

A Review on CMOS Operational Trans-conductance Amplifier

Bhoomi P. Patel¹, Kaushani H. Shah², Mohammed G. Vayada³

PG Student [EC], Dept. of ECE, Silver Oak Engineering College, Ahmedabad, Gujarat, India¹

PG Student [EC], Dept. of ECE, Silver Oak Engineering College, Ahmedabad, Gujarat, India²

Assistant professor, Dept. of ECE, Silver Oak Engineering College, Ahmedabad, Gujarat, India³

ABSTRACT: An operational transconductance amplifier (OTA) is a voltage controlled current source. The operational transconductance amplifiers are used in analog circuits and systems which were implemented by operational amplifiers previously. Present time is about development of VLSI technology and everything is related to size of transistor and decreasing power supply in a circuit. Operational transconductance amplifier is mostly used for analog circuitry for example instrumentation amplifier, converters and filters. This paper represents design concept and review on different types of OTA such as single input single output OTA, differential input single output OTA, differential input differential output OTA and differential input balanced output OTA. Here also reviewed two types of techniques.

KEYWORDS: Operational Transconductance amplifier, Gain, Rail to Rail, Transconductance

I. INTRODUCTION

Recently Operational transconductance amplifier (OTA) has been widely used in filter design and electronic circuits. Operational transconductance amplifiers (OTA) have been one of the most important building blocks in analog and mixed-mode circuits, such as transconductance-C filter (Gm-C filter), variable gain amplifiers (VGAs), voltage-controlled oscillators (VCOs) and data converters^[1]. The main concept is to produce an output current which is proportional to the differential input voltage. In recent few years the design of integrated circuits has gone in the direction of low supply voltage and low power consumption, such as portable applications that their power is given even by a single cell battery. For this reason, many OTAs should be designed for low supply voltage and low power consumption with proper linearity and noise performance.

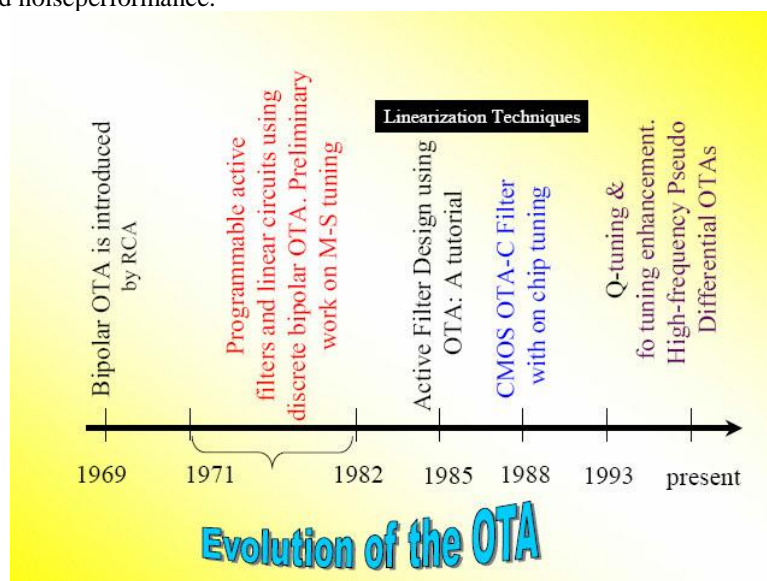


Fig. 1 Evolution of OTA (Operational transconductance amplifier)^[2]

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 12, December 2015

The bipolar OTA was commercially introduced in 1969. CMOS OTA has become vital component in number of electronic circuits both in open loop and close loop applications. The continues time filters with OTA and capacitors are known as Gm-C or OTA-C are very popular as application of OTA.

II. TYPES OF OTA

There are four different types of Operational Transconductance Amplifier based on its input and output.

1. Single input Single output OTA
2. Differential input single Output OTA
3. Differential input differential Output OTA
4. Differential input balanced Output OTA

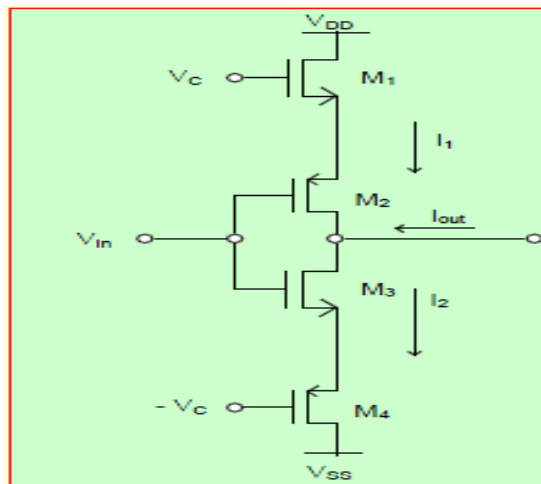


Fig. 2 Single input single output OTA^[2]

Circuit diagram of single input single output OTA is presented in figure 2. Single input V_{in} is given and output current I_{out} is obtained.

Output current $I_{out} = G_m V_{in}$
Gain $G_m = 2K_{eq}(V_c - V_{T_{eq}})$

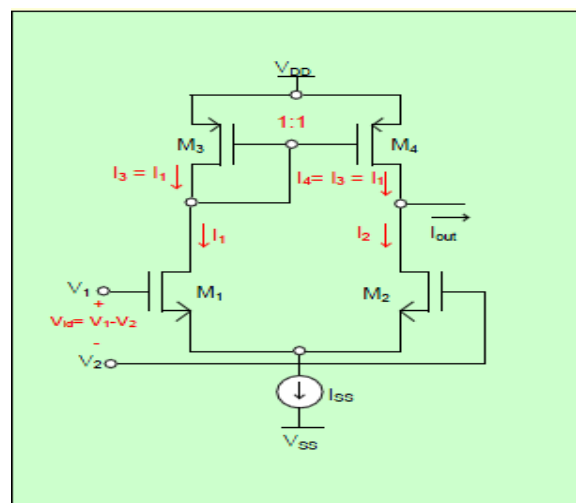


Fig. 3 Differential input single output OTA^[2]

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 12, December 2015

Figure 3 represents Differential input single output OTA. As shown in figure two inputs V_1 and V_2 are given and single output I_{out} is obtained.

$$I_{out} = G_m (V_1 - V_2)$$

$$I_{out} = I_1 - I_2 = \sqrt{I_{ss} K V_{id}} \left(\sqrt{1 - \frac{V_{id}^2}{4I_{ss}/K}} \right)$$

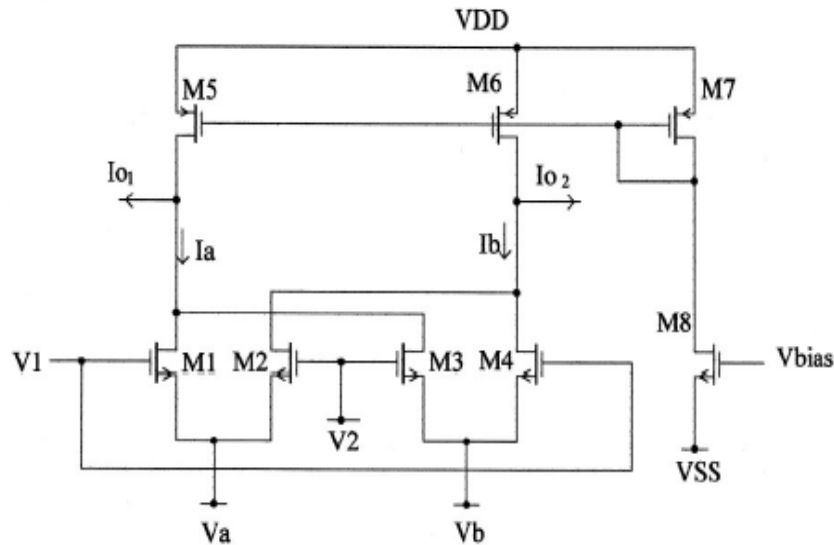


Fig. 4 Differential input differential output OTA^[2]

Figure 4 represents circuit diagram of Differential input differential output OTA. It means two inputs and two outputs. Here two different inputs are given and based on the inputs V_1 and V_2 , we will gain two different outputs I_{out1} and I_{out2} .

$$I_{out1} - I_{out2} = I_b - I_a = (I_2 + I_4) - (I_1 + I_3)$$

$$I_{out1} - I_{out2} = K(V_b - V_a)(V_1 - V_2)$$

$$I_{out1} - I_{out2} = G_m (V_1 - V_2)$$

$$G_m = K(V_b - V_a)$$

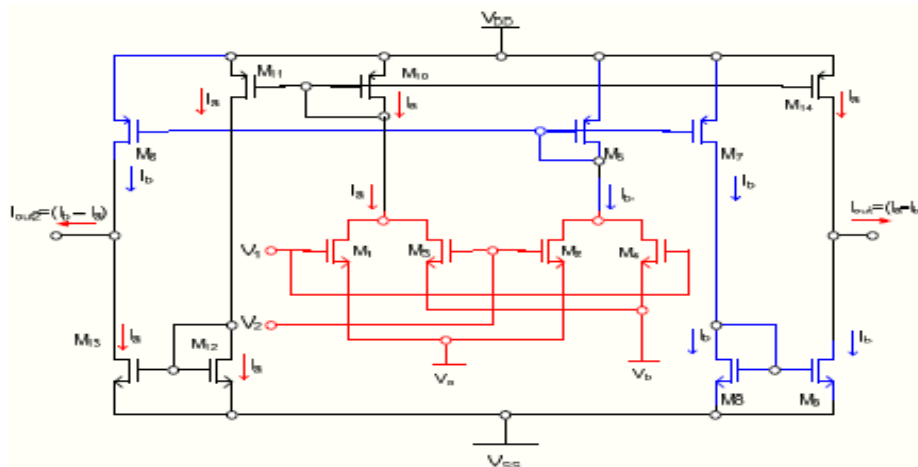


Fig. 5 Differential input balanced output OTA^[2]

Circuit diagram of simple Differential input balanced output OTA is presented in figure 5. It is same as the differential input differential output OTA. The only difference is, in single input balanced output OTA, the output currents are



International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 12, December 2015

same in magnitude but different is direction i.e. $I_{out1} = -I_{out2}$. Which are different in magnitude in differential input differential output OTA.

$$I_{out1} = -I_{out2} = I_b - I_a = (I_2 + I_4) - (I_1 + I_3)$$

$$I_{out1} = -I_{out2} = K(V_b - V_a)(V_1 - V_2)$$

$$I_{out1} = -I_{out2} = G_m (V_1 - V_2)$$

$$G_m = K(V_b - V_a)$$

III TECHNICS OF OTA

There are two types of techniques of OTA.

1. Gate driven OTA

In MOS there are total four terminals Gate, Drain, Source and Bulk. In Gate driven technique input is given to gate terminal of MOS and the bulk terminal is fixed to a specific bias voltage.

2. Bulk driven OTA

In bulk driven technique, the input is given to bulk terminal and the gate terminal is fixed to a specific voltage.

IV. LITERATURE REVIEW

Shahabi, Mehdi[1] in their research paper on low power high CMRR OTA, have proposed a gate driven CMOS OTA using CMFF (common mode feedforward technique). This design is carried out in 0.18 μ m technology.

Common Mode Rejection Ratio	110 db
Gain	46 db
Phase margin	85°
Bandwidth	14 MHz
Capacitive Load	2pf
Power consumption	28 μ W
Supply Voltage	1.2 V

Table 1. Different parameters of proposed OTA[1]

In this paper input voltage range is not considered since this design use gate driven technology, maximum possible input range is $V_{DD} - 2V_{DSAT}$.

Lee, Dong-Soo, Ali Dadashi, and Kang-Yoon Lee [3] in their research paper have proposed high DC gain Modified CMOS OTA. This paper represents design of Gate driven CMOS OTA in 0.35 μ m Technology. In this paper, conventional triple folded cascade structure is presented. In this paper enhancement in gain without affecting phase margin, bandwidth and output voltage is achieved. It provides high linearity of the output in larger output swing.

Supply Voltage	3.3 v
Gain	87db
Phase margin	70°
Bandwidth	485 MHz
Output Voltage Swing	Vdd – 6Vsat
Power consumption	8 mv

Table 2. Different parameters of proposed OTA[3]



International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 12, December 2015

In this paper as input power supply is 3.3v, this OTA cannot be used for low power application. The power consumption is 8 mv which is high compare to bulk driven OTA. Unity gain bandwidth is good. The gain of this OTA is 87db which is good compare to bulk driven OTA. Phase margin is good. In this paper PVT (Process-Voltage-Temperature) analysis is carried out. Output voltage swing is $V_{dd} - 6V_{sat}$, which is not good.

Yodtean, Apiradee[4] in their research paper have proposed Bulk driven OTA having high gain. This OTA is designed in 0.18 μ m Technology. In this paper the trans-conductance is tuned electronically. Symmetric structure is used. Using this OTA, Gm-C Biquard filter application is tasted.

Supply Voltage	0.8 v
Gain	76db
Phase margin	86°
Bandwidth	423 KHz
CMRR	148 db
Power consumption	4.58 μ w
Area	0.4 mm ²

Table 3. Different parameters of proposed OTA[4]

The input voltage range is very low so this OTA can be used in low supply voltage applications. Power consumption is also very low. The gain is high compare to other bulk drive OTA and low compare to gate driven OTA.

Abdelfattah, Omar, et al have presented 0.35 v Bulk driven self biased OTA with rail to rail iput range in 65 nm technology. In this paper common mode feed forward circuit is used.

Supply Voltage	0.35 v
Gain	46 db
Phase margin	56°
Bandwidth	3.6 MHz
CMRR	17 μ W

Table 4. Different parameters of proposed OTA[5]

In this OTA there are no limitations due to threshold voltage because using bulk driven technology input power supply range is reduced. Power consumption is reduced using self-biased circuit. Gain and phase margin is reduced which is not good for OTA. Bandwidth is improved in this OTA.

V. SIMULATION

Sabat, Samrat L., Shravan K. Kumar have presented Differential evolution and swarm intelligence techniques for analog circuit synthesis. This OTA is presented in 130 nm technology using gate driven technology. The proposed OTA is differential input differential output OTA.

Below are the simulated results of the same OTA.

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 12, December 2015

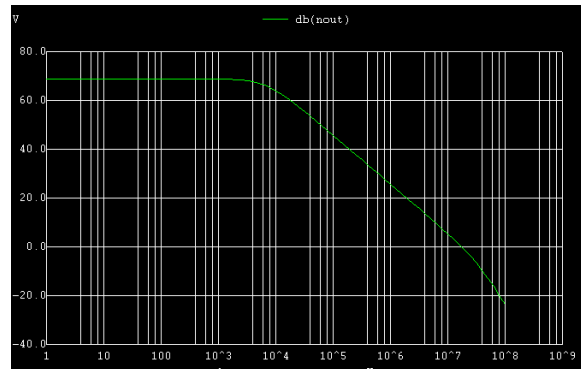


Fig. 6 Gain = 69db

Figure 6 shows output voltage versus frequency which represents gain in db. In this OTA gain obtained is 69db which is high compare to bulk driven OTA.

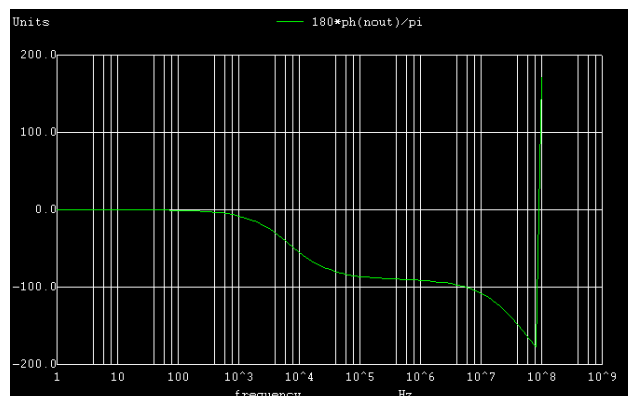


Fig. 7 Phase Margin = 64°

As per above Figure 7, which shows graph of output current with respect to input voltage measured in degree. Here obtained phase margin is 64° which is good.

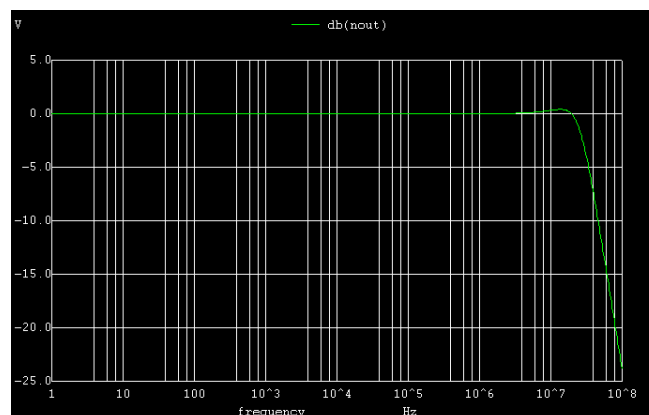


Fig.8 Bandwidth = 29 MHz

Figure 8 represents graph of Unity gain bandwidth. Which is product of bandwidth and gain of OTA. In this OTA, 29 MHz bandwidth is obtained which is high.



International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 12, December 2015

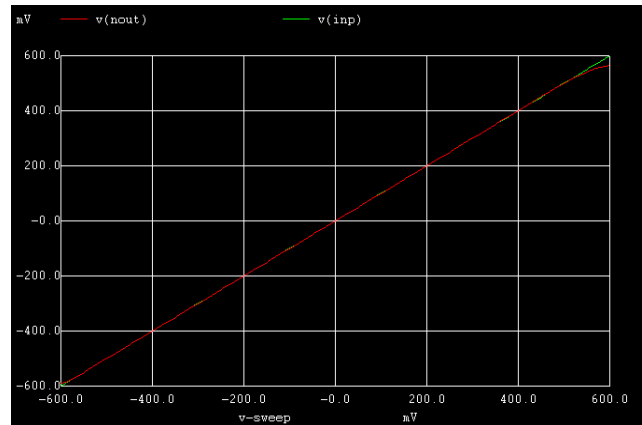


Fig. 9 ICMR = -0.5 To 0.5 = 1 V

The graph of Input voltage versus output voltage is represented in figure 9 which is called as input common mode rejection ratio(ICMR).As shown in fig. obtained ICMR is -0.5 to 0.5 v which is not rail to rail as the OTA is gate driven OTA.

VI.CONCLUSION

This paper describes types of OTA and different techniques for implementation of OTA. Literature survey is carried out on OTA design technique and about its applications. Bulk driven technique is quite useful to deal with low power and low voltage application^{[4][5][9][11]}. Using bulk driven technology, the threshold voltage of MOSFET can be reduced or even removed from signal path^{[4][5][9][11]}. Bulk driven technology does not suggest any change in existing technology^{[4][5][9][11]}. This technique reduces the threshold voltage^{[4][5][9][11]}, thus low voltage and low power design is possible. Drawback of bulk driven technique is this technique provides relatively small DC gain^{[1]-[12]} and requires complex calculations.

REFERENCES

- [1] Shahabi, Mehdi, et al."A novel low power high CMRR pseudo-differential CMOS OTA with common-mode feedforward technique." Electrical Engineering (ICEE), 2015 23rd Iranian Conference on. IEEE, 2015.
- [2] Dr. Soliman Mahmoud, "Microelectronics" German University of Cairo, 2006
- [3] Lee, Dong-Soo, Ali Dadashi, and Kang-Yoon Lee. "A high DC-gain modified CMOS OTA." SoC Design Conference (ISOCC), 2013 International. IEEE, 2013.
- [4] Yodtean, Apiradee."A CMOS OTA and Implementation" Intelligent Signal Processing and Communication Systems (ISPACS), 2014 International Symposium on. IEEE, 2014.
- [5] Abdelfattah, Omar, et al. "A 0.35-V bulk-driven self-biased OTA with rail-to-rail input range in 65 nm CMOS." Circuits and Systems (ISCAS), 2015 IEEE International Symposium on. IEEE, 2015.
- [6] Sabat, Samrat L., Shravan K. Kumar, and Siba K. Udgata. "Differential evolution and swarm intelligence techniques for analog circuit synthesis." Nature & Biologically Inspired Computing, 2009. NaBIC 2009. World Congress on. IEEE, 2009.
- [7] Ferreira, Luis HC, and Sameer R. Sonkusale. "A 60-dB gain OTA operating at 0.25-V power supply in 130-nm digital CMOS process." Circuits and Systems I: Regular Papers, IEEE Transactions on 61.6 (2014): 1609-1617.
- [8] Linares-Barranco, Bernabé, et al. "CMOS OTA-C high-frequency sinusoidal oscillators." Solid-State Circuits, IEEE Journal of 26.2 (1991): 160-165
- [9] Haga, Yasutaka, et al. "Design of a 0.8 Volt fully differential CMOS OTA using the bulk-driven technique." Circuits and Systems, 2005. ISCAS 2005. IEEE International Symposium on. IEEE, 2005.
- [10] De Carvalho, Luís Henrique, and Ferreira E. Pimenta. "An ultra low-voltage ultra low power rail-to-rail CMOS OTA Miller." Circuits and Systems, 2004. Proceedings. The 2004 IEEE Asia-Pacific Conference on. Vol. 2. IEEE, 2004.
- [11] Rosenfeld, Jonathan, Mücahit Kozak, and Eby G. Friedman. "A bulk-driven CMOS OTA with 68 dB DC gain." Electronics, Circuits and Systems, 2004. ICECS 2004. Proceedings of the 2004 11th IEEE International Conference on. IEEE, 2004.
- [12] Duangmalai, Danupat, and Khanittha Kaewdang. "A linear tunable wide input range CMOS OTA." TENCON 2014-2014 IEEE Region 10 Conference. IEEE, 2014.