March- April 2020
ISSN: 0193-4120 Page No. 3708 - 3713

Design of FGMOS based OPAMP and its Implementation in Low Pass Filter and Bandpass Filter

S.Kiruthiga[1], U.Venkateshkumar[2],M.Navin kumar[3], M.Gokul[4]

[1]currently working as Assistant Professor in the department of Electronics and Communication Engineering,Sri Krishna College of Technology,India, PH-0422-2604567. *E-mail:kiruthiga261992@gmail.com*

[2]currently working as Assistant Professor in the department of Electronics and Communication Engineering, Sri Krishna College of Technology, India, PH-0422-2604567. *E-mail:uvenkatesh2002@gmail.com*

[3]currently working as Assistant Professor in the department of Electronics and Communication Engineering, Sri Krishna College of Technology, India, PH-0422-2604567.*E-mail: navinkumar.m@skct.edu.in*

[4]currently pursuing his bachelor of engineering degree from Sri Krishna College of Technology, India, PH-0422-2604567.

E-mail:17tuec042@skct.edu.in

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Abstract:

Operational amplifiers (Opamp) are the key parts of construction in most of the digital and analog circuit applications, leading to the need for the researchers to work on the bandwidth and gain to meet out the demands of integrated circuits market.The proposed work is Floating Gate MOSFET (FGMOS) based two stage Opamp construction in order to achieve high gain, less offset voltage with better bandwidth. Such Opamp finds wider usage in integration, summation units of synapse multiplier circuit, active filters. Bandwidth utilization can be increased from MHz range to GHz range by usage of FGMOS based Opamp. The proposed work achieved a bandwidth of 1.337 GHz and gain of 160db with 1.1pF load capacitance which are capable of driving large load capacitances. The above work is simulated in Cadence Virtuoso with 180 nm technology with +1.8V/-1.8V supply voltage.

Keywords: *Operational amplifier, Floating Gate MOSFET, Low pass filter, Band pass filter, Gain, Current Mirror, Gain Bandwidth Product.*

I. INTRODUCTION

DESIGNof circuits with low power consumption and increase in performance like increase in slew rate, CMRR, gain, bandwidth become necessary with portable devices. Operational amplifier became the important building blocks of circuit design in analog domain. Opamp has very high gain due to negative feedback closed loop circuit. When large gains are required for certain design, multiple stages of opamp are combined. By proper choosing of W/L for 180nm process of MOSFET based Opamp, various parameters which are best obtained are DC open-loop gain of 74.89dB, Unity gain bandwidth of 7.26MHz, Phase margin of 48°,Power dissipation of 0.402mW, Supply voltage of ±1.8V[1].Still higher phase margin can be achieved by growing the compensation capacitance which leads to more area and higher dynamic power consumption[17].

Activation function-based circuits which uses

TEST Engineering & Management

March- April 2020
ISSN: 0193-4120 Page No. 3708 - 3713

synapse multipliers for Artificial Neural Networks (ANN) requires efficient opamp with high gain given in [4,16]. Efficient Opamp is designed by using a multi-terminal device - FLOATING GATE MOSFET which replaces conventional MOSFET for the design of analog and digital circuits to achieve high gain, preferable bandwidth and required CMRR.

II. FLOATING GATE MOSFET (FGMOS)

Density of the transistors integrated into the circuit gets increased

day by day but the constraint with it is less chip area. A demand for portable electronic devices arised with usage of analog circuits with low power supply, high reliability and high gain. In order to get less power operated devices, threshold voltage (V_t) parameter has to be focused and need to be kept very minimum. Commonly used MOSFETs generally have high threshold voltage taking longer time to switch ON [2]. Without varying the feature size, slew rate of FGMOS can be improved just by controlling switching threshold [3].

The data storage can be done by the usage of FGMOS in Electrically Erasable Programmable Read-Only Memory (EEPROM), Erasable Programmable Read Only Memory (EPROM) and FLASH memories because of its improvement in storage devices with long-term non-volatile information retaining capacity. The size of the input electrode can be determined based on the number of capacitors connected to floating gate which is varied by the factor

$C_i = (\varepsilon_{sio2}/t_{sio2})A_i$, where ε_{SiO2} indicates the permittivity of the silicon dioxide, t_{SiO2} is thickness of the silicon dioxide between Floating gate and the number of inputs and A_i is area of capacitor plate at the input.

Floating gate MOSFET can be constructed from the ordinary MOSFET where additional capacitors are introduced between the normal gate and the multi-input gate. Based on the biasing of the multi-input gates of FGMOS, threshold voltage can be lowered. Floating gate is inside the island of highly resistive material so this node can be acting like floating node. Based on the programming of FGMOS the capacitors which are attached to the floating node gets charged varyingly will shift the threshold voltage through which the device switching is controlled as shown in [6],[7],[8],[9].

Floating gate has voltage as given in [11] as

$$V_{FG} = \sum_{i=1}^{N} C_i V_i + C_{fd}V_{DS} + C_{fs}V_{SS} + C_{fb}V_{BS} + Q_{FG} \Big/ C_T \quad (1)$$

Where $C_T = \sum_{i=1}^{N} C_i + C_{fd} + C_{fs} + C_{fb}$

$\sum_{i=1}^{N} C_i$ = Sum of the input capacitances at the floating gate.

I FLOATING GATE MOSFET (FGMOS) BASED OPAMP

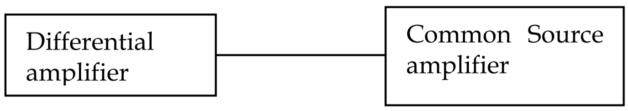

Figure 1. Two stages of Opamp

Floating gate with capacitance present at both ends of the Opamp can be biased with various inputs to improve the bandwidth of the design. Current mirror loads can be used to design a differential pair for the Opamp. Fig.1 shows two stages of conventional Opamp. The floating gate MOSFET used in the Fig.2 has two inputs. One input is fed to the reference voltage, V_{DD} and other input is fed as common input, V+ or V-. The stability of the opamp is also ensured with negative feedbacks applied. The opamp consist of eight transistors in which two transistors are Floating Gate MOSFETs. In the first stage, NMOS transistors g_m has dependency on the gain of the opamp whereas PMOS transistors are designed to have high output resistance to accomplish larger gain. The proposed Floating Gate MOSFET based Opamp uses DC current of 22 uA

TEST Engineering & Management

March- April 2020
ISSN: 0193-4120 Page No. 3708 - 3713

for the design. CMRR can be obtained by connecting the V+ and V- terminal of the input sources to common voltage source of 1V with AC amplitude of 1mV and frequency of 1 KHz. AC simulations results of operational amplifier shows that frequency range covered is very high which is targeted on mobile communication and broadcasting applications. Monte Carlo simulation based results can be extracted for the proposed Floating Gate MOSFET based opamp which is subjected to process corner variations[5]. Unity gain frequency of 250 MHzis attained usingFloating Gate MOSFET based opamp which is higher compared to two stage conventional opamp.

Biomedical applications uses various filters to filter out the weak signal present with noise. Those filters should have broad cutoff range varying from minimum to maximum frequency. The cut off frequency is set based on the necessity of the application. When filters are designed with Opamp which uses MOSFET as the main device, excellent amplification is produced but the frequency range cannot be varied as the MOSFET threshold is getting fixed based on technology which is used. MOSFET has higher switching threshold voltage which reduces the performance in analog as well in digital circuits. The proposed Floating Gate MOSFET based Opamp finds its application in filters. Low Pass Filter in Fig.3 filters out the signals which is lower than that of threshold and attenuates the signals with higher cutoff frequency. It is used widely in audio applications. Band Pass filters in Fig.4 filters out a band of signal.

II RESULTS AND CONCLUSION

Fig.2 details the design of Low Power, Low Voltage-FGMOS proposed Floating Gate MOSFET based dual stage Opamp with low load Capacitance and high gain. Fig.3 and Fig.4 details the design of filters.

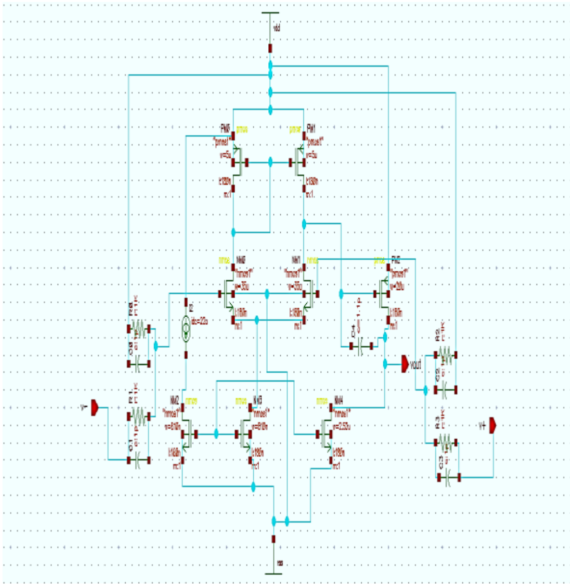

Figure 2. Floating Gate MOSFET OPAMP

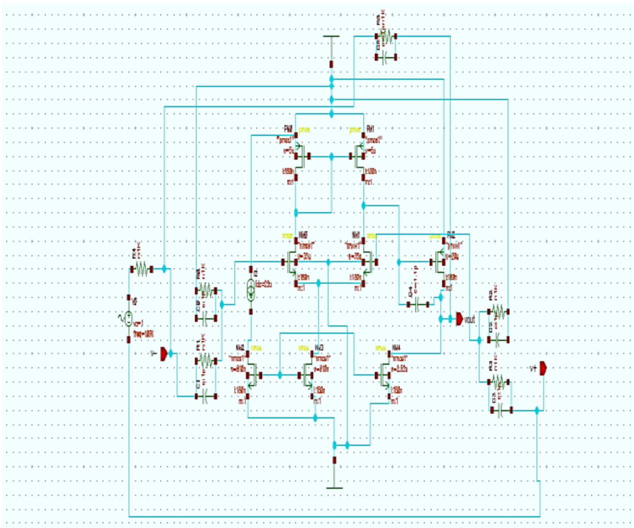

Figure 3. Low Pass Filter(LPF)

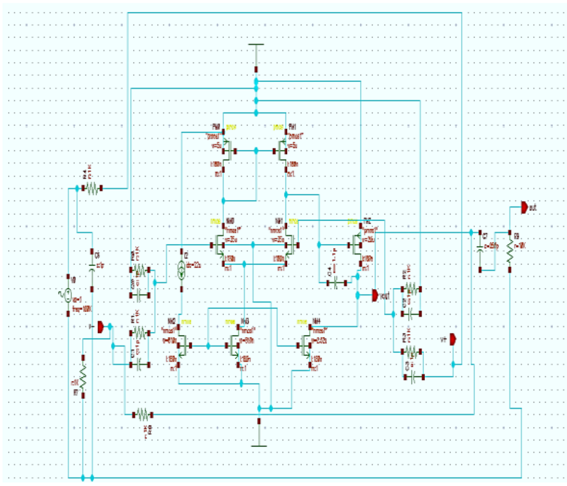

Figure 4. Band Pass Filter(BPF)

TEST Engineering & Management

March- April 2020
ISSN: 0193-4120 Page No. 3708 - 3713

AC analysis is performed at various stages of operation and found that Opamp operates in saturation region. Various parameters are observed which is comparatively better than the conventional Opamp. Compared to three stage Opamp, proposed Floating Gate MOSFET based dual stage Opamp has less number of transistors that contributes to less area and power with high gain of 160dB.The load capacitance used in this circuit is 1.1pF which is very low when compared to conventional Opamp which uses MOSFETs in the design. Low pass and Band Pass filters designed using Floating Gate MOSFET gives wide range of bandwidth. Phase Margin of Low pass filter and Band Pass filter constructed are 79.84 deg and 121.8 deg. 3-db Bandwidth for low pass filter is 346KHz which filters the high frequency signals and 3-db Bandwidth for Band pass filter is 899.9MHz. Table.1 shows the simulation results of proposed Floating Gate MOSFET based Opamp and filters constructed with the same.

Analysis of Magnitude and phase plot of Floating Gate MOSFET based Opamp, Low pass filter, Band pass filter are shown in Fig.5, Fig.6, Fig.7. Floating Gate MOSFET based Comparators, multipliers also find its applications using the proposed Floating Gate MOSFETOpamp design.

TABLE 1RESULTS AND COMPARISON

Parameter	ref[15]	FGMOS opamp	LPF	BPF
Supply Voltage	+1.8V to -1.8V	+1.8V to -1.8V	+1.8V to -1.8V	+1.8V to -1.8V
Unity Gain frequency	30.19 MHz	250 MHz	5.843 MHz	1.678 MHz
Gain	81.32 dB	160 dB	30 dB	29 dB
Phase Margin	50.68 deg	63.01 deg	79.84 deg	121.8 deg
CMRR	81.09 dB	93 dB	33.14 dB	27.69 dB
Bandwidth	-	1.337 GHz	181.4 KHz	899.9 MHz
Load Capacitance	1pF	1.1pF	1.1pF	1.1Pf
3-db Bandwidth	5.41 KHz	1.2 MHz	346 KHz	274.72 MHz
GainBandwidth product	439.94 KHz	221.4 MHz	5.790 MHz	451.3 MHz

March- April 2020
ISSN: 0193-4120 Page No. 3708 - 3713

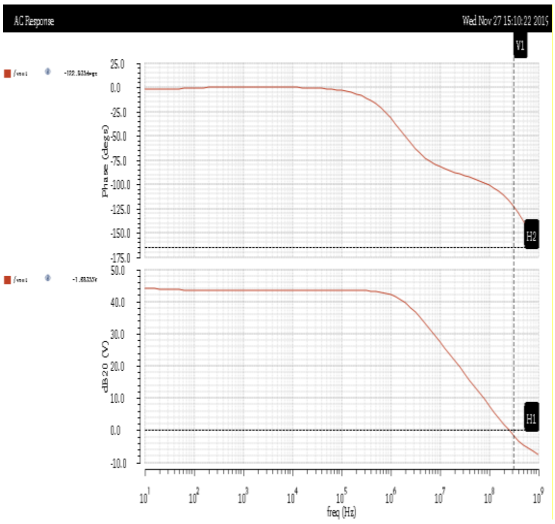

Figure 5. Magnitude And Phase Plot (FLOATING GATE MOSFET based OPAMP)

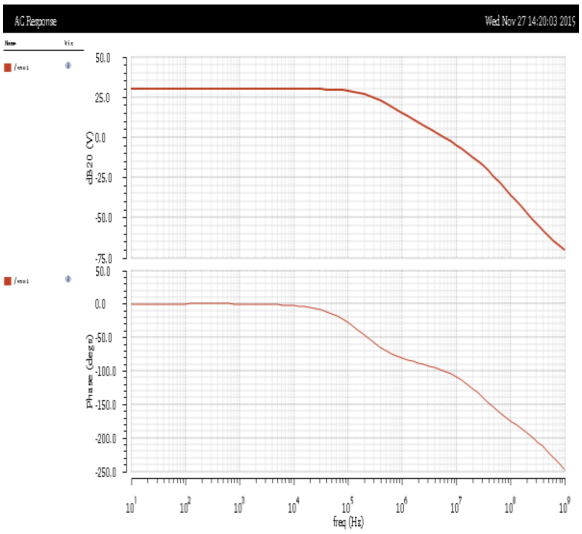

Figure 6. Magnitude And Phase Plot(LPF)

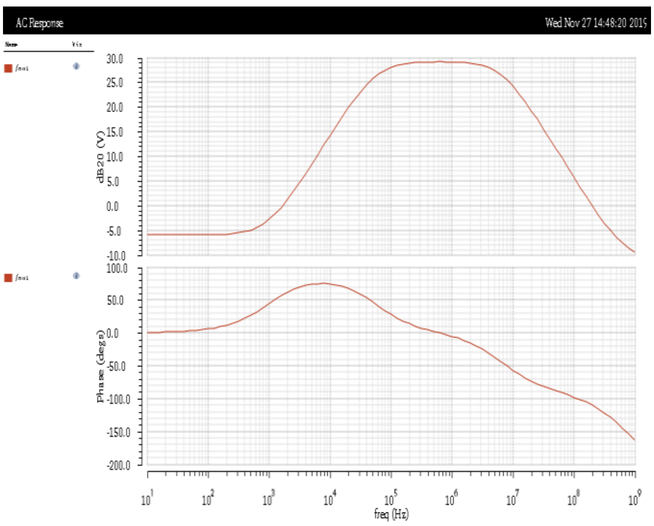

Figure 7. Magnitude And Phase Plot (BPF)

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