Design and Analysis of CMOS Telescopic Operational Transconductance Amplifier for 0.35μm Technology

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Abstract: ***Designing high performance analog circuits is becoming increasingly challenging with the persistent trend toward reduced supply voltages. At large supply voltages, there is a trade-off among speed, power and gain, amongst other performance parameters. Often these parameters present contradictory choices for the op-amp architectures. In this paper telescopic OTA is designed for 0.35µm technology with the help of P-spice Orcad simulator. This designed telescopic OTA achieved gain 40db, phase margin of 70degree, CMRR 75db, which are the basic performance parameters of the OTA.***

Keywords: OTA, UGB, Gain, Phase Margin, ICMR, CMRR.

1. Introduction

The OTA is basic building blocks found in many analog circuits such as data converter's (ADC &DAC) and Gm-C filters. Performance of Gm-C filters is related to the OTA's performance. The OTA is a Transconductance device in which the input voltage controls the output current, it means that OTA is a voltage controlled current source whereas the op-amps are voltage controlled voltage source. An OTA is basically an op-amp without output buffer, so it can only drive loads.

The Operational Transconductance Amplifier (OTA) is the block with the highest power consumption in analog integrated circuits in many applications. Low power consumption is becoming more important in handset devices, so it is a challenge to design a low power OTA. There is a trade-off between speed, power, and gain for an OTA design because usually these parameters are contradicting parameters. There are three kinds of OTAs: two stage OTAs, folded-cascode OTAs, and telescopic OTAs. The telescopic amplifier consumes the least power compared with the other two amplifiers, so it is widely used in low power consumption applications. It has also high speed compare to other two topologies [1][2].

An operational transconductance amplifier (OTA) is a voltage input, current output amplifier. The input voltage V_{in} and the output current I_o are related to each other by a constant of proportionality and the constant of proportionality is the transconductance "g_m" of the amplifier.

$$I_o = g_m V \quad (1)$$

Where g_m= Transconductance of OTA.
V_{in}= Differential input voltage

Figure 1 shows how to represent OTA symbolically.

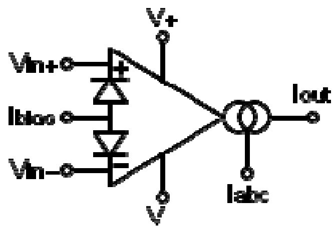


Figure 1: OTA symbol

The transconductance g_m of the OTA can be varied by varying the value of the external controlling current I_C.

$$g_m = KI_C \quad (2)$$

Where K = suitable constant of proportionality

Substituting equation (1) into equation (2), we get,

$$I_o = KV_{in}I_C \quad (3)$$

Equation (3) tells us that output current is proportional to the product of V_{in} and I_C. [8]

2. Different Configuration of OTA

There are different configurations of OTA topologies. Each topology has its own advantage and disadvantage [1][8].

2.1 Single –Stage OTA

Single stage OTA is as shown in figure 2. This single stage OTA is less complex compare to other types of OTA topology. Because of its less complex property its speed is higher compare to other topology.
The drawback of this type of OTA is lower gain due to the fact that output impedance of this type configuration is

relatively low. However this low impedance also leads to high unity gain bandwidth and high speeds.

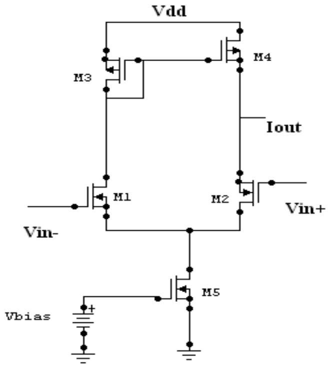


Figure 2: Single stage OTA

2.2 Two –Stage OTA

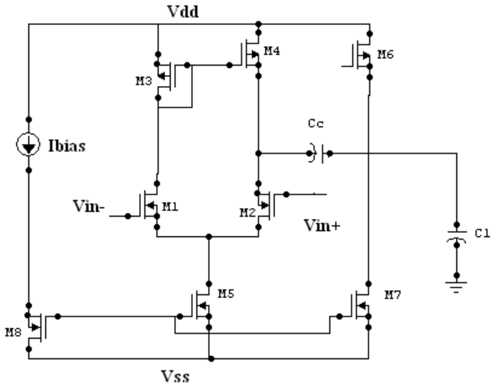


Figure 3: Two stage CMOS OTA

Advantage:

1. It has high output voltage swing.
2. It has higher gain compare to single stage OTA.

Disadvantage:

1. It has a compromised frequency response.
2. This topology has high power consumption because of two Stages in its design.
3. It has a poor negative Power Supply Rejection at higher Frequencies.

2.3 Telescopic Cascode OTA

The Telescopic Cascode OTA configuration is as shown in figure 4.

Advantage:

1) It provides higher speed.
2) It has lower power consumption.

Disadvantage:

1) Limited output swing.
2) Shorting the input and output is difficult.

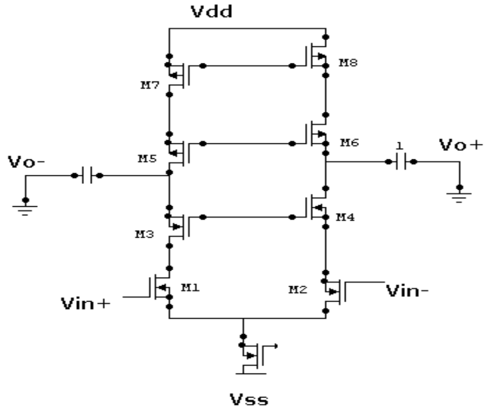


Figure 4: Telescopic amplifier

2.4 Regulated Cascode (Gain Boosting) OTA

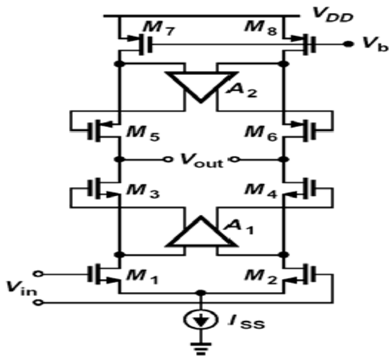


Figure 5: Regulated Cascode (Gain Boosting) OTA

Advantage:

1. This topology has highest gain.

Disadvantage:

1. The Speed is low.

2.5 Folded Cascode OTA

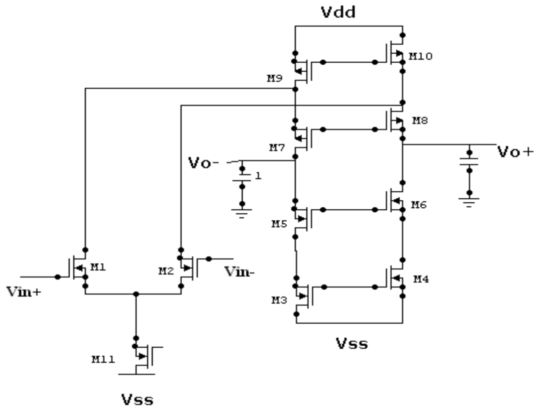


Figure 6: Folded Cascode OTA

Advantage:

1) This design has corresponding superior frequency response than two – stage operational Amplifiers.
2) It has better high frequency Power Supply Rejection Ratio

(PSRR). The power consumption of this design is approximately the same as that of the two-stage design.

Disadvantage:

1) Folded cascode has two extra current legs, and thus for a given settling requirement, they will double the power dissipation.
2) The folded cascode stage also has more devices, which contribute significant input Referred thermal noise to the signal.

3. Telescopic OTA Implementation

In this design telescopic OTA is used because of its simplicity over other designs, allowing for higher-speed operation. In a folded-cascode design, there is an input differential pair and two separate current branches for the differential output. The input currents are mirrored with a cascoded configuration to produce the output currents.

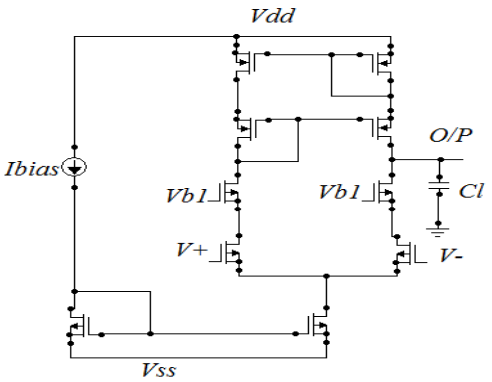


Figure 7: Telescopic OTA

The telescopic architecture puts both the input differential pair and the output on the same two current branches. This approach eliminates the noise problems caused by the current mirrors and also leads to a more direct signal path, which allows for higher speed. Another advantage of the telescopic architecture is that it uses half the bias current of a folded-cascode design because it has two fewer branches for current [3][4].

4. Simulation Results

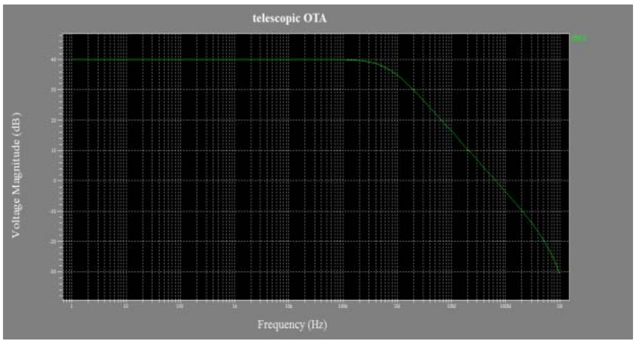
The CMOS Telescopic operational transconductance amplifier is simulated on P-spice software for 0.35µm Technology for obtaining different parameter such as UGB (Unit gain bandwidth), gain, phase margin etc. These parameters are shown below.

Specification	*Results*
Technology	*0.35µm*
UGB	*60MHz*
C_L	*1pf*
Supply Voltage	*±2.5V*
Gain	*40db*
CMRR	*76db*
Phase Margin	*70º*
Power cons.	*2.46µW*

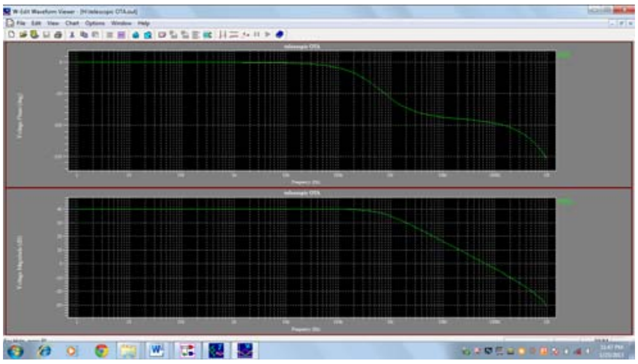
Simulated results waveforms

4.1 Gain Measurement

The gain obtained for this telescopic Operational Transconductance Amplifier is about 40db.

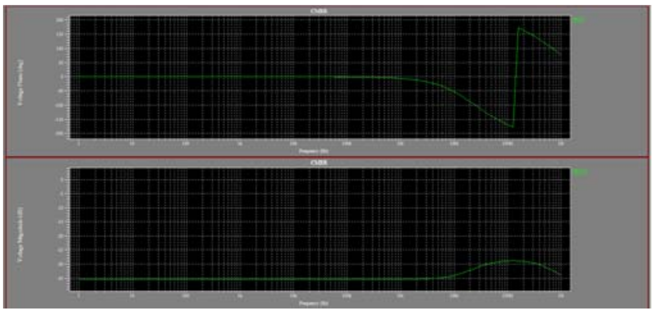


4.2 Phase margin



4.3 CMRR

Common mode Rejection Ratio (CMRR) is defined as the ratio of differential gain to common mode gain. Value of CMRR estimated to be more than 60db. [9]



5. Conclusion

In this paper, the basic concept of different OTA is described along with its advantage and dis-advantage. The telescopic OTA is designed for 0.35µm technology with the help of P-spice Orcad simulator. The unit gain bandwidth achieved for the design is 60MHz, the gain is 40db and phase margin is of 70degree. Also the CMRR is of 76db.

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