

Performance Analysis of CMOS OTA

Shireen T. Sheikh
Nagpur University,
Department of Electronics Engineering,
Ramdeobaba college of Engineering and
Management, India.

D.J. Dahigaonkar
Nagpur University,
Department of Electronics Engineering,
Ramdeobaba college of Engineering and
Management, India.

ABSTRACT

A Fully differential OTA is designed and analyzed in this paper which has Transconductance of 8ms over GHz Frequency range and worked on supply voltage of 1.4V. 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. 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 Gain, Power consumption, Frequency range, supply voltage, temperature, etc. The OTA has been simulated by using ADS Tool with 180nm as target technology.

KEYWORDS

Operational Transconductance Amplifier (OTA), CMOS, Transconductance, frequency range.

1. 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.

2. CLASSIFICATION OF OTA

According to their input/output topologies, they can be categorized into three types, i.e., single input/output, differential-input single-output, and differential input/output.

2.1. SINGLE INPUT OUTPUT

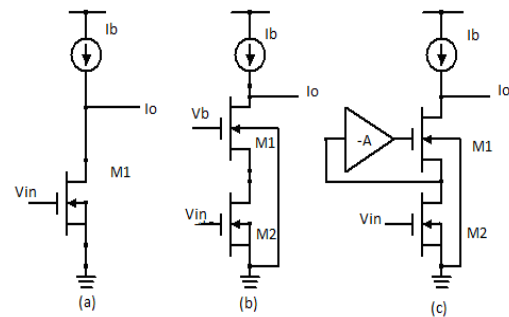


Figure1: OTA Topologies

Fig.(a) Indicates simple Transconductance amplifier where M1 is in saturation & converts input voltage to output current. It suffers from disadvantages such as low output impedance and linearity. Fig. (b) Indicates Cascode transconductor where M1 is in linear region & M2 provides isolation between I/O terminals. Advantages as compare to (a) are improved linearity and output impedance. Fig.(c) is a regulated Cascode feedback topology that makes use of negative feedback via amplifier 'A'. Any change in the source voltage is inversely amplified by the amplifier which nullify the effect of voltage change hence Linearity is improved. This topology results in better stability.

2.2. Differential OTAs

Fig.2 indicates Differential I/O topology of OTA. In this topology, two current mirrors are used to improve balance between differential paths. The current mirrors have size ratio B to boost output current by B-times. As v_{i+} increases it results in increase in value of i_{d+} , which is transferred to output side with B-times multiplication. Similarly, the change in i_{d-} , due to current mirror on right side it gets B-times as compare to i_{d-} .

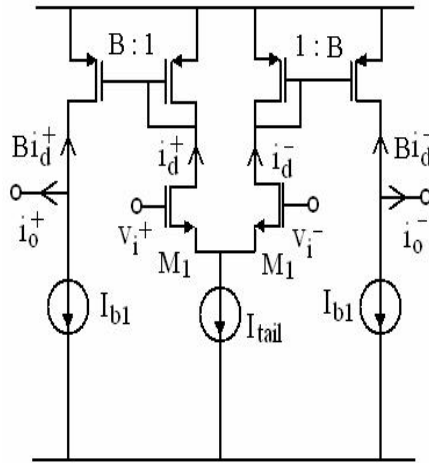


Figure 2: Differential I/O Topology of OTA

3. Feed- forward Regulated Cascode 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 3 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:

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

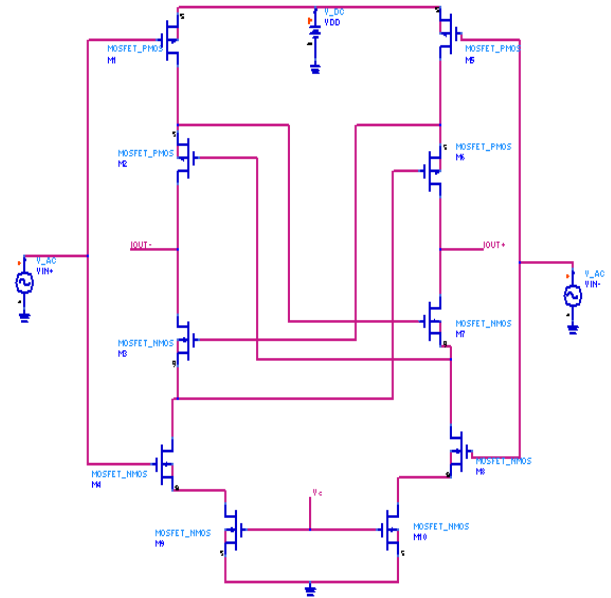


Figure 3: Feed forward Regulated Cascode OTA

4. EXPERIMENTAL RESULT

4.1. Transient Analysis

For Transient analysis, a sine wave of 10 mVpp is applied at the input of OTA Terminals as shown in fig.4 and the total current swing is found to be 60 uA as shown in fig.5. The positive input and negative input are 180° out of phase with each other.

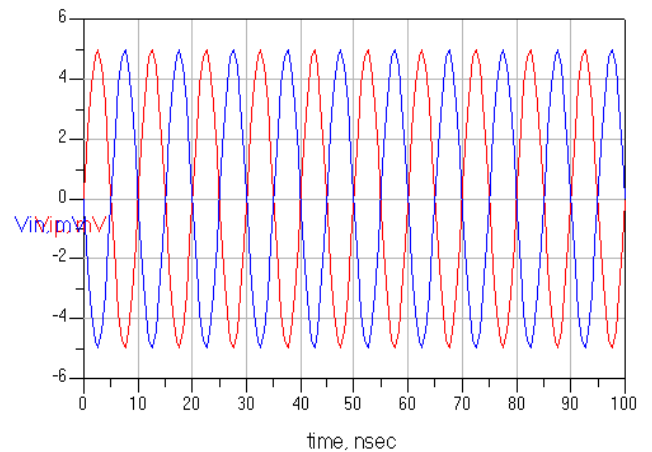


Figure 4. Differential Input Voltage in time domain

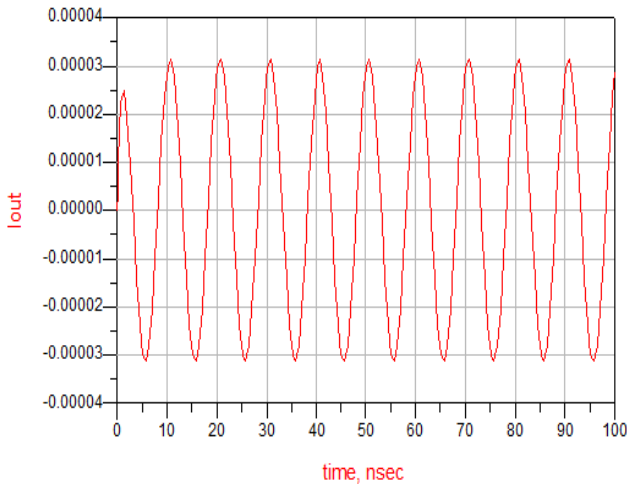


Figure 5. Differential output current in time domain

4.2. AC Analysis

For AC Analysis of the circuit, 1V ac Signal is applied at the positive and negative input of OTA. Fig.6 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.

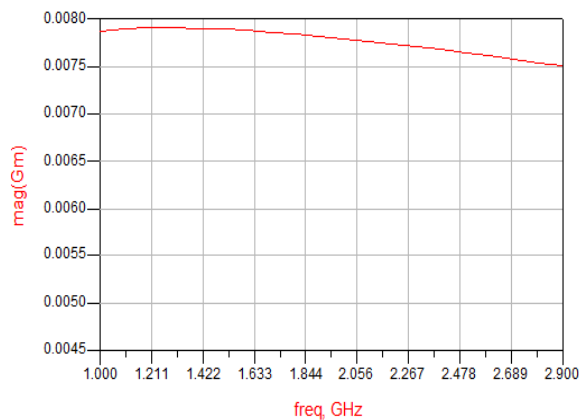


Figure 6. Simulated OTA's Transconductance

4.3. 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.

4.3.1. Effect of Input Voltage Variation on Output Current Swing:

The effect of input voltage is observed on output currents. The input voltage is varied from 1mV to 1V peak to peak and

output swing is observed. Fig.7 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.

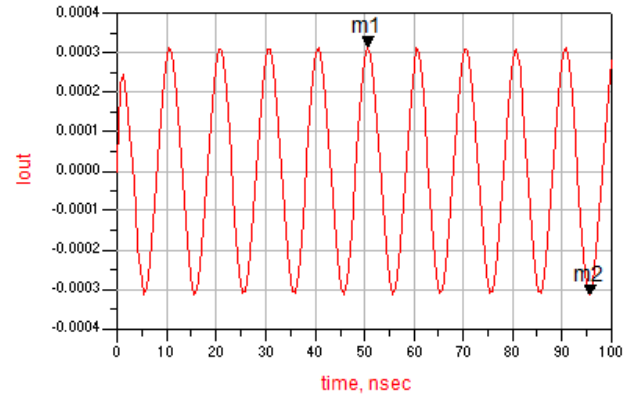


Figure 7: Output Current at 100 mVp-p

4.3.2 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. 8 shows that output current swing of 155 uA is obtained for same input voltage and output is still linear.

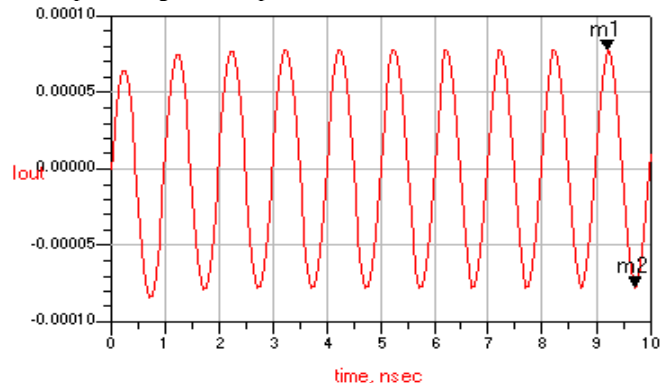


Figure 8: Output Current at 1 GHz

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.

4.3.3 Effect of Supply Voltage Variation on output Current Swing:

For observing effect of supply voltage on output current swing, the input is fixed at 10mV and output current is plotted. The supply voltage is varied from 1.1V to 1.6V and changes in output current are observed.

Fig.9 shows that output current swing of 182.72 uA is obtained for supply voltage of 1.5V.

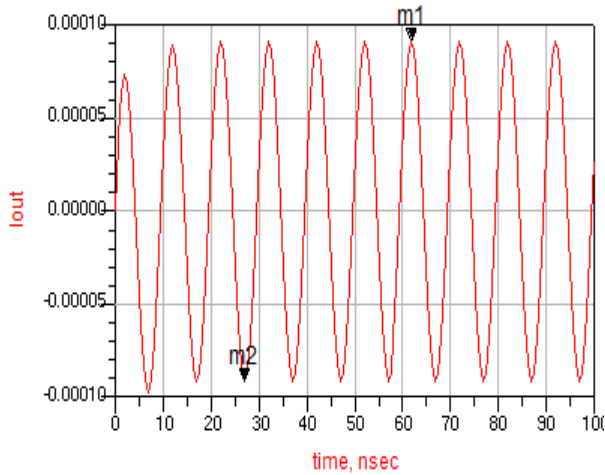


Figure 9: Output Current at 1.5V at Supply Voltage

Table 1: Simulation Results of This Work

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.

4.3.4 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°C to +200°C and changes in output current are observed. Fig.10 shows that output current swing of 177.37 uA is obtained for temperature of 100°C.

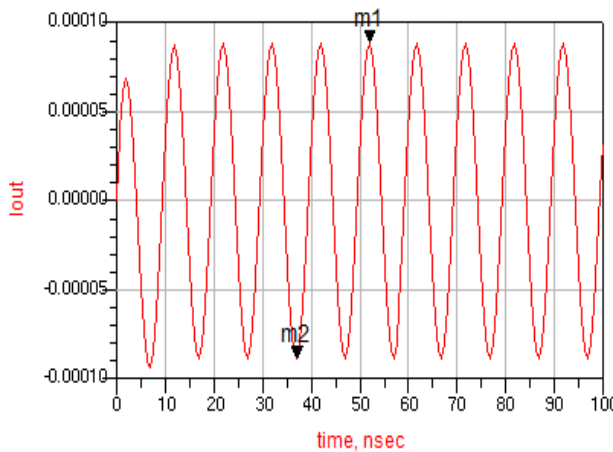


Figure 10: Output Current at 100°C temp.

It is observed that the output is linear for temperature range of -10°C to 100°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°C, the output is not linear and distorted.

5. 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 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 and its comparison with reported OTAs is as tabulated below:

REFERENCES

- [1] T. Deliyannis, Y. Sun and J. K. Fidler, Continuous-Time Active Filter Design. Boca Raton, FL: CRC Press.
- [2] R. L. Geiger and E. Sanchez-Sinencio, "Active filter design using operational Transconductance amplifiers: A tutorial", IEEE Circuit and Device Magazine, vol. 1, pp. 20-32, Mar. 1985.
- [3] Bogdan Pankiewicz, Mariusz Madej, "Design of high frequency OTA in 130nm CMOS technology with single 1.2V power supply", 2nd International Conference on Information Technology, Gdansk, POLAND, organised by Photonic society of Poland, 2010.
- [4] You Zheng and Carlos E. Saavedra, "Feedforward-Regulated Cascode OTA for Gigahertz Applications", IEEE Transactions on Circuits and Systems, 2008.
- [5] Anil Kavala, Kondekar P. N, and Yang Sun, "A low voltage, low power linear pseudo Differential OTA for ultra-high frequency applications", IEEE, International workshop on Antenna Technology, 2009.
- [6] M.Siripruchyanun & W.Jaikla, "Current controlled current conveyor Transconductance Amplifier (CCTA): a building block for analog signal processing", Electrical Eng (2008) 90:443-453 Springer-Verlog, 2008.
- [7] Berg, Y., "Novel ultra low voltage Transconductance amplifier", Proceedings of 2010 IEEE International Symposium on Circuits and Systems, 2010.
- [8] Milad Razzaghpour & Abbas Golmakani, "An ultra-low-voltage ultra-low-power OTA with Improved gain-bandwidth product", IEEE International Conference on microelectronics, 2008.
- [9] N. Raj, R. K. Sharma, A. Jasuja and R. Garg, "A LowPower OTA for Biomedical Applications", Cyber Journal: A multi disciplinary Journal in science & technology, 2010.
- [10] Montree Kummgern, "High Frequency and High Precision CMOS Full-Wave Rectifier", IEEE International Conference on Communication Systems (ICCS), 2010.
- [11] Sheng-Wen Pan¹, Chiung-Cheng Chuang², Chung-Huang Yang³, Yu-Sheng Lai., "A novel OTA with dual

bulk-driven input stage”, IEEE International Symposium on Circuits and Systems, 2009.

[12] Y.L. Li, K.F. Han, X. Tan, N. Yan and H. Min, “Transconductance enhancement method for Operational Transconductance amplifiers “, Electronics Letters (International journal on rapid Communication by IET, UK), 2010.

[13] Daoud, H.; Bennour, S.; Fakhfakh, M.; Loulou, M., “Optimizing CMOS operational Transconductance amplifiers through heuristic programming“, 3rd IEEE International Conference on Design and Technology of Integrated Systems in Nano scale Era, 2008.