# Design of MOSFET Differential Amplifiers

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#### Aim

- \* In this experiment, we wish to design and test Simple Current Mirror.
- \* We will also design and test MOSFET Differential Amplifiers with resistive and active loads.(Using ALD1106 and ALD1107).
- \* This experiment mainly aims at understanding the internal working of OPAMP.

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#### Simple Current Mirror

Current sources are extensively designed and used to bias different kinds of circuits. An ideal current source supplies a constant current irrespective of the voltage supplied across it. In this experiment, we study two such current sources which are designed using MOSFETs.

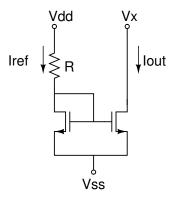


Figure: 2

Figure 1 shows a Differential Amplifier which you have already studied in class. Analyse the circuit and find the expression for gain. Write the derivation of gain in postlab report.

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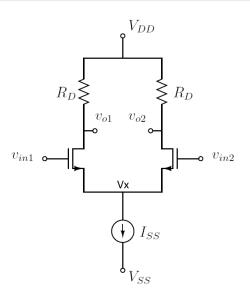


Figure 1: Simple MOSFET Differential Amplifier

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Small signal model of the above circuit is as follows:

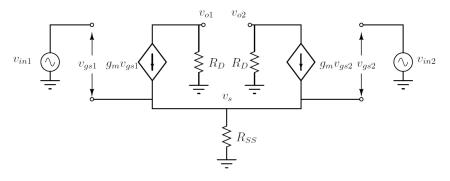


Figure 3: Small signal model of MOS Differential Amplifier

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Suppose we wish to design a differential amplifier as in Figure 1, with a gain of 5, given supply voltages of 3.3V and -3.3V.

Let us assume  $I_D = 0.4 mA$  through each transistor, which gives

 $V_{GS} - V_{TN} = 1.24 V$ .

Substituting in Equation 8, we obtain  $R_D = 7.76$  k.

Since the drain current for each transistor is 0.4 mA, we need a biasing current source  $I_{SS} = 0.8mA$ .

Read "Microelectronic Circuits" by Sedra and Smith for more information.

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#### Pre Lab Work

- 1 Read up on differential amplifiers. Familiarize yourself with the terms "Common Mode Gain" and common mode rejection ratio (CMRR).
- 2 Similar to the way we derived the differential small signal gain expression, derive the expression for common mode gain.(Hint: You may have to assume that there is a slight mismatch between the transistors, and also the two drain resistors- say  $R_D$  and  $R_D + \Delta R$ )
- 3 Design the circuits to be used in each of the three parts of the experiment.
- 4 Simulate your designs in SPICE.

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#### Part 1- Simple MOSFET Differential Amplifier

In this part, we will use the same circuit as shown in Figure 1. Instead of current source, use current mirror as given in Figure 2 (Precaution: Set the supply voltages properly before connecting them to the circuit. The maximum supply the device can tolerate is roughly -5.5V - 5.5V)

- 1 Assemble the circuit, to get  $I_{out}$  of 1mA. Calculate the value of Kn or Kp with the help of the values tabulated in the datasheet.
- 2 For supply voltages  $V_{DD} = 4.5V$  and  $V_{SS} = -4.5V$ , find the value of  $R_D$  required for a gain of 7. Will the output voltage swing be symmetric?
- 3 Wire up your circuit and apply a 50 mV peak, 1 kHz sine wave to (i)  $v_{in1}$  and (ii)  $v_{in2}$ .While applying a signal to one input, keep the other input grounded. Ensure that there is no distortion in the output. Measure the differential voltage gain  $A_d$  in each case. (How will you observe differential signals on the CRO?)
- 4 Find out the maximum symmetrical output swing of your circuit at 1 kHz.

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## Part 1- Simple MOSFET Differential Amplifier

- Repeat step 3 for frequencies 10 kHz, 100 kHz and 500 kHz and 1 MHz.
- Now short both the input terminals and apply a common-mode signal. Measure the common- mode voltage gain Ac at the above frequencies. Calculate the CMRR (in dB) for each frequency.
- 7 Measure the input offset voltage of your differential amplifier (you may neglect the effects of input bias current).
- Compare your results (differential gain, CMRR, offset voltage) with two other groups and tabulate them.

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### Part 2-Differential Amplifier with Active Load

We will now replace the two drain resistors  $R_D$  in Figure 1 by a PMOS current mirror, as in Figure 4, and take a single-ended output.

Why do we use this configuration over resistive load?, Mention reasons in postlab report.

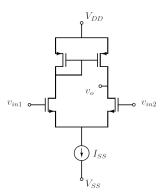


Figure 4: Differential Amplifier with Active Load

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#### Part 2-Differential Amplifier with Active Load

- 1 Use supply voltages  $V_{DD}=4.5V$  and  $V_{SS}=-4.5V$ , find the expression for gain, find the value of  $I_{SS}$  required for a gain of 50. (Hint: This time, the drain-source resistance  $r_o$  of the transistors need to be considered. Given the channel length modulation parameter  $\lambda$  for the NMOS and PMOS are approximately 0.036).
- 2 Use an appropriately designed current mirror for  $I_{SS}$ . (Keep the value of  $I_{SS}$  less than 100uA).
- 3 You may have to vary the potentiometer in current mirror to adjust the  $I_{SS}$  which in turn adjusts the gain of the amplifier.
- 4 Wire up your circuit and apply a 20 mV peak, 1 kHz sine wave to (i)  $v_{in1}$  and (ii)  $v_{in2}$ . Measure  $A_d$  in each case.

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### Part 3-Differential Amplifier with Active Load

- 5 Draw the small signal model of above circuit in postlab report.
- 6 Report the dependence of Gain on *I<sub>SS</sub>*. Mention all the challenges you face in designing and explain why?.
- 7 Find out the maximum symmetrical output swing of your circuit at 1 kHz.
- 8 Repeat step 3 for frequencies 10 kHz, 100 kHz and 500 kHz and 1 MHz.
- 9 Measure the common-mode voltage gain Ac and the CMRR (in dB) at the above frequencies.
- 10 Measure the input offset voltage of your differential amplifier.
- 11 Compare your results with two other groups and tabulate them.

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