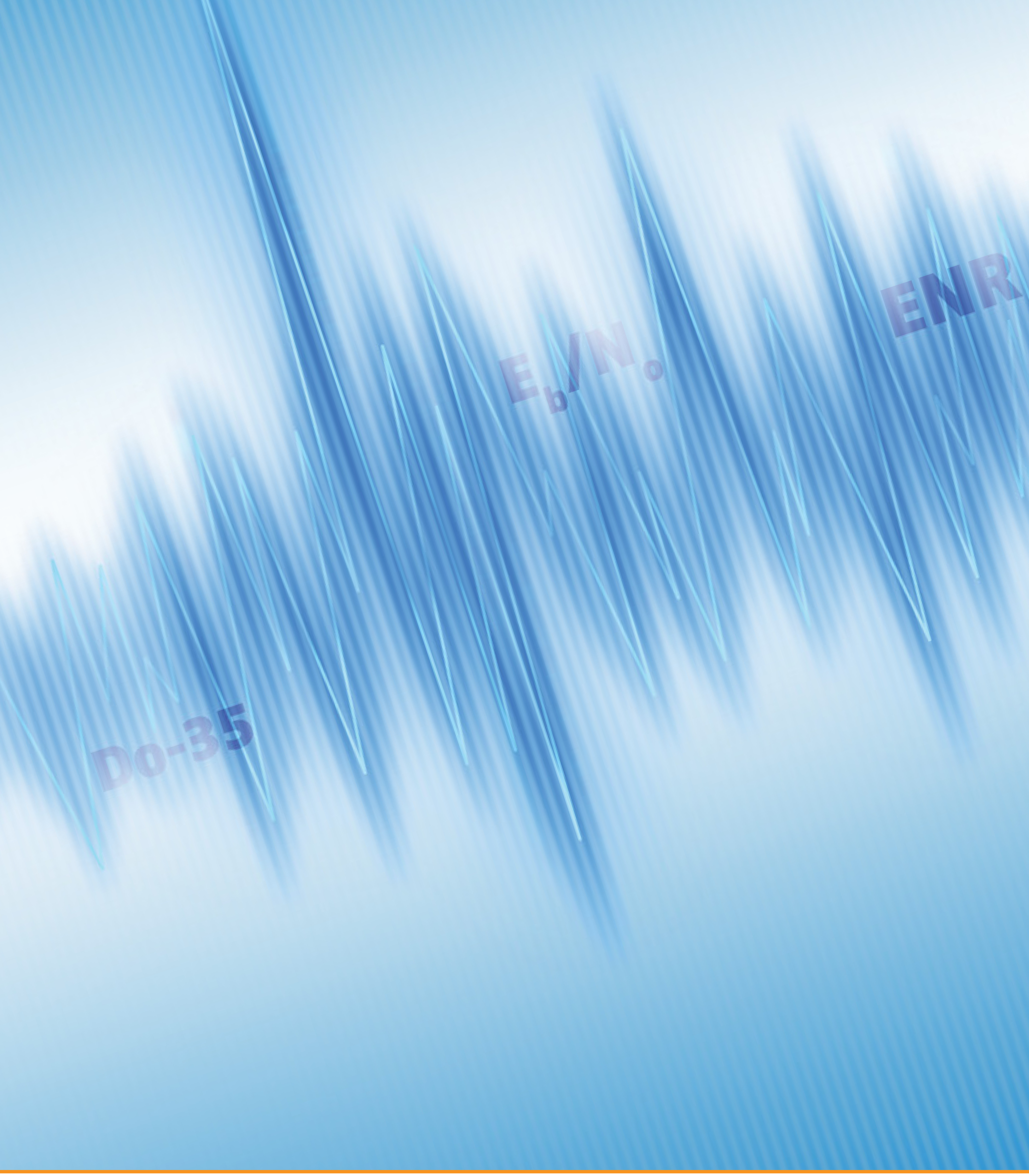


Noisecom

Noise by the Numbers

1 What can I do with noise?

The two primary applications for white noise are signal jamming/impairment and reference level comparison. Signal jamming/impairment is further divided into two categories: secure signal jamming and telecommunication signal impairment. Secure signal jamming is high power broadband noise for the purpose of disrupting communication signals. Telecommunication signal impairment is a gradual change in Signal to Noise Ratio (SNR) to measure the robustness of the receiving network. This type of impairment is for coaxial and wireless applications. Digital Engineers working with PCIexpress, SATA, or 10GigE refer to these coaxial impairments as "jitter" or Rj. Wireless RF Engineers working with WiMax, WCDMA, or LTE consider it E_b/N_o or C/N. In either case the noise requirements are the same.

For reference level comparison, a calibrated noise source with a flat band across a large spectrum is compared to the noise floor of the instrument under test. This is typical for spectrum analyzers, but any device that requires an absolute noise floor for operation can use this method. This same noise signal is used by design engineers to calculate noise figure (NF) and amplifier gain. This is less expensive than using a precision sweeping sine generator for these measurements.

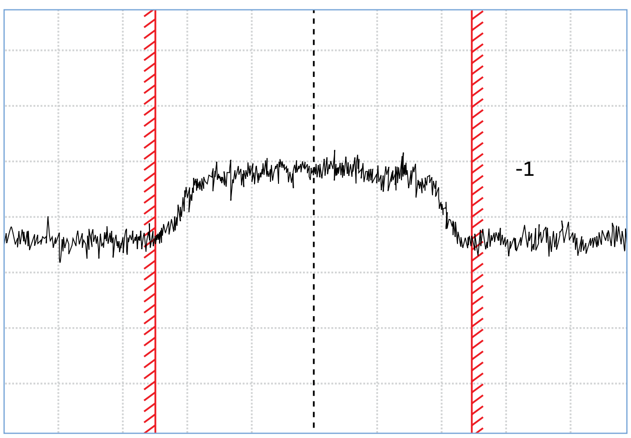


Fig 1

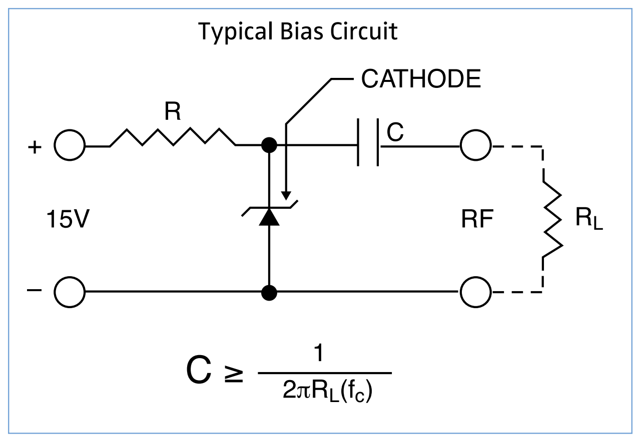


Fig 2

2 How is noise created?

The average temperature of the earth's surface is approximately 62.3°F, 16.8°C, or 290°K and provides the energy to the surrounding matter that generates natural background noise. The thermal noise generated due to this temperature equals -174 dBm/Hz or a few nanovolts. While these power levels are of concern to astronomers and astrophysicists, most engineers require higher power levels for their purposes. The simplest source for higher power analog white Gaussian noise is a reversed biased diode (fig 2). Due to the quantum nature of electron-hole pairing on a semiconductor substrate, a truly random noise signal is generated 25 to 30 dB above the -174 dBm thermal noise floor. These power levels are now measurable on modern RF and Microwave equipment, like a spectrum analyzer or Vector Network Analyzer (VNA). The power must be increased by an additional 40 to 50 dB for an oscilloscope or Bit Error Rate Testing (BERT).

3 What types of noise do we provide?

We manufacture devices that output analog white Gaussian and Digital pseudo-random noise. A simple circuit containing a reverse biased diode (fig 2) will create a white noise signal with a flat frequency response curve over a broad band (fig 1) and a Gaussian amplitude distribution in the time domain (fig 3) up to 105 GHz. The key features of this noise are its true random nature and very broad bandwidth (BW).

Digital pseudo-random noise is available up to a maximum BW of 70 MHz and a dynamic range of 50 dB. The base-band noise signal can be up-converted for microwave applications. The digital noise waveform can be configured in specific profiles, allowing custom waveforms for many applications.

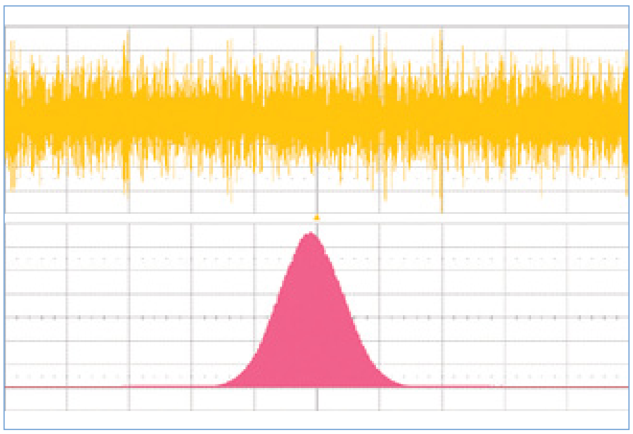


Fig 3

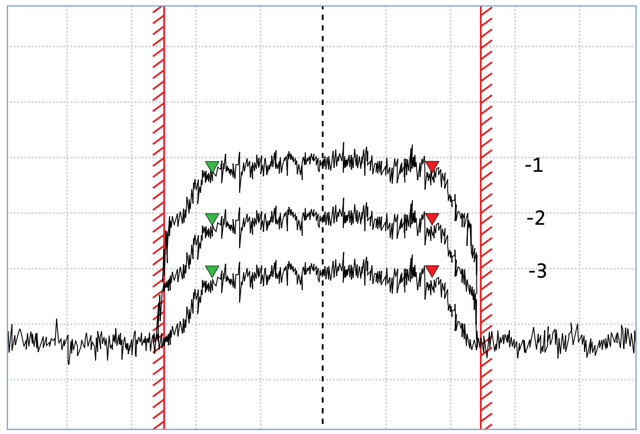


Fig 4

4 How do I control noise?

Most noise sources are designed with a fixed output power level and can be controlled with either a precision attenuator or a filter. Precision attenuators are rated for BW, maximum power input and flatness. They are typically specified in dBm and step sizes are multiples of 10, 100, 10, 1, and 0.1.

Precision attenuators are monotonic in nature to provide a consistent noise spectrum through all power levels (fig 4). Filters can be switched into the signal path to create specific noise profiles and are usually single or double pole, low pass, high pass, band pass or band reject.

5 What Products are available from Noisecom?

Noisecom components include diodes, calibrated & amplified modules, built-in-test PC board components (through-hole, or surface mount). The diodes are available in several package types for different circuit board requirements and range in frequency from audio to microwave bands up to 105 GHz (fig 5). Calibrated noise modules come in several different packages and range in BW from a few KHz to 105 GHz. They have low power, a flat frequency band and either a coaxial or waveguide connector. They require either a two wire or BNC voltage input (fig 6). The NC1000A amplified modules have three standard form factors but can be custom designed for a specific application. They also require a two wire power input and have coaxial output connectors (SMA typical). They have power outputs up to +13 dBm and frequency ranges to 10 GHz.

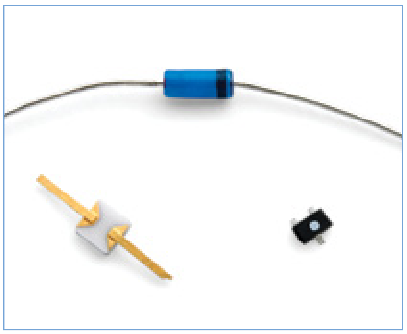


Fig 5

Fig 6

Fig 7

Fig 8

Fig 9

Fig 10

Noisecom programmable instruments include our general purpose, precision SNR and digital noise generators. The NC6000A manual series of instruments are designed for direct connection to a DUT and simple operation. They have output power to +30 dBm, BW's to 40 GHz and optional connectors, filters and combiners (fig 7). The Noisecom 7000A remote control series consists of the UFX, PNG and J series. They have a touch screen GUI interface and standard Ethernet remote control capability. There are several options including multiple sources, multiple filter paths, signal input combiners and external outputs. Power outputs, up to +30 dBm and BW's to 40 GHz are available (fig 8). The UFX EbNo is a precision signal to noise generator with an internal power meter. The incoming user signal is measured and combined with the appropriate amount of noise for a selected SNR value. The output SNR can be adjusted from +5 dBm to -55 dBm, with a 0.2 dB (RSS) accuracy and up to 40 GHz BW (fig 9). The digital noise generators can produce specific profiles from a spreadsheet-like GUI or in a MatLab program. The BW is from 10 KHz to 70 Mhz.

6 What do I need to know before purchasing a noise solution?

Choose an application

Noise signal requirements:

What is your required noise frequency band?

(KHz, MHz, GHz)

How much power is required?

(dBm, dBmV, mV)

What form factor?

Component: Diode

Module: Calibrated or Amplified

Instrument: Manual or Programmable

7 Helpful formulas for specific noise parameters

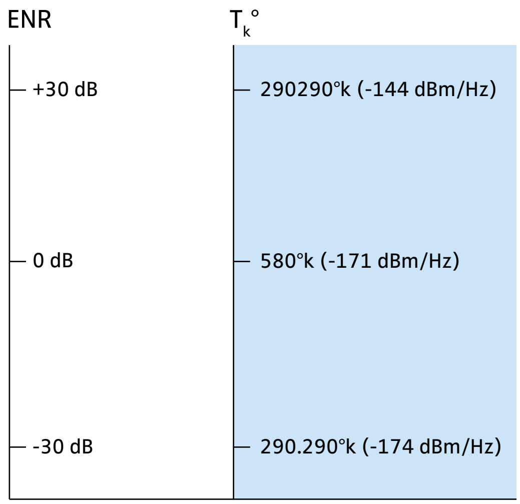
What is total power in dBm if my noise bandwidth is 1 MHz to 2 GHz with a desired power spectral density PSD = -90 dBm / Hz?

- dBm = dBm / Hz + 10log(noise BW)
- total power (dBm) = -90 dBm / Hz + 10log(2e9 Hz)
- total power (dBm) = -90 + 93 = 3 dBm

What is the ENR (Excess Noise Ratio) for a module having -130 dBm / Hz?

- PSD (dBm/Hz) = - 174 dBm / Hz + ENR
- ENR (dB) = 174 dBm / Hz – PSD (dBm / Hz)
- ENR (dB) = 174 dBm / Hz – 130 dBm / Hz
- ENR (dB) = 44 dB

Noise Power Conversion Table



Calculating Noise Figure requires a knowledge of noise temperature, excess noise ratio (ENR) and noise power relative to 1 mW. The Noise Power Conversion Table is a graphic illustration of these relationships and is supported by mathematical definitions with example calculations.

Noise Power

The formula: N_p = kTB, equates noise power in watts to temperature in Kelvin(°K), an absolute non-negative reference scale.

N_p = noise power in watts based on system BW and Boltzmann constant

k = Boltzman constant (normalizing the power to an atomic level)

B = noise BW; normalizing to 1 Hz allows the use of power spectral density (PSD) in dBm/Hz for simple calculations

T = temperature in °K

Example calculation at 290°K or ≈ 62°F (17°C)

N_p = (1.38065e-23)*(290°K)*(1 Hz)

N_p = 4.004e^{-21} W/Hz

Note: 62°F, 17°C 290°K is the average temperature of the surface of the Earth and is chosen to model an external antennae temperature. Using 290°K as a reference equates to a noise power value of 4.00e^{-21}, and is easily calculated using a slide ruler.

Normalizing the noise power to 1 mW in a 50 Ω system for convenience

The following calculation for a noise power value is normalized to 1 mW in a 50Ω system for convenience when using T&M equipment. It is displayed using a logarithmic scale.

N_p (dBm/Hz) =
10_{log}(4.004e^{-21}/.001W) = -174 dBm/Hz

This value is equivalent to 50Ω resistor power output at 62°F (17°C), and is commonly used as a noise figure measurement reference point.

Deriving an Excess Noise Ratio (ENR) scale

ENR is a logarithmic scale that displays the ratio of hot (T_h), and cold (T_c) noise temperature values for calculating noise figure. The scale range is arbitrary and based upon the selection of the lowest hot (T_h) temperature chosen for the calculation.

ENR = (T_h/T_c - 1); where T_h > T_c (290°K);
T_h = temperature hot; T_c = temperature cold

By selecting a temperature value close to 290°K, a large ENR log scale can be calculated.

The following example references a T_h of 290.290°K. Selecting this value creates a logarithmic scale from -30 dB to +30 dB ENR.

Example calculations

T_k of 290.290°K
ENR = (290.290/290 - 1) = 0.001;
ENR dB = 10_{log}(.001) = - 30 dB

T_k of 580°K
ENR = (580/290 - 1) = 1; ENR dB = 10_{log}(1) = 0

T_k of 290290.00°K
ENR = (290290/290 -1) = 1000;
ENR dB = 10_{log}(1000) = +30

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