship of angular and voltage resolution.

The linearity of a potentiometer is its ability to provide a resistance between the slider and the zero end of the resistance which is directly proportional to the angular rotation of the shaft. Dividing the resistance at the slider by the total resistance of the potentiometer winding provides a percent resistance which can be plotted against percent shaft rotation. It is normally expressed as the maximum deviation between the plotted curve and the desired linear curve.



These pots and trimmers are rated at 1.5 to 7 watts.

Fig. 4 was plotted in such a manner using a typical 4-watt potentiometer. It will be noted that the plotted curve departs considerably from the straight line drawn from the two extremes of mechanical rotation. This is due to overtravel or short outs which are often applied at the end of the resistance element to provide low end resistance. The linearity, however, is normally specified as independent linearity, which is the deviation from the best straight line which can be passed through the plotted curve and closely approximates a straight line from the extremes of effective or electrical rotation.

Temperature coefficient of resistance in a wirewound potentiometer is normally taken to be the temperature coefficient of resistance of the wire and may be computed as follows: $T.C. = (R2\text{-}R1)/(R1[t2\text{-}t1])$, where $T.C.$ = temperature coefficient in ohms per ohm per degree centigrade; $R1$ = resistance at reference temperature; $R2$ = resistance at test temperature; $t1$ = reference temperature in degrees C; and $t2$ = test temperature in degrees C.

The resulting $T.C.$ is sometimes multiplied by 10^2 and expressed as percent per degree centigrade or more often it is muliplied by 10^6 and expressed as parts per million per degree centigrade.

End resistance is normally not a problem but tends to be higher with potentiometers of higher total resistance. It can be minimized by applying precious metals to the resistance wire at the point of contact with the terminal and by welding or soldering the wire to the terminal.

"Noise" in potentiometer terminology refers to spurious or unwanted resistance changes occurring at the output. One type of noise inherent in general-purpose wirewound potentiometers is resolution noise and results from the small step-like progressions of resistance or voltage change which occur as the slider is moved from one turn of wire to another. It is inversely proportional to the number of turns used in the resistance winding.

A common cause of noise is contamination of the wiper

Table 1. Readily available general-purpose wirewounds.

	WATTAGE RATING		RESISTANCE RANGE (ohms)	
TYPE NUMBER	D.C.	AUDIO		MANUFACTURER
JWP-JWL	1.5		50 to 30,000	CE
49M	1.5		5 to 20,000	CL
110	1.5		0.5 to 5,000	CT
C	2.0		6 to 15,000	MA
43C1-43C2	2.0	4.0	5 to 50,000	CL
2W	2.0	10.0	1 to 50,000	CT
252	2.0		3 to 15,000	CT
39	2.0		5 to 5,000	CL
SSS-4	2.0		1 to 15,000	ME
R	3.0	10.0	2 to 20,000	MA
M	4.0	15.0	1 to 100,000	MA
58C1-58C2	4.0	10.0	1 to 50,000	CL
25	4.0		3 to 25,000	CT
WW	5.0	20.0	1 to 100,000	CE
VW	5.0		1 to 25,000	MA
E	7.0		3 to 150,000	MA
VWG	10.0		1 to 25,000	MA
MG	12.5	50.0	0.5 to 100,000	MA

Manufacturer's Code: Mallory—MA; CTS Corp.—CT; Centralab—CE; Clarostat—CL; Mel-Rain—ME.

path by oxidation of the wire or wiper and/or foreign particles lodged between the resistance winding. There are other more complex factors which contribute to noise such as galvanic action between metal parts in the current path, friction between moving parts and fixed parts, wear and abrasion between the slider and the winding, etc. Lubrication in the area of wiper contact reduces or prevents some forms of noise. (A noise tolerance is not usually specified for general-purpose controls.)

Dielectric strength of a potentiometer is normally 900 or 1000 volts r.m.s. a.c. depending on the type control and the manufacturer's specifications. It is sometimes referred to as hi-pot voltage or voltage breakdown.

Military Specs

Many manufacturers of wirewound potentiometers are approved to supply units which meet the requirements of MIL-R-19. This specification is approved by the Department of Defense for procurement of variable wirewound resistors for use by military departments. It has been widely accepted by industry and many manufacturers as well as users have adopted it as a standard in establishing portions of their own specifications.

Table 2. Characteristics of general-purpose wirewound controls.

POWER RATING	From 1.5 w. to 7 w. at room ambient, derated to zero at 105°C with phenolic insulation. From 10 w. to 12.5 w. at room ambient, derated to zero at 250°C with other insulation.
RESISTANCE RANGE	0.5 ohm to 150,000 ohms
RESISTANCE TOLERANCE	± 5 percent and ± 10 percent
RESOLUTION	See text
LINEARITY	See text
TEMPERATURE RANGE	With phenolic insulation to 105° C; with other insulation to 250°C.
TEMPERATURE COEFFICIENT	20 to 1500 p.p.m. depending on resistance. See text.
MECHANICAL ROTATION	From 280° to 307°.
ELECTRICAL ROTATION	From 255° to 295°.
INSULATION RESISTANCE	Several hundred megohms.
DIELECTRIC STRENGTH	Depending on the manufacturer, either 900 volts a.c. r.m.s. or 1000 volts a.c. r.m.s. for one minute.
TORQUE (ROTATION)	0.5 to 6 inch-ounces, depending on model.
TORQUE (STOP)	8 to 12 inch-pounds, depending on type.
MAXIMUM VOLTAGE ACROSS RESISTIVE ELEMENT	Not to exceed wattage ratings.

MIL-R-19 at the present time covers three styles of wirewound potentiometers. Style RA10 is a one-watt control, style RA20 is a two-watt control, and style RA30 is a four-watt control. Several modifications of each control, such as attached switch, locking-type bushings, and tapered windings are also covered in the specification.

In most cases, potentiometers supplied to comply with MIL-R-19 are commercial units with improved materials and/or finishes to meet the more stringent environmental requirements such as salt spray, humidity, reduced pressure, etc. which are not encountered in most commercial applications. As might be expected, these improved materials and finishes add to the cost of the controls. Many times the user may realize cost savings by avoiding reference to MIL-R-19 on his drawings and specifications when commercial construction is adequate for his application.

Specifying Controls

The first consideration when specifying a general-purpose wirewound control is the wattage rating. A generous safety allowance of 25 to 50 percent is considered good engineering practice. If for non-critical applications the three basic requirements—wattage, size, and resistance—are not unusual, a standard design or off-the-shelf item may be used at minimum cost. If, however, you need special temperature coefficient, resolution, linearity, tapered windings, or mechanical features, it will be necessary to draw up a print incorporating all these specifications. All special controls are purchased from samples submitted by the vendor to the customer's print specifications.

When specifying mechanical features, you will be limited by several factors. If yours is a low-wattage control, you can save money by using a phenolic-cased control with a plastic shaft. But, remember, you will be limited to 105°C temperature operation. Also remember that when you are buying miniature controls, if you do not need this size feature, their use involves unnecessary expenditure. Bushing materials are usually dictated by the type case the control has. Plastic shafts (when available) are the least expensive, followed by steel, aluminum, or brass. If you are using a setscrew knob, a plain round shaft will be cheaper than a flatted or other special type shaft end. ▲

PRESSURE AND PENDULUM POTENTIOMETERS

Pressure-Operated Potentiometers. These forms of potentiometers are arranged so that their wiper contact is moved across the resistance element as a function of air (or other gas) pressure, or vacuum, applied to a bellows which, in turn, is mechanically coupled to the wiper arm.

Typical of these pressure-operated potentiometers is a pair manufactured by *Computer Instrument Corp.* One is an altitude transducer producing a linear change in resistance with reduced air pressure and capable of indicating to 70,000 feet altitude with an effective resolution of 10 feet.

The other is an airspeed transducer having a linear change in resistance with increased air (or other gas) pressure and capable of indicating up to 1000 knots at an effective resolution of .15 knot. Although both of these are aircraft components, they can be used in ground-based simulators, or wherever vacuum or pressure testing (within prescribed limits) need be done. Other instruments are available to cover the pressure ranges of 0-.3 to 0-5000 lbf/in^2 (psi) with either linear or non-linear outputs.

Pendulum-Operated Potentiometers. In some design applications, it may become necessary to generate a signal that is a function of how a particular object is positioned with respect to the gravity component existing at that point. Typical applications include pitch angle detection of torpedoes, railroad track leveling, directional sensing in automatic remote mining machinery, level sensing in horizontal platforms, and leveling of machine tool control systems.

In a typical pendulum potentiometer manufactured by *Lebo Electronics Corp.*, a pendulum is suspended on two low-torque bearings and attached to a wiper arm that contacts a resistance segment attached to the potentiometer case. The output from the potentiometer is proportional to the angular displacement of the case from the vertical reference. The mechanism is hermetically sealed in silicone oil which acts as a damping medium. Mechanical rotation for useful output is up to 45° off the horizontal. Internal switches can be provided to indicate when the pendulum hits the limit stops. ▲

PRECISION

Wirewound Potentiometers

By GEORGE W. BOYD / Clarostat Mfg. Co., Inc.

Widely employed in military and industrial applications, these pots are electromechanical transducers that deliver an output voltage depending on the shaft position and the applied voltage, to a high degree of accuracy.

THE development of precision potentiometers can be traced to the initial demand for accurate and stable devices for use in laboratory test equipment. The subsequent need for more sophisticated electronic measuring equipment during World War II and the advent, in more recent years, of computers, servo mechanisms, and an unlimited variety of commercial and military applications has firmly entrenched the position of the precision potentiometer as a vital component in the growth of our present-day electronics industry.

A precision potentiometer is defined as an electromechanical transducer dependent upon the relative position of a moving contact (wiper) and a resistance element for its operation. It delivers a voltage output that is some specified function of applied voltage and shaft position, to a high degree of accuracy.

The practical limitations of certain characteristics are of major concern to potentiometer users. We will deal briefly with these characteristics, the effects and importance of the relationship with one another, and the factors governing their performance capabilities.

Important Characteristics

Resistance: Due to the normal use of potentiometers as voltage dividers with functional output measurements taken in terms of voltage ratio, tolerances of better than ±5% of the total resistance are generally not required. Depending upon other factors such as: the size of the potentiometer, the magnitude of the total resistance, and the method of termination, special tolerances of ±1% or better are obtained.

Extremely low resistance values yield relatively poor resolution (except in the case of slide-wire types) due to the bulkiness of the wire required to fabricate the resistance element. Extremely high resistance values yield excellent resolution characteristics: however, the fineness of the resistance wire required makes it impractical and expensive to fabricate.

Resolution: Theoretical voltage resolution is the ratio of the maximum incremental change in voltage (ΔV) to the total applied voltage (V), *i.e.*, $(\Delta V)/V$.

The maximum incremental change in voltage (ΔV) is merely the applied voltage (V) divided by the total number of turns of resistance wire (n) in the effective electrical travel.

Therefore, *theoretical voltage resolution* $= (\Delta V)/V = (V/n)/V = 1/n$. Hence, theoretical voltage resolution is equal to the reciprocal of the total number of turns of resistance wire in the effective electrical angle. The ratio is often multiplied by 100 and expressed as a percent.

Travel resolution is the maximum angular or linear displacement of shaft travel that can be measured before a discrete change in output ratio is encountered. This value is measured in degrees for rotary-type potentiometers and inches in linear-motion or rectilinear types.

Linearity & Conformity: Precision potentiometers are so defined because of their ability to generate a linear or nonlinear electrical output in extremely close compliance with prescribed theoretical function characteristics.

The degree of accuracy to which the potentiometer must conform to the prescribed electrical output is often the determining factor in designating whether or not a precision potentiometer is required for the application.

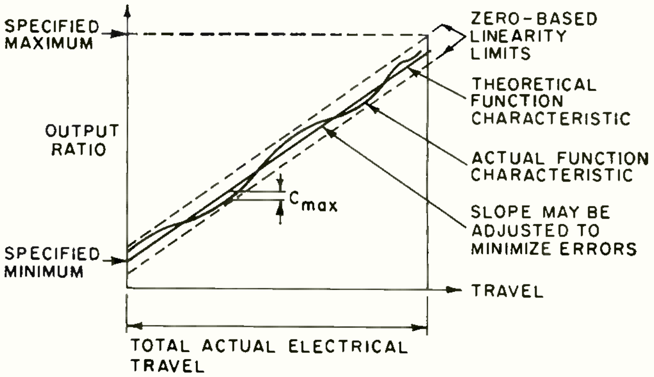
The electrical characteristics desired are commonly specified as the ratio of output voltage to input voltage e/E which varies as a function of the potentiometer shaft rotation (θ).

The allowable deviation from the theoretical electrical output is referred to as linearity for straight-line function characteristics (Fig. 1) or conformity in the case of nonlinear function characteristics (Fig. 2), and is generally expressed as a percentage of the total applied voltage. $e/E = f(\theta) \pm C$.

Temperature Coefficient: The temperature coefficient $(TC) = [(R_2 - R_1)/R_1(t2 - t1)] \times 10^6$, where R_1 and $t1$ are, respectively, resistance in ohms and temperature in degrees centigrade at the reference temperature. R_2 and $t2$ are, respectively, the resistance in ohms and the temperature in degrees centigrade at the test temperature.

Power Rating: The ability of a potentiometer to dissi-

Fig. 1. Straight-line function linearity.



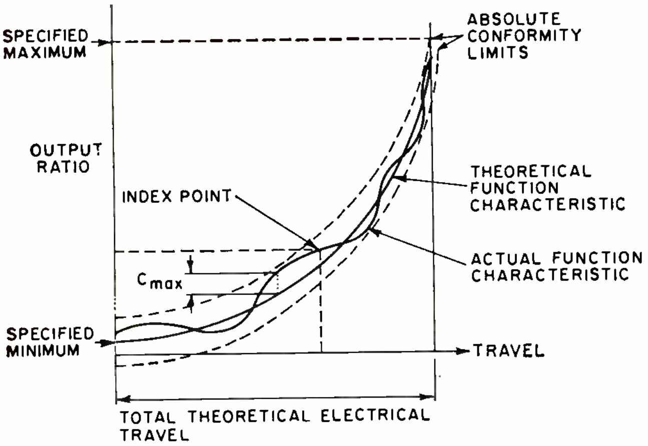


Fig. 2. Non-linear function conformity.

pate power over a specified range of operating conditions without experiencing permanent deterioration in performance characteristics or structural distortion, is a pertinent factor in selecting the type and size potentiometer to be used.

Noise: The presence of noise may be attributed to a number of causes: foreign materials formed on the resistance element as a result of wiper abrasion, dust particles, the formation of oxide film on contact surfaces, and the mechanical trueness governing the relationship between contact and winding surfaces.

Other contributing factors may be traced to self-generated voltage resulting from electrical energy produced from the abrasive action of the slider rubbing on the resistance wire (tribo-electric effect), the effect of external or frictional heat (thermo-electric effect). and chemical contamination of resistance wire (chemico-electric effect).

In spite of these effects, the noise level in precision wirewound potentiometers may be held to 100 mV or less.

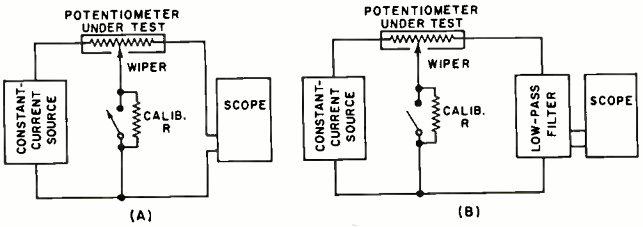
The presence of noise contributes mainly to system instability in the form of a hunting action in servo feedback applications and must, of necessity, be kept to a minimum.

Recent studies reveal that earlier, arbitrarily set methods of measuring noise levels do not accurately depict the circuitry in which the potentiometer will be used.

The bandwidth of the commonly used oscilloscope shown in the Fig. 3 A standard test circuit is, conservatively a thousand or more times greater than the bandwidth of most servo systems which constitute a large percentage of precision pot applications. Consequently, the potentiometer manufacturer is often confronted with the unnecessary burden of complying with test requirements which are non-representative of the limits allowed by the intended application.

The alternate test method (Fig. 3B) incorporates a 1000-Hz low-pass filter at the input to the oscilloscope. Less noise will. of course, be indicated: however, the bandwidth of 1000 Hz is well in excess of the bandwidth of most servo systems and is therefore more representative of the type of noise test to which precision potentiometers should be subjected.

Fig. 3. Conventional noise-test circuit using oscilloscope.



Noise measurement in terms of "output smoothness" or, the absence of noise, is another method gaining increased popularity among manufacturers and users of both precision wirewound and non-wirewound potentiometers.

The accuracy (linearity) of the potentiometer is normally the primary design objective. Generally speaking, increased physical size of a potentiometer will yield a greater degree of accuracy. The increased winding length of the resistance element obtainable in larger units will be composed of a greater number of turns of resistance wire for a given resistance value, resulting in a higher degree of sensitivity or resolution. Size. of course, is limited to the space available in the system.

High mechanical precision is capable of being designed into the potentiometer and although this feature is essential to the satisfactory performance of the unit, it is not regarded as a limiting factor on standard models.

Resolution, in turn, is dependent upon the size and type of wire selected to satisfy the specified temperature coefficient and total resistance requirement.

Selecting suitable wire sizes of various resistivity within the specified temperature coefficient and varying the width of the form on which this wire is wound are a few of the various techniques used by the potentiometer designer to achieve maximum potentiometer performance. A high degree of flexibility regarding the limitations placed on these characteristics by the potentiometer user may often result in a considerable amount of savings in the cost of the particular end item employed.

Standard Types of Precision Pots

Single-Turn Rotary: This class easily represents the most common variety of precision potentiometers in use today. Some of the most significant features of this type include:

1. Sizes from ½″ to 3″ in diameter are readily available. Diameters of up to 7″, although uncommon, are also available.
2. Larger diameters offer excellent resolution and accuracy: however, the accuracy of these characteristics diminish with a decrease in size for a corresponding resistance value.
3. Especially adaptable to ganging.
4. Basic construction lends itself easily to variations in physical characteristics to satisfy customer design requirements.
5. Inherent stability due to construction characteristics and availability of low temperature coefficient resistance wire.
6. Broad selection of resistance values ranging from a maximum of 25 kilohms in ⅞″ diameter to a maximum of 300 kilohms in 3″ diameter.
7. Especially long life. normally up to one million cycles; extremely low torque values.
8. Standard items may often be obtained from stock or within a minimum period of time.
9. Especially adaptable to non-linear function characteristics.

Multi-Turn Rotary Types: This type is generally restricted to those applications requiring high resolution and accuracy. Outstanding features include:

1. Available in up to 60 shaft revolutions. Standard construction normally calls for 10 turns. Available in sizes similar to the range of single-turn types.
2. High resolution and accuracy are inherent features due to the increased winding length that is afforded by the helical construction of the resistance element.
3. Inherently stable due to construction characteristics and availability of low temperature coefficient resistance wire.

4. Fairly inflexible in physical variations and ganging in excess of two sections due to elongated construction.

5. Life characteristics are normally less than similar sized single-turn types.

6. Torque values are higher in comparison to single-turn types due to basic construction.

7. Highest range of resistance values available in any precision wirewound potentiometer for any given size.

Specific values relating to the practical limitations of each characteristic previously discussed are given in Tables 1 and 2 for single-turn and multi-turn precision wirewound potentiometers.

Linear-Motion Potentiometers: This type of potentiometer is used in applications measuring linear displacement. Electrical characteristics offered by this type are essentially the same as those noted under single-turn rotary types for equivalent lengths of resistance elements. Other notable features include:

1. Availability of multiple independent potentiometers contained within a single housing.
2. Eliminates the need for rack and pinion or other converting mechanisms.
3. Capable of furnishing a variety of non-linear output functions.
4. Precise mechanical construction is required in order to maintain mechanical stability and to insure functional performance with a minimum of friction.
5. Available with stroke lengths of up to 15 inches.

Slide-Wire Potentiometers: This class of potentiometer satisfies those applications requiring extremely high resolution and accuracy in comparatively small sizes. Its features include:

1. Available in both single- and multi-turn types.
2. Range of total resistance is limited to low values due to uncoiled single-wire resistance element construction, necessary to permit uninterrupted slider contact.
3. Errors contributed by the effects of end resistance and contact resistance are significant and difficult to control.
4. Construction enables units to be furnished with extremely low torque values.
5. Reduced rotational life due to single fine-wire construction.
6. Highest resolution of all wirewound types.

Precision potentiometer manufacturers have long demonstrated their ability to comply with the most stringent requirements imposed upon them. However, keeping in mind the ever increasing cost of manufacturing, wherever possible, personnel responsible for over-all systems cost and performance will be wise to question the need to specify "special" electrical and mechanical features. This same awareness may also be applied to minimizing the tendency to "overdesign" by taking unnecessary safety factors and arbitrarily specifying compliance to rigid environmental conditions where the need does not exist.

The potential savings in the cost of materials might, more often than not, warrant the initial expenditure in time and effort required to accurately define potentiometer specifications without jeopardizing systems performance.

Obviously, certain applications demand nothing less than the ultimate in precision potentiometer performance. In any case, consultation with various manufacturers regarding questionable design parameters is highly recommended. ▲

Nom. Diam.	1/2"	7/8"	1 1/16"	1 7/16"	2"	3"
Range of Total Res. (ohms)	50-100k	5-110k	5-125k	5-150k	5-200k	10-300k
Total Res. Tolerance (%)	±5	±5 to ±1	±5 to ±1	±5 to ±1	±5 to ±1	±5 to ±1
Power Rating (watts)	2 @ 70°C 0 @ 150°C	2 @ 70°C 0 @ 125°C	2 @ 70°C 0 @ 125°C	3 @ 70°C 0 @ 150°C	5.5 @ 40°C 0 @ 125°C	6 @ 40°C 0 @ 125°C
Resolution (%) at Max. Res.	to 0.1	to 0.08	to 0.07	to 0.05	to 0.03	to 0.019
Linearity (Indep.)	to ±.5% for high R_T	to ±.2% for high R_T	to ±.2% for high R_T	to ±.15% for high R_T	to ±.1% for high R_T	to ±.075 for high R_T
Elec. Rot. (deg.)	to 350° nom.	to 354° nom.	to 354° nom.	to 354° nom.	to 358° max.	to 358° nom.
Mech. Rot. (deg.)	continuous	continuous	continuous	continuous	continuous	continuous
Working Volt (max. V d.c.)	300	400	400	400	400	400
End Res. (% of total res. or ohms, whichever is greater)	.25% of R_T or .5 ohm	within lin. tol. or 2% of R_T	within lin. tol. or 2% of R_T	within lin. tol. or 2% of R_T	within lin. tol. or 2% of R_T	within lin. tol. or 2% of R_T
Starting Torque (oz. in max)	0.5	0.25	0.25	0.5	0.8	1

For all units listed, the temperature coefficient of resistance wire used is 20 ppm/°C, operating temperature range is −55°C to 125°C, or 150°C, the ENR noise is 100 ohms maximum, the insulation resistance is 1000 megohms at 500 V d.c., and the dielectric strength is 1000 V r.m.s. for 5 sec.

Table 1. Characteristics of single-turn rotary precision wirewound potentiometers.

Table 2. Characteristics of ten-turn rotary precision wirewound potentiometers.

Nom. Diam.	1/2"	7/8"	1"	1 7/16"	2"
Range of Total Res. (ohms)	15-100k	25-125k	25-150k	50-350k	50-750k
Total Res. Tolerance (%)	±5 to ±2	±3 to ±1	±3 to ±1	±3 to ±1	±3 to ±1
Power Rating (watts)	2 @ 40°C; 0 @ 125°C	4 @ 40°C; 0 @ 125°C	4 @ 40°C; 0 @ 125°C	6.5 @ 40°C; 0 @ 125°C	12 @ 25°C; 0 @ 125°C
Resolution (%) at Max. Res.	.015	.010	.008	.006	.004
Linearity (Indep.)	.1% for high R_T	.05% for high R_T	.03% for high R_T	.025% for high R_T	.015% for high R_T
Elec. Rot. (deg.)	3600° +20° −0°	3600° +5° 0°	3600° +4° −0°	3600° +3° −0°	3600° +3° −0°
Mech. Rot. (deg.)	3600° +20° −0°	3600° +10° −0°	3600° +10° −0°	3600° +3° −0°	3600° +3° −0°
Working Volt (max. V d.c.)	500	600	670	1000	1000
End Res.	within lin. tol. or .5 ohm whichever is greater	within lin. tol. or .1 ohm max. for $R_T < 50\Omega$	within lin. tol, or .1 ohm max. for $R_T < 100\Omega$	within lin. tol. or .1 ohm max. for $R_T < 100\Omega$	within lin. tol. or .1 ohm max. for $R_T < 100\Omega$
Starting Torque (oz. in max)	0.5	0.75	0.75	1	1

For all above units, the temperature coefficient of resistance wire used is 20 ppm/°C, operating temperature range is −55° to 125°C, the ENR noise is 100 ohms maximum, the insulation resistance is 100 megohms min. at 25°C and 85% relative humidity, the dielectric strength is 500 V r.m.s. for 5 seconds for two smaller sizes and 1000 V r.m.s. for three larger sizes.

PRECISION

Wirewound Adjustment Potentiometers

By GARY L. KOUNKEL / Applications Engineer, Bourns, Inc., Trimpot Div.

The adjustment potentiometer (trimmer) industry began in 1952 with the release of a single model. Today, this is a multi-million dollar market with over 20 major suppliers and over 100 standard types available to electronic circuit designers.

THE adjustment potentiometer is a miniature device that is used to adjust voltage, current, or resistance in a circuit. In the majority of applications this device is used to compensate for variations of fixed components.

The ability to design in an adjustment potentiometer eliminates the need for selection of fixed resistors in order to adjust parameters during the assembly of a circuit. This saves valuable assembly time and eliminates the need for an extensive inventory of fixed resistors.

Not only is the adjustment potentiometer an economical means of initial adjustment, it also provides for the rapid readjustment of fixed components as they drift during their normal life. By being able to readily compensate for these changes, equipment life is extended and down time to change fixed resistors is eliminated.

The adjustment potentiometer offers small size, suitable and varied forms for mounting, a high degree of angular resolution for ease and accuracy of adjustment, and a high degree of stability.

The most basic and vital part of the potentiometer is the resistance element. All varieties of resistance elements can be divided into one of two categories: wirewound or non-wirewound. The wirewound elements are made by helixing high-grade resistance wire onto a suitable mandrel and terminating with a welding or brazing process.

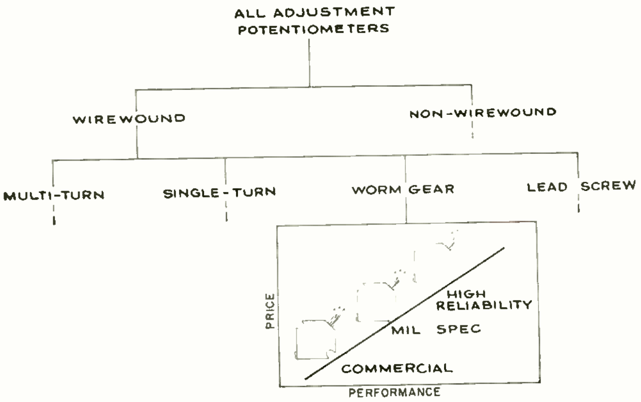


Fig. 1. All adjustment pots may be subdivided as shown here.

The wirewound units are generally chosen over non-wirewound types for their superior performance in the areas of temperature coefficient and environmental stability. In comparison to the non-wirewound element, it is difficult to match the stability of high-grade nickel-chrome alloy resistance wire. In addition, it is possible to achieve tighter standard specifications for noise, end settings, and total resistance tolerance on wirewound units.

When adjusting a wirewound potentiometer, the wiper must travel from one turn of wire to another. Hence, the electrical output is in the form of small discrete resolution steps.

Normally, the resistance range of wirewound units is limited to about 100,000 ohms, since beyond this point the very small diameter of resistance wire makes manufacture impractical and reliability questionable.

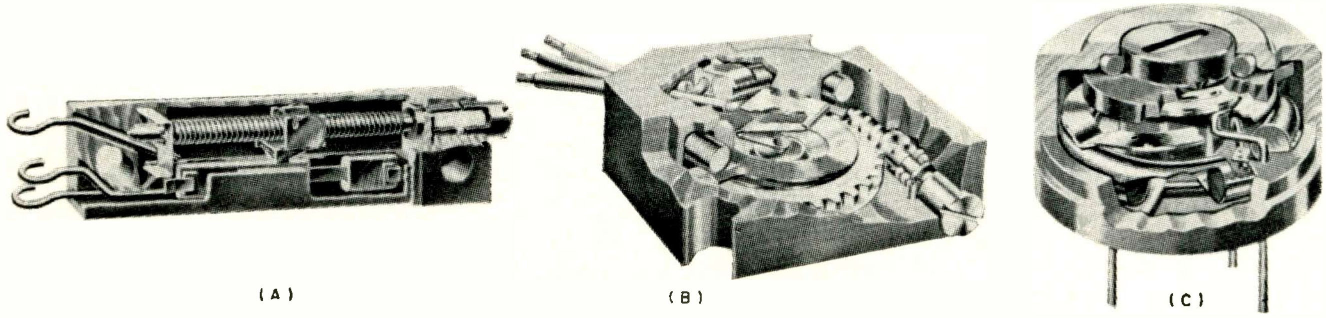
Variety Available

The hundred or so different standard models include variations in such broad parameters as: size, configuration, type of element, price, specifications, performance, and reliability. It is helpful to view the available variety of adjustment potentiometers with the aid of Fig. 1.

For each of the basic element types there is a complete variety of configurations available. These include: lead-screw actuated (LSAP), worm-gear actuated (WGAP), single-turn (ST), and multi-turn (MT).

The LSAP was the original design and is the simplest mechanism to understand. An example of this type of design is shown in Fig. 2A. The resistance element is wound on a straight mandrel. The wiper is affixed to a post and is moved along the element when the lead screw

Fig. 2. (A) Lead-screw actuated, (B) worm-gear actuated, and (C) single-turn adjustment potentiometers.



(A) (B) (C)

is rotated. A clutch mechanism is designed so that the wiper will idle when the post reaches the end of travel. The wiper current is carried to the No. 2 terminal with the use of a contact bar or, in some cases, the adjustment shaft.

The LSAP design provides excellent angular rotation. This means that a relatively large change in angular position of the adjustment shaft provides a relatively small change in output voltage ratio. This permits an accurate degree of fine settability.

The WGAP was designed to provide a greater element length for unit volume of size. A very common example of this configuration is the ½″-square unit shown in Fig. 2B. This unit has specifications similar to an LSAP unit which is 1¼″ long.

When the adjustment shaft is rotated, the worm engages the teeth in the gear and forces the gear to rotate. The wiper is then driven by the frictional force between the gear and wiper assembly. When the wiper reaches the end of the element and contacts the positive stop, the unit clutches as the frictional force between the gear and the wiper assembly is overcome.

In addition to the ½″-square unit, similar designs are available in ⅜″ and ¼″ packages, including panel mount versions on all except the ¼″ unit. These units incorporate all of the advantages of the LSAP in a smaller, more versatile package.

The single-turn unit is shown in Fig. 2C and is generally considered for the less critical applications. This is due to the lower degree of angular resolution which is achieved with the single turn as compared with other adjustment potentiometer configurations.

The design of the single-turn unit provides for a direct drive from the adjustment rotor to the wiper. Consequently, this configuration normally does not have an idling feature, but has positive stops or continuous rotation instead.

On continuous-rotation units, the wiper usually opens as it passes from one end of the element to the other. The single-turn units are more commonly found in ¼″- and ½″-diameter packages and thus provide a small, economical means of fast circuit adjustment.

The WGAP was the ultimate as far as maximum element length per unit volume of size until the recent release of the multi-turn adjustment potentiometer. This unit has over 6 inches of resistance element incorporated into a unit 5/16″ square × 1 1/16″ long. The long element length provides the circuit designer with specifications similar to those found in precision rotary potentiometers in the small adjustment potentiometer package.

A cutaway view of this unit is shown in Fig. 3. As the adjustment shaft is rotated, the clutch turns the rotor of the unit. The wiper carriage and wiper are mounted in the rotor and, therefore, they rotate and move from one end of the unit to the other as the wiper carriage follows the helix of the element. The wiper current is picked off the element and transferred to the cylindrical contact bar by the wiper. The contact bar is stationary in the center of the rotor and extends outside of the unit in the form of the wiper terminal. This 10-turn unit provides the ultimate in adjustment potentiometer performance in such areas as: settability, stability, resolution, temperature coefficient, and power dissipation.

For each of the four major configurations there is also a variety of minor options available such as: terminal style, shaft configurations, and panel-mount versions.

The terminal styles and abbreviations would include flexible insulated stranded wire (L), solid wire leads (W), printed-circuit pins (P), solder "J" hooks (S), and solid wire leads which exit at a right angle to the adjustment shaft (H). Typical examples are shown in Fig. 4.

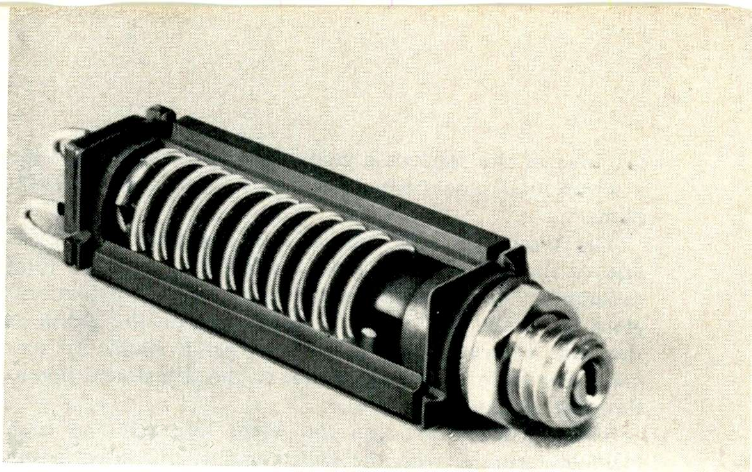


Fig. 3. Cutaway photo of multi-turn adjustment potentiometer.

The standard adjustment shaft is slotted for screwdriver adjustment. Other special shaft configurations include: extended shafts, Allen-head shafts, knurled shafts, flatted shafts, etc. The special versions of the adjustment shafts are usually available only by contacting the manufacturer.

Panel-mount versions are available in virtually all styles of adjustment potentiometers. The panel-mount facilitates the mounting of adjustment potentiometers directly to an instrument panel. This type of mounting does not usually necessitate any degradation to the standard specifications of the unmounted potentiometer.

For every configuration of both wirewound and nonwirewound elements, there is an infinite number of possible variations of performance and reliability. The number of possibilities is limited only by the imagination of the circuit designer and component engineer and the price and delivery of the specified unit.

Specifications

In present-day marketing practices, the user defines the adjustment potentiometer to the manufacturer in the form of the manufacturer's part number or a specification. The manufacturer's part number is the simplest and most economical method when a standard unit is required. In all other cases the most satisfactory communication is the specification. Therefore, it is very important that the specification serve its purpose of defining the unit to be supplied. To adequately define an adjustment potentiometer, the specification should contain the following major requirements:

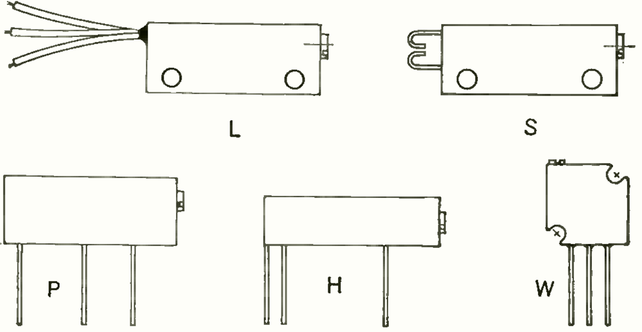
General Description: This should include, in paragraph form, the general purpose and major characteristics of the potentiometer specified. A typical example might be "1-watt miniature wirewound adjustment potentiometer."

Physical Characteristics: These describe in detail the appearance of the potentiometer such as: (1) outline dimensions with tolerances; (2) marking; (3) terminal configuration; and (4) weight.

Electrical Characteristics: These outline the operating specifications at nominal room conditions. Common potentiometer electrical characteristics are as follows:

The *total resistance* of a potentiometer is the resistance

Fig. 4. A wide variety of terminal configurations is available.



in ohms of the resistance element. The normal range for a wirewound potentiometer is 10 ohms through 100,000 ohms.

The *total resistance tolerance* is the allowable deviation of the actual total resistance from the nominal total resistance value. The tolerance on wirewound potentiometers is usually 5% or 10% depending on the grade of the unit. Tolerances down to ±1% are available on special order from the manufacturer of the adjustment potentiometer at additional cost.

The resistance between the wiper terminal and each element terminal with the wiper against the stops is *end resistance*. A typical end resistance specification is 2% of the nominal total resistance or 1 ohm, whichever is greater. Again, tighter specifications are available on order from the factory, if required.

Noise is the dynamic resistance in ohms between the wiper and the resistance element. It is referred to as dynamic since it is only apparent when the wiper is being adjusted in wirewound potentiometers. Noise appears as random interference of the desired output signal when viewed on an oscilloscope. The normal noise specification is 100 ohms, and 10 ohms is the lowest practical value which can be attained. Noise performance generally deteriorates when subjected to temperature environments and is more difficult to control on resistance values below 100 ohms due to the resistance wire alloy used.

Electrical output was described for a wirewound potentiometer as appearing in a step function as the wiper picked up each turn of resistance wire. The average value of each output step, expressed as a percent of the total output, is defined as *resolution*. Resolution is a design function and can be calculated as (1/*number of turns*) × 100. The nominal resolution value is desirable information since it indicates the degree of settability of the unit.

The resistance between the three terminals in common and the exterior of the potentiometer with a fixed voltage applied is defined as *insulation resistance*. Normally, the applied voltage for this test is 500 volts d.c and a typical specification is 1000 megohms minimum.

Mechanical characteristics describe the mechanical criteria of the potentiometer. These include: number of adjustment turns, mechanical stops or idling features, shaft torque, pin-bending tests, and terminal strength.

The environmental characteristics define the performance of the unit at conditions other than room ambient. Standard test methods are outlined in MIL-STD-202. Typical environmental requirements involve temperature coefficient, temperature stability, moisture resistance, vibration and shock, power rating and load life, salt-spray tests, and dielectric strength.

Quality assurance provisions define specific inspection requirements that are to be met on units supplied to the specification. Because they are costly, these should only be specified when it is more desirable to have the manufacturer conduct the inspection rather than the user.

Reliability is most commonly specified in adjustment potentiometers in terms of failure rate. For a failure-rate figure to be meaningful, the following information is necessary: (1) failure rate in %/1000 hours; (2) confidence level; (3) reliability test sequence; and (4) catastrophic failure criteria.

The ideal specification will contain all of the requirements the potentiometer must meet to function adequately in its application. On the other hand, the specification will not over specify or include unnecessary requirements. Standard requirements will be used wherever possible. Specifications which are standard to the industry can be found in manufacturer's literature or in military specifications. The military specifications for wirewound adjustment potentiometers is MIL-R-27208. In order for a requirement to be completely specified, it must include the test method and failure criteria. A simple acceptable method of documenting test procedures is to reference the military specification. Do not, however, specify that non-military-specification units must meet requirements of the military specification since this is usually impossible. ▲

Composition Potentiometers

(*Continued from page* 51)

have already given the designer a substantial margin of safety by being conservative in their published power ratings. A few short tests to determine actual maximum power rating help avoid purchases of unneeded power capacity.

The ability of a potentiometer to operate at elevated ambient temperature is an important characteristic that separates the three general categories.

Fig. 2 illustrates the rated temperature, maximum operating temperature, and derating curves for composition pots. The power rating of a potentiometer is normally derated linearly from full rating at the rated ambient to zero power at the maximum operating temperature.

When a voltage is applied to a potentiometer, there are two separate effects on the resistance of the element. There is the obvious resistance change due to heat and there is the instantaneous change in resistance due to the voltage characteristics of the element. This second effect is an inverse relationship between the voltage applied and the resistance. For resistances under one megohm, the coefficient of this relationship is about 0.02% per volt for carbon-film pots. However, the coefficient is larger for higher resistances. This effect must be taken into consideration for high-voltage, high-resistance applications.

Many environmental tests are dictated by industry and military standards including moisture resistance, temperature cycles, acceleration, salt spray, shock, vibration, etc. These tests are often very severe and require special constructions to meet their requirements. Consequently, the designer should only request adherence to those tests which are dictated by the environment within which a particular potentiometer will be operating.

MIL Specs

The standard Department of Defense military specification for composition potentiometers is MIL-R-94B. This spec is easily met by most cermet pots and can also be met by carbon-ceramic and molded-carbon pots. Special elements and constructions are necessary to bring standard carbon-film pots within this spec.

A relatively new Navy specification, MIL-R-23285, is being used for cermet potentiometers. This specification uses most of the same styles and tests as MIL-R-94B but with more exacting requirements. Table 2 shows some of the major differences between these two military specifications.

Needless to say, MIL Specs should be used only when dictated by requirements since military controls cost two or more times as much as standard commercial controls. Furthermore, designers should avoid using MIL Specs as guidelines in the preparation of specifications for a non-military application. Commercial practice, for instance, is to rate carbon-film controls at 55°C rather than 70°C as required under MIL-R-94B. Specifying that a control should be rated at 70°C could force a supplier to use a high-grade, higher cost element when a standard element would have been sufficient. ▲

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JOHN FRYE

Federal and state agencies, together with universities, are now lending aid and encouragement to potential innovators.

INVENTORS WANTED

BARNEY came whistling into the service shop one bright April morning to find Mac, his employer, going through the mail. The youth idly picked up a pamphlet from the desk and then gave a low whistle of amazement. *"How to Submit Ideas & Inventions to the United States Government,"* he read from the cover. "Hey, Mac, you got an invention? Come on! Don't hold out on me! What you got cooking?"

"Turn down your gain," Mac said. "I simply wondered why I hadn't seen a recent list of the most-needed inventions put out by the National Inventors Council and wrote for a copy. I like to look at the needs in the electrical and electronic fields and dream a little. Anyway, I got this letter back from the Office of Invention and Innovation explaining that staff activities of the National Inventors Council had been discontinued early in 1964 and that publication of their *Inventions Wanted* stopped at the same time.

"The NIC still exists as an advisory group, but it no longer evaluates inventions intended for government use as it once did. Instead, the Office of Invention and Innovation refers proposed inventions to the proper government agency for evaluation there. In addition, the OI&I answers all correspondence relating to inventions received by Congress, the Department of Commerce, and the White House. This correspondence includes suggestions, complaints, proposed laws, infringement actions, and inventors' problems generally."

"I'll bet they get some wacky letters," Barney commented with a grin. "Is that all the OI&I does?"

"Oh, no. It also works with various agencies to help inventors get their inventions into commercial use. One way is by encouraging state invention expositions in as many states as possible. Such an exposition may be called an Inventors' Fair, Inventors' Congress or Inventors' Show; but fifteen states held one of these last year, and it is expected half the states will have held one by the end of 1966."

"What's an invention exposition like?"

"It's usually a two- or three-day affair sponsored by the state economic or industrial development commission, a state Chamber of Commerce, a local Chamber of Commerce, or a state manufacturers' organization. The purpose is to bring together inventors, patent owners, manufacturers, distributors, investors, and others to negotiate the sale or license of patents and arrange for the production and distribution of new inventions and new products. Quite often symposia covering such subjects as patenting, developing, manufacturing, and marketing new inventions and products are offered."

"What does it cost an inventor to show his invention in such an exposition?"

"That depends on how the exposition is financed, but usually the cost for display space is low, say ten or fifteen dollars, and this may include a ticket to a banquet and a special breakfast and luncheon.

"I suppose he should have his device patented before he shows it."

"Yes, for his own protection he should."

"And have a working model?"

"A working model will certainly help interested viewers understand the invention. So will photographs, film strips, and testimonial letters pertaining to the invention in use. Remember, the exposition gives the inventor a wonderful opportunity to display his invention to potentially interested manufacturers, distributors, investors, and consumers; and he should take full advantage of that opportunity. The exposition also permits him to determine consumer reaction to his device, to attend lectures devoted to his problems, and to visit with other inventors and benefit from their experiences."

"But suppose I've just worked out something I think may be worth patenting, but I don't know how to go about getting it patented. Where can I get help?"

"Probably the best thing to do is send for two booklets available from the Superintendent of Documents, Washington, D.C. 20402. One is called *Patents and Inventions—an Information Aid for Inventors*, and the other is *General Information Concerning Patents.* The cost is only 15¢ per booklet."

"I've another question that's been bugging me a long time. Suppose I invent something of great military significance—say a death-ray—and apply for a patent on it. Now publication of this patent may be detrimental to national security. What happens?"

"The Commissioner of Patents will order the invention be kept secret and will withhold the grant of a patent until the disclosure is no longer a threat to national security. You will be entitled to apply for compensation for any use of the invention by the Government if and when your patent application is held to be allowable."

"In that case I'm quitting on the death-ray and going back to work on my electronically controlled skate board."

"Spoken like a true fast-buck boy," Mac chided. "The OI&I has another program just begun last December and recommended by both the National Inventors Council and the Commerce Technical Advisory Board. This program aims to prepare and make available imaginative design cases, based on current Institute of Applied Technology projects, for use in developing the creative potential of future engineers now in engineering schools. Another project of this program is to develop and maintain a closer relationship between IAT and the engineering school. They are going to try to make inventors out of engineers."

"It's funny you should mention this now," Barney said. "Just last night I was visiting with a friend who attends Purdue University, and he was telling me of a new course called 'Creative Engineering Synthesis' given in the Purdue School of Aeronautics, Astronautics, and Engineering Science that is aimed at doing just that: teaching inventiveness to engineers. Oddly enough, engineers are not ordinarily good inventors. They can analyze problems; they can work with the ideas of others; but few really originate ideas. Recently, one large company surveying its corps of 6000 engineers found no more than 30 who could be classified as innovators. Developing a really new product that provides a better answer and not just a skillful repetition of a solution already worked out by somebody else demands courage and a willingness to try something new. But in the discipline of engineering, most courses are devoted

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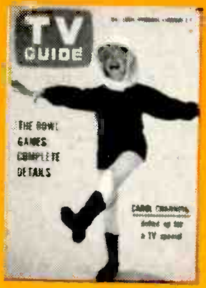

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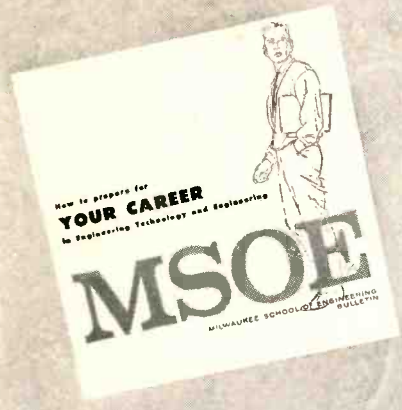

to teaching known facts and procedures; a high premium is placed on recall ability; and, as a result, any willingness to venture is often subdued.

"Professor Joseph Liston, who has been developing this course for the past dozen years, says first you must convince the student there will be no penalty for failure to find a better answer to his problem. After the long regimentation to which the student has been subjected—the course is open only to seniors—this takes a lot of reassurance by the instructor before the student will really believe it.

"Secondly, there is the need for motivation, and Prof. Liston says money is still the best motive. If the student works to solve a real problem and invents a product that could have a potentially large market and produce a sizable income, he will put forth his maximum effort; so don't put me down for working on my skate board!"

"Okay. But seriously, I think this sort of thing is excellent. The day of the basement inventor is about over. Most simple inventions have already been invented. Today we have a sophisticated society and a sophisticated technology. You have to have a good technical background to understand and try to supply the sophisticated needs of our society. Engineers have that background, and we must look to them more and more for our future inventions. By the way, how does an engineering student in this new inventor's course operate?"

"Ordinarily he works alone. At the beginning of the semester, he is required to pick a project. He focuses on some need, examines present expedients, and spells out the characteristics of a non-existent product that could meet the need more effectively. Doing this may take up to a month. Then the rest of the semester is spent trying to invent the product. The course meets twice a week in a classroom; the rest of the time students work where they please. Bi-weekly they submit brief summaries of what they've been doing and what they plan to do next. Professor Liston usually sees each student once a week for a private discussion."

"Have any of the students come up with worthwhile inventions?"

"You bet. Last year a third of them came up with ideas for new devices that merited invention disclosure, patent research, and application. Among them was a pressure-sensitive coating that can be painted on obstetrical forceps to show a doctor when the instrument is pressing too hard on a baby's head, a variable-intensity stoplight that shows the following car how hard the brakes are being applied, and an automatic feed for soldering guns."

"That's fine. You know, we service technicians should be in a favorable position to do some inventing in the electronics field. We have the technical know-how, and we've not had our inventiveness stifled by the regimented study of the engineer. I personally know several technicians who have worked out clever service tools and instruments, but few of them ever bother to patent these—probably because they think getting a patent is too complicated and too expensive for the limited market the gadget would enjoy. In some cases—but not all—this is true.

"Actually, what I think we technicians should do is lift our eyes from the service bench and look about for needs outside the service business to which we can apply our knowledge of electronics and come up with useful inventions. Such a need may be spotlighted by a talk with a doctor, an automobile mechanic, a police official, an industrialist, or even a production-line worker.

"The main thing is for the technician to think of himself as a potential inventor and not just as a radio and TV mechanic. He can put himself in this frame of mind by boning up on the procedure for obtaining a patent, by attending invention expositions in his state, and by keeping constantly alert to needs he may be able to satisfy through his knowledge of electronics."

"Okay," Barney said agreeably; "from now on just call me Tom—Swift that is!" ▲

For the Record

(*Continued from page* 6)

we will not take music power or dynamic measurements but will stick to continuous sine-wave power measurements as we have in the past.

These are really the only changes that will be apparent. There are, of course, many differences in testing procedures which do not reflect in our reports directly.

In any document as detailed as this, especially where an entire industry is trying to set standards, there are bound to be disagreements. For example, engineers in our industry have diverse opinions as to the value of an intermodulation distortion test. There are many who feel such a measurement is important but the panel, after conducting open hearings, eventually decided simply to mention this type of test but indicated that manufacturers need not report this particular distortion characteristic.

The question, of course, is whether or not IM distortion measurements are important. We feel they are. Since all of our tests are made in the same laboratory under the same conditions and with the same test equipment, we do feel that such distortion figures afford a comparison among units; therefore, we plan to continue to publish our results.

Even though there are some minor disagreements, all in all the new standard was badly needed and was extremely well done. Congratulations are in order to all those involved. ▲

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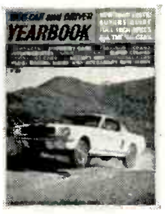

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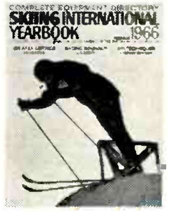

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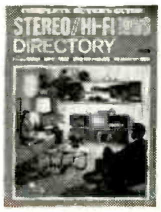

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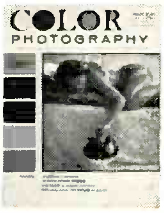

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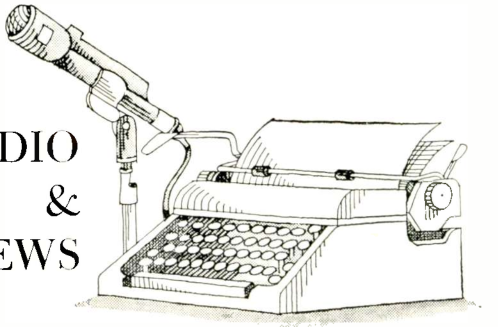
RADIO & TV NEWS



ONE of the big problems in military communications is that short-haul signalling (100 to 700 miles) presents a problem in that short-wave systems have skip and fading situations while u.h.f. or microwave systems must either have line-of-sight, or scatter techniques must be used. In scatter systems, relatively cumbersome ground equipment must be used at both ends, while an extended line-of-sight approach means the use of repeaters whose installation may not be practical.

Engineers at *Sylvania* have developed what they think is the best answer. By installing a solid-state repeater, 12 inches square by three inches thick, complete with its own batteries in a balloon, and allowing the balloon to reach relatively high altitudes, the airborne repeater acts like a low-altitude communications satellite.

In one test, when the balloon reached 30,000 feet, two-way communications in both voice and teletypewriter were established over a 250-mile path while voice communication was established over a 600-mile path. Communications were maintained for four hours before the repeater was released from the balloon and allowed to parachute down.

Voice communication was also established with an aircraft operating at low altitude beyond a mountain range which would have precluded direct ground-to-air communication.

25-Megawatt Battery

A 25-million-watt rechargeable nickel-cadmium battery, capable of producing an extended series of 5000-ampere, 5000-volt pulses has been developed by *Gulton Industries* for use in a laser power supply for military research.

The 25-megawatt battery contains several thousand pounds of active electrode and is about the size of a telephone booth.

In conventional rechargeable cells, the positive (nickel) and negative (cadmium) plates are kept from making internal contact by a separator, and are connected to the cell terminals that extend outside the cell container. Current flows from cell to cell *via* external connectors, and internal resistance can result in sizable energy loss. *Gulton's* research department has developed a very thin (three mils) impervious metal sheet which is clad on either side with nickel and cadmium plates. This backing sheet serves as the connector with the result that almost no energy is lost.

Tiny Diodes

Another step towards reducing the size of electronic components has been taken as *General Instrument Corp.* released information on its Beam-Lead diode.

This diffused epitaxial silicon diode measures .015 by .025 by .002 inch and it takes 4,000,000 of them to make one pound. A pair of gold bonding leads are the contacts.

Manufactured in batch process production similar to the fabrication of integrated circuits and some forms of transistors, 1500 diodes are formed at a time on a slice of silicon the diameter of a half dollar.

Characteristics of the tiny diodes were not given and expected use is in hybrid integrated circuits or manufactured as diode arrays for computer matrix use. ▲

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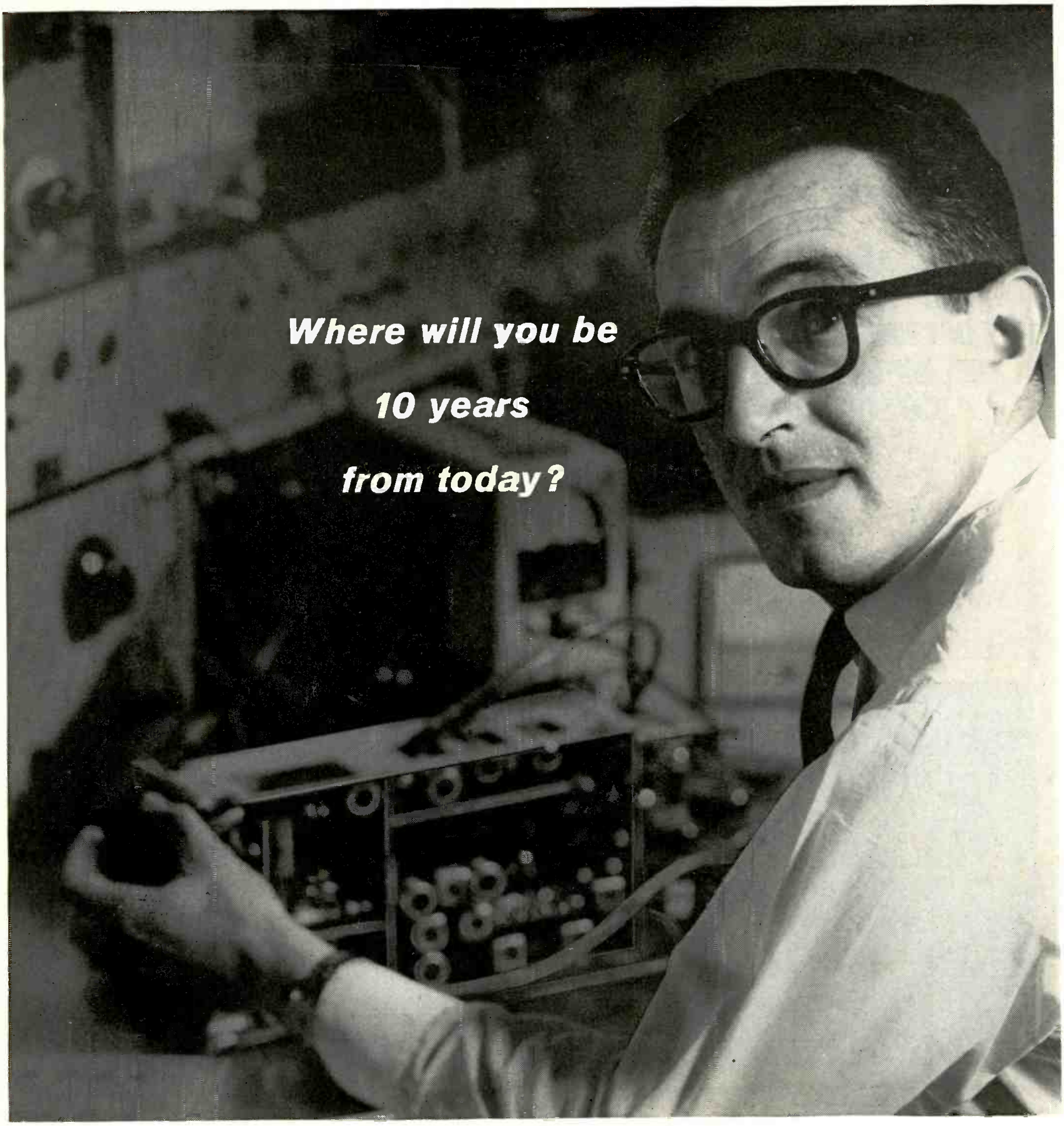

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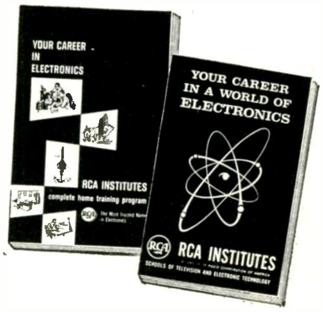

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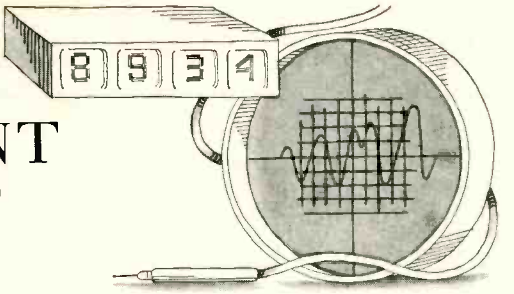


Tektronix 106 Square-Wave Generator

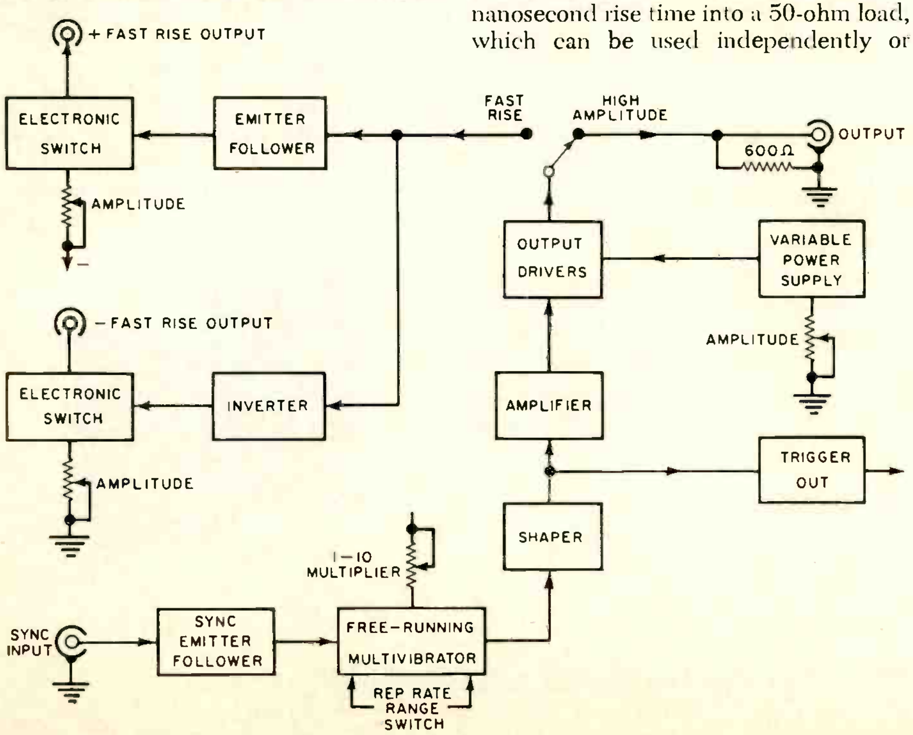
For copy of manufacturer's brochure, circle No. 152 *on Reader Service Card.*

THE design of the *Tektronix* Type 106 square-wave generator resulted from the need for a fairly fast rise square wave with maximum flatness, variable repetition rate, and variable amplitude. Some of the possible applications include adjusting time constants of attenuators, adjusting vertical amplifiers for best transient response, checking transient response of amplifiers, diode recovery testing, core testing, and digital and analog design procedures.

The Type 106 can be used as a laboratory or general-purpose instrument. It produces variable repetition rate square waves with high-amplitude slow-rise characteristics, or low-amplitude fast-rise characteristics. One unique feature of this instrument is that all square-wave outputs are from either a positive or negative potential to ground, providing a very flat pulse top.

The high-amplitude function provides variable square-wave amplitudes up to 130 volts with no external terminations, or to 12 volts (240 milliamperes) when working into a 50-ohm load.

The fast-rise function provides variable-amplitude, positive- and negative-going square waves of less than 1 nanosecond rise time into a 50-ohm load, which can be used independently or simultaneously by means of two output connectors.



Provision has been made for sync input and trigger output *via* front-panel BNC connectors. The Type 106 will synchronize with sine waves, square waves, or pulses. The trigger output waveform is a differentiated square wave which coincides with the square-wave outputs.

In referring to the block diagram, it can be noted that a free-running multivibrator produces square waves from 10 Hz to 1 MHz, as determined by "Repetition Rate Range" and "Multiplier" control settings. The square wave from the multivibrator is then shaped and amplified to provide a drive pulse to the output tubes. These tubes are then run from zero bias to cut-off at the predetermined repetition rate.

When at zero bias, the output current flows through 600 ohms to ground, in parallel with whatever is loaded on the output connector. The current flow is determined by a negative supply which is variable from about 20 to 180 volts by means of an amplitude control. When the tubes are cut off, the current flow ceases and the output starts moving toward ground (zero volts) thereby producing a flat-topped square wave.

The instrument is 6″ high by 9″ wide by 15″ deep and its case can be tilted upward if desired. Price of the generator is $590. ▲

Waveforms 610B Audio Sweep Generator

For copy of manufacturer's brochure, circle No. 153 *on Reader Service Card.*

THE *Waveforms* 610B is a no-moving-parts audio sweep generator. It is voltage-tuned and may be directly interconnected in systems with scopes and recorders for automatic frequency response plotting.

A sweep generator may be built using a beat frequency oscillator, but such equipment is bulky, complicated, and usually requires mechanical tuning. The 610B is simple and small in size. The oscillator is of the voltage-tuned type with a broad tuning range, from 20 Hz to 20 kHz. It is tuned with a control voltage that is generated internally or externally. One volt tunes the oscillator to 20 Hz; 10 volts tunes it to 20 kHz.

The control voltage varies the resistive elements in the oscillator's Wien bridge *RC* tuning network. The resistors are photosensitive (sensitive to light) and are excited by miniature lamps driven by a differential amplifier, one input of which is the 1- to 10-volt control voltage.

A logarithmic frequency sweep characteristic is highly desirable for audio work and is achieved in a closed-loop correction system, see below. Correction is based on using a truly logarithmic

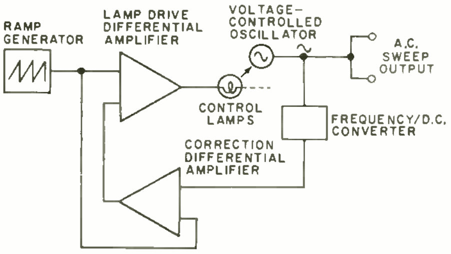
element in the closed loop as a reference. This element is a logarithmic frequency-to-d.c. converter with output of 1 volt for 20-Hz input, and 10 volts for 20-kHz input—the same basic range as the control voltage.

Converter output voltage and control voltage differ in proportion to the deviation of the oscillator from the exact logarithmic transfer characteristic. This difference is used to correct the oscillator frequency to where it should be. Oscillator frequency is corrected by feeding both converter and control voltages into a differential amplifier whose output is their difference. The difference is fed to the other input of the differential lamp-drive amplifier, closing the loop and making the necessary modification to lamp drive for log transfer.

Oscillator signal output is fed to a power amplifier which delivers 2.5 volts into a 600-ohm load with a 600-ohm source impedance.

The control voltage source is selectable. An external source, such as a retransmit pot of a recorder, may be used. A front-panel potentiometer permits manual-sweep or fixed-tone operation. A control ramp generator is built into the 610B. Output of a constant-current generator circuit advances linearly from 1 to 10 volts and resets itself to 1 volt for the next sweep. A front-panel control permits continuous or one-shot sweeping. A push-button delivers the start command for one-shot operation.

A frequency meter, 100-dB signal attenuators, and a.c. power supplies complete the electronics. Although 53 transistors are used, a miniature package size has been achieved. Panel size is 6" x 4¼" and case depth is 6". Price is $1000. ▲



Biddle "Major Megger" Insulation & Continuity Testers

For copy of manufacturer's brochure, circle No. 154 on Reader Service Card.

THE new "Major Megger" insulation and continuity testers open up a new field of usefulness for those responsible for electrical tests in the plant or in the field. The two models available, with their multi-voltage and multi-range facilities, meet an extremely wide variety of modern testing needs.

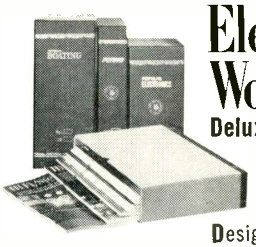
The testers are employed for detecting and diagnosing faulty insulation before serious and costly damage occurs. Their chief applications include tests on motors, generators, transformers, power cables, control equipment, switchboards, appliances, and electronic and communications equipment.

One model, the low-range instrument, has a range of zero to 200 megohms with four voltages of 100 to 1000 volts. Included is a continuity range of zero to 100 ohms. The high-range model has three voltages of 250, 500, and 1000 volts and discharge ranges from zero to 2000 megohms, together with a continuity range of zero to 20,000 ohms.

The movement is the famous "Megger" cross-coil ohmmeter—not simply a voltmeter calibrated in ohms; therefore, the accuracy is not affected by variation in test voltage. The hand-driven brushless a.c. generator, working with a solid-state rectifier and stabilizing circuit, supplies constant test voltage. There is no dependence on batteries or other supply source. A minimum of tuning effort is required; operation is smooth and quiet.

These new instruments are small and light yet are sturdy and resistant to the ravages of rough and constant use in the shop or field. They represent a practical answer to insulation resistance testing problems.

The low-range instrument is priced at $250, and the high-range instrument, with the discharge feature, is $275. ▲



EW Lab Tested

(*Continued from page 22*)

zero. The calibration of the tracking-force dial was very good, within 0.2 gram on a balance-type gage. There was no measurable change in force over a 1-inch change in the height of the arm.

Turntable speeds were, of course, adjustable to exact values, using the stroboscopic disc supplied with the unit. The range of adjustment was between approximately 2 percent slow to approximately 4 percent fast. Speeds were unaffected by line voltage variations from 100 to 130 volts.

Rumble was even lower than that of the 1009 previously tested. It was about −36 dB, mostly in the lateral plane. This is very low, comparable to the very best manual-play turntables, and far better than most automatic record players. The wow and flutter were also extremely low, 0.07 and 0.02 percent, respectively, at 16⅔ and 33⅓ rpm. At 45 and 78 rpm, the wow increased slightly to 0.09 percent and at 78 rpm the flutter rose to 0.04 percent. All of these figures are of the magnitude one expects from good professional equipment, and are far better than those encountered in ordinary record changers.

The *Dual* 1019 was found to be exactly as represented—without a doubt one of the finest record-playing mechanisms we have used. It combines the best features of manual and automatic players in an unusually compact package priced at $129.50. ▲

Grado Model "B" Phono Cartridge

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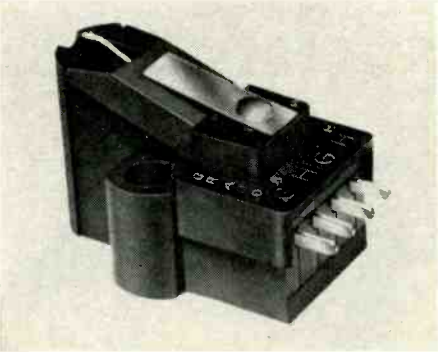


AFTER many years of association with magnetic, moving-coil phono cartridges of the highest quality, *Grado Laboratories* is now offering a solid-state cartridge which features the firm's traditional performance standards at a much lower price. The new Model "B" stereo pickup uses two tiny stress generators to produce its output voltage, but is in all respects interchangeable with magnetic cartridges and requires no adapters or external power supplies for equalization. (*Editor's Note: This cartridge appears to be a special piezoelectric ceramic type with built-in equalization and loading.*)

The Model "B" has its stylus decoupled from the elements so that it can take advantage of the small tip mass and high compliance necessary for top quality phono reproduction, without the need for flexing a relatively stiff generator element. It is designed to be connected to the standard 47,000-ohm preamplifier input used with magnetic cartridges, and has an output of about 4 millivolts, comparable to any good magnetic cartridge.

The stylus assembly is easily removable without tools and is, therefore, replaceable by the user, unlike the delicate stylus assemblies used in the moving-coil *Grado* cartridges. It is available as the Model BR (which we tested) with a 0.6-mil spherical diamond stylus, the Model BE with a 0.3 × 0.6 mil elliptical stylus, and the Model B3, with a 3-mil stylus for playing 78-rpm discs. Due to the exceptional simplicity of stylus changes, it is perfectly practical to use one cartridge and change stylus assemblies for different records.

The design of the cartridge brings with it several noteworthy advantages over magnetic cartridges. Obviously, there is no susceptibility to magnetically induced hum. Furthermore, the internal impedance of the Model "B" is only 12,000 ohms, in contrast to the nearly infinite impedance of most ceramic cartridges. This makes it equally insensitive to electrostatic hum pickup, which is sometimes a problem with high-impedance ceramic cartridges. Also, the elimination of unavoidably heavy magnets and pole pieces results in a very lightweight cartridge—3.5 grams—which is desirable from the standpoint of reducing the mass of the entire pickup system.

We had to use a tracking force of 3 grams to minimize distortion at the very high velocity (30 cm/sec) of the 1000-Hz bands on a *Fairchild* 101 test record. The lowest frequency bands of the *Cook* Series 60 record required 5-grams force, but this represents an extreme condition which we have never found on stereo records. We used a 3-gram force for all our subsequent testing. *Grado* rates the cartridge as operable from 1.5 to 5 grams with optimum tracking at 2.3 grams, and we indeed found that it did not exhibit any audible distortion on almost all stereo records at a 1.5-gram force. In all probability, a 2- to 3-gram force would be optimum for most users.

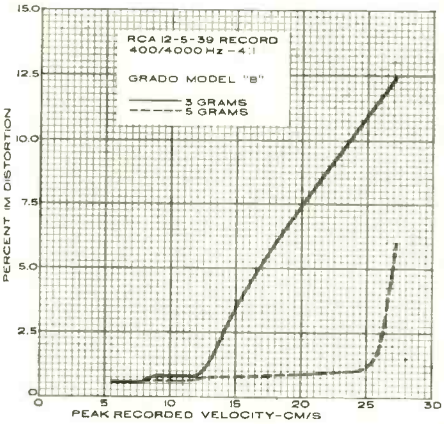
The frequency response with the *CBS* STR-100 record, was extremely smooth, with no peaks or holes exceeding 0.5 dB over the range from 20 to 14,000 Hz.

The high frequencies were slightly de-emphasized (not a drop-off, but a very gradual slope starting at a few thousand cycles) but without any stylus resonance apparent all the way to 20,000 Hz. The channel separation was about 27 dB at middle frequencies, decreasing smoothly to 10.5 dB at 10,000 Hz and disappearing at 15,000 Hz and higher.

The intermodulation distortion, using the 78-rpm *RCA* 12-5-39 record, was extremely low at normal record velocities. The IM was under 1% for velocities up to 12.5 cm/sec at a 3-gram force and at 24 cm/sec with a 5-gram force. Although we did not measure the distortion at 1.5 grams, it does not differ audibly from the 3-gram condition.

There was absolutely no hum when using the cartridge. It had a clean, smooth sound which, to our ears, was as good as anything we had heard previously. To satisfy our curiosity, we A-B compared it against the deluxe Model "A," which sells for more than twice its price. The only difference we could find was a slightly more brilliant extreme high end in the Model "A," which imparted a slight sheen to strings and certain percussive sounds. This difference could not be detected except by an instantaneous switchover between the two.

Selling for only $19.95, the *Grado* Model "B" offers the finest quality sound at a real bargain price. The 3-mil stylus version is $19.95; the elliptical stylus cartridge is $32.50. ▲

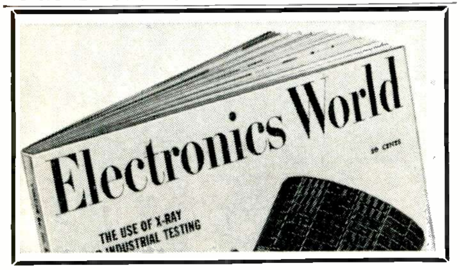


SCA "MUSIC PIRATES" SUED

THE Los Angeles Muzak Franchise has won a permanent injunction and substantial cash damages in its suit against background music "pirates."

A number of manufacturers of SCA background music receiving equipment have been permanently enjoined from making, selling, leasing, distributing, installing, giving away, or using an SCA tuner or adapter.

Muzak contended that Section 605 of the FCC regulations covering wire tapping, covered the interception or use of content of any private point-to-point communications, including private radio broadcasts intended for subscribers and licensees of SCA services. ▲



Derived Center-Channel STEREO SYSTEM

By DAVID HAFLER/President, Dynaco, Inc.

A simple method of deriving a center or third channel without the use of an extra transformer or amplifier.

WE have long felt that the trouble with conventional stereophony is not the reproduction of stereo sound, but the reproduction of the monophonic content of the sound. The monophonic component is the part which is identical in both channels—and if you sit on the centerline between the speakers, this portion sounds centered between the speakers. However, if you change position, the sound seems to emanate from the closer speaker, and the center effect is lost. If you rebalance, it can be maintained in the center, but only for one specific listening location, and other listeners do not have this centered component of sound.

If the monophonic portion can be kept in the center, such as with a center speaker, while the stereo (or non-common) portion can be kept in the sides, then the original spread of sound can be maintained relatively independent of the listener's position.

There have been several ways to combine left and right channels to feed the composite into the center speaker. Some of these systems require an extra amplifier. Some require a "floating" output winding without normal ground reference. All the systems are intended to present the sum of the two channels as being representative of the monophonic sound. It is evident that it is the *sum* which is required rather than the *difference*, because the difference of the two channels cancels out the common portion of the sound, thus eliminating the portion which should be retained.

The *Dynaco* system (Fig. 1) is a very simple connection in which the sum of the two channels appears in the center. The signal from each side divides between center and its side. The parts of the signal which are common add in the center so that this common portion is 6 dB higher in the center than in the sides. Thus, the common portion, which should appear in the center, predominates in the center and sounds centered irrespective of the listener's position.

One limitation of this system is that the signal from one side "leaks" over to the other side *via* the center common impedance. This introduces some crosstalk which has limited the usefulness of this system. However, this system introduces a way to eliminate this crosstalk.

Examination of the basic hookup reveals that the crosstalk signal drives the speakers from the side opposite to which they are driven by the amplifier. In other words, the crosstalk is out of phase with the signal which would appear through the amplifier. This leads to the unexpected possibility of *blending* the inputs of the amplifier and introducing crosstalk which cancels the out of phase and undesired crosstalk. Fig. 2 shows the simple circuit (on which a patent is pending) in which blending is used.

The source impedances of the amplifiers must be taken into consideration to obtain the proper amount of blending. If all the speakers have the same impedance characteristics, a signal on one side should produce a crosstalk signal of 6 dB less magnitude in order to get the optimum results. If a variable blend is used, it can be adjusted very simply by using one input source only and adjusting until there is a distinct signal null on the other channel.

The result of using the blending is that monophonic signals (or the common portion of stereo signals) sound as if they come from the center speaker—in fact they do emanate principally there. One-sided signals appear to come from between the speaker on the one side and the center speaker. This narrows the apparent separation somewhat. However, by extending the space between the speakers, the original separation is still obtainable while having the benefit of centralization of the common

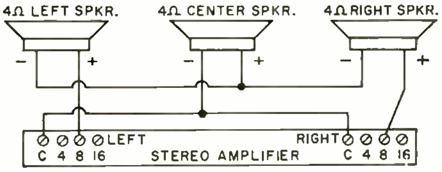
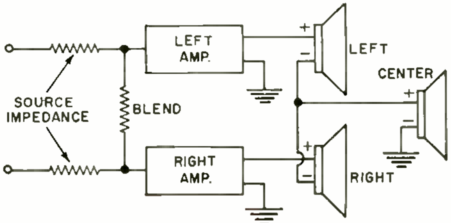


Fig. 1. Note that 4-ohm speakers are connected to 8-ohm amplifier taps. Eight and 16-ohm speakers connect to 16-ohm taps.

Fig. 2. By blending the inputs it is possible to cancel out undesired crosstalk.



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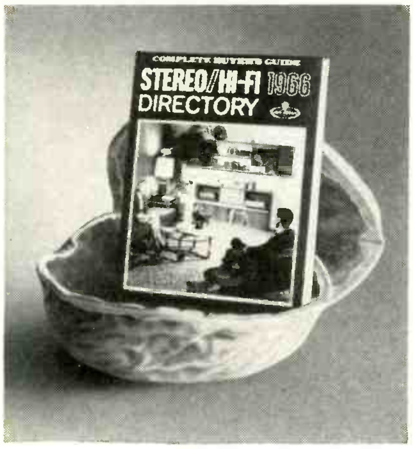

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sound. The stereo perspective remains independent of listener's position.

For a one-sided signal, the side and center speakers appear as a series load. Therefore, optimum impedance matching would be to use 4-ohm speakers on the 8-ohm amplifier outputs, and 8-ohm speakers on 16-ohm outputs. The system offers a slight mismatch when both sides are driven. Fortunately, however, in that case both amplifiers are combining outputs, so plenty of power is available despite the mismatch. When one side only is functioning, the match is correct for maximum power transfer.

If the center speaker is to be used as a remote monophonic speaker, the stereo pair performs normally, with the remote handling the sum of both channels. If the level of the remote must be separately controlled, this can be done with a shunt potentiometer (zero resistance giving 100% attenuation) across the remote. Then, however, it is necessary to make a new setting of the blend resistor for any change in the remote attenuator. The procedure for finding this setting is to select the resistance which produces a null in the left speaker when only the right side is furnished signal, or *vice versa*. This blend setting must be established *after* the level is set for the remote loudspeaker. By following this procedure, there is no crosstalk introduced into the stereo setup by use of the remote. ▲

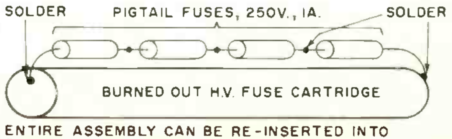
FUSE PROTECTION

By CHARLES C. MORRIS

WHILE working with high-voltage power supplies, several instances occurred where output voltage failed due to overload but the fuses did not blow. The power supplies are designed to operate at 2500 v.d.c., 1 ampere, and are regulated by a transistorized feedback circuit. The supplies are supposedly protected by 5000-V, 1-ampere fuses in the output circuit.

However, when an overload occurred, transistors and other components burned up in the regulator circuit before the fuses would blow. This was due to the slow fuse burn-out time as compared to that of transistors and diodes. The trouble was corrected by mounting a string of 1-ampere, 250-V fuses across the burnt out high-voltage fuse cartridge. The smaller fuses have a considerably faster burn-out time.

The number of fuses in the string depends on the voltage levels used. For example, four 250-V fuses would be used in a 1000-V supply. The composite fuse block should be covered since small glass fuses can explode during burn-out. ▲



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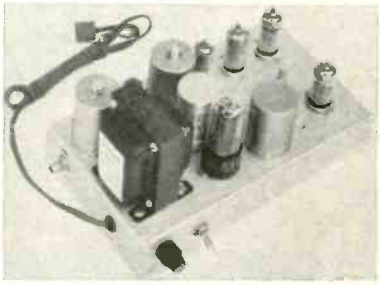

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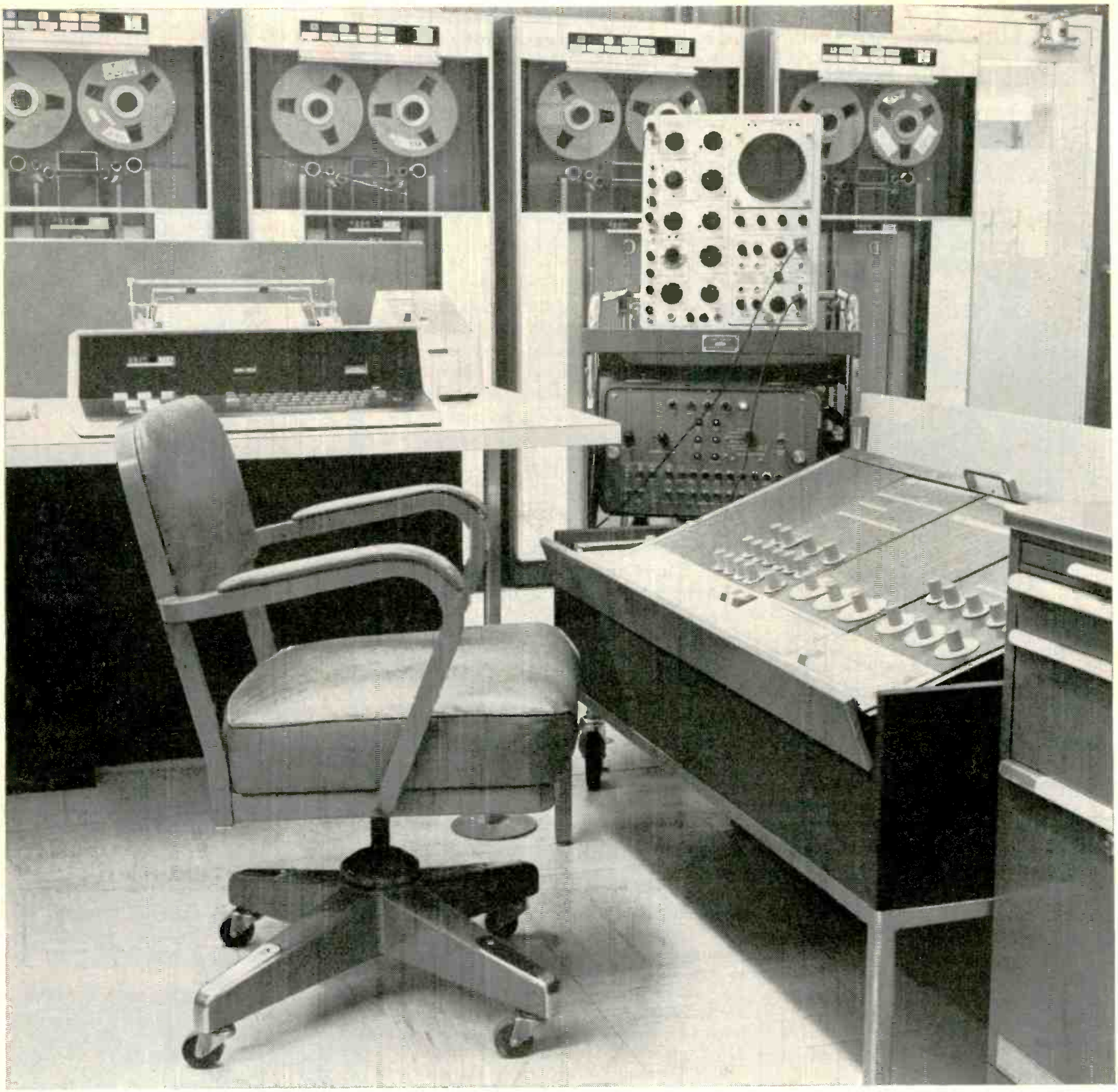

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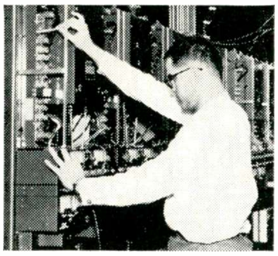

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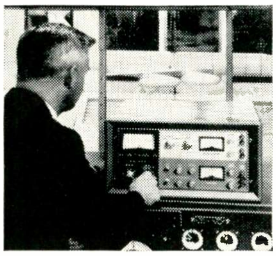

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EFFECTIVE USE OF THE V.O.M.

By CARMEN J. DIODATI
Army Metrology & Calibration Center, Frankford Arsenal, Philadelphia

A knowledge of the meter specifications, along with their proper interpretation, are required for effective use.

NO one who has purchased a v.o.m. will deny the fact that he has made a wise purchase. Whether the multimeter cost him $10 or $100, he will assure you that above all—it is accurate. Yet in some instances the inaccuracy of the meter exceeds 100 percent.

The meter can only be depended upon if you know what it is supposed to read and how to interpret the reading. Therefore, the effective use of a v.o.m. requires a knowledge of the specifications and the proper interpretation of those specifications. Only then can the v.o.m. take its rightful place as the most versatile and most frequently used instrument in the electrical and electronics field.

Meter Specifications

The design of any item is developed around specifications. In v.o.m.'s, the most generally known particulars are sensitivity (ohms/volt) and range. Beyond that, knowledge of the specifications becomes superficial. For example, the voltage and current accuracy are given as some percentage of full-scale. Full-scale is defined as the movement of the meter pointer from its rest position (zero) to the last scale division. In many instances, the term "full-scale" is not included as a part of the specifications; however, unless otherwise stated, full-scale accuracy is implied. If the average user of a v.o.m. is questioned regarding the accuracy of the meter, a flat statement of 3 percent (for example) is given. The accuracy statement is accepted with no consideration as to its meaning. The general assumption is that any measurement made with the meter will be within 3 percent of the dial indication. The fallacy of this impression can be carried for years and never realized until such time when a critical parameter must be known.

The problem is supposedly solved by substituting a vacuum-tube voltmeter. However, no increase in accuracy is obtained because the accuracy of the ordinary vacuum-tube voltmeter is exactly the same as the v.o.m. The advantages obtained from this substitution are increased sensitivity and/or negligible loading of the circuit under test.

Fig. 1 clearly illustrates the acceptable error of a 3-percent full-scale meter. Observe that the 3-percent error exists only at the last division of the meter scale. As the pointer approaches zero, the meter error remains constant; however, the percentage of error increases until the over-all error reaches and exceeds 100 percent at the very low end of the scale. The explanation for this large variation in accuracy is in the interpretation of what the manufacturer means when he states full-scale accuracy. He means that an exact 100 volts measured on the 100-volt range may, with a 3-percent full-scale tolerance, indicate from a minimum 97 to a maximum off-scale reading of 103 volts. Whatever the error is at full scale, it may also exist at each point of the meter scale.

If the meter is off 3 volts at full-scale, the same 3-volt error may occur at the 3-volt point, and this results in a 100-percent error at that point. If the same scale is used to measure 1½ volts, the error will be 200 percent. Meters which are accurate to a percentage of indicated reading are higher cost, laboratory-type instruments.

The information presented thus far is also applicable to the a.c. ranges of the v.o.m. except that the a.c. scales are usually less accurate than the d.c. scales by one or two percent. Frequency range of the v.o.m. is also a limitation. If this is exceeded, v.o.m. inaccuracy is also increased.

Resistance Ranges

The accuracy specification of the meter for resistance differs from that of the voltage and current ranges. Since the ohms scale is not linear, the allowable error is given as some number of degrees of arc, or percentage of arc length. The arc length of a v.o.m. is usually 90 or 100 degrees—depending upon the manufacturer's design. Since v.o.m.'s also have linear scales, the arc length may sometimes be determined by observing the voltage scale or range. If there is any doubt, a protractor can be used to determine the arc length.

The procedure for determining the allowable error for the ohmmeter scales is as follows. (1) Determine the arc length in degrees. (2) Count the number of divisions on a linear scale. (3) Divide the number of divisions of the linear

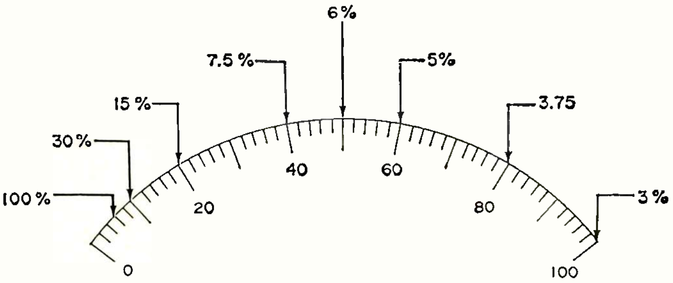


Fig. 1. Error percentage at various readings on meter scale.

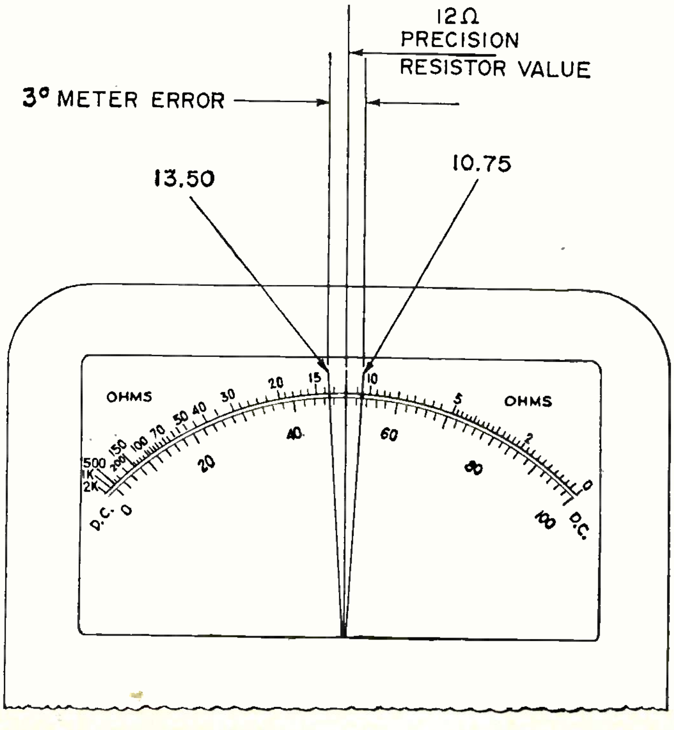


Fig. 2. Meter error within 3 degrees of arc when measuring a 12-ohm precision resistor. In this case, entire scale length is 100 degrees, so error is same as 3 percent of full-scale.

scale into the meter arc length. The result is the number of linear divisions per degree on the meter scale.

Example: Assume the resistance accuracy is within 3 degrees of arc, and that the arc length is 100 degrees, and the scale has 50 linear divisions. Then, each linear division represents 2 degrees of arc. Therefore, the meter indication can be 1½ divisions of the linear scale, projected to the ohms scale on both sides of the ohmic value being measured.

Fig. 2 shows the acceptable limits of meter indications for an exact 12-ohm resistor. When the meter error is considered with the precision resistor, the results can be an inaccuracy of approximately 1.5 ohms in 12 or a total error of 12.5 percent.

If the reading is taken at the high-resistance end of the ohms scale, the over-all error expressed as a percentage becomes even greater. Therefore, all resistance measurements should be made using the lowest resistance portion of the scale whenever possible. ▲

A VERSATILE MULTIVIBRATOR

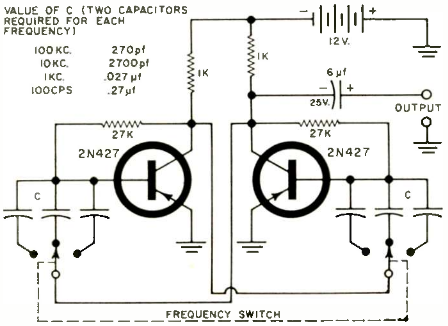
By IRWIN MATH

THE circuit described here is a low-cost, general-purpose multivibrator. It will find use in a multitude of devices built by the electronics technician. One very obvious application is as an audio square-wave generator for use in testing the frequency response of amplifiers, modulators, etc. By choosing various values of coupling capacitors, the multivibrator can be made to operate from 30 Hz or so to better than 100 kHz with good square-wave output. Several values of capacitors are given for various frequencies.

Essentially, the collector-coupled multivibrator is a simple, conventional resistor-capacitor coupled amplifier with the output of one stage coupled to the input of the other stage. Since the signal at each collector is in phase with the signal at the opposite base, regenerative feedback results and the circuit oscillates.

This circuit is capable of supplying a symmetrical 10-volt peak-to-peak square wave to a high-impedance load such as a vacuum tube. ▲

Circuit diagram of a simple, low-cost, general-purpose multivibrator suitable for use in testing the frequency response of audio amplifiers, modulators.



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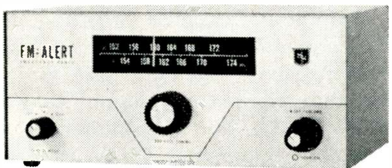

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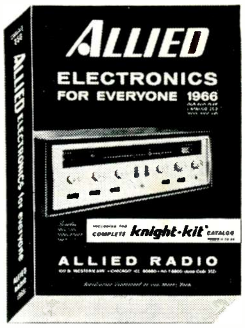

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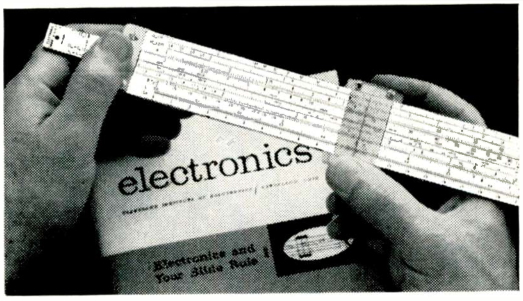

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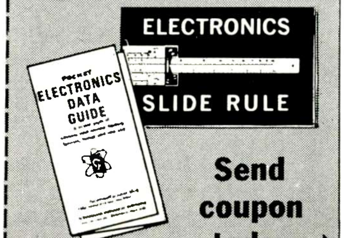

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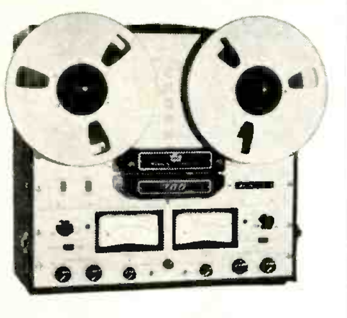
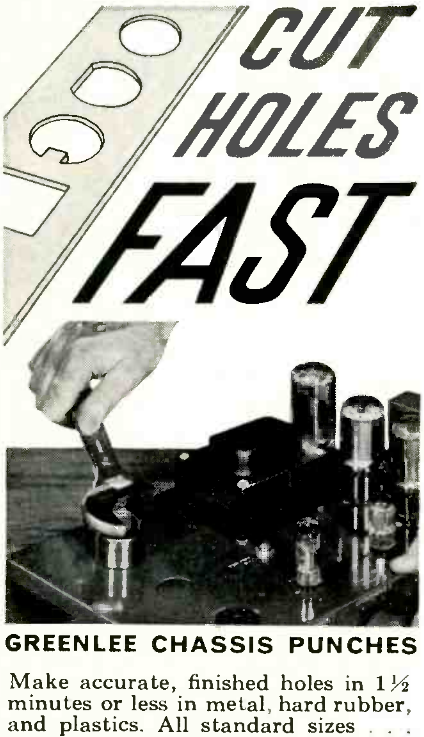




V.H.F. Radio Conference

(*Continued from page 29*)

additional channels available to them or (2) increasing the number of shore stations to give satisfactory coverage. All the elements of a communications "squeeze play" are present.

In the New York area, for instance, there are—according to Mr. Mattern—approximately 100 subscribers (v.h.f.) to their service. Asked what his estimate was of the maximum channel-loading, Mr. Mattern said: "Fifty."

In other words, the two operational v.h.f./FM marine operator frequencies in the New York area are already at their traffic maximum (two channels × 50 subscribers = 100 subscribers, which is what they now have) *and the N.Y. Telephone Company has yet to give any indication of expansion!*

"Manufacturers could organize their own 'common carrier company,' " said Mr. Mansbach of the New York Federal Communications Commission field office when asked for his comments. "I'm sure the Commission in Washington would go along with such a company if there is enough public interest, convenience, and necessity for this service."

That the telephone companies might awaken was the stand taken by Mr. V. K. Lewis of *RCA*.

"I think the telephone companies look at the economics of communications like anyone else," was his opinion, "and if there's going to be traffic there, they're going to program for it."

When? seemed to be the question in everyone's mind.

It's very evident that the phone companies have a problem. To give proper, complete marine v.h.f. telephone service, they must equal or better the Coast Guard v.h.f. installation according to many. The marine two-way radio is firmly wedded in the average recreational-boater's mind to the telephone. He even refers to it as his "ship-to-shore phone." It's his link with land—and the telephone company.

"The ability to put in a phone call with fairly good quality and good signal," said Mr. B. H. Ballard of the *Konigsberg Company*, "is important to people."

Coast Guard Coverage

For the various companies involved to duplicate the U.S. Coast Guard's impressive coverage in v.h.f. marine will be a tremendous job. But it certainly must be done.

With 18 authorized channels; a "marina" or "yacht club" frequency; provisions for direct contact with bridge and lock-tenders; with a massive Coast Guard shore and vessel installation program virtually complete; a continual 5:30 a.m. to 10:30 p.m. taped weather forecast soon available from 18 stations of the Weather Bureau (162.55 MHz) along the East Coast and more planned—the v.h.f./FM marine band will present a crippled public image if but 40% of the Public Correspondence channels are being used and these only in a few circumscribed areas.

The U.S. Coast Guard has been waiting impatiently for greater pleasure-boat acceptance and use of the new marine band. Of great concern to them is the congestion (especially during summer months) on the 2-3 MHz AM marine frequencies. In their opinion, v.h.f./FM will aid in solving this problem.

"We're going to conduct as much of our operations as possible on v.h.f./FM," stressed Commander H. J. LeBlanc (East Coast Area Coast Guard Communications Officer), "to relieve the congestion on the 2-3 MHz band."

High Interest in V.H.F.

The Coast Guard, the FCC, the v.h.f.-producing companies and the visitors to the Boat Show weren't the only ones interested in the new v.h.f./FM marine band. Several companies who had, in the past, expressed no interest in equipment for the recreational boater sent representatives. *RCA*, for one.

"We are phasing out of the pleasure-boat market," said a representative of that company on March 30, 1965. Yet—and only 10 months later—they sent a two-man team to a v.h.f. communications conference devoted to v.h.f./FM for the pleasure boater!

One got the feeling, both during the discussion and afterwards in talking to them in their exhibition booths, that the manufacturers of communications equipment (especially newcomers to the v.h.f. marine field) were stunned by the overwhelming interest of the Boat Show visitor in marine v.h.f./FM. One executive was glassy-eyed.

"We've sold over 50 v.h.f. rigs," he said. "It's unbelievable!"

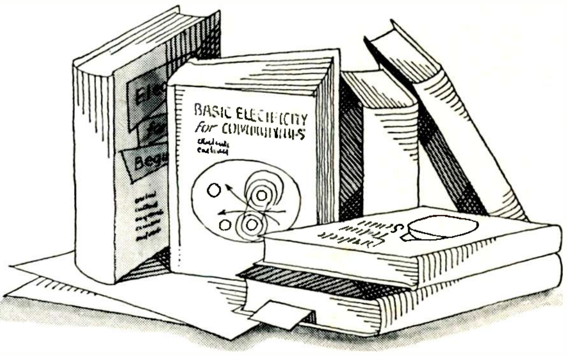
The national sales manager of another company which has only progressed as far as testing the prototype of its v.h.f./FM transceiver told me: "We aren't even *producing* the units yet and I feel like we've been in the v.h.f. business for years. It's all," he nodded at the throng around his booth, "they can talk about."

Mr. Stiles of *Canadian Marconi* forecast that "v.h.f. marine is going to snowball—there's no doubt about it!"

With the unexpectedly large attendance at the Marine Communications Companies' Conference and the intense interest shown by the average Boat Show visitor, it looks like it has started already.

"Quite frankly," the engineer of one major concern commented, "we didn't expect that much snow. . . ." ▲

BOOK REVIEWS



"OPTICAL AND ELECTRO-OPTICAL INFORMATION PROCESSING" edited by James T. Tippett *et al.* Published by *The M.I.T. Press,* Cambridge, Mass. 02142. 775 pages. Price $30.00.

This volume comprises the Proceedings of a Symposium on Optical and Electro-Optical Information Processing Technology held in Boston. The papers discuss optical and electro-optical techniques for storage, logic, display and sensing; recent related device and circuit research on optical generation, detection, modulation, amplification, and control; and recent information processing research, including such fields as optical character reading, information retrieval, and digital processing systems.

This well-illustrated and comprehensive volume will be of special interest to computer engineers, optical physicists, research scientists in the field of optics, and those with a peripheral interest in the field. Much of the treatment is mathematical and it is assumed that readers of this text will be familiar with data processing procedures and equipment.

* * *

"DICTIONARY OF ELECTRONICS AND WAVEGUIDES" by W. E. Clason. Published by *American Elsevier Publishing Company, Inc.,* 52 Vanderbilt Ave., New York, N.Y. 10017. 833 pages. Price $26.75.

This is a revised and enlarged second edition of a multi-lingual reference work which provides cross-referencing of electronic terms in English/American, French, Spanish, Italian, Dutch, and German.

The words or phrases are presented in standard dictionary format, with a definition in the principal language of the edition and then the equivalent word in the five other languages. In the appendix section, the words in each language are listed alphabetically with reference to the basic English listing in the body of the book.

Those whose work involves keeping in touch with foreign technical publications will undoubtedly find this dictionary of value in assigning precise meanings to unfamiliar technical expressions.

* * *

"SEMICONDUCTOR CIRCUITS HANDBOOK" compiled and published by *Tech-Press, Inc.,* Brownsburg, Indiana 46112. 191 pages. Price $2.95. Soft cover.

This is a compilation of over 70 circuits designed specifically for the do-it-yourself hobbyist and experimenter. The circuits are divided into five main categories with a number of variations on each general type. The categories covered include direct-coupled amplifiers, audio-frequency amplifiers, high-frequency amplifiers, a.f. and r.f. oscillators, and switching circuits.

In each case a complete schematic and parts values are given along with a discussion of the circuit, possible variations, and pertinent details on operating parameters.

* * *

"DICTIONARY OF ELECTRICAL ENGINEERING" by K. G. Jackson. Published by *Philosophical Library Inc.,* New York, N.Y. 373 pages. Price $10.00.

This is a compilation of, principally, British engineering terms based on standards used by the Institution of Electrical Engineers and other English professional groups. While many of the terms will be totally unfamiliar to American engineers and technicians, the definitions and, in many cases, explanations of common words should prove helpful.

Included are the more important terms from related subjects such as electronics, lighting, and constructional materials. Mathematical principles are also covered if they are pertinent to electrical calculations. Data on abbreviations and letter and graphical symbols is incorporated in several appendices.

* * *

"MOBILE AND MARINE STATION LICENSE MANUAL" by Leo G. Sands. Published by *Howard W. Sams & Co., Inc.,* 320 pages. Price $6.95. Soft cover.

This is a compilation of FCC Rules and Regulations as they pertain to the marine and land mobile radio services. The advantage with this book is that the author has extracted the relevant material thus saving the prospective licensee a session of wading through a mountain of FCC material.

The book contains hundreds of charts, tables, line drawings, and diagrams and is illustrated by photographs of various types of commercial equipment available for use in the services covered.

* * *

"THE THEORY OF ELECTROMAGNETIC WAVES" edited by Morris Kline and **"ELECTROMAGNETIC THEORY"** by Ernst Weber. Published by *Dover Publications, Inc.,* 180 Varick St., New York, N.Y. 10014. $3.00 and $2.75, respectively. Soft covers.

These two volumes are inexpensive, soft-cover re-issues of material which has long been unavailable to engineers and students. The first volume contains papers presented at the Symposium on the Theory of Electromagnetic Waves held at New York University in 1950. Such well-known contributors as Julian Schwinger, W. Magnus, S. N. Karp, N. Marcuvity, S. O. Rice, K. O. Fredericks, H. Bremmer, S. A. Schelkunoff, and Morris Kline are represented.

The static problems of electromagnetic theory are covered in the second book by Ernst Weber, president of the Polytechnical Institute of Brooklyn. His work is for practicing engineers, applied mathematicians, and physicists and he has assumed a background knowledge of the electromagnetic field and the principles of vector analysis on the part of his readers. Both theoretical and practical aspects of the subject are covered.

* * *

"MODERN RADAR: ANALYSIS, EVALUATION AND SYSTEM DESIGN" edited by Raymond S. Berkowitz. Published by *John Wiley & Sons, Inc.,* New York, New York. 649 pages. Price $19.50.

This volume is based on an intensive course given at the Special Summer Session of the Moore School of Electrical Engineering, University of Pennsylvania during 1960 and 1961. Dr. Berkowitz of Moore School has served both as editor and contributor and he is joined by such contributors as David K. Barton of *Raytheon*; W. R. Bennett of *Bell Labs*; Seymour Charton, consultant; Charles E. Cook of *Sperry*; Louis B. Lambert of Columbia University; George H. Millman of *G-E,* L. S. Nergaard and Walter W. Weinstock of *RCA Laboratories*; M. P. Ristenbatt of the University of Michigan; Mischa Schwartz of Polytechnic Institute of Brooklyn; N. A. Spencer of *Wheeler Laboratories;* and Bernard D. Steinberg and H. Urkowitz of *General Atronics.*

The text is divided into six major sections covering radar basics; basic signal analysis techniques; radar target detection and parameter estimation; resolution, ambiguity, pulse compression techniques; radio-frequency considerations; and radar system analysis and design techniques. ▲

Editor's Note: Books reviewed in this column are generally available from well-stocked bookstores. We ask our readers to please not forward book orders to us. In some cases, where distribution might be limited, we have included the publisher's address. Postage and handling are extra.

DESIGNING A TRANSFORMERLESS *POWER SUPPLY*

By RAYMOND C. BOUCHER

Two charts and a table simplify design of transformerless d.c. power supply useful in many low-current applications.

THIS article presents data that can be used to design transformerless, semiconductor-diode circuits for rectifying 117-volt, single-phase, 60-Hz alternating current. The rectifier circuits considered are the half-wave and full-wave types, using capacitive and resistance-capacitance filters. Because they are economical, these types of filters are widely used where current requirements are relatively low, in power supplies for battery-powered devices, such as intercoms, transistor radios, converters for automobile radios to operate from house current, etc.

Rectifier Circuits & Filters

The four basic rectifier circuits are shown in Figs. 1A through 1D. They consist of the half-wave and full-wave semiconductor-diode types with filtering capacitors *C*1 and *C*2, bleeder resistor R_b, series resistor R_s, and load resistance R_L arranged as shown.

The filters used in the circuits are of two types; capacitive and resistance-capacitance. Figs. 1A and 1B show half-wave rectifiers with capacitive and resistance-capacitance filters, respectively. Full-wave circuits are shown in Fig. 1C with capacitive filter and in Fig. 1D with resistance-capacitance filtering.

Table 1. Approximate ripple percentage for various filters.

Approximate Ripple Percentage	Capacitive Filter		Resistance-Capacitance Filter	
	Half-Wave Rectifier Fig. 1A	Full-Wave Rectifier Fig. 1C	Half-Wave Rectifier Fig. 1B	Full-Wave Rectifier Fig. 1D
	$R_L \times C1$		$R_s \times C2$	
5.0	0.096	0.048	0.053	0.026
4.0	0.12	0.06	0.066	0.033
3.0	0.16	0.08	0.088	0.044
2.0	0.24	0.12	0.132	0.061
1.5	0.32	0.16	0.176	0.083
1.00	0.48	0.24	0.26	0.13
0.90	0.53	0.27	0.29	0.15
0.80	0.60	0.30	0.33	0.17
0.70	0.69	0.35	0.38	0.19
0.60	0.80	0.40	0.44	0.22
0.50	0.96	0.48	0.53	0.27
0.40	1.20	0.60	0.66	0.33
0.30	1.60	0.80	0.88	0.44
0.20	2.41	1.21	1.33	0.67
0.10	4.81	2.41	2.65	1.33
0.09	5.35	2.68	2.94	1.47
0.08	6.01	3.01	3.32	1.66
0.07	6.87	3.44	3.79	1.90
0.06	8.02	4.01	4.42	2.21
0.05	9.62	4.81	5.31	2.66
0.04	12.02	6.01	6.63	3.32
0.03	16.04	8.02	8.84	4.42
0.02	24.06	12.03	13.26	6.63
0.01	48.11	24.06	26.53	13.27

The resistance-capacitance filter is formed by R_s and *C*2. Capacitor *C*1 is considered to be part of the rectifier system which delivers to the *RC* filter section a voltage corresponding to the voltage developed across it. In practical *RC* filters, the reactance of *C*1 is always made small compared with series resistance R_s of the filter section, and also with load resistance R_L. Under these conditions, when a filter consists of more than one *RC* section, the total reduction in ripple voltage produced by the sections is very nearly the product of the voltage reduction factors of the individual sections.

Rectifier Forward-Current Rating

The forward-current rating of the rectifier must be of a value that will permit the unit to function without overload. Ratings of commonly available diodes vary from a few milliamperes to many amperes. The diode chosen for a particular application should have a forward-current rating that exceeds the required current by a comfortable margin.

Rectifier & Capacitor Voltage

For the half-wave rectifier, the peak inverse voltage (p.i.v.) appearing across the diode is about 2.8 times the r.m.s. input voltage. In the full-wave circuit the p.i.v. is about 1.4 times the r.m.s. input voltage. To prevent diode breakdown, you should use a diode with a p.i.v. rating of about 25% higher than required. For half-wave circuits, the p.i.v. rating is then about 400 volts, and for the full-wave rectifier it is 200 volts. Larger ratings will further increase breakdown safety, and will also increase diode life.

Capacitors with working voltages equal to, or slightly higher, than the voltage appearing across them should be used. Let us consider next the bleeder resistor.

Bleeder Resistance

Bleeder resistor (R_b) is used to limit excessive voltage rise when the load is suddenly disconnected. It will also serve to discharge the capacitors to eliminate a possible shock hazard. The value (in ohms) of the bleeder should be not less than ten times the load resistance so as not to change the value of the parallel-connected load resistance (R_L).

Fig. 2 shows the d.c. output voltage developed across capacitor *C*1 at various load currents for the half-wave rectifier, and also shows the approximate ripple percentage. Fig. 3 indicates the same information for the full-wave circuit. The no-load output voltage is very nearly equal to 1.41 times the input (a.c.) voltage. The curves in both figures were compiled using silicon rectifiers, and a line voltage of 110 volts a.c. Since line voltage sometimes varies with loca-

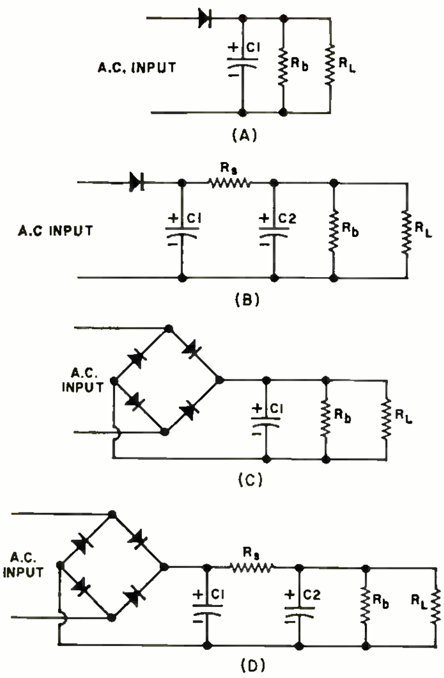


Fig. 1. Rectifier circuits and filters. (A) Half-wave rectifier with capacitive filter. (B) Half-wave rectifier with RC filter. (C) Full-wave rectifier with capacitive filter. (D) Full-wave rectifier with resistance-capacitance type filter.

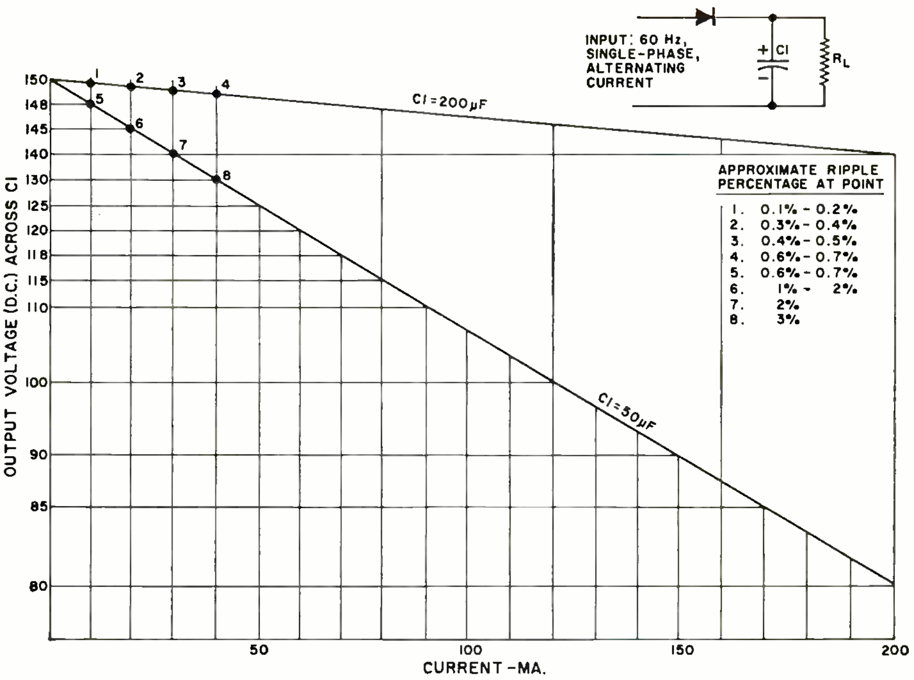
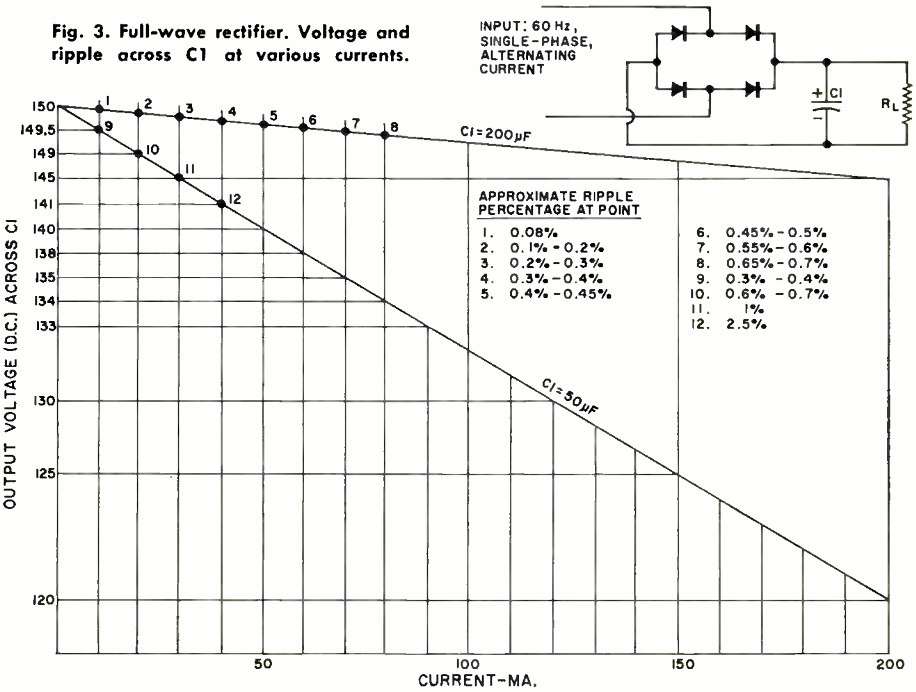


Fig. 2. Half-wave rectifier. Voltage and ripple across C1 at various currents.

Fig. 3. Full-wave rectifier. Voltage and ripple across C1 at various currents.



tion, such curves may be compiled for diodes on hand by using the circuits shown in the diagrams, varying R_L to obtain the desired current range and measuring the voltage across $C1$ at the various currents. The diagrams show values of 50 µF and 200 µF for $C1$. You can, and should, use additional values of capacitance to obtain more curves.

Table 1 shows approximate ripple percentage for the four circuits shown in Fig. 1. For the capacitive filter circuits (Figs. 1A and 1C), the ripple percentage is indicated as the product of $R_L C1$, and for the RC filters (Figs. 1B and 1D), it is shown as the product $R_s C2$. With the use of this data, it is possible to compute a value of capacitance when the load (R_L), series resistance (R_s), and the desired ripple percentage are known.

Use Table 1 to find the approximate ripple percentage when curves such as Figs. 2 and 3 are compiled. Proceed as follows: Referring to Fig. 2, at a current of 30 mA, the voltage across the 50 µF capacitor is 140 volts. By Ohm's Law, this represents a load of 140/.03, or approximately 4700 ohms. Multiplying 4700 times 50 µF gives 0.235. Referring to Table 1 for the half-wave capacitive filter circuit, 0.235 ($R_L \times C1$) shows an approximate ripple of two percent.

Perform the same calculation for all values of current and capacitance used to compile the curves, and for both the half- and full-wave capacitive filter circuits.

Example

A transistor radio operates from a 9-volt batery and draws a current of 30 mA. Design a half-wave power supply to operate the radio from the power line, using capacitive filtering and producing approximately 0.5% ripple.

The basic circuit is shown in Fig. 1A. A series voltage-dropping resistor (R_d) is added as illustrated in Fig. 4.

From Fig. 2, a value of about 200 µF for $C1$ will have to be used to obtain the desired ripple percentage. Also from this figure, at a current of 30 mA, the voltage across the capacitor is about 149 volts. Calculate the resistances R_d, R_b, and R_r (resistance of the radio) as follows: $R_r = E/I = 9/.03 = 300$ ohms; $R_b = 10 \times R_r = 3000$ ohms; and $R_d = (149 - 9)/.03 = 140/.03 = 4700$ ohms.

To calculate the power dissipation of the resistors, proceed as follows: For R_d:$P = IE = (.03)\ (140) = 4.20$ watts (use a 10-watt resistor for safety).

For R_b assume that 30 mA will pass through R_b when the radio is disconnected from the power supply. This is not true, but the error in the assumption is on the side of safety and simplifies calculation. Therefore; $R_b = I^2R = (.03)^2\ (3000) = 2.7$ watts (use a 5-watt resistor for safety).

Since the parallel combination of R_b and R_r is nearly 300 ohms, and R_d is 4700 ohms, the total resistance (R_L) across $C1$ is 5000 ohms. From Table 1, for approximately 0.5% rip-

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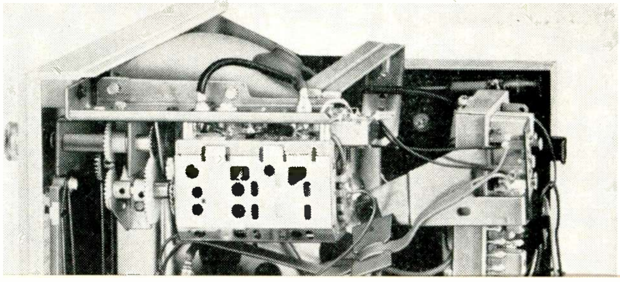
The sync separator section consists of two transistors, one of which acts as a keyed noise gate, similar to the noise-gating circuits used in many vacuum-tube receivers.

The power supply uses a bridge rectifier and a three-stage regulator. A zener diode is used to provide the reference voltage. ▲

Line-Operated Transistor



West Coast Electronics Industry

(*Continued from page 28*)

Firms engaged in these lines have rapidly absorbed surplus technicians and engineers idled by defense cutbacks—and their ads in media all over the country plead for more.

A growing number of engineers, scientists, and technicians have joined the corps of technical talent now being offered by technical services companies. Such companies attract men who enjoy a chance to work on a wide variety of assignments and who find that these companies can give them steady employment because they assign them to project after project as jobs phase out and new needs develop.

The "brains for hire" service is useful to defense and other contractors whose peak load needs generally vary. On a cost basis, this system is preferable to hoarding talent, especially now that most of the defense contracts are figured on an incentive and cost-plus-fixed-fee basis.

Job Opportunities on West Coast

A recent report from the U.S. Department of Labor underscores the vastly improved climate in western electronics. Last fall, the department found "a reversal of the two-year downtrend among aerospace and electronics activities" in the San Francisco-Oakland area. "Electronics firms," it reported, "require engineers in circuit design, servomechanisms, or microwave designs, but few local applicants could qualify." Only six months earlier, the same source reported "little activity among electronics and other aerospace employers in the area."

Similarly, in Los Angeles-Long Beach, the local employment office reported "major new needs" for electrical engineers. Here, too, was a pronounced turnaround from only six months earlier when openings were so limited that "surplused engineers reportedly showed more interest in job prospects in states as distant as Florida and Alabama."

Reports from individual companies promise continuing strength in western electronics labor markets. *North American Aviation*, California's largest private employer, with more than 100,000 on its payroll, reports it "is hiring faster than workers can be found for the jobs." *Hughes Aircraft* expects to add 1000 employees in the next six months for its electronics and space projects. And *Douglas*, prime contractor on the MOL, wants 3550 engineers and scientists in the next six months. *Lockheed* will be hiring several thousand engineers and scientists over the next few months to work on its C 5-A transport plane program.

Motorola, Arizona's biggest employer, has 12,000 in its three Phoenix divisions, and is hiring at the rate of 200 a week. However, nearly 85% of the 10,500 employed in *Motorola's* semiconductor division are women.

A *Litton* spokesman says his company expects to hire about 500 new engineers, designers, and technicians in its Western operations in the next few months. And Santa Monica-based *Lear-Siegler*, which employs about 2000 in its California operations (out of a total of 12,000) foresees "substantial increase in employment in our Astronautics Division when we enter the production phase on flight control systems for the A-7A Corsair Navy attack plane."

Some trouble spots remain, to be sure. Salt Lake City and Denver are the most conspicuous examples of areas where surpluses persist. But even here there are hopeful signs.

International Business Machines will open a new Boulder, Colorado plant in 1966 and employ 2000 to start. This, of course, won't absorb all the workers idled by phase-out of missile production at *Martin-Marietta*, but it is bound to attract satellite plants.

Engineering Education in the West

	Bachelor's Degrees 1963-64	Undergraduate Enrollment, Fall '64	Graduate Degrees 1963-64	Graduate Enrollment Fall '64
Arizona				
Ariz. State U	134	1,181	43	335
Univ. of Ariz.	222	1,384	77	302
California				
Cal. Inst. of Tech.	52	203	147	289
Cal. State Coll.-Long Bch.	112	943	—	162
Harvey Mudd Coll.	15	28	—	—
San Diego State Coll.	66	834	9	245
San Jose State Coll.	222	1,722	21	416
Stanford University	170	674	509	1,372
U.S. Naval Postgrad Sch.	181	450	55	60
Univ. of Calif.	725	3,968	715	2,531
Univ. of Santa Clara	44	264	33	618
Univ. of So. Calif.	139	688	354	2,184
Colorado				
Colo. School of Mines	164	1,019	17	163
Colo. State Univ.	99	842	31	185
U.S. Air Force Acad.	91	839	—	—
Univ. of Colorado	286	2,297	115	639
Univ. of Denver	43	319	13	83
Idaho				
Univ. of Idaho	130	807	17	41
Montana				
Montana School of Mines	37	224	7	17
Montana State Coll.	116	854	24	96
New Mexico				
New Mex. State Univ.	139	1,396	38	135
Univ. of New Mex.	102	959	99	351
Nevada				
Univ. of Nevada	52	429	3	47
Oregon				
Oregon State Univ.	206	1,435	39	149
Utah				
Brigham Young Univ.	60	891	17	36
Univ. of Utah	155	1,252	46	360
Utah State Univ.	99	552	30	106
Washington				
Seattle Univ.	51	219	20	117
Univ. of Wash.	369	2,199	176	746
Wash. State Univ.	170	1,079	34	72
Wyoming				
Univ. of Wyoming	156	872	39	97
Total, western states	**4,607**	**30,823**	**2,728**	**11,954**
Total, U.S.	**30,850**	**205,765**	**12,292**	**53,324**
West % of U.S.	**14.9**	**15.0**	**22.2**	**22.4**

Source: Journal of Engineering Education

Denver, too, is one of 14 cities tentatively approved for location of the big AEC facility that the state of Washington is wooing. A project of this magnitude would create thousands of professional jobs, a good many of them in electronics.

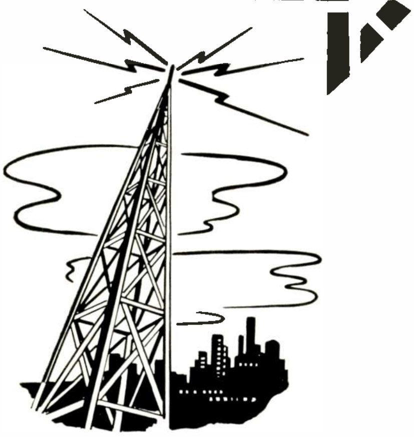
Salt Lake City still has a long uphill climb before its recovery may be safely assured. But it, too, has a few good things going for it. For one, *Litton Industries'* guidance and control systems plant, opened eight years ago, has boosted its payroll more than 33% to over 1500 in the past two years, and is still growing.

Hill Air Force Base and the Ogden Air Materiel Area survived the recent DOD decision to close military bases. Hill, alone, is expected to generate over 5000 additional civilian jobs by 1968; and many of these will require skilled electronic hands.

Utah, like most western states, hitched its economic wagon to a defense-oriented aerospace-electronics star. For a while it had quite a ride; but the inevitable re-entry brought with it some bitter lessons.

The new steam in electronics growth in the western states may cloud over the short-lived recession of recent memory; but the industry should have learned by now that its future will be assured only when consumer-industrial-institutional markets provide its main thrust. ▲

SELLING THAT RECORDER? BUYING A RECEIVER?



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JUNE ISSUE CLOSES APRIL 1st.

FET Phono Equalizer

(Continued from page 33)

response in Fig. 5. The dashed curve may be used for reproduction of music with pronounced low frequencies (organ music, for example). Measured performance is given in Table 1. The same basic feedback circuit is used as in the other circuits, with feedback from the last drain into the first source. Due to the low current drain of FET's, biasing is somewhat different than with vacuum tubes. The first stage has been designed particularly for low noise. FET's show a noise level which depends directly on leakage current and transconductance, among other factors. A good compromise is achieved with the first drain operated from a 30-volt supply, achieved by dropping resistors from the voltage supply. The optimum load resistance for least noise, as well as best overload, is 100,000 ohms independent of FET, supply voltage, and other externals. Correct bias is achieved by a resistance in the source of the first stage. Due to the low drain current, a relatively large resistor is needed for proper biasing. To avoid heavy local feedback, the greater portion of this bias resistance is bypassed and only 1000 ohms are used for the connection of the over-all feedback loop.

The excellent performance of this circuit is evidenced by high output capability, low noise level, and extreme stability (see Table 1 and Fig. 6). The measurements indicate a 7-dB lower noise level than the best tube circuit and a 5-dB higher overload level, not to mention the even larger improvement in dynamic range as compared with conventional transistors. The input impedance of the FET itself is about 100,000 megohms at high frequencies with the feedback connected in parallel with about 2 pF. A 120,000-ohm gate resistor is used because this value is the highest impedance required by phono cartridges. The temperature stability of FET's is excellent, and measurements taken on FET's showed there was no significant change in performance when the units were submerged in liquid nitrogen (−200°C) or were tested at +150°C, where mainly an increase in noise level was observed. Such performance is far in excess of what was possible in the past by any active device, and it opens new fields of application. It is hoped that power FET's will soon become available for the design of complete hi-fi circuits.

Editor's Note: The FET's described in this article range in price from $3 to $10 depending on quantity and type. They are available from stock from Dickson Electronics Corp., *310 South Wells Fargo Ave., Scottsdale, Ariz. 85252.* ▲

POWER-PACKED! Engineered for rugged business use!

Excellent performance, dependability and operational convenience provided by FM-40 reflect the experience and design ability that has made Sonar the undisputed leader in this demanding form of business radio art. Greater range because of Voice-Power designed circuitry • Compact and lightweight • Easily installed in smallest vehicles • Smartly styled for office use • Noise free squelch for crisp clear communication • Accessory plug for Sonar Call, selective Calling System • Accessory plug for high power Linear Amplifier • 12 VDC & 117VAC • 1 year warranty • Size: 4¾"H x 9½" x 11¼"L • Weight: 10 lbs.

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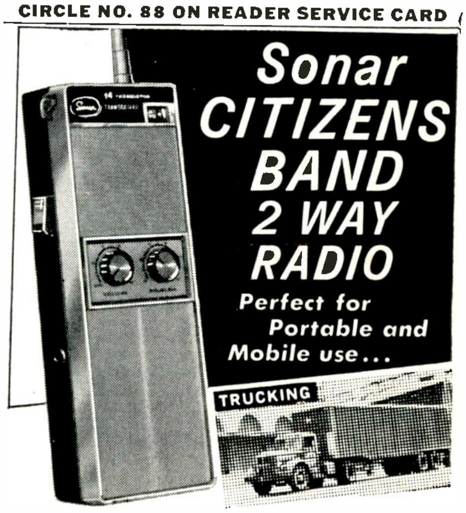

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NEW PRODUCTS & LITERATURE

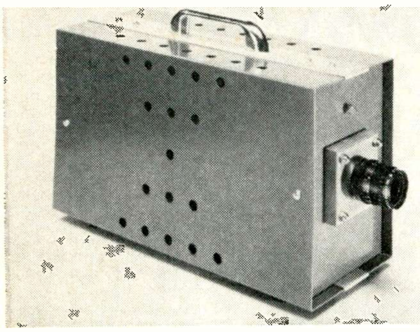
Additional information on the items covered in this section is available from the manufacturers. Each item is identified by a code number. To obtain further details, fill in coupon on the Reader Service Card.

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

TV CAMERA IN KIT FORM

A low-cost utility TV camera which is available in either kit or factory assembled versions comes complete with vidicon, all tubes, lens, and operating instructions.

The Model 800's r.f. output permits instant attachment to the antenna terminals of any standard TV set. No special monitor or booster units are required and up to six sets may be operated at a distance of 1000 feet without further signal amplification.



The unit may be tuned for any unused channel 2 through 6. Reception of regular TV programming is not affected. A precision f1.0 lens and equivalent 12-tube circuit are said to produce clear, sharp images even under subnormal lighting conditions. Generally, the light from a single 150-watt bulb is sufficient for good viewing of any subject.

Optional accessories for use with the camera include wide-angle lens, telephoto lens, and professional-type tripod. Conar

Circle No. 1 on Reader Service Card

MICROMINIATURE TRIMMER

A microminiature wirewound trimmer potentiometer, designed for printed-circuit mounting on a 1⁄10" grid spacing is now available. The unit is "O"-ring sealed and will withstand all the conditions of humidity, vibration, shock, and altitude as specified in test methods of MIL-STD-202-B.

This single-turn unit is housed in a "Hi-Temp" plastic case. Standard resistance values are 20, 50, 100, 200, 500, 1000, 2000, and 5000 ohms. Standard tolerance is ±20%. The mechanical rotation is 360° and the electrical rotation is 270°. Insulation resistance is 1000 megohms at 500 volts d.c. and power rating is ¼ watt to 50°C linearly derated to zero at +105°C. Minelco

Circle No. 126 on Reader Service Card

EPOXY SILVER COLD SOLDER

A new epoxy compound, called "Shurbond #114", is designed for use on a wide variety of electrical and electronic equipment. A two-component compound, the new silver cold solder comes in two identical "hyp" applicators in a 2:1 mix. It will bond to any surface in one hour and is especially applicable on components or crowded circuits that are sensitive to heat or for the repair of printed-circuit boards. Anchor Alloys

Circle No. 127 on Reader Service Card

SUBMINIATURE INCANDESCENTS

A new line of subminiature incandescent lamps, T1, T1¼, and T1¾, has recently been introduced. Features of this new line include an aging process which is continued until filament stability has been reached; a light meter test for proper mean spherical candlepower to assure light characteristics that meet design specifications; and specially blown bulbs designed to ensure near-perfect centering of filaments.

Complete information on this new line will be supplied by the manufacturer. Industrial Electronic Engineers

Circle No. 128 on Reader Service Card

AEROSOL FLUX REMOVER

A new solder flux remover in aerosol form provides a fast, convenient, yet thorough method of removing flux residues from electronic circuits. The product employs DuPont's "Freon TMC," a solvent widely used on production lines in bath form to deflux assembled circuits.

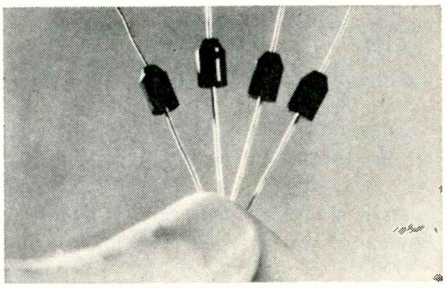
As an aerosol, the product is now available for laboratory, light production, and repair work. It comes in 16-ounce cans equipped with an extension nozzle to reach all parts of densely packaged circuits. Miller-Stephenson

Circle No. 2 on Reader Service Card

MOISTUREPROOF SILICON RECTIFIERS

New moistureproof epoxy silicon rectifiers that combine high ratings with high reliability for power-supply applications in television, high-fidelity systems, radios, phonographs, and test equipment have recently been put on the market.

The rectifiers are rated at 1.5 amps when the case temperature is 40°C. Surge rating is 50 amps, measured as the peak one-half cycle current at 60 Hz under full load conditions.



Details on the complete line, including prices, will be supplied on request. Westinghouse Semiconductor

Circle No. 129 on Reader Service Card

LINEAR-MOTION POTS

Two designs of linear motion conductive plastic potentiometers, in both cylindrical and rectangular configurations, are now available: Model LMPS (single element) and Model LMPD (dual element). These units are designed for applications such as actuator assemblies, flight-control servos, nose-wheel steering servos, stabilizer controls, position indicators, flow process instrumentation, etc.

Resistance range is 200 ohms to 30,000 ohms per inch of travel at a tolerance of ±10%. Independent linearity is ±1% standard and ±0.25% on special order. The electrical stroke is 1" to 11" and resolution is essentially infinite. Ambient temperature range is −40 to +125 degrees C. New England Instrument

Circle No. 130 on Reader Service Card

RESISTANCE THERMOMETER LINE

A family of eleven new resistance thermometers, designed for most industrial, commercial, and laboratory applications, is now available. Their temperature range (−328°F to +500°F) and size (0.125" to 12" long, 0.125" to 0.278" diameter), and the availability of both body-sensitive and tip-sensitive models makes this family especially useful.

Designed for use with the firm's direct-reading thermal-indicator electronic thermometer or other accurate resistance measurement equipment, the units feature relatively high impedance and a high resistance change of several ohms per degree, allowing leads to be spliced, switched, or extended considerable distances with minimum error in output signal. A specification and catalogue sheet is available on request. Minco Products

Circle No. 131 on Reader Service Card

NUT & SCREWDRIVER SET

A hip-pocket size, 12-blade nut and screwdriver set is now being marketed as the 99PS-50. The kit includes a 4⅛" amber plastic (UL) handle and twelve interchangeable blades: seven nutdrivers (3⁄16" hex through ⅜" hex), two Phillips screwdrivers (#1 and #2), two slotted screwdrivers (3⁄16" and 9⁄32"), and an extension blade that provides an added 4" reach.

The handle and extension feature an exclusive, positive-locking device. The blades fit snugly, are held firmly for turning, yet are easily removed. Xcelite

Circle No. 3 on Reader Service Card

GARAGE-DOOR OPERATOR

A new garage door opener, which utilizes a winch-type principle with gearing, weighs only 15 pounds and can be installed by most homeowners in approximately 30 minutes.

The unit plugs into any 117-volt outlet, has a positive-locking mechanism, and an automatic light which goes on when the unit is in operation. A unique safety feature stops the door as soon as it strikes any obstruction. Unlike most automatic garage door openers, it reverses itself once it is started again to prevent the door from striking the obstruction a second time.

The remote radio control is not an integral part of the unit and is marketed separately at extra cost. Nautilus Industries

Circle No. 4 on Reader Service Card

SELF-SEALING CONNECTORS

A two-part connector assembly consisting of a special high-temperature plated metal insert and special Teflon tube is now available for applications where high temperatures, corrosive atmospheres, high reliability, and long life are problems in connecting wires ranging from 22 to 4 gauge.

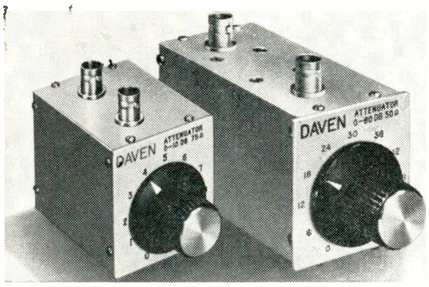
These insulated connectors permit end users to make insulated crimp solderless connectors. After crimping the insert on either a butt or parallel splice, the Teflon tube assembly is slipped over the joint, properly positioned, and then heated with a hot air torch. Heating the assembly causes it to both shrink on the outside and melt on the inside, thereby forming a completely sealed connection capable of withstanding temperatures of 600°F when used with Teflon wire. Positive Connector

Circle No. 132 on Reader Service Card

R.F. ATTENUATORS

Two new rotary, coaxial r.f. attenuators, developed for use in signal generators and transmitters as well as for calibration of audio and r.f. equipment and testing of transmission lines, are now available as the Models 10240 and 10440.

Both models are available in either 50 or 75



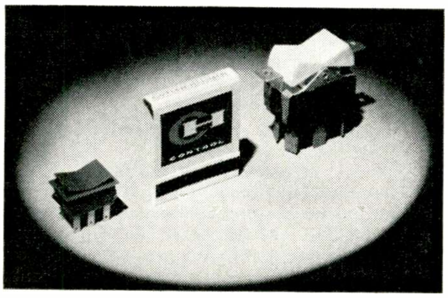
ohm impedances. Model 10240 frequency response extends from d.c. to 500 MHz, while standard units can be supplied in 0-10 dB in 1-dB steps, 0-20 dB in 2-dB steps, or 0-30 dB in 3-dB steps. Model 10440 with frequency response of d.c. to 250 MHz (usable to 500 MHz) has standard units in 0-60 dB in 6-dB steps or 0-60 dB in 10-dB steps. A square design is employed in both models for easy packaging. Daven

Circle No. 133 on Reader Service Card

MINIATURE ROCKER-TYPE SWITCHES

A new line of miniature "Rockette" switches combining small size, modern styling, low cost, and snap-in mounting is being offered in five circuit arrangements: s.p.s.t., s.p.d.t., d.p.s.t., d.p.d.t., and two-circuit. They are available in two- or three-position types with positive detent, and maintained or momentary contacts.

All designs are UL and CSA approved with ratings up to 6 amps at 125 volts a.c. and 0.5 amp at 30 volts d.c. They require minimum panel space ($^{19}/_{32}$" x $^{29}/_{32}$") and can be accommodated on panels ranging from $^{1}/_{32}$" to $^{1}/_{8}$" thick without modification. Cutler-Hammer

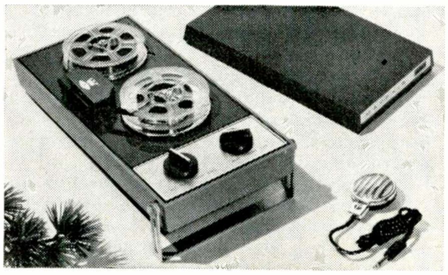


Circle No. 134 on Reader Service Card

HI-FI—AUDIO PRODUCTS

PORTABLE TAPE RECORDER

An inexpensive, four-transistor solid-state tape recorder is now available as the "Mayfair" Model 1602. Measuring only 10¼" x 2½", the unit is operated by means of a single selector knob. It comes equipped with a highly sensitive crystal-type microphone. Arctic Import



Circle No. 5 on Reader Service Card

FM/AM STEREO TUNER

A new solid-state stereo FM/AM tuner, the Model KG-790, has been added to the "Superba" series in the "Knight-Kit" line.

The unit uses 22 transistors and 14 diodes. The front-end and i.f. strip are factory assembled and adjusted. All coils and transformers are likewise professionally aligned. The circuit features four FM front-end tuned circuits and four double-tuned i.f. stages. Adjustable interstation muting eliminates noise between stations. The circuit will automatically switch to the stereo mode whenever a stereo broadcast is being received. An SCA filter reduces storecast interference.

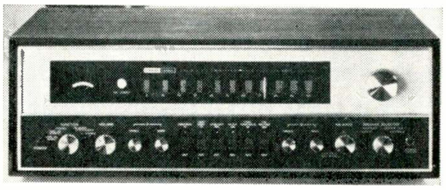
The kit comes complete with all parts, detailed assembly instructions, and a Sierra gold panel. A walnut wood case is available as an extra. Allied Radio

Circle No. 6 on Reader Service Card

100-WATT STEREO RECEIVER

A 100-watt, solid-state FM stereo receiver is now on the market as the "Stratophonic SR-900B." At full 100 watts, the SR-900B maintains its ultra-wide frequency bandwidth from 5 to 100,000 Hz. This power bandwidth and frequency response is attributed to the use of germanium diffused-junction output transistors in the circuit.

The receiver has an easy-to-read d'Arsonval tuning meter and a positive-action automatic FM-stereo indicator light. Harman-Kardon



Circle No. 7 on Reader Service Card

STEREO TAPE DECK FOR CARS

A 4-track car tape deck that requires no installation has been put on the market as the 603M. The unit is housed in an enclosure which is designed to fit over the hump on the floor of any car. Adjustable speakers can be raised or lowered. The system plugs directly into the car's cigarette lighter while a 25-foot extension cord permits portability. Also available is an a.c. converter to permit the deck to be used on power lines.

The company claims that over 10,000 musical selections are available for use with this system. Martel

Circle No. 8 on Reader Service Card

VERSATILE DICTATING MACHINE

A portable dictating machine which can be operated on "C" batteries, on a 12-volt auto battery, or from 105 to 240 volt a.c. without an adapter or changeover switching is now available as the Model G-540.

This magnetic tape unit may be used for transcribing and conference recording as well as dictating. It operates two hours on one self-loading reel of tape. A remote-control microphone starts and stops the tape. Complete controls are available for dictating, stop, review, transcribing, fast rewind, and fast forward.

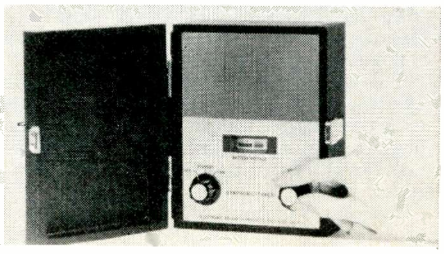
The unit weighs only 6 pounds and comes complete with carrying case, shoulder strap, remote microphone, tape, and batteries. StenOtape

Circle No. 9 on Reader Service Card

ELECTRONIC TUNING FORK

A portable tuning instrument, battery powered and engineered with solid-state devices to provide a precise reference tone has been developed for symphonies and bands.

The "Symphonic-Tuner" is 99.995% accurate at room temperature and almost immune to temperature changes from 40° to 100°F. The unit derives its "A" from a high-frequency tuning-fork-controlled oscillator. The frequency is divided within the unit to produce a tone of 440 Hz. Any special frequency such as 442 Hz can be engineered into the unit.



The unit comes complete with an earphone for individual auditing and a jack for speaker amplification. Electronic Research Products

Circle No. 10 on Reader Service Card

CARTRIDGE TAPE RECORDER

A cordless, portable tape recorder, featuring solid-state circuitry and instant-loading tape cartridges with 60 minutes' recording capability is being marketed as the Wollensak 4100 cordless cartridge tape recorder. The unit comes complete with carrying case, dynamic microphone, batteries, and three tape cartridges.

This low-cost recorder operates in the mono mode, features solid-state circuitry for instant operation, capstan-driven tape transport, separate volume and recording level controls, and a single switch which controls record/playback/fast-search functions, and a dual-purpose battery condition/recording level meter.

The unit operates on five "C" cells and will record up to 30 minutes of mono material on each side of the snap-in cartridges. Frequency response at 1⅞ ips is 120 to 6000 Hz ± 3 dB with a signal-to-noise ratio of better than 45 dB.

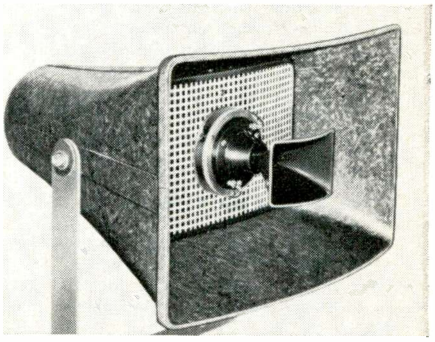
The recorder measures 7¾" x 4½" x 2¼" and weighs 3 pounds including batteries. 3M

Circle No. 11 on Reader Service Card

P.A. SPEAKER

A new public-address speaker with a frequency range of 150 to 12,000 Hz is now available as the 150A bi-acoustic horn system. Housed in a durable weatherproof fiberglass enclosure, the system is suitable for use in any indoors or outdoors environment requiring a combined music and paging sound system.

The system embodies the "bi-acoustic" principle in that it uses a single high-efficiency transducer with two sound paths emanating from both sides of the diaphragm. Lower frequencies are directed through a long reflex air column while tones above 1000 Hz are directed through a straight sectoral horn. The driving element itself consists of a ceramic magnetic structure, copper voice coil, and a phenolic diaphragm.



Sound distribution is 120 degrees horizontal and 90 degrees vertical, impedance is 8 ohms, power rating is 40 watts. With a matching transformer, the system can be adapted to 70-volt line operation. Altec Lansing

Circle No. 12 on Reader Service Card

TRANSCRIPTION TAPE MACHINE

An office tape transcribing machine, the "Fidelitape MP-100," has been put on the market to meet the need for a specialized machine to allow the typist to transfer standard tape recordings to paper. The machine has no recording facilities.

The unit features a special footswitch control device which operates almost instantaneously with mechanical linkages specifically designed to withstand the constant reversal of routine transcription work.

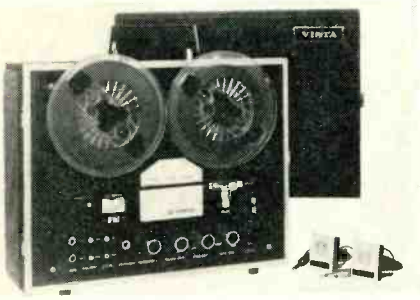
The machine will handle tapes from any standard recorder. It transcribes at three speeds, 1⅞, 3¾, and 7½ ips and takes reels up to a full 7 inches in diameter. The standard model accommodates dual-track recording but four-track capability is available on special order. Fidelity Sound

Circle No. 13 on Reader Service Card

4-TRACK STEREO MACHINE

A new four-track stereo tape recorder with single "T" function control for play/record, rewind, and fast forward, has been introduced as the "Vista 910."

Equipped for sound-on-sound recording, the machine operates at 7½ or 3¾ ips with 7" reels. Design features include built-in mono and stereo amplifiers, built-in stereo preamplifiers, and built-in twin 4" x 6" speakers for extra compactness.



The unit is equipped with two vu meters, instant reset counter, inputs for radio or microphones, outputs for external speakers or stereo headset. Frequency response is from 50 to 15,000 Hz at 7½ ips.

The recorder measures 17" x 14" x 5½" and weighs 26 pounds. It comes equipped with two microphones, two patchcords, and reels. Craig Panorama

Circle No. 14 on Reader Service Card

MOBILE P.A. AMPLIFIER

A 25-watt, completely transistorized mobile p.a. amplifier is now available for operation on 12 or 6 volts d.c., positive or negative ground.

The new unit features a full 25 watt output when used on 12 volts d.c. An r.f. filter reduces noise pickup in the microphone lead. Plug-in type printed-circuit boards simplify servicing and improve reliability. Silicon transistors are used exclusively in the preamplifier and driver stages.

Output impedances are 4, 8, and 16 ohms. Controls include microphone volume, auxiliary, and volume/power. The unit measures 3¼" x 6⅜" x 4¼". It weighs 4 pounds. Lafayette

Circle No. 15 on Reader Service Card

STEREO PREAMPLIFIER

A new stereo preamplifier which is being offered in both easy-to-build kit and factory assembled versions is on the market as the PAS-3X.

The preamp utilizes a unique tone-control configuration (on which patents are pending) in which the phase and frequency-controlling elements are removed from the circuit when the control is in the mechanical center of its rotation. Thus the tone controls are effectively out of the circuit in the "flat" position, while retaining the infinite resolution capability of the smooth continuous control.

Harmonic and IM distortion are guaranteed to be below 0.05% at 3 volts out in the range of 20 Hz to 20 kHz, with up to 10 volts out at less than 0.15% distortion into as little as 10,000 ohm loads. Dynaco

Circle No. 16 on Reader Service Card

ALL-SILICON STEREO TUNER

The new Model S-3300 stereo tuner is said to be the first solid-state tuner to feature silicon transistors exclusively. Featuring a sensitivity of 1.6 μV (IHF) with circuitry that is immune to overloading, the tuner incorporates a unique stereo noise filter which reduces unpleasant high-frequency background noise without affecting the frequency response of the program being received. A specially designed dual automatic gain control system maintains proper selectivity under the strongest signal conditions. Sherwood

Circle No. 17 on Reader Service Card

SOLID-STATE STEREO RECORDER

The Uher "Royal Stereo 8000E" utilizes all-solid-state circuitry and features 4-track mono and stereo recording and playback; two separate recording heads to permit monitoring ahead of the recording head or from the tape after recording, with built-in mixer control for both channels; 4 speeds, 4 heads; synchronous sound-with-sound recording; multi-play sound-on-sound; echo effects; a built-in automatic slide-projector control; automatic end-of-tape stop; A-B monitoring; and an all-new swing-away chassis for instant inspection and servicing. Martel

Circle No. 18 on Reader Service Card

CB-HAM-COMMUNICATIONS

HAM-BAND TRANSMITTER

A new amateur band transmitter employing advanced single-conversion signal path circuitry has been announced as the HT-46. The new unit provides 180 watts p.e.p. input on SSB and 150 watts on c.w. Frequency coverage is 3.5-4, 7-7.5, 14-14.5, 21-21.5, and 28-30 MHz in four 500-kHz steps. A crystal is provided for 28.5-29 MHz coverage. Other 10-meter crystals are optional.

Housed in a compact cabinet measuring 5⅞" high x 13⅛" wide x 11" deep, the HT-46 has a 9-MHz quartz filter for upper or lower sideband, grid block keying for c.w., and push-to-talk operation with provision for optional plug-in VOX. Solid-state circuitry is used in the self-contained power supply. Hallicrafters

Circle No. 19 on Reader Service Card

FM EMERGENCY RECEIVER

The "FM Alert," an emergency receiver with provision for two crystal/receive channels plus tunable control, is now on the market. This v.h.f. receiver is designed for those who constantly monitor two channels and also offers the additional convenience of a variable tuner. The user has a choice of two frequency ranges: the Model 152 covers from 152 to 175 MHz while the Model 30 covers from 30 to 50 MHz.

The receiver utilizes a quadrature detector and high-gain i.f. to provide clean, smooth, quiet reception over a wide range of signal strengths and modulation levels. An adjustable squelch maintains silence when there is no incoming signal. A separate, matching 3" x 5" PM speaker is available as an accessory. Squires-Sanders

Circle No. 20 on Reader Service Card

5-CHANNEL CB TRANSCEIVER

An all-solid-state two-way CB radio which measures only 6$\frac{7}{16}$" wide x 2½" high x 8½" deep is now being marketed as the "Messenger 100."

This five-channel transceiver is designed to be used in mobile applications but can also be used in a base station with a 117-volt a.c. accessory power supply, or as a portable field unit with its nickel-cadmium battery-powered pack set attachment.

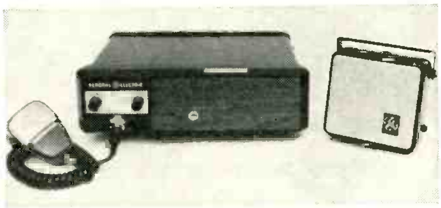
The unit is designed to operate over a temperature range of −22°F to +140°F. It is equipped with a circuit breaker that eliminates the need for fuse replacement and can be automatically reset by simply turning the unit to "off" and back "on" again. Front-panel controls include an "off-volume" control, 5-position channel selector, and an adjustable squelch control.

It is supplied complete with crystals for one channel and a dynamic microphone with push-to-talk bar and coiled cord. E. F. Johnson

Circle No. 21 on Reader Service Card

FM MOBILE TWO-WAY RADIOS

A new "Executive Series" consisting of several FM mobile two-way radios has been added to the "MASTR Progress Line." These new mobiles are 4" high x 12¼" long x 12¾" wide and are designed to be mounted up front under the dash, back in the trunk or elsewhere in the vehicle—either level, slanted, or on their side. For front mounting, the control head is recessed into the unit and fits flush with a walnut-grain front panel designed to harmonize with modern car interiors.



The transmitters are set up for single-frequency operation with up to four frequencies available at the user's option. Silicon transistors are used for consistent transmitter and receiver performance at high temperature levels.

The units are available in 132-174 MHz and 25-50 MHz versions. Full details on the new line will be supplied on request. General Electric Communication Products

Circle No. 22 on Reader Service Card

FOUR-BAND RECEIVER

The new SX-130 communications receiver is designed to provide foreign, amateur, aircraft, marine, standard AM broadcast, and CB coverage. Code, voice, and SSB signals may be received over the entire tuning range. A front-panel control permits ready selection of either upper or lower sideband for simplified tuning of the SSB signals.

In addition to having a circular main tuning dial and a slide-rule electrical bandspread dial, the SX-130 features both crystal filtration and crystal-controlled selectivity. A built-in "S" meter is included as well as a calibrated b.f.o. for use on USB, LSB, and c.w. Balanced or unbalanced antenna inputs are provided as well as a front-panel antenna trimmer control.

The circuit uses seven tubes and one diode and is housed in a grey steel cabinet measuring 8" high x 18⅞" wide x 9¾" deep. Hallicrafters

Circle No. 23 on Reader Service Card

CB RADIO FOR MARINE USE

A new all-solid-state CB unit which is designed for compact installation on motorboats or sailboats where 12-volt battery power is available, has been introduced as the "Mark 10."

The transceiver has 12 crystal-controlled channels and an all-silicon transistor complement for dependable operation at high temperatures. It weighs less than 4½ pounds and occupies a space of slightly more than $\frac{1}{10}$ of a cubic foot. RCA Electronic Components and Devices

Circle No. 24 on Reader Service Card

V.H.F./U.H.F. SILICON TRANSISTORS

Two new v.h.f./u.h.f. silicon "n-p-n" transistors for use in battery-operated communications equipment are being marketed as the RCA-40404 and 40405. Both are designed to provide high power gains and high efficiency as class-C frequency multipliers and amplifiers in transmitters and other communications equipment. They are especially suited for applications in equipment using low d.c. supply voltages and operating at frequencies up to 400 MHz.

The 40404 is designed to operate at frequencies up to 170 MHz, can deliver up to 500 mW of r.f. output power as a straight-through class-C amplifier, and can double, triple, and quadruple with high efficiency and high power gain. The 40405 will operate at up to 400 MHz, can deliver 700 mW of r.f. output power, and can also double, triple, and quadruple.

Both types are hermetically sealed in miniature JEDEC TO-52 metal packages. RCA Electronic Components and Devices

Circle No. 135 on Reader Service Card

COMPACT MICROWAVE TRANSMITTER

The development of a low-cost, compact microwave transmitter designed for use in air-to-ground communications, including earth satellites, has been announced. The transistorized unit weighs 3½ ounces and is slightly larger than a cigarette lighter. It has its own power supply, a battery that is smaller than a penlite cell.

Circuits in the transmitter are designed for a bandwidth of 2 MHz which is more than sufficient to carry all of the information now transmitted in the entire standard broadcast band. Sylvania

Circle No. 136 on Reader Service Card

FM COMMUNICATIONS RECEIVER

The HA-520 is a ten-tube, two-band FM communications receiver that tunes 30-50 MHz and 152-174 MHz with a sensitivity of 3 μV for 20 dB quieting. It features a tuned r.f. amplifier on both bands for better image rejection and uses a nuvistor on the 152-174 MHz band. Built-in variable squelch quiets the receiver during periods of no signal, reducing operator fatigue.

An illuminated slide-rule dial simplifies night operation. The receiver has a 4" PM speaker with 1.2 watts audio output and a front-panel 8-ohm headphone jack. The power supply is silicon-diode full-wave transformer operated.

The unit is housed in a metal cabinet measuring 11⅞" wide x 5 7/16" high x 7¾" deep. Lafayette

Circle No. 25 on Reader Service Card

MANUFACTURERS' LITERATURE

SHIELDED-CABLE CONNECTOR

Information on a new one-piece "wobble-action" connector for shielded and coaxial conductors is contained in a new 4-page illustrated bulletin (S-7).

Included in the booklet is a comparison of typical test results against MIL Spec MIL-F-21608B. In addition, installation tools for the connector are described. Thomas & Betts

Circle No. 137 on Reader Service Card

COMPONENTS CATALOGUE

A new 24-page illustrated short-form catalogue (No. 66) listing a complete product line of jacks, plugs, switches, connectors, and audio accessories for commercial, industrial, and military applications is now available. Switchcraft

Circle No. 138 on Reader Service Card

POWER SOURCES FOR MEDICINE

A new 16-page illustrated booklet describing the use of high-reliability power sources for application in medical electronics has been issued.

Entitled "One Hundred Million Heartbeats," the brochure discusses pacemakers and other electronic stimulators with special emphasis on the power cells used in these devices. The booklet covers in detail the Certified Cell Program instituted by the company to provide the highest possible uniformity and reliability in primary power sources to manufacturers of implantable electronic equipment. Mallory Battery

Circle No. 26 on Reader Service Card

FLAT-BRAID CABLE SHIELDING

A new 4-page brochure (Bulletin No. 6) covering construction, comparative weights and sizes, mechanical strength, and electrical properties of flat-braid cable shielding has been released. Raychem

Circle No. 139 on Reader Service Card

MAGNETIC PICKUPS

Complete technical information, including operating principles, gear tooth size, load impedance, and effects of surface speed, is provided in a new 6-page, fully illustrated brochure on electromagnetic pickups. Bulletin F-8 also lists seven standard pickup types available from the company. Airpax

Circle No. 140 on Reader Service Card

VARIABLE TRANSFORMERS

A complete line of manual and motorized "Powerstat" variable transformers is described and illustrated in a new 76-page catalogue (P1065G). Line correctors, 10-volt types, oil-cooled and explosion-proof models, and positioner systems are among the products listed.

Also included is a 9-page rating chart section. Superior Electric

Circle No. 141 on Reader Service Card

R. F. CONNECTORS

Two new series of threaded-coupling r.f. connectors are described and illustrated in a new 4-page engineering data sheet. Series STM (subminiature) and STMM (microminiature) are designed to give improved electrical performance at frequencies up to 12 GHz. Star-Tronics

Circle No. 142 on Reader Service Card

A.C. & D.C. AMMETERS

Information on a complete line of "Tong Test" a.c. and d.c. current-measuring devices is provided in a new 6-page illustrated catalogue. Models are capable of taking readings from 10 A and less up to 1000 A and operate simply by snapping the jaws of the instrument around the cable or bus bar without breaking the circuit or scraping the insulation. Columbia

Circle No. 143 on Reader Service Card

TEST INSTRUMENTS

Resistance standards and boxes, portable and laboratory-type Wheatstone bridges, Kelvin bridges, potentiometers, and voltage dividers are among the precision laboratory standards and test instruments described and illustrated in a new 8-page catalogue (Bulletin 60-66). Biddle

Circle No. 144 on Reader Service Card

MICROWAVE DEVICES

A new 4-page short-form catalogue covering a standard line of traveling-wave tubes, backward-wave oscillators, and solid-state delay devices is now available.

Information on low-noise, low-, medium-, and high-power traveling-wave tubes and other products is given. Microwave Electronics

Circle No. 145 on Reader Service Card

SWITCH CATALOGUE

A complete line of subminiature, rotary, lever, push-button, slide, and snap switches is fully illustrated and described in a new 82-page catalogue (No. 106).

Prefacing the product listings is a 14-page section containing general engineering information as well as data on rotary- and push-button-switch terminology, MIL Specs, shields and brackets, concentric shafts, and identification methods. Oak

Circle No. 146 on Reader Service Card

PLEXIGLAS FOR LIGHTING

A revised and expanded 44-page, illustrated design data booklet (No. PL-585a) that discusses the use of Plexiglas acrylic plastic for lighting in building applications is now available.

Covered in detail are basic types of Plexiglas; optical properties; stability to outdoor, fluorescent, mercury vapor, and incandescent exposure; physical and chemical properties; various applications; and designing the lighting system. Rohm & Haas

Circle No. 147 on Reader Service Card

MOTOR CATALOGUE

Complete technical information on stepper motors, stepper motor driver and logic, synchronous motors, seven standard-sized servo motors, viscous- and inertial-damped servo motors, and a.c. special-purpose motors is contained in a new 32-page illustrated catalogue. Kearfott Division, General Precision

Circle No. 148 on Reader Service Card

CB ANTENNAS

A new 6-page illustrated catalogue (No. CB-659) covering a full line of Citizens Band base-station and mobile antennas, mounts, and accessories has been issued.

Featured in the brochure is the Model MJ-27 "L-O-N-G Ranger" ½-wave-long, vertical dipole, base-station antenna. Mark Products

Circle No. 27 on Reader Service Card

IRON-CORE COMPONENTS

Two new catalogues covering the firm's iron-core components have been announced. Vol. 1 is a 52-page publication covering transformers, inductors, and "Magamps." Vol. 2 features 24 pages of electric wave filters, high-"Q" coils, and inductors. All of the items listed are available from stock for immediate delivery.

In addition, details on a wide range of special custom-built components are provided.

Prepared for the design engineer and/or purchasing agent, each catalogue includes a cross index on the front cover and a condensed exposition of MIL Specs applicable to the listed components. UTC

Circle No. 149 on Reader Service Card

FREQUENCY & TIME STANDARDS

A comprehensive discussion of frequency, time, and laboratory standards is provided in an entirely revised 108-page text (Application Note No. 52).

Four sections cover system operation of frequency and time standards, methods of comparing standards, time determination, and spectral purity in frequency standards. The latest schedules for U.S. and international time-signal broadcasts are included, along with a glossary and a set of nomograms and tables. Hewlett-Packard

Circle No. 150 on Reader Service Card

NOISE-FIGURE MEASUREMENTS

An 18-page discussion of theory, definitions, and techniques of noise-figure measurements together with the instrumentation used for such measurements has been made available.

Covered under methods of measurement are input conditions, receiver-output measurements, manual and automatic techniques, and pitfalls. Noise generators, noise-figure indicators, and special test sets are described in the instrumentation section. Airborne Instruments

Circle No. 151 on Reader Service Card

SCREWDRIVER SET

Nutdriver-screwdriver set No. 99PS-50, ideal for assembly and service work, is described in a new flier (Form S-1065). The hip-pocket-sized set consists of 12 interchangeable blades and plastic handle in a plastic carrying case. Xcelite

Circle No. 28 on Reader Service Card

CB TRANSCEIVERS

Information on two Citizens Band transceivers, the "23'er" (23 channels) and the new "S5S" (5 channels) is contained in a new catalogue sheet.

Also listed are various accessories, including a.c. power supplies, p.a. adapter, and remote speaker. In addition, a detailed explanation of the "Noise Silencer" circuit which defeats noise caused by auto ignition or power lines is provided. Squires-Sanders

Circle No. 29 on Reader Service Card

DECADE BOXES

"Claro-Dec" miniature precision resistance decade boxes designed for use by experimenters, technicians, and hobbyists are offered in a new 4-page illustrated folder. Units are available in a series of seven individual boxes with resistance values ranging from .1 ohm to 900,000 ohms. Clarostat

Circle No. 30 on Reader Service Card

TRANSISTOR EQUIVALENTS

An 11-inch x 17-inch wall chart which lists the transistors capable of being replaced by the firm's line of five "universal" units is now available on request.

According to the company, 2977 transistor types can be replaced by the firm's AA1, a "p-n-p" all-purpose oscillator, mixer, converter, i.f. or audio amplifier transistor; the AA2, an "n-p-n" version of the AA1; the AA3, a high-frequency oscillator, mixer, or converter; the AA4, an all-purpose diamond base "p-n-p" germanium power transistor; and the AA5, a circular-base stud-mounted power transistor. All are listed with their appropriate equivalents. Workman

Circle No. 31 on Reader Service Card

VIDEOTAPE RECORDER

Descriptions, specifications, and applications of the VR-7000 portable videotape recorder and VR-7100 "Videotrainer" system are contained in a new brochure (No. VO22) and separate data sheet (No. V023).

The recorder is a helical-scan unit with two video outputs weighing only 80 pounds, while the "Videotrainer" is a complete, balanced system for recording and playback that includes the VR-7000 recorder, 9" television monitor, audio amplifier/speaker, microphone, and vidicon TV camera. Ampex

Circle No. 32 on Reader Service Card

NEW STANDARDS

Three new engineering standards have been published. The first, "EIA Standard on Type Designations for Receiver-Type Tube Sockets," is No. RS-167B (revision of RS-167-A) and costs $1.30.

The second, "EIA Standard on Color Codes for Microwave Devices with Wire Leads, Including Traveling Wave Tubes, Klystrons and Crossed-Field Devices," is No. RS-235-B (revision of RS-235-A) and costs 25¢.

The last, "EIA-NEMA Standard on Numbering of Electrodes in Multiple Electrode Semiconductor Devices and Designation of Units in Multiple Unit Semiconductor Units," is EIA No. RS-321 (NEMA No. SK-514) and costs 30¢.

The new standards are available from Electronic Industries Association, Engineering Dept., 2001 Eye Street, N.W., Washington, D.C. 20006. Minimum order is $1 unless standards coupons are used. ▲

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JAPAN & Hong Kong Electronics Directory. Products, components, supplies. 50 firms—just $1.00. Ippano Kaisha Ltd., Box 6266. Spokane, Washington 99207.

ELECTRONIC Ignition Kits, Components. Free Diagrams. Anderson Engineering, Epsom, New Hampshire 03239.

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CANADIANS, transistors, all semiconductors and components. Free catalogue contains reference data on 300 transistor types. J.&J. Electronics (Dept. EW), P.O. Box 1437 Winnipeg, Manitoba, Canada.

TRANSISTORS—Miniature Electronic Parts. Send for Free Catalog. Electronic Control Design Company, P. O. Box 1432M, Plainfield, N.J.

ELECTRONIC Bargains—Free Catalog, Tubes, Diodes, CRT's Tuner Cleaner, etc. Cornell, 4213-W University, San Diego, Calif. 92105.

METERS—Surplus, new, used, panel and portable. Send for list. Hanchett, Box 5577, Riverside, Calif. 92507.

TRANSISTORIZED Products Importers catalog. $1.00. Intercontinental. CPO 1717, Tokyo, Japan.

MESHNA'S TRANSISTORIZED CONVERTER KIT $4.50 Two models——converts car radio to receive 30-50 mc or 100-200 mc (one mc tuning). Meshna, Lynn, Mass. 01901.

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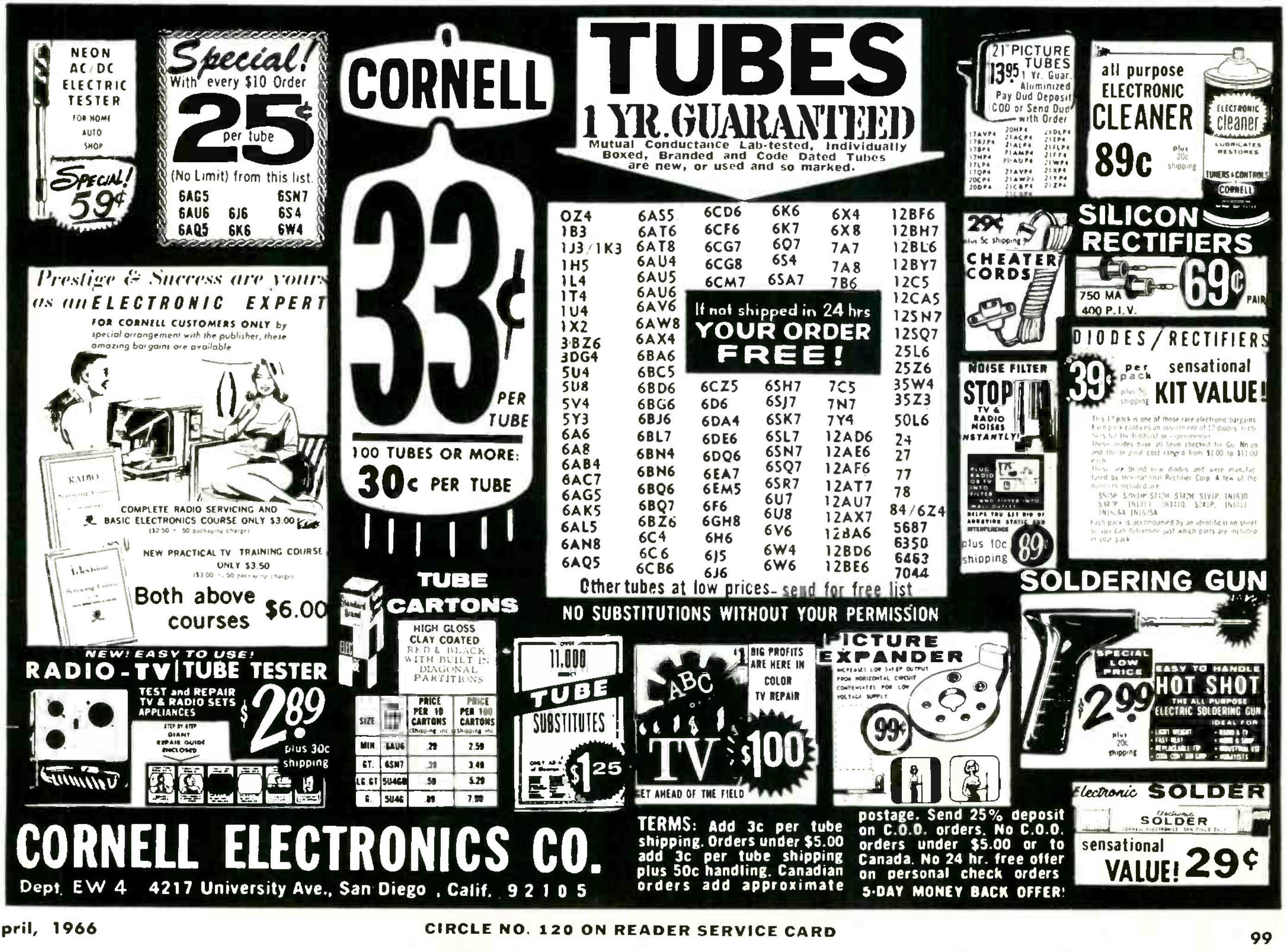

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6BD6
6BG6
6BJ6
6BL7
6BN4
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6BQ6
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6BZ6
6C4
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6U8
6V6
6W4
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6X4
6X8
7A7
7A8
7B6
7C5
7N7
7Y4
12AD6
12AE6
12AF6
12AT7
12AU7
12AX7
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6CG7
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6W4
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6X4
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7B6
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7E6
7F7
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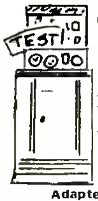

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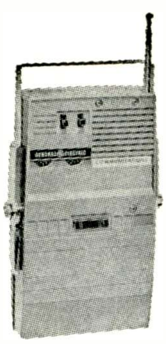

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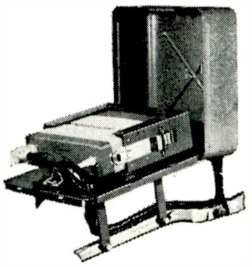

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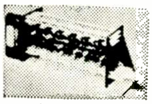

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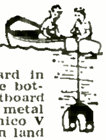

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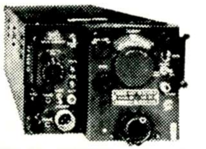

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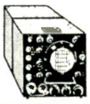

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