Telescopic Cascode Amplifier

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Abstract

The goal of the design is to simulate a telescopic cascode amplifier and plot the AC and Transient analysis of the circuit. The simulation is done using eSim, Ngspice and Sky130 PDK libraries. The circuit uses 4 NMOS and 4 PMOS to generate proper amplification of the input signal. The output is taken in a single-ended way with a 20pF capacitor attached. The benefits of using an amplifier in a telescopic cascoded manner are also mentioned.

Keywords

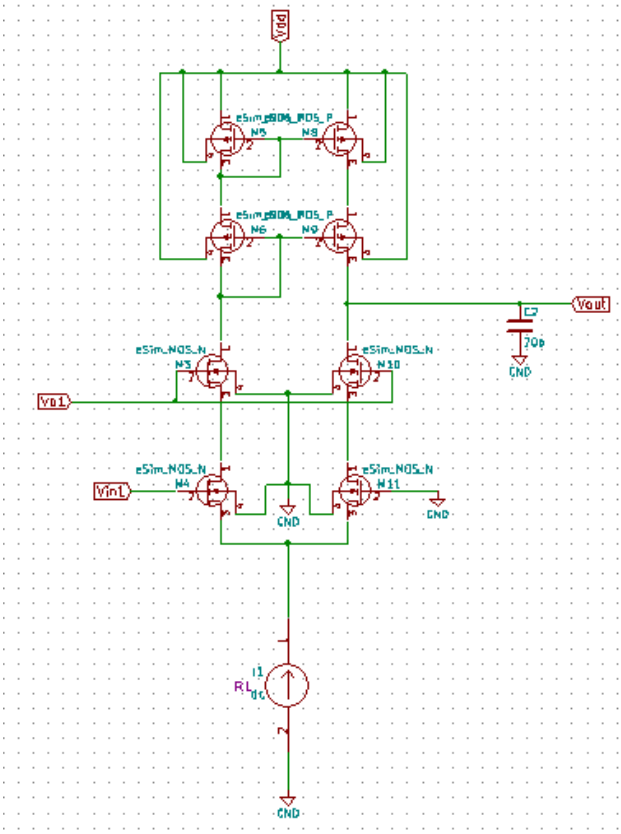
Operational amplifier (opamp), telescopic, aspect ratio (W/L), bandwidth, gain, output swing

Introduction

Important aspects of an amplifier are open loop gain, bandwidth, output swing, noise, supple requirement and linearity. Any operational amplifier is designed with appropriate trade-offs between these parameters. It is important for any designer to take into account the advantages and disadvantages of a specific configuration of the amplifier.

A single-stage differential amplifier uses NMOS and PMOS and a reference current mirror circuit for appropriate current biasing. Such devices do not achieve high gain and their bandwidth is limited by the capacitor used at the output. To achieve higher gains cascoded configurations of MOSFETs are used. There are two such types of configurations - Telescopic and Folded Cascode. This paper goes over the schematic and design of the Telescopic one.

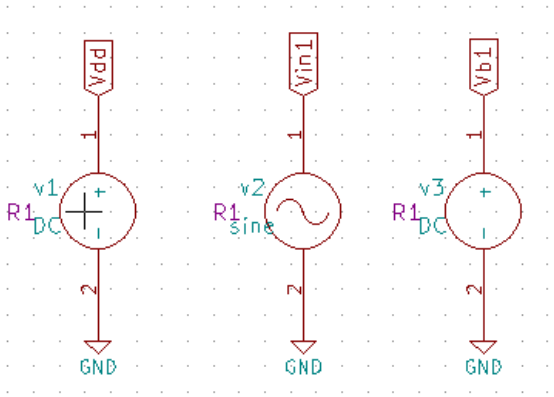
Schematic Diagram



Circuit Description

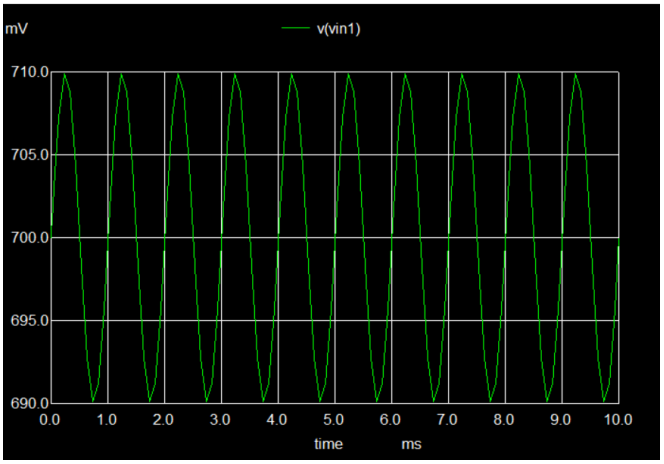
The above circuit consists of 4 NMOS ith appropriate biasing and 4 PMOS whose gate and drain are shorted. The advantage this topology provides is that NMOS transistors conduct time varying currents while PMOS transistors conduct constant currents. This ends up increasing the speed of opamp as mobility of NMOS is higher. This configuration uses the Common Source - Common Gate Cascode idea to increase gain of the amplifier. Since the MOSFETs are connected in a straight line like refracting telescopic, it has been given the name.

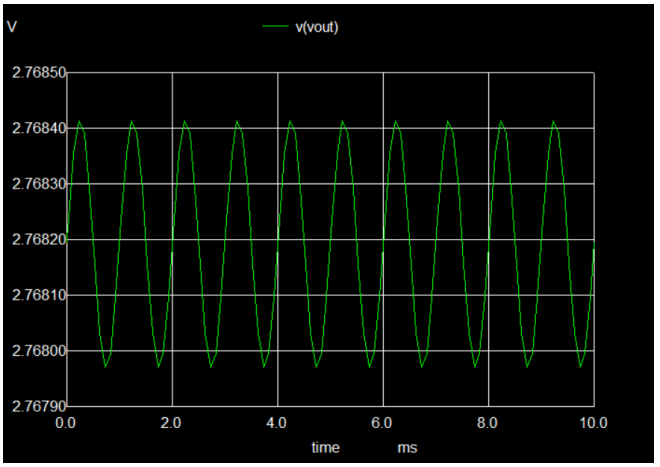
It is important to maintain all the MOSFETs in saturation region to achieve highest gain. The PMOS is always in saturation as its gate and drain are shorted. 2 NMOS are saturated using Vb1 dc voltage source (1V). The input must be given with an appropriate dc value and a small signal (ac) on top of that. Here 0.7V is dc bias with 10mV as the ac amplitude. The power supply Vdd is given as 3V. The connections to sources are made as shown below.

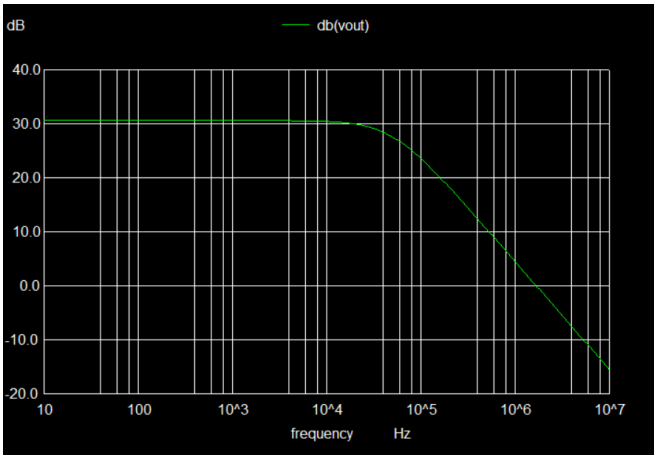


The transient analysis is done with the source values mentioned as above. AC analysis is also done with frequencies ranging from 10Hz to 10MHz. There is a drop off in gain after the 3db frequency. The plots are of input, output and gain vs frequency are given below.

Plots







Conclusion

The telescopic cascode amplifier gives a higher gain as compared to a single stage amplifier but it has lesser output swing. Simulation using ngspice and eSim was done and expected results were obtained. It is necessary to bias all MOSFETs properly with appropriate aspect ratios. A current mirror can be used for the dc current biasing given as 3mA in the above simulation. Folded Cascode Technology can be used to keep the high gain value but also increase the output sing.

References

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[2] D. K. Shedge, P. W. Wani, D. A. Itole, S. B. Pokharkar and M. S. Sutaone, "CMOS telescopic cascode operational amplifier," *2013 International Conference on Green Computing, Communication and Conservation of Energy (ICGCE)*, 2013, pp. 87-89