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Analysis and Comparison of Two Stage and Single Stage Operational Amplifiers Using 0.18μm Technology

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Abstract: Operational amplifier exists in many numbers of configurations. The there are many types of the Operational amplifiers. These are: two stage, single stage, three stage and multistage amplifiers. Identifying the better op amp is important to get better application. The better op amp will be selected by considering the performance parameters (DC Gain, Slew Rate, Power Dissipation, etc.) of op amp. In project work a two stage cmos and single stage CMOS operational has been compared and contrasted based on values of their performance parameters by using 0.18μm CMOS technology and the same power supply (5V). Based on these values, By comparing the performance parameters single stage CMOS op amp is more stable and operate longer duration of time than two stage cmos op amp with small energy loss; while two stage op amp produces the output which is twice larger than single stage op amp, and also the noise in the output of two stage op amp is less than single stage op amp. So to get more output it is better to use two stage op amps. By results and reasons suitable choices for high gain and high performance applications are two stage topologies.

Keywords: Single Stage CMOS Op Amp, two Stage Op Amp, Gain, Phase Margin

1. Introduction

An amp- op is device that can be used to increase the magnitude of DC as well as AC input signals [1]. It produces high gain mostly containing of single or more differential amplifiers followed by a level transistor and output stage [2]. The best common building block of most of the electronic systems is Op amp. Op-amps are linear devices which are used for DC amplification as well as conditioning signal, filtering and for performing mathematical operations for instance subtraction, integration, Differentiation, addition etc [1, 2]. In General, an op amp is a three pin instrument. It mainly consists of an inverting input terminal denoted by a negative sign, ("-") and the other a non-inverting input denoted by a positive sign ("+") in the symbol for op-amp. Both inverting and non-inverting inputs are very high resistance [3]. The output signal of an Operational Amplifier is the magnified difference between the two input signals or in other words the amplified differential input. Input stage of an Operational amplifier is often a differential amplifier [3].

There are some structures used for operational amplifier [4]. Among those topologies Single stage and two stage cmos operational amplifiers are mentioned [4]. Two stage structures takes two stages in cascade form. In this structure gain of first stage is not enough, so second stage (common source) is included in cascade to the first stage to increase the gain of the first stage and it produces the properly magnified output at the final stage [4].

Figure 1 shows general topology of operational amplifier.

Figure 1. *The block diagram of operational amplifier [1].*

Input differential amplifier stage is first block is, which is structured to that it produces very high input impedance, a small offset voltage, small noise, high gain, high CMRR, PSRR, [5]. The second stage does add gain, and differential to single ended converter and level shifting [6]. Output buffer is third block is the [5]. The output buffer may sometimes be jumped to form a large output resistance buffered op-amp often referred to as Operational trans-conductance amplifier. Those which have the final output buffer stage have a low output resistance (Voltage operational amplifiers) [5, 6].

Comparison between Single stage and two stage CMOS operational amplifiers:

1) Single stage CMOS operational amplifier:-

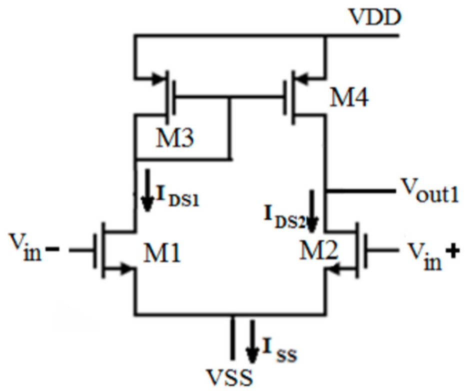

Figure 2. *The circuit of single stage Cmos operational amplifier [7].*

The topology of single stage is shown in figure 2. This single stage has smaller complexity when compared to two stage topology [7, 8]. Since it has smaller complexity property so its slew rate is larger compare to two stages [6]. The disadvantage of single stage CMOS op-amp is smaller gain because of the reality that that output impedance of this class topology is commonly small [9]. But this small resistance also provides to large speed and large unity gain bandwidth than double stages [7].

2) Two stage CMOS operational amplifier:-

The disadvantage of having small amplification of the one stage topology is solved by double stages. In this class of topology double stages are useable. So one of them produces large amplification continued by next stage which produces large voltage swing [11]. This adjustment enlarges the amplification up to some certain extent compared to single stage. However this addition of additional stage also enlarges complexity [12, 13-15]. So the enlarged complexity will lower the slew rate in comparison to a single stage amplifier [14, 15].

Use of two stage CMOS operational amplifier are the following [8]:

1) Two stage CMOS operational large output voltage swing.
2) Two stage CMOS operational larger amplification compare to single stage.

Drawback of two stage CMOS operational amplifier are the following [15]:

1) Two stage CMOS operational has a compromised frequency response.
2) Two stage CMOS operational has large energy dissipation because of two stages in its design.
3) Two stage CMOS operational has a very low negative power supply rejection at larger frequencies.

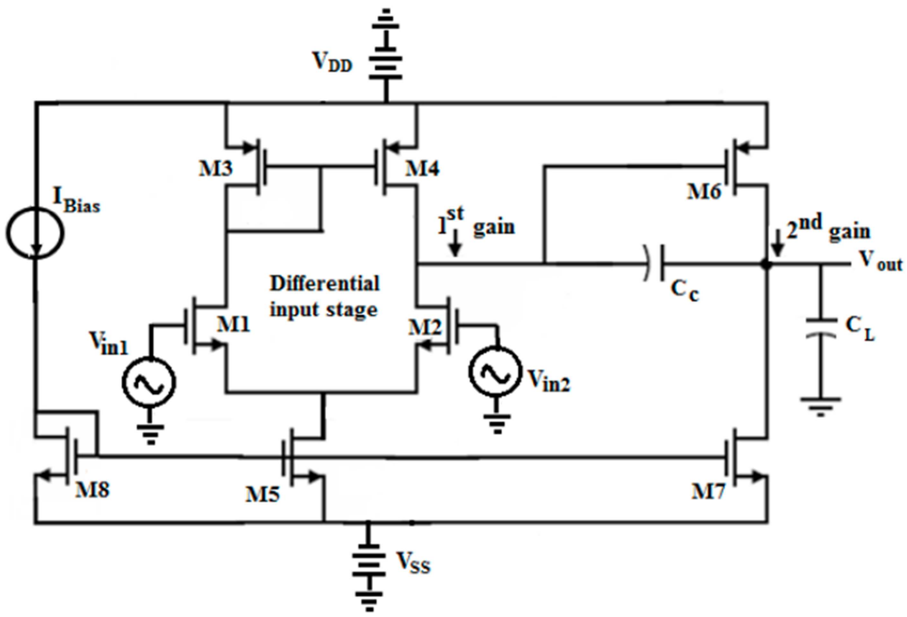

Figure 3. *The circuit of two stage CMOS operational amplifier [13].*

Op amps are applicable in a vast variety of applications in electronics. Some of the more common applications are: as a voltage follower, selective inversion circuit, a current-to-voltage converter, active rectifier, integrator, a whole wide variety of filters, and a voltage comparator [10].

Researchers were continuously working towards trades-off solutions to identify a best type of CMOS op amp by comparing their gain, output swings, speed, power dissipation, bandwidth etc which are used for specific applications. But identifying high gain and high output swing analog circuits is becoming increasingly challenging. For example a high quality microphone that senses the music may generate instantaneous voltage swing that vary more than four orders of magnitude, demanding that subsequent amplifiers and filters handle large swings and achieve low noise. [3] Thus in this study high gain circuits with improved output swing CMOS op amp can be identified.

Designing analog circuits with high performance is important. The main under consideration are: high gain, low power dissipation, high speed, high output swing etc. [8] Significance of this study is to identify a better type of CMOS operational amplifier with high performance analog circuit. Since not only high gain but also high output swing is the main indicators of high performance circuit. [1] For instance a high quality microphone requires high swing to accommodate wide range of signal amplitudes and high gain in addition to keeping other parameters constant. [3] So, if we identify a best type of CMOS operational amplifier a with high performance parameters, then it may be used for such circuits.

2. Data

The simulation result of single stage op-amp and two stage op-amp by using the same supply voltage (3.3V) and the same technology (0.18µm) is given in table 1.

Table 1. *Simulation result of single stage op-amp and two stage op-amp.*

Design Specification	Single Stage OP-AMP	Two Stage OP-AMP
Technology	0.18µm	0.18µm
Supply voltage	3.3V	3.3V
Dc gain	36dB	72dB
Output swing	4.5V	5.6V
CMRR	39dB	77dB
Slew rate	75V/µs	133V/µs
PSRR	30dB	57dB
Power dissipation	1.3mV	1.8mV
Capacitance	1pF	1pF
Phase margin	68˚	51˚

3. Result and Discussion

3.1. Result

The performance parameters of single stage CMOS op amp and two stage CMOS op amp is shown in the figure 4.

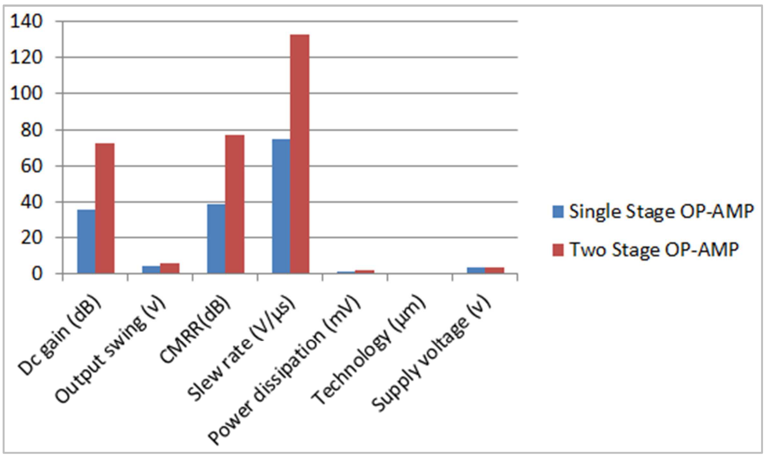

Figure 4. *Performance parameters of single stage CMOS op amp and two stage CMOS op amp.*

3.2. Discussion

The performance parameters of one stage and double stage CMOS operational amplifiers are different even if we use the same technology and supply voltage. Here 0.18µm technology and 3.3V supply voltage. But the performance parameters for each type of op amp are different see figure 4.

As seen from the figure 4 we will give the following dissections about two stage and one stage CMOS operational amplifiers.

1) The single stage CMOS op amp has lower power dissipation than two stage CMOS operational amplifier. This indicates that single stage CMOS op amp will operates longer duration of time than two stage CMOS op amp. In addition it indicates that single stage op amp

is cheaper than two stage op amp.

2) Phase margin of single stage op amp is higher than two stage op amp. This indicates that single stage op amp is more stable than two stage op amp.
3) Dc gain of two stage op amp is almost two times Dc gain of single stage CMOS op amp. This indicates that two stage op amp produce larger output than single stage op amp with the same input.
4) CMRR of two stage op amp higher than CMRR of single stage CMOS op amp. This indicates that the noise of two stage op amp is less than single stage op amp.

4. Conclusion

In this paper work, two stage and single stage CMOS op amp has been compared and contrasted by using the same technology and power supply. By comparing the performance parameters; in this work we can conclude that single stage CMOS op amp is more stable and operate longer time than two stage op amp with small power dissipation. So if we want a device which can operate for longer duration of time, we must use single stage CMOS op amp. In addition in this work we would conclude that two stage op amps produces the output which is twice larger than single stage op amp, and also the noise in the output of two stage op amp is less than single stage op amp. This indicates that if we want a device which can produce more amplified signal, we must use two stage CMOS op amp.

We have identified the applications of each type of CMOS op amp according to their performance parameters. Thus, we recommend that these circuits could be physically fabricated and studied for device applications.

Abbreviations Used

Abbreviation	Expanded Form	Abbreviation	Expanded Form
op-amp	Operational amplifier	PD:	Power Dissipation
AC:	Alternating current	PMOS:	Positive Channel MOS
CMOS:	Complementary Metal Oxide Semiconductor	SR:	Slew Rate
CMRR:	Common Mode Rejection Ratio	$(V_B$:	Bias Voltage
DC:	Direct Current	UGB:	Unity Gain frequency
dB:	Decibel	V_{DD}:	Drain Voltage
IC:	Integrated Circuit	V_{ss}:	Source Voltage
ICMR:	Input Common Mode Range	C_L	Load capacitance
PSRR	Power Supply Rejection Ratio	V_{in}:	Input Voltage
NMOS:	Negative Channel MOS	V_{out}:	Output Voltage

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