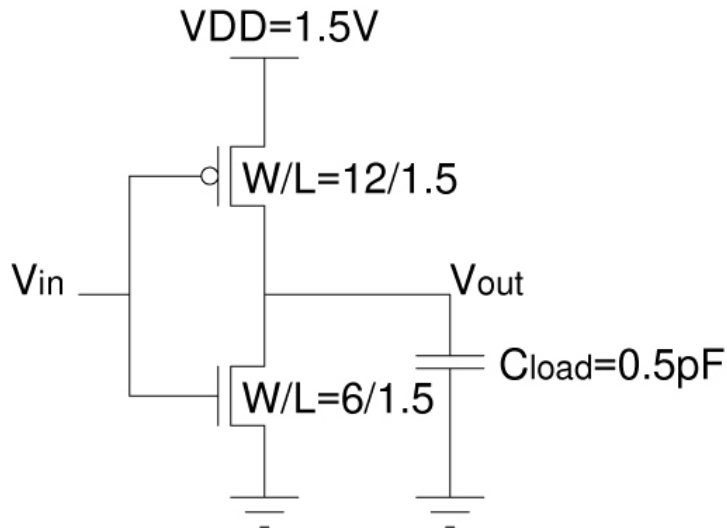


Massachusetts Institute of Technology
Department of Electrical Engineering and Computer Science
6.012
Microelectronic Devices and Circuits
Spring 2007
March 16, 2007 - Homework #4
Due - March 23, 2007

Problem 1

Consider the CMOS inverter pictured below. Take channel length modulation into account.



Parameter	NMOS	PMOS
V_{TO}	0.5 V	-0.5 V
μ	220 cm ² /Vs	110 cm ² /Vs
λ	0.1 V ⁻¹	0.1 V ⁻¹
T_{ox}	15 nm	15 nm

• Dimensions of W and L are in μm

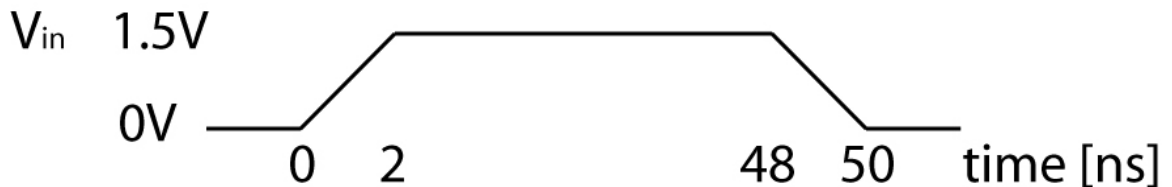
- Calculate V_M , the voltage midpoint.
- Calculate A_V , the voltage gain at $V_{in}=V_M$.
- Calculate N_{ML} and N_{MH} , the noise margin low and noise margin high.
- Calculate t_{PHL} and t_{PLH} , the propagation delay from high-to-low and propagation delay from low-to-high.

Problem 2

We will now use the following SPICE model and compare our hand calculations from Problem 1 with simulated results.

```
.MODEL N15 NMOS LEVEL=1 VT0=0.5 TOX=1.5e-8 U0=220 LAMBDA=1.0e-1  
+GAMMA=0.6 CJ=1e-4 CJSW=5e-10 PB=0.95  
.MODEL P15 PMOS LEVEL=1 VT0=-0.5 TOX=1.5e-8 U0=110 LAMBDA=1.0e-1  
+GAMMA=0.6 CJ=3e-4 CJSW=3.5e-10 PB=0.9
```

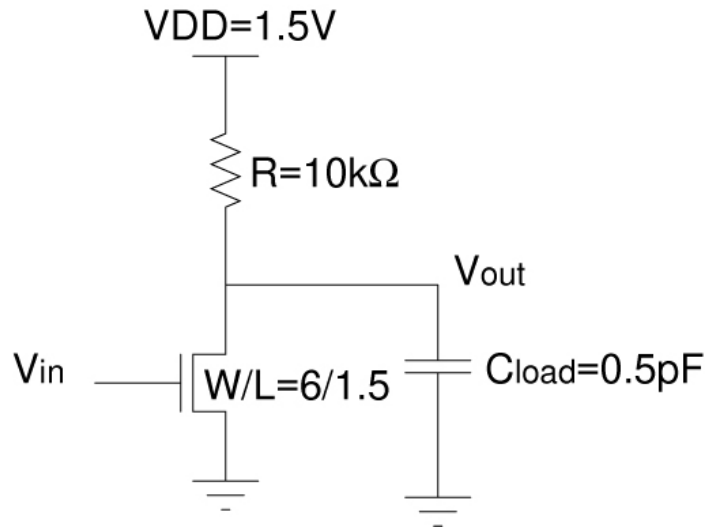
- Use the DC sweep on the input voltage to simulate transfer characteristics using SPICE. Compare V_M , A_V , N_{ML} , N_{MH} , with the calculated results.
- Use the Pulse input to simulate an input waveform shown below using SPICE. Compare t_{PHL} and t_{PLH} with your hand calculations.



Problem 3

Consider the circuit below, which consists of an NMOS device and resistor load. Disregard channel length modulation for this problem.

- Calculate V_M , V_{OH} , V_{OL} . Remember, for hand calculations we assume $V_{OH}=V_{MAX}$, and $V_{OL}=V_{MIN}$.
- Calculate the voltage gain of this circuit, when $V_{in}=V_M$.



Problem 4

Consider the circuit below, which consists of an NMOS device and PMOS current source load. *Do not* neglect channel length modulation.

- Calculate the width of the PMOS device so its saturation current is $50\mu\text{A}$.
- Calculate V_M , V_{OH} , V_{OL} . Remember, for hand calculations we assume $V_{OH}=V_{MAX}$, and $V_{OL}=V_{MIN}$.
- Calculate the voltage gain of this circuit, when $V_{in}=V_M$.

