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DTMOS Based Sigma Delta Modulator Design

Bhawna[1], M.Gupta[2], V.Bhatia[3]

PG Student [VLSI], Dept. of ECE, Indira Gandhi Delhi Technical University for Women, Kashmere Gate, Delhi, India[1]

PG Student [VLSI], Dept. of ECE, Indira Gandhi Delhi Technical University for Women, Kashmere Gate, Delhi, India[2]

Assistant Professor, Dept. of ECE, Indira Gandhi Delhi Technical University for Women, Kashmere Gate, Delhi, India[3]

ABSTRACT:This sigma delta modulator Contains a Filter, a Quantizer(which consist of a comparator and D latch) & D to A Converter. A current mirror based D to A converter is used and DTMOS technology is applied to this D to A converter then a new current mode D to A converter and a new comparator is used and DTMOS technology is applied to both. Properties of comparator and DTMOS comparator have been compared. Gain and power consumption of comparator is better than the gain of DTMOS comparator but other properties like rise time, fall time, propagation delay of DTMOS comparator with 0.5V supply voltage is better than the normal comparator with supply voltage of 1.2V.
Then there is a Comparison of power spectral densities and Signal to noise ratio of Sigma Delta modulator. PSD using DTMOS comparator is better than that of normal comparator. While signal to noise ratio of DTMOS comparator is better than normal comparator. After that a DTMOS based Sigma Delta modulator is designed and its Power spectral Density and Signal to Noise ratio has also been calculated. PSD of new DTMOS based sigma delta modulator is not better but there is a big increment in the peak SNR value. The OTA based filter is implemented using OrCADPspice and other circuits are implemented using Cadence Virtuosos. The simulation has been done using 0.18um technology. The OTA filter provides a unity gain and gives a control on performance.

KEYWORDS: Operational Transconductance Amplifier, Analog to Digital Converter, Comparator, Current Mode logic, Dynamic Threshold MOS technology.

I.INTRODUCTION

Sigma delta modulator is useful in low power applications of portable electronic system. In digitizing biomedical signals such as ECG, EEG etc. these modulators used and to reduce power consumption and cost. A continuous time current mode circuits provides a possibility of getting results in low power and voltages. In this project we are going to change the filter used in modulator. In the design of a low power second-order continuous-time sigma-delta modulator in biomedical applications a filter, a quantizer and a digital to analog converter is used. For current mode, a Gm-C technique is used that is based on FGMOS. This filter circuit is very complex because we have to apply voltage to current and current to voltage converter before and after the Gm-C circuit and it gives you a non-linear output. So in this project, we are trying to implement OTA based filter that has a very simple structure and gives you linear output. Then we have calculated the power spectral density and signal to noise ratio from the output.The proposed modulator in [1] is based on FGMOS. It is a nonlinear loop filter that means it produces a nonlinear output. Aim of this work to replace this nonlinear loop filter by a linear loop filter and an OTA based filter is used and figure 1 shows the CMOS OTA based filter. OTA has differential input and current output.A quantizer is also used which provides a discrete and usually finite output. A good quantizer represents original signal with minimum loss or distortion. Current mode logic has been applied to all the circuits.
This work is divided in five chapters. Chapter 1 presents an account of the evolution of current mode signal processing and a brief introduction of the work. Chapter 2 is devoted to the study of the literature involved. After that for implementing DTMOS technology on the modulator it also been studied and simulation is done by using PSPICE and Cadence VIRTUOSO. Chapter 3 is report on present investigation OTA based filter simulation and a brief review of existing literature in the area is also presented. Chapter 4 is a record of results and simulation of CMOS OTA based Filter, modulator based on this filter and modulator with current mirror based Digital to Analog converter. Than results

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taken from DTMOS based modulator is also recorded. After that a small discussion on the results has been done.In Chapter 5 contains summary and conclusion of the whole project has been provided.

II.REVIEW OF LITERATURE

2.1 FGMOS BASED MODULATOR

In [1] the design of a low power second-order continuous-time sigma-delta modulator for biomedical applications is presented. a nonlinear transconductance capacitor (Gm-C) is used to implement The loop filter of this modulator by employing current-mode technique. The nonlinear transconductance uses floating gate MOS (FGMOS) transistors. This FGMOS transistor operates in weak inversion region. The modulator proposed in [1] provides low power consumption (<80uW), low supply voltage and dynamic range of 62dB. This modulator has been simulated using HSPICE which confirms that it is very suitable for designing of low power biomedical instruments.Figure 1 shows a fully differential structure for a sigma-delta modulator which is consists of a fully-balanced current-mode loop filter (to filter out the errors in the signal), a quantizer (to produce output in discreate and finite value) and a NRZ DAC(to convert digital value coming out fromquantizer in analog signal) [7].The complete circuit diagram of the proposed second-order loop filter is also provided in [1].

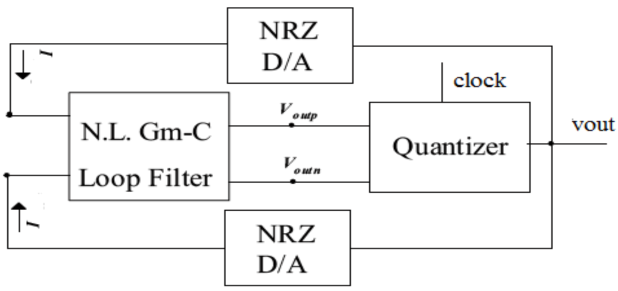

Fig. 1 Proposed modulator block diagram in [1]

2.2 OTA BASED MODULATOR

In [2], different type of OTAs has been designed and filters are implemented using those OTAs. As it is well known that OPAMPs work well for low-frequency applications, such as audio and video systems but for higher frequencies, OPAMP designs become difficult due to their frequency limit. So at high frequencies, operational transconductance amplifiers (OTAs) are used which are the best option to replace OPAMPS as the building blocks. In [2] basically illustration of an application of OTA as an active low pass filter has been done. They are using current mirror as a primary building block of an OTA and different current mirrors are used to design the LPF. Also a comparative study of CMOS OTA & NMOS OTA is also illustrated in [2] but our main objective to study about the CMOS OTA based filter to replace the FGMOS based filter in the modulator given in [1]. The OTA is used to amplify a signal like the ECG signal having low frequency, supply voltage of 0.8v is applied to the amplifier.

2.3 COMPARATOR

In [3] CMOS comparator design has been discussed. In these types of digital circuits, different parameters like; parameters gain and offset voltage has been calculated in that paper. Talking about working of comparator, it has 2 or more than 2 inputs and one single output. These 2 inputs have compared according to the properties like speed, power, internal reference, output type etc. that is required at the output and one of the inputs is the output of that comparator. Design of CMOS comparator gives high performance using virtuoso tools with GPDK 90nm technology on which all this parameter has been optimized. These comparators can be used as null detector, zero crossing detector, relaxation oscillator, level shifters, ADC's and window detector.

2.4 DTMOS TECHNOLOGY

In [4] dynamic threshold MOS (DTMOS) and its application in a current mirror have been discussed. In area as to larger current motivating capacity and low leakage current, DTMOS is eye-catching for low power applicationsThe

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market ultimatum for transportable and well-organized electronic devices have hard-pressed the industry to enterprise chip with high integration concentration, low power consumption and improved performance. To get hold of these objectives the technology size of the CMOS has to face continuous scale back. As the technology is existence concentrated day by day with the lessening of channel size that is Length of the MOSFET and the other parameter dimensions also prerequisite to be minimized. Figure 2 shows a DTMOS transistor. The DTMOS technique in which
body (bulk) terminal is associated to the gate terminal is an encouraging method for accomplishing enhanced performance deprived of even transforming the existing structure of MOSFET [8].This is the most important advantage of DTMOS as it is fully compatible with the conventional CMOS process.

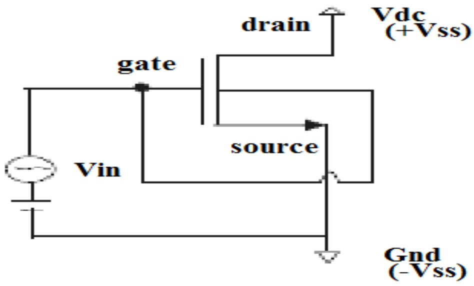

Fig. 2 DTMOS transistor

2.5 NEW D TO A CONVERTER

Digital to analog converter is simply get into picture by its name. In [5] a current mode D to A converter has been design which only contains PMOS and NMOS. It has current output and voltage input. This type of sigma delta D to A converter has been used as a feedback in sigma delta modulator. As the output of this converter is current type so, current feedback goes into the modulator. Intended for high-resolution, high dynamic range conversion, $\Sigma\Delta$ A/D converter may be a respectable candidate. On the other hand, classical converters used predominantly in telecommunication and consumer electronics applications has been written off as by their signal processing constraints, such as dynamic range and signal-to-noise ratio (SNR), as in these applications typically a running waveform prerequisites to be digitized uninterruptedly and predominantly the spectral performance of the signal is essential.

III.PRESENT INVESTIGATION

3.1 A LINEAR FILTER

Filter is used to clean the unwanted error present or has been added by the procedure itself in the output. An OTA based filter has been proposed [2] and DTMOS technology is applied to get a DTMOS based OTA filter.CMOS OTA [2] is used to make the linear filter in which input is coming from resistance and capacitance circuit which is the important part of the filter as it is used to adjust the transconductance of the OTA. Figure 3 Shows the OTA based filter whose output is connected to one of the input of OTA to make it work like a loop filter.

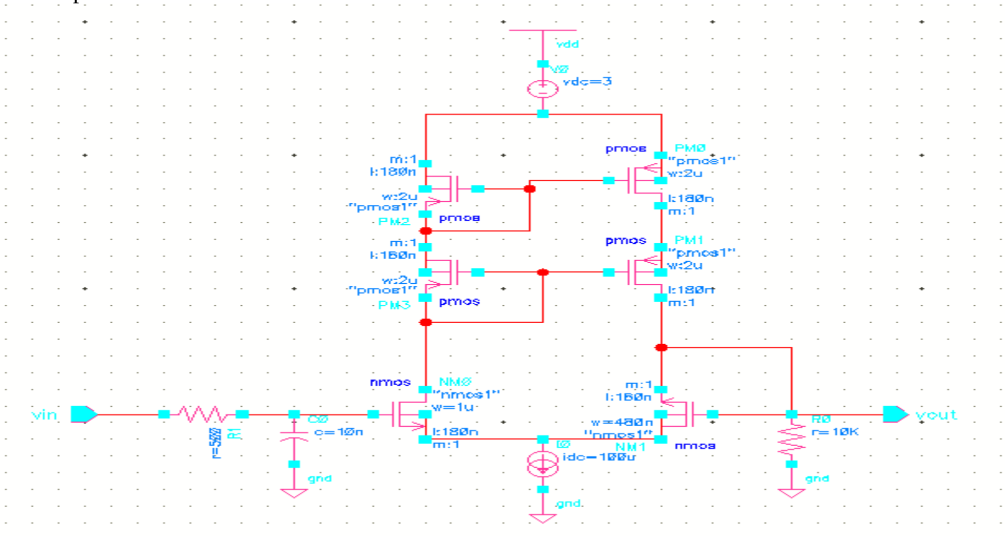

Figure 3. CMOS OTA based filter.

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At 3volts power supply, it provides cutoff frequency in megahertz. Advantages of using OTA are that it reduces the static power dissipation, provides unity gain and reduced bias voltage. Its cutoff frequency can be adjusted by changing resistance and capacitance value at input of the OTA. Advantage of using OTA based filter are Simple structure, linear output, increased reliability and high frequency performance as discussed earlier. Figure 4 shows a DTMOS based OTA filter. DTMOS technology has been applied to get a DTMOS OTA filter. 0.5uA of supply voltage at Vcc and also -0.5uA is provided to the ground to balance the noise effects. Transistor gets “ON” when gate voltage is equal to bulk voltage and gets “OFF” when Vdd>Vth.

3.2 DIGITAL TO ANALOG CONVERTER

Different design of D to A converter has been designed and implemented. First a current mirror based D to A converter [9] has been designed by Ms.Veepsa Bhatia in her PHD thesis in 2017. Then DTMOS technology has been implement on the same current mirror based D to A converter. Second, a new current mode D to A converter has been implemented [5] and then DTMOS technique is applied to that current mode D to A converter.

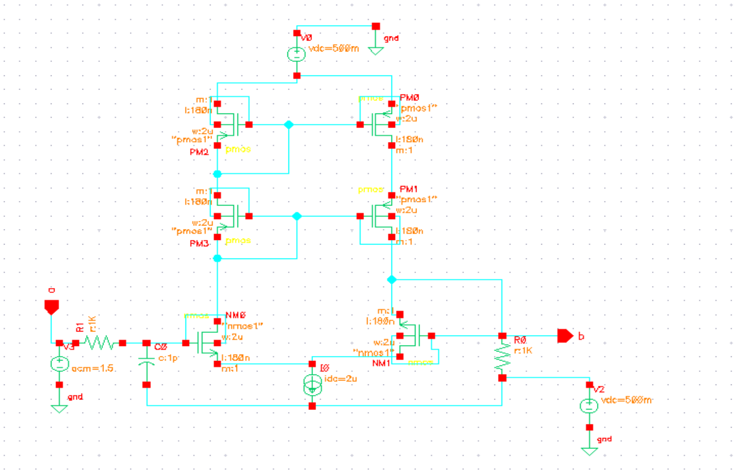

Figure 4. DTMOS based OTA filter

3.2.1 CURRENT MIRROR BASED DIGITAL TO ANALOG CONVERTER

In figure 5, a current mirror based digital to analog converter is shown [9]. It consists of PMOS and NMOS. There are two inputs and two outputs and a reference current is provided at the source of Q2 and Q4. It uses a digital input and converts it into an analog signal. The third specification is the smallest voltage drops crosswise the output part of the mirror necessary to create it and make it work correctly. This minimum voltage is verbalized by the necessity to keep the output transistor of the mirror in active mode.

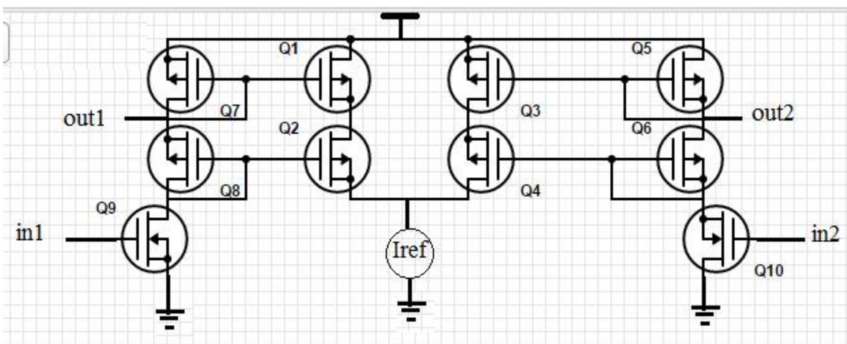

Figure 5. Current mirror based Digital to Analogconverter[9].

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DTMOS based current mirror D to A converter has been designed and implemented in figure 6. A 0.5v of positive and negative voltage is applied to the supply and ground respectively. The gate and body of each of the transistors has been connected with each other so that the gate voltage must be equal to bulk voltage. An extra resistance is applied at both the output junction to get voltage as output. This output is connected to the input of the filter so; it can be directly connected to the filter without using a resistance as the input of this filter should be in current mode.

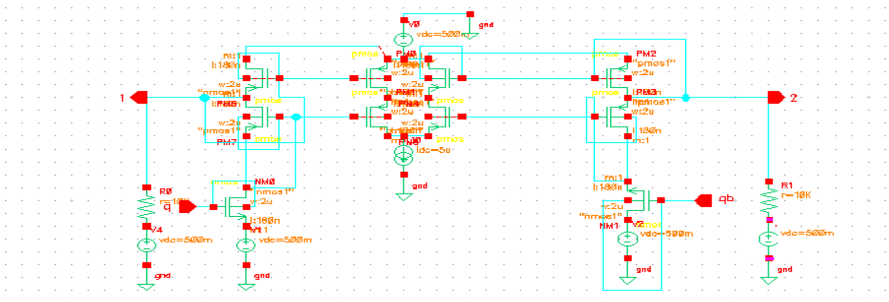

Figure 6. DTMOS based D to A converter.

3.2.2 CURRENT MODE DIGITAL TO ANALOG CONVERTER

The current mode D to A converter has been taken from [5]. Input to this converter is a voltage so, pull up and pull down transistor has been applied to convert the current into voltage. Current mode D to A converter has been designed and implemented in figure 7 using Virtuoso. A 1.5v of positive voltage is applied as supply voltage. An extra resistance is applied at the output junction to get voltage as output. In figure 8 DTMOS technology has been applied to new current mode D to A converter.

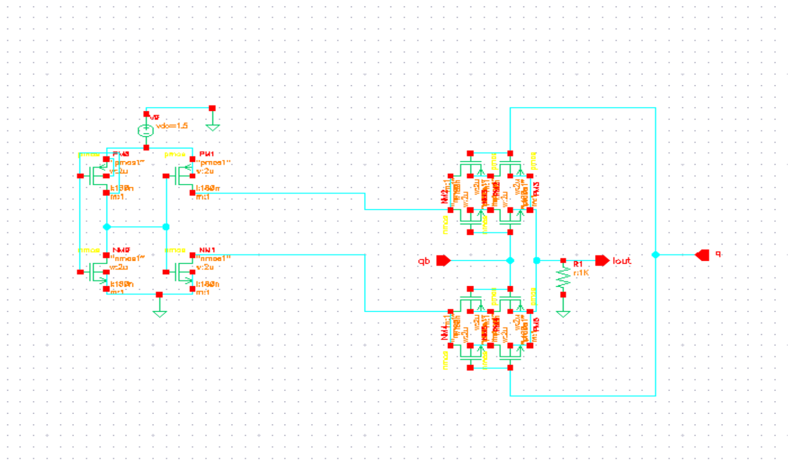

Figure 7. Current mode Digital to Analog converter

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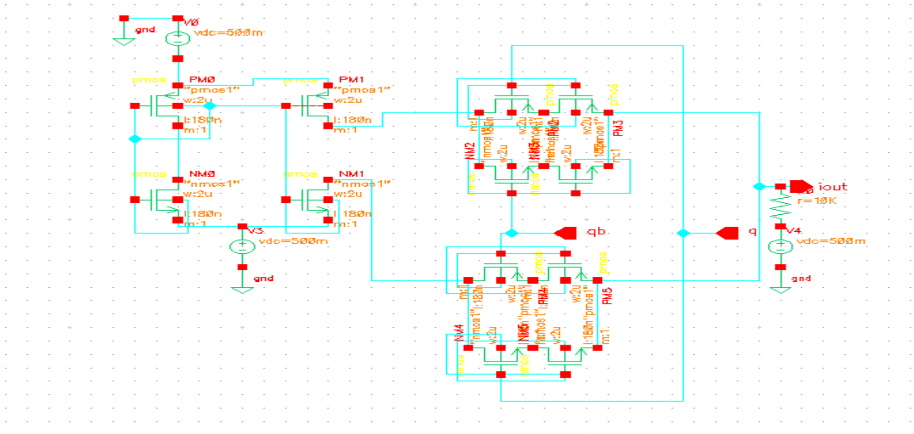

Figure 8. DTMOS based new D to A converter

3.3 MODULATOR DESIGN

By making the combinations of number of filters, number of Digital to Analog converters and number of comparator, different modulators has been designed. This modulator contains a filter, a quantizer (which contains a comparator and D-latch) and Digital to Analog converter.

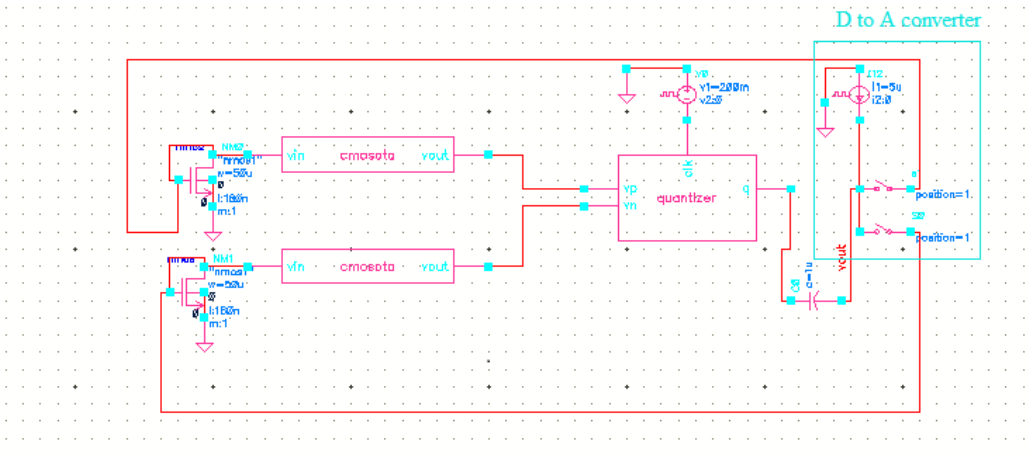

Figure 9. OTA based Modulator with Digital to Analog converter.

3.4 COMPARATOR DESIGN

Old comparator design [1] has been replaced by a new comparator that has been proposed in [5]. After that DTMOS technology has been applied to the new current mode comparator.

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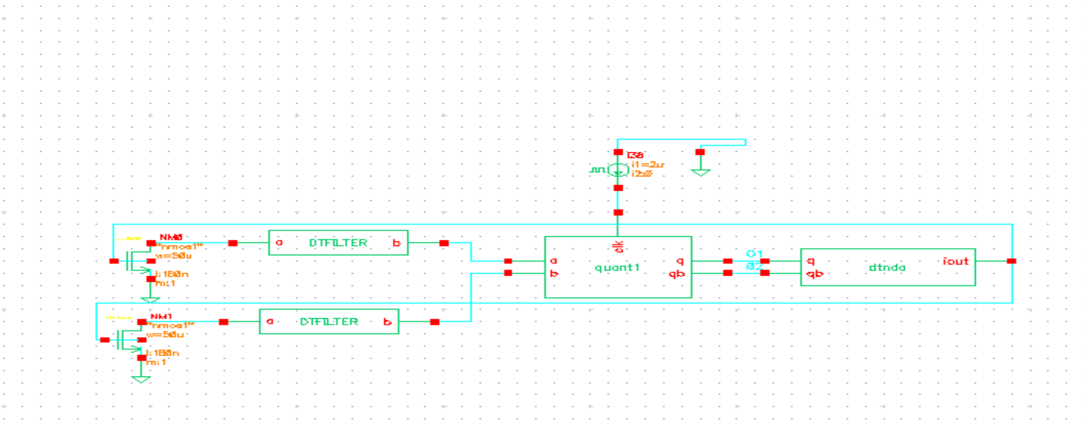

Figure 10. DTMOS based sigma delta modulator

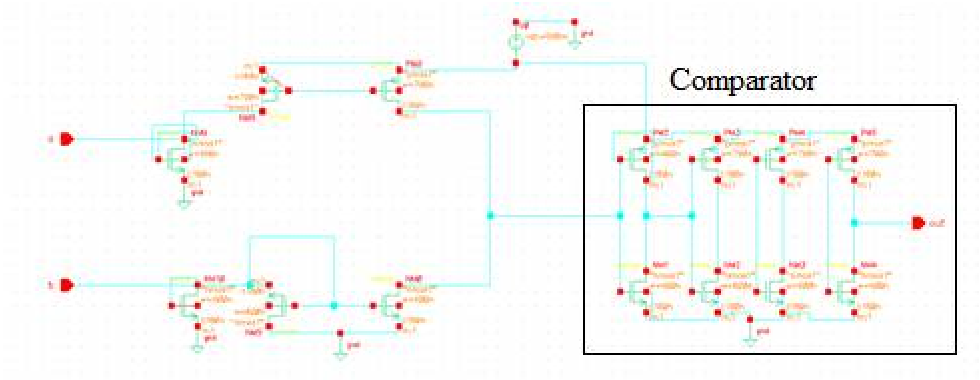

Figure 11. Current mode comparator

Figure 11 represents a current mode comparator in the block. To make it work in current mode, Current input has been applied to a & b but comparator has a voltage type input so another current to voltage converter circuit is used. In figure 12, DTMOS technology has been applied to the comparator in figure 12.

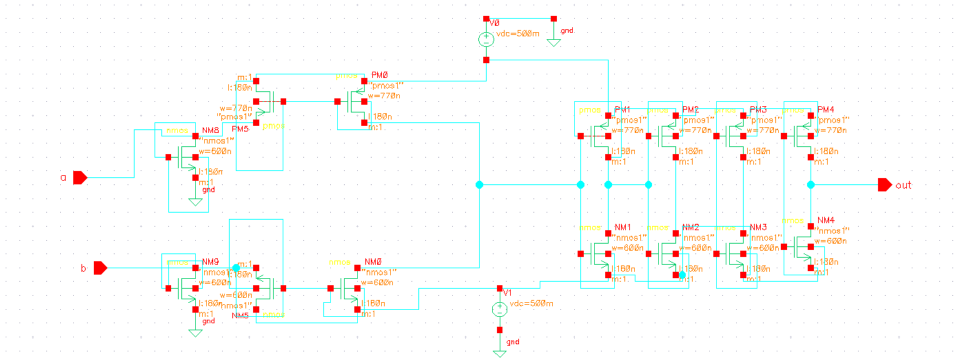

Figure 12. DTMOS based Current mode comparator.

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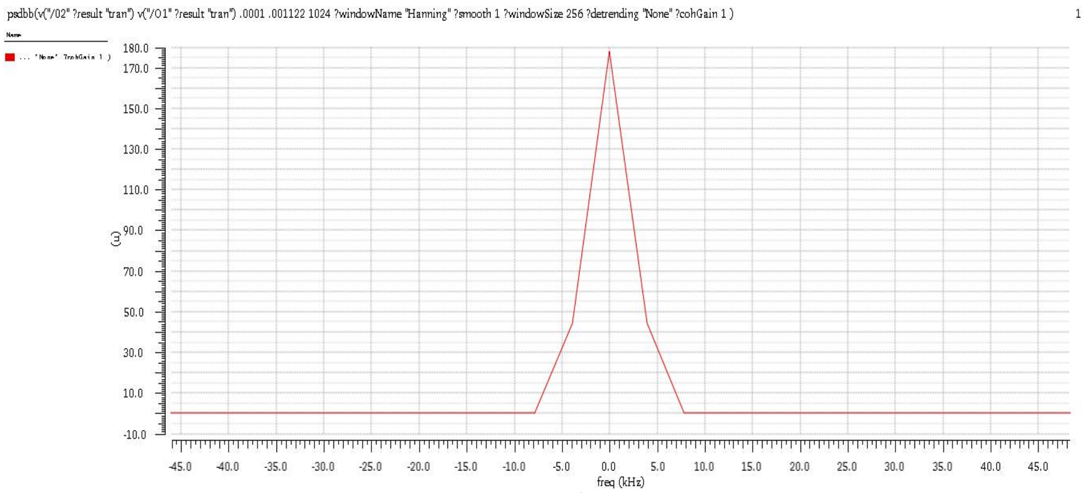

Figure 13. PSD of Modulator

IV.RESULTS AND DISCUSSIONS

4.1 PSD COMPARISION

	With comparator		With DTMOS comparator	
	Power	**Frequency**	**Power**	**Frequency**
Current mirror D to A converter	177 W	10KHz	185 W	10KHz
DTMOS current mirror D to A converter	225 W	10KHz	237 W	10KHz
New D to A converter	180W	8KHz	195 W	8KHz
DTMOS new D to A converter	695 W	8KHz	725 W	8KHz

Table 4.1: PSD comparision of different Modulators.

It is clear from table 4.1 that after applying DTMOS technique to D to A converter, strength of signal has been increased.

4.2 SIGNAL TO NOISE RATIO

After calculating gain of simple current mode comparator, the analysis of DTMOS based comparator has been performed. First transient analysis is performed than by doing the AC analysis, Gain has been calculated as vout/vin versus frequency. Now SNR is calculated by taking noise analysis than calculating SNR in dB. After calculating all SNR values, comparison between the modulators on the basis of SNR value has been performed.

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	With DTMOS Comparator		With Comparator	
	Peak value	**Current**	**Peak value**	**Current**
1. Current mirror D to A converter	675 dB	10^{-9}A	674 dB	$10^{-5.5}$A
2. DTMOS Current mirror D to A converter	654.75 dB	10^{-8}A	600 dB	10^{-8}A
3. CM D to A conv.	675 dB	$10^{-6.61}$A	650 dB	10^{-5}A
4. DTMOS CM D to A converter	675 dB	$10^{-5.4}$A	652 dB	$10^{-5.35}$A

Table 4.2: SNR comparison of ∑Δ modulators.

SNR comparison of different ∑Δ modulator has been defined in table 4.2. By using DTMOS technique SNR has been improved.

4.3 COMPARATOR

Transient analysis of new current mode comparator and DTMOS based current mode comparator has been done using PSPICE. After that AC analysis has been performed for both comparator and DTMOS comparator to calculate the gain. By changing the length of PMOS and NMOS transistors provided in the circuit of comparator, better results has been calculated in terms of rise and fall time. Going forward to calculate other characteristics, after working on D to A converters, comparators has been studied and designed on the basis of DTMOS technology.

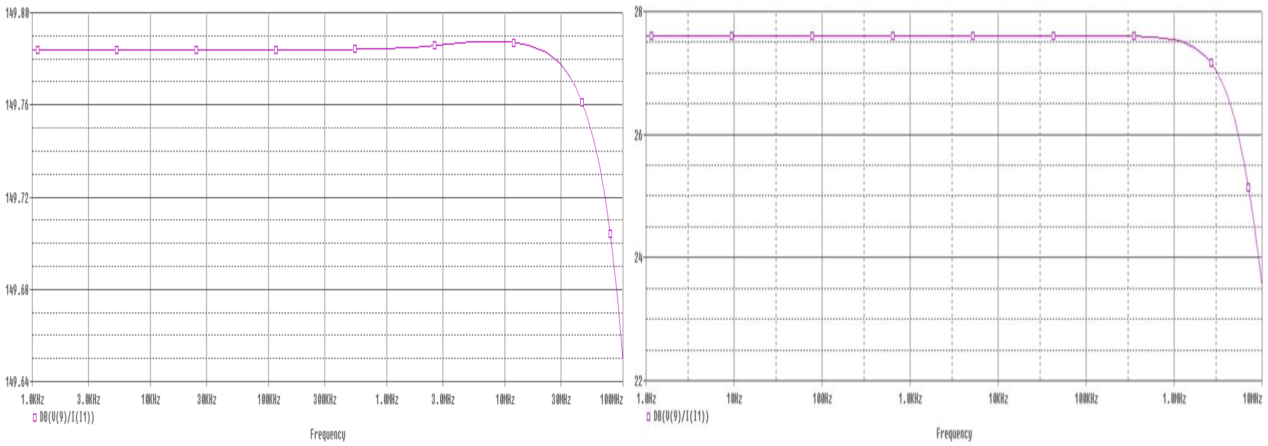

Figure 14.Gain(dB) VS frequency of 1) new comparator, 2) DTMOS comparator

4.3.1 PROPERTIES OF COMPARATOR

By comparing DTMOS comparator with current mode comparator, it has been analyzed from table 4.3 that rise time, fall time and propagation delay has been improved by using DTMOS comparator. Both comparator and DTMOS comparator are working on 0.18 um technology but power supply of normal comparator is about 1.2 volts and for DTMOS comparator it is around 0.5 volts although DTMOS circuits can also work on 0.2 volts. Gain of DTMOS comparator is reduced and there is better gain provided by normal current mode comparator. Power dissipation has also been reduced in DTMOS comparator.

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Properties	**Comparator**	**DTMOS Comparator**
Rise time	2.10nsec	2.47nsec
Fall time	1.33nsec	2,52nsec
Delay	158.24nsec	292.3nsec
Power dissipation	1.49E-07	8.18E-06
Gain	149.77(30MHz)	27.2(4MHz)
Power supply	1.2v	0.5v
Technology	0.18um	0.18um

Table 4.3:properties of Comparator and DTMOS Comparator.

VI.CONCLUSION

In comparison of DTMOS based sigma delta modulator and a simple sigma delta modulator, It has been concluded that better PSD results and better SNR Ratios had been obtained. Properties of comparator and DTMOS comparator have been compared. Gain and power consumption of comparator is better than the gain of DTMOS comparator but other properties like rise time, fall time, propagation delay of DTMOS comparator with 0.5V supply voltage is better than the normal comparator with supply voltage of 1.2V. In OTA based modulator and DTMOS based modulator; gain can be adjusted by adjusting power supply and reference current. Better results in terms of rise time and fall time in case of comparison of different design of D to A converter. These modulators can be used in biomedical application and also in communication field where sigma delta modulators are popular.

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