Problem set #9, Issued: Nov. 9, 2001  
Due: Nov. 16, 2001, at beginning of lecture

Reading: In Sedra & Smith, Sect. 5.10 (to the bottom of p. 444), and for the topic of NMOS inverters there is some material of very limited usefulness in Sect. 5.7.4, up to the top of p. 423. For a more detailed look at the topic of NMOS inverters and inverter design, look at the reserve book: Microelectronic Circuit Design by Jaeger, Sects. 7.1-7.4. The lecture material will follow this relatively closely.

Problems: Use $k_n' = 25 \mu A/V^2$, $k_p' = 10 \mu A/V^2$, $V_{t,n} = 1 V$, and $V_{t,p} = -1 V$ unless otherwise indicated.

#1 What are the values of $C_{GS}$ and $C_{GD}$ for a MOS transistor with $C_{ox} = 1.4 \times 10^{-3} F/m^2$, $W = 10 \mu m$, $L = 1 \mu m$, and $L_{ov} = 0.1 \mu m$, when the transistor is operating in (a) the triode (or linear) region, (b) in the saturation region, and (c) in the cut-off region?

#2 Find $V_{OH}$, $V_{OL}$, and the power dissipation (for $v_o = V_{OL}$) for the logic inverter with resistor load drawn below.

#3 Design an inverter with a resistive load for $V_{DD} = 3.3 V$ and $V_{OL} = 0.2 V$. Assume $I_D = 33 \mu A$, $k_n' = 60 \mu A/V^2$ and $V_{t,n} = 0.75 V$.

#4 (a) Design a saturated load inverter with $V_{DD} = 3.3 V$ and $V_{OL} = 0.2 V$. Assume $I_D = 33 \mu A$.

(b) Recalculate the values of $W/L$, this time including the body effect, with the body of the switching MOSFET tied to its source, and the body of the load MOSFET tied to ground.

#5 The logic input of the saturated load inverter drawn above is connected to +5 V. What is $v_o$ for this input voltage? You may wish to take advantage of a math solver like MATLAB to perform an iterative solution on your resulting equation.

#6 We know that the body effect deteriorates the behavior of NMOS logic gates with depletion-mode loads. Assume that the depletion-mode load device has $V_{bd} = -3 V$ and is operating in an inverter circuit with $V_{DD} = 5 V$. What is the largest value of the body-effect parameter $\gamma$ that will still allow $V_{OH} = V_{DD}$?