ISSN 2319 - 5975

Volume 1, No.2, October - November 2012
International Journal of Networks and Systems
Available Online at http://warse.org/pdfs/ijns02122012.pdf

Design and Analysis of Operational Transcondactance Amplifier

Bharat Kumawat
M.Tech (scholar), Mewar University, Chittorgarh, Rajasthan (India)
bharatkumawat83@gmail.com

ABSTRACT

Differential amplifiers most important amplifier in the analog circuit design because of their outstanding performance as input amplifiers and the directly onward application with the possibility of feedback to the input. The traditional differential amplifier faces the disadvantage of the nonlinearity of the transfer characteristic, especially for large values of the differential input voltage amplitude. The differential amplifier circuit characterized in terms of common-mode rejection, voltage gain, and the power consumption. In this paper a Operational transconductance amplifier (OTA) using TSMC 0.18µm technology is designed. Operational transconductance amplifier (OTA) is one of the most significant building-blocks in integrated circuit. It has an output swing of VDD-3VDD. The simulated output for a supply voltage of 1V and 3 V using TSMC 0.18µm technology. DC gain is -4.47dB and -20.05 dB, power consumption is 0.1143mW and 4.395mW and delay is 9.93ns and 4.8 ns for 1V and 3V respectively.

Keywords: OTA, CMRR, Operational Amplifier, Differential Amplifier**.**

1.INTRODUCTION

We are going through a period of micro-electronics revolution. For a common person, the role of electronics is limited to audio-visual gadgets like television and radio, but the truth is, today the growth of any industry like communication, control, instrument, or computer is dependent upon electronics to a great extent and integrated circuit are heart of electronics industries[1]. The integrated circuit or IC is a miniature, low cost electronics circuit consisting of active and passive components that are irreparably joined together on a single crystal chip of silicon. Most of the component used in IC's is not similar to conventional components in appearance although perform similar electrical function.The Integrated circuits offer a number of distinct advantages over those made by interconnecting discrete components [2]. These are listed as follows:

Miniaturization and increased equipment density
1Cost reduction due to batch processing.
2.Increased system reliability due to elimination of soldered joints.
3I.mproved functional performances.
4.Matched devices
5.Increased operating speeds
Reduce in power consumption
Integrated circuit offers a wide range of application and could be broadly classified as:

- Digital IC's
- Analog IC's

Based upon the above requirements, two distinctly different IC technology named Monolithic technology and hydride technology have been developed. In Monolithic integrated circuit, all circuit component, both active and passive elements and their interconnection are manufactured into or on top of a single chip of silicon. The monolithic circuit is ideal for application where identical circuits are required in very large quantities and hence provides lowest per unit cost and highest order of reliability. In hybrid circuit, separate component parts are attached to a ceramic subtracts and interconnection by means of either metallization pattern or wide bonds [3]. This technology is more adaptable to small quantity custom circuit. Based upon the devices used, IC's can be further be classified as Bipolar and unipolar. IC's can be further be classified depending upon the isolation technique or type of FET used. Classification of IC is shown in Figure 1.

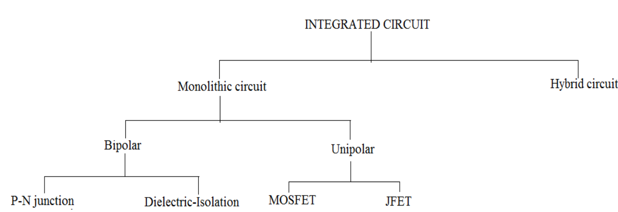


Figure 1: Calcifications of Integrated Circuit

2. AMPLIFIER FUNDAMENTALS

It is a two port device, which accepts an input signal and produce an output signal proportional to the input such that (output = gain x input), is called as an amplifier. The proportionality constant between input and output is as a gain of an amplifier

There are variety of amplifier available depending upon the input and output signal. These types are:
1. Voltage amplifier. (Voltage input and voltage output)
2. Current amplifier. (Current input and current output)
3. Transconductance amplifier. (Voltage input and current output)
4. Transresistance amplifier. (Current input and voltage output)

3. DIFFERENTIAL AMPLIFIER

The differential amplifier is the basic building block of operational amplifier, the discussion of differential amplifier in this section sets the groundwork for analysis and design procedures for the operational amplifier. The analysis of differential amplifier not only classifies the operation of the operational amplifier but also makes the characteristic of the operational amplifier easy to understand. In addition, the analysis procedure developed in this section provides a means of checking operational amplifier parameters such as voltage gain and input and output resistance that are specified on the manufacturer's data sheets. Differential Amplifier is the ultimate amplifier. It is a special type of amplifier, which can amplify the difference of input signals. Hence, it is called differential amplifier [4]. It is used in another special type of amplifier circuit called Operational Amplifier (OPAMP). The differential amplifier has two inputs: inverting input (input–1) and non-inverting input (input–2). Its output signal is 180° OUT OF PHASE with inverting input signal and IN PHASE with non-inverting input signal. For example, when –ve voltage is connected to inverting terminal we get +ve voltage at output. Similarly, when –ve voltage is connected to non-inverting terminal, we get –ve voltage at output. The figure shows circuit of differential amplifier. It is symmetrical circuit, i.e. it has same components on both sides. It works in two different modes: the differential mode and the common mode, as explained below –

Differential mode input – here two different input signals are connected as V1 and V2. The output (Vo) is taken across only one transistor T1. This type of circuit is called differential input, single ended output mode. According to Figure 2The output voltage of the circuit is given by
Vo = A (V1 – V2)
If V1 = V2 in magnitude, but opposite in signs, then we get -
Vo = A [V1 – (-V1)] = 2AV1

Common mode input – if two input signals are applied at two inputs such that V1 = V2 both in magnitudes and polarity, then –
Vo = A (V1 – V2) = A (V1 – V1) = 0

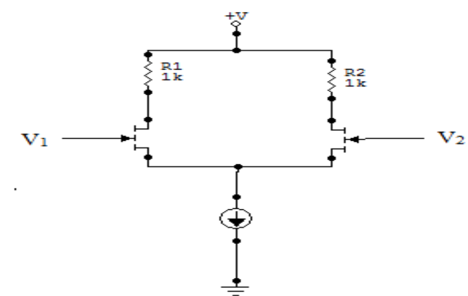


Figure 2: Circuit diagram of Differential Amplifier

4. OPERATIONAL AMPLIFIER

Linear integrated circuit are used in a number of electronics application such as in field like audio and radio communication ,medical electronics, instrumentation electronics, etc. An important linear IC is operational amplifier which will be discussed hear the circuit scheme of op-amp is a triangle as in Figure3 .It consists of two input terminal and one output terminal. The terminal with a (-) sign is called inverting terminal and the terminal with (+) sign is called non inverting terminal. The +V and –V power supply terminal are connected to DC voltage sources. The +V pin is connected to the positive terminal of DC source and –V is connected to negative of DC source.

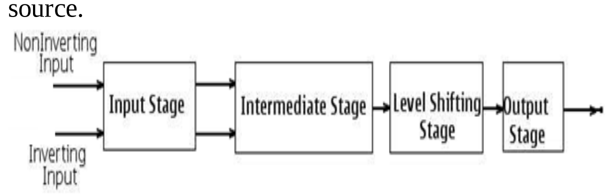


Figure 3: Block diagram of operational amplifier

Commercial integrated circuit op-amp usually consist of four cascaded blocks which are shown in Figure3. there description are as

Input Stage: The input stage is a differential amplifier. The differential amplifier used as an input stage providesdifferential inputs and a frequency response down to d.c. Special techniques are used to provide the highinput impedance necessary for the operational amplifier. all such requirements are achieved by using the duel input balance output differential amplifier

Intermediate Stage: The second stage is a high-gain voltage amplifier. This stage may be made from several transistors toprovide high gain. A typical operational amplifier could have a voltage gain of 200,000. Most of this gaincomes from the voltage amplifier stage. For such requirement we use duel input unbalanced output i.e. single ended output amplifier

Level Shifting Stage: The final stage of the OP AMP is an output amplifier. The output amplifier provides low output impedance. The actual circuit used could be an emitter follower. The output stage should allow the operational amplifier to deliver several milli amperes to a load.For this purpose we use push pull amplifier.

5. IMPLEMENTATION AND RESULT

A voltage to current converter is an amplifier which produces an output current proportional to an input voltage. The constant of proportionality is the transconductance of the amplifier and therefore such amplifiers are also known as transconductance amplifier which is shown below in Figure4It is consist of six PMOS and eight NMOS Transistor. Transistor M1 and M2 form a differential pair. Transistor M3 andM12 makes current mirror. M4 and M5 is also form current mirror which is called duplicate current mirror. Transistor M5 and M13 are also form duplicate current mirror. The specification of OTA is given in table 1and schematic diagram of OTA is shown in Figure 4.

Table 1: Specification of OTA

S. No.	Parameters		Value
1.	Vdd		1.8 V
2.	Technology		180 nm
3.	PMOS	width	1140nm
		length	180nm
4.	NMOS	width	570nm
		length	180nm

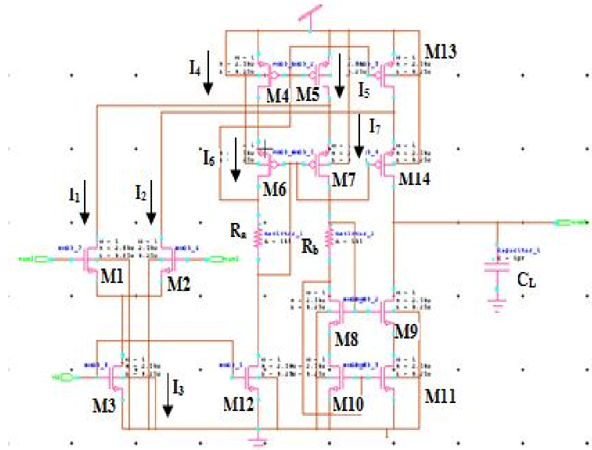


Figure 4: Schematic of folded cascade OTA

The output of OTA depends on input Vb. When Vb is high then the Vout is low and when Vb is low then Vo output of OTA is Vout high as shown in Figure 5.

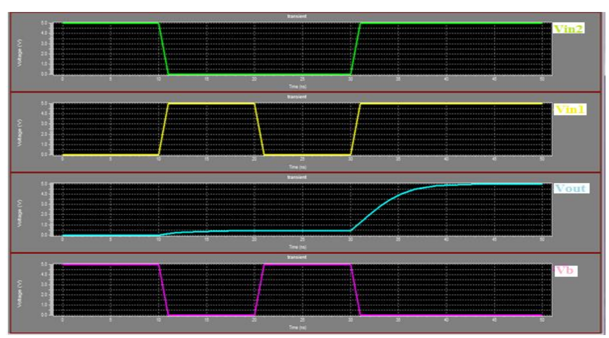


Figure 5: output and input waveform of OTA

5.1 Common mode rejection ratio (CMRR)

It is defined as the ratio of differential mode gain (Ad) to common mode gain.

$$CMRR = \left| \frac{Ad}{A_C} \right|$$

CMRR at Threshold voltage (Vth) at 0.39V, when input Vin1 Vin2 and Vb are common then the common mode gain will be

$$A_c = \frac{V_o}{V_{in}} = \frac{3.1}{5} = 0.2$$

And Differential mode gain;

$$A_d = \frac{V_o}{V_{in1} - V_{in2} - V_b}$$

$$A_d = \frac{5}{5-2-1} = 2.5$$

$$CMRR = \frac{A_d}{A_c} = \frac{2.5}{0.2} = 1.612$$

So

The wave form of CMRR of OTA Shown in Figure 6

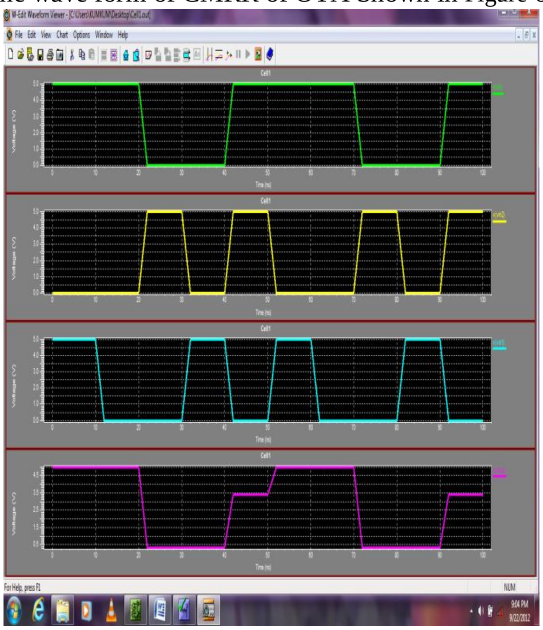


Figure. 6: Waveform of CMRR

Similarly the value of CMMR at different Vth and same input voltage (Vin1= 5, Vin2= 2 and Vinb= 1) its value is calculated and is shown in Table 2.and relative graph I shown in Figure 7

Table 2: Value of CMRR at different Vth

S No.	Vth	CMMR
1.	0.29	1.6129
2.	0.39	1.612
3.	0.49	1.5629
4.	0.59	1.53374
5.	0.69	1.49254

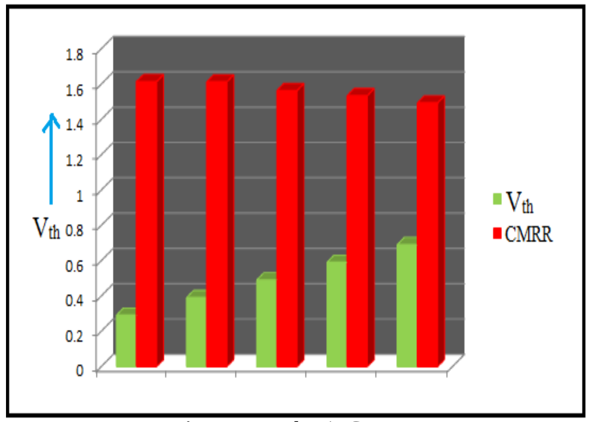


Figure 7: Vth v/s CMRR

5.2 Analysis of DELAY

Delay is defined as it is the average of the rising end of any input and filling end of output. In purposed design we calculate delay at Vdd equal to 1volt is 9.98nsec.which is shown in Figure 8.

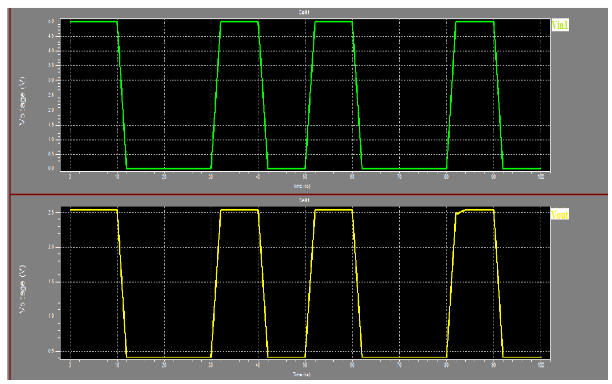


Figure 8 :Delay in OTA

In similar way we calculate delay at different Vdd whose value is shown in table3below. And relative graph is shown in Figure 9.

Table 3: Value of Delay at different Vdd

S.no	Vdd(V)	Delay(ns)
1.	3.0	4.8
2.	2.5	6.77
3.	2.0	9.48
4.	1.5	9.70
5.	1.0	9.93

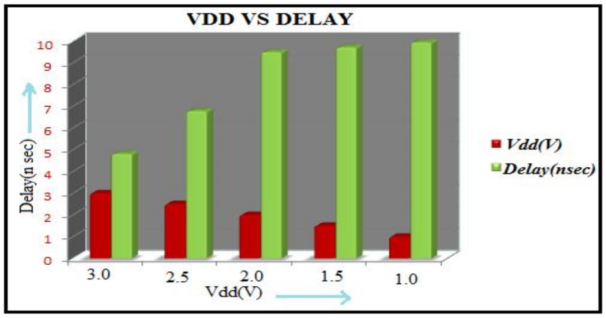
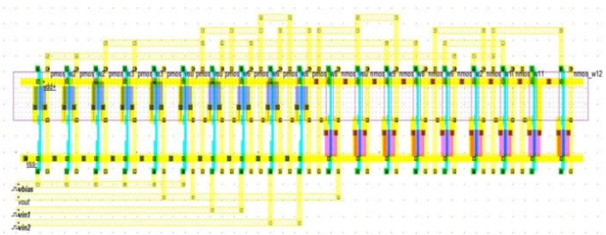


Figure 9: Graphs between Vdd and Delay

The layout diagram of OTA is shown in Figure 10.



Area of OTA [348 μm^2]

Figure 10: Layout diagram of folded cascaded OTA

6. CONCLUSION

In this paper a high performance CMOS Operational transconductance amplifier (OTA) circuit has been designed. This circuit best suited for low voltage and high common mode rejection ratio (CMRR) applications. All simulation result using the tanner tool at tsms 180 nm technology. An 180nm OTA with gain of -4.47dB and -20.05 dB for both 1V and 3V without using gain boosting technique and it consume less power for low voltage. This OTA can further be used for analog portable devices. The circuit can be used in design of low voltage and CMRR operational amplifiers, Voltage controlled oscillators (VCO). By the analysis we conclude that by increasing in Vdd

- Speed of circuit increases because the delay decreases..
- Delay Decreases.

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