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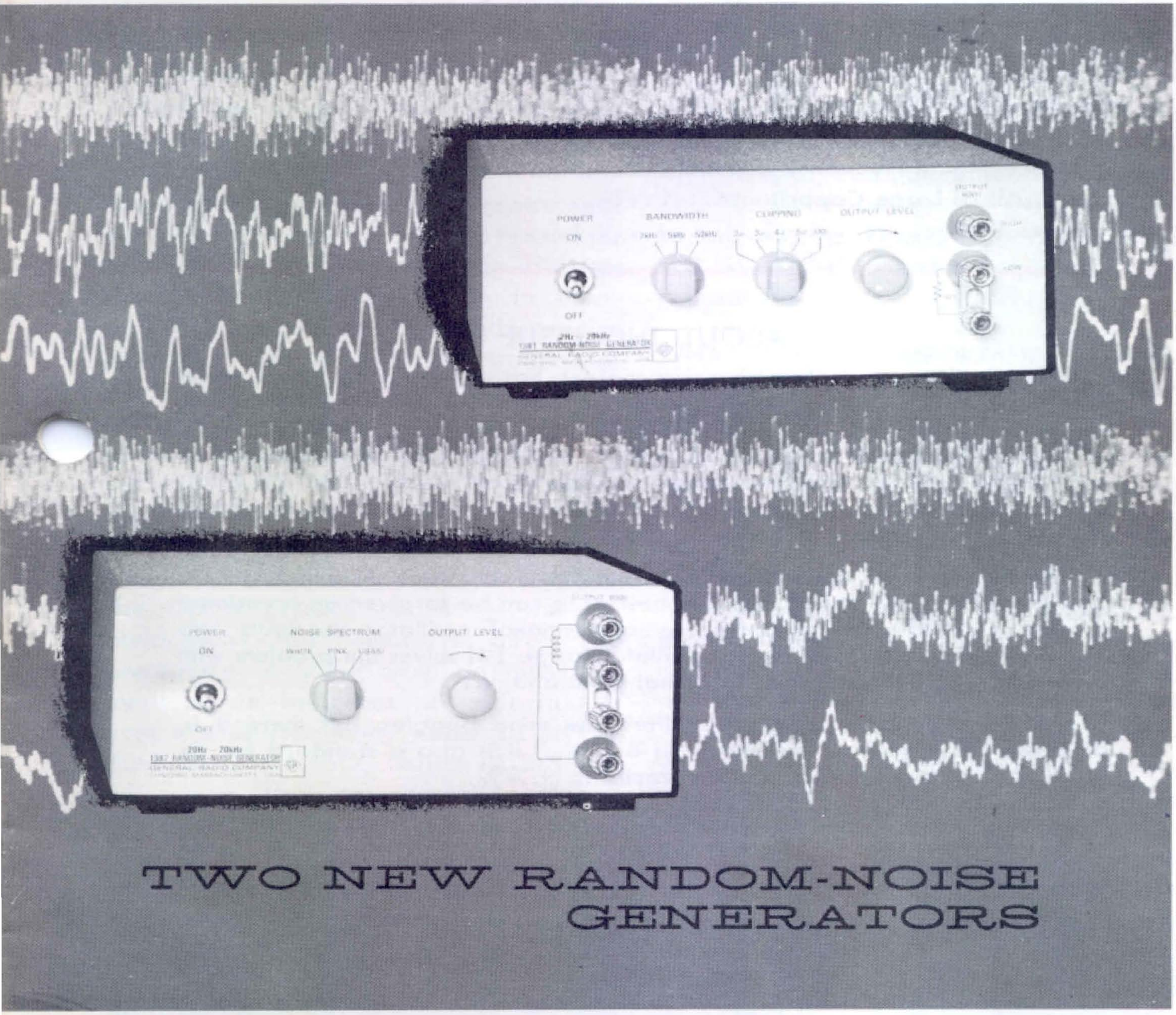

TWO NEW RANDOM-NOISE GENERATORS

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the Experimenter

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CONTENTS

ABOUT THIS ISSUE

Noise, in the electrical-engineering context, has come a long way toward respectability since it was first defined as an "unwanted signal in an electronic communication system." To a fast-growing body of engineers, noise is regularly wanted and used as a test signal, and the random-noise generator has an established role in many test programs. This month's feature article introduces two new, solid-state generators that deliver random noise in a variety of forms used in audio and subaudio testing.

How does your RC oscillator indicate 20.0 kHz? As 200 × 100 Hz? As 2.00 × 10 kHz? As 20000 Hz? Even the best of us can be forgiven an occasional slipped decimal point in converting conventional oscillator readouts into practical terms. GR's new digital oscillator (page 14) solves the problem with an in-line readout that includes decimal point and units.

A one-percent, one-farad capacitor? The mind boggles, but there it is, on page 20. It seems anticlimactic to add that it is also a standard for six other values down to 1 μF, with accuracies to ±¼%.

On the Cover: Oscillograms show various types of Gaussian noise produced by GR's new random-noise generators. From top to bottom: noise in the three bandwidths (50, 5, and 2 kHz) of the 1381 and the white, pink, and USASI noise outputs of the 1382.

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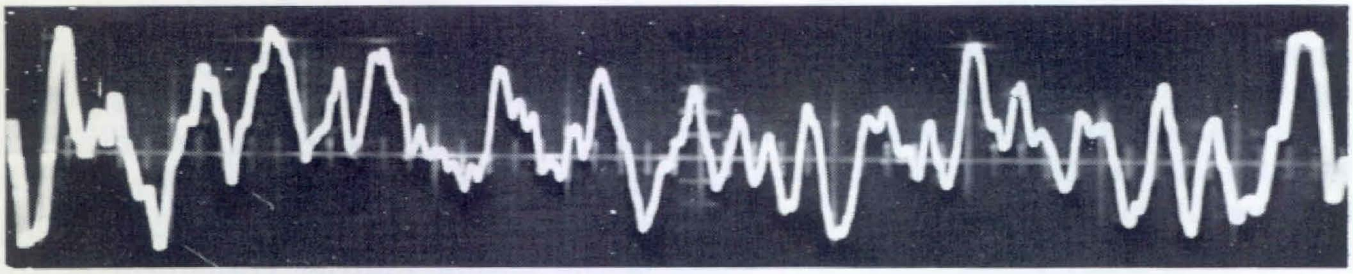

RANDOM-NOISE GENERATORS

The uses of laboratory random-noise generators have multiplied rapidly since the introduction of the first commercially available model some years ago. At first they were principally used in laboratory studies of methods of overcoming the effects of noise in communications systems; the random-noise generator was a controlled source of noise disturbance for such tests. Now, however, random noise has come into its own, and in many applications it has become the test signal. It is useful in electrical measurements because its wide, continuous frequency spectrum and its amplitude distribution simulate the characteristics of many natural phenomena and because it offers the possibility of using a single measurement as an indicator of performance over a wide frequency band. In acoustical measurements, bands of random noise are used to smooth response curves that might otherwise be difficult to interpret. The use of random noise in psychoacoustical experiments has greatly increased our understanding of the process of hearing. Also, because random noise best simulates the vibrations that aircraft and rockets are subjected to in flight, it is commonly used in vibration and fatigue testing of aerospace components, assemblies, and structures.

Random-noise generators can be classified according to the spectrum of their output, and instruments are available to cover frequencies from near dc to microwave. Our consideration here will be limited to audio-frequency noise generators.

WHAT ARE THE IMPORTANT CHARACTERISTICS OF AUDIO-FREQUENCY RANDOM-NOISE GENERATORS?

Just as it is desirable that sine waves have low harmonic distortion and that rectangular pulses have short rise and fall times, there very definitely are desirable characteristics for random noise. However, measuring and specifying them requires the use of different concepts than those needed for sine-wave, pulse, and other periodic waveforms.

Random noise is a signal whose instantaneous amplitude cannot be precisely predicted. It can be described only in terms of certain average properties, of which the most important are the spectrum and the amplitude distribution. For accuracy, measurements of these properties must be averaged over a long period of time, as there is always some fluctuation present in measurements of a random function. For instance, when the spectrum of random noise is measured with an analyzer, there is always some fluttering of the meter pointer. The user expects such fluctuation, as it assures him that he is measuring random noise, and he chooses the averaging time to reduce the fluctuation to an adequately low level.

The Spectrum

The spectrum of a periodic signal is composed of discrete lines, each corresponding to a component in the frequency spectrum. Such a signal is predictable, not random, because of the periodicity of each of its components. The spectrum of random noise, on the other hand, is a continuous function of frequency, containing no line components.

The function used to describe the spectrum of random noise is *spectral intensity*, expressed in units of volts squared per unit frequency. (When divided by the resistance across which that voltage appears, it becomes the power spectrum, expressed in watts per unit frequency.) The spectral intensity is the cosine Fourier transform of the autocorrelation function, and it is a convenient function in theoretical considerations of noise. It is not, however, the most convenient function for practical measurements; spectra are usually measured (as with an analyzer) as voltage in a given bandwidth, and filter responses, used in shaping noise spectra, are usually measured in terms of voltage (not voltage squared or power) as a function of frequency. We therefore

A WORKING GLOSSARY OF NOISE TERMINOLOGY

Amplitude Density Distribution: a function giving the fraction of time that the voltage dwells in a narrow range.

Amplitude Distribution Function: a function giving the fraction of time that the instantaneous voltage lies below a given level.

Gaussian or Normal Distribution: a particular amplitude distribution of great fundamental importance in the theory of probability—the Gaussian Probability Density Distribution is the "bell-shaped curve."

Noise: any unwanted signal, including noise, hum, crosstalk, etc.

Pink Noise: noise whose spectral intensity is inversely proportional to frequency over a specified range, therefore dissipating in a constant resistance equal power in any octave bandwidth in that range.

Random Noise: a signal whose instantaneous amplitude is determined at random and is therefore unpredictable. Truly random noise contains no periodic frequency components and has a continuous spectrum.

Spectral Intensity: a function precisely defining the spectrum and having the units of voltage squared per unit frequency.

Spectrum: the distribution of the components of a signal across the frequency range.

Stationarity: a property that random noise is said to have if its spectral intensity and amplitude distribution do not change with time.

Voltage Spectrum: a function which is the square root of the Spectral Intensity, having the units of voltage in a unit frequency band.

White Noise: noise whose spectral intensity is constant over a specified range, therefore dissipating in a constant resistance equal power in equal bandwidths anywhere in that range.

use, practically, the *voltage spectrum*, whose units are sometimes inelegantly called "volts per root hertz," but which we prefer to express in terms of "voltage in a one-hertz bandwidth." Numerically, it is the square root of the spectrum level, as defined above.

The most generally desirable spectrum for random noise is one that is constant over a wide range of frequencies. Such noise is called "white noise" by analogy with white light, which contains more or less equal intensities of all visible colors.* There are, of course, other spectra more convenient for certain uses; some of these will be discussed later.

In measuring the spectra of modern wide-range noise generators, it is necessary to use analyzers that cover a wide range of frequencies. This generally means using several analyzers covering different ranges, and it also means knowing the effective bandwidth of each so that data can be accurately reduced to the same equivalent bandwidth. The characteristics of the detector in each analyzer must be known, too; peak, average, and true rms detectors respond differently to random noise, and appropriate corrections must be applied.

The Amplitude Distribution

The relationships between the root-mean-square, the rectified average, and the peak value of sine waves, pulses, and other well-defined periodic waveforms are generally easy to determine by mathematical calculation. Knowledge of these relationships is necessary in the use of voltmeters of different types, which may measure the rectified average, the peak, or the rms value of a voltage, but which are generally calibrated to indicate the rms value of a sine wave. To determine the response of a voltmeter to random noise, it is necessary to know the relative occurrence of various amplitudes in the noise voltage, given by the *amplitude density distribution*, $p(v)$ or by the *amplitude distribution function*, $P(v)$. These functions describe the amplitude distribution in terms of probability. The value of $p(v_o)dv$ is the probability, on a scale from 0 to 1, that at any instant in time the amplitude of the noise will lie between v_o and $(v_o + dv)$. $P(v)$ is the integral of $p(v)$; $P(v_o)$ gives the probability that at any instant in time the amplitude of the noise will lie below v_o.

The normal, or Gaussian, amplitude distribution is of fundamental importance in statistical theory and describes many natural phenomena. The central-limit theorem of statistics states, in essence, that the distribution of the sum of a number of independent random variables approaches the Gaussian distribution as the number of such variables is increased, regardless of the distributions of the individual variables. By extension of this reasoning, reducing the bandwidth of a non-Gaussian random noise will generally make it more Gaussian. In that sense, the Gaussian distribution is a stable distribution. It is the distribution of normally occurring random errors in experimental measurements. It is also the amplitude distribution of natural electrical noise (e.g., shot noise in an electron stream and thermal noise in a resistance). The properties of the Gaussian distribution have been studied intensively and are well known. For all these reasons, the

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* Although, as Bennett (Ref. 1, p. 14) points out, the analogy has been drawn incorrectly, since spectroscopists were measuring intensity as a function of wavelength, and they found it to be substantially constant per unit *wavelength*, *not* per unit *frequency*.

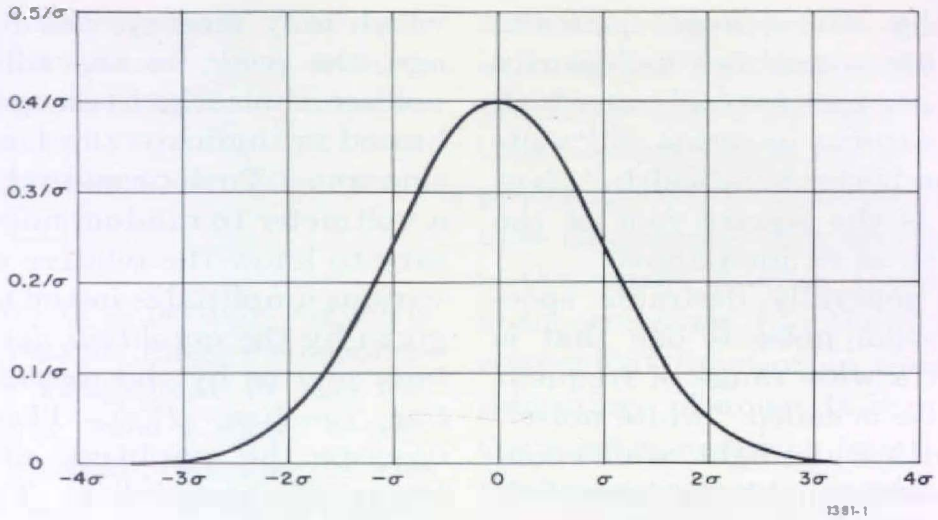

Figure 1. The amplitude density distribution $p(v)$ of Gaussian random noise.

Gaussian distribution is most desirable for a general-purpose random-noise generator.

The Gaussian probability density distribution, $p(v)$, is characterized by the well known bell-shaped curve shown in Figure 1. It is plotted in terms of σ, the rms amplitude of the noise (the standard deviation in statistical theory). The Gaussian probability distribution function, $P(v)$, is plotted in Figure 2, again in terms of σ. It can be seen from Figure 2, for example, that a Gaussian random noise exceeds its positive root-mean-square amplitude only about 16% of the time and twice that value only about 2% of the time.

The rms amplitude of a noise with Gaussian amplitude distribution is σ; the rectified average value is $\sigma\sqrt{(2/\pi)}$. In a measurement of Gaussian noise, a voltmeter that responds to the rectified average and that is calibrated to indicate the rms of a sine wave will indicate a voltage that is low by the factor 0.891 (−1.05 dB).* In general, rectified-average-responding voltmeters are recommended (with the above correction being used) over true-rms-responding meters for measuring noise voltages; the response time is usually faster, and the time constant required for a particular degree of smoothing is slightly less. Although the response of peak-responding voltmeters to random noise is known[2], calibration depends upon accurate knowledge of the constants of the voltmeter circuit; because of this, peak-responding voltmeters are not recommended for noise measurements, except where the application requires their wide frequency range.

The *amplitude distribution function* can be measured with commercially available amplitude-distribution analyzers. These generally comprise level-crossing detector circuits, together with some system for measuring the average fraction of time that the level is exceeded. Direct measurement of the *amplitude density distribution* requires two level-crossing detectors arranged to determine the fraction of time that the voltage lies within a very small range (dv). Other, less accurate, methods are also useful in assessing the amplitude distribution of random noise.

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* Much practical information concerning random noise is contained in Reference 13.

For instance, an oscillographic display of the noise can be photographed through an optical wedge,[3] with a long time exposure to give some idea of the distribution of a noise voltage containing frequencies too high for level-crossing detector systems. Sampling techniques can also be useful in determining the amplitude distribution of high-frequency noise.

Other Characteristics

Other desirable attributes of random noise are

1. Stationarity;
2. Freedom from contaminating signals such as hum; and
3. True randomness.

The output of a random-noise generator is said to be stationary* if its average characteristics do not vary with time. The noise voltage is constantly changing, of course, and never repeats the same pattern with time, but, if the noise is stationary, its spectrum and its amplitude distribution remain exactly the same. The property of stationarity is important to the experimenter simply because he wishes to be assured that the characteristics of the noise do not change during the course of his experiment. Rigorous methods of checking for stationarity have been developed[4].

It is important that random noise not be contaminated by hum related to the power-line frequency, by $1/f$ noise, which might arise in amplifiers, or by other disturbances. Periodic signals could possibly be correlated with components of other signals being used, producing erroneous results in sensitive measurements. The presence of periodic signals or low-frequency semiconductor noise ($1/f$ noise) could alter the spectrum of the noise. In a random-noise generator, such contamination should be kept as low as possible.

An important property of random noise is true randomness. Pseudo-random noise, available as a substitute, is periodic, repeating one pattern over and over. Among the limitations of pseudo-random-noise generators are a relatively low crest factor (ratio of peak to rms amplitude) and a significant departure from Gaussian amplitude distribution. For many of the reasons that lead one to select random noise as a test signal in the first place, he is generally better off with noise that is truly random.

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*Bennett, W. F., Ref. 1, p 52.

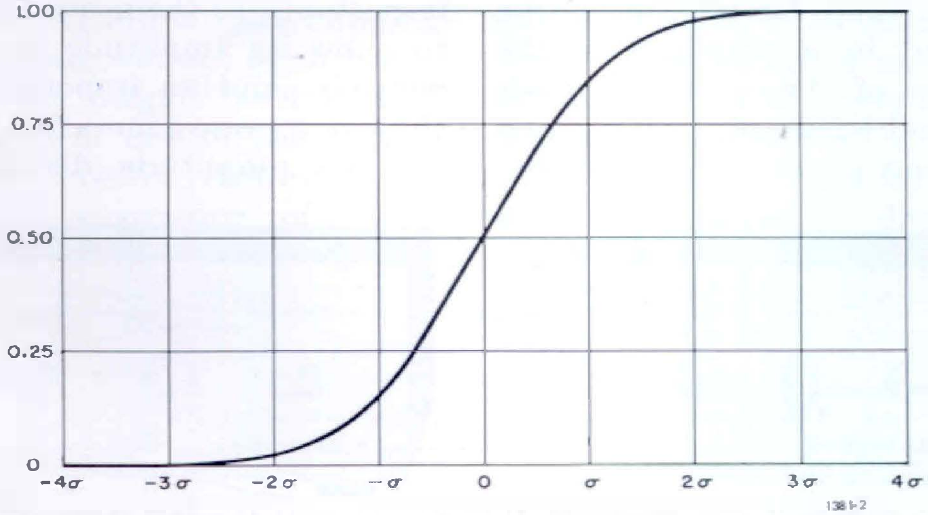

Figure 2. The amplitude distribution function $P(v)$ of Gaussian random noise.

TWO NEW NOISE GENERATORS

The new Types 1381 and 1382 Random-Noise Generators (Figure 3) embody many improvements over previously available instruments:

1. The amplitude distribution is symmetrical and is accurately Gaussian to beyond 4σ.
2. These generators use a semiconductor noise source and transistor circuits so there is excellent stability and no "warmup" time delay.
3. The method of generating and processing the noise ensures no contamination with $1/f$ noise.
4. A variety of spectra is available, built into the instruments.
5. The output impedance is 600 ohms.

The different characteristics of the two units give the user a convenient choice of noise generator for his specific application. The Type 1381 has three different output spectra: white, with upper cutoff frequencies of 2, 5, and 50 kHz; each flat down to 2 Hz; and amplitude clipping, if desired, at 2, 3, 4, or 5 σ. The Type 1382 has three spectra, white, "pink," and USASI noise (the latter specified in a standard of the United States of America Standards Institute) [5], and balanced, floating output. Both noise generators have continuous output-level controls that permit the output voltage to be reduced over a range of 60 dB from the maximum of 3 volts open-circuit.

CHARACTERISTICS OF THE NEW NOISE GENERATORS

The two instruments use the same method of generating random noise; they differ mainly in the spectral filters and output circuits. In each instrument the noise is generated by a semiconductor noise diode in a band extending roughly from 80 to 220 kHz. The amplitude in this bandwidth is kept constant by an automatic level circuit, which corrects for the temperature coefficient of the diode. The output from the noise diode is heterodyned down to the audio-frequency band in a balanced, symmetrical modulator, thus making the amplitude distribution symmetrical. It becomes even more accurately Gaussian because of the subsequent further bandwidth reduction by filtering.

It is becoming of increasingly greater importance to the user of random noise to know its amplitude distribution accurately, and an important feature of these new noise generators is a specification on amplitude distribution. This

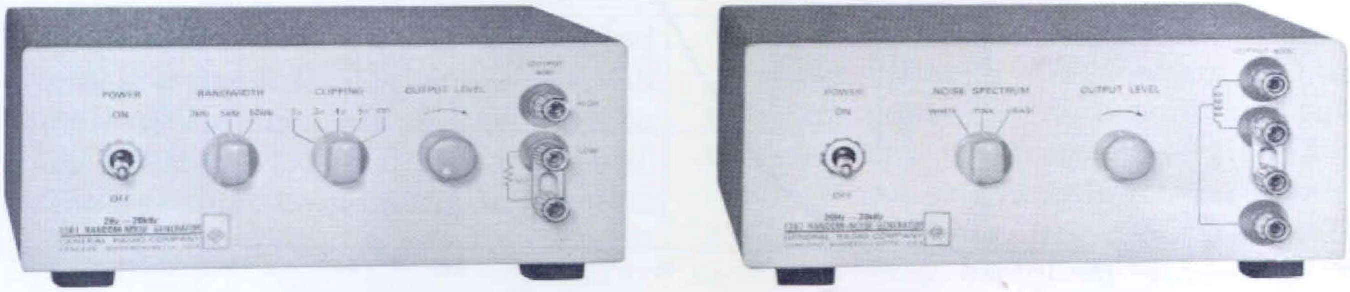

Figure 3. Types 1381 (left) and 1382 Random-Noise Generators.

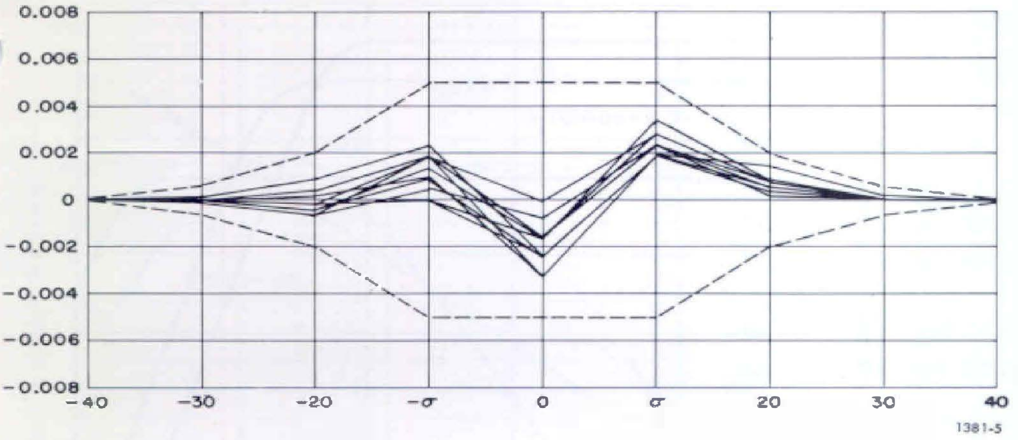

Figure 4. Departure from Gaussian amplitude-density distribution of output of 1381 and 1382 random-noise generators. Measurements were made on 10 different units with a "window" of 0.2σ centered at 0, ±1, ±2, ±3, and ±4 σ. Broken line shows limits of specifications on amplitude distribution of these noise generators.

specification is given in terms of the amplitude density distribution as measured with a window, *dv*, of finite width, in this case, 0.2σ. The specification is stated at 0, ±1, ±2, ±3, and ±4 σ. Peaks of even higher levels are present in the output noise, but these are usually of little importance. The energy contribution due to peaks above 4σ is entirely negligible. The results of measurements of the amplitude density distribution of a number of these instruments are shown in Figure 4. Measurements were made in a "window" of 0.2σ, and the adherence to the Gaussian distribution out to 4σ is seen to be very good. The maximum crest factor of the noise is limited by the voltage or current swing capability of the output amplifier stage. At full output, clipping in the output stage will not occur below 4σ; reducing the output level to half the maximum will ensure that peaks to 8σ can be present. However, the probability of occurrence of peaks above 5σ is so slight that waiting for one to occur lies somewhere between tedium and hopelessness.

1381 RANDOM-NOISE GENERATOR

The 1381 is intended as a noise source for driving vibration test systems and as a general-purpose noise source in the audio-frequency range. A block diagram of it is shown in Figure 5.

The output spectra of the 1381 are white (flat ±1 dB) over three ranges, from 2 Hz to 1, 2.5, or 25 kHz. The upper cutoffs are determined by Butterworth filters having slopes of −12 dB per octave, and upper cutoff frequencies of 2, 5, and 50 kHz, respectively. As the bandwidth is reduced, the gain is increased so that the output power is the same for each range. The voltage spectra of these three outputs of the 1381 are plotted in Figure 6.

The output of the 1381 can be symmetrically clipped, if desired, at ±2,

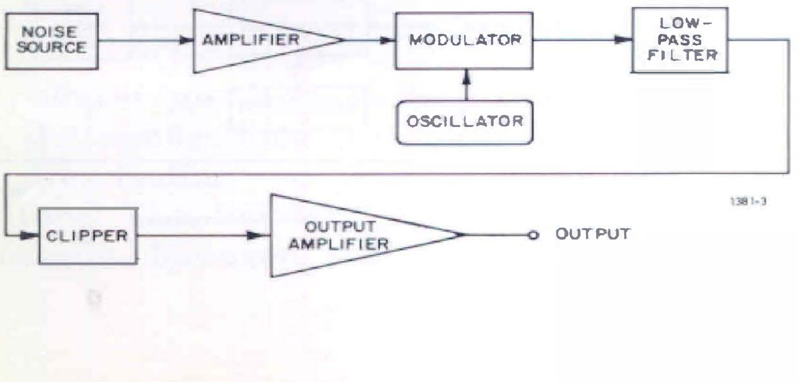

Figure 5. Block diagram of the 1381 Random-Noise Generator.

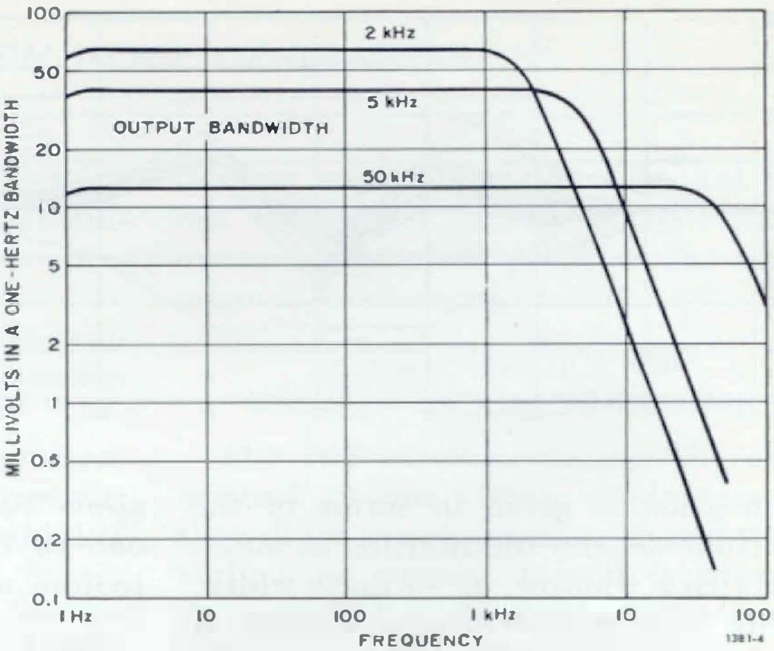

Figure 6. Voltage spectra of the 1381 for the three different output bandwidths at 3 volts rms output level.

±3, ±4, or ±5 σ. Such clipping has almost negligible effect on the total power or on the shape of the spectrum. Clipping is useful in cases where high-power amplifiers are being driven at levels where occasional overloads from noise peaks could be harmful. Such clipping is also used for precautionary reasons in vibration testing.

1382 RANDOM-NOISE GENERATOR

The 1382 is intended specifically for use in the audio-frequency range, as a broadly useful generator of test signals. A block diagram of it is shown in Figure 7. The 1382 Random-Noise Generator also offers three choices of spectrum: white noise, "pink" noise, and "USASI" noise. The white noise is flat (±1 dB) from 20 Hz to 25 kHz and has an upper cutoff frequency (−3 dB) at 50 kHz, with an upper cutoff slope of −12 dB per octave. Pink noise, by further (and a little more appropriate) analogy with optics, is so called because of its emphasis on lower frequencies, as in reddish light. Pink noise has a spectral intensity that is inversely proportional to frequency, that is, a voltage spectrum that is inversely proportional to the square root of frequency. It has equal energy in each octave band and is therefore useful in measurements made with constant-percentage-bandwidth analyzers.[14] The pink-noise output of the Type 1382 is pink over the range from 20 Hz to 20 kHz. The spectrum of

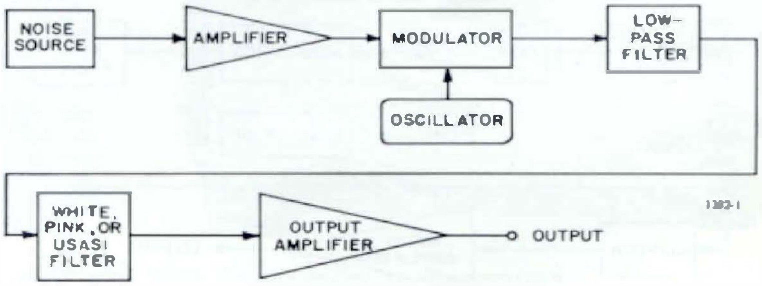

Figure 7. Block diagram of the 1382 Random-Noise Generator.

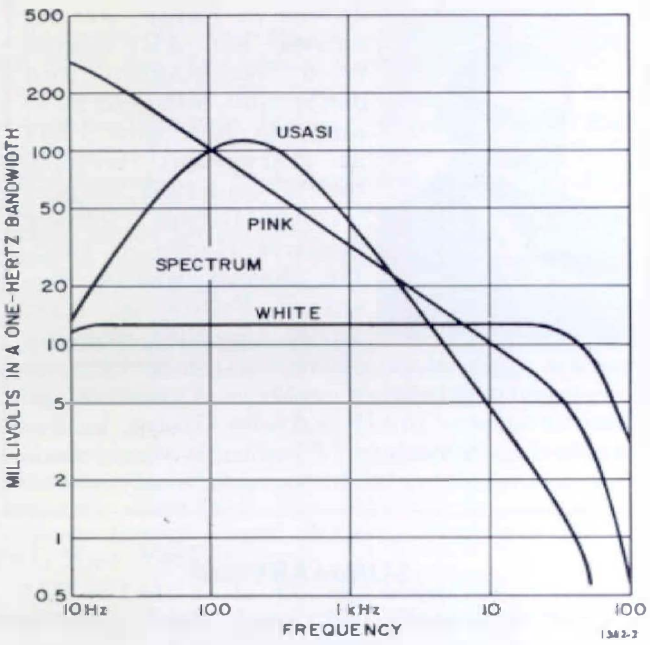

Figure 8. Voltage spectra of the 1382 for the three different output spectra at 3 volts rms output level.

USASI noise results from the passage of white noise through two simple RC filters: a high-pass unit with a cutoff frequency of 100 Hz and a low-pass unit with a cutoff frequency of 320 Hz. The spectrum accurately follows these characteristics from 20 Hz to 20 kHz. USASI noise roughly simulates the distribution of energy with frequency in speech and music, and it has been used for testing amplifiers and loudspeakers. These three outputs of the 1382 are plotted as voltage spectra in Figure 8. In this instrument, the output amplifier includes a transformer, so that the output can be taken floating, single-sided, or balanced.

APPLICATIONS

It is almost impossible to keep track of all the applications that ingenious users are finding for random-noise generators. The following list should demonstrate, however, that the ever-expanding applications of random noise now extend into many fields, for each of which random noise has some unique properties that have by now made its use standard procedure. We can divide the uses of noise generators into five broad categories:

Simulation of Naturally Occurring Noise of Controlled Characteristics

Noise of known amplitude and known spectral characteristics is the most effective for testing various methods of signal detection and recovery in the presence of noise, as in radio, telemetry, radar, and sonar systems. It also can be used for simulation of noise on telephone lines, for noise interference tests on multi-channel systems, and as background noise in comparisons of signal-processing systems.

As a Test Signal for Electrical Measurements

Noise has many uses as the test signal itself in electrical measurements. These include intermodulation-distortion and crosstalk measurements on multi-channel communications systems,[6] the simulation of randomly occurring traffic in communication systems, tests on servo amplifiers, and studies made with analog computers. Wideband noise can be used for determination of the impulse response of networks and systems by cross-correlation of the output with the input. It is commonly used for setting levels on carrier equipment. Its relatively high and symmetrical crest factor makes it suitable for measuring overload characteristics of amplifiers. Broadband noise can also be applied to two supposedly identical networks, their outputs then being compared by Lissajous pattern techniques.

As a Test Signal in Acoustical and Psychoacoustical Measurements

Bands of noise are often used in making frequency-response measurements on microphones, loudspeakers, and rooms, to smooth the resultant curves for easier interpretation.[7] Noise is an excellent test signal for measurement of reverberation time[8] and for reverberant testing of acoustical properties of materials. Similar applications include tests of the sound-transmission properties of walls, panels, and floors[8] and measurements of sound attenuation in ducts. Noise is also used in testing of silencers for air-conditioning systems and sound-proofing of aircraft. In psychoacoustics, noise is used in many hearing tests and masking experiments[9] and in tests of intelligibility of speech in the presence of noise. Random noise is also used in studies of the application of correlation techniques to acoustic receiving systems.[10]

As a Driving Signal for Vibration Testing

Random noise is used to drive shakers for vibration tests of components, assemblies, and structures[11] and is similarly applied to loudspeakers for subjecting the same test objects to high-intensity sound waves. It is also used for fatigue testing of structures subjected to sound or vibration.[15]

In Demonstrations of Statistical Theory and Information Theory

In the classroom, random-noise generators are naturally called upon to familiarize students with properties of random noise, including amplitude distribution.[12] In the laboratory, noise is useful in experiments on signal-detection and signal-processing systems, including correlation detection systems.

James J. Faran, Jr. received his AB degree from Washington and Jefferson College in 1943 and his MA and PhD at Harvard University in 1947 and 1951, respectively. Before joining General Radio in 1952, Dr. Faran was a Research Fellow at Harvard University, working on the application of correlation techniques to acoustic receiving systems. As a development engineer in GR's Audio Group, he has worked on a variety of instruments, including recorders, voltmeters, and analyzers.

SUMMARY

The diversity of uses for random noise led us to offer two compact, inexpensive generators, each of which includes those features most desirable in a certain family of applications. To summarize the characteristics of each instrument, from the applications viewpoint:

The 1381 generates noise that is flat down to 2 Hz and is especially well suited for random-vibration tests and for general-purpose use in the audio and subaudio range. The upper frequency limit can be switched to 2, 5, or 50 kHz, and the output signal can be clipped symmetrically at 2, 3, 4, or 5 times the rms amplitude. Amplitude distribution is Gaussian.

The 1382 generates noise in the 20-Hz to 20-kHz band and is ideal for electrical, acoustical, and psychoacoustical tests. Three spectra are offered: white (flat), pink (−3 dB/octave), and USASI. The output can be taken balanced or unbalanced, floating or grounded.

Both instruments are housed in cabinets only 3½ in. high and 8½ in. wide, with rack-mounting options.

J. J. Faran, Jr.

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.

SPECIFICATIONS

TYPE 1381

Spectrum: Flat ±1 dB from 2 Hz to 1, 2.5, or 25 kHz; upper cutoff frequency (3-dB point) can be switched to 2, 5, or 50 kHz. Spectral density at 3-V output and for 1-Hz bandwidth is approx 64, 40, and 13 mV, respectively, for 2-, 5-, and 50-kHz upper cutoff. Upper cutoff slope is 12 dB/octave. (See Figure 6.)

Waveform:

Voltage	*Gaussian Probability Density Function*	*Amplitude Density Distribution*
0	0.0796	0.0796 ± 0.005
$\pm\sigma$	0.0484	0.0484 ± 0.005
$\pm 2\sigma$	0.0108	0.0108 ± 0.003
$\pm 3\sigma$	0.000898	0.000898 ± 0.0002
$\pm 4\sigma$	0.0000274	0.0000274 ± 0.00002

These data measured in a window of 0.2 σ, centered on the indicated values; σ is the standard deviation or rms value of the noise voltage. Noise can be clipped at approx ±2, ±3, ±4, or ±5 σ to remove the extremes of amplitude. Such clipping has negligible effect on the spectrum or rms value of output.

Output Voltage: $>$ 3 V rms max, open-circuit, for any bandwidth.

Output Impedance: 600 ohms, unbalanced. Can be shorted without causing distortion.

Amplitude Control: Continuous adjustment from full output to approx 60 dB below that level.

Terminals: Output at front-panel binding posts and rear-panel BNC connector.

Accessories Supplied: Power cord, spare fuses, rack-mounting hardware where appropriate.

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

Mounting: Convertible-bench cabinet.

Dimensions (width x height x depth): Bench, 8½ x 3⅞ x 9⅞ in. (220 x 99 x 250 mm); rack, 19 x 3½ x 9 in. (485 x 89 x 230 mm).

Weight: Net, 5½ lb (2.5 kg); **shipping,** 10 lb (4.6 kg).

TYPE 1382

Spectrum: Choice of (a) white noise (constant energy per hertz bandwidth) ±1 dB, 20 Hz to 20 kHz, with 3-dB points at approx 10 Hz and 50 kHz; (b) pink noise (constant energy per octave bandwidth) ±1 dB, 20 Hz to 20 kHz; or (c) USASI noise, as specified in USA Standard S1.4-1961. (See Figure 8.)

SPECIFICATIONS (continued)

Waveform: Same as 1381, except clipping is not provided.

Output Voltage: Same as for 1381; see above.

Output Impedance: 600 ohms. Output is floating, can be connected balanced or unbalanced.

Amplitude Control: Same as for 1381; see above.

Terminals: Output at front-panel binding posts and rear-panel jacks for double plugs.

Accessories Supplied:
Power Required:
Mounting:
Dimensions:
Weight:
} Same as for 1381; see above.

Catalog Number	*Description*	*Price in USA*
	Random-Noise Generator	
1381-9700	2 Hz to 20 kHz, Bench Model	$375.00
1381-9701	2 Hz to 20 kHz, Rack Model	398.00
1382-9700	20 Hz to 20 kHz, Bench Model	375.00
1382-9701	20 Hz to 20 kHz, Rack Model	398.00

WIDE-RANGE RC OSCILLATOR WITH IN-LINE DIGITAL FREQUENCY READOUT

Central to the popularity of the general-purpose RC oscillator is its continuously adjustable frequency dial. In fact, the RC oscillator did not become popular until variable air capacitors were used to provide continuous adjustment over 10:1 frequency bands. This method of frequency selection, with dial and vernier, provides a convenient compromise between ease of reading, settability, resolution, and ability to sweep. It will no doubt continue to be most popular for general laboratory use.

As requirements for greater accuracy and resolution and for digital programmability have had their effect on signal sources, noncontinuous or discrete frequency controls have replaced the continuously variable air capacitor. This trend is most apparent in sources using synthesizer techniques, where seven or eight digits of resolution are common, and also in RC oscillators where push-button and rotary switches are used to control three or four digits. Since the use of discrete steps allows closer tracking of the tuning elements, this type of tuning most often appears on high-performance, high-cost instruments, where the objective is to improve performance characteristics of the source, such as stability of output, distortion and noise. In almost all cases the actual method of frequency selection was resorted to as an undesirable necessity,

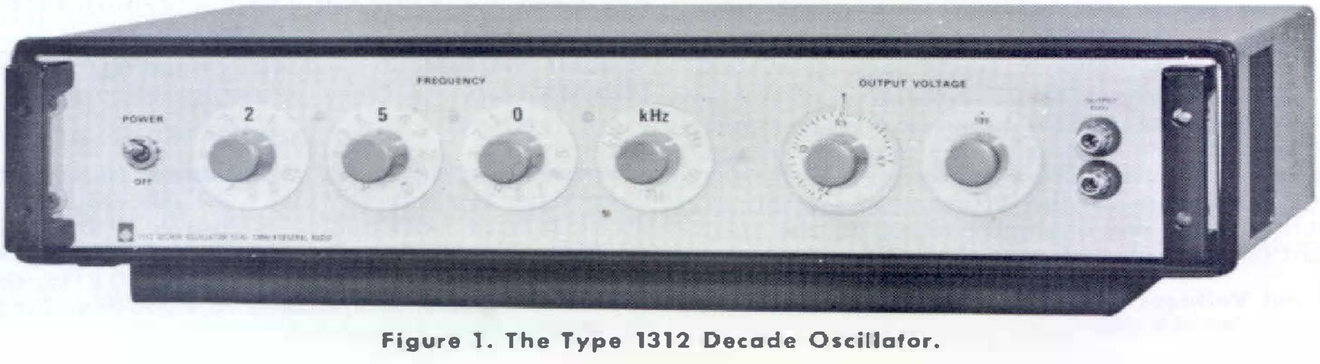

Figure 1. The Type 1312 Decade Oscillator.

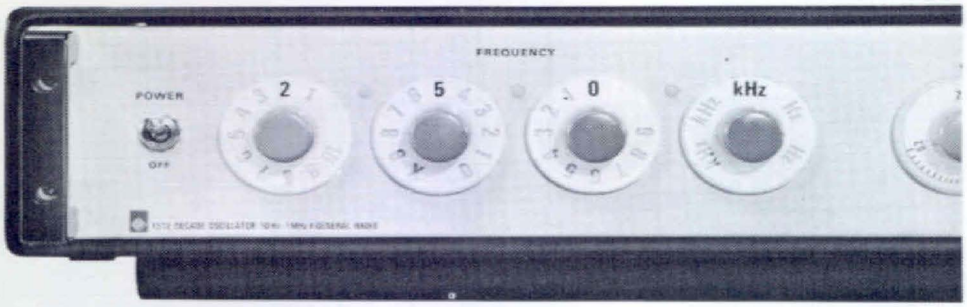

Figure 2. In-line readout of frequency with positioned decimal point and units. Least significant digit is continuously variable with a detent at zero.

and little attempt was made to utilize the discrete steps to provide a more readable or more easily set control. The use of X1, X10, etc range multipliers and confusing decimal-point locations with strange units is still common.

And yet, this type of frequency selection can be quite desirable in its own right. Its greatest advantage is that the same frequency can be reset very accurately, over and over again, limited only by the stability of the oscillator. And it can eliminate perhaps the worst disadvantage of the continuously adjustable dial: difficulty in reading the frequency quickly, accurately, and unambiguously.

The new General Radio Type 1312 Decade Oscillator provides for the first time a general-purpose oscillator with a discrete repeatable type of frequency selection, at a price comparable to that of other general-purpose solid-state oscillators. The 1312 embodies many of the characteristics of the popular Type 1310-A[1], with additional features of an 80-dB step attenuator on the output and a rack-width package with front and rear output terminals.

The frequency range is 10 Hz to 1 MHz with an accuracy of ±1% of reading. The frequency is determined by four rotary controls, which provide an in-line three- or four-digit readout with positioned decimal point and frequency units. The decimal-point location and units have been selected so that the frequency appears as it is normally written. Twenty kilohertz appears as 20.0 kHz, not as 20000 Hz, 2.00 X 10 kHz, or 200 Hz X 100. A single exception is that 1 megahertz appears as 1000. kHz, a frequency indicated by some oscillators as 999 kHz.

The first two most-significant digits and the units control are multi-position rotary switches with a light but positive detent mechanism for easy setting. The third digit is a continuously adjustable potentiometer with a detented zero position. This allows the selection of 100 discrete, highly repeatable frequencies within each decade and continuous coverage in between. Rotary controls were selected over push-buttons because of operator preference in high-rate testing. This in-line readout of the rotary switch is generally preferred over the columnar readout of the push-button, just as it is on electronic counters.

The high repeatability of this type of frequency selection is illustrated by the two examples shown in Figure 3. These show the frequency of a typical 1312 after warmup in a normal production environment. Three frequencies, one decade apart, were selected. The same three frequencies 10 minutes later are all within 0.002% of their original

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[1] R. E. Owen, "A Modern, Wide-Range RC Oscillator," *General Radio Experimenter*, August 1965.

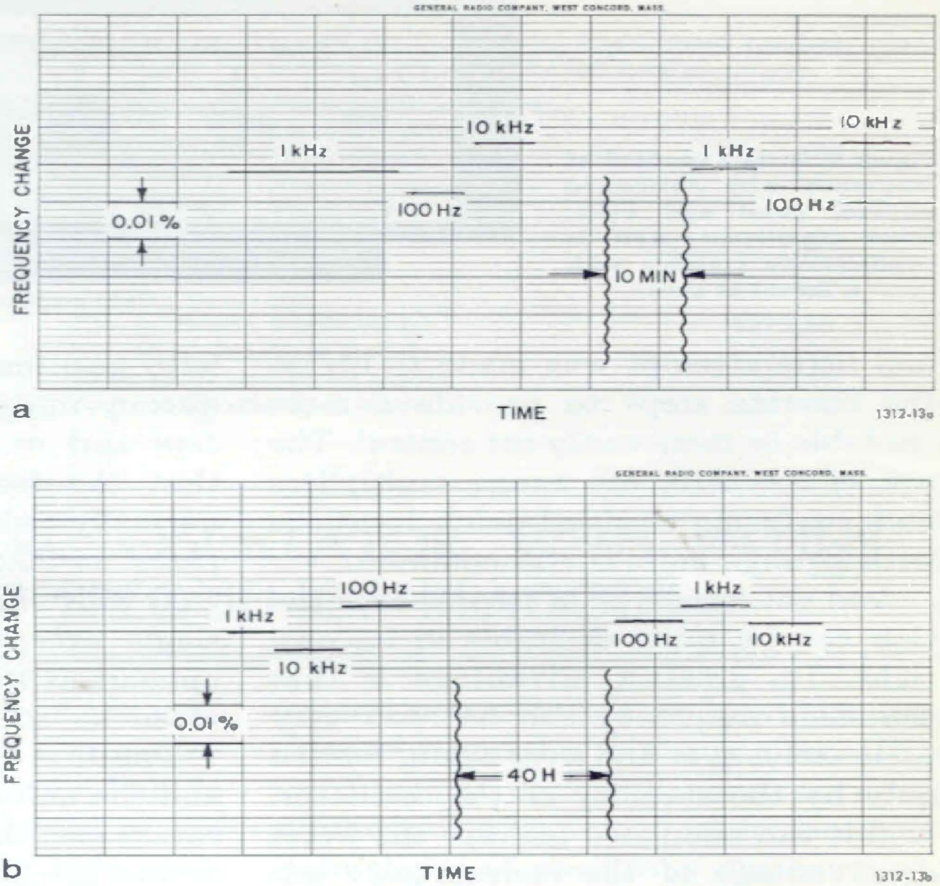

Figure 3. Frequency resettability of the 1312. Difference in frequency at 100 Hz, 1 kHz, and 10 kHz after (a) 10 minutes and (b) 40 hours.

value. Even after 40 hours the change is less than 0.01%. The effects of line-voltage changes on the output frequency are also seen to be small (Figure 4).

The oscillator output is 20 volts open-circuit behind 600 ohms. The voltage is quite constant with changes in frequency (Figure 5). Frequency-response measurements can be made quickly, since controls do not have to be adjusted to keep the output constant. The distortion in the output is low, particularly in the middle of the frequency range, and remains low regardless of the size of the load or attenuator setting. Even a short circuit at full output will not cause clipping of

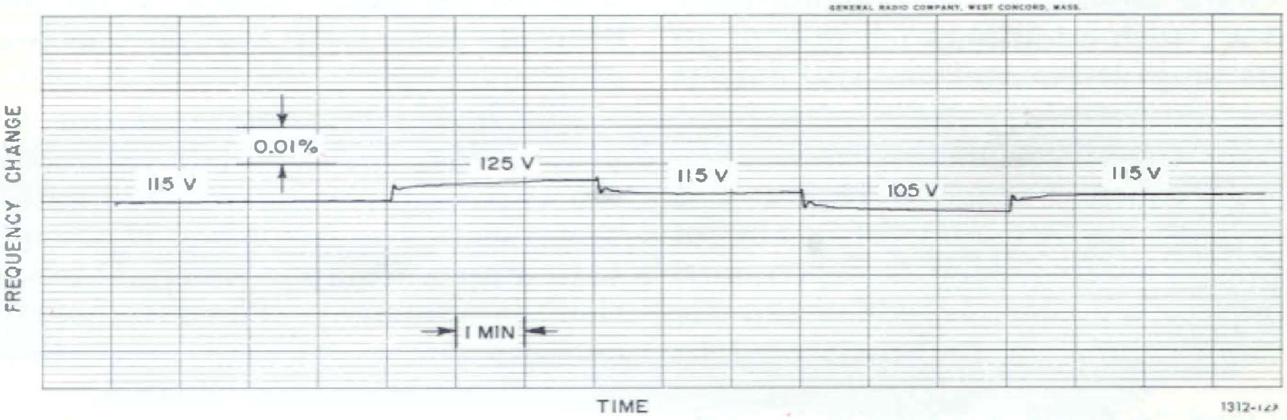

Figure 4. Stability of 10-kHz output frequency with ±10-volt line voltage changes.

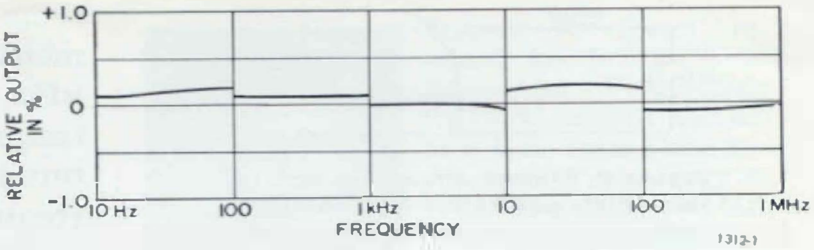

Figure 5. The output-voltage-vs-frequency characteristics of a typical 1312 with 600-ohm load.

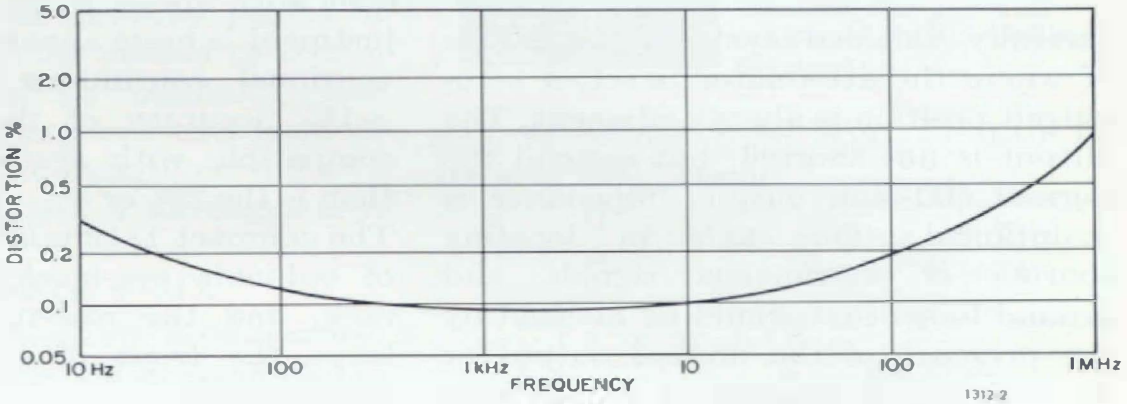

Figure 6. Typical output distortion of the 1312 with 600-ohm load.

the waveform. Noise at frequencies far from a 1-kHz fundamental, measured in a bandwidth of 5 Hz to 500 kHz, is typically less than 0.02%. Noise close to the fundamental is also low, as a close-in spectrum analysis of the 1-kHz fundamental shows (Figure 7).

The output level of the oscillator can be reduced to 200 μV open-circuit by means of a stepped 80-dB attenuator (20 dB/step) and a continuously adjustable attenuator with a range of more than 20 dB. The continuous control is not calibrated but is marked with the approximate open-circuit output voltage. The closely spaced numbered graduations permit convenient return to a given attenuator setting.

Between the 20-dB step positions of the attenuator are so-called "zero-volt-output" positions. This feature, also available on other GR oscillators, provides a convenient transient-free means of reducing the output to zero without disturbing the continuous control setting or shorting or disconnecting a

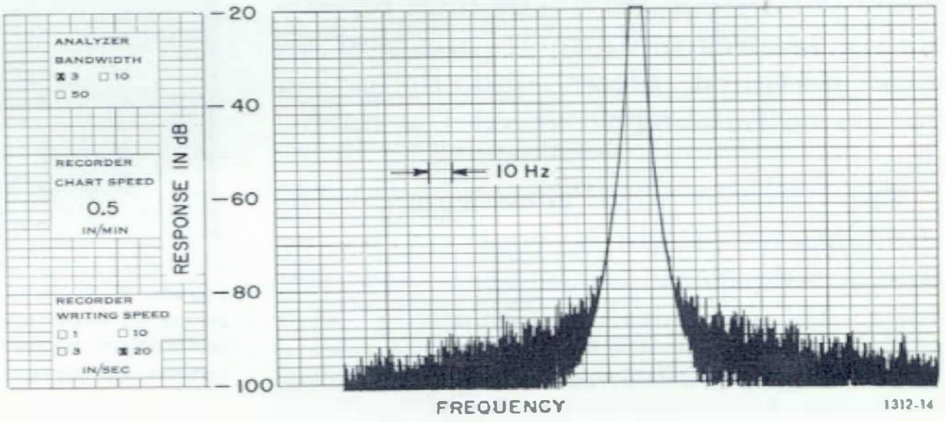

Figure 7. Noise spectrum close to 1-kHz output. Note — 100-dB resolution.

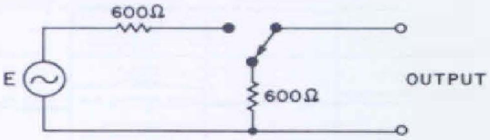

Figure 8. Output attenuator has intermediate positions where voltage is reduced to zero with 600-ohm output impedance maintained.

carefully shielded system. Regardless of where the attenuator is set, a zero-output position is always adjacent. The output is not shorted, but instead the normal 600-ohm output impedance is maintained. This aids in locating sources of extraneous signals and ground loops that would be masked by the presence of the normal output or by shorting. A rear-panel female BNC output is in parallel with the front-panel binding posts.

The 1312 has the external-synchronization feature[2] originally introduced on the General Radio line of RC oscillators. This permits locking the oscillator frequency to an external signal's frequency, and it also provides a constant 0.8-volt output regardless of the attenuator setting. Connection is made by way of a rear-panel female BNC connector.

The 1312 has obvious applications in production or quality-control testing. Repetitive measurements at a variety of widely separated frequencies can be made very accurately. The high repeatability assures uniform testing and allows pretuned filters and distortion meters to be used to speed the operation.

The 1312 is also very valuable in applications in which, contrary to the above, frequency is changed very seldom. In capacitance-measuring systems, for example, almost all measurements are made at 60 Hz, 120 Hz, 1 kHz, 100 kHz, or 1 MHz. Once the frequency is set it is rarely changed, but it must often be verified that the frequency is in fact the desired one. The unambiguous readout makes this easy even with low-skill operators. A misadjustment is more apparent than on conventional continuous dials, and the ±1% accuracy of the 1312 is more compatible with system requirements than is the 2% or 3% of dial oscillators. The compact 1312 takes up a minimum of valuable eye-level space in a test rack, and the rear-panel connections leave the front of the rack free of clutter.

How It Works

The 1312 Decade Oscillator uses the modified Wien circuit shown in Figure 10. This circuit oscillates (i.e., its trans-

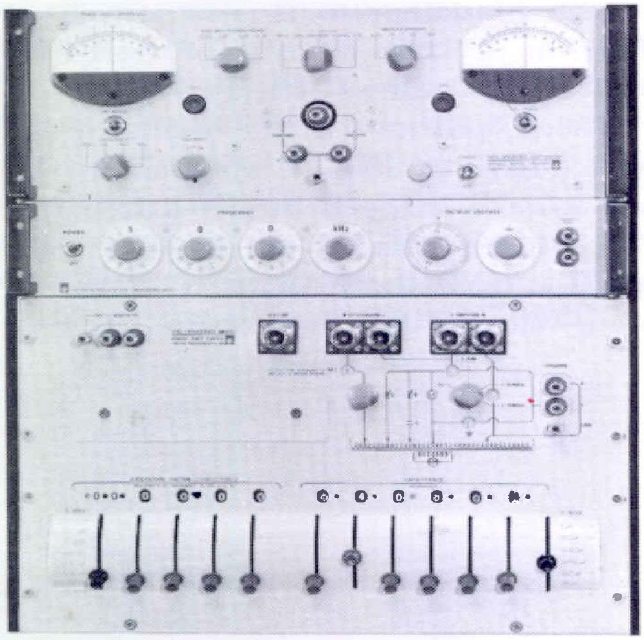

Figure 9. A low 3½-inch rack panel height, rear panel connections, and an easy-to-read frequency indication make the 1312 ideal for systems. Verification of correct operating frequency takes but a glance.

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[2] General Radio *Instrument Note* IN-109 "Principles and Applications of Oscillator Synchronization."

fer function, $\frac{e_o}{e_i}$, is real and at maximum) at a frequency

$$\omega_o = \frac{G}{C}\sqrt{1 + \frac{\alpha g}{G}}$$

The values of capacitance C are switched in decade steps by means of the dimensional-units switch to obtain the five ranges of the oscillator. The conductance G comprises two conductance decades that determine the two most significant digits of the frequency. That is

$$G = \overline{G}\,(L + M),$$

where $\overline{G}$ is a normalizing conductance, L varies from 0.1 to 1.0 in steps of 0.1, and M varies from 0.00 to 0.10 in steps of 0.01. Then

$$\omega_o = \frac{\overline{G}}{C}(L + M)\sqrt{1 + \frac{\alpha\, n}{L + M}}$$

$$= \frac{\overline{G}}{C}\left[L + M + \frac{\alpha n}{2} - \frac{\alpha^2 n^2}{L + M}\ldots\right]$$

where $n = \frac{g}{\overline{G}}$. If $\alpha\, n \ll 1$ then

$$\omega_o \approx \frac{\overline{G}}{C}\left[L + M + \frac{\alpha\, n}{2}\right].$$

n is made equal to 0.02 so that $\frac{\alpha n}{2}$ varies continuously from 0.000 to 0.009 as α varies from 0 to 0.9.

R. E. Owen

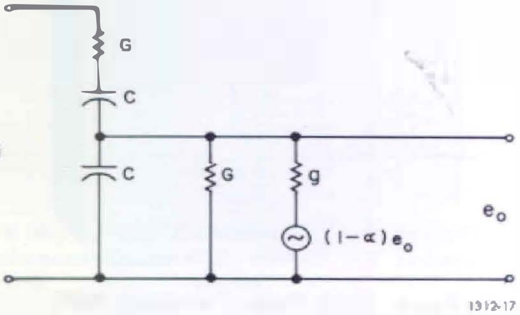

Figure 10. The RC frequency-determining network used in the 1312.

Robert E. Owen received his B.E.E. from Rensselaer Polytechnic Institute in 1961 and his M.S.E.E. from Case Institute of Technology in 1963. He came to GR as a development engineer in 1963 and has for the past few years concentrated on RC oscillator designs.

SPECIFICATIONS

FREQUENCY

Range: 10 Hz to 1 MHz in five decade ranges.

Accuracy: ±1% of setting.

Stability (typical at 1 kHz): Warmup drift, 0.1%. After warmup: 0.001% short term (10 min), 0.005% long term (12 h). Resettable within 0.005%.

Control: Step control of two most significant digits, continuously adjustable third digit with detented zero position. In-line readout with positioned decimal point and frequency units.

Synchronization: Frequency can be locked to external signal. Lock range ±3 % per volt rms input up to 10 V. Frequency controls function as phase adjustment.

OUTPUT

Voltage: >20 V open circuit.

Power: >160 mW into 600 Ω.

Impedance: 600 Ω. Isolated from chassis by 10 Ω across 0.1 μF.

Attenuation: Continuously adjustable attenuator with >20-dB range, and 80-dB step attenuator with 20 dB per step. Intermediate steps reduce output to zero while maintaining 600-Ω output impedance.

Distortion: <0.25%, 50 Hz to 50 kHz with any linear load. Oscillator will drive a short circuit without clipping.

Hum: <0.04% of max output or 4 μV, whichever is greater.

Amplitude vs Frequency: ±2%, 10 Hz to 100 kHz with >600-Ω load; ±4%, 100 kHz to 1 MHz with <600-Ω load.

Synchronization: Constant-amplitude (0.8-V) high-impedance (27-kΩ) output to drive counter or oscilloscope.

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