New 2-2 Sigma-Delta Modulators for Different Applications

Slim Tahri, Nizar Khitouni, Med Slim Bouhlel

Abstract**:** ***This work presents the design of a new 2-2 programmable sigma delta modulator architecture, for different applications, this transformation design of the ΣΔ modulator low-pass, band-pass and high-pass or vice versa with loopbacks addition, which improved the linearity of the converter and reduced the quantization noise. In this work, the MASH structure enables the implementation of stable and high-order modulator. This makes low voltage and low power applications ideal. The simulation result for sigma delta modulator for biomedical applications exhibit a signal to noise ratio is 95 dB @ 250Hz bandwidth and a 75dB @ 200KHz ,85dB @1MHz for pass band modulator. The SNR is about 70dB for 5MHz bandwidth and for high pass application. This tool will allow a development contribution and characterize a system optimization set from the start while remaining at a high level of design that is suitable for electronic systems and models VHDL-AMS, RF, Biomedical.***

Keywords**:** ***Signal processing, Sigma delta, MASH, Low pass, band pass, high pass, Biomedical, EMG, ECG, EEG, RF.***

I. INTRODUCTION

This Sigma delta (MΣΔ) modulators are widely used in signal processing and electronics for low power [7],[8],[9] high speed applications due to low over sampling rate (OSR) and digital and programmable techniques to significantly impact [1],[2].

Analog techniques in many fields such as signal processing, telecommunications [4] (coding, decoding, modulator-demodulator), radar, medical applications [3] (EMG, EEG, ECG, NMR, etc.), imaging, M ΣΔ setting shaped high-order noise without any stability problem [5]. To achieve higher resolutions zero optimization is a good technique to reduce in-band quantization noise without increasing the number of integrators. To do this the local resonance strategy can be used the M ΣΔ MASH 2-2 can affect the digital filters [6].

Thus their implementation becomes complicated, the realization of the transfer function of the signal STF unity, the integrators do not ideally deal with the quantization error relaxing their requirements of nonlinearity of amplifier gain and oscillation of exit. Another zero optimization approach called global resonance has been presented in M ΣΔ MASH 2-2. This zero optimization technique is performed using the output inter-stage feedback paths that the digital filters in the MASH modulators do not
change therefore, in some cases the overall resonance may be a better choice for M ΣΔ MASH 2-2, in this paper a simple approach is presented for optimizing a zero pair of noise transfer signal (STN), in a typical discrete time ΣΔ MASH modulator.

This is added between the floors. However, with a minimum additional circuit the zero optimization can be performed for a conventional M ΣΔ MASH 2-2 modulator underperforming the digital filters.

II. SECOND ORDER SIGMA-DELTA MODULATOR

The transfert functions of the integrators to achieve different structures are given in Table 1.

Table- I: Transfer function

Integrator	Function	Realization
Low pass	$\frac{1}{1-z^{-1}}$	
Band pass	$\frac{-1}{1+z^{-2}}$	$\frac{1}{1-z^{-1}} * \frac{-z^{-1}}{1+z^{-1}}$
High pass	$\frac{-z^{-1}}{1+z^{-1}}$	

II.1. SECOND ORDER LOW PAS SIGMA DELTA MODULATOR

The ΣΔ modulator, which uses a single integrated quantizer, is called single loop topologies to formalize with this architecture, their performance, their implementation at the circuit level as well as other practical aspects. The second order ΣΔ modulator is represented by figure 1.

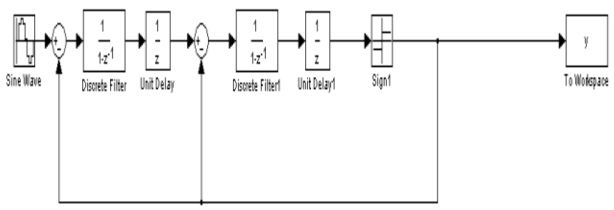

Figure 1: Second order sigma-delta modulator.

Manuscript received on November 20, 2021.
Revised Manuscript received on November 29, 2021.
Manuscript published on November 30, 2021.

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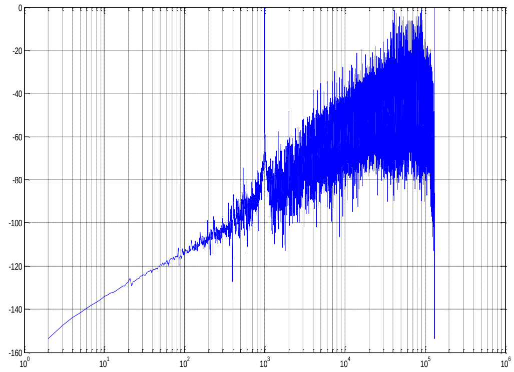

Figure 2: Structure of the second order low pass ΣΔ modulator.

II.2. BAND PASS SIGMA DELTA MODULATOR

The architecture of the second-order band-pass modulator aims to simplify the sensor electronics interface, through the complete digitization of the measurement chain. This makes it possible to reduce the number of analog blocks, and to increase the modularity of the architecture. A ΣΔ band pass modulator performs the same operation as a low pass modulator, but around a resonant frequency f_R around which the pass band is defined. To achieve a second order band pass ΣΔ modulator, it is necessary to make a change in the transfer functions of the integrators by multiplying by $\frac{-z^{-1}}{1+z^{-1}}$

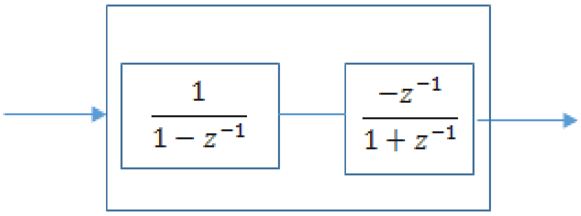

Figure 3: Realization of a band pass integrator

A. The advantage of performing this transformation is twofold: we retain the performance in SNR, and the band-pass modulator is stable. This analogy makes it possible to simplify the design of a band-pass modulator by relying on stable low-pass architectures. Figure 4 shows the band pass sigma-delta modulator.

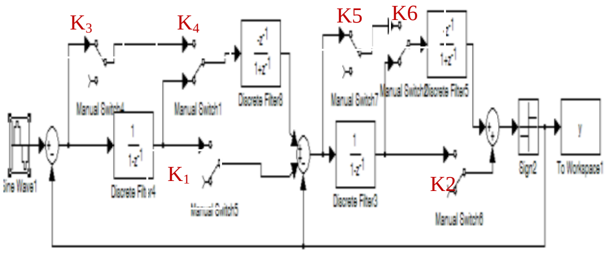

Figure 4: Band pass second-order modulator

The design of the second order sigma delta modulator in band pass of a single stage by setting for this model that one can write the STF and NTF of the modulator. It is necessary to close the switches K4, K6 and open K1, K2, K3, K5. Figure 5 shows the output spectrum at the system level for a frequency band of 30KHz and the signal to noise ratio is in the order of 55dB.

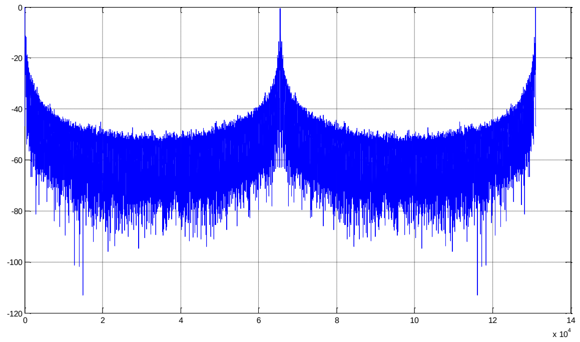

Figure 5: Spectrum of pass -Band sigma delta modulator.

II.3. SECOND ORDER HIGH PASS SIGMA DELTA MODULATOR

When switching to high pass, it only allows frequencies above a specific frequency, called the "cut off frequency" fc, to pass. It attenuates the others (the low frequencies). In other words, he lets through what is high. It is a bass attenuator for an audio signal. You could also call it low cut. To determine the second order high pass architecture, you have to open switches K1, K2 and close K3, K4, K5, K6.

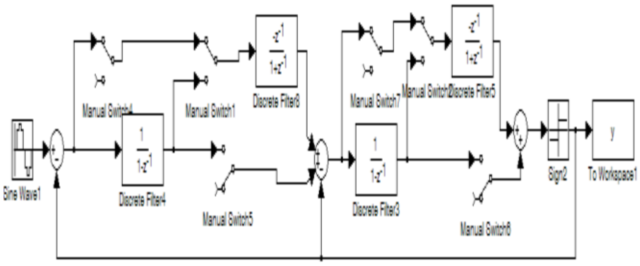

Figure 6: Second order High Pass sigma delta modulator

Figure 7 shows the output spectrum at the system level for signal to noise ratio is in the order of60dB.

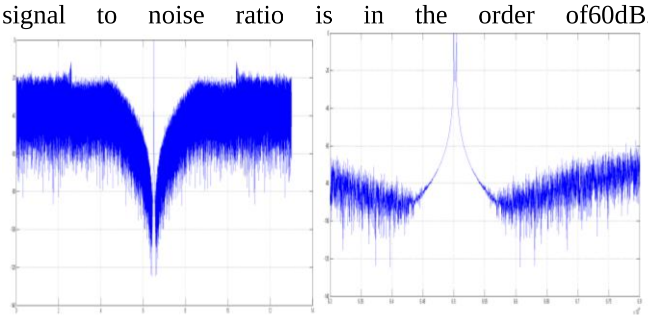

Figure 7: Spectrum of the High-pass sigma delta modulator

Table 2 gives the command of the switches (low pass, band pass and high pass).

Table-II: Switch control

Switches	Low Pass	High Pass	Pass Band
K1	1	0	0
K2	1	0	0
K3	0	0	1
K4	0	1	1
K5	0	1	1
K6	0	0	1

Retrieval Number: 100.1/ijrte.D66291110421
DOI: 10.35940/ijrte.D6629.1110421
Journal Website: www.ijrte.org

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III- ΣΔ MASH CASCADE 2–2 MODULATOR:

Based on the previous development and simulations we propose a new architecture of MASH 2–2 sigma delta modulator, this is illustrated in figure 9. In this figure, the coefficients denote respectively the inter-stage gain and its numerical estimate.

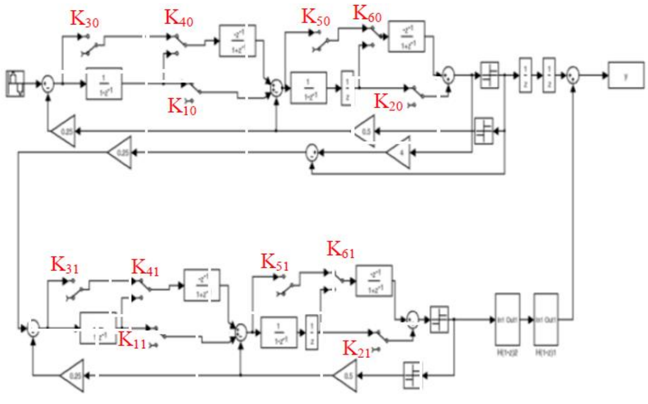


Figure 8: Architecture of M ΣΔ MASH 2-2.

The same modulator architecture can be dynamically adapted to the different DR and BW requirements of several applications (biomedical, audio and RF) by simply adjusting on the OSR, and the sample rate. The modulator coefficients are obtained from a simulation-based procedure that optimizes the modulator's performance in terms of signal-to-noise ratio. The passage from one band to another is done by tilting the switches which is given in table 3.

Table-III: switch control

Switches	Low pass	Band pass	high pass
K10	1	0	0
K20	1	0	0
K30	0	0	1
K40	0	1	1
K50	0	0	1
K60	0	1	1
K11	1	0	0
K21	1	0	0
K31	0	0	1
K41	0	1	1
K51	0	0	1
K61	0	1	1

To optimize NTF zeros in a low pass cascade MASH 2–2 modulator, the local and global resonance strategies are shown in Figure 8, respectively. The proposed MASH 2–2 is compared to these two structures. The proposed modulator needs only one analog coefficient.

II. RESULT OF THE SIMULATIONS:

An ideal 2-2 mash modulator with 1-bit quantization is sufficient to meet DR requirements. In the 250Hz band of interest and an OSR of 128, it is possible to achieve a DR above 95dB. For band pass mode, a single bit is also sufficient but with a higher order to reach between 75 dB to 85dB at 200 KHz and 1MHz. For the high-pass case where the band is 5 MHz, the signal ratio can reach 70dB. The simulations performed validate a new sigma delta modulator structure for different applications. Future work deals with real tests (signals: ECG, EEG, EMG, audio, RF) each application on its own. Figures 9, 10 and 11 respectively show the output spectra for conditions shown in Table 4.

Table -VI : Condition Simulation.

	Low pass	Band pass	High pass
Band	250Hz	200KHz/1MHz	5MHz
Sampling frequency	2.048MHz	17.5MHz	10MHz
SNR(dB)	95	75/85	70

The output spectrum of the 2-2 sigma delta modulator is given by figure 9.

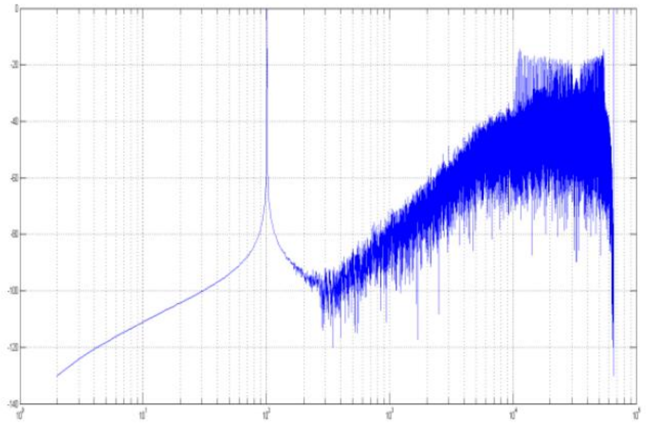
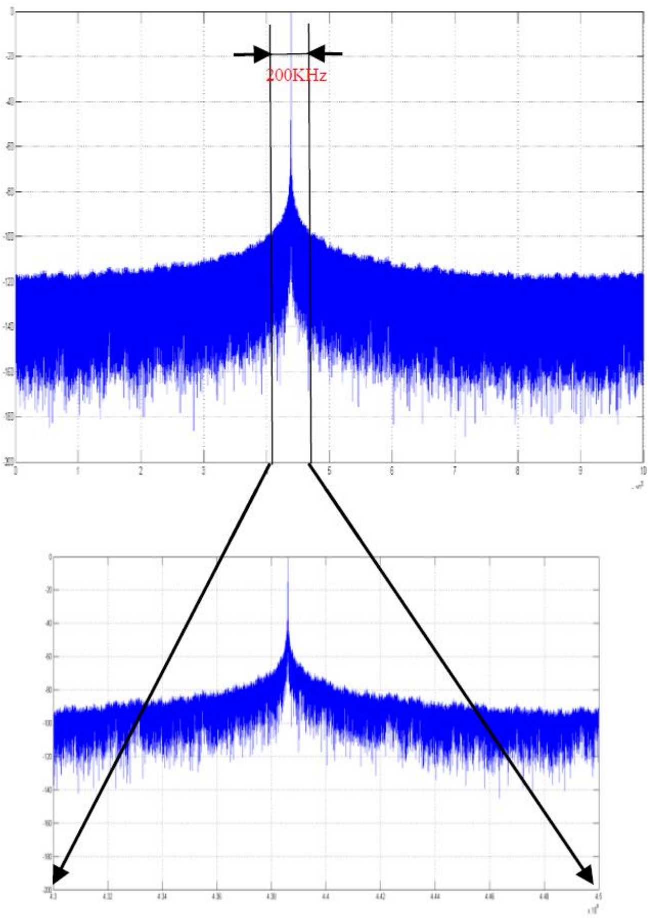


Figure 9 : MASH 2-2 Löw Pas Simulation.

The simulation of the M Σ MASH 2-2 Band passes architecture represented by figure 10 (a) and (b).



(a)

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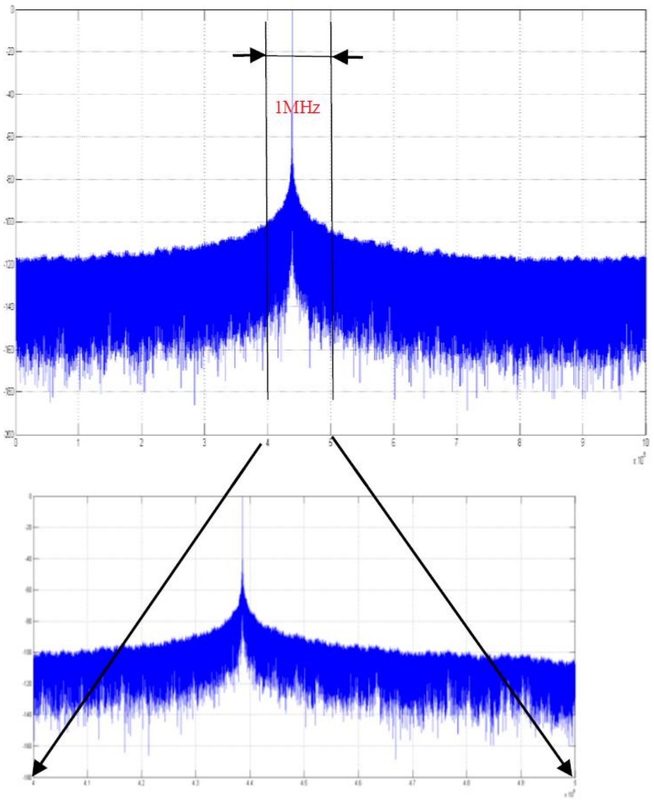

(b)

Figure10: (a) spectrum of 2-2 sigma delta of 200KHz band pass and (b) spectrum of 2-2 sigma delta of 1MHz band pass.

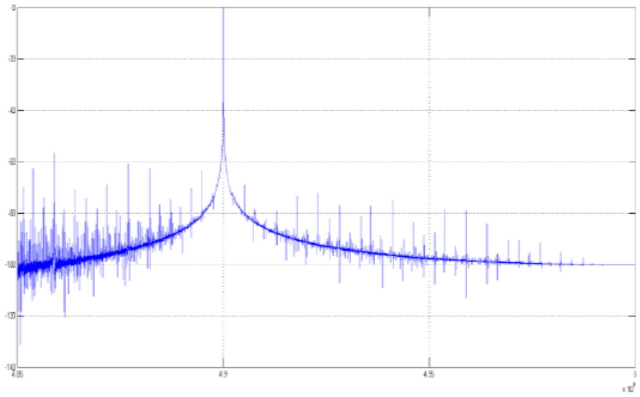

Figure 11: Spectrum of 2–2 high pass modulator.

III. CONCLUSIONS

In this paper, a new structure of MASH modulator is presented to reduce in-band quantization noise significantly. This reduction is achieved by improving the noise shaping capability of the one-order modulator and also optimizing a pair of NTF zeros. All of these benefits are only achieved by using two additional analog feedback paths without increasing the number of active blocks. This modulator is simulated at system levels using MATLAB simulink. The simulation result for sigma delta modulator for biomedical applications exhibit a signal to noise ratio is 95 dB @250Hz bandwidth and a 75dB/85db @ 200KHz /1MHz for pass band modulator. The SNR is about 70dB for 5MHz bandwidth MHz for high pass application. This modulator can be dedicated to portable device for diver's biomedical signals (ECG, EEG, EOG) audio and RF signals.

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Slim Tahri, student prepare in phd thesis , received the master in electrical engineering at 2011 and in his professional Mater in instrumentation and telecommunication degree in 2006 from the National School of Engineers, He has nine publications in international journals and eight publications in international conferences. His research interests are the synthesis of analog circuits applied to the sigma delta modulator.

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