NOISE GENERATOR

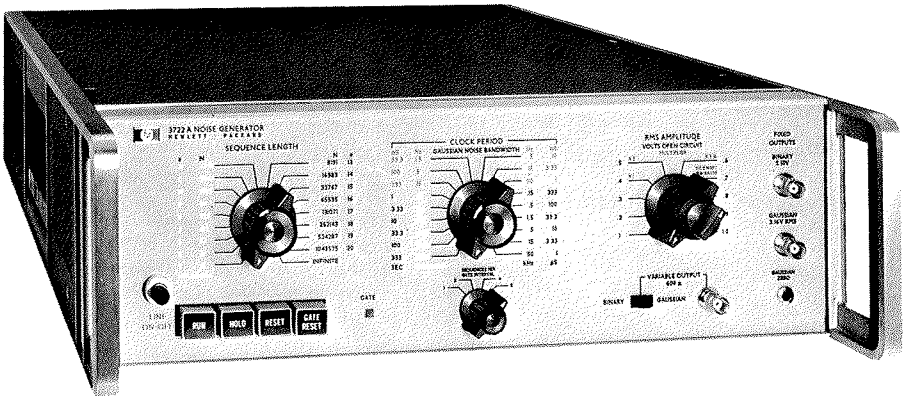
Produces calibrated noise patterns

Model 3722A

The Model 3722A Noise Generator uses digital techniques to synthesize binary and Gaussian noise patterns. These pseudo-random' patterns, which are of known content and duration, are repeated over and over without interruption. Since one pattern is identical with the next, each pattern has the same effect on the system under test: for this reason, pseudo-random noise signals cause no statistical variance in test results. The Model 3722A also generates truly random binary and Gaussian noise.

Basis of the Model 3722A is a binary waveform generator—a shift register which operates under the control of either a feedback mechanism (pseudo-random mode) or a random noise source (random mode). The shift register is clock triggered, with the result that transitions between output levels of the binary waveform can occur only in time with beats of the clock—although whether or not a transition occurs on a given beat is determined by the feedback mechanism or random noise source. The binary output has a $(\sin x/x)^2$ shaped spectrum and the Gaussian output, which is derived from the binary signal by precision low-pass filtering, has an almost rectangular spectrum. Both binary and Gaussian outputs are controllable in bandwidth, but the output power remains constant regardless of selected bandwidth—a particularly useful feature, of importance in applications where usable noise power must be made available in a very restricted frequency band. Frequency of the first null in the binary spectrum is selectable from 0.003 Hz to 1 MHz, and the bandwidth (at —3 dB point) of the Gaussian noise is selectable from 0.00015 Hz to 50 kHz.

Outputs from the Model 3722A are available at fixed amplitudes of ±10 V (binary) and 3.16 V rms (Gaussian), and a precision amplitude control provides a variable output of either signal ranging from 0.1 V rms up to the level of the fixed outputs.



3722A

Specifications

Binary output (fixed amplitude)

Amplitude: ±10 V.

Output impedance: <10Ω.

Load impedance: 1 kΩ minimum.

Rise time: <100 ns.

Power density: approximately equal to (clock period x 200) V^2/Hz, at low frequency end of spectrum.

Power spectrum: $(\sin x/x)^2$ form: first null occurs at clock frequency and −3 dB point occurs at 0.45 x clock frequency.

Gaussian output (fixed amplitude)

Amplitude: 3.16 V rms.

Output impedance: <1Ω.

Load impedance: 600Ω minimum.

Zero drift: <5 mV change in zero level in any 10°C range from 0° to +55°C.

Power density: approximately equal to (clock period x 200) V^2/Hz at low frequency end of spectrum.

Power spectrum: rectangular, low pass: nominal upper frequency f_o (−3 dB point) equal to 1/20th of clock frequency. Spectrum is flat within ±0.3 dB up to $\frac{1}{2}f_o$, and more than 25 dB down at $2f_o$.

Crest factor: up to 3.75, dependent on sequence length.

Variable output (Binary or Gaussian)

Amplitude (open circuit)

Binary: 4 ranges: ±1 V, ±3 V, ±3.16 V and ±10 V, with ten steps in each range, from x 0.1 to x 1.0.

Gaussian: 3 ranges: 1 V rms, 3 V rms, and 3.16 V rms, with ten steps in each range, from x 0.1 to x 1.0.

Output impedance: 600Ω ±1%.

Main controls

Sequence length switch: first 17 positions select different pseudo-random sequence lengths: final position selects random mode of operation (INFINITE sequence length). Sequence length (N) is number of clock periods in sequence: possible values of N are 15, 31, 63, 127, 255, 511, 1023, 2047, 4095, 8191, 16383, 32767, 65535, 131071, 262143, 524287, 1048575. $N = 2^n - 1$, where n is in the range 4 to 20 inclusive.

Clock period switch: selects 18 frequencies from internal clock:

Clock period	Clock frequency	Gaussian noise bandwidth
333 s	0.003 Hz	0.0015 Hz
100 s	0.01 Hz	0.0005 Hz
33.3 s	0.03 Hz	0.0015 Hz
10 s ↓ 3.33 μs	0.1 Hz ↓ 300 kHz	0.005 Hz ↓ 15 kHz
1 μs	1 MHz	50 kHz

Internal clock

Crystal frequency: 3 MHz nominal.

Frequency stability: $< \pm 25$ ppm over ambient temperature range 0° to +55°C.

Output: +12.5 V rectangular wave, period as selected by CLOCK PERIOD switch.

External clock

Input frequency: usable BINARY output (pseudo-random only) with external clock frequencies up to 1.5 MHz.

Input level: negative-going signal from +5 V to +3 V initiates clock pulse.

Maximum input: ±20 V.

Secondary outputs

Sync: negative-going pulse (+12 V to +1.5 V) occurring once per pseudo-random sequence; duration of pulse equal to selected clock period.

Gate: gate signal indicates start and completion of selected number of pseudo-random sequences (1, 2, 4 or 8, selected by front panel control). Two outputs are provided:—

1. Logic signal: output normally +12.5 V, falls to +1 V at start of gate interval and returns to +12.5 V at end of interval.
2. Relay changeover contacts: gate relay switching is synchronous with logic signal.

Binary relay: relay changeover contacts operate in sync with binary output signal.

Remote control

Control inputs: remote control inputs for RUN, HOLD, RESET and GATE RESET functions are connected to 36-way receptacle on rear panel.

Sequence length indication: 18 pins plus one common pin on the 36-way receptacle are used for remote signalling of selected sequence length (contact closure between common pin and any one of the 18 pins).

General

Dimensions: 16¾" wide, 5-7/32" high, 16⅜" deep (425 x 132.6 x 416 mm).

Weight: net 23 lbs (10,5 kg); shipping 30 lbs (13,5 kg).

Price: Model 3722A $2,650 ($2,400 at factory in Scotland).

Option 01

Zero moment option: shifts relative position of sync pulse and pseudo-random binary sequence such that first time moment of sequence, taken with respect to sync pulse, is zero (sequence shift mechanism is operative only when selected sequence length is ≤1023): option 01 also provides facility for inverting binary output signal. ADD $50 ($45 at factory in Scotland).

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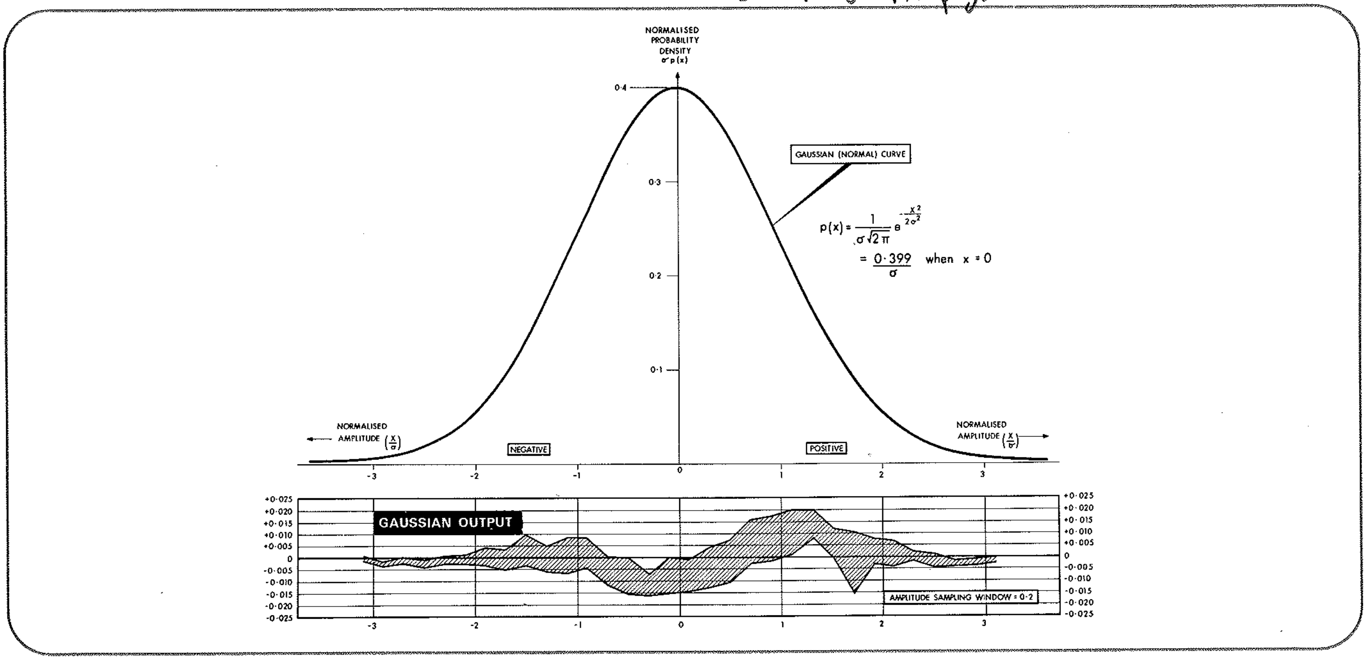


Envelope (shaded area) shows measured departures from the normal curve of 3722A Gaussian output p.d.f.'s for sequence lengths of 8,191 and greater.

Most systems, from simple servos to suspension bridges, are subject to random disturbances which must be accounted for in the design and—if possible—simulated at the prototype test stage. For the purpose of simulation it seems appropriate to use a randomly varying test signal—that is, low frequency noise—rather than the traditional sine wave. In environmental testing, too, the real-life 'shock environment' can often be reproduced accurately with a noise-stimulated transducer. The desirability of noise as a test signal has been appreciated for many years, but general acceptance of the technique has been slow—principally owing to the lack of satisfactory generators and related test gear for low frequency noise.

Conventional noise generators employ natural sources such as the gas discharge tube and temperature-limited diode. Generators of this type have the disadvantage that their total power output is subject to unpredictable long term variations: their power spectra, too, can often be unpredictable at low frequencies—in particular, below 50 Hz, where much of the interest in noise testing is focused.

Characterizing noise

The power spectrum describes only the frequency content of the noise signal, but does not characterize its waveshape: this is specified by the probability density function (p.d.f.), a statistical indication of the proportion of time spent by the signal at various amplitudes. The most commonly encountered p.d.f. is the classical bell-shaped, or Gaussian curve so familiar in statistics: this particular p.d.f. characterizes most random phenomena (for example, atmospheric changes) and for this reason, a noise signal designed to simulate such phenomena must have a p.d.f. which closely approximates the Gaussian curve. The question of p.d.f. is another problem area with conventional noise generators. How can 'Gaussianness' be specified? And, more difficult, over what period of time must the signal be evaluated to be certain that its amplitude characteristics tend to be Gaussian? Are the signal properties observed in a given period representative of the next similar period? This suggests that a series of identical experiments involving truly random noise will yield different results each time. This 'statistical variance' can often be reduced to acceptable limits by increasing the observation (that is, averaging) time—but it can never be entirely eliminated.

Pseudo-random noise

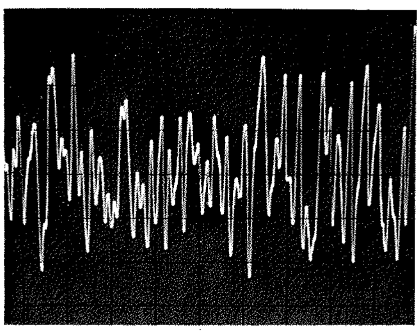
The need exists, then, for a test signal having the desirable properties of random noise—that is, broad spectrum and Gaussian probability density function—yet not having the bad property . . . randomness. In other words, the signal should be one which introduces no statistical variance into test results, even though the measurements are made in a finite time.

Such a signal exists . . . *pseudo-random* noise is a signal which looks and acts like random noise, but is in fact periodic. This kind of noise is the main product of the Hewlett-Packard Model 3722A Noise Generator.

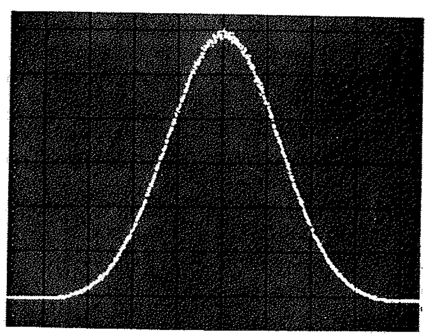
Pseudo-random waveforms from the 3722A consist of completely defined patterns of selectable length, repeated over and over without interruption. They have power spectra and p.d.f.'s similar to those of random noise but, because the waveforms are synthesized, their statistical properties are precisely known. Perhaps the most important feature of pseudo-random noise testing is the fact that, if the measurement time is made exactly equal to the length of one pseudo-random pattern, the results of the experiment will be identical at every repetition, provided nothing else has changed.

This repeatability of pseudo-random noise is especially valuable when parameters of the system under test are varied—for example, in an analog computer model of a complex system. In such tests, it is reassuring to know that changes in test results arise from parameter manipulation and not from statistical variance in the test signal. The basic output from the Model 3722A is two-level, binary noise (random telegraph signal), available as a pseudo-random signal in a variety of pattern lengths, and also as a truly random, non-repeating signal. Binary noise is commonly used in testing systems controlled by two-state elements such as switches, relays, fluid control valves, and so on. Recently, however, binary noise has assumed greater importance in connection with actual identification of systems . . . that is, obtaining the impulse response of a system by injecting low-level binary noise into the system and then cross-correlating the input and output signals. This technique can be demonstrated very simply using the Model H01-3722A Generator, a standard Model 3722A instrument with two separate binary outputs, one of which can be variably delayed with respect to the other.

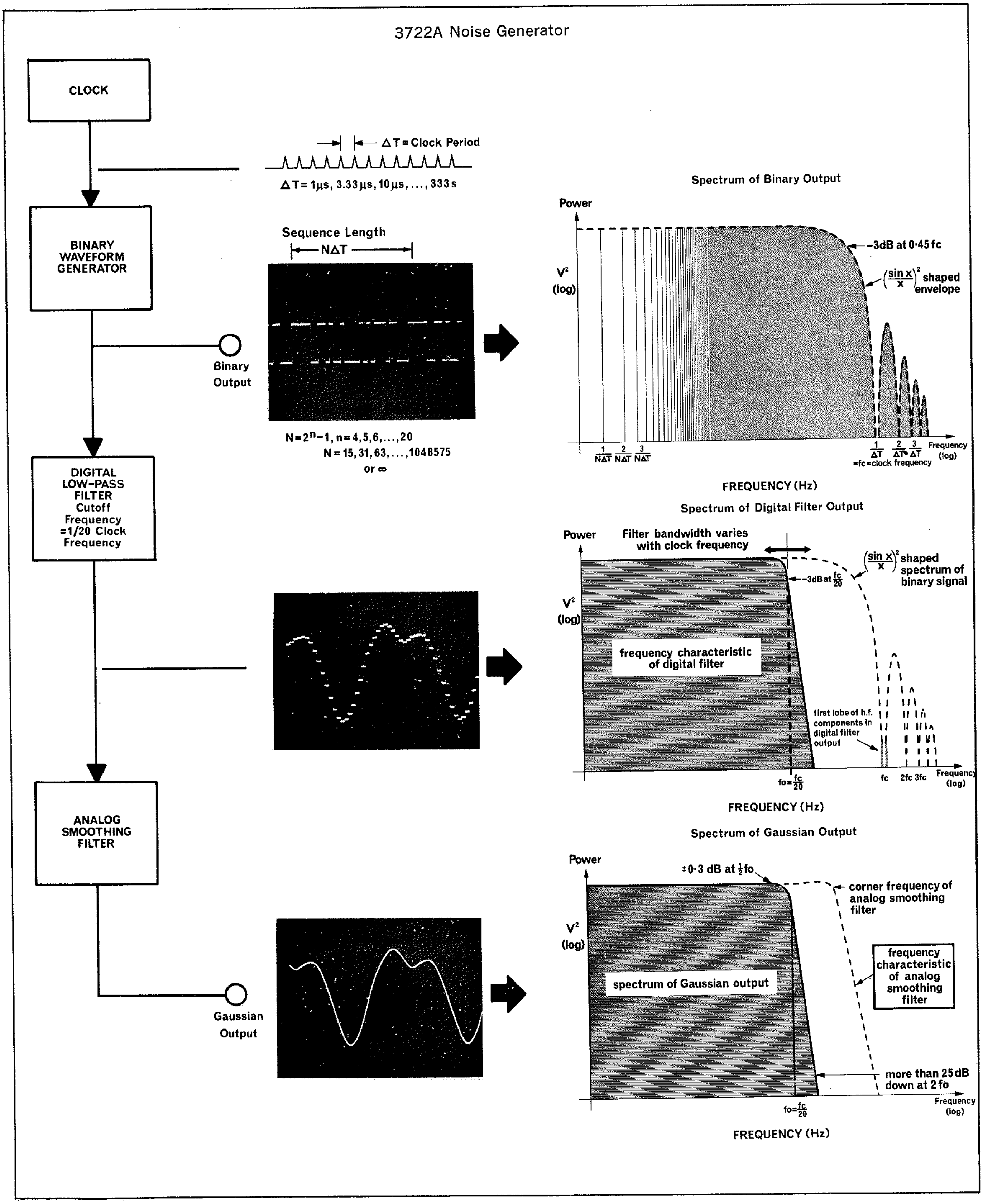
The principal output from the Model 3722A is Gaussian noise, which is derived from the binary signal by low-pass filtering. A unique method of digital filtering is employed to give an almost rectangular power spectrum with very little power beyond a selectable cut-off frequency. The particular advantage of this digital filter, as opposed to the conventional analog filter, is that it yields a signal of constant power regardless of cut-off frequency (in any event, analog filtering is not practicable at the very low frequencies useful in noise testing—the lowest cut-off frequency of the digital filter in the Model 3722A is about 1 cycle in 100 minutes!).



Part of a pseudo-random Gaussian noise sequence generated in Model 3722A from 524, 287-bit binary pattern. Clock period is 1 μs, giving noise bandwidth of 50 kHz.



Probability density function of pseudo-random Gaussian noise (same sequence as at left) displayed on Model 5400A Multi-channel Analyzer.



Model 3722A Noise Generator synthesizes pseudo-random or random binary signal in a digital waveform generator which is timed by a crystal-controlled clock. Clock rate and length of pseudo-random sequences are variable. Gaussian signal is derived from binary output by digital low-pass filtering. Discrete steps in digital filter output are removed by analog filter. Pseudo-random binary output of noise generator has line power spectrum having a flat envelope from dc to an upper 3 dB frequency which is selectable from 0.00135 Hz to 450 kHz. Spectrum of pseudo-random Gaussian output has flat envelope from dc to an upper 3 dB frequency which is selectable from 0.00015 Hz to 50 kHz. Random outputs have continuous power density spectra having same shapes as envelopes of spectra of pseudo-random outputs.