

A High-performance Folded Cascode Amplifier

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Abstract. Based on the CMOS SMIC 0.18 μ m technique, this paper presents a high-performance folded cascode amplifier, which replaces the traditional telescopic structure with the classic cascode structure. Through the spectre simulation of Cadence, under 3.3V, the circuit's DC gain is as high as 96.29dB, and the phase margin is 83.5 degree with a high stability; the bandwidth gain is larger than 5MHz, the power consumption is smaller than 0.1mW.

Keywords: CMOS; folded; cascode; amplifier; spectre

1. Introduction

Currently, digital chips have occupied a large part of the chip market, but in practical application they still cannot do without analog circuits, which transform analog signal into digital signal, and the core part of analog circuits is the amplifier.

Operator amplifier is an integral part of analog system and mixed signal system. The system uses a large number of operational amplifiers implement various functions, from the generation of DC bias to high-speed amplification or filtering. With each generation of CMOS technology, the decrease in supply power voltage and transistor length continuously brings more complex issue for the design of the op amp.

The design of high-performance operational amplifier has always been one of the hot spots of analog integrated circuit design. With the continuous development of integrated circuit technology, high-performance operational amplifier is widely used in high-speed ADC, DAC, switched capacitor filter, band-gap voltage reference, precision comparators and other circuit systems. It has become the core unit of analog integrated circuit and mixed signal integrated circuits design, and its performance directly affects the overall performance of circuits and system[1].

2. Folded Cascode Amplifier

Many integrated CMOS operational amplifiers are designed only to drive capacitive loads, so that they only operate capacitive load and voltage buffer is not required to obtain low output impedance. Therefore, we can design an operational amplifier with a higher speed and greater amplitude than the operational amplifier with only capacitive load. If there is only one high impedance node on the output end of the operational amplifier that only drives capacitive load, then the performance could be improved. The admittance and transconductance of MOS observed by the operational amplifier are of the same magnitude, thus they have low impedance.

The compensation in the op amp is usually achieved by the load capacitance. Thus, when the load capacitance increases, the operational amplifier usually becomes more stable. One of the most important parameters of modern transistor is transconductance, ie the ratio of output current to input current. Therefore, these modern op amps are also known as transconductor operational amplifier or operational transconductance

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amplifier. Using folded cascode operational amplifier structure can optimize second-order performance indicator.

Folded cascode operational amplifiers, compared to the ordinary telescopic amplifiers, have a larger output swing. Because of the relatively large output swing, input and output can be short circuited which makes it easier for selection of input common-mode level. Folded cascode op amp is more widely used than telescopic structure. Folded cascode op amp has an important feature which is that it allows the input common-mode level to be close to the power supply voltage. With NMOS input, the common-mode level of gate pole can reach VDD. With PMOS input, it can lower the input common-mode level to 0V[2].

Folded cascode amplifier, compared to the ordinary op amp, is a high gain, a single-pole operational amplifier with large output swing, because compared to two-stage or multi-stage amplifier, the biggest advantage of single-pole amplifiers is that the phase margin is very high and stable. Secondly, its small signal gain can be very large, which is very suitable for deep negative feedback. The focus of this paper is, on the premise of ensuring the stability of single-pole amplifier, to increase the small-signal gain as much as possible and increase the output voltage swing as much as possible, so that input and output can be short circuited.

3. The design of high-performance folded cascode amplifier

3.1. This amplifier is designed with Cadence simulation based on the technique library of SMIC 0.18um.

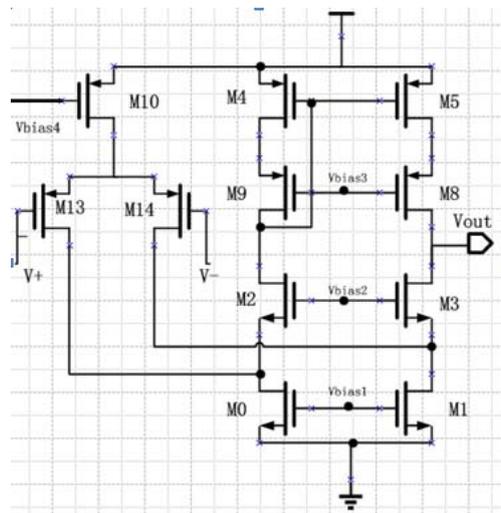


Fig. 1 Folded cascode amplifier

3.2. Calculation and explanation

In order to improve the gain of the amplifier, use cascode structure. CMOS cascode operational amplifier usually has two structural forms: telescopic and folded. Telescopic structure has the good frequency, low power consumption, large gain, low noise and other characteristics, but it's difficult for its output swing and common-mode input range to achieve the desired standard. Although folded structure is smaller than the telescopic one, its common-mode input and output swing are easier to determine.

This input common-mode level of the op amp designed in this paper is about 750mV, and the $1/f$ noise of the PMOS transistor is 2 to 5 times lower than NMOS. From the application point of view, it is more reasonable to use PMOS differential input folded - cascode structure, as shown in Fig. 1. In Fig. 1, M13 and M14 are the PMOS differential input pair, M10 provides bias current for differential input pair. M2, M3 and the input pipe M13, M14 compose of the input cascode tube[3]. M4, M5, M8, M9 compose of low-voltage cascode current mirror which transforms the double-ended output into single-ended output. By connecting the gate of M4 directly to the drain of M9, one can transform M4 and M9, respectively, into gate-drain connected diode, but this reduces the output swing. In this structure, the maximum value of output V_{out} is limited as $V_{dd} - |V_{gs9}| - |V_{gs7}| + |V_{th8}|$, which decrease the output swing by one PMOS threshold voltage. Therefore, the circuit in Fig. 1 should the choice[4].

Conduct small-signal analysis on the circuit, which will show that the gain of folded - cascode operational amplifier is:

Folded cascode amplifier structure is easy to get a great gain, when the power supply voltage is 3.3V, the amplifier's gain is greater than 80dB. Voltage Vbias1, Vbias2, Vbias3 are provided by the bias circuit. Make sure during the work of the amplifier, all MOS tubes are in the saturation region. The structure of bias circuit is shown in Fig. 2:

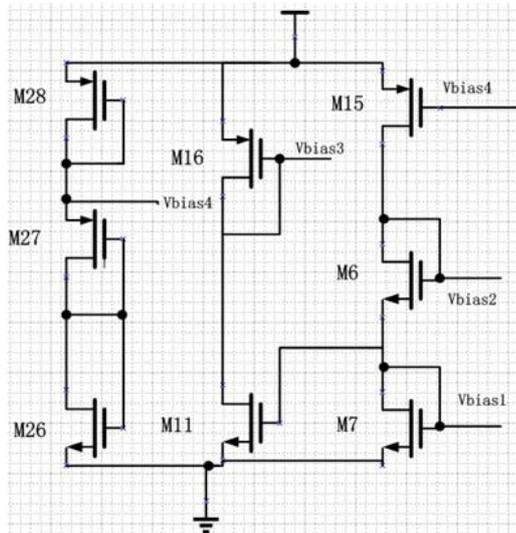


Fig. 2 Amplifier's bias circuit

3.3. Schematic diagram

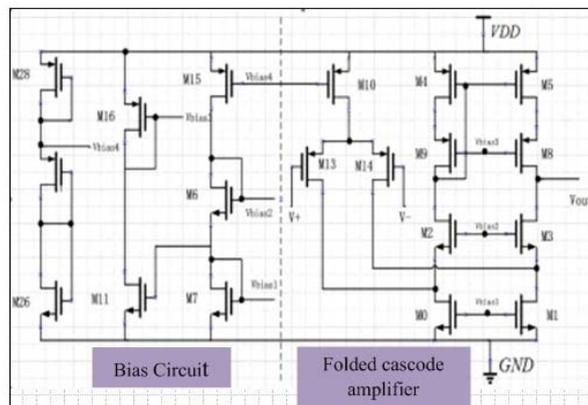


Fig. 3 schematic diagram

3.4. Stimulation result

The gain of this amplifier can reach 96.29dB, and the phase margin is 83.5 degree, as shown in Fig. 4.

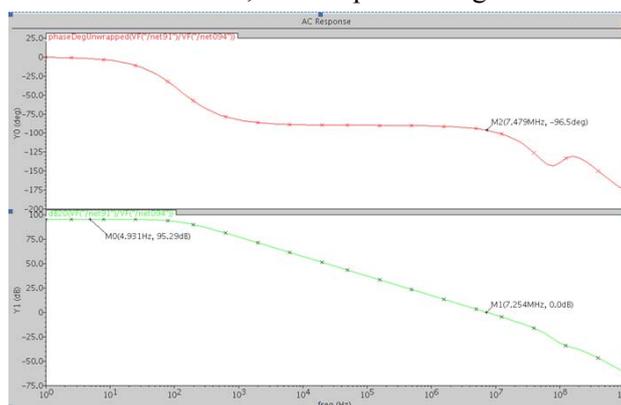


Fig. 4 Stimulation result of reference folded cascode amplifier

3.5. Layout

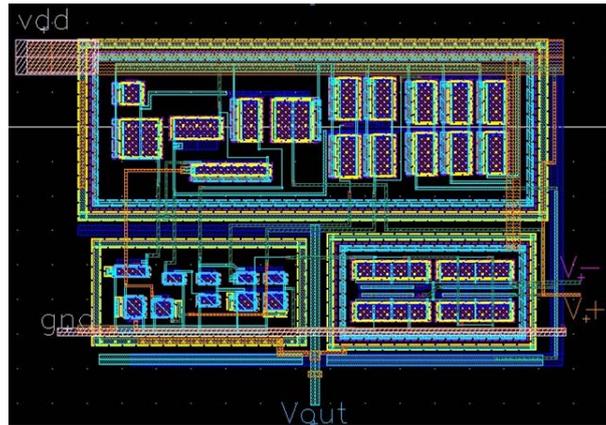


Fig. 5 layout

4. Conclusion

This paper presents a high-performance folded cascode amplifier based on the CMOS SMIC 0.18 μ m technique, which replaces the traditional telescopic structure with the classic cascode structure. Through the spectre simulation of Cadence, under 3.3V, the circuit's DC gain is as high as 96.29dB, and the phase margin is 83.5 degree with a high stability; the bandwidth gain is larger than 5MHzm which satisfies the need of analog signal; the power consumption is smaller than 0.1mW, which is relatively low. These performances can ensure that the amplifier be applied in reference, LDO and other analog modules.

5. Acknowledgment

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6. References

- [1] Behzad Razavi.Design of Analog CMOS Integrated Circuits[M], McGRAW-HILL INTERNATIONAL EDITION, 2001.
- [2] PAUL R.GRAY.Analysis and Design of Analog Integrated Circuits[M].John Wiley &Sons, Inc, 2001.
- [3] Analog integrated circuit and design, He Lenian, Wang Yi, 2008.
- [4] A design of self-biased complimentary folder cascode amplifier, Zhu Wenlong, Huang Shizhen, Lin Wei, 2006.