MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Department of Electrical Engineering and Computer Science

6.012
Microelectronic Devices and Circuits

Fall 1999
October 15, 1999 - Homework 5
Due October 22, 1999

Reading: Chapter 5

Use the following device data for this problem set.

NMOS Transistor Data

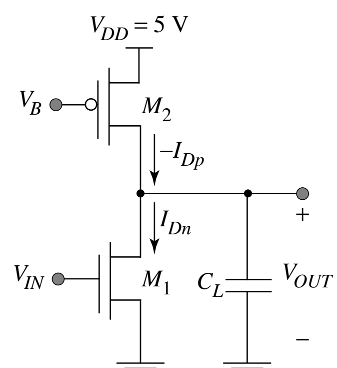
$V_{TO} = 0.7V$
$\mu_n = 220 cm^2/V\text{-sec}$
$\lambda_n = 0.067V^{-1}$
$T_{ox} = 15nm$
$C_{jn} = 1 \times 10^{-8} F/cm^2$
$C_{jswn} = 5 \times 10^{-12} F/cm$
$L_{diffn} = 6\ \mu m$

PMOS Transistor Data

$V_{T0} = -0.7V$
$\mu_p = 110\ cm^2/V\text{-sec}$
$\lambda_p = 0.067V^{-1}$
$T_{ox} = 15nm$
$C_{jp} = 3 \times 10^{-8} F/cm^2$
$C_{jswp} = 3.5 \times 10^{-12} F/cm$
$L_{diffp} = 6.0\ \mu m$

- Dimensions of W and L are in μm.
- Assume area of source/drain = 6 x W μm^2.
- Assume perimeter of source/drain = 12 + W μm.
- Use zero voltage capacitance values for hand calculations. This yields conservative results.
- $C_{jn,p}$ is the zero voltage depletion capacitance/area of the source/drain.
- $C_{jswn,p}$ is the zero voltage depletion capacitance/length of the "sidewall" or perimeter of source/drain.

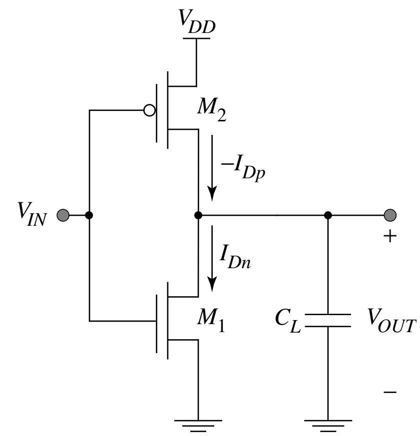
Problem 1 An NMOS inverter with a current source pull-up shown below has $(W/L)_n = (W/L)_p = 15/1.5$ and $V_B = 3.0$ V.



a) Sketch the voltage transfer characteristic and label V_{IL}, V_{IH}, V_M, V_{OH}, V_{OL}.

b) If a 300 fF load capacitor C_L is connected to the output, calculate t_{PHL} and t_{PLH}. Assume that no gates are connected to the load. Include C_{DB} in your calculation.
c) What is the static power dissipated by this circuit?
d) Redesign $(W/L)_n$ and $(W/L)_p$ such that t_{PHL} and t_{PLH} are reduced by 50% from that calculated in part (b).

Problem 2 Given the CMOS inverter shown below with $(W/L)_n = 20/1.5$, $(W/L)_p = 30/1.5$, and $C_L = 1\text{pF}$, $V_{DD} = 3\text{V}$.

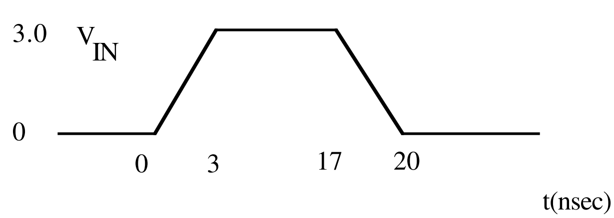


Problem 2a

a) Calculate V_M.
b) Calculate A_V.
c) Calculate NM_L and NM_H.
d) Calculate t_{PHL} and t_{PLH}.

Problem 2b

a) Use the DC sweep on the input voltage to simulate the transfer characteristics using SPICE. Compare V_M, A_V, NM_L and NM_H with the calculated results.
b) Use the Pulse input to simulate an input waveform shown below using SPICE.



Compare t_{PHL} and t_{PLH} with the hand calculated values.

Spice Model Card

.MODEL N15 NMOS LEVEL=1 VTO=0.7TOX=1.5E-08 UO=220.0
+ LAMBDA=6.7E-02 GAMMA=0.6
+ CJ=1.0E-04 CJSW=5.0E-10 PB=0.95

.MODEL P15 PMOS LEVEL=1 VTO=-0.7 TOX=1.5E-08 UO=110.0
+ LAMBDA=6.7E-02 GAMMA=0.7
+ CJ=3.0E-04 CJSW=3.5E-10 PB=0.9