Designing and Simulation of Differential Amplifier

Sudeep Saurabh

Content

Introduction

For this project, I wanted to create a practical application , so I studied various real world applications of the circuits I could create in LTspice using a CMOS inverter. I chose to make a CMOS differential amplifier because I wondered how a person controls the music and sound equipment.

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Theory

A differential amplifier (also known as a difference amplifier or op-amp subtractor) is a type of electronic amplifier that amplifies the difference between two input voltages but suppresses any voltage common to the two inputs. A differential amplifier is an analog circuit with two inputs (V1 and V2) and one output (V0) in which the output is ideally proportional to the difference between the two voltages.

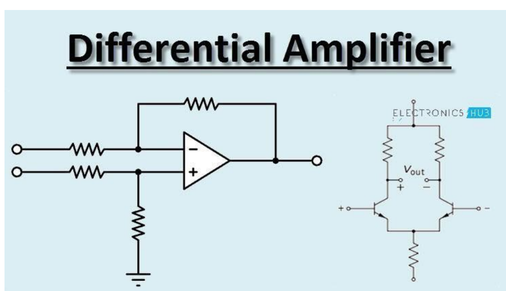


Fig1: Differential Amplifier using OP-AMP

The formula for a simple differential amplifier can be expressed:

$$V_0 = A_d(V_1 - V_2)$$

Where

- V0 is the output voltage
- V1 and V2 are the input voltages
- Ad is the gain of the amplifier (i.e. the differential amplifier gain)

From the formula above, you can see that when V1 = V2, V0 is equal to zero, and hence the output voltage is suppressed. But any difference between inputs V1 and V2 is multiplied (i.e. amplified) by the differential amplifier gain Ad.

This is why the differential amplifier is also known as a difference amplifier – the difference between the input voltages is amplified.

There are three different types of differential amplifier

1) Source coupled pair

2) Source cross-coupled pair

3) Current differential amplifier

The differential gain of an amplifier calculation shown below.

$V_O = A_d (V_1 - V_2)$

$V_d = (V_1 - V_2)$

$VO = A_d V_d$

$Ad = V_o / V_d$

If the applied input voltage is differential or they are out of phase with each other. V1 is a sinusoid signal biased at 2.5V with an amplitude of 5mv.

In the case of a fully differential signal at V2 will be 180 degrees out of phase with V1 biased at 2.5V.

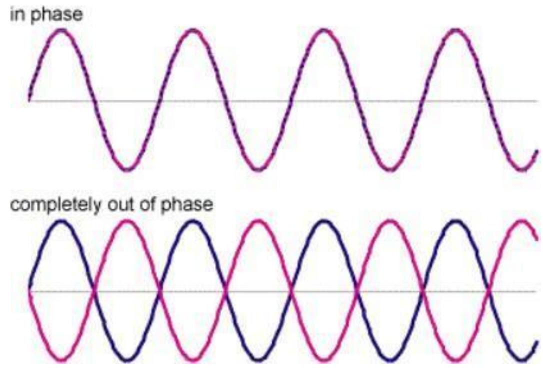
The common-mode voltage $V_C = V1 + V_2/2 = 2.5$, $V_1 = 2.5 + 0.05 \text{ Sin } (w^o t)$, $V_2 = 2.5 - 0.05 \text{ Sin } (w^o t)$

For a differential mode voltage, we must subtract the input signal.

$V_D = (V_1 - V_2)/2$

The differential mode voltage will be half of the difference between the two voltages. $V_D = 0.05 \text{Sin } (w^o t)$

For an ideal differential amplifier, the differential gain must be infinite and the common-mode gain to be zero, but in reality, this is not possible.



Complementary metal–oxide–semiconductor is a type of metal–oxide–semiconductor field-effect transistor (MOSFET) fabrication process that uses complementary and symmetrical pairs of p-type and n-type MOSFETs for logic functions. CMOS technology is used for constructing integrated circuit (IC) chips, including microprocessors, microcontrollers, memory chips (including CMOS BIOS), and other digital logic circuits.
CMOS technology is also used for analog circuits such as image sensors (CMOS sensors), data converters, RF circuits (RF CMOS), and highly integrated transceivers for many types of communication.

Application of Diffrential Amplifer

Volume controller

An audio signal is applied to one end of a potentiometer, whose other end is grounded. A mechanical slider is then allowed to move anywhere along the length of the potentiometer's resistance, creating an adjustable voltage divider. The output audio signal is a copy of the input signal, at reduced amplitude. A stereo audio system will have two of these, one for each audio channel, mechanically connected so they are adjusted concurrently.

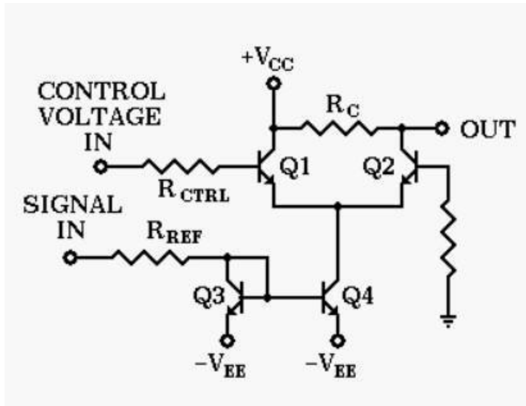


Fig 3 :Volume controller

While this is a very simple, direct, and inexpensive way to adjust audio volume (or any signal amplitude), it has a few problems. Since the movable contact must slide directly on the resistance material, it will cause some wear. Even worse is that the exposed contact can readily collect dirt or dust, causing the contact to be intermittent and noisy.

Now consider the circuit to the right. The audio signal is now providing the reference for the current mirror. This means that the emitters of Q1 and Q2 now receive current that matches the audio signal. However, only the emitter current of Q2 actually reaches the output terminal; any current through Q1 is lost.

The control voltage can vary from -VBE for full volume to +VBE for zero signal level. Most commonly it comes from a small digital to analog converter driven by a binary counter that can count up or down on signal. This is how remote control volume works on modern television receivers, for example.

Project Objective

- Our project objective is to design a CMOS differential amplifier
- Convert the design into a Component.
- Test the component
- To use the designed component as Volume Controller.

Software Used

We have decided to use LTSpice XVII to design and simulate our project. LTspice is a SPICE-based analog electronic circuit simulator computer software, produced by semiconductor manufacturer Analog Devices. It is the most widely distributed and used SPICE software in the industry.

Components Required

1. NMOS
2. PMOS
3. Voltage source
4. Wire
5. Ground.

Schematic of Differential Amplifier

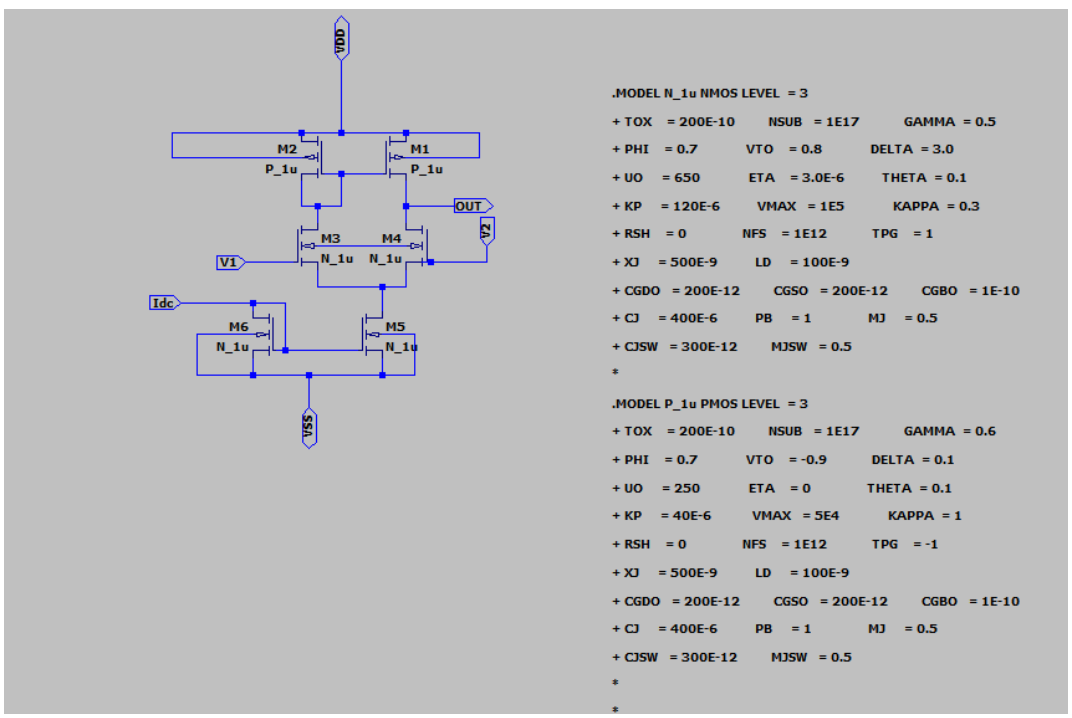


Fig 4: Schematic of Differential Amplifiers

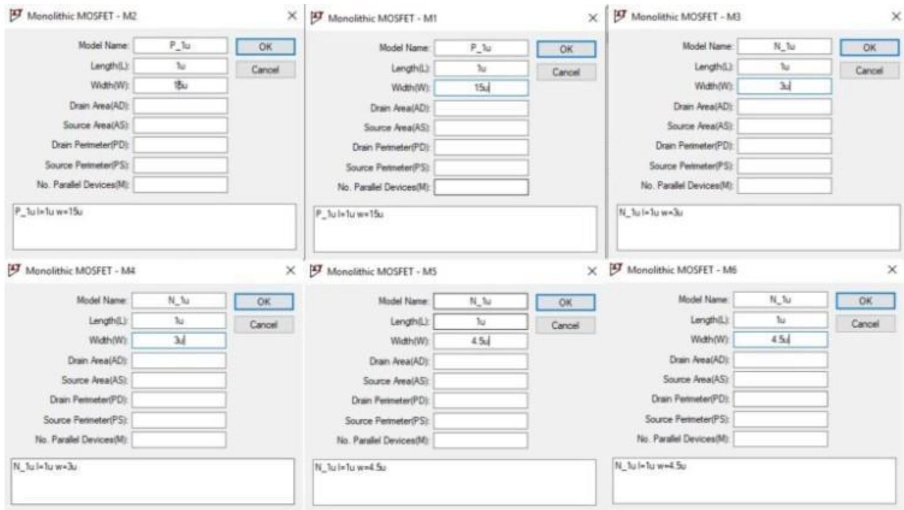


Fig 5: Setting size of the device

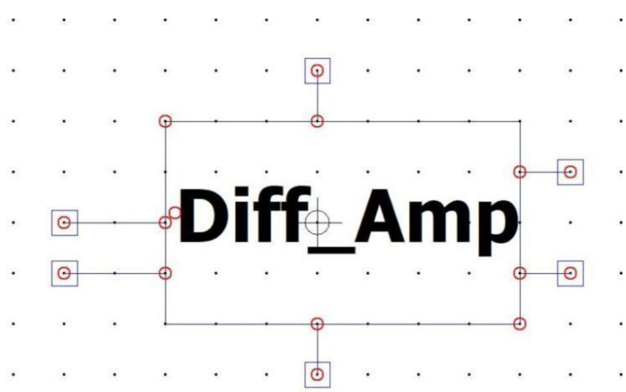


Fig 6: Symbol of the designed differential amplifier

Schematic of Differential Amplifier

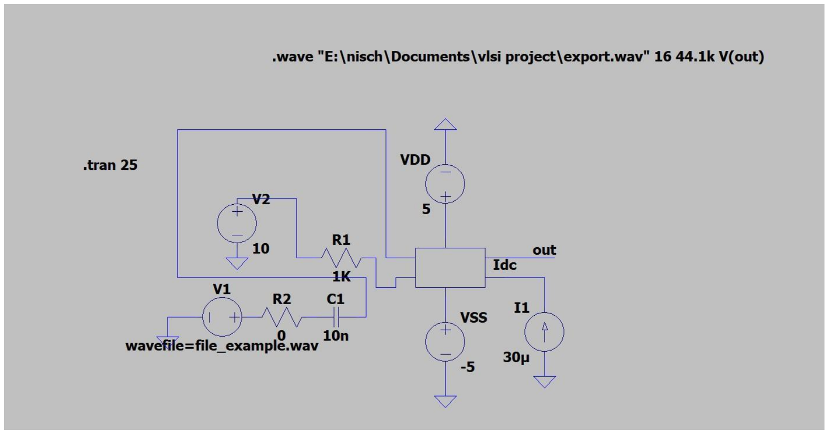


Fig 7: Volume controller schematic

LTspice can produce a sound output in .WAV format. In our simulation, the output sound is stored as export.wav. Sample at the rate of 16 bits. 44.1K is the number of samples per simulated second.

Simulation of Volume Controller

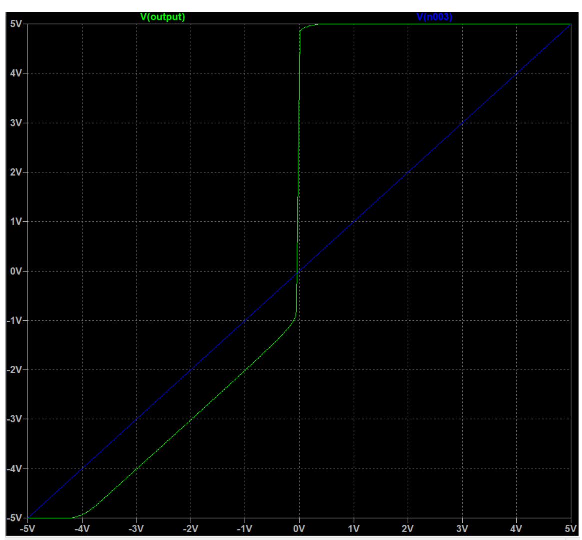


Fig 8: DC sweep analysis

The first source of sweep will be V1, the start value to be -5, and stop value as 5 with 1mv increment.

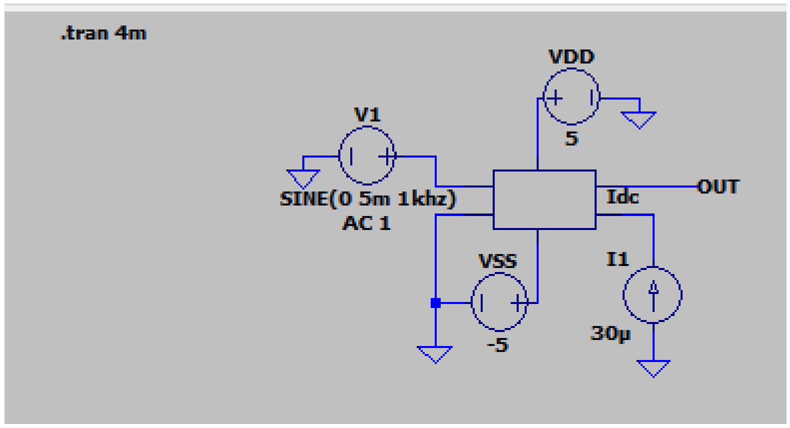


Fig 9: Volume controller schematic

Here we did a transient analysis by giving a sine wave of 1Khz as input and analysed the output.

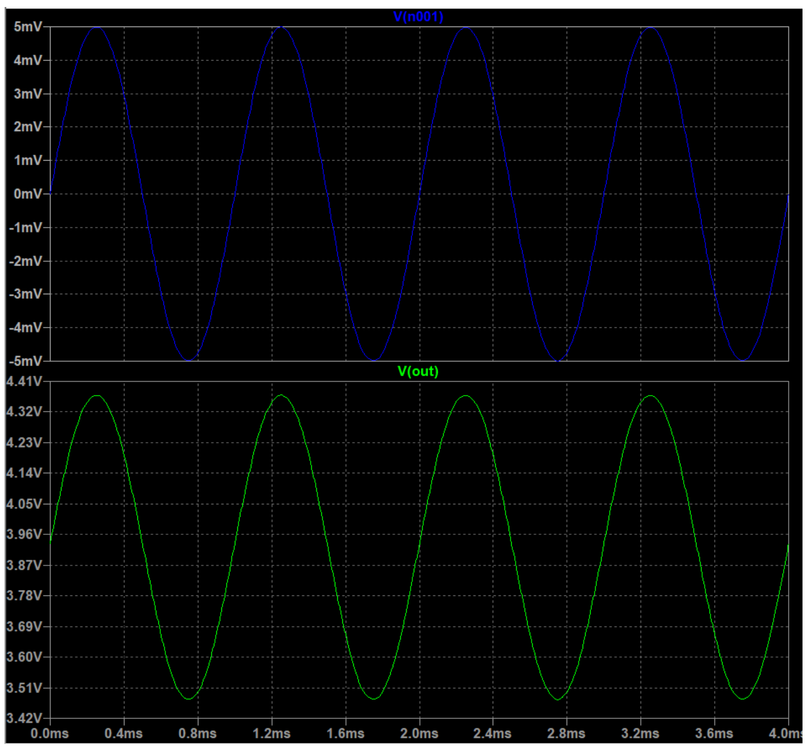


Fig 10: Output obtained for transient analysis

Simulation of Volume Controller

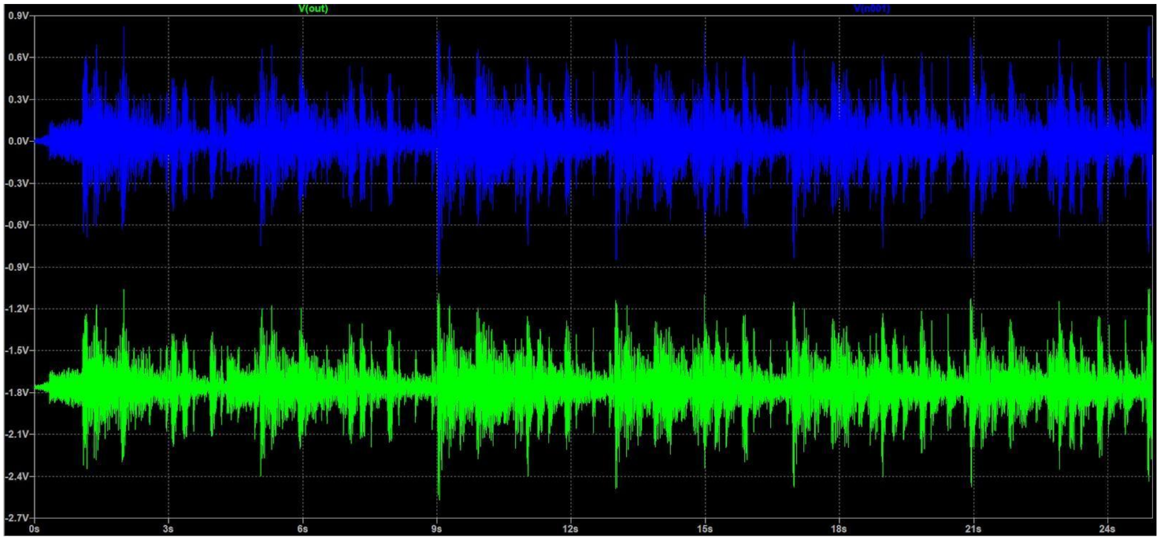


Fig 11: Output obtained from volume controller

The volume of the input file was reduced successfully and obtained the desired output.

Conclusion

I was able to send an input audio file in .wav format in the circuit, I was able to do this because of the feature of LTSPICE, then I got the output also in .wav form where I was able to hear the low volume version of the original audio file . Hence my project was successfully done.

References

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