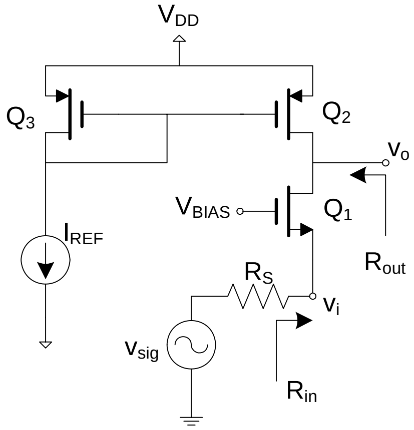
American University of Beirut

DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING
EECE 311 – Electronic Circuits (Sections 1 & 2)
Spring 2008

HOMEWORK 3
Due Wednesday March 26, 2008 at 1:00 PM

Problem 1.

Consider the common-gate CMOS amplifier shown below. Assume V_{DD} = 1.8 V, I_{REF} = 15 μA, R_S = 50 Ω, and that the signal source DC component is zero.
The P-channel MOSFETs are matched and have k'_p = 100 μA/V^2, W/L = 10, V_t = –0.5 V, and $|\lambda|$ = 0.35 V^{-1}.
The N-channel MOSFET has k'_n = 350 μA/V^2, W/L = 2, V_t = 0.45 V, λ = 0.4 V^{-1}, and χ = 0.2.



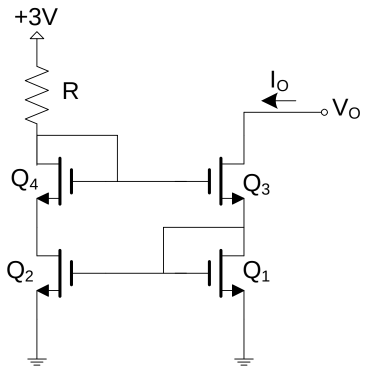
a) Find the value of V_{SG} for Q_3.
b) Find the value of the drain current of Q_2 when $v_o = V_{DD}/2$.
c) Find the required value of V_{BIAS} needed to obtain $v_o = V_{DD}/2$ when v_{sig} = 0. Neglect the change in the threshold voltage of Q_1 due to body effect.
d) Find the values of g_{m1}, r_{o1}, r_{o2}, R_{in}, and R_{out}.
e) Find the voltage gain v_o/v_{sig}.
f) How large can v_{sig} be (peak-to-peak) while maintaining saturation-mode operation for both Q_1 and Q_2?
g) Verify, using PSpice, the results of parts (e) and (f). Use a DC sweep for v_{sig} from –1V to +1 V in steps of 1 mV. Use the following model for the N-channel MOSFET to account for body effect and to give the required value of χ:
`.model cmosn nmos kp=350u vto=0.45 lambda=0.4 gamma=0.4 phi=1`
h) Given that Q_1 has C_{gs} = 25 fF, C_{gd} = 5 fF, C_{db} = 10 fF, C_{sb} = 10 fF, and that the other capacitances in the circuit may be modeled by a single capacitance connected from the output node to ground, with a value C_L = 50 fF, calculate the two amplifier pole frequencies, and the 3-dB frequency, *assuming that channel-length modulation is negligible*.
i) Verify, using PSpice, the results of part (h). Use an AC sweep for v_{sig} from 1 Hz to 100 MHz, with 10 points per decade. Use the `cmosn` model of part (g) for the N-channel MOSFET. Make sure to include the capacitors of part (h) in the PSpice netlist. Show the Bode plot of the magnitude of V_{out}. Compare the 3-dB frequency obtained from PSpice with the estimate of part (h).

Problem 2.

a) In the circuit of Figure 6.58 in the textbook, find the output current and (approximate) output resistance for the cascode current source. Assume I_{REF} = 10 μA, V_O = 2.5 V, $k'_n(W/L)$ = 1 mA/V^2, V_t = 0.5 V, and V_A = 10 V. Do *not* neglect channel length modulation in the output current analysis.
b) What is the minimum value of V_O?

Problem 3.

Assume R = 10 KΩ in the Wilson current source shown below.



a) What is the output current if $(W/L)_1 = 5$, $(W/L)_2 = 20$, $(W/L)_3 = 20$, $V_t = 0.4$ V, and $k'_n = 200\ \mu A/V^2$? What value of $(W/L)_4$ is required to balance the drain voltages of Q_1 and Q_2?
b) Assuming $\lambda = 0.15\ V^{-1}$, find the output resistance of the current source.
c) What is the minimum value of V_O? For the range $V_O = V_{Omin}$ to $V_O = 3$ V, what is the variation in the output current (in μA, and as a percentage)?

Problem 4.

a) An inverting op-amp amplifier configuration uses two resistor $R_1 = 5.6$ KΩ and $R_2 = 560$ KΩ to achieve a gain of –100 V/V. Find the actual closed-loop gain if the open-loop gain is 8000.
b) The op-amp has, in addition to the finite open-loop gain of 8000, a unity-gain frequency of 2 MHz. Find the closed-loop gain at a frequency of 15 KHz. If the input voltage is 2 sin(ωt) mV, what is the corresponding output voltage?

Problem 5.

An audio amplifier is to be designed to deliver 10 Watts to an 8 Ω speaker (load), for a sinusoidal input signal at a frequency of 20 KHz. What must be the slew-rate specification of the amplifier to avoid slew-rate distortion?

Problem 6.

a) A differential amplifier has $v_o(t) = 2400\ v_1(t) - 2391\ v_2(t)$, where $v_1(t)$ and $v_2(t)$ are the amplifier inputs. Find the CMRR in dB.