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A Novel Approach for Better OSR in 4th Order Sigma-Delta Modulator using GA

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Abstract— **Sigma delta modulators (ΣΔMs) form part of the core of today's mixed-signal designs. The ongoing research on these devices shows the potential of ΣΔ data converters as a promising candidate for high-speed, high-resolution, and low-power mixed-signal interfaces. This paper addresses the design of a fourth-order multi-bit sigma-delta modulator suitable for Wireless Local Area Networks (WLAN) receivers with feed forward path and the optimum coefficients were selected using genetic algorithm (GA) -based search method.**

Keywords- **ΣΔMs, fourth order ΣΔM, GA, WLAN.**

I. Introduction

ΣΔ data converters, also known as scalar predictive quantizer or oversampling Analog-to-Digital converters, are widely used in audio [1], [2] and communication systems [3], [4], [5]. These systems can achieve a very large dynamic range without the need for precise matching of circuit components. This is especially attractive for implementation in scaled technologies where transistors are fast but not very accurate. They are also among the most power efficient ADC architectures [4].

There is a large demand in wired and wireless communication systems for high-performance analog to- digital converters which have a wide signal bandwidth and high resolution. Oversampling ADCs use more digital signal processing to perform analog-to-digital conversion compared with Nyquist-rate ADCs. The advantage is significantly relaxed matching requirements on analog components, while still achieving medium to high resolution [6]. Furthermore, oversampling ADCs don't need a steep roll-off anti-alias filtering typically required in Nyquist-rate ADCs. Conceptually, delta-sigma ADCs provide high resolution and linearity while using a low-resolution quantizer by taking advantage of oversampling and noise shaping. There are several design parameters: quantizer resolution, loop filter order, oversampling ratio (OSR). Increasing any of these parameters improves the SQNR [6]. Most of the publications in the past were just regarding the NTF of the system so that the focus of most of the optimization methods tends to increase the signal to noise ratio (SNR) or the dynamic range (DR) to a maximum level [7].

II. Proposed Methodology

A. *Using GA in ΣΔ ADC Design*

In the design of ΣΔ ADCs, we need to optimize a large set of parameters including the overall structures and the performance of the building blocks to achieve the required signal-to-noise ratio. So, behavioural simulations were carried out using a set of Simulink models in MATLAB Simulink environment in order to be optimized in a sigma-delta modulator are the gain coefficients in order to achieve the desired signal-to-noise ratio. GA is one of the finest optimization methods which finds a global optimum solution without taking much of the computational power.

The steps involved in the process of optimization using GA are shown in Fig. 1. There are two common schemes for coding the solutions: (i) binary coding (ii) decimal coding. The binary coding has been used where 0s and 1s are used to form a chromosome of length l depending on the precision needed. After defining the chromosome, an initial population is gotten by randomly producing an N number of

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chromosomal solutions called the first generation. The next step, called pairing, consists of selecting the chromosomes that will pair together to reproduce the offspring. This is done by using roulette wheel selection method. These pairs will be utilized for reproduction. Reproduction ensures that chromosomes with higher fitness will have a higher probability of reproduction than chromosomes with inferior fitness. Reproduction is the application of mutation, crossover and elitism operators over the selected chromosomes.

Mutation rate (MR) is set to a very low value. A high MR introduces high diversity, but might cause instability. However, a very low MR makes it difficult for the GA to find a globally optimal solution. In addition to crossover and mutation the best chromosome present in a particular generation is passed on to the next generation so that it will not be lost until the next best arrives. In this way the stability of the GA is enhanced. A fitness function or objective function has to be obtained to evaluate the performance of the chromosomes and compare their performance. In the modelling of sigma-delta modulator we need to optimize the coefficients for a maximum signal-to-noise ratio (SNR).

$$fitness = (1/Error)$$

Where

$$Error = Desired\ SNR - Obtained\ SNR$$

After evaluating the fitness function, fitness values will be allocated to each chromosome. If the best fit chromosome has arrived, the GA can be stopped and the coefficient values can be decoded. Otherwise the chromosomes are sent back to the selection module and the whole procedure is repeated again until the best arrives or the maximum number of generation set is reached. It is to be noted that the number of chromosomes should not be very small or very high. Too small a population size will lead to the very fast convergence of the GA and thus one may not obtain an optimum solution. Too high a population size will take a lot of computation time for the GA to converge which needs sufficient computing power.

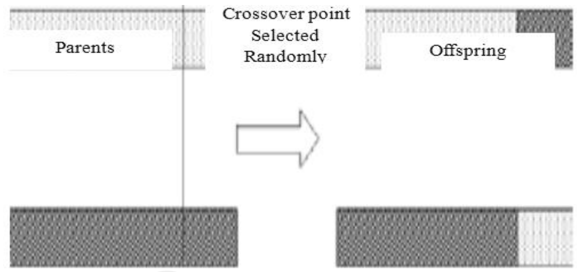

Figure.1: Single point crossover process

B. Fourth order ΣΔ modulator

The 4th order modified cascaded ΣΔ modulator architecture employs two key design methods. One is the 2nd order sigma-delta modulator with feed forward signal path, which has a high linearity even at low OSR. The other is the structural method, which combines the qualities of modified cascaded topology and multibit quantization in the last stage to make all quantization noise sources negligible at low oversampling (OSR). The scaling coefficients have been used to achieve the peak signal-to-noise and distortion ratio (SNDR), to control the input of the second stage and to utilize the full dynamic range of the next stage. By combining these methods the performance improvements of the ΣΔ modulator are outstanding. The output of the first stage of the modulator is given by

$$Y_1(z) = X(z) + \frac{(1-z^{-1})^2}{(1+g_1g_4-2)z^{-1} + (1+g_1g_2g_3-g_1g_4)z^{-2}} Q_1(z)$$

The output of the second stage is

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$$Y_1(z) = X(z) + \frac{g_1 g_2 z^{-2}}{(1+g_1g_4-2)z^{-1}+(1+g_1g_2g_3-g_1g_4)z^{-2}} Q_1(z) + T(z)$$

Where

$$T(z) = \frac{(1-z^{-1})^2}{1+(\omega_1\omega_4-2)z^{-1}+(1+\omega_1\omega_2\omega_3-\omega_1\omega_4)z^{-2}} Q_2(z)$$

And $Q_1(z)$ and $Q_2(z)$are the quantization errors of the first and second stages respectively and $g_1, g_2, g_3, g_4, \omega_1, \omega_2, \omega_3, \omega_4$ are the analog coefficients. The final modulator output after the cancellation logic is given by

$$Y_1(z) = z^{-2}X(z) + T_1(z)$$

Where, $T(z) =$

$$\frac{1}{g_1g_2}\frac{(1-z^{-1})^2}{1+(\omega_1\omega_4-2)z^{-1}+(1+\omega_1\omega_2\omega_3-\omega_1\omega_4)z^{-2}} Q_2(z)$$

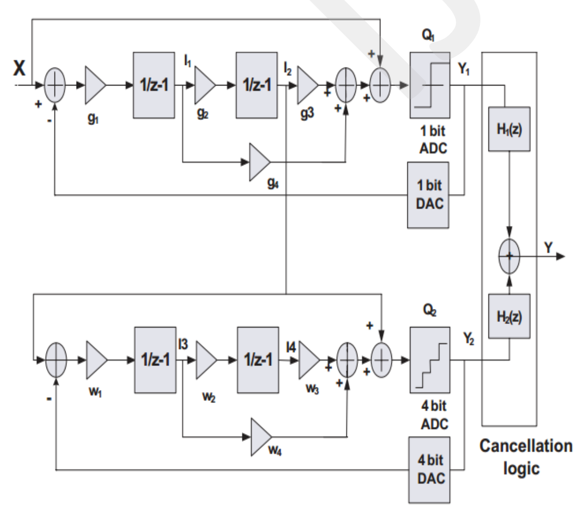

Figure.2: Modified cascaded sigma-delta modulator

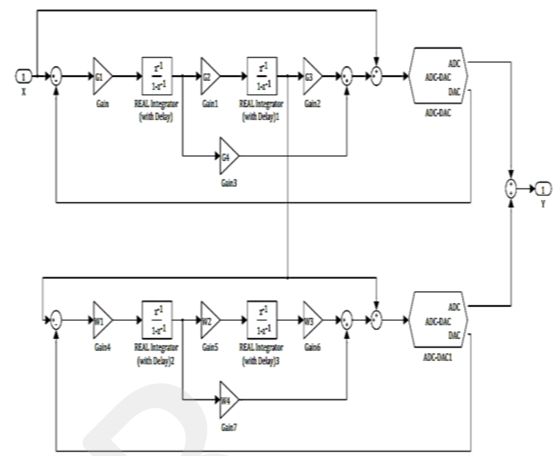

Figure. 3: Proposed 4th order sigma delta modulator

III. RESULT

Simulation Parameters

$Fs(Hz) = 11289600$

$Ts(s) = 8.857710e-008$

$Fin(Hz) = 11714.0625$

$BW(Hz) = 22050$

$OSR = 256$

$Npoints = 16384$

$tsim(sec) = 0.001$

$Nperiods = 17.000$

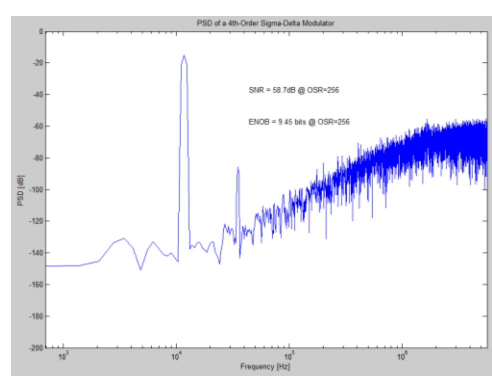

Figure.4: PSD of SDM in real time condition with arbitrary gain values

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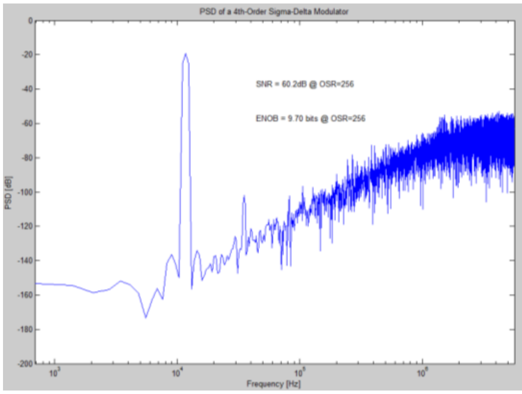

Figure.5: PSD of SDM in real time condition with optimized gain values

IV. CONCLUSION

In this paper, GA has been successfully used to improve the performance of a 2-2 cascaded feed forward sigma-delta ADC, which is proposed for WLAN applications. The coefficients were optimized using GA which results in an extended dynamic range. It has also been applied to a traditional second order feedback topology to find peak SNR values with good stability. Design examples and numerical results demonstrate the effectiveness of our proposed method.

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