EEC 210 Fall 2005 Midterm

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Name:

Instructions: This test consists of 4 problems and 13 pages, including the cover sheet. Please make sure that you have all of them. This is an open-book, open-notes test. State any assumptions you make and show complete work to receive credit. The time limit is 80 minutes. The problems are weighted as shown below

Grading:

Problem	Maximum	Score
1	12	
2	16	
3	10	
4	12	
Total	50	

1 CMOS Inverter Amplifier

Figure 1 shows a CMOS inverter biased as a linear amplifier. For this problem, use the transistor parameters in Table 1.

Parameter	NMOS	PMOS
V_t	1 V	-1 V
L_d	0	0
X_d	0	0
k'	300 μA/V^2	100 μA/V^2
γ	0	0
W/L	2	6
λ	0.1 V^{-1}	0.1 V^{-1}

Table 1: Problem 1 Transistor Parameters.

Problem 1.1 (**3 points**) Assume $V_I = 1.5$ V. For what range of V_O will the circuit best act as an amplifier? What is the output voltage swing?

Problem 1.2 (**2 points**) Find the power dissipation assuming the bias conditions in Problem 1.1.

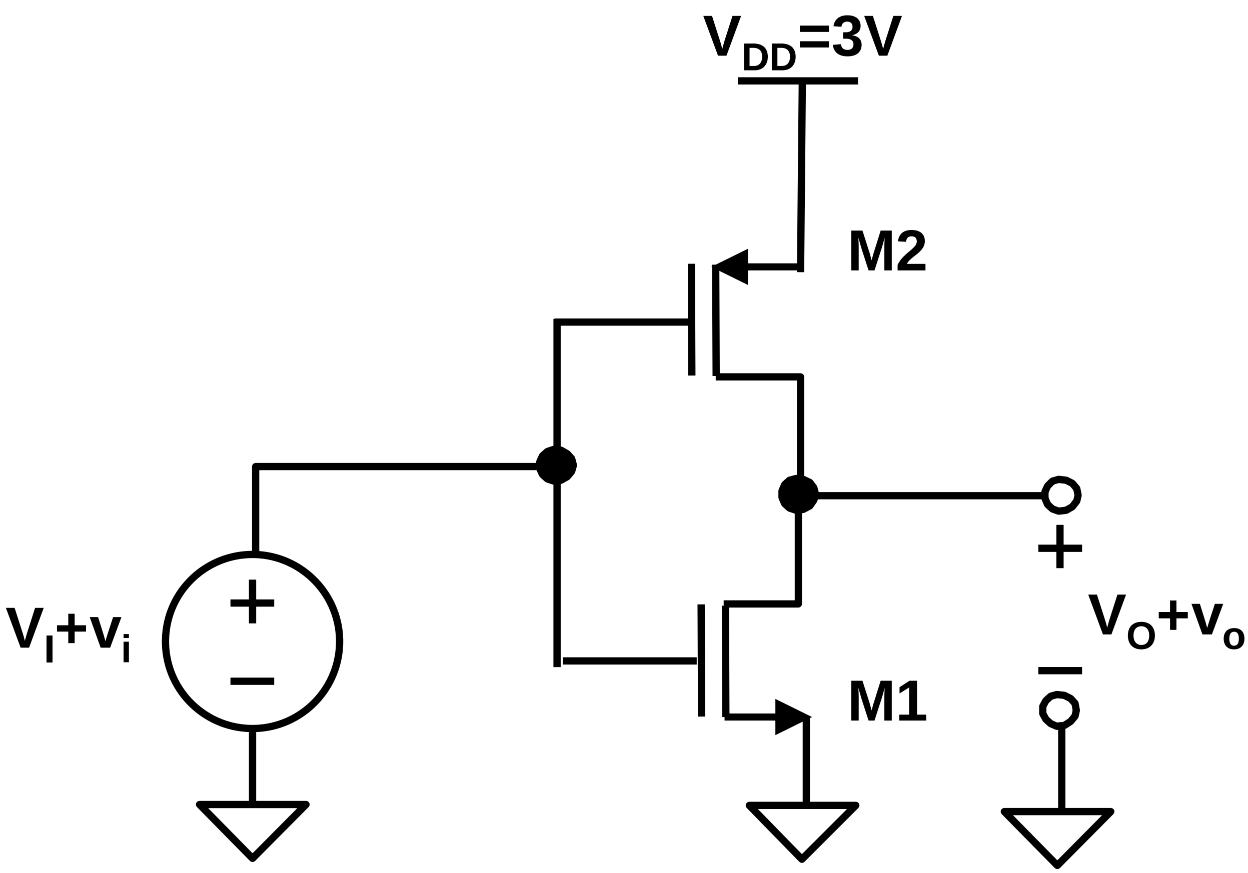

Figure 1: CMOS inverter as linear amplifier.

Problem 1.3 (**2 points**) Find the small-signal output resistance R_o assuming the bias conditions in Problem 1.1.

Problem 1.4 (**3 points**) Find the small-signal gain assuming the bias conditions in Problem 1.1.

Problem 1.5 (**2 points**) Suppose that γ is nonzero and that through source-well biasing, $V_{tn} = 1.25$ V and $V_{tp} = -1.25$ V. How does this affect the small-signal gain (assume the bias conditions in Problem 1.1)?

2 Differential Amplifier

Figure 2 shows the circuit schematic for a differential amplifier. For this problem, use the transistor parameters in Table 2. Assume the following circuit parameters: $I_{TAIL} = 590\mu\text{A}$, $R_{TAIL} = 30\ \text{k}\Omega$, $R1 = 3\ \text{k}\Omega$, $R2 = 6\ \text{k}\Omega$, $(W/L)_1 = (W/L)_2 = 8$.

Parameter	NMOS	PMOS
V_t	1 V	-1 V
L_d	0	0
X_d	0	0
k'	300 μA/V^2	100 μA/V^2
γ	0	0
λ	0	0

Table 2: Problem 2 Transistor Parameters.

Problem 2.1 (**3 points**) Find V_I such that $V_s = 300$ mV.

Problem 2.2 (**3 points**) Find $(W/L)_3 = (W/L)_4$ such that $V_O = 1.5$ V, assuming the bias conditions you found in Problem 2.1.

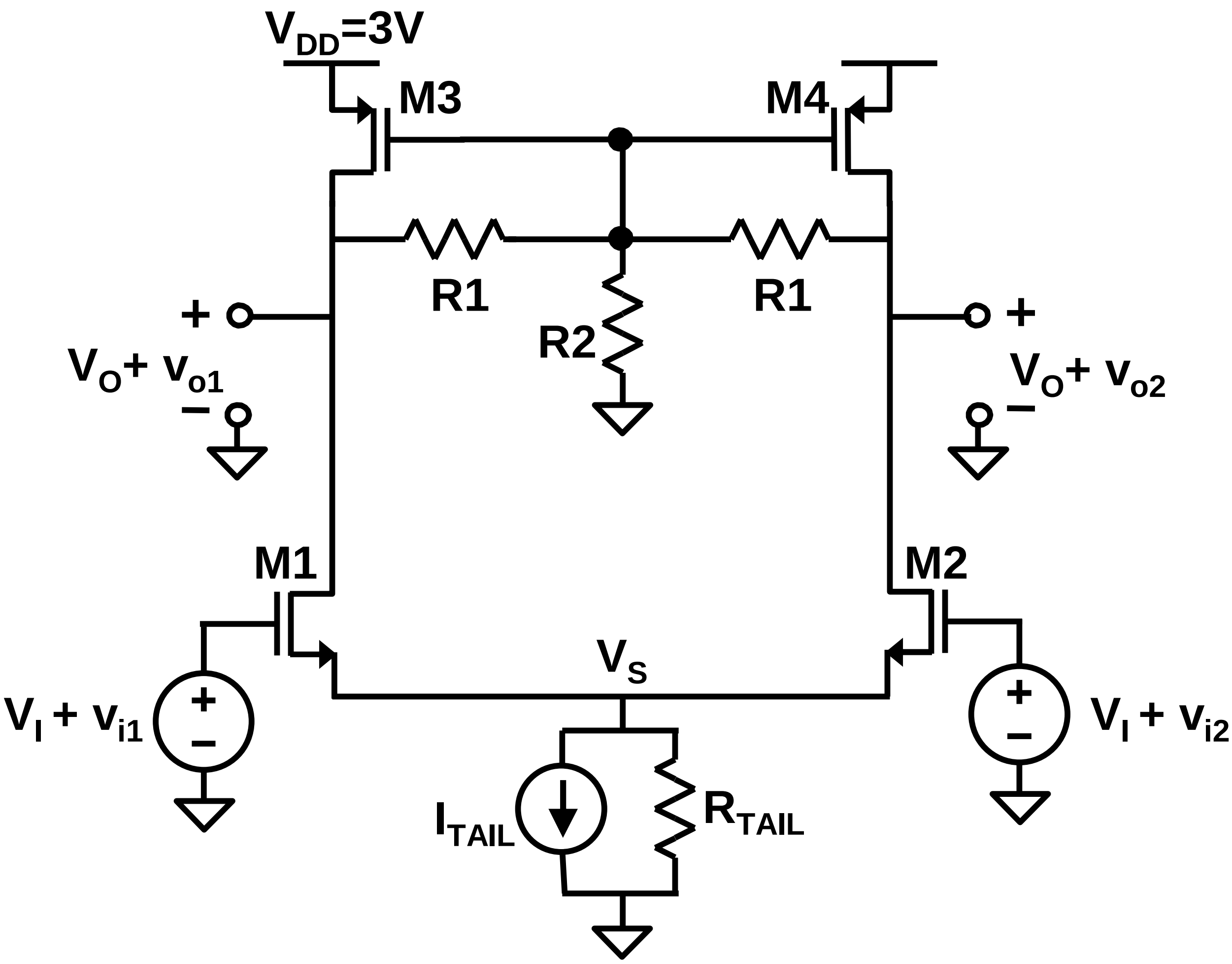

Figure 2: Differential amplifier.

Problem 2.3 (**4 points**) Draw and label the small-signal differential-mode half circuit, and find the differential-mode gain, $\frac{v_{od}}{v_{id}}$, where $v_{id} = v_{i1} - v_{i2}$ and $v_{od} = v_{o1} - v_{o2}$.

Problem 2.4 (**6 points**) Draw and label the small-signal common-mode half circuit, and find the common-mode gain, $\frac{v_{oc}}{v_{ic}}$, where $v_{ic} = 0.5(v_{i1} + v_{i2})$ and $v_{oc} = 0.5(v_{o1} + v_{o2})$.

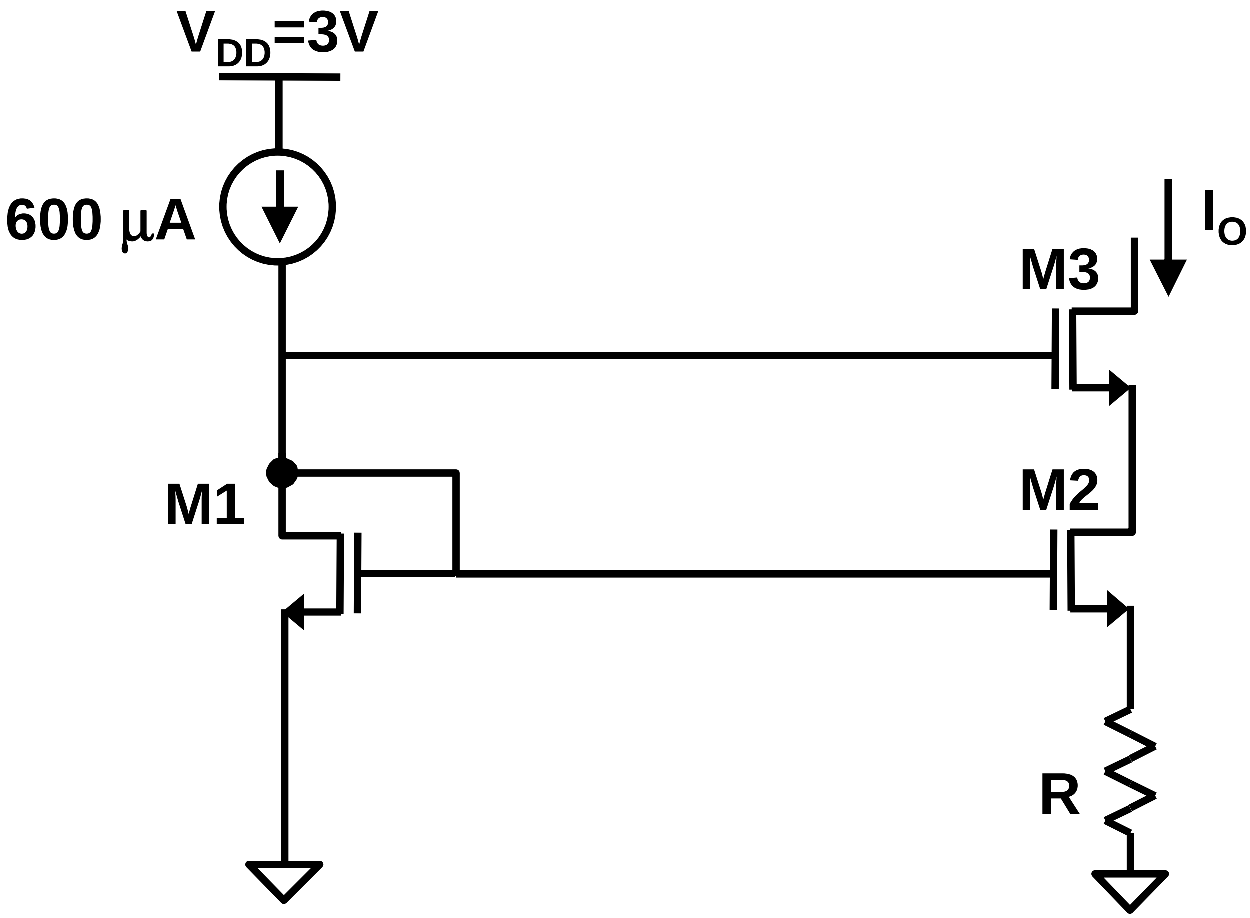

Figure 3: Current source.

3 Current Source

Figure 3 shows a current source circuit. For this problem, use the transistor parameters in Table 3. For the circuit in Figure 3, assume the following circuit parameters: $R = 10\ \text{k}\Omega$, $(W/L)_1 = (W/L)_3 = 2$, $(W/L)_2 = 20$.

Problem 3.1 (**2 points**) Find the output current I_O.

Parameter	NMOS	PMOS
V_t	1 V	-1 V
L_d	0	0
X_d	0	0
k'	300 μA/V^2	100 μA/V^2
γ	0	0
λ	0.1 V^{-1}	0.1 V^{-1}

Table 3: Problem 3 Transistor Parameters.

Problem 3.2 (**3 points**) Find the minimum output voltage $V_{OUT}(MIN)$.

Problem 3.3 (**3 points**) Find the output resistance R_o.

Problem 3.4 (**2 points**) Resistor R can be used to model the parasitic resistance associated with routing current sources for long distances on an IC. Find the largest value for R such that I_O is within 1% of the current reference value in Figure 3. Assume $(W/L)_1 = (W/L)_3 = (W/L)_2 = 2$.

4 Current Source Reference

Figure 4 shows a current reference circuit. For this problem, use the transistor parameters in Table 4. For the circuit in Figure 4, assume the following circuit parameters: $R = 10\ \text{k}\Omega$, $(W/L)_1 = (W/L)_2$, $(W/L)_3 = 2$, and $(W/L)_4 = (W/L)_5 = (W/L)_6 = 6$.

Parameter	NMOS	PMOS
V_t	1 V	-1 V
L_d	0	0
X_d	0	0
k'	300 μA/V^2	100 μA/V^2
γ	0	0
λ	0	0

Table 4: Problem 4 Transistor Parameters.

Problem 4.1 (**6 points**) Find $(W/L)_1 = (W/L)_2$ and $(W/L)_7$ such that I_O is dependent on process parameters only (i.e., independent of bias point to first order).

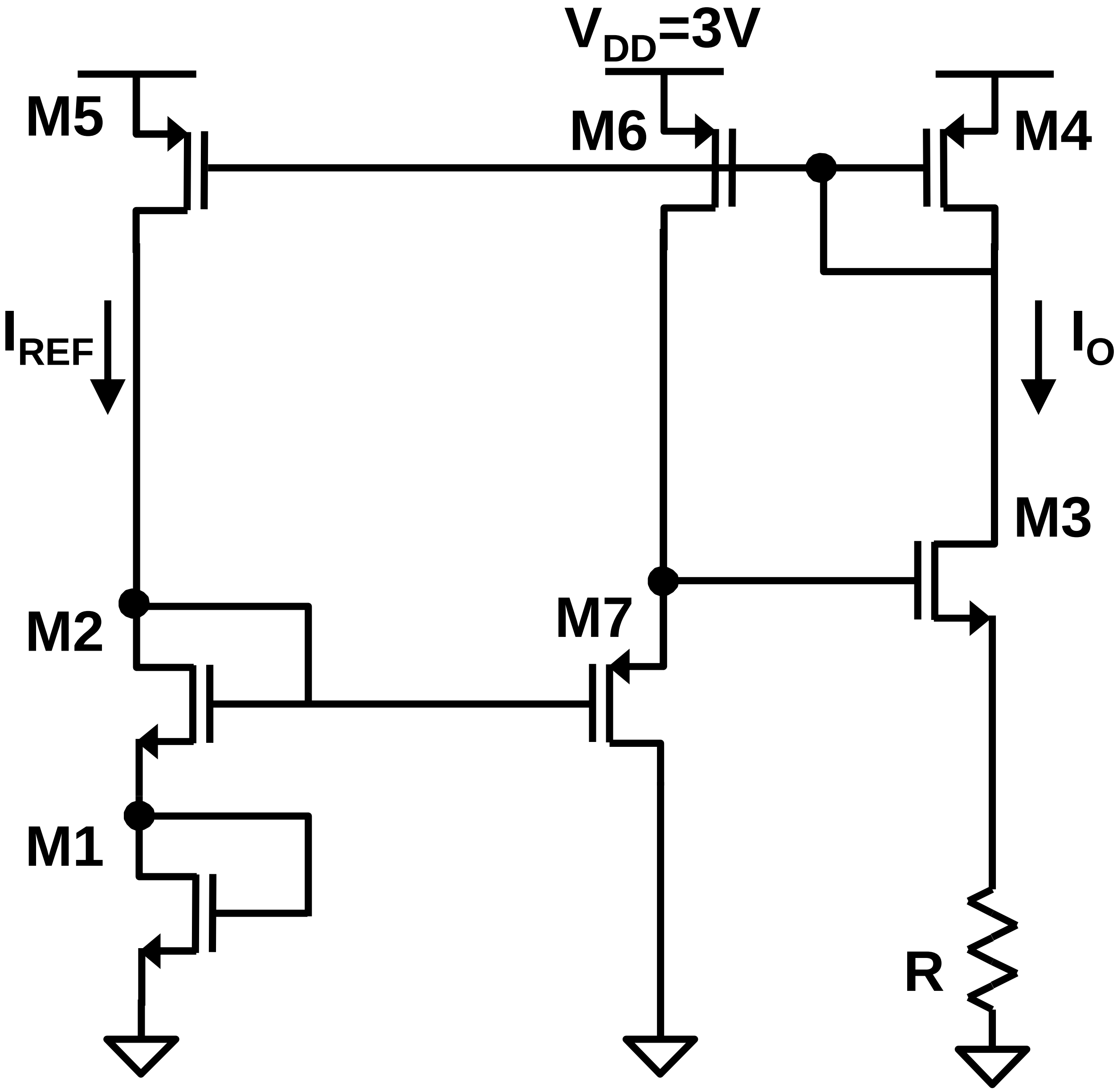

Figure 4: Current source reference.

Problem 4.2 (6 points) One can model the thermal noise of resistor R as a small-signal current source i_n in parallel with R. Quantify the impact of the noise current source on the total output current $I_O + i_o$, assuming the bias point you found in Problem 4.1 and $|i_n| = 1\mu\text{A}$.