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2nd Order Sigma Delta Modulator Design using Delta Sigma Toolbox

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***Abstract* - This paper discusses the block level design of 2nd order sigma delta using the Delta Sigma Toolbox and Simulink .An optimized modulator is designed with scaled coefficients, giving a low power, low frequency and high OSR modulator. The modulator presented has an OSR of 256, bandwidth of 200Hz, SNR of 100dB, SNDR of 96 dB, ENOB of 16 bits (approx.).The designed modulator is ideal for low power and low frequency applications, as in case of conversion of brain wave signals which are in the frequency range of 10-100Hz.This work provides the baseline for the design of the same modulator using switched capacitor in CMOS technology of 0.18µm TMSC CMOS technology with VDD of 1.8V.The coefficient values a, b, g, c are the ratios of capacitors in switched capacitor level design.**

Keywords: **Sigma Delta, Delta sigma, Simulink, MATLAB, CMOS, ADC, EEG Sensor.**

I. INTRODUCTION

The increasing demand for audio devices for portable or autonomous apparatuses used in daily life continues to drive the need for highly power-efficient data converters with high resolution. Delta-sigma modulators (ΣΔ)are the preferred solution and the ones based on switched capacitor (SC) are optimal for low power medium conversion speed because of their accurate setting of zeros of the noise transfer function (NTF) and their insensitivity toward clock jitter and process Sigma delta (ΣΔ) analog-to-digital converters (ADCs) are generally utilized to achieve a high signal-to-noise ratio (SNR). The SNR of a ΣΔ ADC can be found using the conventional formula given in equation (1) and in decibels using equation (2), in which L represents the order of the ADC and N is the number of bits in the quantizer. To achieve the targeted SNR value, L, N, and oversampling ratio (OSR) values can be chosen as desired. Usually, the design is simpler when the ADC is 2nd order and N is 1, which leads to high OSR values. There arevarious methods of obtaining the desired transfer function, such as adding feedforward paths in the designs. Using feedforward paths in the ADC is a common method to cancel the effect of the input at the outputs ofthe integrators.[1] [2]

$$SNR = \frac{\frac{3}{2}(2L+1)}{\pi^{2L}} OSR^{2L+1} 2^{N-1} \quad (1)$$

$$SNR = 6.02M + 1.76 + 3.01(2L+1)log_2 OSR - 10log_{10}\left(\frac{\pi^{2L}}{2L+1}\right) \quad (2)$$

$$ENOB = \frac{SNR - 1.76}{6.02} \quad (3)$$

This paper explains the block level design of the Σ Δ modulators of 2nd order with a high OSR value using the Delta Sigma Toolbox and Simulink. This procedure forms the starting step in the circuit level design of Σ Δ modulators using CMOS technology. As the block level design in MATLAB is used to calculate the all-important modulator coefficients which serve the purpose of desired modulator response and constraints. The present work aims at showing the design of a sigma-delta modulator as part of an analog-to-digital converter (ADC) for low frequency and low power application used in digitizing the brain wave signal from an EEG headband sensor. Digitization of Brain waves requires high accuracy (more than 16 bits) or ENOB (Effective number of bits given by equation (3) and a bandwidth that range from 1Hz to 200Hz. Hence, the main focus of this work is to design a SD modulator that accomplish the application requirements considering the issues at each stage of the top-bottom design flow (from the system level to physical design). Following is the specification table of the modulator to be designed.[4]

TABLE I MODULATOR SPECIFICATIONS

Parameter	Value
SNR_{peak}	>96dB
BW	10-200Hz
OSR	256
Fs	100KHz
V_{DD}	1.8V
Modulator Order	2
Modulator Topology	Full Feed Forward
Domain	DT
ADC Levels	2
Topology	CIFF

II. SYSTEM LEVEL DESIGN

The paper focuses on the design and definition of the parameters of the Modulator blocks using the Delta Sigma toolbox and Simulink. The modulator coefficients are obtained and these values are optimal for providing maximum SNR and occupied the lowest area. Finally the overall 2nd order modulator were characterized and specified with these parameters and simulated as a block in Simulink.[3]

A. Delta Sigma Toolbox

Delta Sigma toolbox is an added tool in MATLAB environment for specific designing of ΣΔ based blocks. This toolbox is important for design and complete analysis of ΣΔ