A Survey on SNR Limit for different order of Quantizer bit of Sigma Delta Modulator

Aparna Alone[1], Sonika[2]

Assistant Professor, Dept of Electronics & Telecomm Engg, Chhatrapati Shivaji Institute of Technology, Durg, C.G,India[1]

Professor, Dept of Electronics & Telecomm Engg, Chhatrapati Shivaji Institute of Technology, Durg, C.G, India[2]

ABSTRACT: In this Survey paper, the performance of sigma delta modulator is measured and observed in the terms of signal to Noise ratio, for different Oversampling ratios for different order of Quantizer bit. Also the sigma delta modulator is analysed for different quantization level for the different parameters like Signal to noise distortion ratio, quantization noise rejection capability.

Keywords: Sigma delta modulator, Signal to Noise Ratio ,Dynamic Range , Quantization Noise, Effective Number of Bits (ENOB)

I. INTRODUCTION

Modern society relies on signal processing. It is applied in communication equipment, medical devices, automated production facilities, computers, weapons, navigation equipment, tools etc.[1] The first step performed by a signal-processing system is to convert a considered signal into a form that can be processed by an electronic circuit. Sometimes a dedicated electro-mechanical system (called a sensor) will be required to sense the signal and convert it into a voltage, charge or current signal, and sometimes the signal is readily available in one of these forms. The signal processing that needs to be performed can vary from very simple operations (e.g. amplification) to extremely complex ones involving computation of several parameters, such as standard deviation, spectral composition, correlation coefficients, etc.[2] A fundamental property of analog electric signal processing is that each operation will be associated with a degradation of the signal-to-noise ratio (SNR). Hence, if substantial analog signal processing (ASP) is performed, stochastic artifacts (noise) will accumulate, and the resulting signal may not represent the desired signal with the required significance. This work focuses almost exclusively on delta-sigma modulation as chosen technique for A/D and D/A conversion. Based on the combination of oversampling and quantization error shaping techniques,[1] ΔΣMs achieve a high degree of insensitivity to analog circuit imperfections, thus making them a good choice (the best one in many cases) to realize embedded analog-to-digital interfaces in modern systems-on-chip (SoCs) integrated in nanometer CMOS[3]. Inspite of all the above mentioned advantages , this modulator have some practical issues and trade off related to power consumption, silicon area etc, which must be taken into account for optimized performance. The paper is organized as follows: Section II gives the overview of different blocks of SDM, Section III provides the realization of first order SDM, Section IV provides the SNR Limit for different order and different OSR, Section V provides the Conclusion on the basis of comparison.

II. BUILDING BLOCK OF SIGMA DELTA MODULATOR

A. Over Sampling

In signal processing, over sampling is the process of sampling a signal with a sampling frequency significantly higher than twice the bandwidth or highest frequency of the signal being sampled. Oversampling helps avoid aliasing, improves resolution and reduces noise. Oversampling is the process of increasing the sampling frequency by generating new digital samples based on the values of known samples.

Over sampling Factor: An oversampled signal is said to be oversampled by a factor of β, defined as

$$\beta = f_s / 2B \qquad (1)$$

$$\text{or} \quad f_s = 2 \beta B \qquad (2)$$

where:

- f_s is the sampling frequency

- *B* is the bandwidth or highest frequency of the signal; the Nyquist rate is 2*B*.

B. Quantization and Quantization Error.

Discretization in amplitude domain of any continuous signal is said to be Quantization. This continuous-to-discrete transformation in amplitude generates an error, commonly referred to as *quantization error*. The quantization itself introduces a fundamental limitation on the performance of an ideal ADC. It degrades the quality of the input signal whose continuous-value levels are mapped onto a finite set of discrete levels
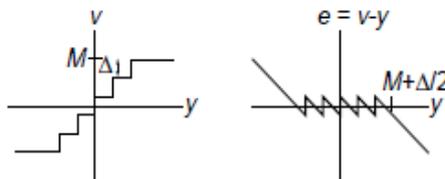

Fig. 1. Quantization process. (a) Ideal characteristic. (b) Quantization error.

Fig. 1(a) shows the transfer characteristic of an ideal quantizer, where e stands for the quantization error. This error is a nonlinear function of the input signal, as shown in Fig. 1(b). Note that, if x is confined to the full-scale input range [−X_{FS} /2, X_{FS} /2], the quantization error is bounded by [−Δ/2, Δ/2], with being the quantization step, defined as the separation between adjacent output levels in the quantizer. As long as the quantizer does not overload $|e| \leq \Delta/2$. The number of quantization levels is large, then the quantization noise is white with a power $\sigma e^2 = \Delta^2/12 = 1/3$ for Δ=2.

C. Noise Shaping

The accuracy of Oversampling ADC / DAC can be increased by applying methods to reduce quantization noise. A method in which the inband noise is pushed in the frequency out of interest. Such a phenomena is called Noise Shaping ,where the quantization error conceptually generated by the difference of the input signal, , from an analog version of the quantizer output, —is *shaped* by a filter with a transfer function, usually called noise transfer function (NTF), which can be either of high-pass type or band-stop type. In case low pass oversampled signal ,the low frequency inband component the removal of quantization Noise can be done through Differentiator in z domain transfer function is given by :

$$NTF (z) = (1 - z^{-1})^L \quad - \quad (3)$$

Where L denotes the order of filter.[3]

D. Collectively: Sigma Delta Modulator

A Sigma Delta Modulator contains feedback loop, containing a loop filter which is in the forward path of the loop. Replacing as before the quantizer by its linear model, the linear sampled-data system of Fig. results.
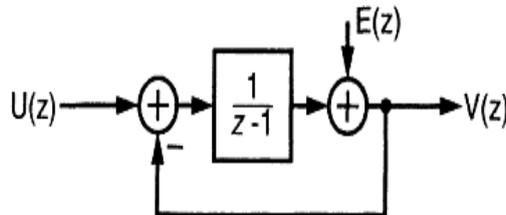

Fig 2: Sigma Delta Modulator: Linear model in z – domain (used as an ADC)

Analysis gives

$$v(n) = u(n-1) + e(n) - e(n-1).$$

Thus, the digital output contains a delayed, but otherwise unchanged replica of the analog input signal *u,* and a differentiated version of the quantization error *e.* the differentiation of the error *e* suppresses it at frequencies which are small compared to the sampling rate f_S. In general, if the loop filter has a high gain in the signal band, the in-band quantization "noise" is strongly attenuated, a process now commonly called *noise shaping*.

III. REALIZATION

First order Sigma Delta Modulator is realized using MATLAB [4],by providing the input parameters as OSR = 32, Quantization Level = 8 by the usage of specifically DelSig Toolbox. Figure 3 (a) shows the magnitude response of the NTF, Figure 3 (b) shows the Time domain analysis of SDM, Figure 3 (c) shows the Frequency domain analysis of SDM
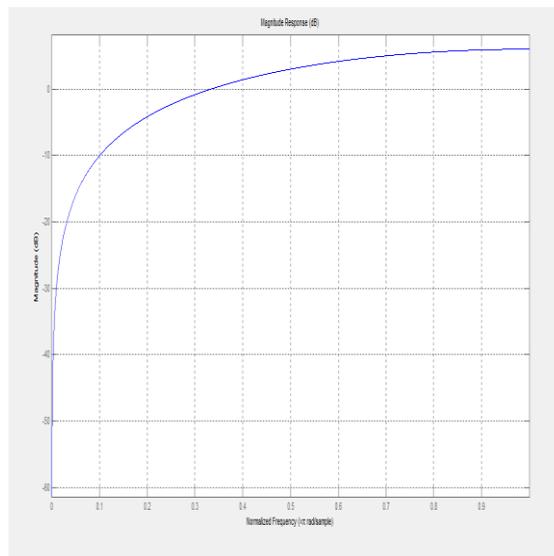

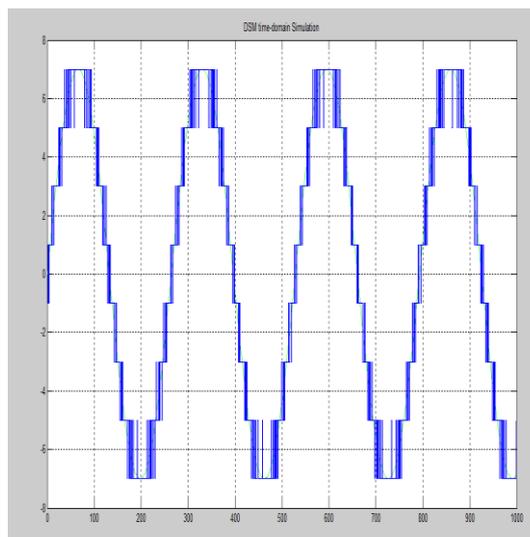Fig 3 (a) Magnitude response of the NTF
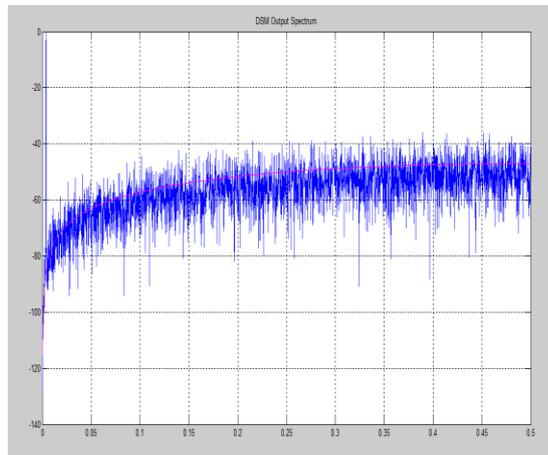
Fig 3 (b) Time domain analysis of SDM

Fig 3 (c) Frequency domain analysis of SDM

IV. SNR LIMIT AND COMPARISON OF QUANTIZATION LEVELS

For different order of filters ranging from n = 1 to n= 8with varying the OSR range from 16 to 1024, the graph is plotted to signify the SNR Limit. Figure 4 shows the variation of SNR with respect to varying OSR and order for binary low pass Sigma Delta Modulator.
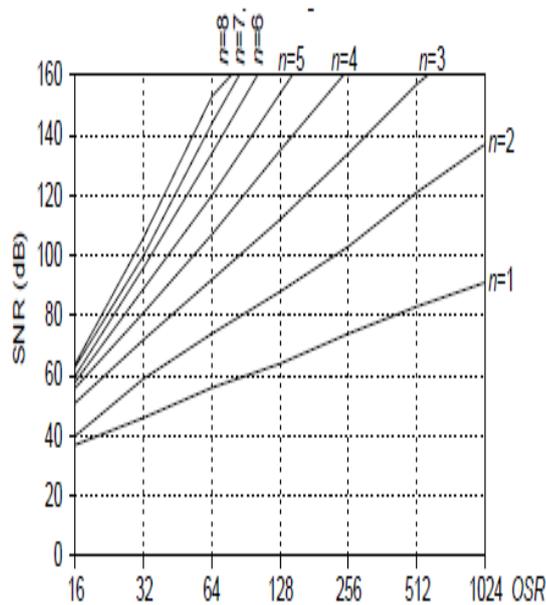

Figure 4 : SNR limit for binary low pass SDM

As the quantizer and filter introduces error in the modulator and reduces SNDR. The signal-to-noise-plus-distortion ratio (SNDR) of the filter as the desired output signal power divided by the sum of the corresponding noise and distortion powers. Typical filtering applications require that the SNDR at the output of the filter be higher than a minimum specified value SNDR (spec). The range of signals over which the SNDR requirement is met is defined as the usable dynamic range (UDR) of the filter.

Table 1 shows the comparison values of SNDR ENOB and Quantization Noise Reduction for Quantization level = 8

Sr. No.	Over Sampling Ratio	Signal to Noise Distortion Ratio (in dB)	Quantization Noise Reduction
1.	2	20.58	1.28
2.	3	21.30	1.50
3.	4	23.40	2.38
4.	8	30.33	9.90
5.	16	36.33	23.41
6.	32	42.73	41.52
7.	64	28.88	56.60
8.	128	-18.73	3.86

Table 2 shows the comparison values of SNDR ENOB and Quantization Noise Reduction for Quantization level = 16

Sr. No.	Over Sampling Ratio	Signal to Noise Distortion Ratio (in dB)	Quantization Noise Reduction
1.	2	29.22	2.19
2.	3	31.57	3.79
3.	4	33.96	6.32
4.	8	39.84	21.25
5.	16	43.37	36.60
6.	32	44.08	60.05
7.	64	28.88	97.01
8.	128	-18.61	2.68

V. CONCLUSION

From the above survey, it is concluded that as the order of quantizer bit increases the peak SNR value can be achieved at lower OSR, after a certain level the increase in OSR will not affect the SNR value. Also, up to a specific level of quantization with the increase in OSR(at OSR = 8) ,the SNR suddenly increases, with increase in ENOB and increase in Quantization noise reduction.

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Biography

Aparna Alone is currently working as Assistant Professor in Department of Electronics and Telecommunication Engineering ,Chhatrapati Shivaji Institute of Technology ,Durg, Chhattishgarh Swami Vivekanand Technical University Bhilai, India. She received BE degree from, Chhattishgarh Swami Vivekanand Technical University Bhilai, India in 2009. She is presently also pursuing M.E. from Chhatrapati Shivaji Institute of Technology, Durg. Her current research interests include signal processing, VLSI & Wireless Communication.

Sonika, received her B.E. (Electronics&Telecommunication) from BIT, DURG, INDIA in 1998. She earned her M. Tech. degree in VLSI from IIT, Delhi, INDIA in 2008. Presently she is Associate professor in Department of Information Technology, Chhatrapati Shivaji Institute of Technology, DURG (CG). She has more than twelve years of experience in the same profession. Her research interest include signal processing usingVLSI.