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Some Notes on Noise

The ATIS Telecom Glossary 2000 at the Alliance for Telecommunications Industry Solutions (www.atis.org/tg2k/) provides several definitions for *noise*:

noise: 1. An undesired disturbance within the frequency band of interest; the summation of unwanted or disturbing energy introduced into a communications system from man-made and natural sources. 2. A disturbance that affects a signal and that may distort the information carried by the signal. 3. Random variations of one or more characteristics of any entity such as voltage, current, or data. 4. A random signal of known statistical properties of amplitude, distribution, and spectral density. 5. Loosely, any disturbance tending to interfere with the normal operation of a device or system.

General Definitions

Definitions (1), (2) and (5) are general and don't require any further explanation. The only critique that might be offered is that these definitions could also be construed as including interference. Technically, noise is random, while interference is not, although interference can be complex and generally uncertain in its behavior, which might be interpreted as noise-like. Rather than argue the point, let's just consider the common language definition as being "noise plus interference."

Internally Generated Noise

This is definition (3) above, where the noise is introduced into the system via the signal path, whether directly or indirectly via other circuit elements. There are many possible noise contributors, with some of them listed below (including some that are not necessarily random):

- Noise figure of active devices
- Amplified noise when overcoming losses in passive devices
- Oscillator phase and amplitude noise
- Power supply noise
- Quantization noise in direct digital synthesizers, ADCs and DACs.
- Digital clock and data crosstalk
- Intermodulation products among these noise sources as well as with desired signals

Some of these internal noise sources can be hard to locate and eliminate. Some of the most difficult include power supply noise (may be intermittent and/or load-related), digital noise sources (edges generate many harmonics with significant amplitudes) and quantization noise (may be level-dependent or device-specific).

A final problem area is ground circuit noise, caused by the finite resistance of ground planes, p.c. board traces, cable shields and device packages. Voltage and current "bounce" can occur, shifting active device operating points, and unwanted noise can be coupled to or from other portions of the circuitry.

Statistically Defined Noise

Definition (4) covers noise test signals, which have known characteristics. The ATIS glossary explains some of the noise parameters in these noise sources:

Noise temperature—At a pair of terminals, the temperature of a passive system having an available noise power per unit bandwidth at a specified frequency equal to that of the actual terminals of a network. Note: The noise temperature of a simple resistor is the actual temperature of that resistor. The noise temperature of a diode may be many times the actual temperature of the diode.

Noise power—The power generated by a random electromagnetic process.

Noise power density—The noise power in a bandwidth of 1 Hz, i.e., the noise power per hertz at a point in a noise spectrum. Note: The noise-power density of the internal noise that is contributed by a receiving system to an incoming signal is expressed as the product of Boltzmann's constant, k, and the equivalent noise temperature, T_n. Thus, the noise-power density is often expressed simply as kT_n (or just kT).

Spectral density—For a specified bandwidth of radiation consisting of a continuous frequency spectrum, the total power in the specified bandwidth divided by the specified bandwidth. Note: Spectral density is usually expressed in watts per hertz.

Peak-to-average ratio (p/a r)—The ratio of the instantaneous peak value, i.e., maximum magnitude, of a signal parameter to its time-averaged value. Note: The peak-to-average ratio can be determined for many signal [*including noise signals*] parameters, such as voltage, current, power, frequency, and phase.

Noise is both a potential source of problems and a valuable test tool for all electronic equipment, especially at high frequencies. Hopefully, this short note serves as a useful reminder of noise basics. Also, the Web site noted includes useful definitions for many other telecommunications terms.