Noise Basics

What Is Noise?

All materials produce noise at a power level proportional to the physical temperature of the material. The noise is generated by random vibrations of conducting electrons and holes in the material. This noise is often referred to as thermal noise. Thermal noise is white and has a Gaussian amplitude distribution. (see Figure 1)

White Noise

Just as white light includes power at all colors, noise that has its power evenly distributed over all RF and microwave frequencies is called white. The power spectral density of white noise is constant over frequency, which implies that noise power is proportional to bandwidth. So if the measurement bandwidth is doubled, the detected noise power will double (an increase of 3 dB). Thermal white noise power is defined by: N=kTB, where N is the noise power available at the output of the thermal noise source, $k = 1.380 \times 10^{-23}$ J/K is Boltzmann's constant, T is the temperature, and B is the noise bandwidth.

Gaussian Noise

Thermal noise is also characterized by having a Gaussian amplitude distribution and is sometimes referred to as white Gaussian noise. Note that Gaussian noise does not have to be white and white noise does not have to be Gaussian. All of the products in this catalog produce white Gaussian noise.

Noise level can be expressed in units of dBm/Hz, $V/\sqrt{Hz}$ or Excess Noise Ratio (ENR). Table 1 contains formulas for conversion between these units.

TABLE 1

USEFUL WHITE NOISE CONVERSION FORMULAS	
dBm = dBm/Hz + 10log (BW)	
dBm = 20log (V_{RMS}) - 10log (R) + 30 dB	
dBm = 20log (V_{RMS}) + 13 dB	for R = 50 ohms
dBm/Hz = 20log ($\mu V_{RMS}/\sqrt{Hz}$) -10log (R) - 90 dB	
dBm/Hz = -174 dBm/Hz + ENR	for ENR > 17 dB

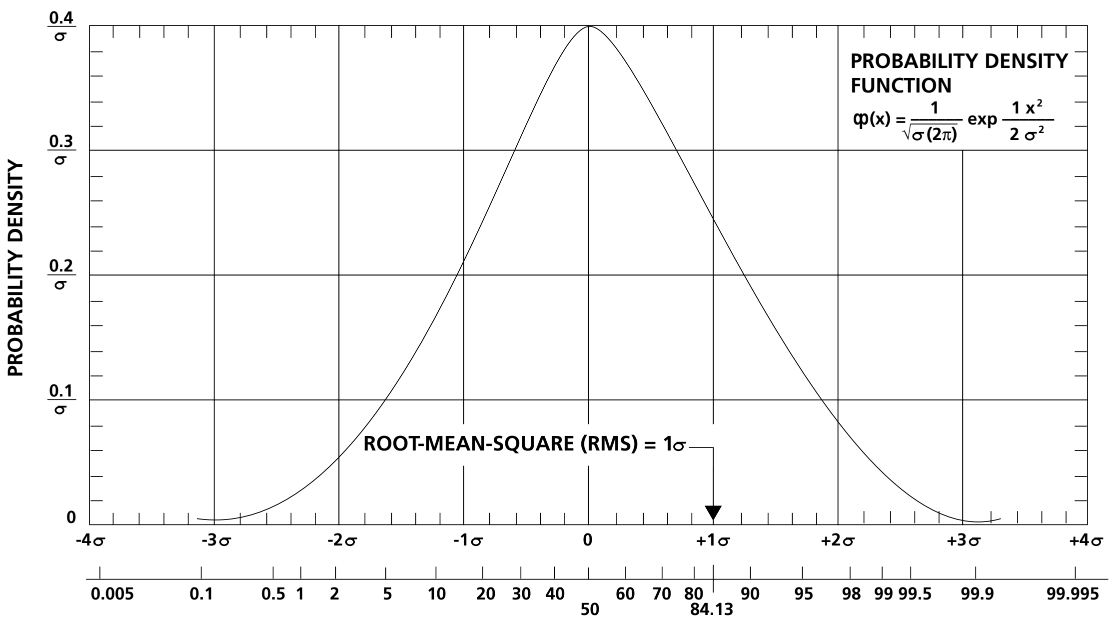

Figure 1. Gaussian Voltage Distribution

Built-in Test Applications

A noise source that produces white noise is essentially an inexpensive broadband signal generator with an extremely flat (constant) power density output versus frequency. Noise sources are almost insensitive to temperature and supply voltage variations. Noise sources are therefore used for Built-in Testing (BIT), Fault Isolation Testing (FIT), and calibration in communication and radar warning systems to ensure the reliability and performance of the link.

Receiver gain, noise figure, phase tracking, and bandwidth can be measured using built-in noise sources. They may also be used to align the gain and phase balance of I and Q or multichannel receivers and randomizing of the quantization errors of high-speed A/D converters. Using a noise source is faster than most other signal sources because it generates all frequencies simultaneously.

Noise figure is an important measure of the additive noise produced by the receiving system. It is usually desirable to maintain the lowest possible noise figure so that the transmitter's Effective Isotropic Radiated Power (EIRP) can be minimized. It is generally less expensive to lower the noise figure than it is to increase the transmitter power.

Noise figure is defined as:

$$NF \text{ (in dB)} = ENR - 10\log(Y-1)$$

where: $Y = P_{on}/P_{off}$.

P_{on} and P_{off} are the output in watts from the DUT while the noise source is biased on and off respectively. For ambient temperatures much different than 290 K, a correction factor (10logA) should be added to the right-hand side of the above equation with "A" defined as:

$$A = 1 - [(T_C/290)-1] \times [Y/10^{(ENR/10)}]$$

The correction is only significant when measuring low noise figures and it can, in most cases, be disregarded in order to simplify the measurements. Corrections for second-stage effects (the preamplifier plus analyzer noise figure) can be made using the following equation:

$$F_{actual} = F_{measured} - [(F_1-1)/G_a] - [(F_2-1)/(G_a \times G_1)]$$

$$NF \text{ (in dB)} = 10\log(F_{actual})$$

where:

$$G_a = \frac{P_{oON} - P_{oOFF}}{k \times B \times (T_h - T_c)}$$

F_{actual} = the actual noise factor of the DUT (not in dB)

$F_{measured}$ = the measured noise factor (not in dB)

F_1 = the noise factor of the next stage (not in dB)

G_1 = the available gain of the next stage (not in dB)

G_a = the available gain of the DUT (not in dB)

B = noise bandwidth of the measurement system

$T_h = 290 \times [1+10^{(ENR/10)}]$ in degrees K

T_c = room temperature in degrees K

The second stage correction needs to be calculated only when the output noise of one stage is within 16 dB of that of the next stage. That is:

$$G_a \text{ (dB)} + NF_{measured} \text{ (dB)} - 16 < NF_{next\text{-}stage} \text{ (dB)}$$

Impedance mismatch between the DUT, the noise source, and the preamplifier leads to measurement ripple, so the measurement accuracy is improved when using a well-matched Noise Com noise source.