High Performance Op Amp Design – Review

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ABSTRACT

In a never-ending effort to reduce power consumption and gate oxide thickness, the integrated circuit industry is constantly developing smaller power supplies. Furthermore, in an effort to reduce costs and integrate analog and digital circuits onto a single chip, MOS devices are used in the weak inversion region or the subthreshold inversion region to minimize dc source power. A feasible configuration for high gain, low power op amp design utilizing subthreshold operation along with active operation is proposed. This paper discusses and compares the existing compensation methods for operational amplifiers. In this paper comparison is made between different methodologies of op amp design , such as Nested Miller Compensation Method, Feedforward Compensation technique. Two stage and Three stage op amp using Nested Miller Compensation method, adaptive biasing CMOS op-amp with enhanced DC gain ,Three stage op amp using Indirect Compensation technique. The comparison table 1, shows that the nested miller compensation method provides a high gain of 114.3 dB, high uniy gain bandwidth of 103Mhz, and the low power consumption of about (< 3 mW) ,As compared to the other methods. And feedforward compensation method is also have a low power consumption of upto 18 mW, and it requires a low power suppy of 1.2V.

Keywords

multi-stage amplifier, frequency compensation, high gain, low power consumption.

1. INTRODUCTION

An op amp is a key building block in analog circuit design. It is a DC coupled high gain electronic voltage amplifier. An op amp has differential input and usually a single ended or double ended output. An op amp produces an output voltage that is typically hundreds of thousand times larger than the voltage difference between its input terminals. They were used in many linear, non linear and frequency dependent circuits. In a low voltage op-amp, the minimum supply value is imposed by the differential pair of the input stage and is equal to the threshold voltage (Vth). Within the next few years most mixed signal systems will require operation with supply voltage (vdd<1v) for Power dissipation reduction, Technology downscaling, Volume, Weight reduction, Extended battery life. Different topologies of op amp are single stage op amp, cascode op amp, folded cascade op amp, Two stage op amp, Three stage op amp. The cascade of CS & CG stage is called a cascode topology. The idea behind the cascode structure is to convert the input voltage to a current and apply the result to a common gate stage. The input device and the cascode device need not be the same type. Cascoding is a well known means to enhance the dc gain of an amplifier without degrading the high frequency performance. Cascode circuits have some advantages compared to cascade circuits. Cascode circuits need fewer stages to achieve a high gain. Circuits with fewer stages are easier to compensate. The current consumption of a cascade stage is lower than that of two cascaded stages with the same total gain. Two stage op amp has two stages 1st stage is for high gain and 2nd is for high swing. The gain of the single stage op amp is limited and cascoding in circuits increases the gain, while limiting the output swing. In such cases we use two stage op amps with the 1st stage providing a high gain and 2nd providing large swing. A three stage op amp achieves higher gain than a two stage op amp but has limited bandwidth. Multistage amplifiers are widely used in the analog and mixed signal circuits to achieve higher dc gain and large output signal swing simultaneously. Different Performance parameters of operational amplifier are gain, unity gain bandwidth, noise, slew rate, common mode rejection ratio, power supply rejection ratio, output swing. By using different frequency compensation methods these parameters get affected or get enhanced. Op amps are employed from dc bias applications to high speed amplifiers and filters. General purpose op amps can be used as buffers, summers, integrators, differentiators, comparators, negative impedance converters, and many other applications.

2. OP-AMP DESIGN OBJECTIVES

In general, operational amplifiers are amplifiers with an open loop gain high enough to ensure the closed loop transfer characteristic with negative feedback is approximately independent of the op amp gain. An adequately high gain is the key requirement of an op amp to utilize the negative feedback configuration.The objective is to design the op amp having high gain, high speed, high unity gain bandwidth and low power consumption using frequency compensation method, by verifying the results of different frequency compensation methods such as nested miller compensation, feedforward compensation, adaptive biasing principle and indirect compensation method. So that this op amp topology could be used in a very low voltage application with a typical supply voltage of 1.2V or below, making it ideal for the various applications where the power dissipation is an important specification for life time battery.

3. DIFFERENT METHODOLOGIES FOR HIGH PERFORMANCE OP-AMP DESIGN

To ensure high gain, stability, enhance the unity gain bandwidth for low power consumption and obtain a better transient response, various frequency compensation techniques such as Nested Miller Compensation Method, Feed-forward Compensation Method, Two stage and Three stage op amp using Nested Miller Compensation method, Adaptive biasing principle of CMOS op amp with enhanced DC gain and Three stage op amp using Indirect Compensation technique, have been proposed. The following is brief and necessary overview of the literature on frequency compensation of multistage amplifiers.

3.1 Nested Miller Compensation Method

A design for a low power cascaded three stage operational amplifier[1] , with frequency compensation by Nested Miller Compensation, which could be made to operate at low voltage supplies. The nested miller compensation scheme has repeated application of the miller compensation. It has two capacitors connected from the output of the third stage to the output of stage 1 & 2 respectively. Both the capacitors are in negative feedback loop as the gain of the second stage is positive and that of the third is negative. The multipath technique is used to increase the bandwidth by converting the system into a two stage amplifier at high frequencies. Here the three stage op amp constitutes of a single ended differential amplifier followed by a fully differential stage. The op-amp is designed in 180nm technology and operates at a 3V power supply with a gain of 115 dB, bandwidth of 103Mhz, phase margin of 45 degrees & a settling time of 80-90 ns. Block diagram of Miller compensated three stage op-amp is shown below.

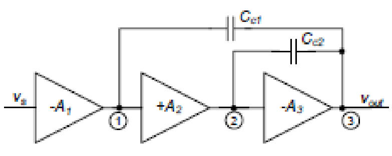

Figure – Block diagram of a Miller compensated three-stage op-amp.

By using nested miller compensation method we get high gain and high unity gain bandwidth. The nested miller compensation and multipath technique is incorporated to enable proper functioning of the system. The use of low power cascaded topology enables the use of the op amp in portable devices such as mobile phones which operate at low voltages. The continuous scaling of voltages makes the cascade topology ideal choice for op amp design.

3.2 Feed-forward Compensation Method

The implementation of a high speed pseudo differential three stage operational amplifier using a feed-forward compensation technique[2], in a standard 0.13 um CMOS technology. It is implemented by keeping a single stage pseudo differential amplifier in the feed-forward path in order to achieve very high speed and stability. The three stage cascaded amplifier on path A provides a gain of $-(Ao)^3$ at low frequency, where –Ao is the gain of each cascaded amplifier. At high frequencies, since path B is faster, the amplifier will typically have a gain the three stage inverter based op-amp with feed-forward compensation achieves 11 GHz of unity gain bandwidth for a nominal power consumption 18 mW, and exhibits 39 dB of DC gain with phase margin of 62° when driving a differential load of (2x300 fF) at a 1.2 V power supply voltage.

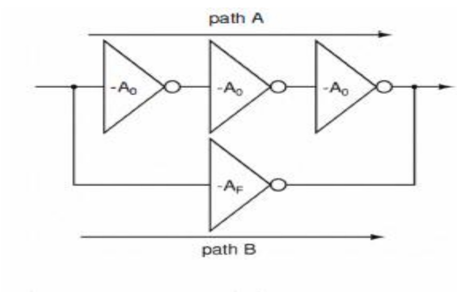

Fig.: Block diagram of proposed three stage operational amplifier with feed-forward compensation.

By using feed-forward compensation method we get high speed, low power consumption, and high stability.

3.3 Two stage and Three stage op-amp using nested miller compensation method

A comparison between two stage and three stage op amp using nested miller compensation technique[3], which shows that the three stage op amp has high gain, reasonable output swing and high frequency performance as compared to two stage op amp. Two stages refer to the number of gain stages in the op amp. The first gain stage is a differential input single ended output stage. The second gain stage is normally a common source gain stage that has an active load. Since op amps are designed to be operated with negative-feedback connection, frequency compensation is necessary for closed loop stability. The simplest frequency compensation technique employs the miller effect by connecting a compensation capacitor Cc across the high gain stage. Op amp consists of one or more differential stages and usually followed by additional gain stages depending upon the requirements

3.4 Adaptive bias principle of CMOS op amp

A new circuit topology for a low-voltage low power class AB amplifier is presented[4]. The circuit uses adaptive bias to have a better efficiency in driving high capacitive loads. Indeed, being the amplifier bias current dependent on the applied input signal, its slew rate strongly improves so enabling the op-amp to deal with large input signals. Differently than the typical adaptive biased amplifier, we introduce a positive feedback at the input stage to enhance the op-amp DC-Gain up to 90dB. The circuit has been designed in a 0.5um CMOS technology. In this paper we get the parameters such as high gain, high slew rate , low power consumption. In this paper a low power, low voltage amplifier which regulates its own bias current has been presented. If no signal is applied, the amplifier operates in "sleeping mode" at very low current level. On the other hand, when a differential signal is applied to the op-amp, the current in the input differential pairs is boosted to enhance the slew-rate.The op-amp achieves then a good settling time. The use of a positive feedback structure enhances the overall op-amp gain up to 90dB. To design the op-amp with desired constraints such asHigh gain, high speed, high unity gain bandwidth, low powerConsumption the different frequency compensation methods used were studied and on the basis of that a low voltage, low power, three stage operational amplifier is designed using frequency compensation method which will be influenced by the nested miller compensation method and feedforward compensation method. To meet the desired constraints of the op amp design. The simulation and verification of the results will be done by comparing the results of different designs and if required modifications will be done.

4. COMPARISON AND DISCUSSION

Table 1.

parameters	**Ref . Paper 1.**	**Ref. Paper 2.**	**Ref. paper 3.**		**Ref. Paper 4.**
			Two stage	**Three stage**	
technology	0.18 um	0.13 um	0.18 um	0.18 um	0.5 um
gain	114.3 db	39 db	75 db	90 db	90 db
Phase margine	45 degree	62 degree	60 degree	55 degree	85 degree
UGB	103 Mhz	79 Mhz	16 Mhz	30 Mhz	1.2 Mhz
Power consumption	<3 mW	18 mW	50 uW	300 uW	24 uW
Power supply	3 v	1.2 v	1.8 v	1.8 v	2.4 v

As we can see from the above comparison table the nested miller compensation method used [1] gives the high gain as compared to other methods and high unity gain bandwidth and low power consumption. Many gain boosting schemes are present to improve the gain. In general, the gain enhancing designs require more complicated circuit structure and a larger power supply voltage, but generate smaller output swing. As a result, multiple stage amplifiers might be more suitable for low power, low voltage, high density analog circuit designs. The feed forward compensation method used[2] requires the power supply of 1.2 V.

5. CONCLUSION

Different methodologies for high performance op amp design has been seen above. It shows that low power cascaded three stage amplifier with multipath NMC[1], and feedforward compensation technique for three stage op amp[2], is found better by the above comparison to get the parameters such as high gain of 114.3db, high unity gain bandwidth of 103 Mhz, low power consumption of < 3 mW, And in feedforward compensation method[2] requires a supply voltage of 1.2 V which is lowest as compared to the other methods.

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