Analog IC Design: Project - Part 2

Spring 2018

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1 Objective

In part 1 of this project we designed a Operational-Amplifier from scratch. This was done by following a step by step incremental process. This allows for the understanding of each component of the circuit before moving forward to more complicated steps. In continuation of that theme we are going to take that previously constructed circuit and cascade it to increase its overall gain. After that is accomplished we will then attempt to cascade it again but with a single ended output.

1.1 Primary Tasks

The purpose of this project can be simplified into to primary tasks as given.

1. Determining the biasing circuit configuration

2. Designing/calculate all the MOSFETs parameters to achieve the desired amplifier specifications.

1.2 Circuit Requirements

The following are given circuit requirements that will be adhered to.

1. Do whatever modifications necessary to your circuit in the first part to cascade the differential stage, as shown in figure 9.13(a) in the textbook.

2. The new differential gain should be equal to 104 (with a tolerance of no more than 20%, but the gain should be at least 104)

3. Allowed 1 resistor (to be placed outside the IC), any number of n-type and p-type enhancement mode MOSFETS.

4. Allowed a maximum of 2 power supplies (excluding the test input signal source of course)

5. λ for all MOSFETS should be at least 0.02

6. W and L should be at least 1m (assuming a 1m technology).

1.3 Custom MOSFETS

We will be using the MOSFETs that were designated in part one of the project. They are as follows

- NMOS

  .SUBCKT enmos001 1 2 3
  M 1 2 3 3 enmos001
  .MODEL enmos001 NMOS (KP = 500E-6 VTO = 1 LAMBDA = 0.02 W=2u L=1u)

.ENDS enmos001

- PMOS

  .SUBCKT enmos002 1 2 3
  M 1 2 3 3 enmos002
  .MODEL enmos002 PMOS (KP = 500E-6 VTO = 1 LAMBDA = 0.02 W=2u L=1u)
  .ENDS enmos002

Using Multisim's component wizard we can import this settings and create custom MOS-FETs for use in our simulation.

1.3.1 Problems Encountered

In part one of the project the above MOSFETs where causing wild variations in readings, switching to Multisim 14 helped to solved those problems. Multisim 14 was also used in part two of the project to prevent further issues.

2 Initial Circuit

The design that I designed in the previous project is as follows. The sections are colored to show the purpose of each area of the circuit. This is the circuit that will be cascoded for this project.
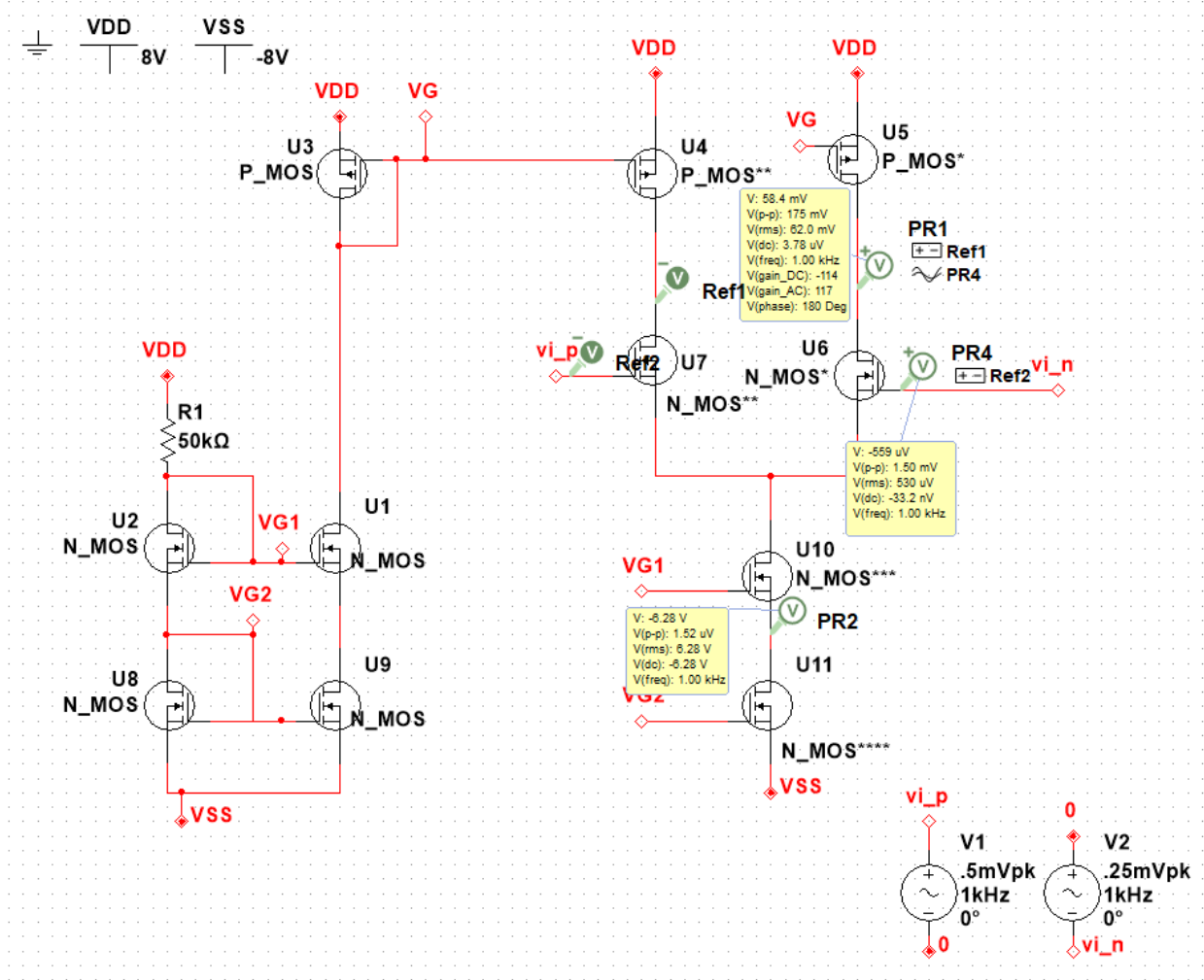
Figure 1: Project: Part 1
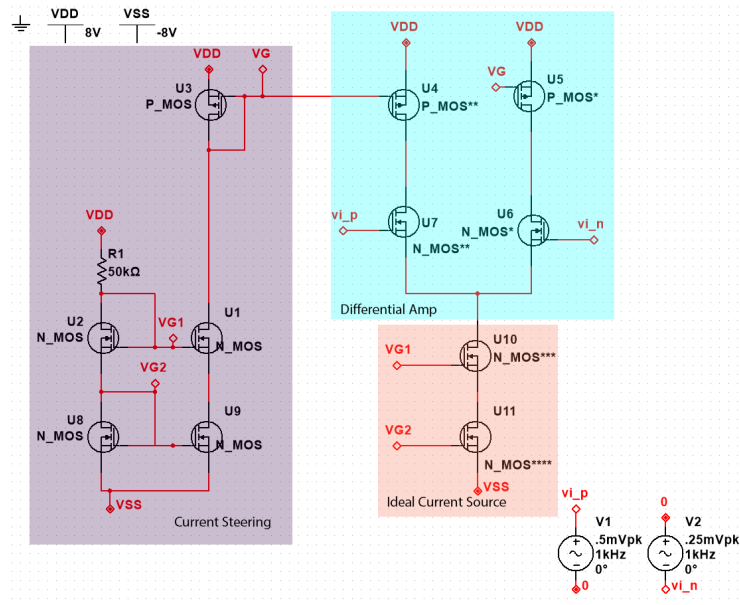
2.1 Analysis

The analysis of the designed circuit shows that a gain of 100 is being obtained. This is at Probe 1 in reference to Probe 4. For our doubled ended cascoded amplifier we will be aiming for a gain of 10000

Figure 2: Final Circuit Analysis

3 Double ended Cascoded Amplifier

For our amplifier to work in a cascoded configuration we must calculate several values, including biasing voltages, drain current, and a new resistance value.

3.1 Gain Equation

Be fore we can start solving for other parts of the circuit we need to go ahead and find a equation for the gain of our circuit. From the book we can see that the gain can be obtained

by the differential-half circuit of the cascoded amplifier, it is as follows

$$A_d \equiv \frac{V_{od}}{V_{id}} = g_{m1}(R_{on}||R_{op})$$

where

$$R_{on} = (g_{m3}R_{o3})R_{o1}$$

and

$$R_{op} = (g_{m5}R_{o5})R_{o7}$$

with those equations and our equation for transconductance

$$g_m = \sqrt{2K_n I_D}$$

we can begin to solve for A_D

$$R_{on} = \frac{1}{\lambda I_D}\frac{1}{\lambda I_D}g_m$$

$$R_{on} = \frac{1}{\lambda^2 I_D^2}g_m$$

$$R_{on} = \frac{1}{\lambda^2 I_D^2}\sqrt{2K_n I_D}$$

$$R_{on}||R_{op} = \frac{1}{2}\frac{1}{\lambda^2 I_D^2}\sqrt{2K_n I_D}$$

Now we take $R_{on}||R_{op}$ and plug it into our gain equation $A_d \equiv \frac{V_{od}}{V_{id}} = g_{m1}(R_{on}||R_{op})$

$$A_d = \frac{1}{2}\frac{1}{\lambda^2 I_D^2}\sqrt{2K_n I_D}\sqrt{2K_n I_D}$$

which simplifies to our gain equation,

$$A_d = \frac{K_n}{\lambda^2 I_D}$$

3.2 Calculating Drain Current I_d

With the given constants $K_n = K_p = .5m$ and $\lambda = .02$ we can effectively solve for I_D using the gain equation and $A_d = 10000$

$$A_d = \frac{K_n}{\lambda^2 I_D}$$

$$I_D = 250\mu A$$

4   Conclusion

The project so far has been challenging but rewarding. In terms of progress so far, by chopping the assignment into pieces and individual circuits it made tackling the final circuit that much easier. The Differential amplifier using the given transistors does in fact work, which on its own is very satisfying. I look forward to continuing and completing the design.