Indian Institute of Technology, Delhi
EEL782: Analog Integrated Circuits
Minor 1, February 13, 2009

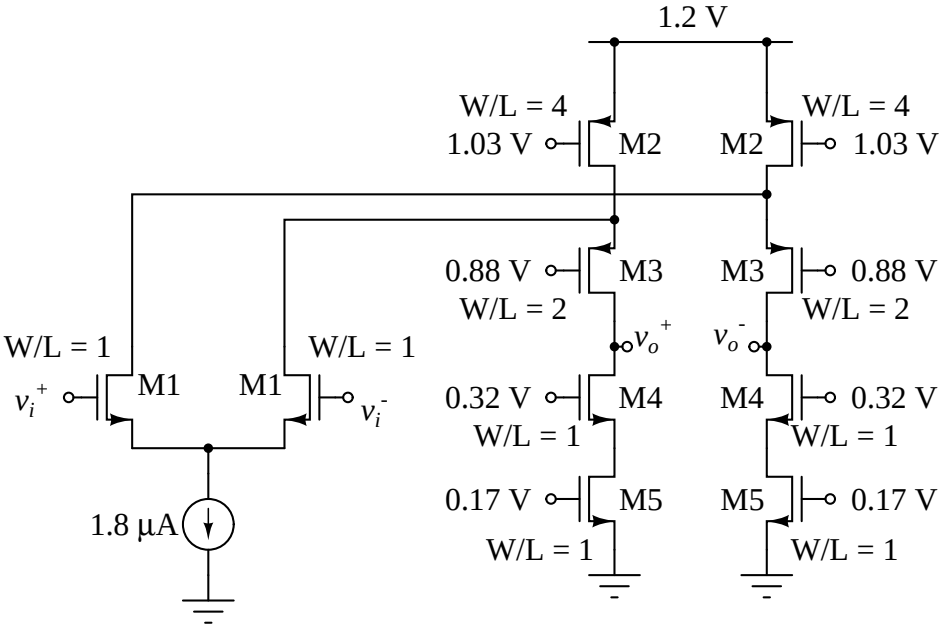
Answer all the questions. Read the instructions carefully. No books or notes allowed. You should have a working calculator. Full marks is 40. Approximate answers are ok. Incompatible units or unrealistic answers will invoke the wrath of the examiner. Good luck!

If you are unable to solve question 2, use $g_m = 1$ mS and $g_{ds} = 50$ μS for all the devices shown in the circuit, for questions 3 and 4.

Consider the following circuit diagram. All nMOS and pMOS devices in the circuit are in weak inversion and follow the device equation given by:

$$I_{DS} = I_0 \exp\left(\frac{|V_{GS}|}{\zeta v_T}\right)\left(1 - \exp\left(-\frac{|V_{DS}|}{\eta v_T}\right)\right)$$

$v_T = kT/q = 25$ mV at 300 K, $\zeta = 1$, $\eta = 2$. For nMOS devices $I_0 = W/L \cdot$ 1 nA, and for pMOS devices $I_0 = W/L \cdot$ 0.5 nA. Assume g_{mb} of all devices is equal to 0 S. Assume the nominal quiescent voltage at v_o^+ and v_o^- to be 0.6 V. Also assume that the sources of the input devices marked as M1 are at 0.6 V.



1. Come up with expressions for g_m and g_{ds} based on the device equation given above. (5)
2. Compute the g_m's and r_{ds}'s of all the devices in the circuit. (10)
3. Draw the differential mode half-circuit. Evaluate the small-signal output resistance (R_{out}), as well as the small-signal input-output transconductance (G_m) of the circuit. Compute the small signal differential gain, $A_v = \frac{v_o^+ - v_o^-}{v_i^+ - v_i^-}$, of the circuit. (5+5+5+2)
4. Draw the common mode half-circuit. Assume that the output resistance of the tail current source, R_s, is 100 kΩ. With a short calculation, can you determine whether or not the common mode gain of this circuit, given by $A_c = \frac{v_o^+ + v_o^-}{v_i^+ + v_i^-}$, will be significantly lesser than the small signal differential gain? (5)
5. Assume that the minimum $|V_{DS}|$ required to keep each of the devices in saturation is 150 mV (for both nMOS and pMOS devices.) What is the maximum output peak-peak differential swing? (3)