INSTRUCTION MANUAL

TYPE 1381

RANDOM-NOISE GENERATOR

2 Hz – 50 kHz

GENERAL RADIO COMPANY

A

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TYPE 1381

RANDOM-NOISE GENERATOR

2 Hz – 50 kHz

Form No. 1381-0100-A
ID No. 2495
April, 1968

NOTE: This instrument is equipped with our new snap-on knob for added convenience and safety. Refer to the Service Section for details.

GENERAL RADIO COMPANY
WEST CONCORD, MASSACHUSETTS, USA

Specifications

Spectrum: Flat (constant energy per cycle bandwidth) ±1 dB from 2 Hz to half of upper cutoff frequency. Upper cutoff frequency (3-dB-down point can be switched to 2, 5, or 50 kHz. Upper cutoff slope is 12 dB per octave.

Waveform: Table below shows values of Gaussian probability density function and specifications on amplitude density distribution of the noise generator, as measured in a "window" or 0.2σ, centered on the indicated values:

Voltage	Gaussian Prob. Dens. Function	Amplitude Density Dist. of 1381 Random-Noise Gen.
0	0.0796	0.0796 ±0.005
±σ	0.0484	0.0484 ±0.005
±2σ	0.0108	0.0108 ±0.003
±3σ	0.000898	0.000898 ±0.0002
±4σ	0.0000274	0.0000274 ±0.00002

σ is the standard deviation or rms value of the noise voltage.

Clipping: The noise can be clipped internally to remove the occasional wide extremes of amplitude. Clipping, if desired, is adjustable to approximately 2, 3, 4, or 5σ. Such clipping has negligible effect on the spectrum or the rms amplitude.

Output Voltage: Maximum open-circuit output voltage is at least 3V, rms, for any bandwidth.

Spectral Level: At 3V output, spectral level is approximately 64, 40, and 13 mV in a 1-Hz bandwidth for upper cutoff frequencies of 2, 5, or 50 kHz, respectively.

Output Impedance: 600 ohms, unbalanced, shortable without causing distortion.

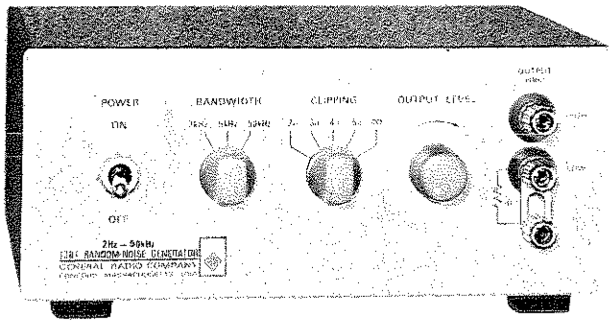
Amplitude Control: Output amplitude is continously adjustable from full output to approximately 60 dB below that level.

Power Required: 6W at 100 to 125 V, or 200 to 250 V, 50 to 400 Hz.

Weight:

Net — 5 lb (2.3 kg)
Shipping — 8 lb (3.8 kg)

General Radio Experimenter Reference: Vol. 42, No. 1, Jan, 1968



Section 1–Introduction

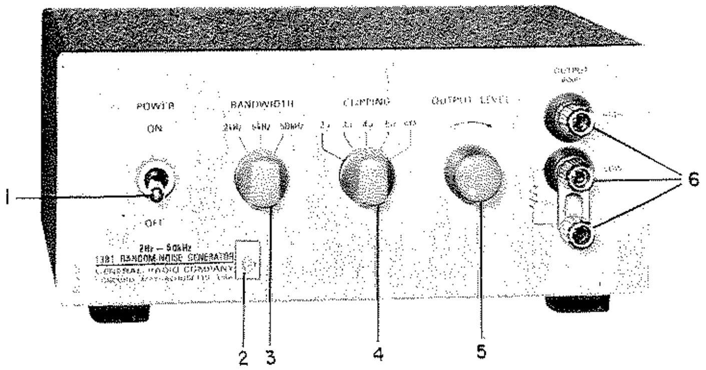


Figure 1-1.
Type 1381 Random-Noise Generator (2 Hz to 50 kHz).

1.1 PURPOSE.

The Type 1381 Random-Noise Generator (Figure 1-1) provides a high level of electrical noise at its output terminals. This type of signal is useful in room-acoustics studies, loudspeaker and microphone tests, psychoacoustic tests, filter tests, crosstalk measurements, calibration checks on recording systems, modulation of signal generators and test oscillators, shaker-driven vibration tests, and airborne vibration tests. It can also be used for tests of the rms response of meters, observation of resonances in systems, electrical averaging of resonant responses, comparisons of effective bandwidths, and for other tests when a signal with a high peak-to-rms factor is useful, as in overload testing. The low-frequency range of the 1381 Random-Noise Generator makes it particularly suitable for measurements when a flat spectrum down to 2 Hz is necessary. A pair of these generators can be used as signal sources for demonstrations of various degrees of correlation, possible errors of random sampling, and other concepts of statistical theory.

A companion instrument, the Type 1382 Random-Noise Generator, produces three different spectra of noise in the audio-frequency range, including white noise and pink noise. It is designed for floating, balanced or single-sided output.

1.2 DESCRIPTION.

The 1381 Random-Noise Generator consists of a semiconductor noise source, with all-semiconductor amplifiers and power supply.

1.3 CONTROLS AND CONNECTORS.

The controls and connectors on the front and rear panels of the 1381 Random-Noise Generator are listed and described in Tables 1-1 and 1-2 respectively.

Two jack-top binding posts, used as OUTPUT terminals, are provided on the front panel. A third binding post, located 3/4 inch below the LOW post, is connected to the case of the instrument and offers a connection for the ground wire of the power cord. The BNC connector at the rear of the instrument is in parallel with the OUTPUT binding posts on the front panel.

TABLE 1-1

Controls, Connectors, and Indicators on the front panel.

FIGURE 1-1 REF.	NAME	TYPE	POSITIONS	FUNCTION
1	POWER	2-position toggle switch	OFF, POWER	Energizes instrument.
2	BANDWIDTH	3-position rotary selector switch	2 kHz, 5 kHz, 50 kHz	Selects upper cutoff frequency of noise spectrum.
3	CLIPPING	5-position rotary selector switch	2σ, 3σ, 4σ, 5σ, ∞	Selects level at which noise is clipped. (No clipping in ∞ position.)
4	OUTPUT LEVEL	Continuous rotary control	———	Varies output voltage.
5	OUTPUT 600 Ω (HIGH—LOW)	Three Type 938 in-line, jack-top binding posts spaced ¾ inch apart	———	Connection to generator output. LOW post is connected to chassis ground by 10 ohms but can be shorted to chassis ground by captive link.
6	———	Pilot lamp behind GR monogram	———	Indicates when instrument is energized.

TABLE 1-2

Controls and connectors on the rear panel.

FIGURE 1-2 REF.	NAME	TYPE	POSITIONS	FUNCTION
1	OUTPUT	BNC jack	———	Connection to generator output; in parallel with front-panel OUTPUT terminals.
2	FUSE, 0.1 A	Extraction-post fuse holder	———	Holds 0.1-A fuse (Slo—Blo).
3	———	Screwdriver-operated slide switch	100—125, 200—250	Selects proper range of line voltage.
4	———	3-terminal male connector	———	Line-power input connection.

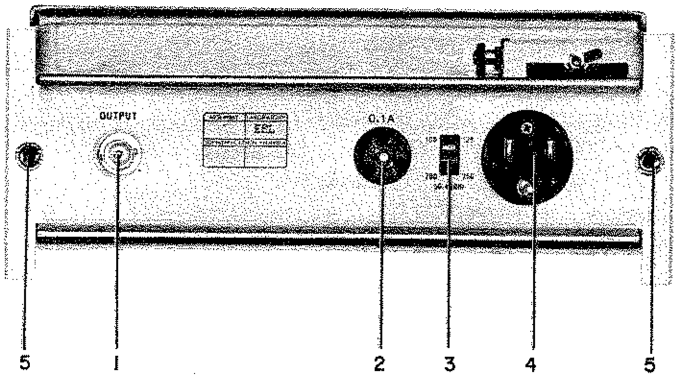


Figure 1-2.
Rear panel of the Generator, showing controls and connectors.

1.4 ACCESSORIES SUPPLIED.

The accessories supplied with the Generator are listed in Table 1-3.

TABLE 1-3
Accessories Supplied.
(Refer also to Parts List.)

	ITEM	GR PART NO.
1	Power Cable, 7-foot, 3-wire	4200-9622
1	Spare Fuse (0.1 A, Slo-Blo)	5330-0400

1.5 ACCESSORIES AVAILABLE.

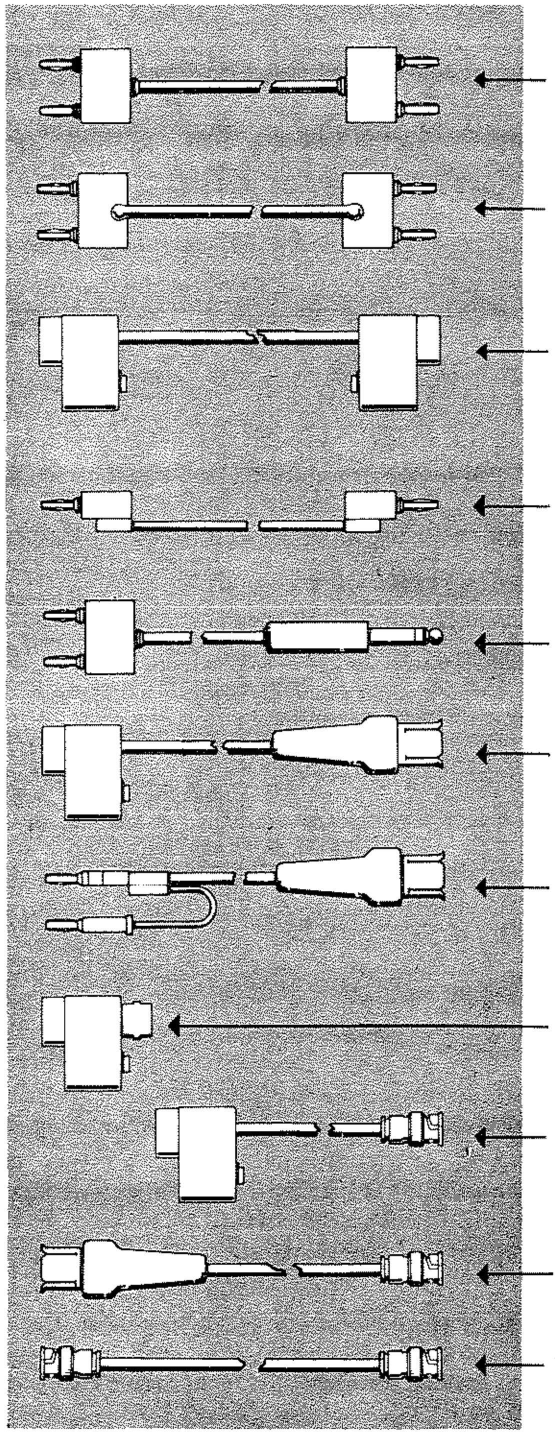
A Rack Adaptor Set (P/N 0480-9722) is available to convert the portable bench model for mounting in an EIA standard 19-inch relay rack (refer to paragraph 2.3). Also available are various patch cords (refer to Table 1-4) for making connections to the OUTPUT terminals.

TABLE 1-4

Available patch cords and adaptors for output connections.

The front-panel OUTPUT binding posts accept banana plugs, standard telephone tips, alligator clips, crocodile clips, spade terminals, and all wire sizes up to number 11. The rear-panel OUTPUT jack is a female BNC connector. A wide variety of GR patch cords is available, as well as a full line of adaptors to convert the OUTPUT terminals for use with most commercial and military coaxial connectors.

NOTE: GR874 connectors are 50 Ω and are mechanically sexless; i.e., any two, although identical, can be plugged together.



TYPE NO.	DESCRIPTION	CATALOG NO.
274-NQ	Double-plug patch cord, in-line cord, 36" long	0274-9860
274-NQM	Double-plug patch cord, in-line cord, 24" long	0274-9896
274-NQS	Double-plug patch cord, in-line cord, 12" long	0274-9861
274-NP	Double-plug patch cord, right-angle cord, 36" long	0274-9880
274-NPM	Double-plug patch cord, right-angle cord, 24" long	0274-9892
274-NPS	Double-plug patch cord, right-angle cord, 12" long	0274-9852
274-NL	Shielded double-plug patch cord, 36" long	0274-9883
274-NLM	Shielded double-plug patch cord, 24" long	0274-9882
274-NLS	Shielded double-plug patch cord, 12" long	0274-9862
274-LLB	Single-plug patch cord, black, 36" long	0274-9468
274-LLR	Single-plug patch cord, red, 36" long	0274-9492
274-LMB	Single-plug patch cord, black, 24" long	0274-9847
274-LMR	Single-plug patch cord, red, 24" long	0274-9848
274-LSB	Single-plug patch cord, black, 12" long	0274-9849
274-LSR	Single-plug patch cord, red, 12" long	0274-9850
1560-P95	Adaptor cable, double-plug to telephone plug, 36" long	1560-9695
874-R34	Coaxial patch cord, double plug to GR874, 36" long	0874-9692
874-R33	Coaxial patch cord, two plugs to GR874, 36" long	0874-9690
274-QBJ	Adaptor, shielded double plug to BNC	0274-9884
776-A	Patch cord, shielded double plug to BNC	0776-9701
776-B	Patch cord, GR874 to BNC	0776-9702
776-C	Patch cord, BNC to BNC	0776-9703

Section 2—Installation

2.1 DIMENSIONS.

The dimensions of the 1381 are shown in Figure 2-1.

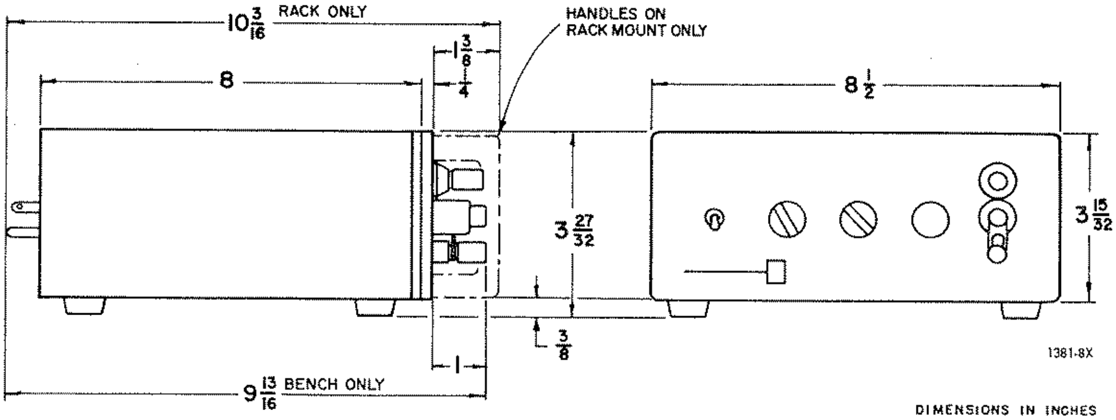


Figure 2-1.
Dimensions of the Generator.

2.2 BENCH MOUNTING.

The 1381 Random-Noise Generator is delivered completely assembled in a metal cabinet, ready for bench use. A convenient bail, located between the front feet, can be pulled down to raise the front of the instrument and provide a better view of the control settings.

2.3 RELAY-RACK MOUNTING.

2.3.1 Single Instrument and Blank Panel (Figure 2-2).

Rack Adaptor Set (P/N 0480-9722) is available to convert the portable bench model for use in an EIA standard 19-inch relay rack. Table 2-1 lists the parts included in the Rack Adaptor Set. The conversion procedure is as follows (see Figure 2-2):

a. Loosen the two captive 10/32 screws (5, Figure 1-2) in the rear of the cabinet until the instrument is free; slide the instrument forward, out of the cabinet.

b. Remove the four rubber feet from the cabinet. Simply push out the two rear feet. Spread the bail (A, Figure 2-2) slightly and the two front feet (B) and the bail will drop out. Be sure to save all parts as they are removed for possible reconversion of the instrument to bench mounting.

c. Pierce and push out the plugs from the four bosses (C) on the inner sides of the cabinet, near the front. Do not damage the threads in the threaded holes.

d. Press the subpanel (D) into the blank panel (E), to form a liner for the latter.

e. Attach the short flange of the blank panel to the front of the cabinet (on either side of the cabinet, as desired) using two 5/16-inch screws (F). Note that the screws enter in opposite directions – one from inside the cabinet and one from the flange side, as shown.

f. Pierce and push out the plug in the lower rear boss (G) on the side toward the blank panel only, as shown.

g. Attach one end of the support bracket (H) to the lower rear boss. The bracket must be placed so that the screw passes through a clearance hole, into a tapped hole. Lock the bracket in position with a 5/16-inch screw (J).

h. Attach the other end of the support bracket to the lower, rear hole in the wide flange, as shown, using a 5/16-inch screw (K).

i. Attach one Rack Adaptor Assembly (handle) to the side of the cabinet opposite the blank panel, using two 5/16-inch screws (L). Again, note that the screws enter in opposite directions, one from inside the cabinet and one from outside. Use the upper and lower holes in the Assembly.

j. Attach the other Rack Adaptor Assembly (handle) to the wide flange on liner (D) and the flange on the blank panel (E). Use two 5/16-inch screws (M) through the two holes in the flange that are nearest the panel and through the upper and lower holes in the Assembly. Again, the screws enter in opposite directions.

k. Install the instrument in the cabinet and lock it in place with the two captive screws through the rear panel that were loosened in step a.

l. Place a straight edge across both the instrument panel and the blank panel. Loosen the screw (J) through the slot in the support bracket (H). Exert a slight pressure on the blank panel (E) so that it forms a straight line with the instrument panel, and tighten the screw (J) in the bracket, to lock the panels in this position.

m. Slide the entire assembly into the relay rack and lock it in place with the four 9/16-inch screws (N) with captive nylon cup washers. Use two screws on each side and tighten them by inserting a screwdriver through the holes (P) in the handles.

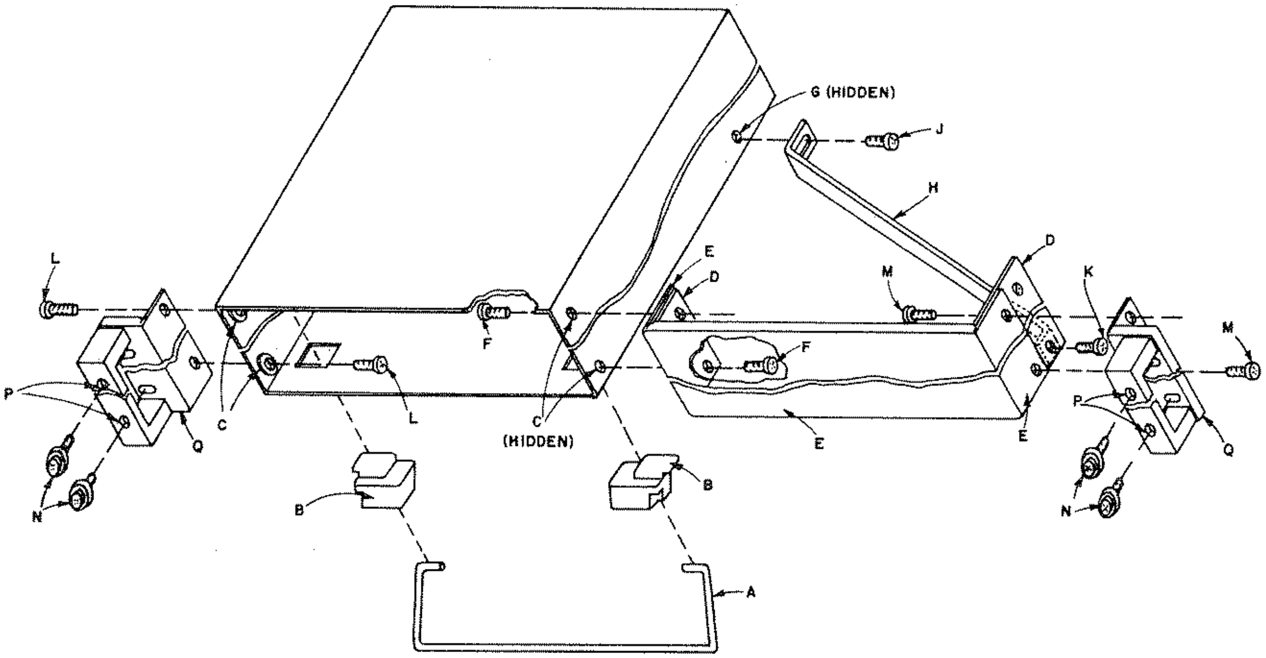


Figure 2-2.
Method of mounting the generator and a blank panel in a relay rack.

2.3.2 Reconverting to Portable Bench Mounting.

To reconvert the instrument for bench use, reverse the procedures of paragraph 2.3.1, first removing the entire assembly of instrument, cabinet, and blank panel from the rack. Next remove:

a. The instrument from its cabinet.

b. The support bracket (H) from the cabinet (see Figure 2-2).

c. The blank panel (E) (with handle attached) from one side of the cabinet.

d. The Rack Adaptor Set (handle) from the other side of the cabinet.

Push the two rear feet into the cabinet; slide the bail (A) and two front feet (B) into place. Install the instrument in its cabinet and lock it in place with the two captive screws through the rear panel (see Figure 1-3).

2.3.3 Rack-mounting Two Instruments.

Two instruments of the same panel size (such as two 1381's or one 1381 and one 1382) can be mounted side-by-side in a standard 19-inch relay rack. Use the procedure of paragraph 2.3.1, substituting the second instrument for the blank panel. Do not use the support bracket (H, Figure 2-2), but insert three screws through the bosses in the adjacent sides of the cabinets, two near the front (C) and one near the rear (G). The four feet and the bail must, of course, be removed from each cabinet. Use the four screws (N) with nylon washers to lock the instruments in the rack. The required hardware is listed below:

3 Screws, BH 10-32 5/16 P/N7080-0800
4 Screws, BH 10-32, 9/16 with nylon washers P/N7207-6310

2.4 CONNECTING THE POWER.

The wiring of the power transformer can be switched, by means of the 2-position slide switch (3, Figure 1-2) on the rear panel, to accept 50- to 400-Hz line power of either 100-125 volts or 200-250 volts.

Connect the 3-wire power cable (P/N 4200-9622) supplied to the line and to the 3-terminal male connector (4, Figure 1-2) on the rear panel. A single 0.1-A fuse is used for either line voltage. Power consumption is approximately 6 W.

TABLE 2-1
PARTS INCLUDED IN THE RACK ADAPTOR SET,
P/N 0480-9722 (see Figure 2-2).

Fig. 2-2 Ref.	No. Used	Item	GR Part No.
E	1	Blank Panel	0480-8932
D	1	Sub-Panel	0480-8952
—	2	Rack Adaptor Assembly	0480-4902
H	1	Support Bracket	0480-8524
—	1	Hardware Set includes	0480-3080
F, J, K, L, M,		8 Screws, BH 10-32, 5/16"	7080-0800
N		4 Screws, BH 10-32, 9/16" w. nylon cup washers	7270-6310

Section 3 – Properties of Random Noise

3.1 DEFINITIONS.

The acoustical term "noise" was applied originally to certain electrical signals because of the undesirable audible effects they produced at the output of radio receivers. Noise, in the electrical sense, is now a broad term that means any unwanted signal, and therefore can include not only input-stage noise and atmospheric noise in radio receivers, but also cross-talk, hum, and distortion.

Random noise is a signal whose exact value at any future moment cannot be predicted. It is even a little more than that; it means a signal containing no periodic component whose future value can be predicted. Unlike periodic signals, whose spectra consist of one or more discrete lines corresponding to the various frequency components, random noise has a spectrum that is a continuous function of frequency, containing no discrete line components.

3.2 DESCRIPTION OF RANDOM NOISE.

It is only possible to describe random noise in terms of its average properties that cannot be measured instantaneously but must be averaged over some finite measurement time. The two most important characteristics of random noise are its amplitude distribution and its spectrum.

3.3 AMPLITUDE DISTRIBUTION.

3.3.1 Amplitude Distribution Functions.

The instantaneous value of a random noise, at some particular instant, cannot be predicted, but for many noises we can speak of the probability that the voltage will lie in some particular range. This probability is given by a function called the amplitude density distribution, p(v). When multiplied by a voltage increment, dv, this function gives the probability that, at any given instant, the voltage lies between v and v + dv. Because the voltage must exist at some value, it follows that the integral

$$\int_{-\infty}^{\infty} p(v)dv = 1.$$

Another useful probability function is the integral over part of that range, called the amplitude distribution, P(v), defined as

$$P(v) = \int_{-\infty}^{v} p(x)dx.$$

Thus defined, P(v) is the probability that the voltage, at any given instant, lies below the value v. The values of these probability functions lie on a scale between 0 and 1, with 1 denoting certainty. A probability of 0.5 denotes a 50% chance of occurance.

3.3.2 The Gaussian Distribution.

The Gaussian or normal distribution is particularly important for several reasons: It describes the "normal" occurrance of random measurement errors in experiments. The amplitude of thermal noise in a resistance and shot noise in a vacuum tube are Gaussianly distributed. The distribution of the sum of many independent time-varying voltages approaches the Gaussian distribution in the limit as the number of such voltages is increased, regardless of the distribution of the individual voltages (derived from the Central Limit Theorem of statistics). An extension of this reasoning leads to the result that filtering that reduces the bandwidth generally makes a non-Gaussian noise more Gaussian, so that, in this sense, the Gaussian is a stable distribution. For these reasons, the Gaussian distribution is of fundamental importance and is the most appropriate distribution of random noise in most experiments. For the Gaussian distribution,

$$p(v) = \left(\frac{1}{\sigma\sqrt{2\pi}}\right) e^{-\frac{v^2}{2\sigma^2}}$$

and

$$P(v) = \frac{1}{2}\left[1 + \operatorname{erf}\left(\frac{v}{\sigma\sqrt{2}}\right)\right]$$

where σ is the root-mean-square voltage (in statistics, the standard deviation), and erf denotes the error function. Values of these functions are given in Table 3.1 and the functions are graphed in Figures 3.1 and 3.2.

TABLE 3-1

Gaussian amplitude distribution functions.

v	p(v)	P(v)
-5σ	$.000\,001\,487/\sigma$	.000 000 287
-4σ	$.000\,133\,8/\sigma$	.000 031 67
-3σ	$.004\,432/\sigma$	.001 350
-2σ	$.053\,99/\sigma$	.022 75
-1σ	$.241\,97/\sigma$	.158 65
0	$.398\,94/\sigma$	.500 00
1σ	$.241\,97/\sigma$	.841 34
2σ	$.053\,99/\sigma$	.977 25
3σ	$.004\,432/\sigma$	.998 650
4σ	$.000\,133\,8/\sigma$	.999 968 33
5σ	$.000\,001\,487/\sigma$	.999 999 713

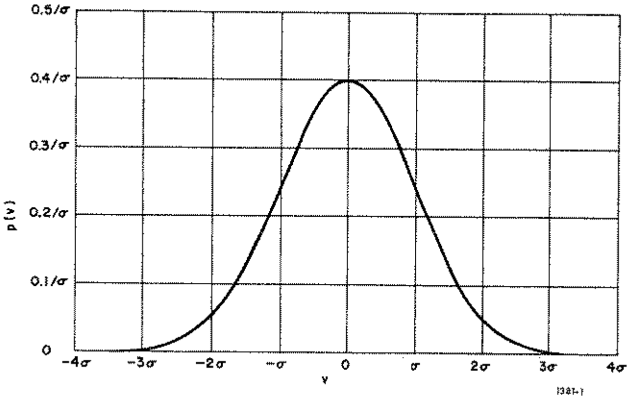


Figure 3-1.
The Gaussian probability density function plotted as a function of σ, the root-mean-square amplitude.

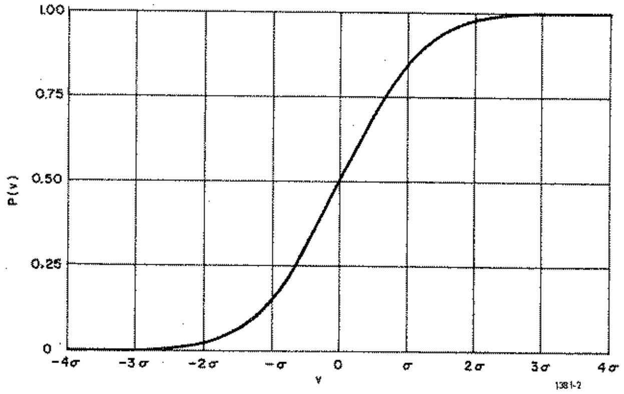


Figure 3-2.
The Gaussian probability distribution function plotted as a function of σ, the root-mean-square amplitude.

It can be seen from Figure 3.2 that a Gaussianly distributed random noise lies below its positive root-mean-square value ($\sigma = 1$) 84% of the time, and therefore exceeds that value only 16% of the time.

3.3.3 Importance of Knowing the Distribution.

Knowledge of the amplitude distribution of a noise is important in measuring its magnitude. Electronic voltmeters respond to different measures of the amplitude of the voltage, such as the rms, the peak, or the (full-wave-rectified) average. The peak and average values of various waveforms having 1-volt, rms, amplitude are given in Table 3-2. A voltmeter responding to the average and calibrated to indicate the rms value of a sine wave will, when measuring Gaussian noise, indicate a value that is low by the factor 0.798/0.900 = 0.887 (-1.05 dB)[1]. Voltmeters that respond to the true rms value are quite appropriate for the measurement of noise, because they can indicate the rms value without correction, regardless of the amplitude distribution. The response of a peak-indicating voltmeter is dependent upon the charging and discharging time constants of its rectifier circuits; when random noise is measured, each may indicate a different value. The response time of a rectified-average-responding voltmeter is usually shorter than that of the true rms voltmeter. Therefore, for measuring the amplitude of Gaussianly-distributed noise, the average-responding voltmeter is probably the most convenient (using the necessary correction factor). In order to measure the rms of non-Gaussian noise, or to make the measurement with no correction factor, it is necessary to use a true-rms instrument.

TABLE 3-2
Rms, peak, and full-wave rectified average voltage values of various waveforms.

	RMS	PEAK	FULL-WAVE RECTIFIED AVERAGE
Sine Wave	1.0	1.414 ($\sqrt{2}$)	0.900 $\left(\frac{2\sqrt{2}}{\pi}\right)$
Square Wave	1.0	1.0	1.0
Gaussian Noise	1.0	∞	0.798 $\left(\sqrt{\frac{2}{\pi}}\right)$

3.3.4 Measuring Amplitude Distribution.

The amplitude distribution, P(v), can be measured by means of a circuit that measures the percentage of time during which the noise voltage exceeds (or does not exceed) the voltage level, v. Apparatus for this purpose generally includes some form of level-crossing detector,and, for high-speed operation, Schmitt-circuit wave-shapers. The measurement must be made by averaging over a time long enough to smooth the fluctuations in the indication to negligible size.

The amplitude density distribution, p(v), can be measured by similar, but somewhat more complicated, apparatus that indicates the percentage of time that the noise voltage exists within the range from v to (v + dv). In making any of these measurements, averaging is important, bacause only the average characteristics of the noise can be measured meaningfully.

3.3.5 Amplitude Distribution of the Type 1381.

Care has been taken to ensure that the amplitude distribution of the noise generated by the Type 1381 Random-Noise Generator is truly Gaussian. The output amplifier has been designed so that clipping cannot occur below 4σ at full output, and below even higher values of σ as the output is reduced. Special attention has been given to the symmetry of the distribution.

A CLIPPING control on the front panel permits the amplitude distribution to be deliberately cut off at various values of σ, for use in those cases where it is desirable to limit the occasional extremes of voltage amplitude, as when the generator is used to drive power amplifiers, loud speakers, or shaker systems. Because the fraction of time in which the noise voltage exceeds 2 σ is very small, such clipping has an almost unnoticeable effect upon the over-all amplitude of the noise.

3.4 SPECTRUM.

3.4.1 General.

The spectrum of a random signal is different from that of a periodic signal, which is composed of one or more discrete lines, each of which corresponds to a frequency component of the periodic signal. A truly random signal contains no periodic frequency components, and has a spectrum that is a continuous function of frequency.

3.4.2 Spectrum Functions.

The frequency content of a random noise is described by a function called the spectral intensity, which has the dimensions of voltage squared per unit bandwidth. (When divided by a value of resistance, it is equal to the power that voltage would dissipate in that resistance, per unit bandwidth). The spectral intensity is the Fourier transform of the autocorrelation function, and is the spectrum function most often used in mathematical analysis of random noise. It is not the most convenient function for practical use, however, because spectra are usually measured as voltage, rather than voltage squared, in a given bandwidth, and filter responses, used in shaping noise spectra, are usually measured as voltage functions. Therefore, for practical use, we define the voltage spectrum as numerically equal to the square root of the spectral intensity. It has units of voltage per square root of bandwidth, but may be spoken of as voltage in a given bandwidth. Spectra shown in Figure 3-3 are plotted as voltage spectra.

3.4.3 White Noise.

Noise whose spectral intensity is constant over a range of frequencies is called white noise, by analogy with white light, which contains more or less equal intensities of all visible colors.[2] White noise cannot contain equal amplitudes at all

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[1] This and much other information concerning random noise is contained in a General Radio publication, "Useful Formulas, Tables and Curves for Random Noise", Instrument Note IN-102 (June, 1963). A copy of this six-page compendium can be obtained free of charge by writing to General Radio, West Concord, Mass. 01781.

[2] Although, as Bennett (op. cit., p. 14) points out, the analogy has been drawn incorrectly, because spectroscopists were measuring intensity as a function of wavelength, and found it to be substantially constant per unit wavelength, not per unit frequency.

frequencies, for then the total power in the noise would be infinite. White noise, therefore, means that the spectrum is flat over the range of interest, for example, throughout the audio-frequency range. Because of its flat spectrum, white noise is particularly convenient as a starting point for many experiments.

3.4.4 Importance of Knowing the Spectrum.

In most experiments involving random noise, knowledge of the spectrum of the noise being used is vitally necessary. When noise is used as a driving-point signal to determine the response of some system, the response is meaningful only when the input spectrum is known, and is usually most conveniently studied when the input spectrum is flat. There are, of course, cases where other spectra are more convenient. If, in such cases, a filter can be constructed whose response has the shape of the desired spectrum, white noise is the proper input for that filter to produce the desired spectrum at its output.

3.4.5 Noise-Spectra Measurements.

The spectrum of a noise can be measured with any wave analyzer whose frequency range is appropriate. For the output indication to be free of fluctuations that might cause reading errors, the product of analysis bandwidth and the averaging time must be large. As in the measurement of the amplitude distribution, the spectrum can only be measured accurately by averaging over a relatively long time interval.

Wave analyzers generally indicate the voltage in the analysis passband. The indication is therefore proportional to w(f), not W(f). It is convenient to reduce all measurements to a common bandwidth basis, and the most-often-used bandwidth is one cycle. Units for W(f) are "volts squared per cycle bandwidth," and considerable use has been made of the unit "volts per root-cycle" for w(f). Now that "cycles" have become "hertz," this term is even more cumbersome, and is perhaps best replaced by "volts in a 1-hertz band."

In order to convert to volts in a 1-hertz band, it is necessary to divide the voltage indication of the analyzer by the square root of the analysis bandwidth. For example, using the General Radio Type 1900 Wave Analyzer, multiply by the factors given in Table 3-3 to convert measured values of random noise to volts in a 1-hertz band.

TABLE 3-3

Correction factors for converting voltage indication of the Type 1900 Wave Analyzer to voltage in a 1-hertz band.

ANALYZER BANDWIDTH	CORRECTION FACTOR[1]
3 Hz	0.650 (-3.7 dB)
10 Hz	0.357 (-9.0 dB)
50 Hz	0.159 (-15.9 dB)

[1] These numbers include the correction for the average-responding voltmeter in the 1900 Wave Analyzer.

In a constant-percentage-bandwidth analyzer, the analysis bandwidth is directly proportional to the center frequency of the pass band. This necessitates dividing the voltage indication by the square root of the frequency as well as by the correction factor for the fractional bandwidth itself. When using constant-percentage-bandwidth analyzers, such as the General Radio Type 1564 Sound and Vibration Analyzer or the Type 1558 Octave-Band Analyzer, multiply the analyzer voltage indication by the appropriate conversion factor in Table 3-4.

TABLE 3-4

Correction factors for converting voltage indication of a constant-percentage-bandwidth analyzer to voltage in a 1-hertz band.

BANDWIDTH	CORRECTION FACTOR
1/10 Octave	$3.80/\sqrt{f}$
1/3 Octave	$2.08/\sqrt{f}$
1 Octave	$1.19/\sqrt{f}$

3.4.6 Spectrum of the Type 1381.

The spectrum of the Type 1381 Random-Noise Generator is flat over three different frequency ranges. The voltage spectrum is flat within 1 dB for frequencies above 2 Hz and typically rolls off less than 3 dB at 1 Hz. The upper cutoff frequency, where the voltage spectrum has rolled off 3 dB, is adjustable to either 2, 5, or 50 kHz. The spectrum is flat within ±1 dB at frequencies below half the upper cutoff frequency. Voltage spectra are shown in Figure 3-3. The total output voltage is the same for the different bandwidths, so the spectral level is higher for the narrower bandwidths.

Clipping, if it is used, has negligible effect on the spectrum, merely transferring a small amount of energy to higher frequencies.

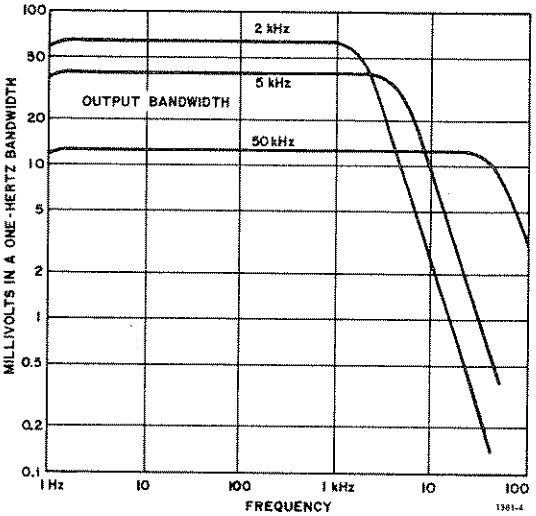

Figure 3-3.
Voltage spectra of the 1381 for the three output bandwidths at 3 volts, rms, output level.

3.5 STATIONARITY.

A random noise is said to be stationary[3] if its various statistical parameters such as the amplitude distribution and the spectral intensity do not change with time. Random noise,

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[3] Bennett, op. cit., p. 52–54.

of course, never repeats the same pattern from one moment to the next, but, if it is stationary, many measurements of the spectrum made at different times will all indicate the same result, except for the unavoidable errors of measuring a random quantity in a finite time. In discussing tests for stationarity, Bendat and Piersol[4] point out that, for most noise-generating processes, it is sufficient to determine that the mean and the variance (square of the standard deviation, σ) do not change with the time at which they are measured. Because the output of the 1381 is ac coupled, the mean is automatically zero, and it is only necessary to observe the rms amplitude to prove stationarity. This can be done by seeing that the fluctuations in long-time recordings of the amplitude of the noise are no greater than the value predicted from the bandwidth of the noise and the smoothing time of the detector.

Tests of this type have been applied to the 1381 and no departure from stationarity is detectable. The importance of stationarity in a random noise generator is analogous to stability of an oscillator; the user is assured that there is no change in the spectrum or the amplitude distribution during the course of the experiment.

3.6 SUMMARY.

Because various terms used in speaking of random noise are sometimes confused, a summary is presented here of the most-often-used words, together with a brief explanation of their meaning: "Noise" is any unwanted signal. "Random noise" is a signal whose future value cannot be exactly predicted and that does not contain any periodic components. To differentiate clearly between the spectrum and the amplitude distribution, in this book the word "density" is used only in connection with the amplitude distribution. The word "intensity" is used only in connection with the spectrum. "Gaussian" applies only to the amplitude distribution and refers to a particular theoretical distribution. "White" refers only to the spectrum, and means that the spectral intensity is constant over some range of interest.

BIBLIOGRAPHY

1. Bennett, W. R., *Electrical Noise*, McGraw-Hill Book Co., Inc., New York (1960).

2. Peterson, A. P. G., "Response of Peak Voltmeters to Random Noise," *General Radio Experimenter*, 31, No. 7, December, 1956, p 3–8.

3. Hilibrand, J., "Characterization of Probability Distributions for Excess Physical Noises," Research Laboratory of Electronics, Massachusetts Institute of Technology, Cambridge, Mass., *Technical Report 276*, September 7, 1956.

4. Bendat, J. S. and Piersol, A. G., *Measurement and Analysis of Random Data*, John Wiley & Sons, Inc., New York, 1966, pp 219–223.

5. American Standards Association (now United States of America Standards Institute), *American Standard Specification for General-Purpose Sound Level Meters, Standard S1.4, 1961*, New York.

6. MIL-STD-188B, U. S. Army Electronics Command, Fort Monmouth, New Jersey.

7. Beranek, L. L., *Acoustic Measurements*, John Wiley & Sons, Inc., New York, 1949.

8. Holtje, M. C., and M. J. Fitzmorris, "A Graphic Level Recorder with High Sensitivity and Wide Ranges," *General Radio Experimenter*, Vol 33, No. 6, June, 1959.

9. A useful bibliography for these applications is: S. S. Stevens, J. G. S. Loring, and Dorothy Cohen, *Bibliography on Hearing*, Harvard University Press, Cambridge, 1955, particularly those references listed in Sections 139 (p 571), 157 (p 573), and 222–228 (pp 579 f).

10. Faran, J. J., Jr., and R. Hills, Jr., *The Application of Correlation Techniques to Acoustics Receiving Systems*, Acoustics Research Laboratory, Harvard University, Cambridge, Mass., Technical Memorandum No. 28, November, 1952.

11. Crandall, S. H., editor, *Random Vibration, Volume 2*, The M.I.T. Press, Massachusetts Institute of Technology, Cambridge, Mass., 1963.

12. General Radio Co., "Distribution of Random Noise Voltages," *Experiments for the Student Laboratory*, No. STX-104, January, 1967. (Copies of this publication may be obtained free of charge from the General Radio Co., W. Concord, Mass., 01781.)

13. General Radio Co., "Useful Formulas, Tables, and Curves for Random Noise," *Instrument Notes, No. IN-103*, June, 1963. (Copies of this publication may be obtained free of charge from the General Radio Co., W. Concord, Mass., 01781.)

14. Kundert, W. R., "New Performance, New Convenience, with the New Sound and Vibration Analyzer," *General Radio Experimenter*, Vol 37, No. 9 & 10, September-October, 1963.

15. Arthur A. Rieger and Harvey H. Hubbard "Response of Structures to High Intensity Noise," *Noise Control*, Vol 5, No. 5, September, 1959, pp 13–19.

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[4] Bendat and Piersol, op. cit., p. 219–222.

Section 4–Principles of Operation

4.1 DESCRIPTION OF CIRCUIT.

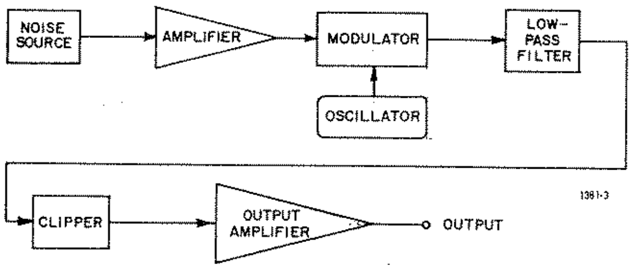

Figure 4-1.
Block diagram of the 1381 Random-Noise Generator.

Figure 4-1 is a block diagram of the Type 1381 Random-Noise Generator (refer also to Figure 7-3). The noise source is a semiconductor diode (CR101). The noise is amplified in a band-pass amplifier with an automatic-gain-control circuit that maintains a constant output level (Q101 through Q106 plus CR102 and CR103). The passband of this amplifier is 100 to 200 kHz. This noise is heterodyned down to the frequency range of 0 to 50 kHz by a balanced modulator (Q107 through Q110). The oscillator that drives the modulator (Q111 and Q112) produces a symmetrical, almost-square wave at 150 kHz. The output of the modulator is passed through a trap circuit to remove remnants of the oscillator signal, through an amplifier (Q113), and then to one of three low-pass filters. These have cutoff frequencies of 2, 5, and 50 kHz and are selected by means of the BANDWIDTH control S101. The noise is then amplified (Q114 and Q115) and is applied to the clipping circuit (CR104–CR110). The clipping is symmetrical and is adjustable by means of the CLIPPING control, S102, on the front panel to 2, 3, 4, or 5σ. In the ∞ (infinity) position of the CLIPPING control, this circuit is disconnected and there is no clipping. The OUTPUT LEVEL control, R146, and the output amplifier (Q116, Q117) follow.

A voltage-regulated power supply (Q501, Q502, Q503) is used to ensure stability of operation over the specified range of line voltage. A slide switch at the rear of the instrument permits easy changeover of the primary connections of the power transformer for operation on either a 100- to 125-volt or a 200- to 250-volt power line.

Section 5 – Operating Procedure

5.1 GENERAL.

With the instrument placed in position on the bench or installed in a relay rack, set the screwdriver-operated line-voltage slide switch (see Figure 1-2) to the range corresponding to the power-line voltage. Connect the instrument to the line power, using the power cable supplied (P/N 4200-9622), and turn on the POWER switch.

Follow the instructions given in paragraphs 5.2, 5.3, and 5.4 for setting the BANDWIDTH, CLIPPING, and OUTPUT LEVEL controls.

5.2 BANDWIDTH CONTROL.

The BANDWIDTH control is a three-position selector switch that sets the upper cutoff frequency of the noise spectrum. At this frequency, adjustable to either 2, 5, or 50 kHz, the spectrum level is down 3 dB. At higher frequencies, the spectrum level falls 12 dB per octave. Changing this switch setting automatically changes the attenuation built into the filter networks, so that the over-all rms noise output remains substantially the same. As a result, in the flat portion of the spectrum, the spectral level of the noise is greater for the lesser bandwidths. At full output (OUTPUT LEVEL control fully CW) and with no load, the output voltage is approximately 3.0 V, rms. The voltage spectral levels in the flat portion of each spectrum, for the three different bandwidths, are given in Table 5.1. In each case, the spectral level remains substantially flat at frequencies down to 2 Hz.

Graphs of the voltage spectra for the three different bandwidths are shown in Figure 3-3.

TABLE 5-1
Voltage spectral levels for different bandwidths, with an output of 3 V.

BANDWIDTH	VOLTAGE SPECTRAL LEVEL IN 1-HERTZ BANDWIDTH
2 kHz	64 mV
5 kHz	40 mV
50 kHz	13 mV

5.3 CLIPPING CONTROL.

The CLIPPING control is useful when it is desirable or necessary to limit the occasional wide extremes of amplitude that characterize a Gaussianly-distributed random noise. The CLIPPING control produces symmetrical clipping of the noise, independent of the position of the OUTPUT LEVEL control. The clipping is adjustable to either 2, 3, 4, or 5 σ, where σ is the rms value of the noise voltage. In the ∞ position of the CLIPPING control, no clipping occurs. Clipping to even the 2-σ level has negligible effect on the rms amplitude (a reduction of about 1%) and upon the spectrum (a slight shifting of energy to higher frequencies). It should be kept in mind that further reduction of bandwidth by filtering in external systems will remove the effect of the clipping, and tend to restore the distribution to Gaussian.

5.4 OUTPUT LEVEL CONTROL.

The OUTPUT LEVEL control is a continuous rotary control by means of which the output level can be set at any selected value between its maximum open-circuit value of approximately 3 V and 3 mV (or less). When setting the output level to some specific value, use an average-responding ac voltmeter for the measurement.

5.5 OUTPUT CONNECTIONS.

5.5.1 Output Impedance.

The output impedance of the Type 1381 Random-Noise Generator is 600 Ω. The maximum open-circuit output voltage is 3 V, rms, and occasional peaks of the noise voltage may exceed 4 times that value. The output can be short-circuited without causing distortion of the noise. The maximum output current into a short-circuited load is 5 mA, rms, with occasional peaks that may exceed 4 times that value.

5.5.2 Grounding.

A captive link on the lower binding post on the front panel can be secured between the lower two binding posts, to connect the LOW OUTPUT terminal directly to the case of the instrument, thereby connecting it directly to the ground wire of the three-wire power cord. When the captive link is open, these two lower terminals are connected internally by a 10-Ω resistor, which keeps the instrument substantially grounded at all times. Opening the link, in effect, inserts the 10-Ω resistor between the LOW OUTPUT terminal and ground, and may be of value in interrupting possible ground loops in which large-amplitude currents at power-line frequencies may contribute to measurement errors.

5.5.3 Rear-Panel Output Jack.

In some situations it may be desirable to use the output connector on the rear panel of the generator, for instance, when the instrument is mounted in a relay rack. A BNC jack is provided for this purpose.

NOTE

The outer shell of the connector, which is the low side of the output, is insulated from the case of the instrument and is connected to the case only when the captive link noted in paragraph 5.5.2 is connected between the lower two binding posts.

5.5.4 DC In The Output.

There may be a small component of dc voltage at the OUTPUT terminals because of leakage in the output coupling capacitor, C124, which produces a voltage drop in R151. Under usual conditions it is less than 0.25 V. When a load having dc resistance that is low compared to R151 (18 kilohms) is connected across the output terminals, this dc voltage is significantly reduced.

5.6 USE OF AUXILIARY EQUIPMENT TO MODIFY OUTPUT.

5.6.1 Generating Lower Levels.

Various attenuating devices can be connected to the OUTPUT of the generator to reduce the power level. General Radio Type 1450 Decade Attenuators, with input and output impedances of 600 ohms, can be inserted between the 1381 and a 600-ohm load, for accurate attenuation in decibel steps.

5.6.2 Generating Higher Levels.

The noise generated by the Type 1381 Random-Noise Generator can be amplified by any amplifier whose frequency range is adequate. The high crest factor of Gaussianly distributed random noise must be kept in mind in choosing the power rating of the amplifier, so that the noise is not clipped. An amplifier capable of driving 40 W, sine wave, into a load will be capable of driving only 5 W of random noise into that load if peaks below 4σ are to be passed without clipping.

5.6.3 Generating Bands of Noise.

In some applications it is desirable to use more or less narrow bands of noise. Because the output impedance is 600 Ω, it is a simple matter to drive a filter designed for operation at that impedance level.

Wave analyzers that make the filtered signal available as an output are convenient for use as a filter. For narrow bands of noise of fixed bandwidth, the General Radio Type 1900-A Wave Analyzer can be used. Its bandwidths are 3, 10, and 50 Hz, and its frequency range is 0 to 50 kHz. For constant-percentage bandwidths, several analyzers are available, and their bandwidths are given in Table 5-2.

TABLE 5-2

Analyzers with constant-percentage bandwidths.

ANALYZER	BANDWIDTH
1558	1 octave
1564	1/3, 1/10 octave
1568	1%

The power available at the OUTPUT terminals of these various analyzers is not great; for general utility, the narrow-band noise from the analyzer will need amplification (refer to paragraph 5.6.2).

When the frequency response is measured with bands of noise, several of these analyzers can be synchronized to the chart paper on the 1521 Graphic-Level Recorder, the abcissae of the chart paper indicating the center frequency of the band of noise.

Wider bands of noise can be generated by use of the Type 1952 Universal Filter, which contains independently adjustable low- and high-pass units. Upper and lower cutoff frequencies can be adjusted over the range from 4 Hz to 60 kHz.

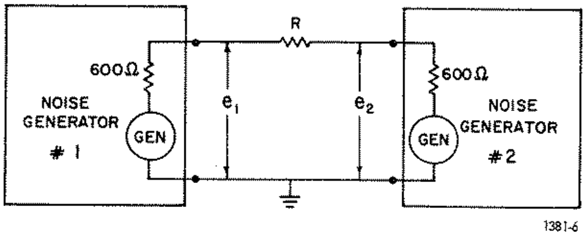

Figure 5-1.
Method of producing varying degrees of correlation between the two noise voltages e_1 and e_2 (see Figure 5-2).

5.7 GENERATING TWO PARTIALLY CORRELATED RANDOM-NOISE SIGNALS.

In experiments on correlation techniques, it is sometimes necessary to generate two random-noise signals having a known degree of correlation. Such a pair of signals can be easily produced from two 1381 Random-Noise Generators by connecting a resistor between their high OUTPUT terminals as shown in Figure 5-1. If the output amplitudes are made equal, the normalized correlation coefficient of the two noise signals will be

$$\rho = \frac{\overline{e_1 e_2}}{\sqrt{\overline{e_1^2}\;\overline{e_2^2}}} = \frac{2R' + 2}{(R')^2 + 2R' + 2}$$

where e_1 and e_2 are the two output voltages, the overbar indicates the time average, R' is $\frac{R}{600}$, and R is the value of resistance used. The magnitude of the output voltage is somewhat reduced by the loading on each terminal, and the ratio, r, of the actual output voltage to the open-circuit output voltage is plotted, together with ρ, in Figure 5-2, as a function of R.

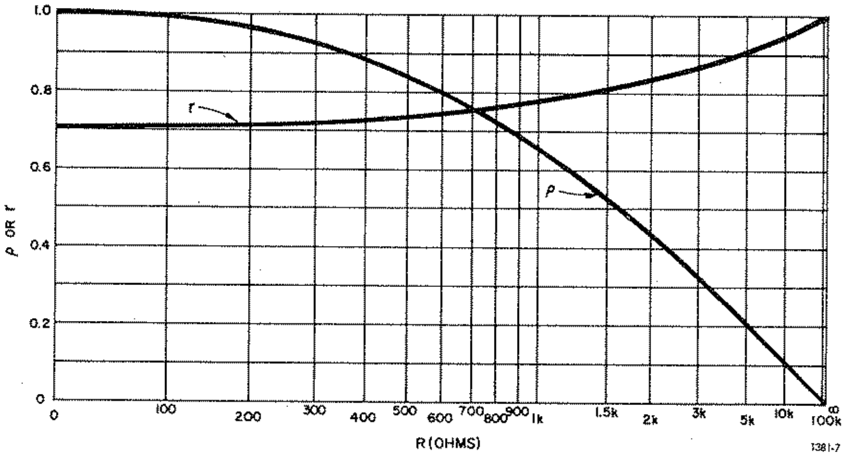

Figure 5-2.
Normalized correlation coefficient (ρ) of outputs of two noise generators and ratio of output voltage to that (v) with no resistor, as a function of the resistance connected between the HIGH terminals of the generators (see Figure 5-1).

Section 6 – Applications

6.1 GENERAL.

The Type 1381 Random-Noise Generator is useful wherever a source of noise having an adjustable bandwidth, variable clipping, and spectral intensity constant to very low frequencies is desirable. Its companion, the Type 1382 Random-Noise Generator, is useful where its features (white, pink, or USASI spectra, and balanced or unbalanced, floating or grounded output) are needed. In many applications either of these instruments will serve well, but there are cases where one or the other is particularly appropriate.

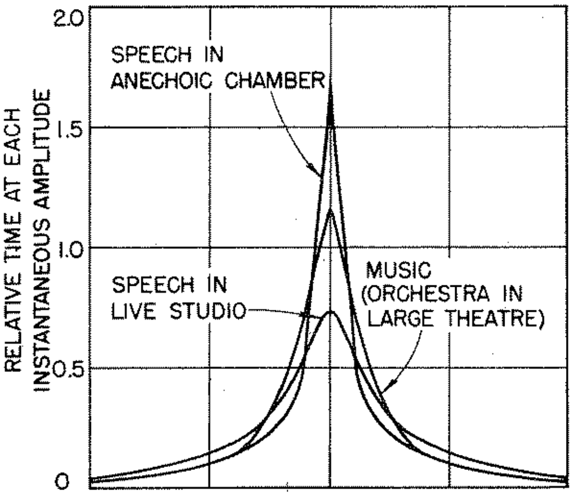

Figure 6-1.
Amplitude distribution curves for various sounds.
(Curves labeled "Speech" are for particular cases of sounds produced from readings of printed matter; curve labeled "Music" is an analysis of an orchestral selection made in a large theater.)

Some applications of a noise generator depend on its amplitude-distribution characteristics. For example, the amplitude distribution is similar to that of speech, music, and many other sounds or electrical disturbances that occur naturally,[1] while the amplitude distribution of a sine wave is entirely different. These similarities and differences can be seen by a comparison of the distributions of Figures 6-1 and 6-2.

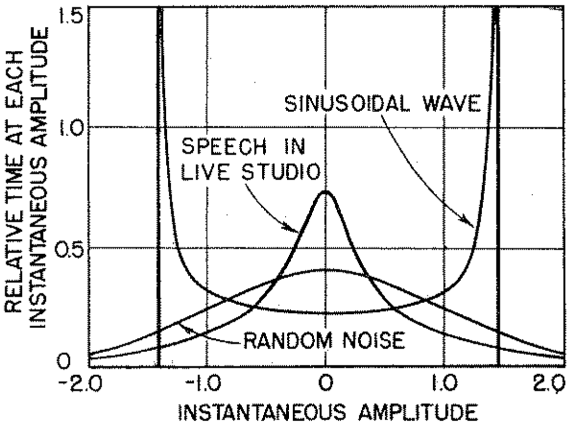

Figure 6-2.
Distribution curves of a single sinusoidal wave and a random noise.

Other applications depend on the various possible frequency spectra of noise. The spectrum is independent of the amplitude distribution, in the sense that a normal (or Gaussian) 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, clipping affects both the amplitude distribution and the spectrum. Linear filter networks used on purely random Gaussian noise do not affect the amplitude distribution but do alter the frequency characteristic and, correspondingly, the time scale. Linear filter networks, used after clipped noise, alter the spectrum and, if they reduce the bandwidth significantly, also tend to make the distribution more nearly Gaussian.

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

6.2 USE OF NOISE IN ELECTRICAL TESTING.

6.2.1 Simulation of Background Noise.

In studying the performance of radio, telemetery, radar or sonar systems with regard to their ability to transmit, detect, and recover signals in noise, it is convenient to simulate the real mixture of signal and naturally occurring noise by adding noise of controlled characteristics to a standard signal. Noise sometimes becomes the signal itself in tests of correlation receivers and other modern signal-processing systems.

6.2.2 Measuring Intermodulation Distortion.

Random noise is used in one very effective method of measuring intermodulation distortion.[2] White noise, which has been passed through a band-stop filter that reduces the level of the noise by, say, 80 dB over a narrow range of frequencies, is applied to the input of a system. Spectrum measurements of the system output indicate how much the "notch" in the noise spectrum has been filled in by intermodulation products. This is an especially significant measurement because white noise contains all the frequencies to which the system responds, and represents, in this sense, a "worst-case" type of test signal.

6.2.3 Measuring Crosstalk.

White noise is a very appropriate signal for use in measuring crosstalk in multichannel telephone, radio, or telemetry systems. Spectrum analysis of the crosstalk signal identifies the frequencies that cause the greatest disturbance, thereby providing some assistance in determining the cause and specifying a cure.

6.2.4 Testing Response of Meter Circuits.

One of the most straightforward methods of showing that an ac voltmeter circuit responds accurately to the peak, the rms, or the average value of the input voltage is to apply signals to it that have different ratios of peak, rms, and average values, and observe the indications. In addition to sine waves, and short rectangular pulses, Gaussian noise is useful for this purpose.[3] Rms, peak, and average values of various waveforms are given in Table 3-2. Although the peak value of Gaussian noise, theoretically, is infinite, the probability of ever observing an extremely large value is very slight. The response of peak-responding voltmeters to Gaussian noise has been studied and is predictable,[4] provided the characteristics of the voltmeter are known.

6.2.5 Measurement of Effective Bandwidth.

When wave analyzers or filters (or more complex systems) are used to measure the spectral density of noise, it is necessary to know the effective bandwidth of the filter or of the system. The effective noise bandwidth can be thought of in terms of an ideal filter having a rectangular frequency characteristic (constant over a range of frequencies, and zero everywhere else). The effective noise bandwidth of a filter is the width of the pass band of the ideal filter whose output is exactly equal to the output of the actual filter when the inputs are the same white noise, provided the maximum transmissions of the two filters are the same. It can be measured by finding the total signal transmitted when white noise of known spectral level is applied to the input. The frequency range of the white noise must include all frequencies for which the filter being measured has appreciable transmission.

When the effective bandwidth of the input noise is known, the necessary computations are simplified. Then the effective bandwidth of the filter is

$$EBW_f = EBW_n \left(\frac{N_{out}}{N_{in} G_{fmax}} \right)^2$$

where EBW_n is the effective bandwidth of the noise;

N_{out} is the output noise voltage;

N_{in} is the input noise voltage;

G_{fmax} is the maximum or peak gain of the filter (as measured with a sinewave signal).

The effective bandwidth of the noise at the output of the Type 1381 Random-Noise Generator is closely equal to 1.11 times the upper cutoff frequency, as indicated by the BANDWIDTH control, i.e., 2.22, 5.55, or 55.5 kHz.

6.2.6 Determining Impulse Response by Cross-Correlation.

The impulse response of an amplifier, network, or system is the cross-correlation function of its output and input when white noise is applied at the input. In practice, the bandwidth of the noise need only be large compared to the frequency-response range of the system under test. If apparatus for measuring the correlation function is available, this method is usually more satisfactory than applying an impulse (delta function) and observing the response directly, as the amplitude of the impulse may have to exceed the overload level to produce an observable signal at the output.

6.2.7 Observing Overload Characteristics.

To observe the effect of overloading an amplifier, it is sometimes desirable to use a signal with a high peak factor, to limit the total rms power. Trains of short rectangular pulses have been used for this purpose, but unless such a signal consists of short pulses of alternating polarity, it is highly unsymmetrical, and, for this reason, may produce undesirable effects. Random noise is a symmetrical signal that can be used for this

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[2] MIL STD–188B.

[3] Its use is suggested in ASA (now USASI) Standard S1.4, American Standard Specification for General-Purpose Sound-Level Meters (Jan. 9, 1961).

[4] Peterson, A. P. G., "Response of Peak Voltmeters to Random Noise," The General Radio Experimenter, December, 1956.

purpose. Gaussianly distributed noise, "white" over the audio band, has peaks greater than 4 σ that occur often enough to be readily observable.

6.2.8 Broad-Band Testing or Burn-In.

When one wishes to test over-all performance of certain types of equipment, such as audio amplifiers, it may be desirable to use a broad-band signal so that the system is being exercised over its entire frequency range all at once.

The continuous spectrum of noise makes it ideal for this purpose. Clipping can be used to limit the peak amplitudes, permitting greater rms levels without overload.

It is also conceivable that certain types of electroacoustical equipment may require some sort of run-in or burn-in for which random noise may be the ideal test signal.

6.3 USE OF NOISE IN ACOUSTICAL AND PSYCHOACOUSTICAL TESTING.

6.3.1 Frequency-Response Measurements.

Frequency-response measurements of electroacoustic devices made with a sine-wave tone source, especially when made in nonanechoic surroundings, are frequently difficult to interpret because of the large fluctuations in the response curve due either to characteristics of the device or to standing-wave patterns. When the response of a loudspeaker in a particular room is measured, for example, fine details are of little significance, because they depend upon the precise placement of the source and receiver in the room. When this is the case, the curve can be made easier to interpret by using a band of noise in place of the sine-wave signal.[5] The noise signal, in effect, averages the measurement over a range of frequencies, producing a smoother curve. A constant-bandwidth wave analyzer, such as the 1900,[6] having the filtered output available, with white noise applied at its input, can produce a band of noise 50-Hz wide, tuneable across the audio-frequency range (with the exception of frequencies below 50 Hz). This band of noise can be amplified and applied to the loudspeaker as the test signal. The response curve can be recorded with the 1521 Graphic Level Recorder[7] driving the tuning dial of the analyzer automatically, as in the 1910 Recording Wave Analyzer.

6.3.2 Measurements Under Reverberant Conditions.

A band of random noise, centered on the frequency of interest, is a very useful signal for measurements of reverberation time.[8, 9] There are many acoustical measurements that are made under reverberant conditions, such as determination of the acoustical absorption of materials. In obtaining the diffuse-field response of a microphone. "It is practically mandatory that a random-noise source be used."[10]

6.3.3 Sound-Transmission Measurements.

In measurements of the transmission of sound through panels, walls, and floors, random noise is often used, mainly because it is necessary to have a diffuse-sound field to obtain reproduceable results. As mentioned above, the use of a random-noise signal is one of the best methods of obtaining a diffuse-sound field. Random noise is, again, a useful signal for measurement of sound attenuation in heating and air-conditioning ducts.

6.3.4 Psychoacoustical Testing.

Random noise is an important signal for psychoacoustical tests, such as masking or interference tests, loudness measurements, determination of critical bandwidths, and audiometric tests. The techniques used in making such tests are discussed in the various issues of the Journal of the Acoustical Society of America and in various psychological journals. There is a useful bibliography for these applications.[11]

6.4 VIBRATION TESTING.

The Type 1381 Random-Noise Generatior is useful as a signal source for driving shakers for random-noise vibration testing.[12, 13] Because the spectrum level is flat down to 2 Hz, it is especially useful for vibration testing of large systems. The adjustable clipping feature is useful also, because it limits the extreme amplitudes, to protect the shakers or loudspeakers that produce the vibrations, and to prevent overload problems in the amplifiers used to drive them. If the bandwidth of the clipped noise is reduced by subsequent filtering, the clipping is removed also, and peaks greater than 3σ again appear. In general, if further spectrum-shaping operations are performed on the output of the Type 1381, the clipping in the generator will not be effective.

6.5 DEMONSTRATING STATISTICAL PROPERTIES.

6.5.1 Measurement of Amplitude Distribution.

An experimental method of measuring the amplitude distribution of random noise is presented in a General Radio

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[5] Beranek, L. L., op. cit. 665–666.

[6] General Radio Experimenter, Volume 38, No. 4, April, 1964.

[7] General Radio Experimenter, Volume 38, No. 9, Sept., 1964.

[8] Beranek, L. L., op. cit. pp. 804–806.

[9] General Radio Experimenter, Volume 38, No. 9, Sept., 1964.

[10] Beranek, L. L., op. cit. pp. 639–640.

[11] Stevens, S. S., Loring, J. G. S., and Cohen, Dorothy, Bibliography on Hearing, Harvard University Press, Cambridge, Mass., 1955; particularly those references listed in Sections 139 (p. 571), 157 (p. 573) and 222–228 (pp. 579f).

[12] Crandall, S. H., Random Vibration, Volume 2, the M. I. T. Press, Cambridge, Massachusetts (1963), Chapter 9.

[13] Harris, C. M., and Crede, C. E., Shock and Vibration Handbook, 3 Vols., McGraw-Hill Book Co., Inc., New York, 1961.

Student Experiment Note.[14] The 1381 is particularly suitable for this purpose because of its clipping feature, by means of which the amplitude distribution can be changed, and because, when clipping is not used, its amplitude distribution is more accurately Gaussian than that of the Type 1390-B, called for in the note.

6.5.2 Demonstration of Correlation Theory.

In experiments on correlation theory, it is often necessary to generate two random signals having a known correlation. Such signals can be generated easily with two 1381 Random-Noise Generators. The procedure for doing so is described in paragraph 5.7.

Correlation is properly measured by multiplying two signals together and averaging the result. When equipment for this purpose is not available, the degree of correlation between two random signals can be observed by means of oscillographic correlegrams or scatterplots.[15] These are substantially equivalent to Lissajous patterns for random signals.

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[14] General Radio Co., Experiments for the Student Laboratory, "Distribution of Random Noise Voltages", No. STX–104 (Jan., 1967). A copy of this note can be obtained free of charge by writing to General Radio, West Concord, Mass., 01781.

[15] Licklider, J. C. R., and Dzendolet, E., "Oscillographic Scatterplots Illustrating Various Degrees of Correlation", Science, Vol. 107, No. 2770, p. 121–124 (Jan. 30, 1948).