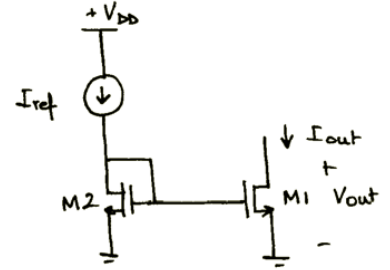


Homework #4 (Due Nov. 3)

1. a) Design a simple MOS current source of the type shown to meet the following constraints:
 - (i) The transistor must stay in saturation for values of V_{out} to within 0.4 V of ground.
 - (ii) The output current must be $50\mu A$.
 - (iii) The minimum value of the output resistance must be $1M\Omega$.
 Make M1 and M2 identical. You are to minimize the total device area within the given constraints. Here device area will be taken to be the total gate area ($W \times L$ product). $V_{DD} = 3V$, $V_{TO} = 0.7V$, $k' = 100 \mu A/V^2$, and $\frac{1}{\lambda L} = \frac{20V}{\mu m}$. Use Spice to verify results with the Level 1 model.



- b) What is the output resistance of the designed current source if the BSIM3 model is used to simulate the design? Use the BSIM3 model parameters from the class web page.

For Problems 2-4 use $V_{TO} = 0.5V$, $k' = 100 \mu A/V^2$, $\gamma = 0$, and $\lambda = 0.05/V$.

2. What are the output currents and output resistances for the current sources shown in Figure P2 if $I_{ref} = 30\mu A$. Verify your results with SPICE and the Level 1 model.
3. For the circuit shown in Figure P3, find the voltages at nodes A and B and the output current. Assume M2 is in saturation. Verify your results with SPICE and the Level 1 model.
4. For the circuit shown in Figure P4, assume all transistors are maintained in saturation.
 - a) What is the output current I_o ?
 - b) What is the minimum output voltage V_{omin} to ensure that all devices are in saturation?
 - c) What is the output resistance?
 - d) Verify your results with SPICE and the Level 1 model.

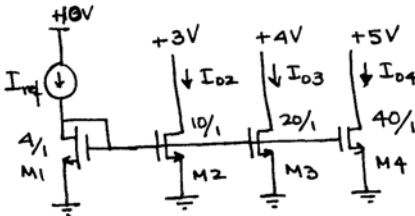


Figure P2

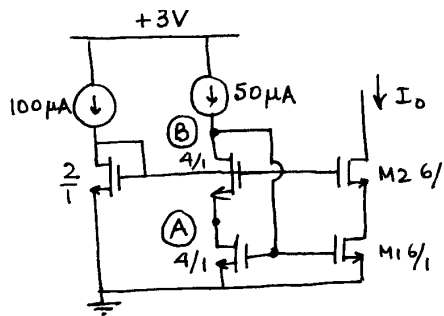


Figure P3

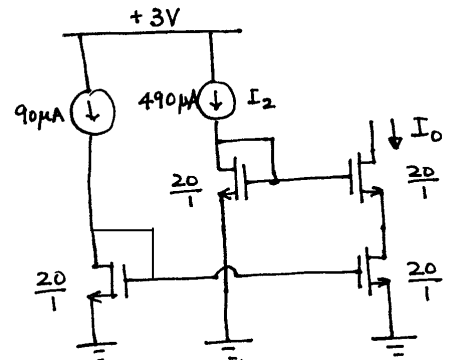
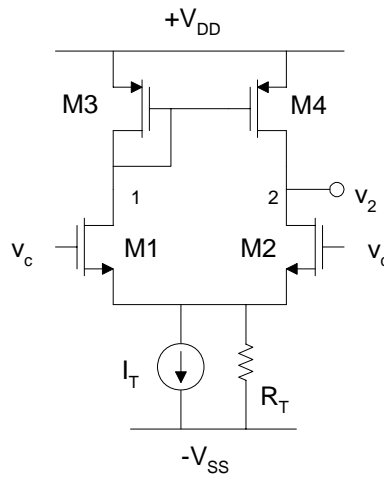


Figure P4

5. Derive an expression for the common mode gain of the amplifier shown below. The simplest way to do this is to draw the complete small-signal circuit for the amplifier and write the nodal equations at nodes 1 and 2 without making any approximations. From these equations you should be able to show that $v_1 = v_2$ for common mode signals. Given that $v_1 = v_2$, the small-

signal circuit will be symmetrical and a half-circuit analysis can be used to derive the expression for the common mode gain. (*Hint: the answer is in your class notes*).



6. Determine the small-signal gain, output resistance and the input common mode range for the differential amplifiers shown below. $(W/L)_N = 10\mu\text{m}/2\mu\text{m}$, $(W/L)_P = 30\mu\text{m}/2\mu\text{m}$, $V_{TON}=0.7\text{V}$, $V_{TOP}=-0.9\text{V}$, $k_N' = 100 \mu\text{A}/\text{V}^2$, $k_P' = 50 \mu\text{A}/\text{V}^2$, and $\frac{1}{\lambda L} = \frac{20\text{V}}{\mu\text{m}}$. Verify your results using SPICE with the Level-1 MOSFET model.

