A NEW GENERATOR OF RANDOM ELECTRICAL NOISE

Noise, to the electronics engineer, presents two contrasting aspects. In the one, it limits the realizable performance of electronic devices and communication channels; in the other, it presents him with a test signal, which has, for many measurements, properties that are more useful than those of a single-frequency signal.

Broad-band electrical noise is often called random noise, because it has a random, or Gaussian, distribution of amplitudes as a function of time. When used as a test signal, it also usually has a uniform spectrum level over its specified frequency range. The random-noise signal, embracing a wide range of frequencies and having a randomly varying instantaneous amplitude, closely approximates the signals normally encountered in many electronic circuits and particularly in busy communication systems.

The properties of random noise were discussed in a previous article,[1] which described the Type 1390-A Random-Noise Generator. This instrument has, during the past several years, been applied to an unusually wide variety of instrumentation problems. This wide use has led to a number of suggestions for improvement, many of which have been incorporated in a new model, the Type 1390-B, shown in Figure 1. The most important of these are:

(1) The noise output spectrum has been extended to lower frequencies than in the earlier instrument (see Figure 3).

(2) The new cabinet is small, convenient for bench use, and yet is readily adapted by means of panel extensions to relay-rack mounting.

(3) The power-supply hum in the output has been reduced to negligibility.

(4) A built-in output attenuator has been added.

(5) The necessary warm-up time delay is provided by an automatic thermal relay.

(6) The stray external noise field has been markedly reduced.

The instrument still supplies the high output level in three bands (5 c to 20 kc, 5 c to 500 kc, and 5 c to 5 Mc) that makes the earlier model so widely useful. In fact, it has been found possible to raise the specifications on maximum output of the lowest band to at least 3 volts

Figure 1. Panel view of the Type 1390-B Random-Noise Generator.

and the next band to 2 volts, while the highest band output remains at 1 volt.

APPLICATIONS

Before describing the new instrument in further detail, let us review briefly a number of its uses. These usually depend on one or more of the following characteristics of the output of the noise generator:

(1) The signal is similar to many that occur in practice.

(2) It follows a definite statistical pattern.

(3) It has a broad frequency spectrum.

The uses can be grouped in four main categories: electrical measurements; acoustical measurements; environmental tests with high-level acoustic noise; and tests with random vibration.

One of the main uses of the earlier model has been as a *signal source for measurements*, among them:

Frequency response of loudspeakers.[2, 3]

Intermodulation and cross-talk tests on multi-channel communications systems.[4, 5, 6]

Over-all calibration of systems.[7]

Simulation of impulse-noise characteristics of telephone-line noise.

Resonance tests.[8]

Tests on servo amplifiers.

Noise interference tests on radar.

Noise source for radar target simulator.

Dynamic range tests on electronic equipment.

Measurement of the rms and peak response characteristics of meters.[9]

Noise signal for electronic countermeasures equipment.

Evaluation of noise in transistors.

Setting levels on carrier equipment.

Study of simulated non-linear systems by correlation methods with an analog computer.

Use as an element of an electronic probability generator.[10]

There are many uses in *acoustic measurements* where the noise source drives a loudspeaker, among them:

Measurements of reverberation time.[11, 12]

Reverberant field calibration of microphones.

Reverberant testing of acoustical properties of materials.[3]

Measurements of sound attenuation in ducts.

Testing of silencers for aircraft and air conditioning systems.

Room acoustic tests.[3]

Frequency response measurements of rooms and microphones.[3]

Testing the sound transmission of walls, panels, and floors.[3]

Hearing tests.[13]

Masking measurements.[13]

In a third group of uses, the random-noise generator drives a loudspeaker to produce *high-level acoustic noise* for the fatigue testing of structures.[14, 15, 16, 17] A particular application is in the design of missiles. Without a design based on these tests, the missile can fail in flight as a result of the high level of random noise impinging on its surface.

In a new and important category of use, the Type 1390-B Random-Noise Generator supplies the signal for a power amplifier *to drive a vibration shaker*. The shaker is used for structural tests of components[18] and assemblies of rocket or jet-engine-driven structures and for microphonic tests of vacuum tubes. Jets and rockets generate vibration that is random in nature, and the logical approach is to test with a random vibration. The test methods have developed rapidly, and there is already a book devoted to the subject.[19] The procedures

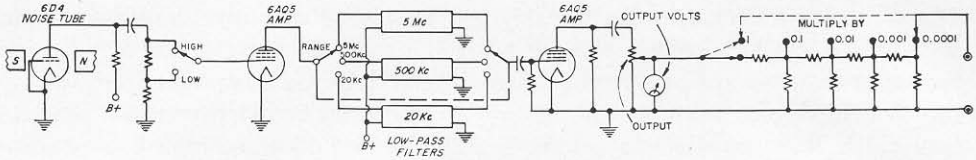


Figure 2. Elementary schematic of the generator.

and analysis of results are not simple, however, and there is some controversy regarding the method and its relation to testing with a swept sine-wave excitation.

In the classroom and laboratory, the noise generator has been used to demonstrate some of the properties of noise. Those who have been accustomed to sine-wave signals find it a new experience to try to handle noise signals. Since noise signals are now commonly encountered and measured, it is helpful to have a controlled source that can be used to familiarize one with the techniques of measurement.

DESCRIPTION OF THE GENERATOR

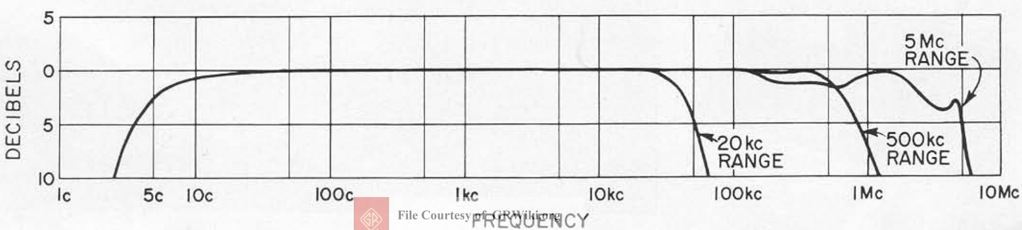
The original source of noise in this instrument is a gas-discharge tube with a transverse magnetic field applied.[20] This gas tube has a comparatively high noise output, which is amplified in a two-stage amplifier. Between these stages the noise spectrum is shaped to provide three output ranges to 20 kc, to 500 kc, and to 5 Mc. The high-frequency ends of these ranges are the same as in the earlier model, but the low-frequency performance has been improved.

Improved Low-Frequency Output

The output at low frequencies has been increased by changes in the time constants in the coupling circuits. The plot of the typical spectrum in Figure 3 shows that the output is down less than 3 db at 5 cycles per second, as contrasted with 10 db in the earlier model.

One of the problems encountered in producing this improvement came in devising a suitable technique for measuring the low-frequency output. This problem was happily solved by the use of the new Type 1554-A Sound and Vibration Analyzer.[2] The nature of this problem illustrates one of the characteristics of noise that is most apparent when measurements are made at low frequencies. Some years ago, when we tried to measure the low-frequency response of the earlier noise generator at frequencies down to 2½ cps on the Type 762-B Vibration Analyzer, we found the fluctuations of the pointer on the instrument were so large that we could not readily arrive at a suitable long-time average level. Calculations show that even for the wider band (5%) on that instrument it would be necessary to average over about a 6-minute period to have a 90% chance of being within ±1 db of the long-time average level.[21] For the third-octave band of the Type 1554-A Sound and Vibration Analyzer, the required time is reduced by a factor of 5.

Figure 3. Typical spectrum of the noise output.



The pointer still fluctuates considerably at these low frequencies, but the measurement becomes a reasonable one with the new analyzer. With a still wider bandwidth it is possible to obtain a quicker result, but then the resolution in terms of the range of frequencies measured becomes poorer. The one-third octave is an excellent compromise bandwidth.

What this problem illustrates is that the accuracy of measurement of level depends upon the bandwidth used and the time devoted to the measurement. Furthermore, the accuracy can be expressed only in terms of a probability figure. Although the concept is old and is not restricted to measurement of noise, the dependence is readily observed in low-frequency measurements of noise, but is usually not apparent in ordinary measurements with higher frequency sine-wave signals.

Attenuator and Reduced Leakage

To reduce and control the output voltage for low-level tests with the A-model it was necessary to use a separate attenuator. The output system on the new instrument consists of a continuous control, followed by a 4-step attenuator of 20 db per step. Metered levels from over 3 volts down to below 30 microvolts are conveniently obtained. When the attenuator is used, the output impedance remains essentially constant as the level is varied by the continuous output control.

This low-level output obtainable from the attenuator necessitated a reduction in the noise field radiated from the instrument at high frequencies. This reduction has been accomplished by additional filtering in the power-line leads in the instrument and by a change in the measuring circuit so that the meter is bypassed to ground.

New Cabinet

When an instrument is used on the bench, it is customary to have it horizontal. Often, however, a tilted position permits the meter to be read more conveniently. In the new cabinet shown in Figure 4 this tilted position is made possible by the extendible legs near the panel.

For relay-rack mounting, wings are supplied to extend the panel to relay-rack width as shown in Figure 5. Thus the user can have the convenience of a small bench instrument for experimental work and yet readily mount it in a rack if the instrument becomes part of a relatively permanent test rack.

ACKNOWLEDGMENT

The new cabinet was developed by H. C. Littlejohn and M. C. Holtje. The electrical circuit redesign was worked out by R. J. Ruplenas.

— A. P. G. Peterson

REFERENCES

1 A. P. G. Peterson, "A Generator of Electrical Noise," *General Radio Experimenter*, Vol. 26, No. 7, December, 1951.

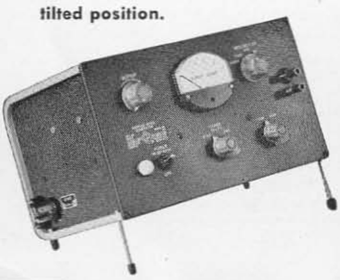


Figure 4. Extendible legs allow instrument to be used in a tilted position.

Figure 5. Panel extensions are furnished to adapt the instrument for relay-rack mounting.

2 J. J. Faran, "A New Analyzer for Sound and Vibration," *General Radio Experimenter*, Vol. 33, No. 12, December, 1959.

3 L. L. Beranek, *Acoustic Measurements*, New York, John Wiley, 1949.

4 L. J. Libois and M. Thue, "Bruit et Diaphonie dans les Liaisons Multiplex a Modulation de Frequence," *Cables & Transmission*, Vol. 10, No. 2, April, 1956, pp. 129-144.

5 R. Grit and G. Levaillant, "Un Diaphonometre a Bruit Blanc: Le FD 692," *Annales de Radioelectricite*, Vol. 14, No. 56, April, 1959, pp. 142-155.

6 J. P. Vasseur, "Les Faisceaux Hertziens a Courants Porteurs devant les Recommendations du CCIF," *Annales de Radioelectricite*, Vol. 9, No. 35, January, 1954, pp. 47-82.

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

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

9 A. P. G. Peterson, "Response of Peak Voltmeters to Random Noise," *General Radio Experimenter*, Vol. 31, No. 7, December, 1956.

10 G. M. White, "Electronic Probability Generator," *Review of Scientific Instruments*, Vol. 30, No. 9, September, 1959, pp. 825-829.

11 C. G. Balachandran, "Random Sound Field in Reverberation Chambers," *Journal of Acoustical Society of America*, Vol. 31, No. 10, October, 1959, pp. 1319-1321.

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

13 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).

14 Jack Evans, "Vibration and Acoustical Problems in Missiles," *Noise Control*, Vol. 4, No. 6, November, 1958, pp. 22-26.

15 Merwin T. Anderson and Leonard L. Robinson, "Laboratory Simulation of Rocket Engine Noise," *Environmental Quarterly*, Vol. 4, No. 4, Fourth Quarter, 1958, pp. 6-9.

16 Merwin T. Anderson, "Acoustic Noise, Its Effect on Components," *Electronic Design*, December 9, 1959.

17 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.

18 J. Robbins, "Standardized White-Noise Tests," *Electronic Industries and Tele-Tech*, Vol. 16, No. 2, February, 1957, pp. 68-69.

19 S. H. Crandall, Editor, *Random Vibration*, Cambridge, Massachusetts: The Technology Press of the M.I.T., 1958.

20 J. D. Cobine and J. R. Curry, "Electrical Noise Generators," *Proc. IRE*, Vol. 35, No. 9, September, 1947, pp. 875-879.

21 R. B. Blackman and J. W. Tukey, *The Measurement of Power Spectra*, New York, Dover Publications, Inc., 1959, pp. 22-23.

SPECIFICATIONS

Frequency Range: 20 kc: spectrum level is uniform from 20 cps to 20 kc within ±1 db. 500 kc: spectrum level is uniform from 20 cps to 500 kc within ±3 db. 5 Mc: spectrum level is uniform from 20 cps to 500 kc within ±3 db and from 500 kc to 5 Mc within about ±8 db. Noise energy is also present beyond these limits. The level is down about 3 db at 5 cps.

Output Voltage: Max. open-circuit output is at least 3 volts for 20-kc range, 2 volts for 500-kc range, and 1 volt for 5-Mc range.

Typical Spectrum Level (with one volt output): 20-kc band: 5 mv for 1-cps band. 500-kc band: 1.2 mv for 1-cps band. 5-Mc band: 0.6 mv for 1-cps band.

Output Impedance: Source impedance for max. output is approx. 900 ohms. Output is taken from a 2500-ohm potentiometer. Source impedance for attenuated output is 200 ohms. One output terminal is grounded.

Waveform: Noise source is a gas tube that has good normal or Gaussian distribution of amplitudes for narrow ranges of the frequency spectrum. Over wide ranges the distribution becomes less symmetrical because of dissymmetry introduced by the gas tube. Appreciable clipping occurs on the 500-kc and 5-Mc ranges.

Voltmeter: Rectifier-type average meter measures output. It is calibrated to read rms value of noise.

Attenuator: Multiplying factors of 1.0, 0.1, 0.01, 0.001, and 0.0001. Accurate to ±3% to 100 kc, within ±10% to 5 Mc.

Accessories Supplied: Power cord, spare fuses, extensions for relay-rack mounting.

Mounting: Metal cabinet.

Power Supply: 105 to 125 (or 210 to 250) volts, 50 to 60 cps.

Power Input: About 50 watts.

Tubes Supplied: 6D4(1), 6AQ5 (2), 3-4 (1), 115-NO3OT (1).

Dimensions: Width 12¾ in., height 7½ in., depth 9¾ in. Panel height for 19-inch relay-rack mounting is 7 inches.

Weight: 12 lb. bench mounting.

Type		*Code Word*	*Price*
1390-B	**Random Noise Generator**	BUGLE	**$295.00**