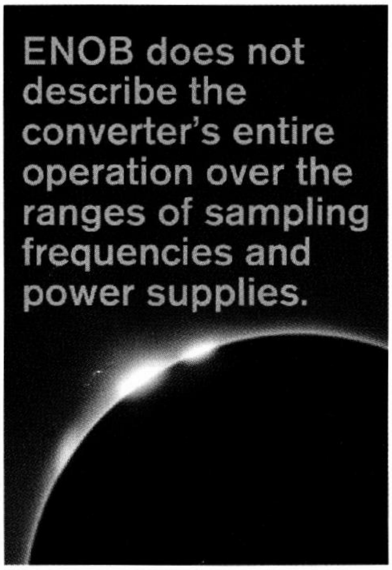
BY BONNIE BAKER

Does ENOB tell the whole story?

Near the beginning and end of a total solar eclipse, the thin slice of the sun that's visible appears broken up into beads of light. These lights are called Baily's Beads, after the British astronomer Francis Baily, who first noted the phenomenon in 1836 (**Reference 1**). At the moment they occur, you can't see the full picture; much more is going on. For a short time, you cannot see the sun. In same way, the ENOB (effective-number-of-bits) spec describes only part of an ADC: noise and distortion—rather than providing a precise or accurate description of an ADC.



Be aware of the ENOB pitfalls. It does not describe the converter's entire operation over the ranges of sampling frequencies and power supplies. Additionally, ENOB numbers exclude dc specifications, such as offset and gain error. Engineers use either an ac or a dc input signal to determine an ADC's ENOB. With an ac input signal, the digital output in an FFT (fast-Fourier-transform) plot shows the fundamental input signal along with the converter's noise and distortion. In the ac environment, you calculate ENOB from the converter's SINAD (signal, noise, and distortion), which is the same as THD+N (total harmonic distortion plus noise) or SNR+D (signal-to-noise ratio plus distortion). SINAD is the calculated combination of the SNR and the THD: $\text{SINAD (dB)} = -20\log_{10}\sqrt{10^{-\text{SNR}/10}+10^{+\text{THD}/10}}$.

THD combines all of the energy from the frequency bins in the FFT that are harmonic multiples of the input signal. To measure SNR, integrate all of the energy in the remaining bins and compare them with the fundamental signal level. Use the following calculation to derive ENOB from SINAD: $\text{ENOB} = (\text{SINAD} - 1.76)/6.02$. In this simple formula, 6.02 is a multiplier of a 20 $\log_{10}$ of the converter's bits, and 1.76 is the quantization noise.

Using a dc input signal to measure ENOB involves the use of a histogram of the digital output. It shows the average dc value of the input signal and the internal noise of the converter. The most common measurement for oversampling or delta-sigma ADCs is to calculate the standard deviation, which is equal to the rms noise. If you apply a dc signal to a delta-sigma ADC and record a large number of samples, you can then derive the standard deviation for these codes. The formula for ENOB is: $N - \log2(\sigma)$, where σ is the standard deviation of data and N is the number of converter bits. With delta-sigma converters, ENOB, or the effective resolution, changes with adjustments to the oversampling or decimation ratio. Generally, the effective resolution of delta-sigma ADCs decreases with increasing data output rates.

ENOB for ac measurements uses a SINAD calculation, which is a combination of the SNR and THD. The ac measurement is dynamic, requiring a sine-wave input. You use this calculation with converter architectures, such as SAR (successive-approximation-register), pipeline, flash, and high-speed delta-sigma converters. ENOB for dc measurements uses rms, or the standard deviation of the noise calculation with a dc input signal. Slower delta-sigma converters use this type of measurement.

In both cases, remember that ENOB is a simple although somewhat superficial figure of merit, but it still has its place. So, when you use ENOB to make decisions, take time to look beyond the Baily's Beads in your eclipse. In some cases, the ENOB value may be misleading, when you may have a perfectly usable converter for your application. EDN

REFERENCE

1 "Baily's beads," http://en.wikipedia.org/wiki/Baily's_beads.

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