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Analysis of Operational Amplifier using 120 nm Technology

Jayanti Kumawat#1, Poonam Pathak*2

#Electronics & Communication, R.G.P.V Bhopal
L.K.C.T. Indore M.P. India
[1]kumavat_4891@yahoo.co.in
[2]poonam484290@gmail.com

Abstract*— In this paper A CMOS single output 2 stage operational amplifier is conferred that operates at 1.5 V power offer at 0.12micrometer (i.e., one hundred twenty nm) technology. It's designed to fulfil a group of provided specifications. The distinctive behaviour of the MOSFET in sub- threshold region not only permits a designer to figure at low input bias current however conjointly at low voltage. This op-amp has terribly low standby power consumption with a high driving capability and operates at low voltage in order that the circuit operates at low power. The op-amp provides a gain of 20.4dB and bandwidth 202 kHz also provide bandwidth of 2.15MHz for unity gain a load at five pF. This op-amp incorporates a PSRR (+) of 85.0 dB and a PSRR (-) of 60.0 dB. It's a CMRR (dc) of 64.4 dB, an output slew rate of 12.465 v/µs. The power consumption for the op-amp is 0.9mW. The op-amp is meant within the 120nm technology.

***Keywords*—CMOS, PMOSFET, NMOSFET, OPAMP, CMRR, SLEW RATE, GAIN, TANNER TOOL.**

Introduction

The operational amplifier is undoubtedly one of the most useful devices in analog electronic circuitry. Op-amps are built with vastly different levels of complexity to be used to realize functions ranging from a simple dc bias generation to high speed amplifications or filtering. With only a handful of external components, it can perform a wide variety of analog signal processing tasks. Op-amps are among the most widely used electronic devices today, being used in a vast array of consumer, industrial, and scientific devices. Operational Amplifiers, more commonly known as Op-amps, are among the most widely used building blocks in Analog Electronic Circuits. Op-amps are used equally in both analog and digital circuits. [1,2]

Op-amps are linear devices which has nearly all the properties required for not only ideal DC amplification but is used extensively for signal conditioning, filtering and for performing mathematical operations such as addition, subtraction, integration, differentiation etc . Generally an Operational Amplifier is a 3-terminal device. It consists mainly of an **Inverting input** denoted by a negative sign, **("-")** and the other a **Non-inverting input** denoted by a positive sign **("+")** in the symbol for op-amp. Both these inputs are very high impedance. The output signal of an Operational Amplifier is the magnified difference between the two input signals or in other words the amplified differential input. Generally the input stage of an Operational Amplifier is often a differential amplifier.[3]

Our aim is to create the physical design and fabricate a low power Op-amp .An ideal op-amp having a single- ended out is characterized by a differential input, infinite voltage gain, infinite input resistance and zero output resistance. In a real op-amp however these characters cannot be generated but their performance has to be sufficiently good for the circuit behaviour to closely approximate the characters of an ideal op-amp in most applications. With the introduction of each new generation of CMOS technologies design of op-amps continues to pose further challenges as the supply voltages and transistor channel lengths scale down.[4-6,35]

An Op-amp have 4 main blocks

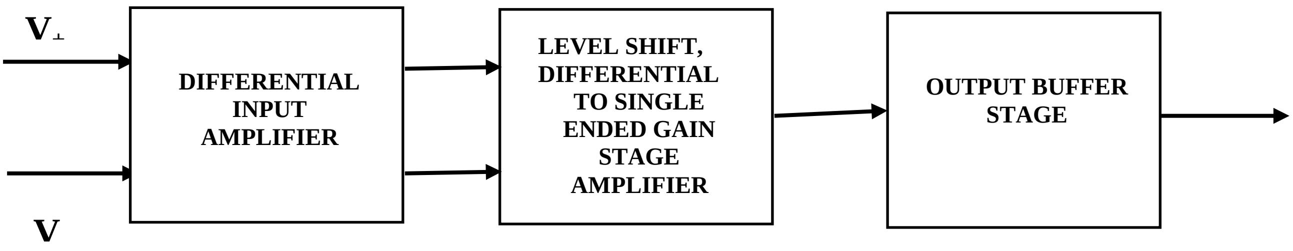
a. Current Mirror

b. Differential Amplifier

c. Level shift, differential to single ended gain stage

d. Output buffer

The general structure of op-amp is as shown in figure below:-



General Structure of op-amp

APPLICATIONS

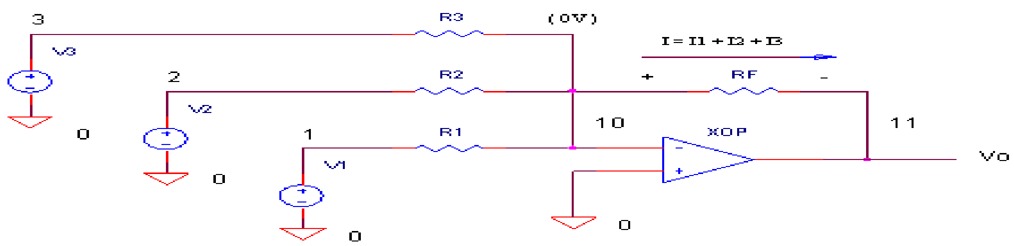
Operational amplifiers are used in so many different ways that it is not possible to describe all of the applications. However we may look into the use of op-amps for some simple yet widely used applications to form an idea of its mode of employment for various applications:

Summing electronic equipment (Adder): The summing amplifier is a handy circuit enabling to add several signals together. the negative terminal close to 0V (virtual ground) the op-amp essentially nails one leg of R1, R2 and R3 to a 0V potential. This makes it easy to write the currents in these resistors.

I1 = V1 / R1; I2 = V2 / R2; I3 = V3 / R3 …………(1)

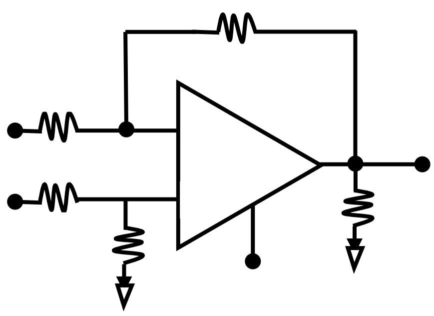
According to Kirchhoff's law, we get I = I1 + I2 + I3 and

V0 = - RF (V1 / R1 + V2 / R2 + V3 / R3) ………... (2)



Op-amp summing circuit

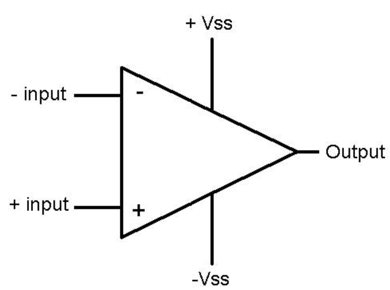
Differential Amplifier: The distinction op-amp produces the algebraically distinction between 2 input voltages that is shown in Figure. Once RF=Rin and RA=RB the output of the electronic equipment may be given as VO= (R_A/R_B) (VA - VB). Therefore the setup amplifies the distinction of 2 voltages by a relentless gain set by the used resistances.



Op-amp differential circuit

OPERATIONAL AMPLIFIER

The general operational amplifier symbol is as shown below:-



General operational amplifier

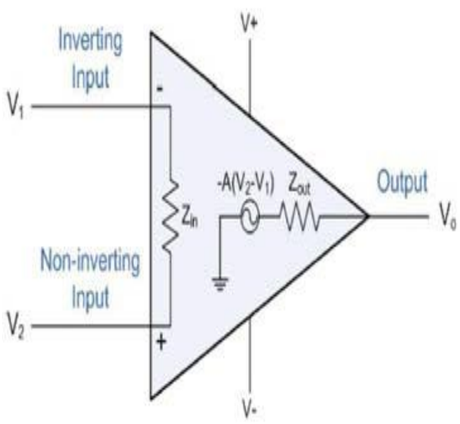
An ideal Operational Amplifier is a 3-terminal linear device. It consists of two input terminals with very high impedance. Basically the Operational Amplifier output signal is nothing but the difference of the two input signals being applied at the high impedance terminals magnified by a constant gain. [17-18]

Thus for an ideal op-amp the input signal is almost always a differential signal and hence a differential amplifier is generally used as the input stage of an Operational Amplifier. The op-amp block diagram shows a common op-amp symbol with two inputs marked by + and – and an output. The terminals VDD and VSS are the terminals for the supply voltages. In general the op-amp is used with dual power supplies. The VSS terminal is made negative to drag down the source potential of the NMOS transistors used in the design to a negative potential. This ensures that the op-amp can be used for wider range of differential inputs. For ideal operation of the op-amp circuit it all transistors are supposed to function in saturation. The negative power supply at VSS ensures even if one of the inputs is grounded the differential pair action as the input stage of the op-amp is in saturation. The output voltage, Vout of the amplifier is given by the difference between the two input signals applied to the differential amplifier multiplied by some constant gain determined by the specs of the designed system. For designing an ideal op-amp many considerations are made. One those considerations involve the use of perfectly matched transistors for the input differential pair as well as at the load of the differential pair. The use of current mirrors in the op-amp circuit also creates the need for generation of matched transistors.

Ideal Operational Amplifiers have in general one output (although there are op-amps with differential outputs as well as many applications have need for them) of low impedance which is mostly referenced to a common ground terminal. In an ideal case the output of the op-amp should ignore any common mode signals in the input, i.e., if signals of identical dimensions are applied to both the inputs the output should be zero ideally. However, in practical amplifiers the output always varies slightly for the common mode input and this change of the output voltage with respect to variations in the common mode input voltage is measured for an op-amp by virtue of its Common Mode Rejection Ratio or CMRR**.**[26].

EQUIVALENT CIRCUIT OF AN OP-AMP

An equivalent op-amp circuit is shown in the circuit below. It consists of two inputs often referred to as the inverting and non-inverting inputs. The input resistance or rather impedance is referred in the diagram as Zin and the output impedance is given by Zout. This is the basic block diagram of a op-amp which generally has a single output.



Equivalent Circuit for ideal operational amplifier

IDEALIZED CHARACTERISTICS

(a) Voltage Gain, (A) **Infinite**

(b) Input impedance (Zin) **Infinite**

(c) Output impedance, (Zout) **Zero**

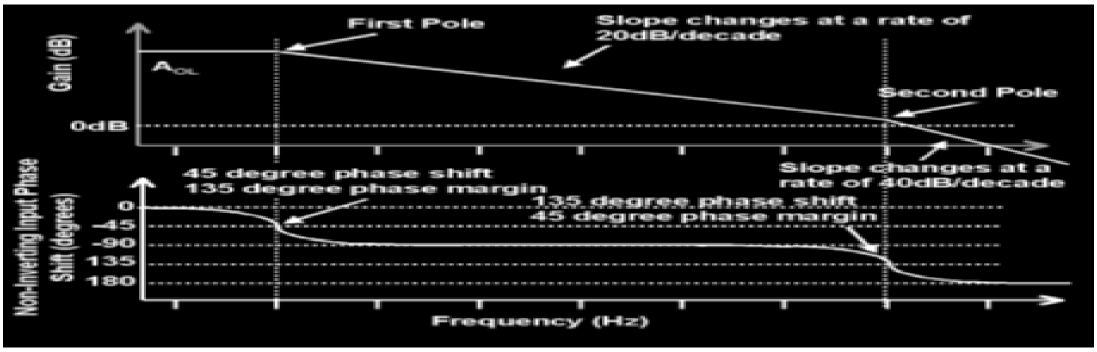
(d) Bandwidth, (BW) **Infinite**

(e) Offset Voltage, (Vo) **Zero**

AN OPERATIONAL AMPLIFIER BANDWIDTH

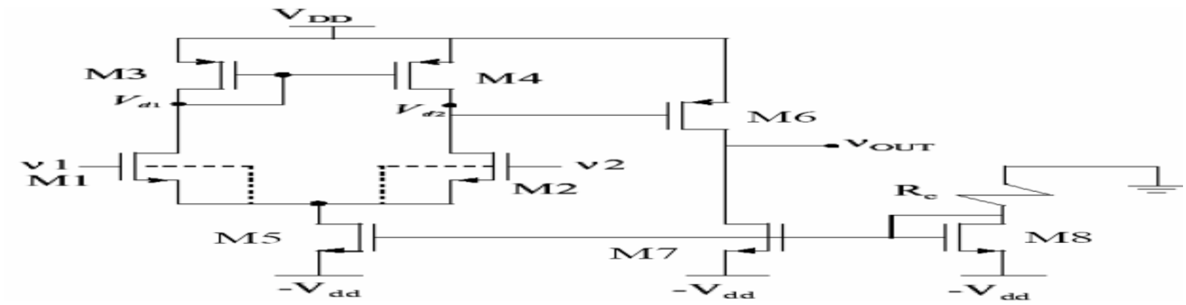
The bandwidth of an operational amplifiers is defined as the frequency range over which the amplifier voltage gain is greater than 70.7% or -3dB (where we consider the maximum gain to be the reference or 0dB) of the maximum output value attained by the gain of the amplifier. Suppose if the maximum gain of an amplifier is

50dB for example then 47dB is given as the -3dB or 70.7% of Vmax down point from the frequency response curve.



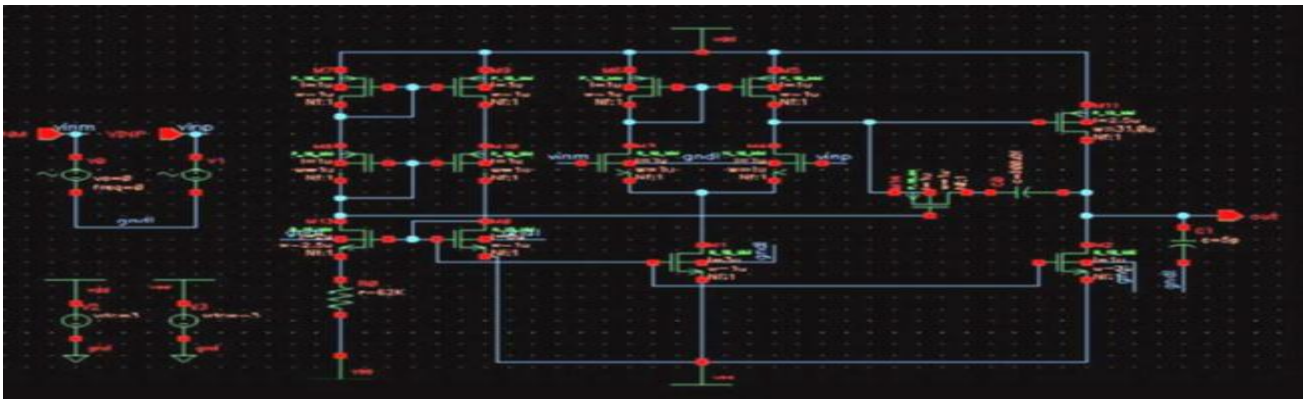
Op-Amp bandwidth sample graph

STRUCTURE OF OP-AMP



Block Diagram for a Practical Op-Amp

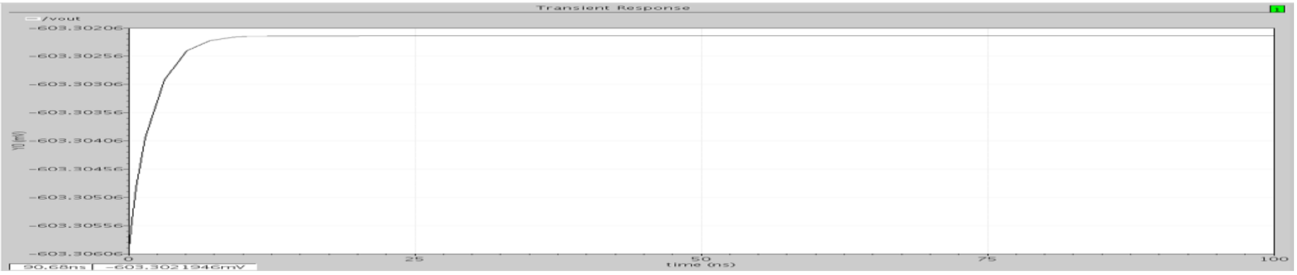
PROPOSED OPAMP CIRCUIT



Op-Amp full schematic

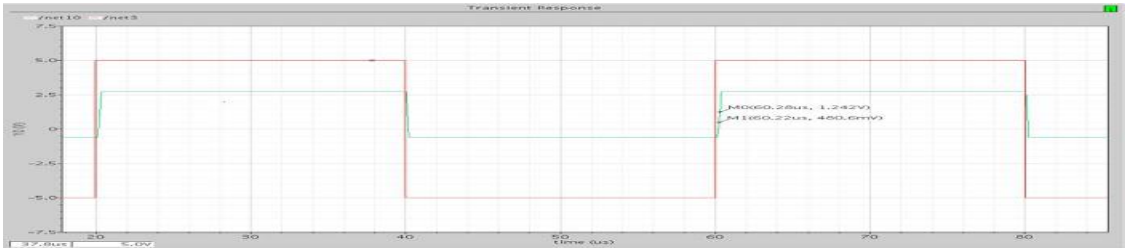
SIMULATION AND RESULTS

OFFSET VOLTAGE : It is the voltage obtained at the output terminals, when the input terminals are connected to ground terminal, i.e., 0 volts. Here the offset voltage calculated for the op-amp is -603mv.

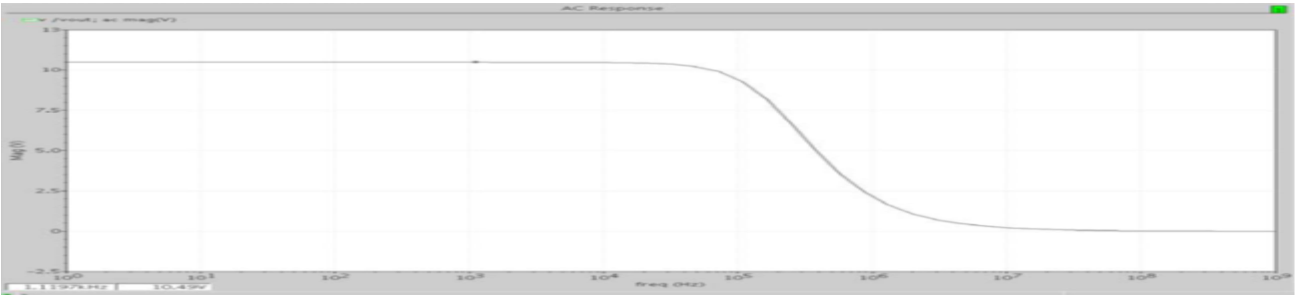


SLEW RATE

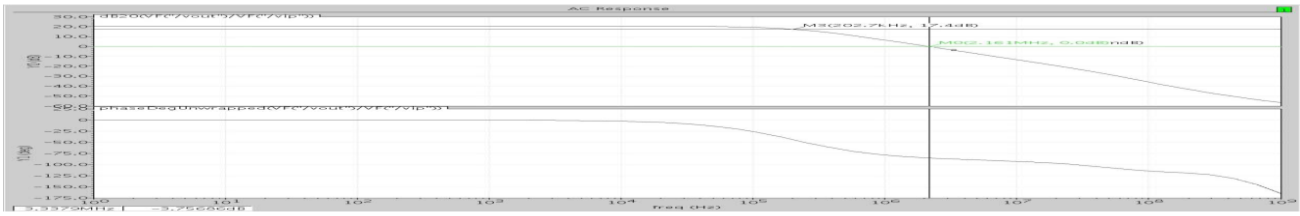
It is the maximum rate of change of output voltage. Here the slope of the curve calculated as 12.5 v/µs.



GAIN: It is defined as the ratio of the output to the input. Here the input voltage given as 1 volts sine wave. Hence the gain is calculated as 10.4v/v.



BANDWIDTH: It is the maximum allowable range of the frequencies. Here the bandwidth of this op-amp calculated as 2.16 MHz for unity gain and 202kHz at -3dB.



POWER DISSIPATION: The power dissipation of this op-amp is calculated as 0.9mW.

CONCLUSION

The proposed design has been able to satisfy most of the specifications provided for the op-amp. The proposed op-amp is a two stage single output op-amp. The input stage is a differential amplifier and a common source stage forms the second stage of the op-amp. The layout of the design has been made and simulated. The post layout simulations abide by the given specification. The entire design has been done in 120 nm technology.

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