

A 3rd order 3bit Sigma-Delta Modulator with Reduced Delay Time of Data Weighted Averaging

Soon Jai Yi, Sun-Hong Kim, Hang-Geun Jeong, and Seong-Ik Cho

Abstract—This paper presents a method of reducing the feedback delay time of DWA(Data Weighted Averaging) used in sigma-delta modulators. The delay time reduction results from the elimination of the latch at the quantizer output and also from the falling edge operation. The designed sigma-delta modulator improves the timing margin about 16%. The sub-circuits of sigma-delta modulator such as SC(Switched Capacitor) integrator, 9-level quantizer, comparator, and DWA are designed with the non-ideal characteristics taken into account. The sigma-delta modulator has a maximum SNR (Signal to Noise Ratio) of 84 dB or 13 bit resolution.

Keywords—Sigma-delta modulator, multibit, DWA

I. INTRODUCTION

Oversampling analog to digital and digital to analog converters employing sigma-delta modulators have been popular in high resolution applications, such as digital audio, where a large dynamic range is required for low bandwidth signal of less than 22 KHz[1]. Recently, due to rapid development of VLSI process, sigma-delta modulators are now being applied to wideband communication systems. Therefore, a sigma-delta modulator should be able to handle a signal with over several MHz bandwidth and maintain a high SNR at a lower oversampling ratio

Two methods have been used to increase the SNR of a modulator. One is to use a high order loop structure which can be realized either by using a single loop configuration or by using the MASH(Multi Stage Noise Shaping) structure. The other is to increase the number of quantizer bits[2-4]. When the number of quantizer bits is increased, the SNR of the sigma-delta modulator decreases because of capacitance mismatch. To overcome the capacitance mismatch problem, DEM(Dynamic Element Matching) techniques can be used. In implementing the DEM techniques, a DWA is commonly used to reduce the hardware complexity[5].

In this work, a new structure of DWA for high speed sigma-delta modulator is proposed. The proposed DWA decreases the feedback delay time by eliminating the latch and the second clock. So the timing margin is increased, leading to

Soon Jai Yi, Hang-Geun Jeong, and Seong-Ik Cho are with the Division of Electronics and Information Engineering, Chonbuk National University, Jeonju, Jeonbuk 561756 South Korea. (e-mail: mir@jbnu.ac.kr).

Sun-Hong Kim is with Samsung Electro-Mechanics, Suwon, Gyeonggi 443743 South Korea. (e-mail: noruck@chonbuk.ac.kr).

a more stable operation. A gain boosting scheme is used to implement the amplifier used in the integrator. The designed sigma-delta modulator has 84 dB SNR or 13 bit resolution.

II. CIRCUIT IMPLEMENTATION

A. Sigma-Delta Modulator Structure and Coefficients Determination

The sigma-delta modulator using a high order loop structure has a disadvantage in stability. Although the stability of MASH structure is guaranteed, the quantization noise of each stage is not perfectly cancelled in the digital filter. A 3rd order single loop structure is chosen in consideration of stability and the noise shaping property. In addition, a 3bit quantizer is adopted considering the signal to noise and the required hardware complexity. The block diagram of the resulting 3rd order 3 bit sigma-delta modulator is shown in Fig. 1.

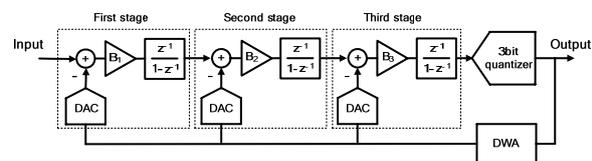


Fig. 1 Structure of 3rd order 3bit sigma-delta modulator

The coefficients are obtained through the behavior simulation. The maximum SNR of sigma-delta modulator is 87 dB. When B_2 is 0.8 and B_3 is 2, as can be seen in Fig. 2.

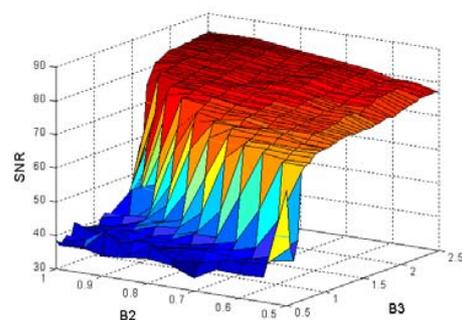


Fig. 2 The SNR characteristic of the modulator as a function of the integrator gain coefficients($B_1=0.33$)

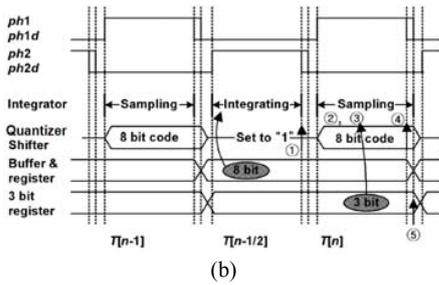


Fig. 6 Proposed DWA (a) block diagram, (b) timing diagram

- When the ph2d changes from ' 1' to ' 0' , the 9-level quantizer samples the output of integrator.
- The output of integrator is converted to 8 bit code by the quantizer.
- Thermometer code is passed to shifter1, shifter2, and shifter3 following control signals(C0, C1, and C2).
- Thermometer code is saved in 8 bit buffer by signal.
- Shift control signal that generates 3 bit register is encoded by signal.

The proposed DWA latches the quantizer output on the falling edge of ph1. The sigma-delta modulator with the proposed DWA increases the timing margin. The timing margin can be expressed in (2) and (3). The conventional DWA structure needs 31.25 % of 8 ns which is the maximum allowable time, but the proposed DWA structure has a delay time of 15 %.

$$\frac{\text{Delaytime of conventional DWA}}{\text{Periode of Ph1}} = \frac{D_Q + 3 \times D_S + CLK_M}{8n} = \frac{0.7n + 1.5n + 0.3n}{8n} \Rightarrow 31.25\% \quad (2)$$

$$\frac{\text{Delaytime of proposed DWA}}{\text{Periode of Ph1}} = \frac{D_Q + D_S}{8n} = \frac{0.7n + 0.5n}{8n} \Rightarrow 15\% \quad (3)$$

III. SIMULATION

Fig. 7 shows the output of DWA. The operation of the prop-

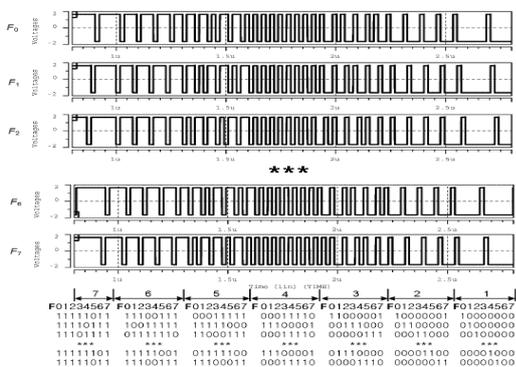


Fig. 7 Output of the thermometer code

osed DWA is verified by checking the thermometer codes. For

example, the code 1000 0000 is followed by the code 0100 0000. The input signal has a magnitude of 1.2 Vp-p and the frequency of 825 KHz. The sampling frequency of sigma-delta modulator is 52.8 MHz. Fig. 8 shows the output of the sigma-delta modulator. The waveform shows the quantization levels of the input signal.

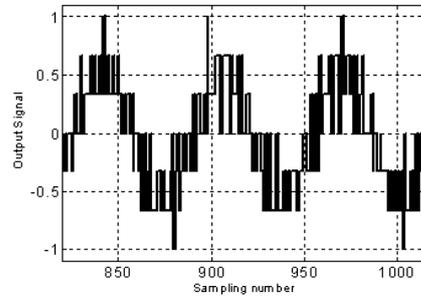


Fig. 8 Output waveform of sigma-delta modulator

The output spectrum of sigma-delta modulator is shown in Fig. 9. The SNR of the sigma-delta modulator is 84 dB. Table II shows the performances of 3rd order sigma-delta modulator with the proposed DWA.

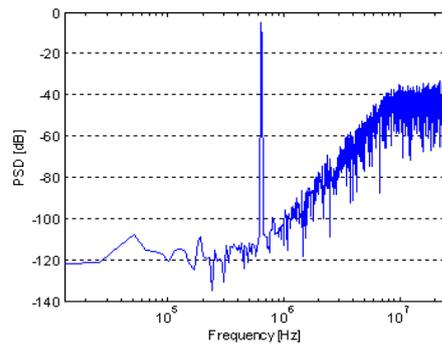


Fig. 9 Output spectrum of sigma-delta modulator

TABLE II
PERFORMANCES SUMMARY

	Sigma-Delta Modulator
Signal Band	1.1 MHz
Sampling Frequency	52.8 MHz
Peak SNR	84 dB
OSR	24
Power Supply	3.3 V

IV. CONCLUSION

This paper presents a method of reducing the feedback delay time in DWA. The proposed DWA only needs a delay time of only 1.2 ns. The timing margin is increased, leading to a more stable operation. The 3rd order 3bit sigma delta modulator with the proposed DWA has 13bit resolution or maximum SNR of

84 dB. The sigma delta modulator is designed using a 0.35 μm CMOS process and can be applied to wideband applications.

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