Keywords: Effective Number Bits, Calculator, ENOB, Data Converter, SINAD, Resolution, Signal, Oversample Rates, DNL, Clock, Jitter, Analog Noise, THD, ADC, DAC, Analog Design, Digital Accuracy, HP50g, INL, Total Harmonic Distortion

TUTORIAL 5061

Effective Number of Bits Calculator Tutorial

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Abstract: The Effective Number of Bits Calculator (ENOB) aids in the design and analysis of data converter application circuits. It calculates ENOB, SINAD, resolution, signal bandwidth, oversample rates, DNL, clock jitter, analog noise, and THD. The calculator can be used with a HP® 50g calculator or a free PC emulator.

Introduction

Steve Edwards, an experienced analog design engineer, has written several calculators to automate repetitive tasks. These tools are being shared to help other analog design engineers who select, specify, and characterize analog circuits. We will summarize the functionality of one such tool, the Effective Number of Bits Calculator.

Effective Number of Bits Calculator

Effective Number of Bits (ENOB) Calculator, a program for the HP 50g calculator, aids in the design and analysis of analog-to-digital converter (ADC) and digital-to-analog converter (DAC) application circuits. ENOB calculates the effective number of bits of an ideal data converter. Each parameter can be entered or found. ENOB can also run on a PC using the free program HPUserEdit 5.4, found at www.hpcalc.org. A link to the ENOB calculator program can be found at Steve's Analog Design Calculators page.
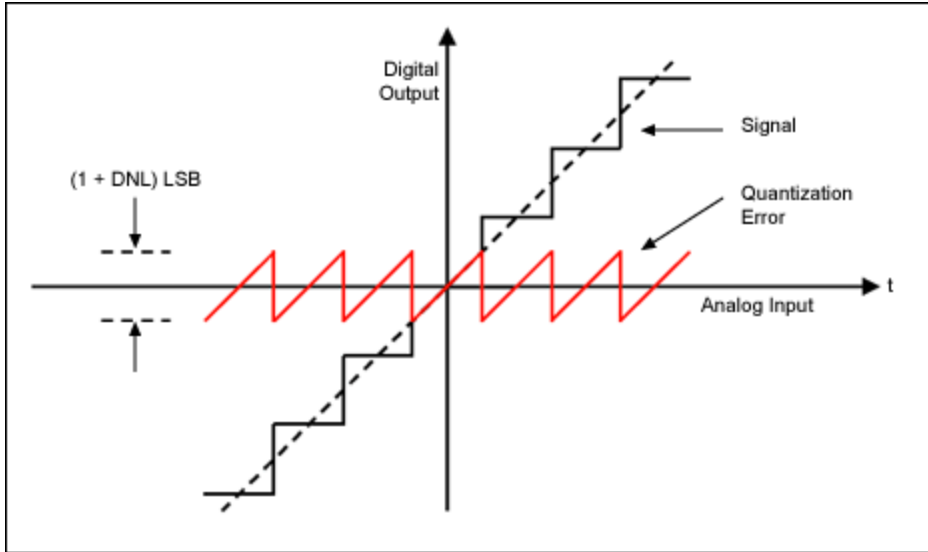
Figure 1. Quantization noise or error is the center saw-tooth waveform; it is the residual left when the signal dotted line is quantized into digital steps.

Nine parameters can be entered or found:
1. ENOB, in bits
2. Signal-to-noise and distortion (SINAD), in dB
3. Resolution (Res), in bits
4. Bandwidth (BW), in % of the Nyquist frequency
5. Oversampling ratio (OSR), as a multiple of the sample frequency
6. Average differential nonlinearity (DNL), in LSB
7. Clock Jitter (Tj), in PPM_{rms}
8. Analog referred noise (Vn), in LSB_{rms}
9. Total harmonic distortion (THD), in % or dB

The ENOB Calculator can find any parameter as a function of the others, making it useful for both design and analysis of ADC and DAC applications circuits. It also can plot any two parameters with respect to each other. These parameters appear in the calculator as shown below:
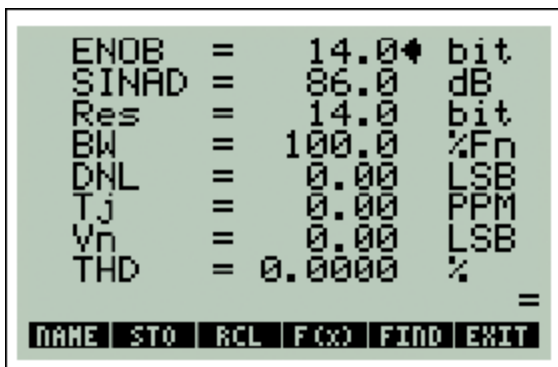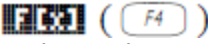

Figure 2. The Effective Number of Bits Calculator display.

The User's Guide, available as part of the ENOB program package, details ENOB and how it is calculated using the four sources of noise and distortion in a data converter: quantization noise (Res,

BW, or OSR, and DNL), clock jitter noise (Tj), analog referred noise (Vn), and total harmonic distortion (THD).

The first practical example uses the ENOB Calculator to select an appropriate ADC (Res, DNL, THD, and Tj), given a system requirement of 80dB SINAD, and the large signal bandwidth of 0 to 100kHz. The example takes us from entering the data, through solving and finding a converter, and provides quick ways to explore alternative accuracy parts to reduce quantization noise.

The second example explains how the ENOB Calculator can plot any two parameters with respect to each other. It demonstrates how to use the ($F4$) function to show the trade-off between clock jitter and input noise, so that SINAD remains unchanged.

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