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HIGH FREQUENCY CMOS OPERATIONAL TRANSCONDUCTANCE AMPLIFIER

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ABSTRACT : *Previous OTAs seldom worked over 200MHz whereas, the higher frequency OTA can be used as basic building block in several RF as well as microwave applications. The performance analysis of conventional OTA techniques, using advanced process technology that can break the previous frequency barrier is a key objective of this paper. A Fully differential OTA is designed and analyzed in this paper which has Transconductance of approx. 8 ms over GHz Frequency range and worked on supply voltage of 1.4V. The OTA has been simulated by using ADS Tool with 180 nm as target technology. Different topologies of OTA have been studied and analyzed. The appropriate topology which has a perfect balance between complexity and performance is suggested. The research includes analysis and comparison of OTA topologies from the point of view of effect of technology scaling on various performance parameters such as Frequency range, Gain, Power Consumption, Supply Voltage, Temperature, etc.*

Keywords – *CMOS, frequency range, Operational Transconductance Amplifier (OTA), Supply Voltage, Transconductance.*

I. INTRODUCTION

Today operational amplifiers (OPAMPs) are widely used as basic building blocks in implementing a variety of analog applications from amplifiers, summers, integrators, and differentiators to more complicated applications such as filters and oscillators. OPAMPs work well for low-frequency applications, such as audio and video systems. For higher frequencies, however, OPAMP designs become difficult due to their frequency limit [1],[2].At those high frequencies, operational Transconductance amplifiers (OTAs) are deemed to be promising to replace OPAMPS as the building blocks. The Operational Transconductance amplifiers (OTA's) are important building blocks for various analog circuits and systems. OTA is an amplifier whose differential input voltage produces an output current and hence it is a voltage controlled current source (VCCS).The best suited component for design of modern OTA is CMOS devices which has less power requirements. CMOS provides the highest analog-digital on-chip integration. As the feature size of CMOS processes reduces, the supply voltage has to be reduced for the reduction of power dissipation per cell. Supply voltage reduction guarantee the reliability of devices as the lower electrical fields inside layers of a MOSFET produces less risk to the thinner oxides, which results from device scaling. Currently, high frequency, high linearity, and low power are the three main concerns of CMOS OTAs.

II. SIMULATED OTA

Topology which can work at low voltage and higher frequencies is desired. The most important aspect of topology selection is improved Transconductance with better linearity at high frequencies.

The feed forward Cascode topology is preferred because it has a perfect balance between complexity and performance [4]. Figure 1 represents a differential input/output topology which has two PMOS Cascode and two NMOS Cascode. The transistors T9-T10 act as DC current source. The circuit arrangement is made in such a way that variation in output voltage is decreased. The topology results in high input output impedance and Transconductance. The performance parameters analyzed for various process technologies include Transconductance Gain (Gm), power consumption, frequency range, supply voltage etc.

It has been observed that Transistor T1, T4, T5 and T8 are in triode Region Whereas Transistor T2, T3, T6 and T7 are in Saturation region. In linear or triode region the MOSFET acts as Variable resistor and in

Saturation region MOSFET behaves like a constant current source. The Transistor T9 and T10 also operate in Saturation region in order to provide DC current.

The Transconductance gm can be found out from following equation:

$$gm = \frac{(\boldsymbol{I_{out+}} - \boldsymbol{I_{out-}})}{(\boldsymbol{V_{in+}} - \boldsymbol{V_{in-}})}$$

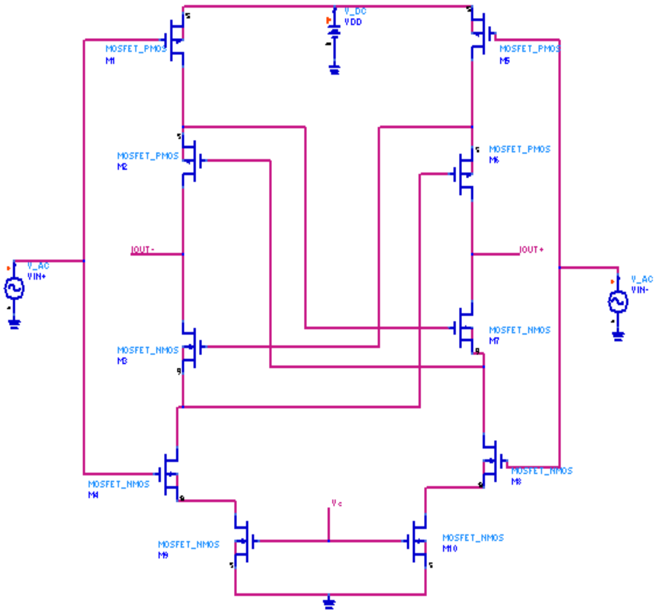

Figure 1: Feed forward Regulated Cascode OTA

III. SIMULATION RESULTS

3.1 Transient Analysis

For Transient analysis, a sine wave of 10 mVpp is applied at the input of OTA Terminals as shown in fig. 2 below and the total current swing is found to be 60 uA as shown in fig. 3. The positive input and negative input are 180° out of phase with each other.

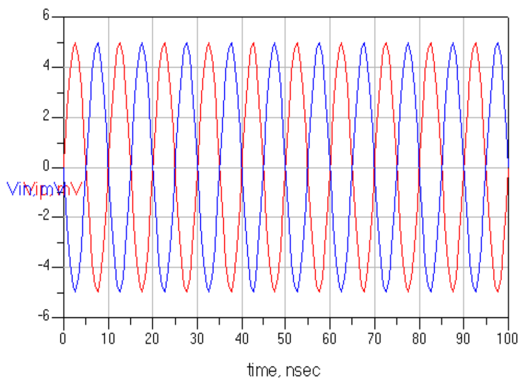

Figure 2. Differential Input Voltage in time domain

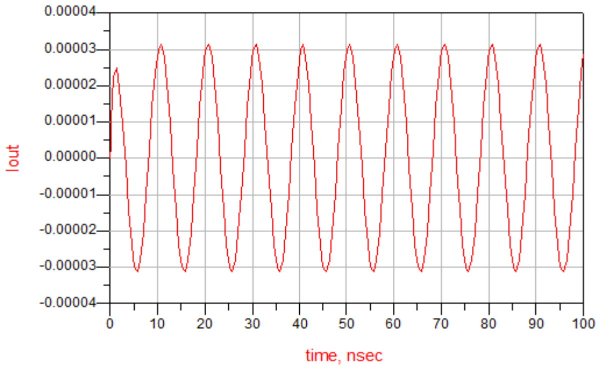

Figure 3. Differential output current in time domain

3.2 AC Analysis

For AC Analysis of the circuit, 1V ac Signal is applied at the positive and negative input of OTA. Fig.4 shows the Transconductance of simulated OTA with control voltage of -0.55V, supply voltage of 1.4 V and a load of 1 pF. It is seen that gm of nearly 8 mS is obtained which is Constant for Frequency 2.9 GHz.

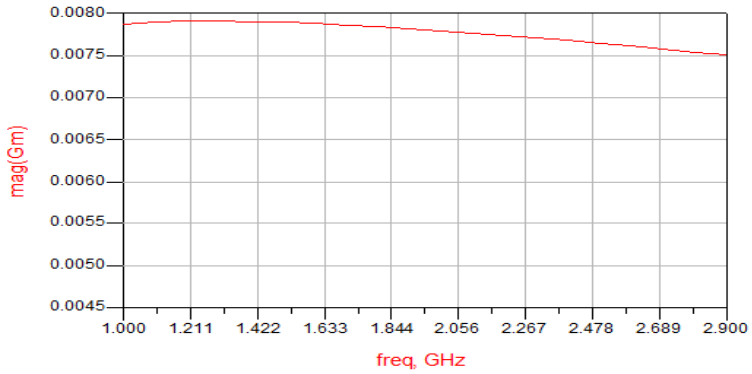

Figure 4. Simulated OTA's Transconductance

3.3. Parametric Analysis

In this analysis, effect of variation of one performance parameter of OTA is observed on the output. The effects of variation of input voltage (Vid), Frequency, supply voltage (Vdd) and temperature are studied and analyzed in this section of paper.

3.3.1 Effect of Input Voltage Variation on Output Current Swing:

The input voltage is varied from 1mV to 1V peak to peak and output swing is observed. Fig.5 below shows that for input voltage of 100mVp-p at same frequency, the output current swing is found to be 628uA. As input voltage increase, the output current swing also increase but it becomes non linear after certain point. The output is linear for input of 100 mV, for 1V input signal the output is distorted.

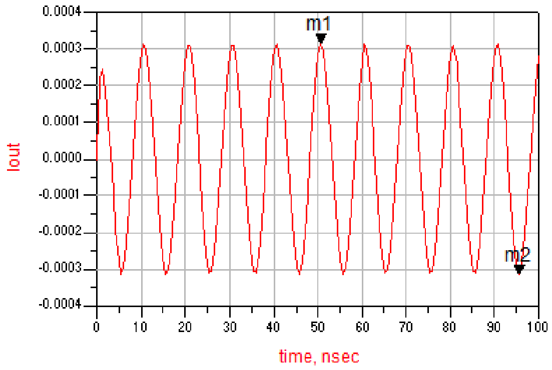

Figure 5: Output Current at 100 mVp-p

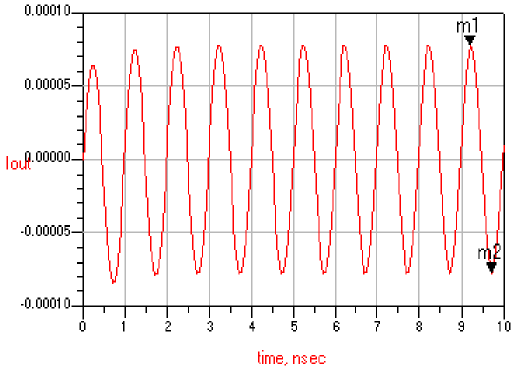

Figure 6: Output Current at 1 GHz

3.3.2 Effect of Frequency Variation on Output Current Swing:

For observing effect of frequency on output current swing, the input is fixed at 10mV and output current is plotted. Fig. 6 above shows that output current swing of 155 uA is obtained for same input voltage and output is still linear. It is observed that the output is linear for frequency range of 1MHz to 1GHz as seen from figures. As frequency increase the output swing also increase but it becomes non linear after certain point. For same input voltage if frequency is increased to 10 GHz, the output is non linear and distorted.

3.3.3 Effect of Supply Voltage Variation on output Current Swing:

For observing effect of supply voltage on output current swing, the input is fixed at 10 mV and output current is plotted. The supply voltage is varied from 1.1V to 1.6V and changes in output current are observed. Fig.7 below shows that output current swing of 182.72 uA is obtained for supply voltage of 1.5V. It is observed that the output is linear for supply voltage range of 1.1V to 1.5V. As supply voltage increases the output swing also increases but it becomes non linear after certain point. For same input voltage if Vdd is increased to 1.6V, the output is not linear and distorted.

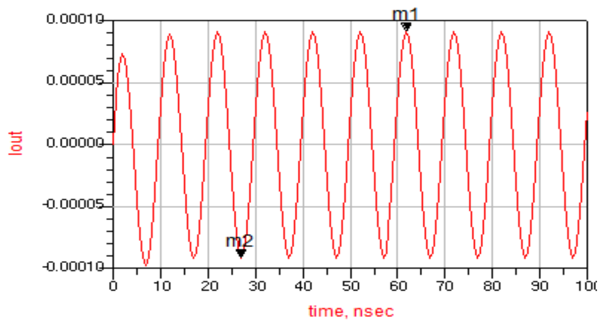

Figure 7: Output Current at 1.5V at Supply Voltage

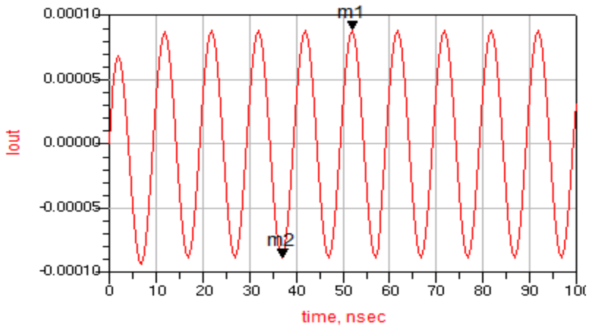

Figure 8: Output Current at 100^{o}C temp.

3.3.4 Effect of Temperature Variation on Output Current Swing:

For observing effect of temperature on output current swing, the input is fixed at 10 mV. The temperature is varied from -10^{o}C to +200^{o}C and changes in output current are observed. Fig.8 above shows that output current swing of 177.37 uA is obtained for temperature of 100^o C. It is observed that the output is linear for temperature range of -10^{o}C to 100^{o}C . As temperature increases the output swing also increases but it becomes non linear after certain point. For same input voltage if temperature is increased above 100^o C, the output is not linear and distorted.

IV. CONCLUSION

In this thesis, the Feed-forward Regulated Cascode Operational Transconductance Amplifier is analyzed using ADS Tool at 180nm as target technology. The OTA works on low voltage, high frequency of around 2.9 GHz and has large Transconductance of 8 mS which makes it very suitable for microwave frequency applications. When the characteristic lengths of CMOS devices are scaled down, both their channel delays and capacitive parasitic are reduced, which increases the cut off frequencies of the transistors. This ultimately results in increased bandwidth of OTA as can be seen from Table 1. In OTA design the high frequency, high linearity and low power are the three main concerns but tradeoffs have to be made among these aspects for designing of practical OTA circuits. The results obtained for this work for 180nm technology are as below:

Table 1: Simulation Results of This Work

CMOS Process Technology Used	Transconductance Obtained	Supply Voltage	Bandwidth Obtained
350 nm	0.76 mS	2 V	537 MHz
130 nm	2.15 mS	1.2 V	1.2 GHz
This Work	8 mS	1.4V	2.9 GHz

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