BY BONNIE BAKER

RMS and peak-to-peak noise trade-off

Have you ever noticed that random noise has a predictable pattern? Nature duplicates this pattern in many ways—the gene pool, gambling, and even my driving "habits."

There are two ways to describe random analog noise. The first uses the standard deviation of a collection of converter digital-output samples. The data's standard deviation is equal to the rms (root-mean-square) value. The second uses the standard deviation and a constant crest factor to describe a converter's noise with a peak-to-peak value. Specifications with rms or peak-to-peak descriptors use statistical methods to arrive at a single number that describes the analog device's noise behavior or an ADC.

You can use rms to describe the system's noise power. "RMS" may appear with the specified units, or it may be implied. Usually, a noise specification includes the rms term. However, an SNR (signal-to-noise-ratio) specification doesn't. SNR uses only decibels for units.

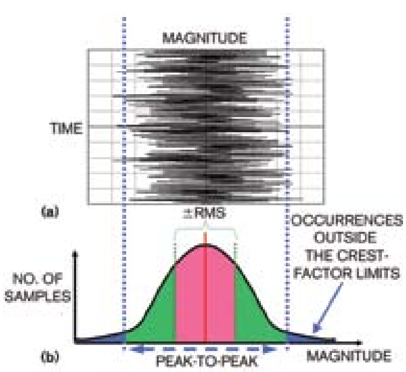

Figure 1 Organize data from a time plot (a) into a histogram to help determine rms and peak-to-peak limits (b).

When describing noise with an rms number, you are referring to the positive and negative range of the data's standard deviation. Although the noise's rms value from a converter is well-defined, you can predict the instantaneous position on the X axis only with the theory of probability. It is possible to create a histogram plot from the dc-output data (**Figure 1a**). By collecting more than 1000 data points, this histogram approaches the shape of a gaussian distribution, or bell-shaped curve. The two standard-deviation or rms lines capture a significant number of the noise occurrences. The probability that the noise from an analog device produces one output value that lands between the two rms lines is approximately 68%.

If you are putting output data from an ADC into a digital display, the peak-to-peak noise representation becomes important. Here, you determine how often and how many display digits can fluctuate, keeping in mind that fluctuating digits create user or customer insecurity. With a histogram plot, the rms limits exclude a considerable amount of data (**Figure 1b**). Multiplying the doubled standard deviation by a crest factor expands the percentage of occurrences underneath the curve. The crest factor for noise occurrences is a statistical estimate that determines the probability that an occurrence of a noisy event will remain within a defined boundary.

TABLE 1 DISPLAY FLUCTUATION

Crest factor	Occurrences inside limits (%)
2.6	99
3.3	99.9*
3.9	99.99
4.4	99.999**
4.9	99.9999

*Industry standard
**Stable to five display digits

Predicting the allowable fluctuation in your data display is relatively simple. After choosing a crest factor, multiply the value of two standard deviations by the selected crest factor. The industry standard is 3.3, which is appropriate for a three-digit display (**Table 1**). If you are keeping a five-digit display stable, use a crest factor of 4.4. The lower digits in your display will fluctuate 0.001% of the time.

Use rms or peak-to-peak figures to describe an analog device's input- or output-referred noise. Data sheets and labels may have noise specifications with units such as volts rms or volts peak-to-peak. You can quickly describe the noise power visible at the output of a converter with the data's standard deviation. Control the fluctuating digits in your display by defining peak-to-peak limits. EDN

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