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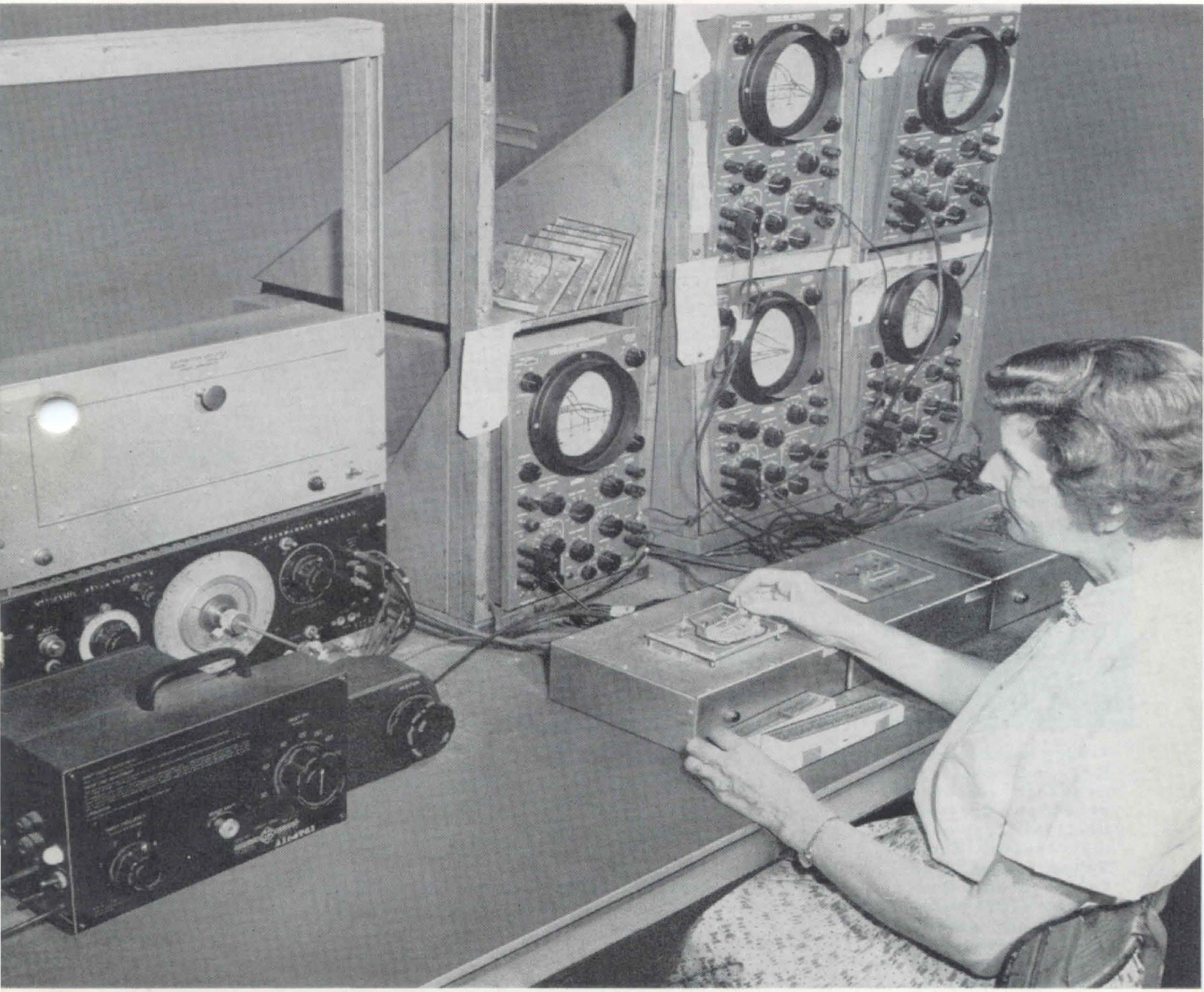

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In This Issue

THE

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CONTENTS

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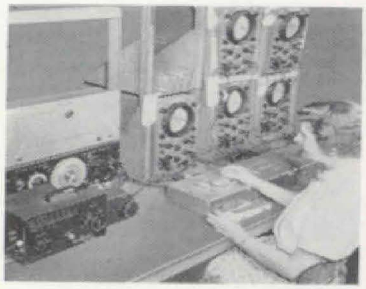

Testing encapsulated R-C networks for frequency response at Philco Corporation. This test used the General Radio Sweep Drive and Beat-Frequency Generator (left foreground) to present the over-all frequency characteristic on a cathode-ray oscilloscope. The lines drawn on the face of the oscilloscope indicate the test limits.

RESPONSE OF PEAK VOLTMETERS TO RANDOM NOISE

Random-noise signals are used in a great variety of electrical, acoustical, and vibrational tests.[1] In these applications a measure of the amplitude of the random-noise signal is usually necessary. Voltmeters with either r-m-s or average response are the most satisfactory types for this measurement, and it has been assumed that peak-responding voltmeters could not be used, because the observed results could not easily be related to those obtained with the other types.

The popular peak-responding voltmeters, such as the General Radio Types 1800[2] and 1803[3] can, however, measure random noise satisfactorily. To show this, some of the important characteristics of random noise and of peak voltmeters will be considered, and comparisons will be made of predicted and actual performance.

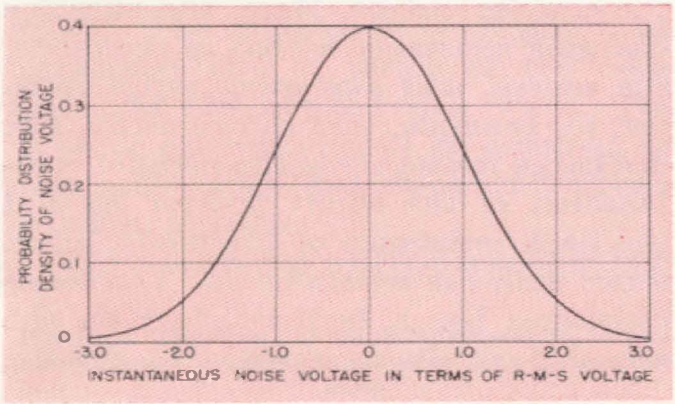

Figure 2. Normal distribution curve of a truly random noise.

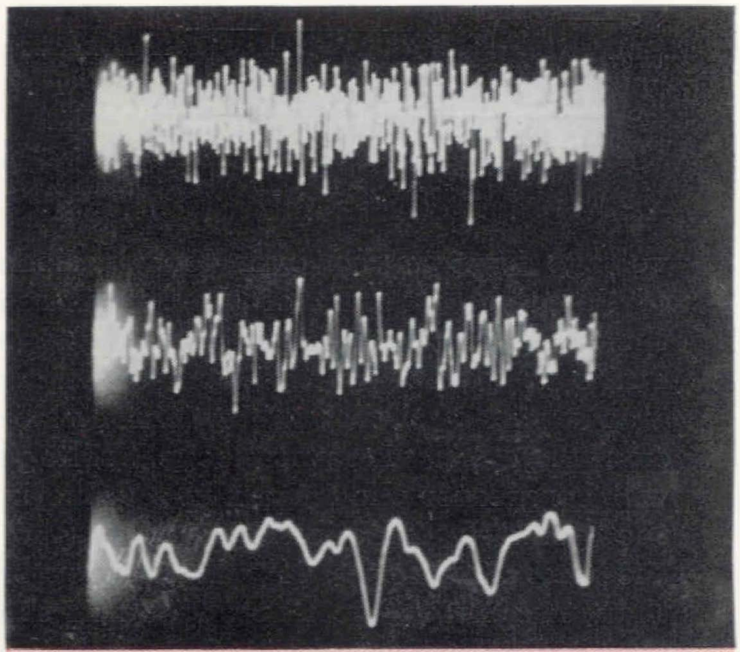

Figure 1. Oscillograms of three different samples of the output voltage from the Type 1390-A Random-Noise Generator. Sweep speeds are in the ratios 1:4:20, top to bottom. A single sweep was used for each oscillogram.

CHARACTERISTICS OF RANDOM NOISE

A random-noise signal is, in some respects, a difficult one to measure, because it is characterized by randomness rather than regularity, as shown in Figure 1. Consequently, noise is ordinarily described by statistical means, and a random noise can be defined as a noise that has a normal distribution of amplitudes. This concept is illustrated graphically by the curve of Figure 2. The probability that a voltage between any two limits will be observed is given by the area under the normal curve between those two limits. Expressed in other terms, if the output

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[1] Arnold Peterson, "A Generator of Electrical Noise", *General Radio Experimenter*, *26*, 7, December 1951; pp. 1–9.

[2] C. A. Woodward, Jr., "The New Type 1800-B Vacuum-Tube Voltmeter", *General Radio Experimenter*, *31*, 4, September 1956; pp. 10–12.

[3] C. A. Woodward, Jr., "The Type 1803-B Vacuum-Tube Voltmeter", *General Radio Experimenter*, *29*, 10, March 1955; pp. 5–8.

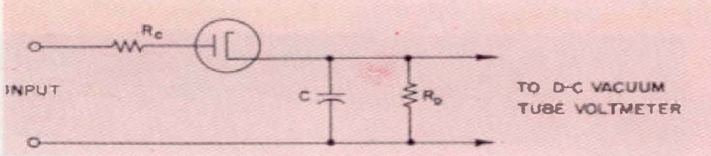

Figure 3. Elementary circuit of a peak-responding diode rectifier.

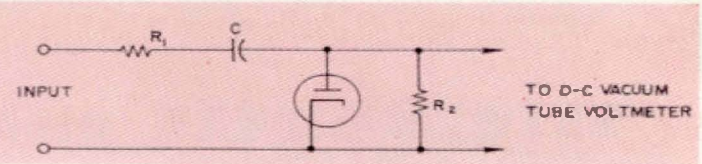

Figure 4. Practical form of the circuit of Figure 3.

voltage is observed over long periods of time, the fraction of the total time the voltage is between the two voltage limits is given by the corresponding area under the probability curve. For example, the instantaneous voltage will be greater than the r-m-s value in the positive direction about 16% of the time. Similarly, it will be greater than two times the r-m-s value in the positive direction about 2.3% of the time. In these two examples, the upper voltage limit was taken as infinity. Naturally, in an electronic system, the usual limitations of amplifiers upset this idealized distribution. In particular, the maximum instantaneous voltage that is obtainable is limited, and some dissymmetry is often introduced, so that the noise is not strictly random. Furthermore, the noise source itself may have similar limitations. But, in general, noise does not have a well-defined peak value, so that the usual simplified concept of the operation of a peak voltmeter cannot be applied to the measurement of noise.

BASIC CIRCUIT OF THE PEAK VOLTMETER

The widely used peak-type voltmeter ordinarily consists of three elements: a diode rectifier, a capacitor, and a d-c voltmeter system, as illustrated in Figure 3. The diode makes it possible for the capacitor to acquire a d-c charge when an a-c voltage is applied to the circuit, and the d-c voltmeter indicates the resulting voltage across the capacitor. In this circuit, the resistance R_C represents the total charging resistance, which includes the effective resistance of the rectifier when it is conducting and the resistance of the source. The resistance R_D is that tending to discharge the capacitor C. The capacitor is charged when the voltage at the input is in such a direction and of such a magnitude that the diode conducts. The net voltage available for supplying charge to the capacitor is reduced as the capacitor voltage increases; and, finally, when the voltage across the capacitor is sufficiently high, no further increase in the voltage across the capacitor occurs. At this point, the charge supplied to the capacitor during the voltage peaks must, on the average, equal the charge that leaks off. How closely the voltage across the capacitor approaches the peak value of the applied wave is dependent upon the charging resistance and the discharging resistance.

A more practical form of circuit developed by Tuttle[4] for a peak-reading voltmeter is that shown in Figure 4. As far as the peak-reading characteristics of this circuit are concerned, the analysis is essentially the same as for the simpler circuit. Here, the effective charging resistance is that of the diode, the source, and any other series resistor, for example, that shown as R_1. The discharge resistance is the parallel combination of the shunt resistor R_2 and the back resistance of the diode, all in series with the resistance R_1. The series resistance has a further effect on the actual d-c voltage supplied to the d-c voltmeter, but this effect is taken care of in the calibration of the voltmeter by a sine-wave signal.

CALCULATION OF RESPONSE

In order to calculate the response of these peak-type voltmeters to any input wave, certain simplifying assumptions are usually made. For input voltage above a few volts it is assumed that the rectifier is a perfect switch but with constant forward resistance and constant reverse resistance. It is also assumed that the discharge time is very long compared to the period of the applied wave. On the basis of these assumptions, the response for a sine-wave signal can be readily calculated, and this response is ordinarily used as the basis for the calibration of the meter. The calibration is usually made experimentally in terms of the r-m-s value of the applied sine wave. This type of calibration will be assumed for the subsequent discussion of response to random noise.

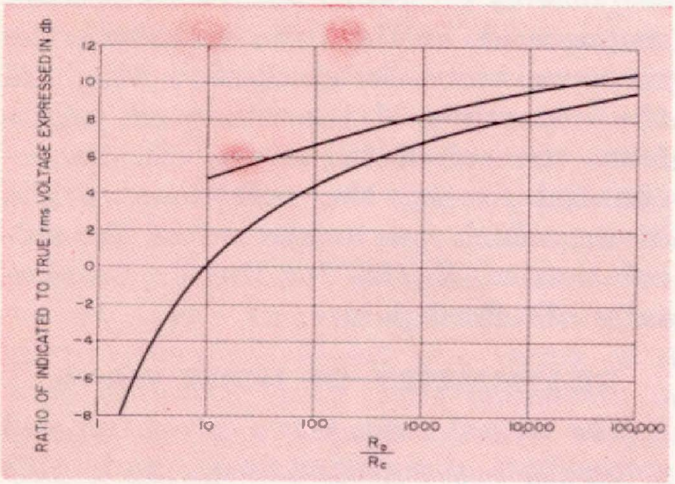

Figure 5. Previously published data of the response of a peak voltmeter to random noise (upper curve, reference (5); lower curve, reference (6).

The response to random noise has been calculated on the basis of the above assumptions,[5, 6] but no correct numerical values appear to have been published. The results published previously are shown in Figure 5. These differ by such large factors that one wonders which is correct. Strangely, neither of them is. Beranek[5] analyzed the problem correctly on the basis of the procedure given above and obtained the equation

$$\frac{1}{E_b}\int_{E_b}^{\infty} EP(E)\,dE - \int_{E_b}^{\infty} P(E)\,dE = \frac{R_C}{R_D}$$

where E_b is the average voltage across the capacitor C, E is the instantaneous value of the input voltage, $P(E)$ is the probability distribution of the instantaneous amplitudes of the input wave, R_C is the total resistance through which the capacitor is charged, and R_D is the total resistance through which the capacitor discharges. He also assumed that the reactance of the capacitor was small compared to R_C and R_D for all frequencies of the input wave. Errors apparently occurred in

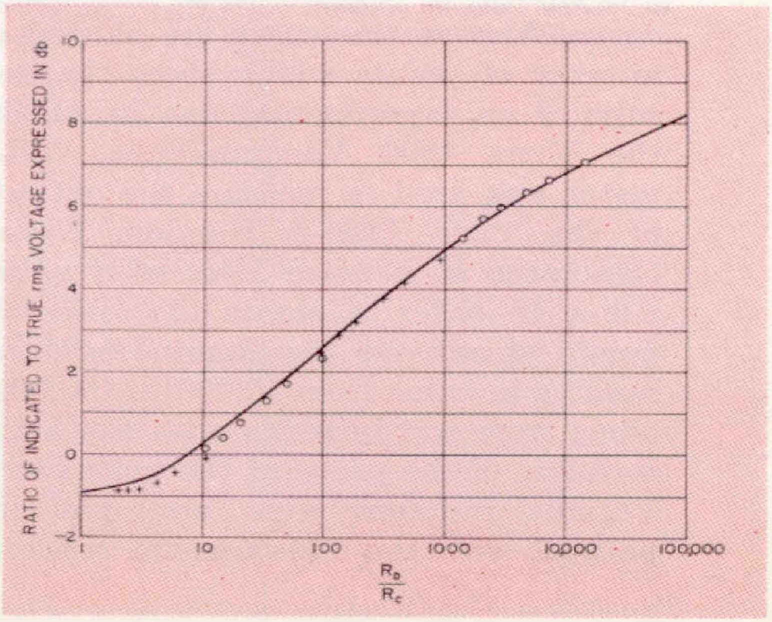

Figure 6. Response of peak voltmeter to random noise. Curve is calculated, points are experimental data.

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[4] W. N. Tuttle, "The Type 726-A Vacuum-Tube Voltmeter", *General Radio Experimenter, 11*, 12, May, 1937; pp. 1–6.

[5] L. L. Beranek, "Acoustic Measurements," John Wiley & Sons, N. Y., 1949, pp. 475–479.

[6] B. M. Oliver, "Some Effects of Waveform on VTVM Readings", *Hewlett-Packard Journal, 6*, 10, June 1955.

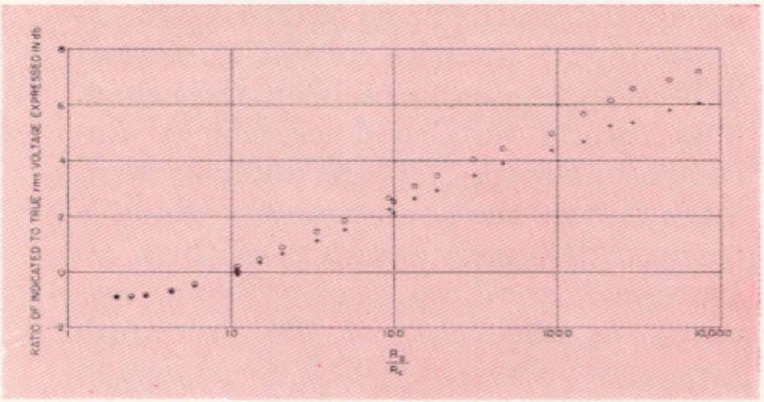

Figure 7. Experimental data for Figure 6, showing spread between positive and negative halves of wave.

the calculation [5], however, and the published curves are not correct. The other analysis [6] involved two important simplifying assumptions beyond those already stated. The first was the assumption that the voltage developed across the capacitor did not affect the charging current, and the second was that, for a sine wave, the indicated voltage was equal to the peak value. The first assumption makes the analysis incorrect for large values of the ratio of discharge and charge resistances, and the second makes the analysis incorrect for small values of this ratio.

This problem was reviewed some time ago, and new data were calculated from Beranek's formula. These are shown in Figure 6 as the solid curve. Also on this curve are plotted a number of points which show the results of an experimental test in which the Type 1800 Vacuum-Tube Voltmeter was used to measure the output of the Type 1390-A Random Noise Generator at a noise level of 3 volts r-m-s. In order to obtain the series of points shown on the figure, resistors ranging in value from 10,000 to 100,000 ohms were put in series with the high terminal of the probe of the voltmeter. Various resistors were also put in parallel with the 125-megohm resistor shunting the diode. For each point, the reading was calibrated in terms of the r-m-s value of a sine wave to give the same reading obtained for the noise. The data are plotted as a function of the ratio of the discharge to the charge resistance. It is seen from this figure that the observed values agree very well with the theoretically calculated curve. At low values of the ratio the response is similar to that of an average meter, and, as the ratio increases, the response increases gradually. Much of the departure of the observed points from the calculated curve can be accounted for by the resistance of the diode, which was neglected in the calculation of R_D/R_C for the experimentally observed points.

DISSYMMETRY OF NOISE WAVE

The actual noise wave measured was somewhat dissymmetrical, and this characteristic is a common one for noise signals. The dissymmetry is not indicated on the usual r-m-s or average-type meter, but it is observable on a cathode-ray oscillograph display of the wave. It can be measured on the peak-type voltmeter by noting the indication for both the positive and negative halves of the wave, and the results of these two sets of measurements are shown in Figure 7. When the voltmeter is operating as a good peak voltmeter, that is, with a discharge resistance many times the charge resistance, the dissymmetry is readily measured, as shown by the example of Figure 7. When the charge resistance is about equal to the discharge resistance, however, the instrument responds essentially to the average value, and the dissymmetry cannot be measured.

The meter used for obtaining the reference r-m-s reading was a full-wave type, and the calculations were based on a symmetrical distribution. Consequently, for comparison with the calculated curve in Figure 6, the average of the two observed readings for each value of the ratio was used.

EFFECT OF VOLTAGE LEVEL

At the voltage level used for the experimental points of Figures 6 and 7, the diode behaved essentially as a switch with a discontinuity in its characteristic, as assumed in the analysis. At low voltage levels, however, the diode rectifies mainly by virtue of the curvature of its characteristic. The voltmeter is then no longer peak-indicating, but rather it approximates an r-m-s indication. The transition between these two modes of operation occurs between about one tenth of a volt and one volt.[7] This transition is shown in the experimentally determined curves of Figure 8 and Figure 9. These curves show the ratio of the applied r-m-s noise voltage to the observed voltage. The behavior is shown here as a correction factor to be applied to the reading of the voltmeter to obtain the r-m-s value of the applied noise voltage. Two curves are shown for each voltmeter. One is for no added series resistance, and the other is for 100,000 ohms series resistance.[8] If intermediate values of resistance are used, the correction factor can be easily interpolated between these two with the aid of the curve of Figure 6 to supply the limiting value.

When no series resistance is used, the indicated voltage is highly dependent on the high instantaneous voltages that occur occasionally. For example, for a random noise at an r-m-s voltage of about 10 volts, the actual d-c voltage developed across the capacitor in the Type 1800-B Vacuum-Tube Voltmeter is about 3½ times the

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[7] C. B. Aiken, "Theory of the Diode Voltmeter", *Proc. IRE*, *26*, 7, July 1938; pp. 859–876.

[8] The 100,000 ohms series resistance affects the sine-wave calibration of the meter by only about 1%. Ibid., p. 876.

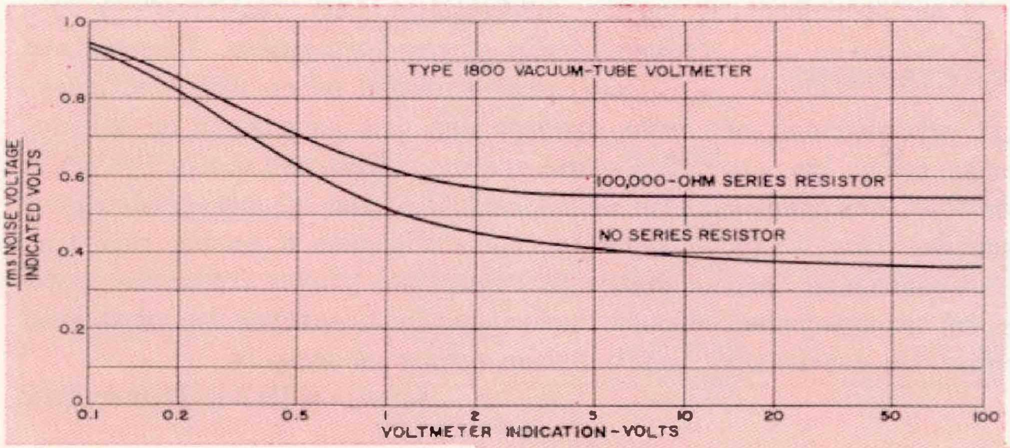

Figure 8. Correction for Type 1800 Vacuum-Tube Voltmeter indication to obtain r-m-s value of random noise.

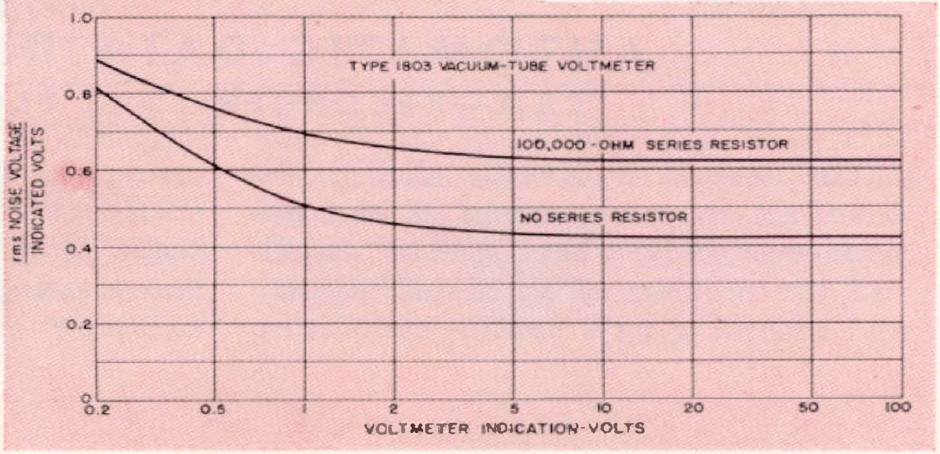

Figure 9. Correction for Type 1803 Vacuum-Tube Voltmeter indication to obtain r-m-s value of random noise.

r-m-s value of the noise. Instantaneous voltages that are still higher must, therefore, occur occasionally to supply the charge for the capacitor. For a normal distribution, the noise voltage is higher than this value only about 0.02% of the time. This direct measurement can, therefore, be a useful indication of the higher voltages existing in the noise; for example, to determine the extent of peak clipping.

A good measure of the r-m-s value can usually be obtained from the reading of a peak voltmeter when it is possible to use a high resistance in series with the diode. The indicated value then depends on a larger sample of the instantaneous voltage. When a 100,000-ohm series resistor is used, the r-m-s value of random noise can be obtained by applying to the meter indication the correction shown in Figure 8 or Figure 9. The one disadvantage of using a series resistor is that it reduces the frequency range over which the voltmeter response is essentially uniform.

FREQUENCY CHARACTERISTIC

One of the important advantages of the peak-type voltmeter with its attached probe is its excellent frequency characteristic, for example, the Type 1800-B Vacuum-Tube Voltmeter can be used to hundreds of megacycles. When measurements must be made up to those frequencies, the probe must be attached at the point where the measurement is desired in order to obtain this good frequency response, and no series resistance should be used. If, however, measurements of audio-frequency noise are being made, high resistances can be inserted in series with the probe terminal without seriously affecting the response to the audio voltage. Thus, for example, if 100,000 ohms is inserted in series with the high terminal right at the probe, the response is down about 10 per cent at 130 kc. If 50,000 ohms is used, the corresponding frequency is raised to 250 kc; or if ½ megohm is used, the 10-per cent point occurs at about 30 kc.

CONCLUSION

The peak-reading voltmeter can be more useful in the measurement of random noise than has heretofore been believed.

The correction curves of Figures 8 and 9 make it possible to relate the meter indications to the true r-m-s amplitude of random noise. These data should prove useful when r-m-s or average meters are not available or where, for some reason, their use is not feasible. In addition, the use of the voltmeter directly, i.e., without a series resistor, yields information about instantaneous peak voltages that cannot be obtained with other types of meters.

— Arnold P. G. Peterson

AUTOMATIC DATA DISPLAY

CRO—RECORDER—X-Y PLOTTER

The several automatic dial drives described in recent issues of the *Experimenter* [1, 2, 3, 4, 5] have greatly simplified the problem of automatic display and recording as a routine laboratory operation. They attach to existing oscillators and make possible both oscilloscope and graphic display without necessitating the use of specialized sweeping equipment. They combine the features of economy and simplicity with the ability to produce highly satisfactory results.

To facilitate a selection of the best drive for a given application, the several drives and their uses have been tabulated below, together with the General Radio oscillators with which they can be used, listed in the order of increasing frequency range.

GENERAL RADIO SWEEP DRIVES

Frequency Range	*Oscillator Type No.*	*Drive Type No.*	*CRO* [10]	*Graphic Recorder*	*X-Y Plotter*
10 c to 100 kc	1302-A	1750-A	x	x	x
20 to 20,000 c 20 kc to 40 kc	1304-B	908-P2	x		
		908-P1		x	
		908-R12		x	x
		908-R96		x	x
		1750-A	x		
20 to 20,000 c 20 kc to 40 kc	1303-A	908-P2	x [6]		
		908-P1		x	
		1750-A	x		
20 to 200μ 0.2 to 2 kc 2 to 20 kc 20 to 200 kc 50 to 500 kc	1210-B	908-P1		x	
		908-P2	x [6, 7]		
		907-R18		x	x
		907-R144		x	x
		1750-A	x		
0.5 to 5 Mc 5 to 50 Mc	1211-B [8]	908-P2	x [6]		
		908-P1		x	
		908-R12		x	x
		908-R96		x	x
		1750-A	x		
5 to 15 kc 15 to 50 kc 50 to 150 kc 150 to 500 kc 0.5 to 15 Mc 15 to 50 Mc	1330-A	908-P1		x	
		907-R18		x	x
		907-R144		x	x
50 to 250 Mc	1215-B [8]	908-P2	x [6]		
		908-P1		x	
		908-R12		x	x
		908-R96		x	x
		1750-A	x		
250 to 920 Mc	1209-B [8]	908-P2	x [6]		
		908-P1		x	
		907-R18		x	x
		907-R144		x	x
		1750-A	x		
900 to 2000 Mc	1218-A [8]	908-P1		x	
		908-R12		x	x
		908-R96		x	x
		1750-A	x		
300 to 5000 Mc	Type 874-LB Slotted Line with appropriate oscillator	874-MD	x [9]		x

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[1] H. C. Littlejohn, "Motor Drives for Precision Drives and Beat-Frequency Oscillators", *General Radio Experimenter*, 29, 6; November, 1954, pp. 1–3.

[2] Eduard Karplus, "A New System for Automatic Data Display", *General Radio Experimenter*, 29, 11; April, 1955, pp. 1–6.

[3] R. A. Soderman, "Automatic Sweep Drive for the Slotted Line", *General Radio Experimenter*, 29, 11; April, 1955, pp. 10–15.

[4] G. A. Clemow, "Synchronous Dial Drives for Automatic Plotting", *General Radio Experimenter*, 31, 3; August, 1956, pp. 5–9.

[5] W. F. Byers, "The Type 1263-A Amplitude-Regulating Power Supply", *General Radio Experimenter*, 29, 11; April, 1955, pp. 6–10.

[6] Horizontal deflection voltage not provided; synchronous drive.

[7] Horizontal deflection voltage can be furnished with the Type 1210-P1 Detector and Discriminator.

[8] Oscillator must be powered by the Type 1263-A Amplitude Regulating Power Supply.

[9] Displays VSWR directly on CRO.

[10] Oscilloscope should have long-persistence screen.

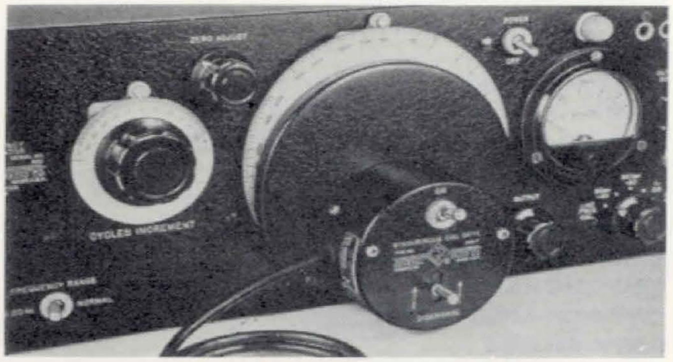
Type		*Code Word*	*Price*
907-R18	X-Y Dial Drive	EARLY	$55.00
907-R144	X-Y Dial Drive	EDUCE	55.00
908-R12	X-Y Dial Drive	EGRET	55.00
908-R96	X-Y Dial Drive	EJECT	55.00

THE TYPE 908-P1 and TYPE 908-P2 SYNCHRONOUS DIAL DRIVES

Simplest and least expensive of the dial drives, these synchronous units will fit both the Type 907-WA and the Type 908-WA Gear-Drive Precision Dials. They do not include the potentiometer for supplying a horizontal deflection voltage. Adjustable stops are provided for limiting travel. Drives are self reversing. The faster model, Type 908-P2, can be used for oscilloscope display if a simple discriminator is provided to supply the X-axis original. The Type 908-P1 is recommended for use with a graphic recorder. A complete description with specifications was published in the *Experimenter* for November, 1954.

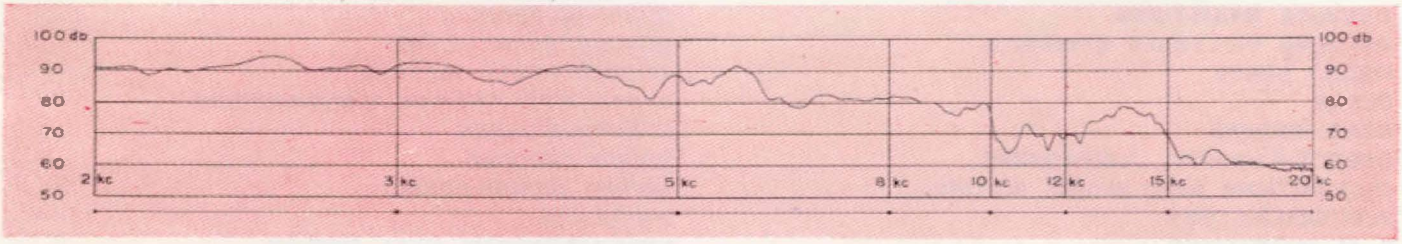
Speed:

Type	*Pinion*	*908 Dial*	*907 Dial*
908-P1	4 RPM	4/15 RPM or 225 secs/rev	4/10 RPM or 150 secs/rev
908-P2	30 RPM	2 RPM or 30 secs/rev	3 RPM or 20 secs/rev

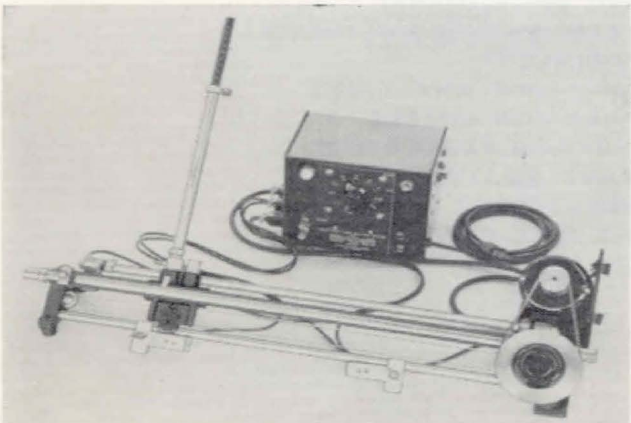


(Above) View of the Type 908-P1 Synchronous Dial Drive installed on a Type 1304-B Beat-Frequency Audio Generator.

(Below) Record of the frequency response of a small loudspeaker in an anechoic chamber. Oscillator was driven by the Type 908-P1 Synchronous Dial Drive.



Type		*Code Word*	*Price*
908-P1	Synchronous Dial Drive	SYNDO	$27.50
908-P2	Synchronous Dial Drive	SYNKA	27.50

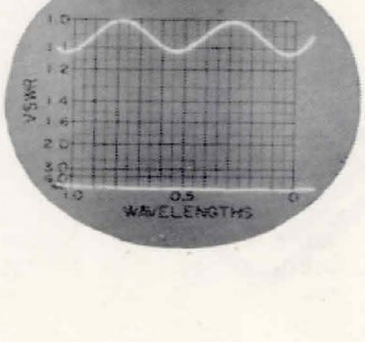


View of the Type 874-LBA Slotted Line with the Type 874-MD Motor Drive.

SLOTTED LINE MOTOR DRIVE

The slotted-line motor drive, designed to drive the probe carriage of the General Radio Type 874-LBA Slotted Line, makes possible the display of VSWR directly on an oscilloscope. Its use greatly speeds up slotted line measurements. See the *Experimenter* for April, 1955, for complete details.

VSWR pattern, as displayed on scope, obtained with the motor-driven slotted line.



Type		*Code Word*	*Price*
874-MD	Slotted-Line Motor Drive..	STORY	$290.00

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BEAT-FREQUENCY OSCILLATORS
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CAPACITANCE BRIDGES
CAPACITORS
COAXIAL ADAPTORS
COAXIAL CONNECTORS
COAXIAL ELEMENTS
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DECADE CAPACITORS
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R–C OSCILLATORS
RESISTORS
SHIELDED CONDUCTORS
SLOTTED LINES
SOUND ANALYZERS
SOUND–LEVEL METERS
STANDARD–SIGNAL GENERATORS
STROBOSCOPES
SWEEP DRIVES
SWEEP GENERATORS
SWITCHES
SYNCHRONOUS DIAL DRIVES
TELEVISION STATION MONITORS
TIME-DELAY GENERATORS
TIME/FREQUENCY CALIBRATORS
TUNING–FORK OSCILLATORS
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VIBRATION METERS
VOLTAGE REGULATORS
WAVE ANALYZERS
WHEATSTONE BRIDGES
X–Y DIAL DRIVES
Z–Y BRIDGES

General Radio Company

extends to all *Experimenter* readers its best wishes for a Merry Christmas and a Happy New Year.

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THE TYPE 1750-A SWEEP DRIVE

(see cover)

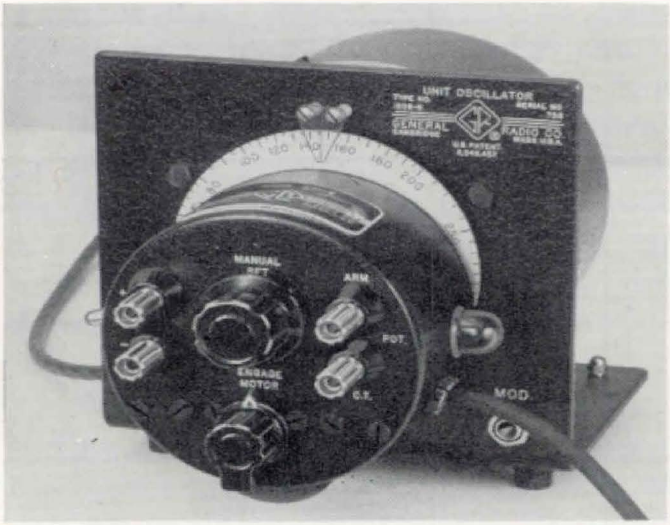
Of all the drives, the Type 1750-A is the most flexible in application, because it fits any knob or dial and is easily adjustable, while operating, both in sweep arc and sweep rate. Speed range is 0.5 to 5 cps over arcs from 30° to 300°. This drive is fully described in the *Experimenter* for April, 1955.

Type		*Code Word*	*Price*
1750-A	Sweep Drive (115 volts, 50–60 cycles)..........	STUDY	$440.00

AMPLITUDE-REGULATING POWER SUPPLY

Where indicated in the table (with Types 1211-B, 1215-B, 1209-B, and Type 1218-A Unit Oscillators) the Type 1263-A Amplitude-Regulating Power Supply is necessary to hold the oscillator output constant. This, with other accessories, is listed below.

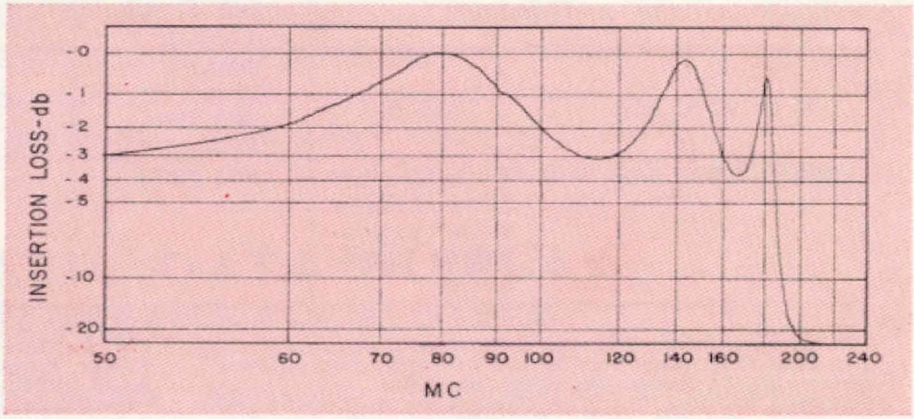
Type		*Code Word*	*Price*
1263-A	Amplitude Regulating Power Supply..........	SALON	$280.00
874-VR	Voltmeter Rectifier..........................	COAXRECTOR	30.00
874-VQ	Voltmeter Detector..........................	COAXVOQUER	30.00
274-NF	Patch Cord..................................	STANPARGAG	1.50
874-Q6	Adaptor.....................................	COAXCLOSER	2.25
874-WM	50-ohm Termination..........................	COAXMEETER	12.50



THE TYPE 907-R and TYPE 908-R X-Y DIAL DRIVES

These drives are designed to fit the General Radio Type 907-WA (4-inch) and Type 908-WA (6-inch) Gear Drive Precision Dials for front-of-panel mounting. Oscillators using these dials are listed in the table for the R-type drives. The drive replaces the knob on the front of the dial and is easily installed. Its synchronous motor rotates the dial at a uniform rate. A potentiometer is rotated simultaneously, providing an output voltage proportional to dial position, which can be used to drive the X-axis of a plotter. A complete description and specifications will be found in the *Experimenter* for August, 1956. Two speeds are available in each size.

(Above) View of Type 907-R-144 X-Y Dial Drive, installed on a u-h-f Unit Oscillator.



(Right) Plot of the frequency characteristic of a Type 874-F185 Filter obtained on an X-Y plotter with the X-Y Dial Drive shown above.

Type	*Dial*	*Speed*	*Rotation*	*Potentiometer*	*Max Pot. Current*	*Resolution*
907-R18	907	18°/min	CCW	20 kΩ	10 ma	0.4°
907-R144	907	144°/min	Self-reversing	20 kΩ	10 ma	0.4°
908-R12	908	12°/min	CCW	50 kΩ	10 ma	0.2°
908-R96	908	96°/min	Self-reversing	50 kΩ	10 ma	0.2°