Design of OTA Based Chebyshev 5^{th} Order Low Pass Filter in 0.18µm CMOS Technology

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1. Abstract: The design of OTA based low pass filter for video applications in Broadband Communication is described in this paper. A low-pass, fifth-order Chebyshev filter based on the Folded Cascode Operational Transconductance Amplifier in 0.18 um CMOS process is designed. Folded Cascode OTA is chosen as it allows shorting of input and output terminals with negligible swing limitations. The designed OTA has a DC gain of 72.75dB and provides a Unity Gain Bandwidth of 17MHz.The filter designed using this OTA has a passband frequency response of 9.2MHz and gain of 0dB. Design and simulation of the circuit is done in Cadence spectre environment using UMC 0.18 µm CMOS technology.

Keywords: Analog IC design, Folded Cascode OTA, Chebyshev low pass filter.

2. Introduction

A filter is defined as an electric network, which passes or allows unattenuated transmission of electric signal within certain frequency range and stops or disallows transmission of electric signal outside this range. The term Chebyshev refers to a type of filter response, not a type of filter. Chebyshev filters have the property that they minimise the error between the idealised filter characteristic and the actual over the range of the filter, but with ripples in the passband. As the ripple increases (bad), the roll-off becomes sharper (good).The response of Chebyshev filters is based on the minimization of the maximum error in the entire passband, resulting in passband ripples with equal amplitude. The greater the ripple amplitude allowed, the steeper the transition roll-off. Chebyshev filters are also known as "equiripple" or "minimax" filters because of their characteristics.

The operational transconductance amplifier (OTA)is basically an op-amp without output buffer.The bias voltage in an OTA controls the bias current flowing through the current mirror circuit, which in turns affects the "gm". All the standard filter parameters of interest are directly proportional to "gm" of the OTA.The primary advantage of folded structure lies in the choice of voltage levels because it does not "stack" the cascode transistor on the top of the input device. The folded cascade does not require perfect balance of currents in differential amplifier because excess DC current can flow into or out of current mirror.

3. Circuit Implementation

3.1 Folded Cascode CMOS OTA Design:

Design of OTA is very important to get accurate filter results. The OTA is characterized by various parameters like Gain at dc (A_V),Unity gain bandwidth(UGB),Input common mode range (Vin (min) and Vin (max)),Load capacitance (C_L).All the sources are connected to their bulk reducing the body bias effect to zero. The input voltage is applied at one end and the other end is grounded. Because the drains of M1 and M2 are connected to drains of M4 and M5, a positive input common mode voltage that can be achieved by using current source loads is achieved. For the maximum gain to achieve, all the transistors are made to work in saturation region.

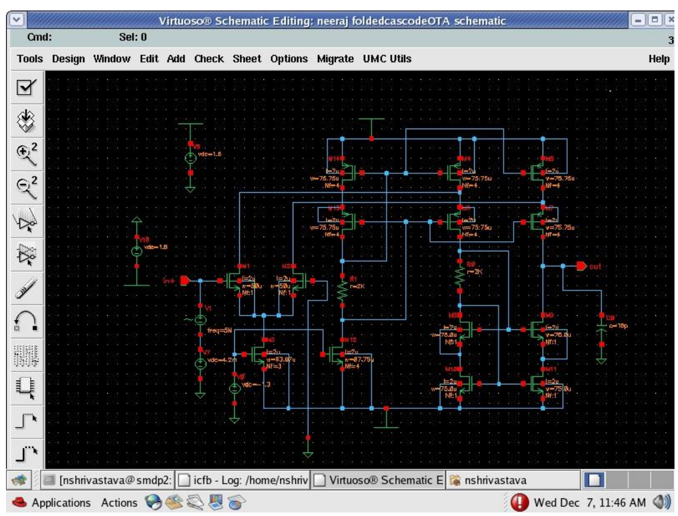

Figure 3.1 Schematic of CMOS OTA

Table.3.1 CMOS Transistor sizing for OTA Design

S. NO.	DEVICE	W/L(um)
1	M1,M2	50/2.0
2	M3	281/2.0
3	M4,M5,M6,M7	303/2.0
4	M8,M9,M10,M11	75/2.0
5	M12	351/2.0

4. Result of OTA:

4.1 Gain and Phase of OTA:

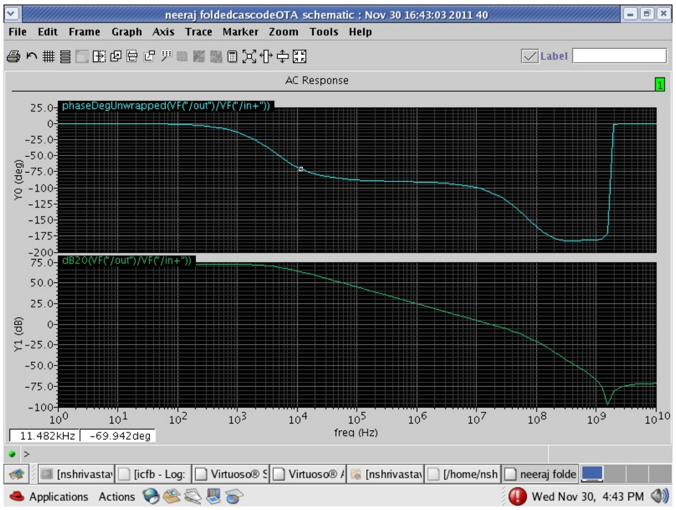

Table.4.1 SUMMARY OF EXPERIMENTAL RESULTS

S.NO.	Experimental	Value
1	VDD	1.8V
2	Gain	72.75 dB
3	3dB frequency	1kHz
4	Input AC supply	2V,5MHz
5	Unity Gain Frequency	16.699 MHz
6	Load capacitance	15pF
7	Input Offset Voltage	4.2mV
8	Input Bias Voltage	-1.3V
9	Gain Margin	36.85dB
10	Phase Margin	73.64^0

5. Architecture of Chebyshev Low Pass Filter

Figure 5.1 shows the schematic of Chebyshev Low pass filter using the Folded Cascode OTA. All the passive components .i.e. resistors (floating and grounded) and inductors are implemented using Folded Cascode OTA and hence an active network of 5th order Chebyshev filter is obtained. The order of a passive filter is equal to the number of reactive components used in the network. Here two inductors and three capacitors form the 5th order network. It uses in total eleven OTAs with five capacitances in between. A power supply of 2 V AC and an offset voltage of 4.3 mV are used.

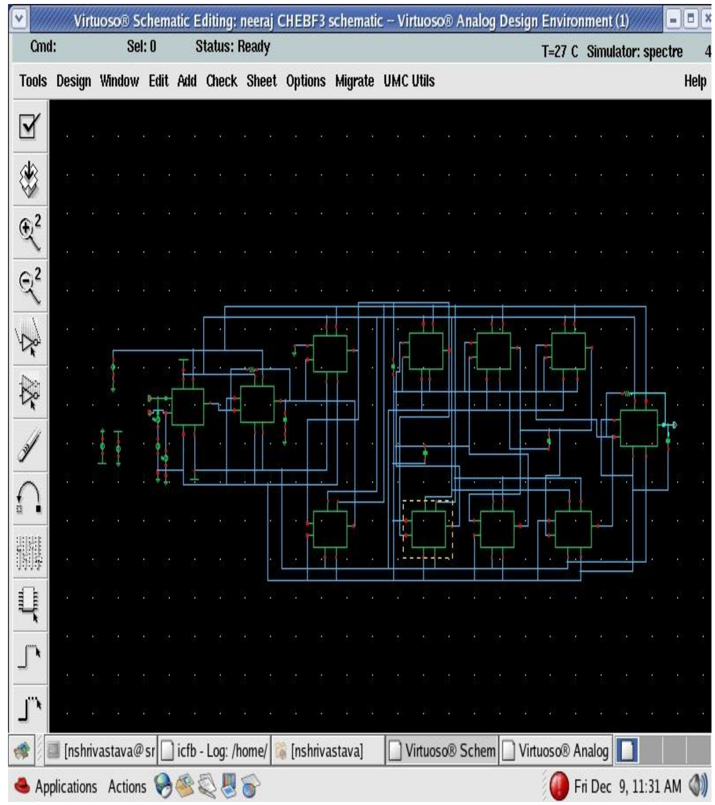

Figure 5.1 Schematic of Chebyshev 5^{th} order Low pass filter

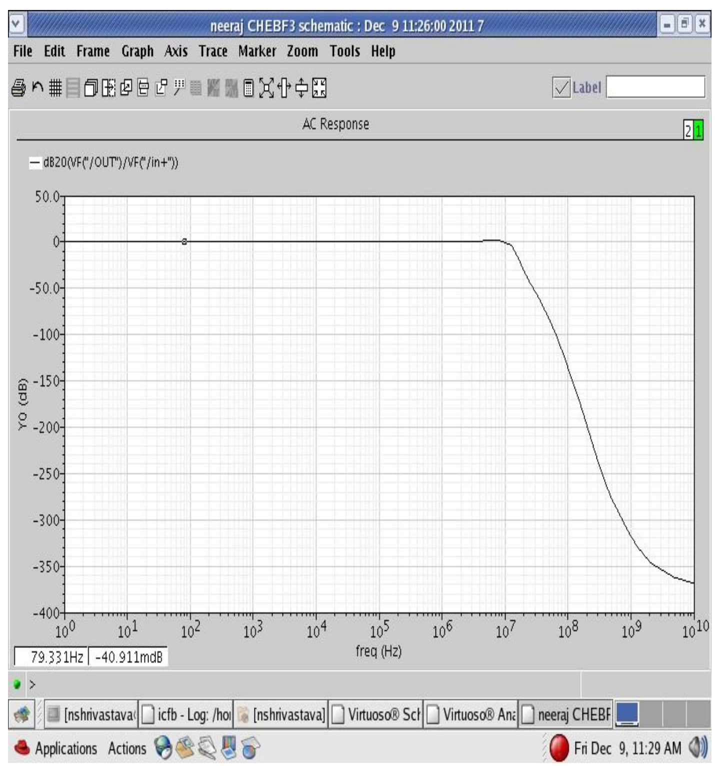

Figure 5.2 AC Respone of Chebyshev Low pass filter:

Table.5.2 SUMMARY OF EXPERIMENTAL RESULTS

S.NO.	Experimental	Value
1	Technology	0.18um CMOS Process
2	VDD	1.8V
3	Gain	0 dB
4	Passband Frequency	9.2MHz
5	C_1,C_2,C_3,C_4,C_5	1pF
6	Input Offset Voltage	4.3Mv
7	Input AC supply	2V,5MHz
8	Input Bias Voltage	-1.3V
9	Passband Ripple	2.081dB

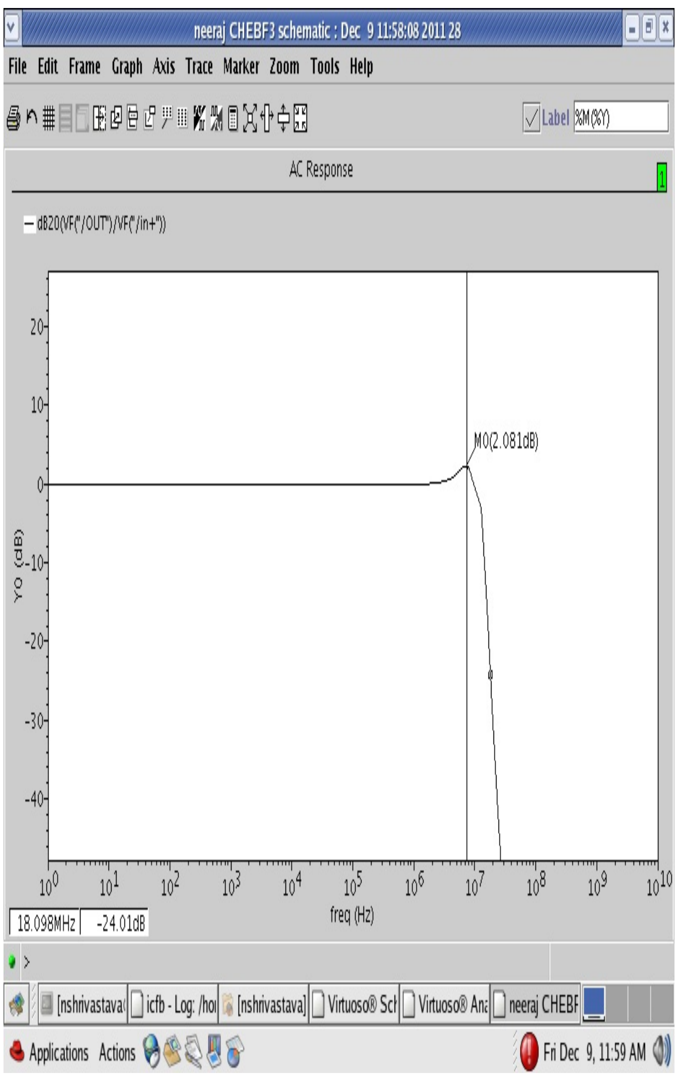

Figure 5.2 Enlarged view of AC Respone to show ripples

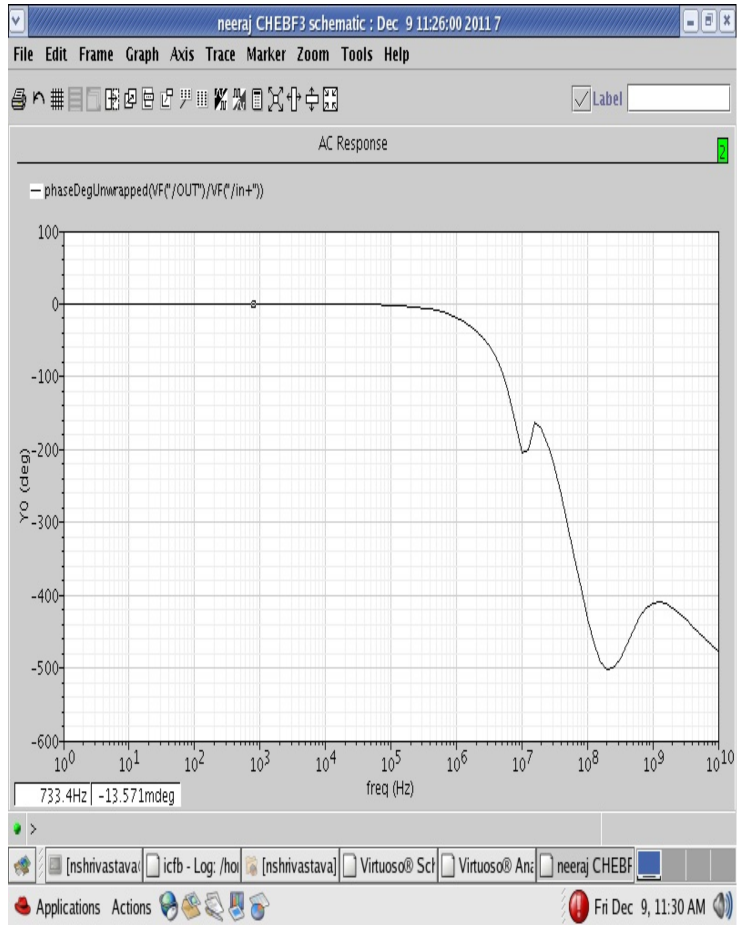

Figure 5.2 Phase Response of Chebyshev 5th order LPF

6. Conclusion

In this design, a low-voltage Chebyshev Low Pass Filter is designed using a Folded Cascode OTA. It shows a maximum gain of 0 dB and a 3dB-frequency of 9.2 MHz, when the OTA used is biased at a voltage of –1.3 V, with all the transistors in saturation. This much 3dB-frequency is pretty good for the video applications.As the ripples in passband characterize the Chebyshev filter, ripples of 2.081 dB is achieved, as shown (fig.5.2) by the enlarged view of the AC response.

7. References:

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