Effect of Current Feedback Operational Amplifiers using BJT and CMOS

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Abstract
The operational amplifier is an extremely efficient and versatile device. Its applications span the broad electronic industry filling requirements for signal conditioning, special transfer functions, analog instrumentation, analog computation, and special systems design. The analog assets of simplicity and precision characterize circuits utilizing operational amplifiers. The aim of the paper is to compare the CFOA implemented using BJT and the Current Feedback Operational Amplifier(CFOA) implemented using CMOS on the basis of Voltage Gain, Input and Output Impedance, Supply Voltage Rejection Ratio (SVRR), Common Mode Rejection Ratio (CMRR) and Slew Rate using Simulation Program with Integrated Circuit Emphasis (SPICE) simulation.

Keywords— *Inverting amplifier; Non inverting Amplifier; Differential amplifier; BJT; CMOS ; CFOA*

I. INTRODUCTION

An operational amplifier is a direct-coupled high-gain amplifier usually consisting of one or more differential amplifiers [1, 2]. The operational amplifier is a versatile device that can be used to amplify dc as well as ac input signals and was originally designed for performing mathematical operations. Originally, the term, "Operational Amplifier," was used in the computing field to describe amplifiers that performed various mathematical operations. It was found that the application of negative feedback around a high gain DC amplifier would produce a circuit with a precise gain characteristic that depended only on the feedback used. By the proper selection of feedback components, operational amplifier circuits could be used to add, subtract average, integrate, and differentiate. As practical operational amplifier techniques became more widely known, it was apparent that these feedback techniques could be useful in many control and instrumentation applications. Today, the general use of operational amplifiers has been extended to include such applications as DC Amplifiers, AC Amplifiers, Comparators, Servo Valve Drivers, Deflection Yoke Drivers, Low Distortion Oscillators, AC to DC Converters, Multivibrators, and a host of others. What the operational amplifier can do is limited only by the imagination and ingenuity of the user. With a good working knowledge of their characteristics, the user will be able to exploit more fully the useful properties of operational amplifiers. The precision and flexibility of the operational amplifier is a direct result of the use of negative feedback. Generally speaking, amplifiers employing feedback will have superior operating characteristics at a sacrifice of gain. With enough feedback, the closed loop amplifier characteristics become a function of the feedback elements. In the typical feedback circuit, the feedback elements are two resistors. The precision of the "closed loop" gain is set by the ratio of the two resistors and is practically independent of the "open loop" amplifier. Thus, amplification to almost any degree of precision can be achieved with ease. CMOS is known for lower power consumption [3]. But this advantage true only for slower amplifiers. As the bandwidth increases, a CMOS amp's current increases dramatically. Because of the exponentially increasing current required for CMOS to achieve high speeds [4], bipolar are typically better suited for high bandwidth applications.

A. *Basic Concept of Operational-Amplifier Configuration:*

Generally there are three types of circuits:

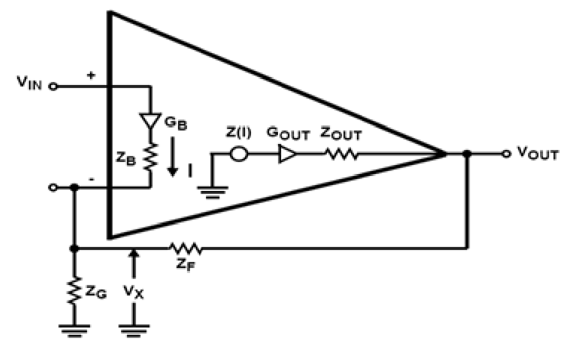
1) Non-Inverting Amplifier: The input is applied only to the non- inverting input terminal and the inverting terminal is *connected to ground.*

2) Inverting Amplifier: The input is applied only to the inverting input terminal and the non-inverting terminal is connected to ground.

3) Differential Amplifier: The input is applied only to the inverting input terminal as well as the non-inverting terminal ground. The op-amp amplifies the difference between the two signals.

II. **CURRENT FEEDBACK OPERATIONAL AMPLIFIER:**

Basically operational amplifier can be made by using voltage feedback and current feedback. In this paper we stress on current feedback operational amplifier (CFOA) [3, 4] using bipolar junction transistor (BJT) and complementary Metal oxide semi conductor (CMOS). CFOA is a type of Trans-Impedance Amplifier. In this model, it can be seen that the non inverting input is connected to the input of a unity gain, which usually takes the form of emitter follower circuit, and is modeled by GB and ZB [5, 6] (Figure 1).Since the non inverting input is the input of a buffer, it's a high-impedance input. Now, because this buffer's output connects to the inverting to input, CFOAs have lower inverting-input impedance,ZB. The current I flowing through the inverting input generates a voltage that is equal to current times the transimpedance Z This voltage is modeled by the output voltage source, Z(I). This voltage becomes the output voltage after passing through the output buffer, which is modeled by GOUT and ZOUT.



A. *CFOA using BJTs:*

It has two stages shown in Figure 2:

Input Buffer Stage.

Output Buffer Stage.

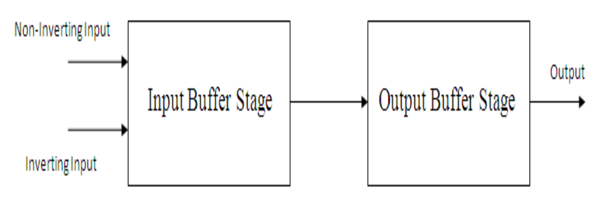


Fig. 2: Block Diagram of CFOA using BJTs

1) *Input Buffer Stage:* It is configured as an emitter-follower. We have given non-inverting input at the base of the transistor therefore it has high impedance and we have given inverting input at the emitter of the transistor therefore it has low impedance.

2) *Output Buffer Stage:* A current flow through the inverting input that generates a voltage which is equal to current times the trans-impedance. This converts high input impedance to low output impedance which must be present at the load to get maximum current in order to drive load of the op-amp. Figure 3 shows the

schematic diagram operational amplifier using BJT

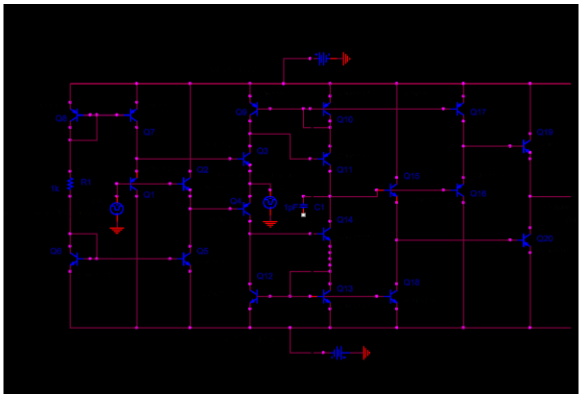


Fig. 3: Operational Amplifier Using BJT

B. *CFOA using CMOS*

It comprises of three subsections of circuit shown in Figure 4, namely

- Differential Gain Stage.
- Bias Strings.
- Second Gain Stage

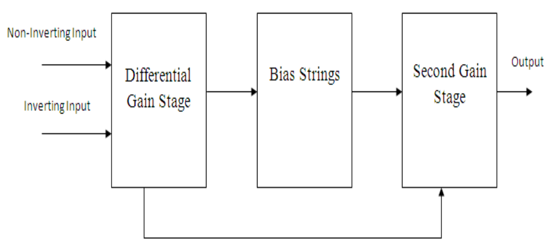


Fig. 4: Block Diagram of CFOA using CMOS

1) *Differential Gain Stage:* Transistors Q1, Q2, Q3, and Q 4 form the first stage of the op amp the differential amplifier with differential to single ended transformation. Transistors Q1 and Q2 are standard N channel MOSFET (NMOS) transistors which form the basic input stage of the amplifier. The gate of Q1 is the inverting input and the gate of Q2 is the non-inverting input. A differential input signal applied across the two input terminals will be amplified according to the gain of the differential stage. The gain of the stage is simply the transconductance of Q2 times the total output resistance seen at the drain of Q2.The current mirror topology performs the differential to single-ended conversion of the input signal. The differential current from Q1 and Q2 multiplied by the output resistance of the first stage gives the single-ended output voltage, which constitutes the input of the second gain stage

2) *Second Gain Stage:* The second stage is a current sink load inverter. The purpose of the second gain stage, as the name implies, is to provide additional gain in the amplifier. Consisting of transistors Q5 and Q6, this stage takes the output from the drain of Q2 and amplifies it through Q5 which is in the standard common source configuration. Again, similar to the differential gain stage, this stage employs an active device, Q6, to serve as the load resistance for Q5. The gain of this stage is the transconductance of M5 times the effective load resistance comprised of the output resistances of Q5 and Q6.

3) *Bias String:* The biasing of the operational amplifier is achieved with only four transistors. Transistors Q8 and Q7 form a simple current mirror bias string that supplies a voltage between the gate and source of Q7 and Q6. Transistors Q6 and Q7 sink a certain amount of current based on their gate to source voltage which is controlled by the bias string. Q8 and Q9 are diode connected to ensure they operate in the saturation region. Proper biasing of the other transistors in the circuit (Q1- Q5) is controlled by the node voltages present in the circuit itself. Most importantly, Q5 is biased by the gate to source voltage (VGS) set up by the VGS of the current mirror load as are the transistors Q1 and Q2.

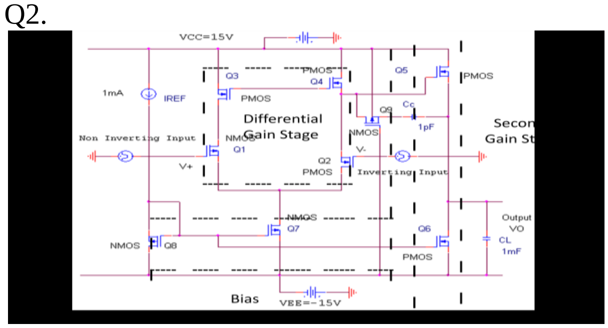


Fig. 5 The schematic diagram of operational amplifier using CMOS

III. RESULTS AND DISCUSSUIONS:

A. *Inverting Amplifier Using BJT* :

As we have applied input to the inverting terminal of op-amp so it is known as inverting amplifier. Fig. 6 shows its input and output waveform

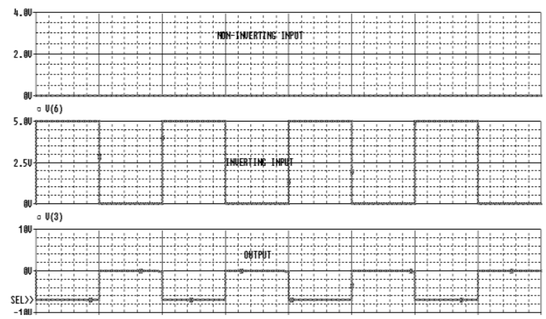


Fig. 6: Simulation results of Inverting Amplifier using BJT

B. *Non- Inverting Amplifier Using BJT*:

As we have applied input to the inverting terminal of op-amp so it is known as non-inverting amplifier. Fig. 7 shows its input and output waveforms**.**

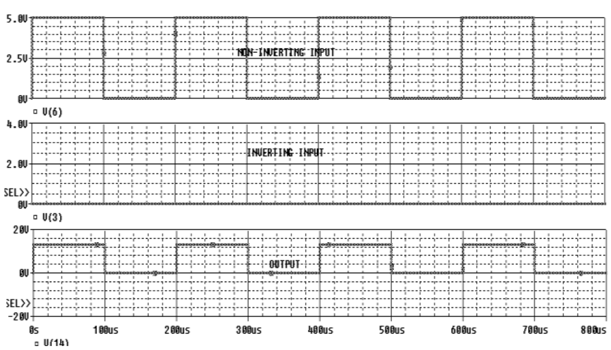


Fig. 7: Simulation results of Non- Inverting Amplifier using BJT

C. *Differential Amplifier Using BJT:*

As we have applied input to the non-inverting terminal and inverting terminal of op-amp using BJT so it is known as differential amplifier. Figure.8 shows its input and output waveforms

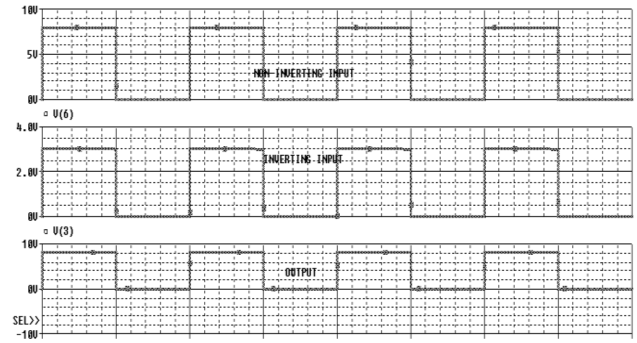


Fig. 8: Simulation results of Differential Amplifier using BJT

D. *Inverting Amplifier Using CMOS:*

As we have applied input to the inverting terminal of op-amp using CMOS so it is known as inverting amplifier. Figure.9 shows its input and output waveforms

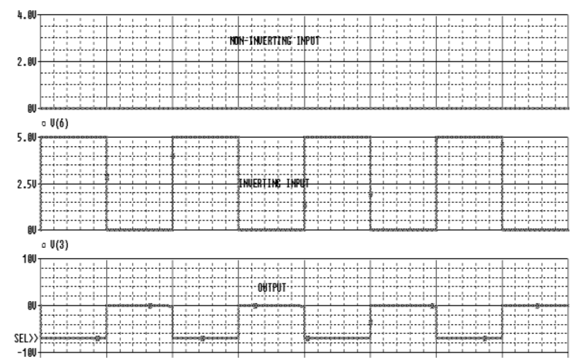


Figure 9: Simulation results of Inverting Amplifier using CMOS

E. *Non- Inverting Amplifier Using CMOS:*

As we have applied input to the non-inverting terminal of op-amp using CMOS so it is known as non-inverting amplifier. Figure.10 shows its input and output waveforms.

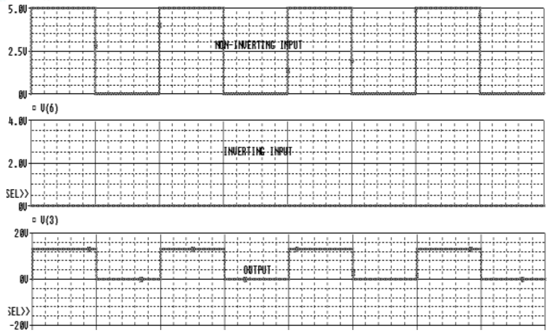


Figure 10: Simulation results of Non-Inverting Amplifier using CMOS

F. *Differential Amplifier Using CMOS:*

As we have applied input to the non-inverting terminal and inverting terminal of op-amp using CMOS so it is known as differential amplifier. Figure.11 shows its input and output waveforms.

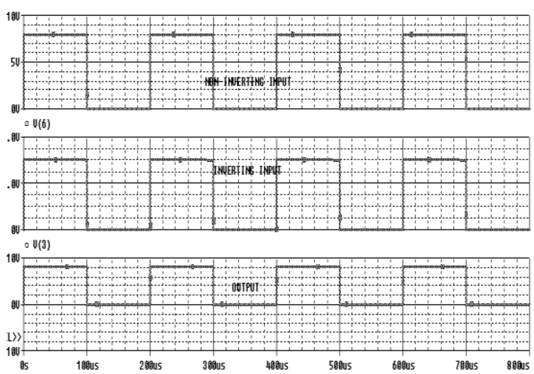


Figure 11: Simulation results of Differential Amplifier using CMOS

V. **CONCLUSIONS:**

In this paper we have implemented basic configurations of current feedback operational amplifier using CMOS and BJT. The voltage gain is found to be the same but the CMOS holds an advantage when it comes to Slew Rate, CMRR, Input Impedance and Power Dissipation whereas the Output Impedance comes out to be better for BJT. When we compare the basic modes the differential mode scores the best on every parameter.

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