Application Brief

Trade-offs of Oversampling Ratios in Modulators

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Introduction

Delta-sigma modulators allow adjusting of the oversampling ratio (OSR) to set the tradeoff between signal fidelity (resolution), latency and bandwidth of the signal chain.

A high OSR reduces the noise level, leading to a higher signal to noise ratio (SNR) and a higher effective number of bits (ENOB). However, a high OSR means more bitstream data, resulting in higher latency, lower effective sampling frequency and therefore lower bandwidth.

A test setup with the TMS320F28P650 C2000™ microcontroller (MCU) was built to investigate the impact of different OSRs on SNR, ENOB, bandwidth and latency of an AMC0336 delta-sigma modulator. The input is shorted with a 50Ω termination resistor. Shorting the input verifies a defined, low-noise voltage level in the middle of the input voltage range at the modulator input. The TMS320F28P650 microcontroller engages the sigma-delta filter module (SDFM) and generates the clock signal of 10MHz. The SDFM module uses sinc3 filter with adjustable OSR. The MCU stores 8192 SDFM output samples to the internal memory. The test setup obtains data for various OSRs 32, 64, 128 and 256. A MATLAB™ script processes the data buffer and displays histograms. Histograms showcase noise reduction as the OSR increases.

Table 1. Effective Sampling Rate and Bandwidth at Different OSRs with Sinc3 Filter

Oversampling Ratio (OSR)	Resulting Effective Sampling Rate (in kHz)	Resulting Effective Nyquist Bandwidth (in kHz)	Resulting Latency (in µs)
32	312.500	156.250	9.6
64	156.250	78.125	19.2
128	78.125	39.063	38.4
256	39.063	19.532	76.8

As a result, higher OSRs limit the signal chain bandwidth significantly and therefore usability in applications that require high-frequency signal processing. Generally, designers must select the OSR appropriate for the application requirements.

Figure 1 shows histograms of the AMC0336 modulator for different OSR settings with the input shorted as described before.

Table 2 is the summary of measurement results.

Assuming the noise follows a Gauss distribution, the root-mean-square noise (RMSnoise) in least significant bits (LSB) equals the standard deviation of the data set. Equation 1 calculates the RMSnoise in volts:

$$\mathrm{RMSnoise} = \sigma \times \mathrm{LSB} \tag{1}$$

Where LSB is the voltage the least significant bit represents.

Equation 2 calculates SNR in decibels:

$$\mathrm{SNR} = 20 \times \log\left(\frac{\mathrm{V_{IN}}}{\mathrm{RMSnoise}}\right) dB \tag{2}$$

Where V_{IN} is the linear input voltage range of the AMC0336Q (±1V).

Equation 3 calculates ENOB in bits:

$$\mathrm{ENOB} = \frac{\mathrm{SNR} - 1.76}{6.02} \tag{3}$$

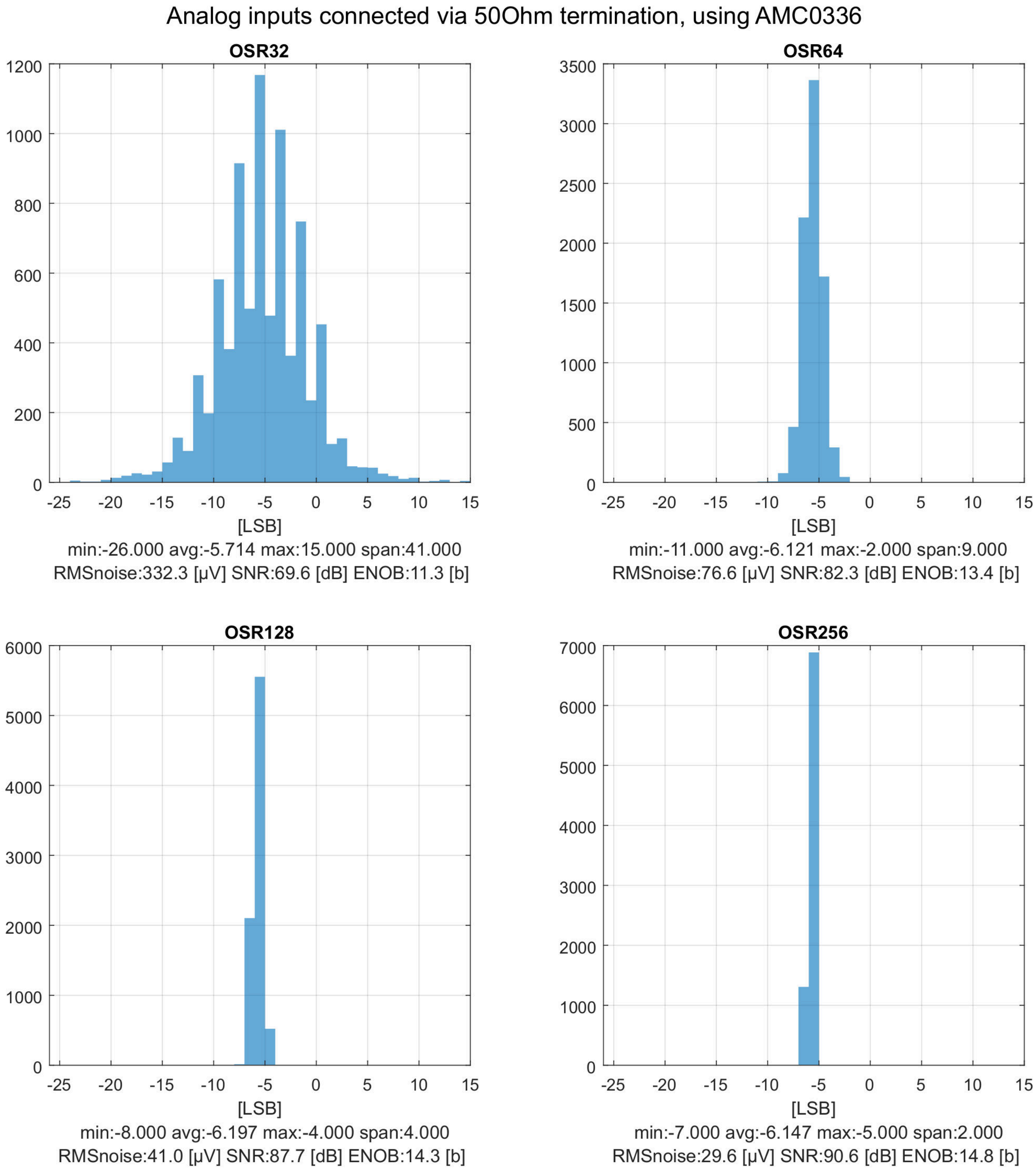

Figure 1. Noise for 50Ω-Terminated Inputs of AMC0336Q at Different OSRs

Table 2. Measurement Results for Different OSRs with Sinc3 Filter

Oversampling Ratio (OSR)	SNR (in dB)	ENOB (in bit)	Nyquist Bandwidth (in kHz)	Latency (in µs)
32	69.6	11.3	156.250	9.6
64	82.3	13.4	78.125	19.2
128	87.7	14.3	39.063	38.4
256	90.6	14.8	19.532	76.8

In conclusion, higher OSRs are best used in applications that require high resolution outputs when latency and bandwidth do not play a role. Lower OSRs are best used in applications that require measurements with low latency and high bandwidth.

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