Configuration of Operational Amplifier using 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. In this paper we will compare the results of non inverting amplifier and inverting amplifier of operational amplifier made by bipolar junction transistor (BJT) and CMOS using Simulation Program with Integrated Circuit Emphasis (SPICE) simulation.

Keywords: Inverting amplifier, Non inverting Amplifier, BJT, CMOS

1. 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.

2. Circuit configuration

Basic concept of Operational-Amplifier configuration:

Generally there are three types of circuits:

1. Inverting Amplifier
2. Non- Inverting Amplifier.
3. Difference Amplifier

2.1 Inverting Amplifier: The positive end of the input voltage V_{in} is connected through a resistor R_1 to the inverting input pin (-) on the op-amp (the negative end of V_{in} is connected to ground) shown in Figure 1. The non-inverting input pin(+) is connected to ground.

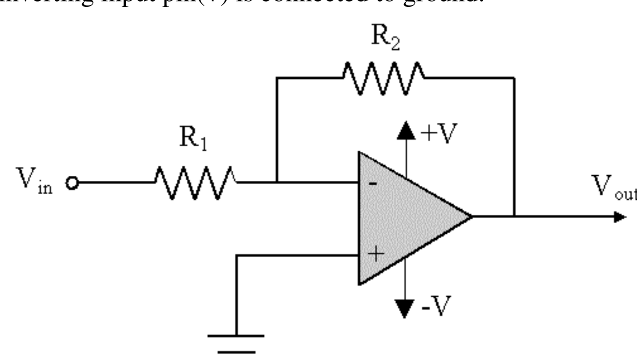

Figure 1 : Inverting Amplifier

The **gain** A_f of an amplifier is defined as the ratio of the output to input voltages.

$$A_f = \frac{V_{out}}{V_{in}}$$

When the input voltage is a DC signal, V_{out} and V_{in} in the above equation represent the actual values of the two voltages. When the input is a sinusoidal AC signal, the output will also be a sinusoidal AC signal. In this case, V_{out} and V_{in} represent the magnitudes of the input and output signals.

For the above circuit, we can assume that the same current flows through both resistors because of the extremely high input impedance and that the voltage at the inverting pin is nearly the same as ground (virtual short). Thus

$$V_{out} = -\frac{R_2}{R_1} V_{in}$$

so that the gain is:

$$A_f = -\frac{R_f}{R_1}$$

When the input and output are sinusoidal AC signals, the negative sign in the above equation indicates a 180-degree phase shift between the output and input.

2.2. Non Inverting Amplifier: The circuit below shows a simple design for a **non-inverting amplifier**. The input voltage V_{in} is applied directly to the non-inverting terminal of the op-amp shown in Figure 2. Negative feedback is provided by the two external resistors R_1 and R_2 which form a voltage divider and apply a fixed fraction of the output voltage to the inverting input terminal of the op-amp.

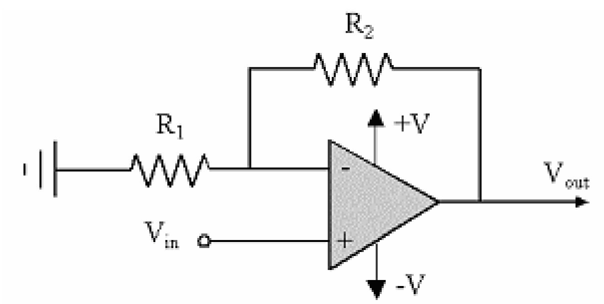

Figure 2: Non inverting Amplifier

The gain of the amplifier is determined by the external resistors R_1 and R_2 according to the equation:

$$A_f = 1 + \frac{R_2}{R_1}$$

2.3 Difference Amplifier: In the previous two circuits (inverting and non-inverting amplifiers), there is only one input signal. A differential amplifier is used to deal with two input signals, and only the difference between the two input signals is amplified. The circuit shown in Figure 3 is a simple **differential amplifier**.

Notice the two resistors connected to V_1 and V_2 should have the same value (well-matched resistors), and the two resistors, one connected to V_{out} and one connected to ground, should also have the same value. The output signal is related to the two input signals according to the following equation:

$$V_{out} = \frac{R_2}{R_1} V_{in}$$

The gain of the differential amplifier is defined as the ratio between V_{out} and (V_2-V_1):

$$A_f = \frac{V_{out}}{V_2 - V_1} = \frac{R_2}{R_1}$$

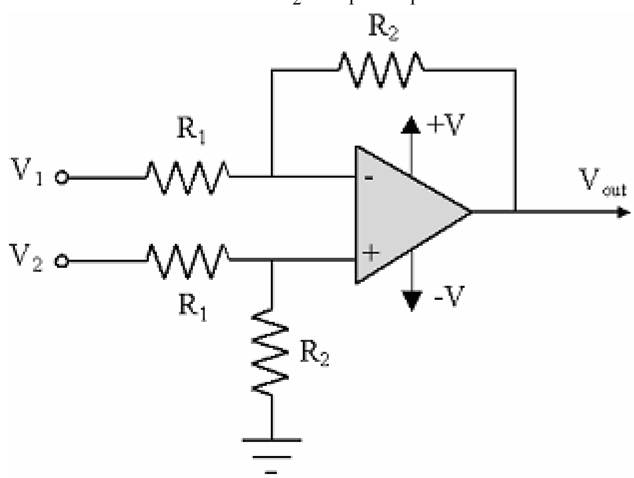

Figure 3: Circuit of a simple differential amplifier

3. Results and discussions

Simulation Program with Integrated Circuit Emphasis (SPICE) is a general-purpose analog electronic circuit simulator. It is a powerful program that is used in IC and board-level design to check the integrity of circuit designs and to predict circuit behavior. Semiconductor devices such as diodes, transistors and integrated circuits can be found everywhere in our daily lives, in Walkman, televisions, automobiles, washing machines and computers. We have come to rely on them and increasingly have come to expect higher performance at lower cost.

The Bipolar Junction Transistor (BJT) was the first type of transistor to be mass-produced. Bipolar transistors are so named because they conduct by using both majority and minority carriers. CMOS was also sometimes referred to as complementary-symmetry metal–oxide–semiconductor (or COS-MOS). The words "complementary-symmetry" refer to the fact that the typical digital design style with CMOS uses complementary and symmetrical pairs of p type and n type metal oxide semiconductor field effect transistors (MOSFETs) for logic functions. Two important characteristics of CMOS devices are *high noise immunity* and *low static power consumption*. Significant power is only drawn when the transistors in the CMOS device are switching between on and off states. Consequently, CMOS devices do not produce as much waste heat as other forms of logic, for example transistor transistor logic (TTL) or NMOS logic, which uses all n-channel devices without p-channel devices. CMOS also allows a high density of logic functions on a chip. "CMOS" refers to both a particular style of digital circuitry design, and the family of processes used to implement that circuitry on integrated circuits (chips). CMOS circuitry dissipates less power when static, and is denser than other implementations having the same functionality. As this advantage has grown and become more important, CMOS processes and variants have come to dominate, so that the vast majority of modern integrated circuit manufacturing is on CMOS processes. Figure 4 and Figure 5 shows the schematic diagram of operational amplifier using BJT and CMOS respectively.

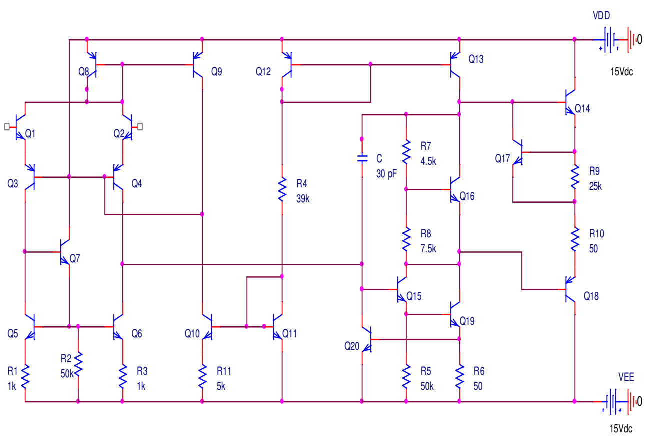

Figure 4: Operational Amplifier Using BJT

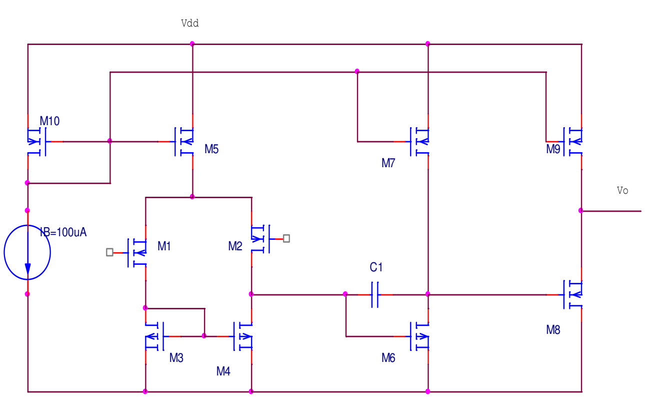

Figure 5: Operational Amplifier Using CMOS

3.1 Inverting Amplifier Using BJT: As we have applied input to the inverting terminal of op-amp so it is known as inverting amplifier shown in Figure.6. Figure 7 shows its input and output waveforms.

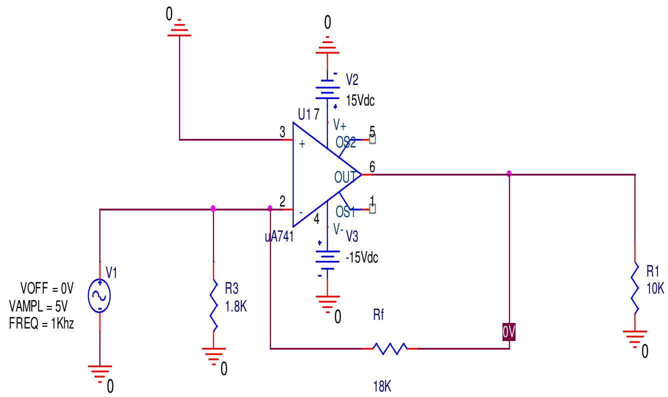

Figure 6: Circuit diagram of Inverting Amplifier using BJT

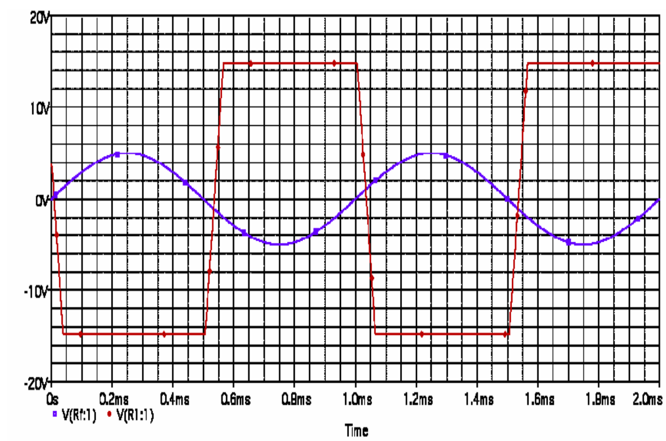

Figure 7: Simulation results of Inverting Amplifier using BJT

3.2 Non- Inverting Amplifier Using BJT: As we have applied input to the non inverting terminal of op-amp so it is known as non-inverting amplifier shown in Figure.8. Fig.9 shows its input and output waveforms.

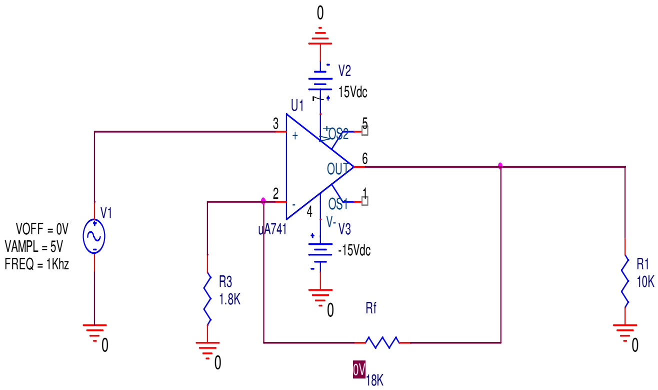

Figure 8: Circuit diagram of Non- Inverting Amplifier using BJT

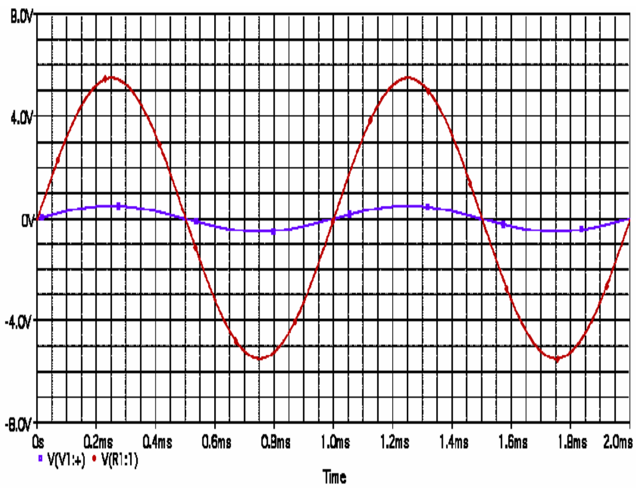

Figure 9: Simulation results of Non- Inverting Amplifier using BJT

3.3 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.10 shows its input and output waveforms.

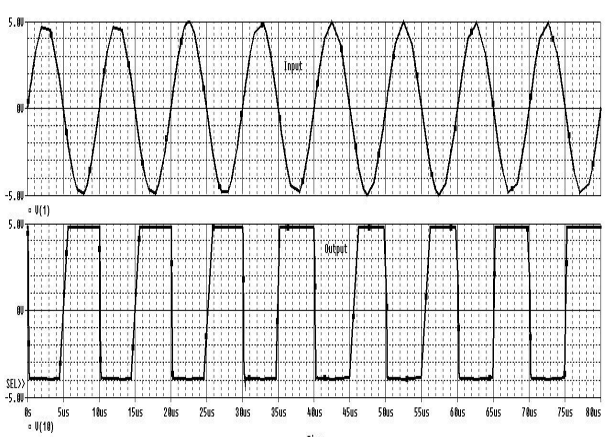

Figure 10: Simulation results of Inverting Amplifier using CMOS

3.4 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.11 shows its input and output waveforms.

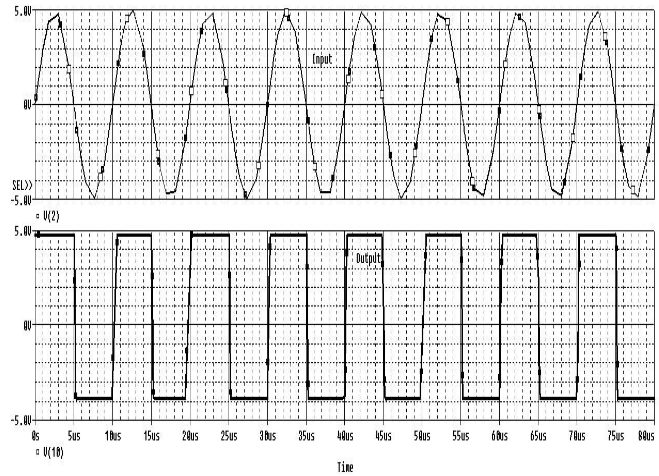

Figure 11: Simulation results of Non-Inverting Amplifier using CMOS

After simulation we get the following results :

1. TOTAL POWER DISSIPATION 2.50E-03 WATTS
2. GAIN = 1.816E+04
3. INPUT RESISTANCE = 1.000E+20
4. OUTPUT RESISTANCE = 1.342E+03

4. Conclusions

In this paper we have implemented basic configurations of operational amplifier using CMOS. Bipolar op-amps hold an inherent advantage over CMOS when it comes to noise performance. CMOS transistors have worse low-frequency noise than bipolar. CMOS have lower trans-conductance relative to similarly sized bipolar transistor, which results in higher broadband noise. Our future work is to make Difference Amplifiers using CMOS and compare the results with existing one.

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