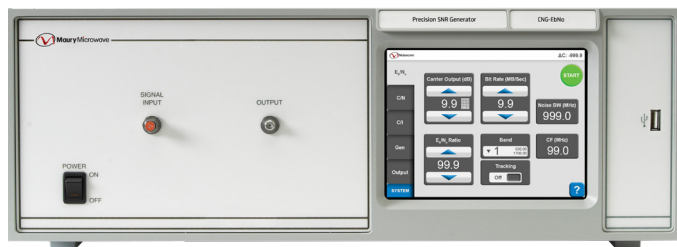


Noise Generation Instruments



Additive White Gaussian Noise

Additive White Gaussian Noise (AWGN) is a type of noise commonly used in signal processing and telecommunications to model random noise that affects the transmission of signals. AWGN (**Figure 1**) can be explained as follows:

Additive

The noise is added to the original signal. It does not alter the signal in any other way except by adding itself to it. The received signal can be represented as:

$$y(t) = x(t) + n(t)$$

where $y(t)$ is the received signal, $x(t)$ is the transmitted signal, and $n(t)$ is the noise.

White

The term 'white' refers to the noise having a flat power spectral density, meaning its power is uniformly distributed across all frequencies. It is analogous to white light, which contains all visible wavelengths equally. This property makes white noise uncorrelated across different frequencies.

Gaussian

The noise amplitude follows a Gaussian distribution, also known as a normal distribution. This means that the noise values are random but have a bell-shaped probability distribution centered at zero (mean = 0). The probability density function (PDF) of Gaussian noise is given by:

$$p(n) = (1 / \sqrt{2\pi\sigma^2}) * \exp(-n^2 / (2\sigma^2))$$

where σ^2 is the variance (measure of the noise power).

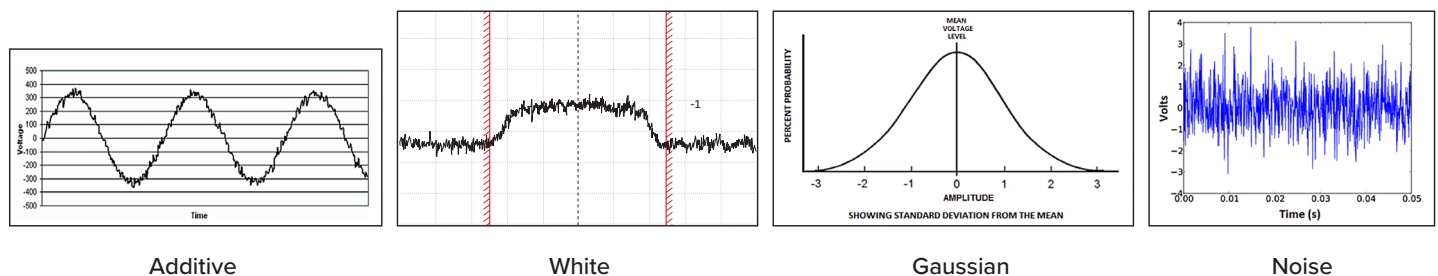


Figure 1. A breakdown of AWGN, illustrating additive noise on a signal; flat power spectral density; Gaussian distribution; and the random, independent nature of noise.

AWGN is stationary, whereby the statistical properties of the noise do not change over time; memoryless: the noise at any time instant is independent of the noise at any other time instant; and linear: the noise does not distort the shape of the signal, only the amplitude is affected.

AWGN is often used in simulations of digital communication systems (e.g., BPSK, QPSK, OFDM) to model the effect of random noise in the channel. It serves as a good approximation for many practical communication channels, especially when there is minimal interference or fading. In electronic warfare (EW), AWGN is often employed to test both offensive and defensive jamming systems.

Typical cases for AWGN include:

- > 5G communications
- > Satellite communications
- > Signal integrity
- > Directed energy weapons

Noise Sources and Noise Generation Instruments

A noise source, such as a NC346-series from Maury Microwave, is a common component used to generate AWGN. A noise source consists of a reverse-biased Zener diode, a series resistor, an operational amplifier, and a capacitor, as shown in **Figure 2**.

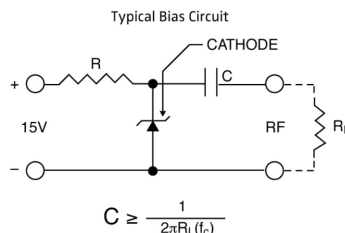


Figure 2. Circuit diagram of a typical noise source.

The noise generated by a Zener diode has a wide frequency range, with a significant portion being white noise (constant power spectral density). The noise voltage depends on the breakdown voltage of the Zener diode. Diodes with lower breakdown voltages (e.g., 5.1V) are often used, as they tend to produce more noise due to the dominance of Zener noise (tunneling effect).

Noise sources can be combined with amplifiers, precision attenuators, and filters to become semi-automated and automated instruments for generating AWGN with specific power levels and frequencies.

» **Maury Microwave customizes noise generation instruments to meet specific use-case requirements.**

The broadband AWGN generator features a powerful single-board computer with a flexible architecture designed to create complex custom noise signals for advanced testing systems. This adaptable platform enables users to address their most demanding design needs. High-precision components deliver strong output power with excellent flatness, while the versatile computer architecture provides control over multiple attenuators, switches, and filter banks (**Figure 3**).

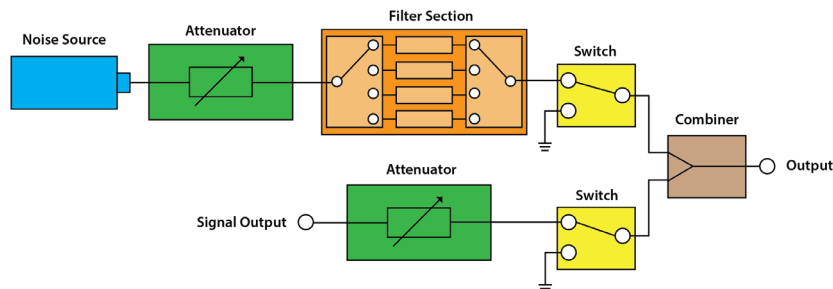


Figure 3. A block diagram of a broadband, AWGN generator, showing a high level of noise control via attenuation, switching, and filtering.

Noise generation instruments can be automated to set and maintain a highly accurate ratio between a user-supplied carrier and internally generated AWGN, across a wide range of signal power levels and frequencies (**Figure 4**). The noise generator provides five operating modes: carrier-to-noise (C/N), carrier-to-noise density (C/No), bit energy-to-noise density (Eb/No), carrier-to-interferer (C/I), and power meter. The instrument can also function as a precision noise generator.

An automated solution includes a step attenuator and power sensor on the signal path and automatically adjusts the attenuation to reach the target signal-to-noise ratio (SNR).

Semi-automated allows a signal to pass through the instrument and combine with noise, but does not adjust the signal level (user must manually adjust).

In both cases, an external signal source is required and supplied by the customer.

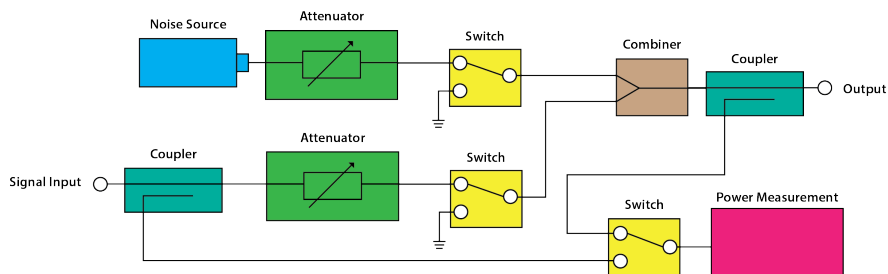


Figure 4. A block diagram showing the internal noise source combined with the user-supplied carrier to generate a precise ratio over a broad range of signal power levels and frequencies.

Noise generation instruments produce AWGN with a high crest factor to simulate realistic “real-world” random jitter (Figure 5). This type of random jitter, often referred to as Rj in the industry-standard jitter hierarchy model, is crucial to manage for the optimal performance of high-speed communication buses and devices. Today’s high-speed digital circuit designers face the challenge of narrow jitter tolerances while striving to achieve high data rates and low bit error rates (BER).

Building a system that not only meets industry specifications but also remains robust against jitter to maintain a low BER is an ongoing challenge, especially as frequency and data rates increase. This noise generation tool allows designers to inject Rj directly into a data stream to assess device performance using typical measurement tools like oscilloscopes or bit error rate testers (BERTs). By adding precise amounts of white noise, the resulting decrease in SNR can be analyzed to evaluate the receiver’s performance. This approach helps minimize the overall timing budget, including necessary margins, to support higher data rates. The noise generator is capable of outputting this random noise (Rj) effectively for these evaluations.

In single-ended transmission, the signal is referenced to a common ground. The data signal is sent over one conductor, and its voltage is measured relative to a shared ground or reference point. Single-ended systems may have lower noise immunity, potentially leading to higher BER, especially in high-speed or noisy environments.

In differential transmission, the signal is sent over two complementary conductors. The voltage difference between the two lines (positive and negative signals) represents the data. Differential signals have better noise immunity since any external noise affects both conductors equally (common-mode noise). The receiver only detects the difference, effectively canceling out the noise.

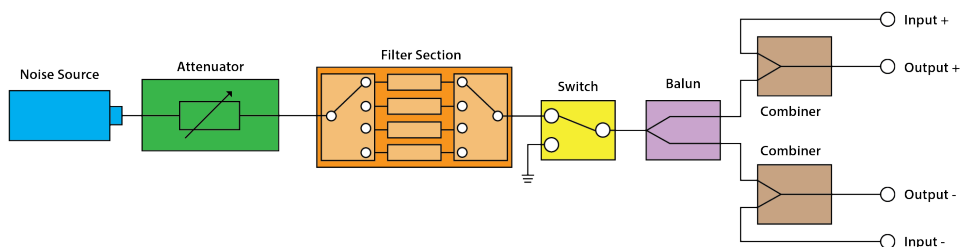


Figure 5. A block diagram of a noise generator designed to generate real-world random jitter.

Examples of delivered Noise Generation Instruments can be found at:

<https://maurymw.com/products/noise-generators/programmable-noise-generators/>

Including the NGX1000, J7000, CNG-EbNo, UFX7000B

» **Contact us to discuss your use-case requirements and custom noise generation instruments.**

Appendix A

5G/Satellite Communications: Amplifier Linearity Testing with Noise Power Ratio

The UFX7000B provides the AWGN signal for a noise power ratio (NPR) test, which is used to determine the linearity of amplifiers in 5G and satellite communications systems. After the band-limited AWGN signal passes through a notch filter, it is applied to an amplifier and analyzed for nonlinearities and IMD by observing the change in notch depth.

<https://maurymw.com/resources/satellite-communications-testing/>

<https://maurymw.com/resources/5g-and-mmwave-testing/>

Satellite Communications: Receiver Sensitivity – Carrier-to-Noise Ratio Testing

The flexible architecture of the UFX7000B, when used in conjunction with a power meter, allows satellite systems designers to create specific carrier-to-noise ratios for testing receiver sensitivity, interference tolerance, and system performance.

<https://maurymw.com/resources/satellite-communications-testing/>

Satellite Communications: Carrier-to-Noise Ratio Generation

The CNG-EbNo is an all-in-one measurement and noise generation solution that greatly simplifies satellite communications link testing, allowing engineers and technicians to simply enter a desired C/N, Eb/No, or C/I ratio without the use of additional instrumentation.

<https://maurymw.com/resources/satellite-communications-testing/>

Signal Integrity: Jitter Tolerance Testing

The J7000B adds random noise to the channel to generate jitter, modeling real-world electrical noise commonly found in high-speed serial data communications links. Engineers can analyze results on an oscilloscope to evaluate device performance and make informed adjustments to optimize designs.

<https://noise.com/resource-library/solutions-guide/power-and-signal-integrity-solutions>

Signal Integrity: Crosstalk and Receiver Sensitivity Analysis

The noise the J7000B introduces to the DUT can be used to quantify the impact of interference and crosstalk from nearby traces or noisy components on the serial data link. With the noise source activated, crosstalk interference appears as jitter on the oscilloscope's eye diagram, causing the eye to close and leading to compliance test issues.

<https://maurymw.com/resources/power-and-signal-integrity-solutions/>

Directed Energy Weapons: Laser Weapon Development

During laser weapon development, the output of the UFX7000B connects to an optical phase modulator, which connects to the laser pump to directly drive coherence spreading.

<https://maurymw.com/resources/directed-energy-weapons-development-solutions/>

CONTACT US:

W / maurymw.com

E / maury@maurymw.com

P / +1-909-987-4715

F / +1-909-987-1112

2900 Inland Empire Blvd

Ontario, CA 91764

