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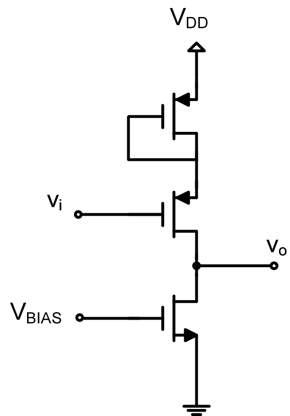
NAME:__________________________ ID Number: _________________

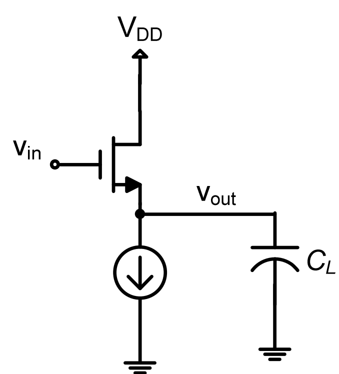
Problem 1. [14 points]

Find the <u>gain</u> v_o/v_i and <u>output resistance</u> R_o of the amplifier shown below. The PMOS transistors are long and have negligible λ, while for the NMOS transistor r_o = 35 kΩ. The transconductances g_m of the MOSFETs are all equal to 1 mA/V.
V_{BIAS} is a DC voltage. All transistors are internal to the amplifier.



Problem 2. [8 points]

The source follower shown below is used as an audio amplifier. The MOSFET is biased such that its g_m = 1 mA/V and r_o = 90 kΩ. The current source has an output resistance of 60 kΩ. Determine the maximum C_L to have an upper 3-dB frequency of 20 kHz.



Problem 3. [5 points]

An operational amplifier has a differential gain of 10^5 and a CMRR of 78 dB. Find the common-mode gain.

Problem 4. [33 points]

a) Consider the current source shown in Figure 1.
Assume V_{DD} = 2.5 V and I_{REF} = 75 μA.
Find the value of R if the MOSFETs have W = 3 μm, L = 1 μm, V_t = 0.6 V, and k'_n = 200 μA/V^2.
Assume that V'_A = 10 V/μm.

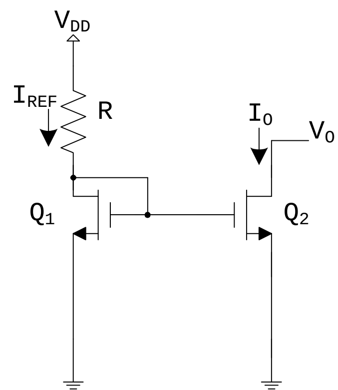


Figure 1

b) What is the lowest possible value of V_O?

c) The two MOSFETs are matched. Find the change in the output current that corresponds to a change in the output voltage from 1 V to 2.5 V.

d) Repeat part (c) if Q_1 has W/L = 3 μm /1 μm but Q_2 has W/L = 15 μm /5 μm.

e) What should be the value of a resistance that is inserted between the source of Q_2 and ground to reduce the output current to 10 μA? The two MOSFETs are matched with W/L = 3 μm /1 μm.

f) With the resistance of part (e) inserted between the source and Q_2 and ground, find the change in the output current that corresponds to a change in the output voltage from 1 V to 2.5 V.

Problem 5. [40 points]

The CMOS common-source amplifier shown in Figure 2 is biased using I_{REF} = 75 μA, and has W/L = 6 μm/0.25 μm for all transistors, k'_n = 250 μA/V^2, k'_p = 100 μA/V^2, V'_{An} = 10 V/μm, $|V'_{Ap}|$ = 5 V/μm, $V_{tn} = -V_{tp}$ = 0.6 V.

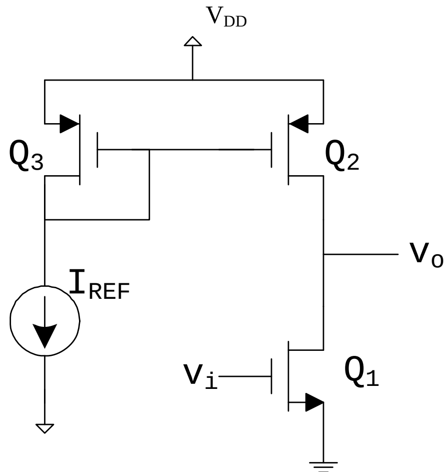


Figure 2

a) Neglecting channel-length modulation in the DC analysis, find: V_{OV1}, g_{m1}, r_{o1}, r_{o2}, and the voltage gain v_o/v_i.

Assume now that for all MOSFETs in the circuit, C_{gs} = 12 fF, C_{gd} = 10 fF, C_{db} = 25 fF, and C_{sb} = 25 fF. The signal source (not shown in the figure) has a source resistance R_{SIG} of 47 kΩ.

b) Using Miller's theorem, and assuming that the input circuit determines the upper 3-dB frequency f_H, find the value of f_H.

c) Based on the complete amplifier transfer function $V_o(s)/V_{sig}(s)$, show *and label* the Bode plots for <u>magnitude</u> *and* <u>phase</u>.

d) Using the open-circuit time constant methods, find the resistance seen by each capacitor, and estimate the value of f_H. Show all work.