THE General Radio EXPERIMENTER

VOLUME XXVI No. 7 DECEMBER, 1951

ELECTRICAL MEASUREMENTS AND THEIR INDUSTRIAL APPLICATIONS

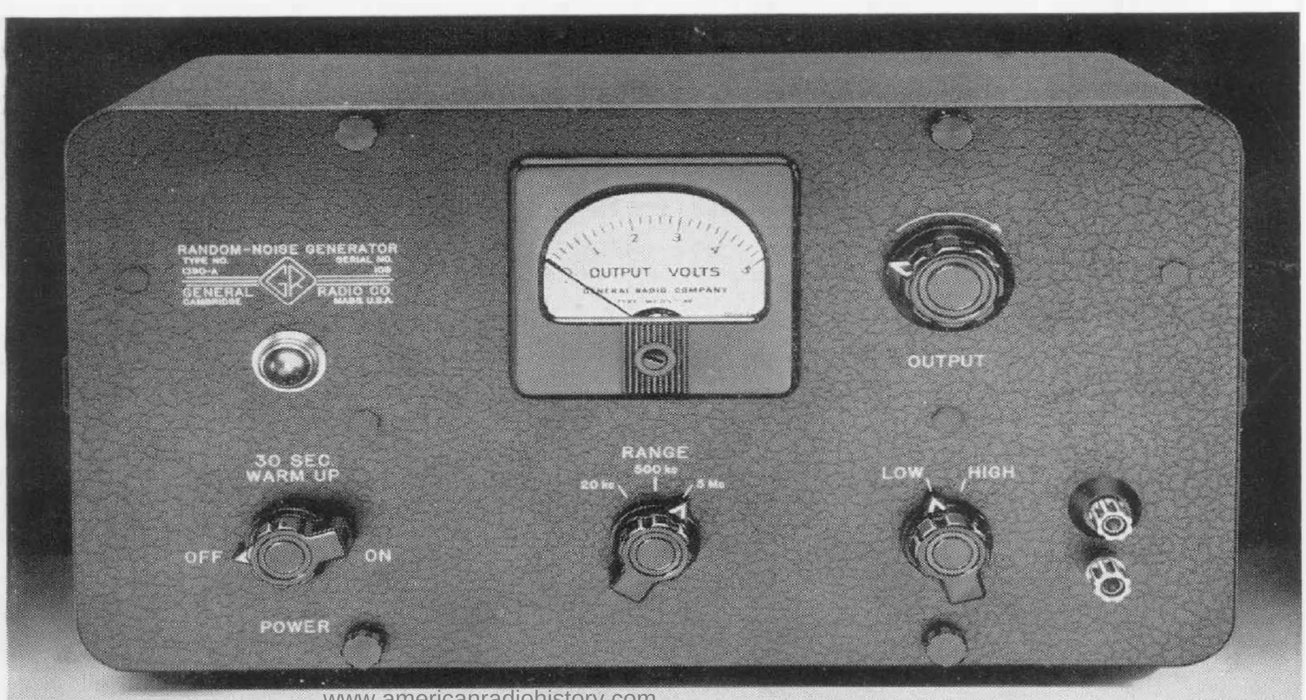
A GENERATOR OF ELECTRICAL NOISE

Also IN THIS ISSUE

● **ELECTRICAL NOISE** is, by definition, an unwanted disturbance, and its reduction in communication circuits is a constant aim of the electronics engineer. When supplied by a properly controlled generator, however, noise becomes a remarkably useful signal, making possible a new approach to many measurement problems. The new General Radio TYPE 1390-A Random-Noise Generator, shown in Figure 1, is such a source. It provides a high level of electrical noise at its output terminals, and its many possible uses make it an indispensable item in the equipment of the modern electronics laboratory.

Typical applications are room acoustics measurements, loudspeaker and microphone tests, psychoacoustic tests, filter tests, calibration checks on recording systems, modulating signal generators and test oscillators, tests of r-m-s response of meters, observations of resonances

Figure 1. View of the Type 1390-A Rondom Noise Generator.



in systems, electrical averaging of resonant responses, comparisons of effective band width, and crosstalk measurements on multi-channel systems.

Furthermore, many college laboratories will find the noise generator helpful in familiarizing students with the characteristics of noise and with the measurement problems associated with noise. In the classroom it can be used for demonstrating various degrees of correlation, possible errors of random sampling, and other concepts of statistical theory.

DESCRIPTION

As shown in the elementary schematic diagram of Figure 2, the TYPE 1390-A Random-Noise Generator uses a gas-discharge tube as the noise source. A transverse magnetic field is applied to the tube in order to increase the noise level at high frequencies and to eliminate the oscillatory nature of the electrical discharge usually obtained in a gas tube.[1] The noise output from this gas tube is amplified in a two-stage amplifier. Between the first and second stages the noise spectrum is shaped in three different ways, depending on the setting of the range-switch control shown just below the meter in Figure 1. At the 20-kc setting, a low-pass filter is inserted, which has a gradual roll-off above 30 kc, with the audio range to 20 kc uniform in spectrum level. The 500-kc setting puts in a low-pass filter that rolls off above 500 kc. At the 5-Mc setting, a peaking network is used that approximately compensates for the drop in noise output from the gas tube at high frequencies, so that a reasonably good spectrum is obtained out to 5 Mc.

The output level is controlled by a potentiometer and a two-position switch, both these controls being located at the right as shown in Figure 1. The rectifier-type, average meter, located in the upper center of the panel, is calibrated to read the r-m-s value of the noise at the output terminals.

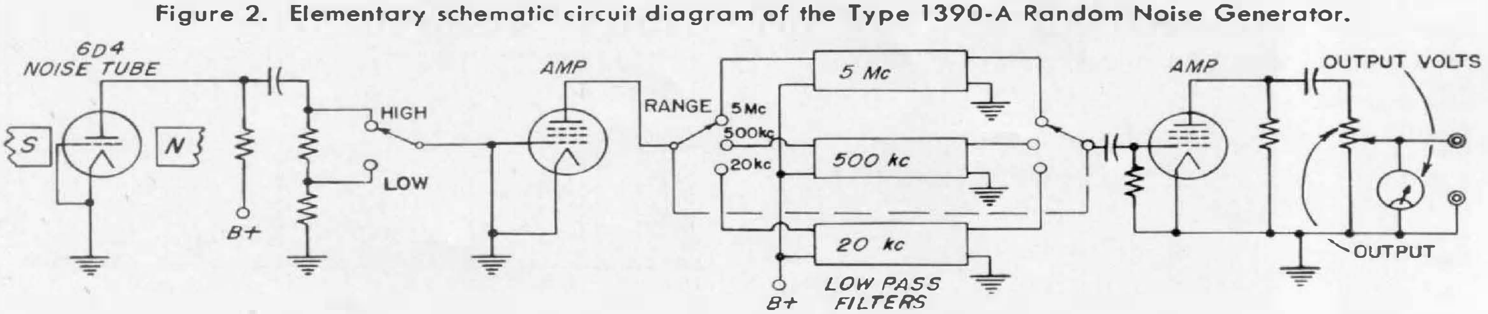
Easily portable and weighing only 14 pounds, the complete generator is mounted in an aluminum cabinet with rounded corners and with rubber feet. The a-c power input to the instrument is about 50 watts.

OUTPUT VOLTAGE

The maximum open-circuit output voltage on any of the three bands is one volt rms. This corresponds to a relatively high noise level, since the output impedance at maximum output is only about 800 ohms. To show how high this level is, it can be expressed in terms of the resistance noise corresponding to 800 ohms at room temperature. The r-m-s voltage in a one-cycle band that is due to thermal agitation in an 800-ohm resistor at room temperature is about 3.6×10^{-9} volts. The level from the TYPE 1390-A Random Noise Generator is about six millivolts for a one-cycle band when there is a total output voltage of one volt on the 20-kc band. This level is then about 1,600,000 times the corresponding voltage for resistance

[1] J. D. Cobine and J. R. Curry, "Electrical Noise Generators," *Proc. I.R.E.*, pp. 875-879, September, 1947.

Figure 2. Elementary schematic circuit diagram of the Type 1390-A Random Noise Generator.



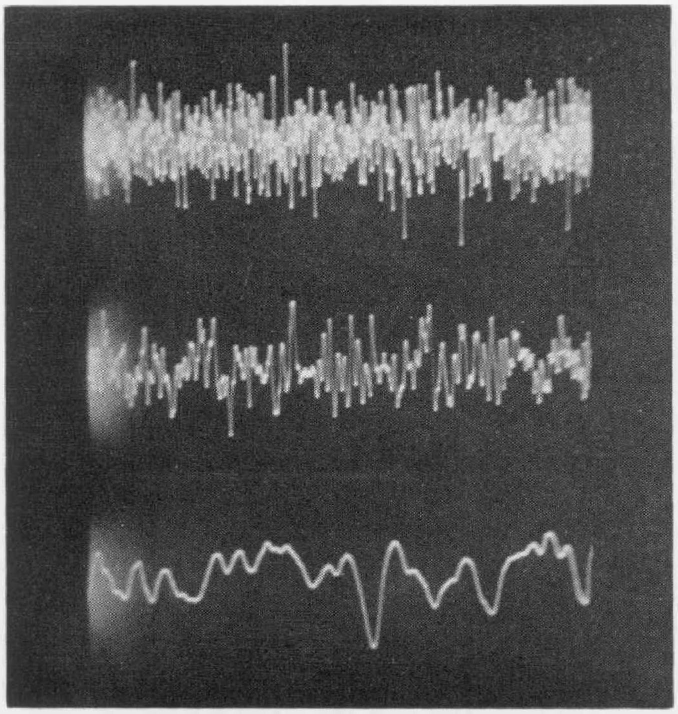


Figure 3. Oscillograms of three different samples of the output voltage wave of the noise generator. Only a single sweep and not a repetitive one was used in each case. The sweep speed for the middle trace was about four times that of the upper trace, and the wave was spread out even further in the lower trace by using a sweep speed of twenty times that of the upper trace.

noise, or about 124 db above resistance noise at the same impedance level.

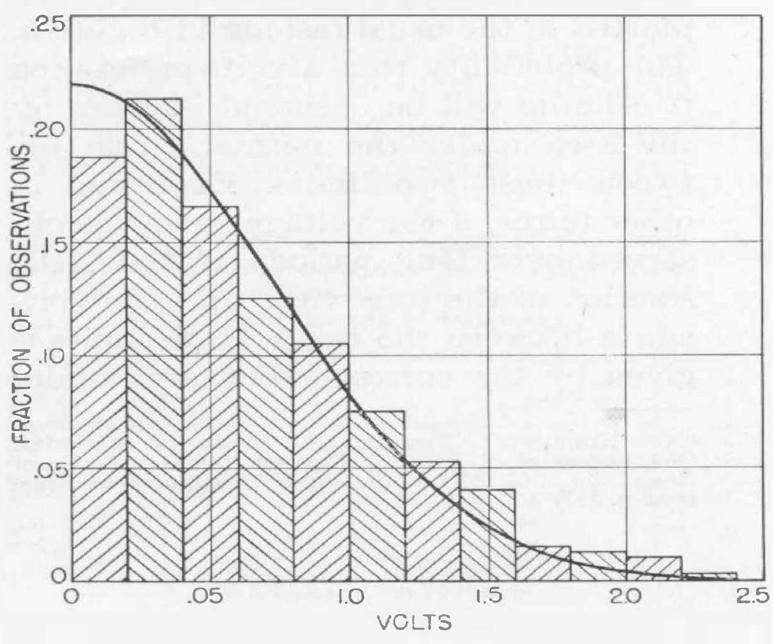
CHARACTERISTICS OF THE NOISE OUTPUT

Describing or specifying a noise signal is more difficult than specifying a sinusoidal signal. A picture of the output waveform such as that given in Figure 3 makes this evident. No regular pattern appears in this waveform; it is characterized by randomness rather than regularity. Because of this randomness, noise is usually described by statistical means,[2] and the noise is characterized by its distribution of instantaneous amplitudes and by its frequency spectrum.

A random noise is frequently defined as one that has a "normal" or "Gaussian" distribution of amplitudes. This concept can readily be understood by illustrating it in terms of the following simple experiment performed on the noise generator. The noise generator was set to the 20-kc band, and a small capacitor was connected across it. The capacitor was disconnected, and the voltage across the capacitor was measured on an electrometer. This voltage is the instantaneous amplitude of the noise voltage at the time of disconnecting the capacitor. This experiment was repeated until 400 readings had been obtained. (For convenience, only voltages of one polarity were measured.) From this set of data the chart of Figure 4 has been prepared. It shows the fraction of the observations that were in each interval of 0.2 volt. This chart shows that most of the observations were relatively low values, but some relatively high values were observed. These same re-

[2] S. O. Rice, "Mathematical Analysis of Random Noise," *Bell System Technical Journal*, Vol. 23, No. 3, July, 1944, pp. 282-332; Vol. 24, No. 1, January, 1945, pp. 46-156.
L. L. Beranek, *Acoustic Measurements*, New York, John Wiley, 1949, pp. 440-515.
J. L. Lawson and G. E. Uhlenbeck, *Threshold Signals* (Radiation Laboratory Series, Vol. 24), New York, McGraw-Hill, 1950, pp. 33-122.
S. Goldman, *Frequency Analysis, Modulation and Noise*, New York, McGraw-Hill, 1948, pp. 205-403.

Figure 4. A chart of the results of a voltage sampling experiment performed on the noise generator. The continuous curve is a normal probability distribution curve adjusted according to the r-m-s value of the noise voltage and the size of the intervals used in plotting the chart.



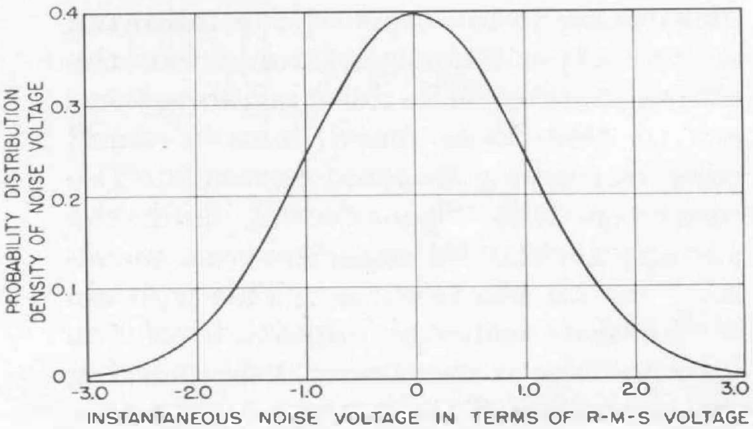


Figure 5. The normal distribution curve of a truly random noise.

sults are also shown in a qualitative way in the oscillographic picture of Figure 3.

The normal (Gaussian or Laplacian) distribution curve is also shown on the chart of Figure 4. It has been adjusted according to the computed r-m-s value of the data (the standard deviation) and the size of the interval used in plotting the data. The experimental data fit the normal curve very closely. The departures from the normal curve are almost entirely a result of having so few observations. If many more observations had been made, the result would have been even closer to the expected values.[3]

This normal curve is more precisely a probability density curve, and it is shown plotted in the usual fashion in Figure 5. The probability that a voltage between two limits will be observed is given by the area under the normal curve between those two limits. Expressed in other terms, if the voltage output is observed over long periods of time, the fraction of the total time that the voltage is between the two voltage limits is given by the corresponding area under the probability curve.[4] For example, the instantaneous voltage magnitude will be no more than one-tenth of the r-m-s value for about eight per cent of the time, and will be greater than three times the r-m-s value only about 0.26 per cent of the time.

DEPARTURES OF OUTPUT OF NOISE GENERATORS FROM TRUE RANDOMNESS

The normal curve of Figure 5 is symmetrical about the origin, and the output of the noise generator is also very closely symmetrical, with no appreciable d-c component being present. Because of the inherent amplitude limitations of vacuum tube amplifiers, however, there is some limiting of the distribution curve at high levels. The normal distribution is modified only slightly on the 20-kc range, while moderate clipping occurs on the other ranges. These limitations are of no importance for the majority of applications.

FREQUENCY SPECTRUM OF NOISE

The meaning attached to the phrase "the frequency spectrum of a noise" is also readily described in terms of an experiment. If a wave analyzer, such as the Type 736-A Wave Analyzer, is used to analyze the output of the noise generator, a fluctuating meter reading will be observed at any setting of the analyzer. If the average value of this reading is taken over a period of time very long compared to 0.2 second (the period corresponding to the five-cycle effective band width of the analyzer), this average value is the level in that five-cycle-wide band. The level determined in this way on any of the ranges of the noise generator is essentially independent of

[3]Nic Knudtzon, "Experimental Study of Statistical Characteristics of Filtered Random Noise," *Technical Report No. 115*, M.I.T. Research Laboratory of Electronics, July 15, 1949.

[4]R. E. Neinburg and T. F. Rogers, "Amplitude Distribution Analyzer," *Radio-Electronic Engineering*, Vol. 46, No. 6, December, 1951, pp. 8-10.

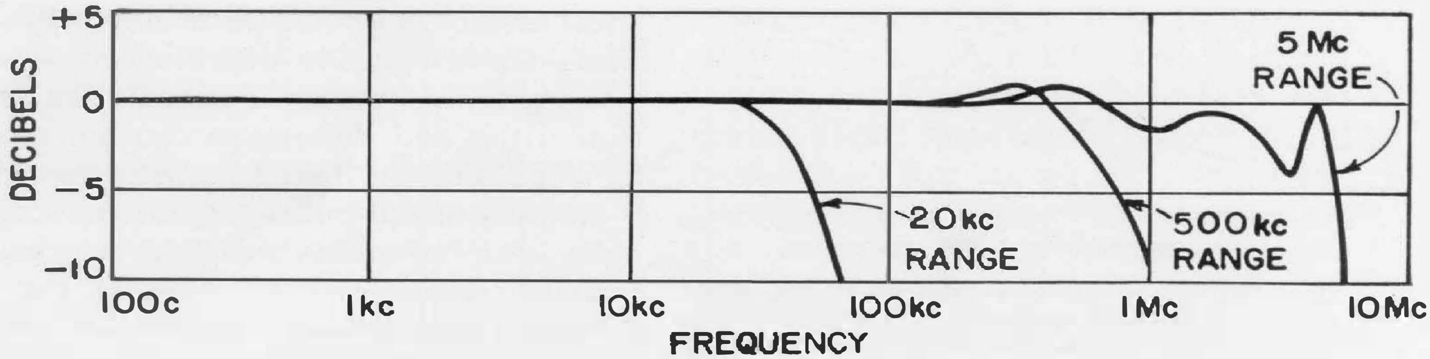


Figure 6. Typical spectrum level characteristics for Type 1390-A Random-Noise Generator.

the frequency setting of the Type 736-A Wave Analyzer. Thus the spectrum in this region is uniform. The relative spectrum of the noise can be determined by using suitable analyzers to cover the full range of the principal energy regions of the noise. A typical result of such an analysis is shown in Figure 6 for the three bands of the Type 1390-A Random Noise Generator. When the spectrum is uniform over a broad band, as shown there, it is frequently called "white noise." The "whiteness" always applies to a definite band only. For example, if the noise spectrum is uniform from 100 kc to 500 kc, the noise is referred to as white in that band.

It is customary to adjust the measured value of analyzed noise to that corresponding to an ideal filter of one-cycle band width. Since noise voltage increases as the square root of the band width, the value determined on the Type 736-A Wave Analyzer is then divided by

$$\sqrt{\frac{5 \text{ cycles}}{1 \text{ cycle}}}$$

to obtain what is called here "spectral voltage density." This value can be defined as the r-m-s voltage corresponding to the energy contained within a band one cycle per second wide.

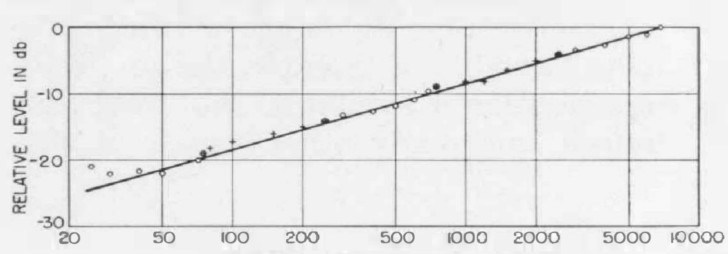
ANALYSIS OF NOISE BY CONSTANT-PERCENTAGE ANALYZERS

If the output of the Type 1390-A Random Noise Generator is analyzed by a Type 760-B Sound Analyzer, the results will be similar to that shown in Figure 7. Here the indicated level increases 10 decibels for each decade increase in frequency. This result is to be expected from the fact that this analyzer has a band width that is essentially a constant percentage of the center frequency. For example, at 5 kc the effective band width for noise is about 160 c, and at 500 c is about 16 c.

ANALYZER LIMITATIONS

Some analyzers cannot handle a noise signal satisfactorily because of the dynamic range required. As an illustration of the difficulty one can encounter, the results of an analysis of the output of the noise generator by one of our earlier Type 760-A Sound Analyzers is shown

Figure 7. The results of an analysis of the output voltage of the noise generator by a Type 760-B Sound Analyzer. The straight line is drawn at a slope of 10 db per decade of frequency.



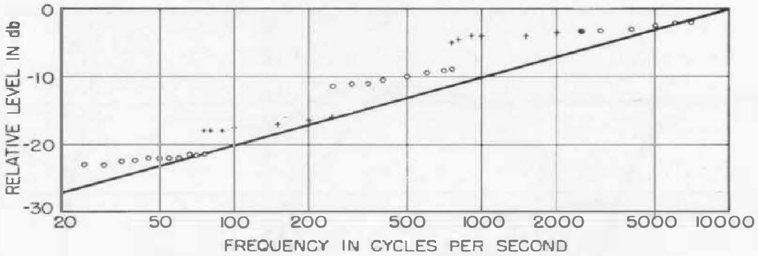


Figure 8. The results of an analysis of the output voltage of the noise generator by the earlier Type 760-A Sound Analyzer. The straight line is drawn at a slope of 10 db per decade of frequency and the departure of the observed points from this slope are a result of the inadequate dynamic range for noise signals of this earlier instrument.

in Figure 8. This analyzer was designed for periodic signal inputs, and it has ample dynamic range for that application. When an attempt is made to analyze noise, however, incorrect readings are obtained as shown. The dynamic range of the instrument is affected by the setting of the tuning control so that the levels within any one band do not follow the 10-db-per-decade slope. Furthermore, at the ends of two adjacent bands at the same frequency setting the available dynamic range is markedly different, and a discontinuity is obtained, while a check with periodic signals shows no such discontinuity. The extent of this discontinuity will vary from instrument to instrument and will depend on the condition of batteries and tubes. In any case the noise generator provides a good source for checking on this effect of dynamic range. As shown in Figure 7, our newer model of this analyzer, the Type 760-B Sound Analyzer, has adequate dynamic range for the noise signal.

APPLICATIONS

Some applications of a noise generator depend on its amplitude distribution characteristics, which are shown in Figures 4 and 5. For example, the amplitude distribution is similar to that of speech, music, and many other sounds or electrical disturbances that occur naturally,[5] while the amplitude distribution of a sine wave is entirely different. These similarities and differences can be seen by comparing the distributions of Figure 9. Because of this characteristic, random noise is an important signal for psycho-acoustic tests.

Other applications depend on the various possible frequency spectra of noise. The frequency spectrum is independent of the amplitude distribution in the sense that a normal distribution of amplitudes is possible with any frequency spectrum, flat, broad, narrow, sloping, or peaked. Systems that affect one characteristic, however, may also affect the other. For example, non-linear clipping affects both the amplitude distribution and the frequency spectrum. Linear filter networks used on purely random noise do not affect the randomness but alter the frequency characteristic and correspondingly the time scale. Linear filter networks used after clipped noise alter the frequency spectrum and also tend to make the noise more nearly random.

Interference Tests

Since noise is a common form of interfering or disturbing signal or signal that limits the threshold of detectability, the noise generator can be used to check receivers, communication systems, and detection systems for their susceptibility to interference. It can also be used as a training aid for operators who must communicate through interference. For these applications relatively low levels of noise are sometimes required, and

[5] H. K. Dunn and S. D. White, "Statistical Measurements on Conversational Speech," *Journal of the Acoustical Society of America*, Vol. 11, No. 3, January, 1940, pp. 278-288.

W. B. Davenport, Jr., "A Study of Speech Probability Distributions," Massachusetts Institute of Technology, Research Laboratory of Electronics, *Technical Report No. 148*, August 25, 1950.

these can be obtained by using a TYPE 700-P1 Voltage Divider or other suitable attenuator as an accessory.

Frequency Response Measurement

For measuring the response of circuits and systems, the noise generator can be used in place of the usual sine-wave oscillator. In this application the selective characteristics of generator and detector are reversed from those ordinarily used in point-by-point measurements; the wide-band noise source and a selective detector replace the single-frequency source and wide-band detector. For speech and music circuits, this technique provides a much closer approximation to operating conditions than does the older system. This approach is particularly useful in testing recording systems.[6] The usual sweeping sinusoidal tests are sometimes inconvenient because of the problem of determining the recorded frequency when playing back. The use of a recorded noise signal that is analyzed on playback eliminates this problem.

[6]S. S. Stevens, J. P. Egan, and G. A. Miller, "Methods of Measuring Speech Spectra," *Journal of the Acoustical Society of America*, Vol. 19, No. 5, September, 1947, pp. 771-780.

Because of its broad frequency spectrum, noise is frequently used to avoid the marked resonance effects that can occur when measuring vibrations in mechanical structures and acoustical systems. Its use as a source in measuring the reverberation characteristics of rooms and the transmission characteristics of building structures results in a type of electrical averaging of the characteristic, provided a reasonably broad noise band is used. This averaging frequently simplifies the comparison of the characteristics of different structures.

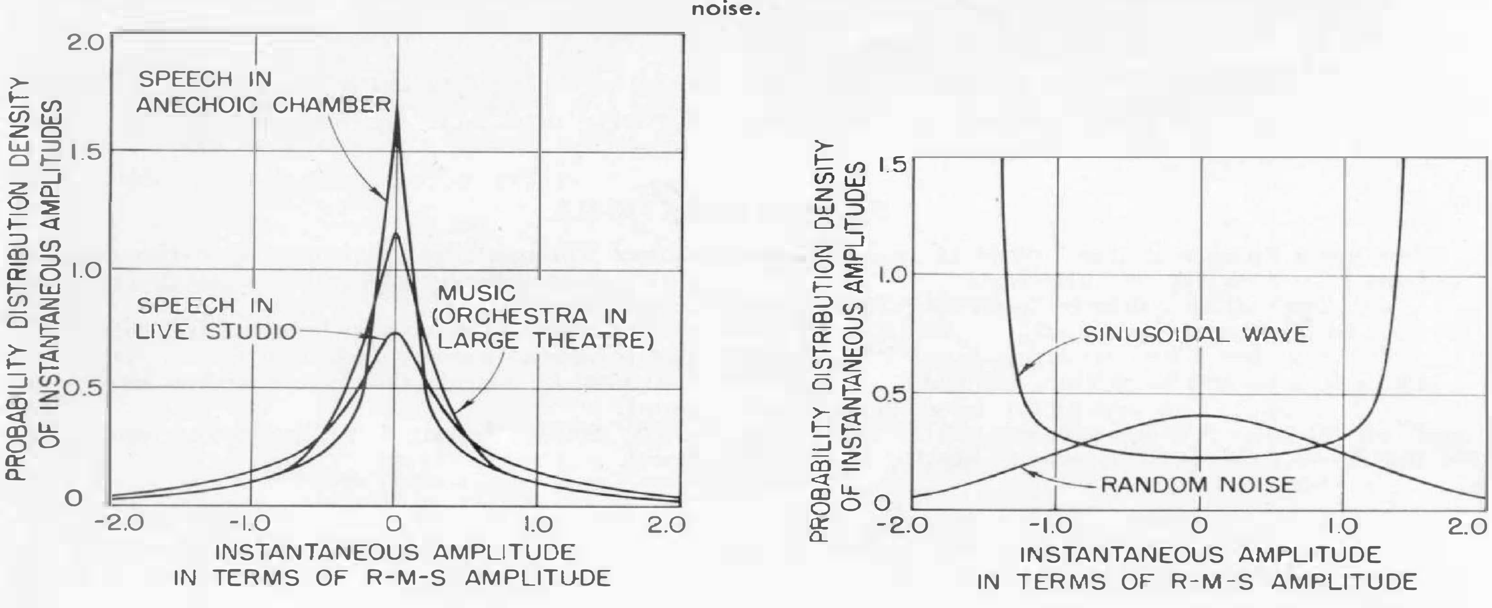
The noise generator is useful for taking response measurements on loudspeaker systems in rooms.[7] The electrically averaged response can be taken so as to determine the optimum characteristic for equalizing networks. It can be used for setting the relative levels of woofer and tweeter units or for adjusting levels of multiple speaker units mounted in different locations in large halls.

Resonance Tests

Because of the broad frequency spectrum of noise, its use can sometimes

[7]Leo L. Beranek, op. cit., pp. 665-668 and 697-702.

Figure 9. The amplitude distribution curves obtained on various representative sounds are shown in the left-hand set of curves. The curves labeled "speech" are particular cases of the sounds produced in reading printed matter,[5] and the curve labeled "music" is an analysis of an orchestral selection made in a large theater.[5] The right-hand set of curves shows for comparison the distribution curves of a single sinusoidal wave and a random noise.



simplify the search for resonant conditions in a system.[8] The resonance produces a peak in the frequency spectrum, which can be observed in oscillographic displays.

Other Uses

Noise generators have been used for some interesting statistical demonstrations. The equipment and methods for demonstrating various degrees of correlation and possible errors of random sampling have been described by Licklider and Dzendolet.[9]

Further interesting applications of noise sources are described in the references cited at the end of this article as well as in many issues of the *Journal of the Acoustical Society of America* (for which there are two comprehensive indices available).

CONCLUSION

The wide frequency range and high level output of the TYPE 1390-A Random Noise Generator make it useful for a wide variety of applications from the audio-frequency into the radio-frequency and video-frequency ranges. The features of compactness and relatively low price also make it particularly attractive to the small laboratory, and its availability should lead to an expansion in applications for a noise source.

— ARNOLD P. G. PETERSON

[8]Emory Cook, "White-Noise Testing Methods," *Audio Engineering*, Vol. 34, No. 3, March, 1950, pp. 13-15.

[9]J. C. R. Licklider and E. Dzendolet, "Oscillographic Scatterplots Illustrating Various Degrees of Correlation," *Science*, January 30, 1948, Vol. 107, No. 2770, pp. 121-124.

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Leo L. Beranek, *Acoustic Measurements*, New York, John Wiley and Sons, 1949, pp. 479 f, 639 f, 647, 665-668, 697-702, 804 ff, 826 f, 831, 873, and 883.

RMA Standard SE-103, *Speakers for Sound Equipment*, April, 1949, p. 6, Standard Test Signal BA.

C. R. Ammerman, "Direct Measurement of Band-width," *Electrical Engineering*, Vol. 69, No. 3, March, 1950, pp. 207-212; *Transactions, A.I.E.E.*, Vol. 69, Part 1, pp. 27-31.

H. R. Clayton and R. S. Young, "Improvements in the Design of Ultrasonic Lamination Detection Equipment," *Journal of Scientific Instruments*, Vol. 28, No. 5, May 1951, pp. 129-132.

P. H. Parkin, "Provisional Code for Field and Laboratory Measurements of Airborne and Impact Sound Insulation," Report of the 1948 Summer Symposium of the Acoustics Group, *The Physical Society, London*, 1949, pp. 36-44.

H. F. Hopkins and N. R. Stryker, "A Proposed Loudness-Efficiency Rating for Loudspeakers and the Determination of System Power Requirements for Enclosures," *Proc. I.R.E.*, Vol. 36, No. 3, March, 1948, pp. 315-334.

The experimental model of the TYPE 1390-A Noise Generator was developed by Mr. Robert Crane while he was an M. I. T. cooperative student at the General Radio Company, working under the direction of Dr. Peterson. The development has been completed by Mr. Corwin Crosby and Mr. Robert J. Ruplenas.

SPECIFICATIONS

Frequency Ranges: Three bands of noise as selected by a switch are provided:

(a) 20 kc: The spectrum level is uniform from 30 c to 20 kc within ±1 db.

(b) 500 kc: The spectrum level is uniform from 30 c to 500 kc within ±3 db.

(c) 5 Mc: The spectrum level is uniform from 30 c to 500 kc within ±3 db and from 500 kc to 5 Mc within about ±8 db.

Output Voltage: The maximum open-circuit output voltage on any of the three bands is about 1 volt rms.

The average spectrum level with 1 volt output is approximately as follows:

(a) 20-kc band: 6 millivolts for one-cycle band.

(b) 500-kc band: 1 millivolt for one-cycle band.

(c) 5-Mc band: 0.5 millivolt for one-cycle band.

The Type 700-P1 Voltage Divider can be used with this instrument to provide low output levels. It has multiplying factors of 0.1, 0.01, 0.001, and 0.0001.

Output Impedance: The source impedance for maximum output is approximately 800 ohms. The output is taken from a 2000-ohm potentiometer. One output terminal is grounded.

Waveform: The noise source is a gas tube that has a very good normal, or Gaussian, distribution of amplitudes for limited ranges of the frequency spectrum. For the 20-kc range, this distribution is modified only slightly by the unavoidable amplitude limitations of a vacuum-tube amplifier. Moderate clipping occurs on the 500-kc range and on the 5-Mc range.

Voltmeter: A rectifier-type, average meter is used for measuring the output voltage. It is calibrated to read the r-m-s value of the noise at the output terminals.

Controls: Frequency range switch, power switch, output potentiometer, and a 10:1 level attenuator.

Terminals: Jack-top binding posts with standard ¾-inch spacing. The lower terminal is grounded to the panel.

Accessories Supplied: Power cord, spare fuses.

Other Accessories Recommended: Type 700-P1 Voltage Divider, for obtaining low output levels.

Mounting: Metal cabinet.

Power Supply: 105 to 125 (or 210 to 250) volts, 50 to 60 cycles. Total power consumption is about 50 watts.

Tubes: The following tubes are used:

1—6D4 2—6AQ5 1—3-4

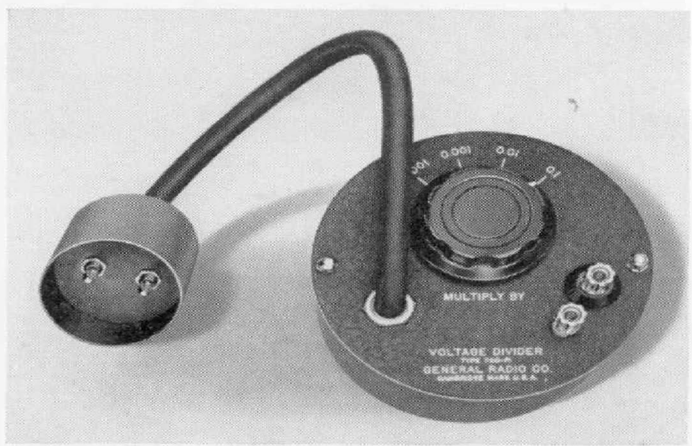
All tubes are supplied.

Dimensions: (Width) 12 x (height) 7½ x (depth) 9¼ inches over-all.

Net Weight: 15 pounds.

Type		*Code Word*	*Price*
1390-A	**Random-Noise Generator**	BUGLE	**$260.00**

TYPE 700-P1 VOLTAGE DIVIDER



The Type 700-P1 Voltage Divider is recommended for use with the Type 1390-A Random-Noise Generator to obtain low output levels. The voltage divider consists of a ladder-type resistive network, mounted in a metal container, which is connected to the generator output by means of a shielded plug and cable. Multiplying factors of 0.1, 0.01, 0.001, and 0.0001 can be selected.

The frequency characteristic of the divider is flat within 10%, for all settings at frequencies up to 5 megacycles.

SPECIFICATIONS

Accuracy: The accuracy of attenuation at low frequencies is ±3%.

Impedance: The input impedance is 2000 ohms; the output impedance is 200 ohms.

Dimensions: (Height) 4½ x (diameter) 4½ inches.

Net Weight: 1½ pounds.

Type		*Code Word*	*Price*
700-P1	**Voltage Divider**	OTTER	**$50.00**

MISCELLANY

CANADA

To meet the steadily increasing demand for General Radio products in Canada, which increase has been especially rapid in recent years, our distributors, Canadian Marconi Company, have added two technical sales engineers to their staff to provide additional competent technical and commercial assistance to our Canadian customers.

ERIC HICKS

Mr. Eric Hicks, after serving five years with the Technical (Signal) Branch of the Royal Air Force, has spent about three years in Canadian Marconi's development and service engineering departments, during which time he worked extensively with electronic test equipment.

Mr. Robert Declercq has been with C. M. for twelve years. The last several years were in the quality control and engineering test departments where General Radio instruments are almost exclusively used.

To bring them completely up to date with the latest General Radio products and policies, both of these men recently completed a training course of several months here at the engineering laboratories and factory in Cambridge.

Their Canadian headquarters for instrument sales are at Montreal and Toronto.

We at General Radio have always been gratified by the wide acceptance of our products in Canada, and it is our desire to serve our customers with continually improving efficiency. We believe the above arrangement will further this ambition. Communications either to us or to our distributors will receive careful and prompt attention. As always, we welcome direct correspondence with our customers.

ROBERT DECLERCQ

I.R.E. PRESIDENT

DONALD B. SINCLAIR

The Institute of Radio Engineers has announced the election of Dr. Donald B. Sinclair, Chief Engineer of the General Radio Company, as its president for 1952.

Dr. Sinclair was educated at the University of Manitoba and the Massachusetts Institute of Technology, receiving the degree of Doctor of Science from the latter institution in 1935. He was a Research Assistant and later Research Associate at M.I.T. from 1932 to 1935, and he joined the General Radio Engineering Staff in 1936. He was appointed Assistant Chief Engineer in 1944 and Chief Engineer in 1950, succeeding Dr. Melville Eastham upon his retirement.

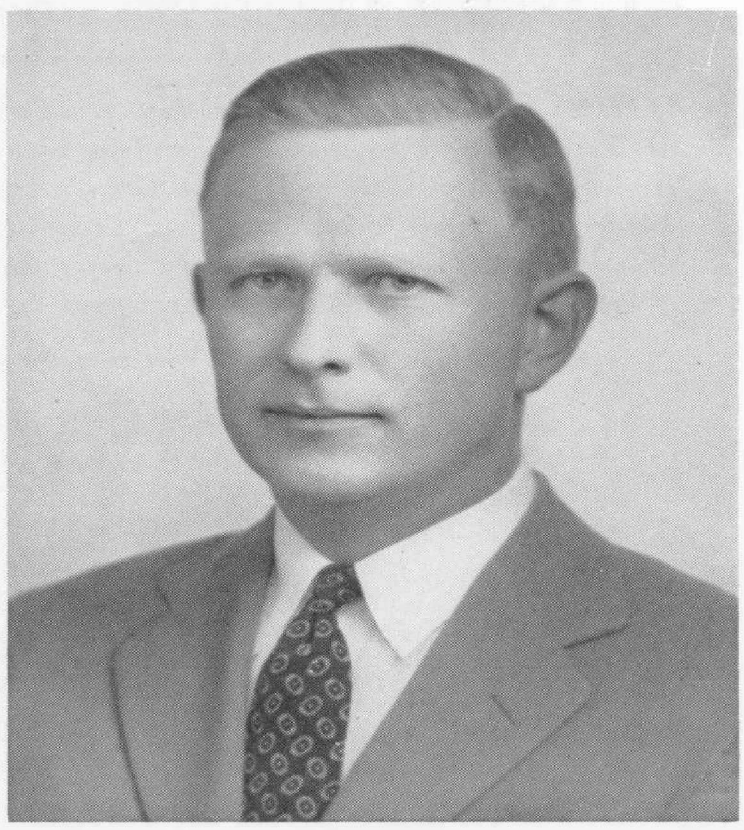
During World War II he served on the National Defense Research Committee in both the Countermeasures and Guided Missiles Divisions, receiving the President's Certificate of Merit for outstanding services.

Dr. Sinclair is a Fellow of the I.R.E., a Fellow of the A.I.E.E., and a member of Sigma Xi. He was Treasurer of the I.R.E. in 1949 and 1950 and has been on the Board of Directors of the Institute since 1945.

R. J. CALDWELL JOINS GENERAL RADIO SALES ENGINEERING STAFF

Robert J. Caldwell, formerly Manager of Sales and Application Engineering for the High-Voltage Engineering Corporation, has joined the Sales Engineering Staff of the General Radio Company.

Mr. Caldwell received his S.B. and S.M. degrees in electrical engineering from M.I.T. in 1936, after which he was employed by the General Electric Company as Student Engineer, Personnel Officer, Application Engineer, and Sales



ROBERT J. CALDWELL

Engineer. During World War II he served as Administration Officer, organizing and supervising enlisted specialists' schools, as Regimental and Battalion Radar Officer, as Executive Officer of an AAA Battalion, and as Military Government Officer in Japan.

From 1947 to 1951, Mr. Caldwell has headed the commercial and sales activities of the High-Voltage Engineering Corporation, manufacturers of high-voltage electrostatic generators.

He is a Member of the American Institute of Electrical Engineers and holds the commission of Lieutenant-Colonel in the Signal Corps Reserve.

VISITORS

RECENT VISITORS to the General Radio plant and laboratories include:

From Canada:

Prof. E. H. Gowan, Physics Department, University of Alberta, Edmonton, Alberta, Canada.

From Switzerland:

Dr. Ernst Baldinger, Professor, Physics Department, University of Basel, Basel, Switzerland.

From England:

Mr. Frederick S. Barton, Principal Director of Telecommunications Research and Development, London; Mr. J. F. Atherton, Director of the Telecommunications Research Establishment, Malvern.

From New Zeland

Prof. R. T. Pollard, Director, Industrial Development Department, Canterbury University College, Christchurch.

From Japan:

Shigezo Takao, President, Yukio Ogawa, Secretary, and Akitaro Nogami, Kobe Kogyo Corporation, Kobe; Minoru Numoto, Director, Foreign Relations, Nippon Electric Co., Ltd., Tokyo; Dr. Tadashi Sasaki, Chief Engineer, Electron Tube Department, Kobe Kogyo Corporation, Akoshi-shi, Hyago-Ken.

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