Design of Current Mirror and Telescopic OTA using 0.18µm Technology

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ABSTRACT
In this paper, two configurations of Operational Transconductance Amplifier (OTA), namely Current Mirror and Telescopic are designed and compared on the basis of voltage gain, slew rate and Common Mode Rejection Ratio (CMRR). The design simulation is done using Cadence Analog Design Environment with 0.18µm technology node. Emphasis is laid on reduced power design as analog or mixed signal IC's require low power and low area circuits. OTA forms the basic building block in many analog circuits and replaces Op-amps. Active filter circuits, Power System on a Chip (PSoC), Bio-signal Amplifiers etc. are designed using OTAs. The simulated values of Voltage Gain, CMRR and Slew rate for current mirror OTA are 34.7814 dB, 93.0159 dB and 18.705 V/µs respectively, and the values of for telescopic OTA are 48.74157 dB, 109.53041 dB and 2.94 V/µs respectively.

Keywords
operational transconductance amplifier (OTA); current mirror OTA; telescopic OTA; voltage gain; Common Mode Rejection Ratio (CMRR); slew rate.

1. INTRODUCTION
There has been a great motivation for developing solutions for circuits operating at very low frequencies.Recently a growing trend has been noticed towards the enhancement of the signal quality of the low frequency bio signals like ECG, EEG, and EMG etc. The challenge faced is the low signal strength and the low frequency of the bio signals. Bio potential amplifiers (BPA) have drawn significant attention from researchers all around the world due to their ability to amplify such signals. The major difference in such amplifiers is the presence of Operational Transconductance Amplifiers (OTA). The op amp is also very similar to the OTA and is a voltage controlled current source. It is a high dc coupled differential amplifier with single ended output, high gain, high input impedance and low output impedance. The characteristics of an op amp depend only on its feedback network due to its high open loop gain [11]. In an OTA all the characteristics are similar to that of op amp except the output impedance that ideally approaches to infinity instead of zero. As a result of this transconductance in comparison to voltage gain is used to best describe the forward gain [12].

The OTA's work as differential amplifier, thereby inheriting the noise cancellation property while facilitated with additional capacitive load. The capacitive load act as short circuit for high frequency noises and thereby passing only the useful low frequency bio signals. The performance of the OTA is very important as it has a direct effect on the power consumption, voltage gain and other performance parameters.

In this paper emphasis has been laid on the study and analysis of various OTA configurations as OTA's can be used for the above stated applications and can drive capacitive loads. Fig. 1 as shown below represents the basic structure of an OTA with Vp representing the positive input, Vn the negative input, Io the output current and I bias is the external current source which can control the transconductance of the amplifier. Here the output current Io is the resultant of the difference of the input voltages Vp and Vn.

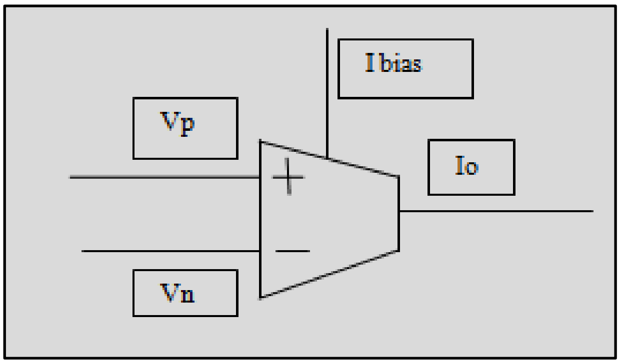


Fig. 1: Ideal OTA model [10]

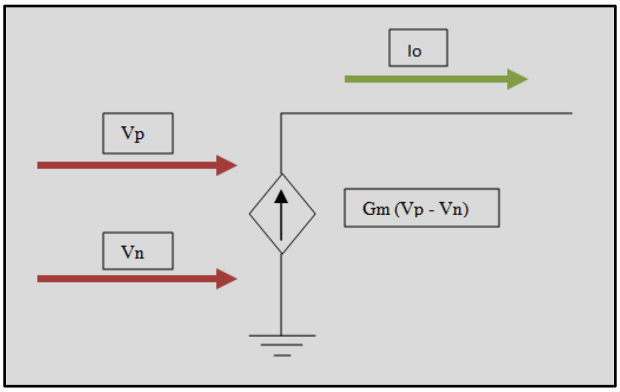


Fig. 2: Equivalent circuit of an OTA [10]

The output current of an OTA can be defined by the equation as follows:

$$Io = Gm(V_+ - V_-)$$

Where, Gm = transconductance of the amplifier.

With the help of OTA's there has been an exceptional improvement and enhancement in the design of Active filter circuits, Power System on a Chip and Bio signal amplifiers etc. Radical improvements have been noticed in the in the field of biomedical applications like monitoring of health [1], detection of disease [2], neural prostheses [3],[4] and therapies of brain simulation [5],[6]. Great emphasis is laid on the low frequency circuits that play an important role in field of biomedical systems, real time speech recognition, telemetry and in field of neural networks [7], [8], [9].

2. DESIGN IMPLEMENTATION AND DISCUSSION

This paper discusses the design implementation and analysis of the current mirror and the telescopic configuration of the OTA.

A. Current Mirror Ota Configuration

It is a modified version of the single stage OTA. The cascode structure of transistors is used at the output side for converting the voltage at the output to current and thereby applying the results to the common gate stage.

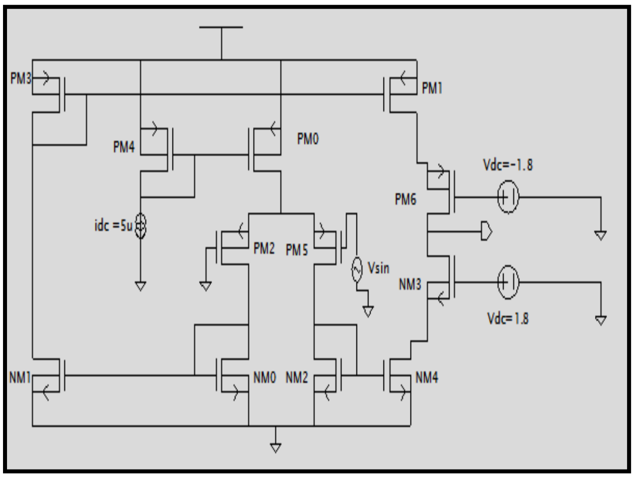


Fig.3: Current Mirror OTA

The circuit in Fig. 3 represents the schematic of the current mirror OTA. A differential voltage is applied across the gate terminals of the pmos transistors PM2 and PM5. At the gate input of PM5 a positive input voltage is applied and at the gate input of PM2 a negative input voltage is applied as a result of whichan amplified differential waveform appears at the output. An external current source carrying a current of 5µA is used in order to control the transconductance of the amplifier. According to the property of the current mirror circuits, the current drawn out of the drain terminal of PM4 is same as the current drawn out of the drain terminal of PM0. Similar to PM0 and PM4, the transistors NM0,NM2 and PM3 also form current mirror circuits. The advantage of using the current mirror OTA topology is the presence of the second stage at the output end which provides a higher voltage swing and thus a higher gain. The transistors PM6 and NM3represent the second stage of the current mirror OTA.

This circuit is simulated using Cadence analog design environment at 0.18 µm technology node using the virtuoso tool. The design is evaluated in order to obtain the values of the parameters voltage gain, CMRR and slew rate.

B. Telescopic Ota Configuration

This configuration is an improved version in comparison to the other configurations such as single stage, current mirror and folded cascode OTA.

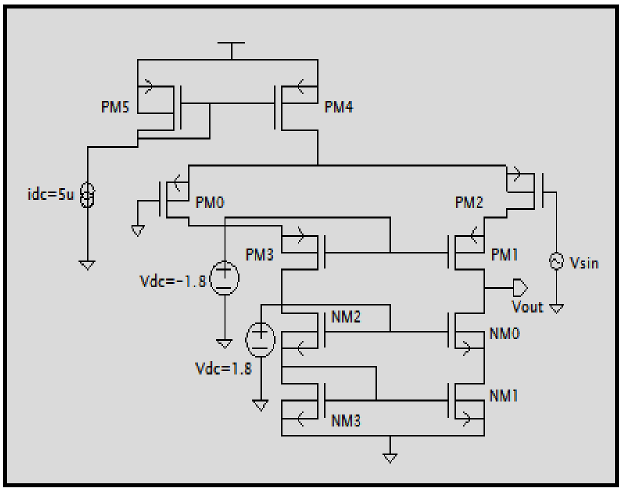


Fig.4: Telescopic OTA

The circuit in Fig. 4 represents the schematic of a telescopic OTA. In this configuration the difference in the input voltage is measured using a differential pair. If a set of transistors are operating in the saturation mode as a transistor pair, then one leg of the transistors will turn on at a particular time while turning the other off. From one leg the current will sink from the load while the current will be sourced to the output from the other leg. In this schematic the differential input is applied across the gate terminals of PM0 and PM2. Here also an external dc current source is used that will control the transconductance of the amplifier. The transistors in this configuration are arranged in a stacked manner one on top of the other which enhances the output impedance and thus the gain. This OTA also provides a higher speed and lower power consumption.

This design is also tested using Cadence analog design environment at 0.18 µm technology node using virtuoso tool for the parameters voltage gain, CMRR and slew rate.

Table 1: Comparison of Current Mirror and Telescopic OTA

Topology	Gain	Power	Speed	Noise
Current Mirror	Low	Medium	Low	High
Telescopic	High	Low	High	Low

3. RESULTS AND DISCUSSIONS

The current mirror and the telescopic OTA have been analyzed for various parameters like gain, CMRR and slew rate. A comparative study for both the OTA's is done on the basis of the mentioned parameters, and hence the best of the two is chosen for the designing of a bio-potential amplifier.

C. Voltage Gain

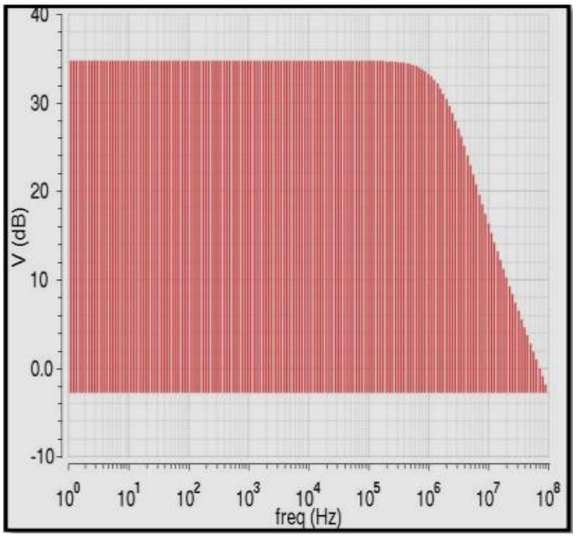
The voltage gain is defined as the ratio of the output voltage divided by the differential input voltage.

$$G_{voltage} = \frac{V_{out}}{V_{id}}$$

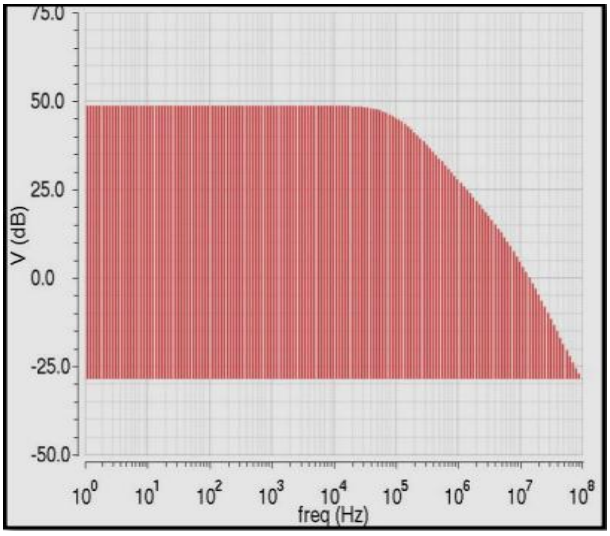
Where,

$$V_{id} = V_{in+} - V_{in-}$$

The voltage gain simulated for the current mirror OTA is 34.7814 dB and that for telescopic OTA is 48.74157 dB.



(a)



(b)

Fig. 5: a) Gain plot of Current Mirror OTA b) gain plotof telescopic OTA

From the Fig. 5it is clear that the telescopic OTA is superior from current mirror OTA in terms of the gain.

D. Common Mode Rejection Ratio (Cmrr)

It is defined as the ability of any device to reject the common mode signals appearing at the input. When a differential signal is to be amplified in presence of large common mode input a high CMRR is required. An ideal amplifier has infinite CMRR.

$$CMRR = \frac{A_d}{A_{cm}} = 20log_{10}\frac{A_d}{A_{cm}}dB$$

If the differential and common mode gains are already in dB, then CMRR can be calculated as

$$CMRR = A_d - (-A_{cm})$$

Table 2: CMRR of current mirror and telescopic OTA

S.No.	OTA topology	Technology	CMRR obtained (dB)	CMRR obtained in reference	Reference
1.	Current Mirror	0.18μm	93.0159	>88 dB	[13]
2.	Telescopic	0.18μm	109.53041	60 dB	[14]

From table 2 it is clear that telescopic OTA is superior from current mirror OTA in terms of CMRR as telescopic configuration has a higher CMRR than the telescopic OTA.

E. Slew Rate

It is the maximum rate of change of output voltage per unit of time.

$$\text{Avg. slew rate} = \frac{(\text{positive slew rate} + \text{negative slew rate})}{2}$$

The positive slew rate is calculated by measuring the slope of the rising edge of the output and similarly the negative slew is calculated by measuring the slope of the falling edge of the output.

The slope for the current mirror configuration is calculated as 11.22 M for the rising edge and -14.97 M for the falling edge. Thus the slew rate of a current mirror OTA is 18.705 V/μs. Similarly the rising edge slope for telescopic OTA is 2.701 M and the falling edge slope is -3.186 M. Thus the slew rate calculated for telescopic OTA comes out to be 2.94 V/μs.

Table 3: Comparison of Current Mirror and Telescopic OTA on the basis of different parameters at 0.18 μm

Parameter	Current Mirror OTA	Telescopic OTA
Voltage Gain	34.7814 dB	48.74157 dB
CMRR	93.0159 dB	109.53041 dB
Slew Rate	18.705 V/μs	2.94 V/μs

The table 3 represents a comparative analysis of the current mirror and telescopic OTA on the basis of different parameters.

4. CONCLUSION

This research has emphasized on the comparative analysis of the current mirror and telescopic configurations of the OTA. The study shows that the telescopic OTA provides improved results over the current mirror OTA in terms gain, CMRR and slew rate. In this research an external DC current source of 5μA is used. Using the Cadence Analog Design environment with 0.18μm technology node the gain of current mirror OTA is 34.7814 dB and that of telescopic OTA is 48.74157. Under the same conditions the CMRR of current mirror OTA configuration is 93.0159 dB and that of telescopic OTA is 109.53041 dB which is greater in comparison to current mirror OTA. Also the comparison is done on the basis of slew rate and it has been analyzed that the slew rate for telescopic configuration is 2.94 V/μs which is far better than the slew rate of the current mirror OTA which is 18.705 V/μs . From the overall comparative analysis it can be concluded that the telescopic OTA is a better option for designing the BPA than the current mirror OTA. Also as the telescopic OTA consumes lesser number of transistors than the current mirror OTA,implies that it acquires a smaller area than the current mirror OTA. Hence all the simulated results show that the telescopic OTA is more preferred for BPA designing than the current mirror OTA. This research can be further enhanced by analyzing the values of PSRR and NEF which will help in more efficient comparative OTA analysis.

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