Measuring Noise

Time, Frequency, And Statistical Domain Analysis

Noise, like most random phenomena, is often hard to quantify. LeCroy oscilloscopes offer measurement and mathematical tools that aid in the characterization of noise in the time, frequency and statistical domains.

Figure 1 contains an example of how measurement parameters can be employed to characterize noise in the time domain. The waveform contains a 500 µs long time record of a band limited noise waveform. Random processes are best described by their statistical properties. In this analysis the key statistical measurement parameters are displayed under the waveform. These include the mean (average) value, standard deviation (sdev), peak to peak, and root mean square (rms) value. A more concise statement of the same information is available in the parameter, labeled data, this optional parameter reads all the sample values that make up the waveform. The parameter statistics of the data parameter show the average, minimum, maximum, and standard deviation of all the sample values. The parameter statistics shows that the noise signal has a near 0 mean value of 0.3 mV and a standard deviation of 16.3 mV. The low and high read-

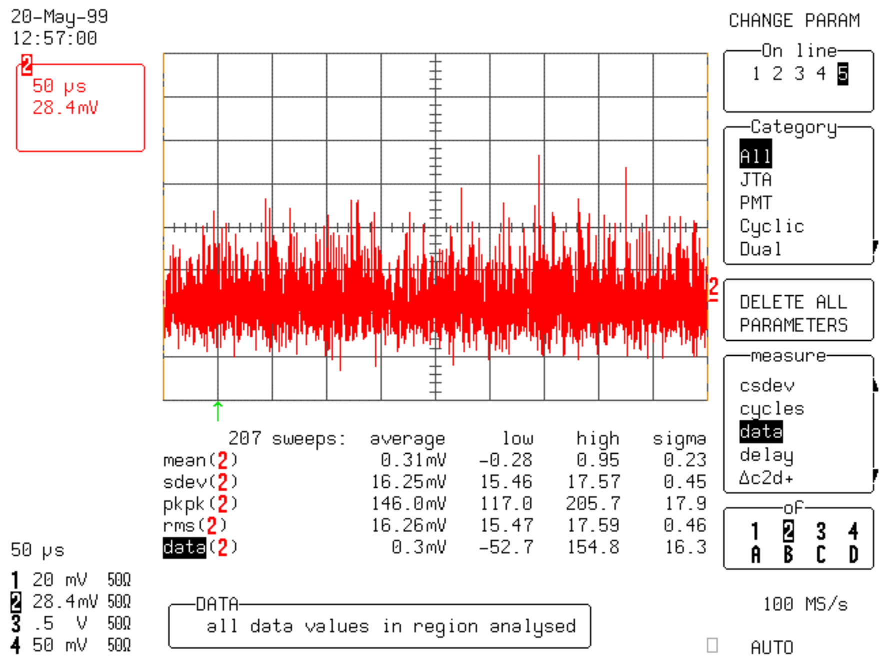

Figure 1-Characterizing a noise waveform in the time domain using parameter s

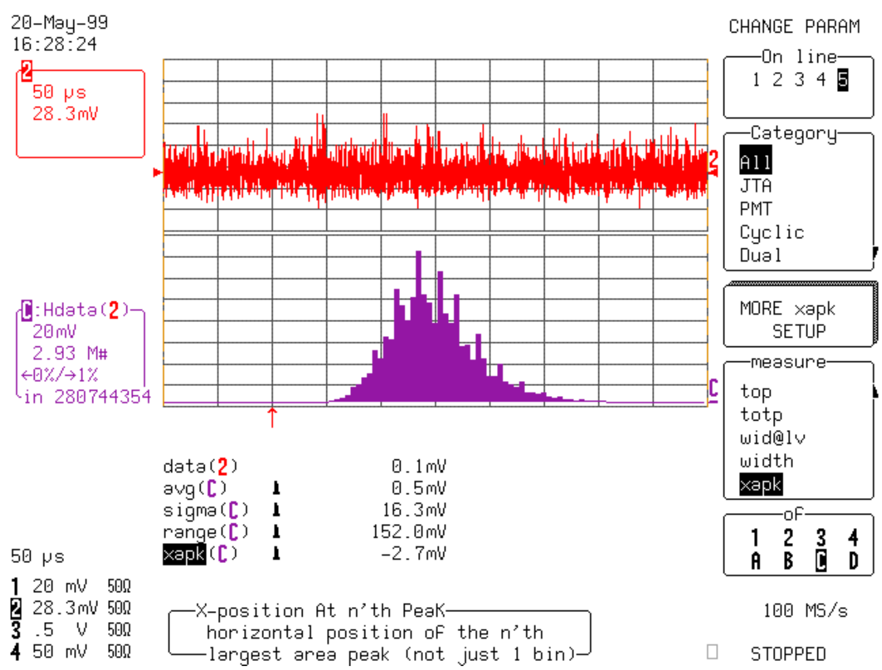

Figure 2 - Viewing the distribution of amplitude values using the histogram of the data parameter.

outs for the data parameter show the range of the sample values is 207.5 mV. The standard deviation, which is a measure of the dispersion of the sample values about the mean, is 16.25 mV. Physically, the standard deviation indicates that 67% of all sample values fall with ± 16.25 mV of the mean value. For a signal of zero mean value the standard deviation and rms value are equal. For signals with a non-zero mean the rms value is the quadrature sum of the mean and standard deviation.

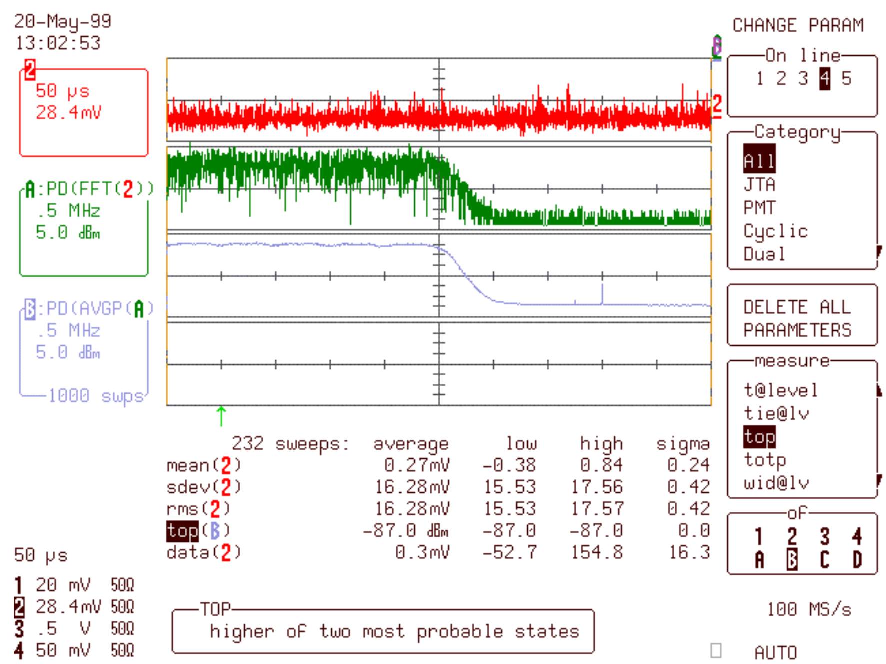

Figure 3 – Frequency domain analysis of the band limited noise waveform

Histograms, which show the probability distribution of parameter values, are available as an option in most LeCroy oscilloscopes. In figure 2 the histogram of the data parameter shows the distribution of amplitude values, plotting the number of values within fixed amplitude ranges or bins versus the amplitude in Volts. Histogram functions show the distribution of parameter values graphically. Analysis of the histogram is aided by the addition of 18 dedicated histogram parameters. In figure 2, the avg (mean), sigma, (standard deviation), range, and xapk (horizontal location of the peak) are used to read the key statistics from the histogram.

The analysis of noise in the frequency domain shows the distribution of power as a function of frequency. The frequency domain analysis, shown in figure 3, uses the power spectral density (PSD) format for displaying the fast Fourier transform (FFT) spectrum of the noise signal. PSD is normalized to the resolution bandwidth of the FFT analysis and presents the power per unit frequency. A vertical logarithmic scale is used to display the data in dBm (power referenced to a milliwatt). This display format is very useful for displaying noise because of the large dynamic range of these signals. Many users would like this reading in terms of W/Hz, V^2/Hz or V/√Hz. This can be accomplished using the following calculations:

$$\mathbf{PSD\ (dBm) = 10Log_{10}(P/.001)}$$

$$\mathbf{P = .001\ (10^{(PSD/10)})}$$

Where:

P is the power spectral density in Watts/Hz

and PSD is the reading in dBm from the scope

In our example, the average PSD level in the signals passband is -87dBm as read using the highlighted parameter (top). This represents a PSD level of 1.99E^{-12} Watts/Hz. To convert this to V^2/Hz, multiply this result by 50 Ohms, the input impedance for the measurement, which yields a value of 9.97E^{-11} V^2/Hz. The square root of the PSD in V^2/Hz is the voltage spectral density (VSD) in V/√Hz which is 9.98E^{-6} for this example.

This brief overview shows the range of tools available in LeCroy oscilloscopes to measure and analyze broadband noise signals.