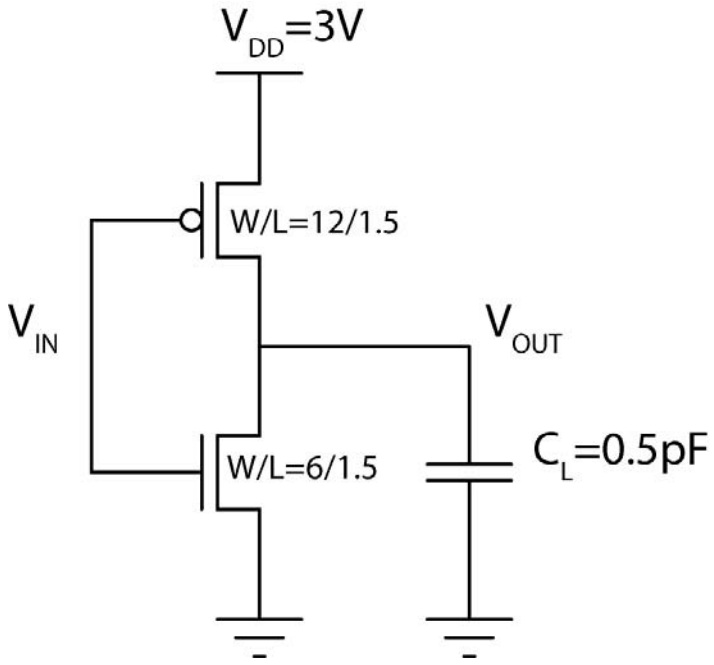
Massachusetts Institute of Technology
Department of Electrical Engineering and Computer Science
6.012 Microelectronic Devices and Circuits
Homework #4

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

a) Calculate V_M, the voltage midpoint.
b) Calculate A_V, the voltage gain at $V_{IN}=V_M$.
c) Calculate N_{ML} and N_{MH}, the noise margin low and noise margin high.
d) 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.

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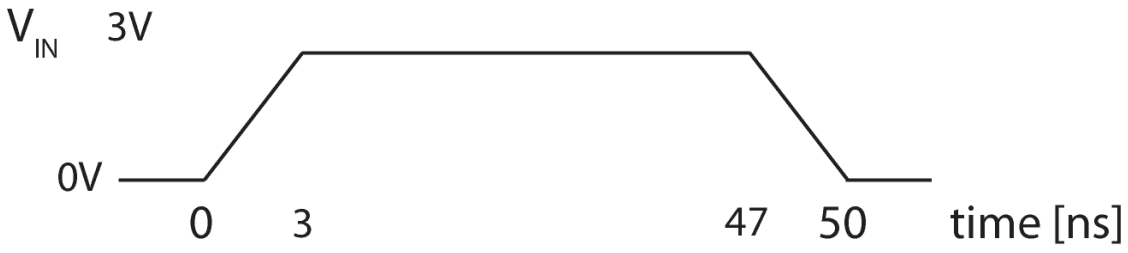
.MODEL N15 NMOS LEVEL=1 VT0=0.5 TOX=1.5e-8 U0=220 LAMBDA=1.0e-1
+GAMMA=0.6 CJ=1e-4 CJSW=5e-10 PB=0.95
.MODEL P15 PMOS LEVEL=1 VT0=-0.5 TOX=1.5e-8 U0=110 LAMBDA=1.0e-1
+GAMMA=0.6 CJ=3e-4 CJSW=3.5e-10 PB=0.9
```

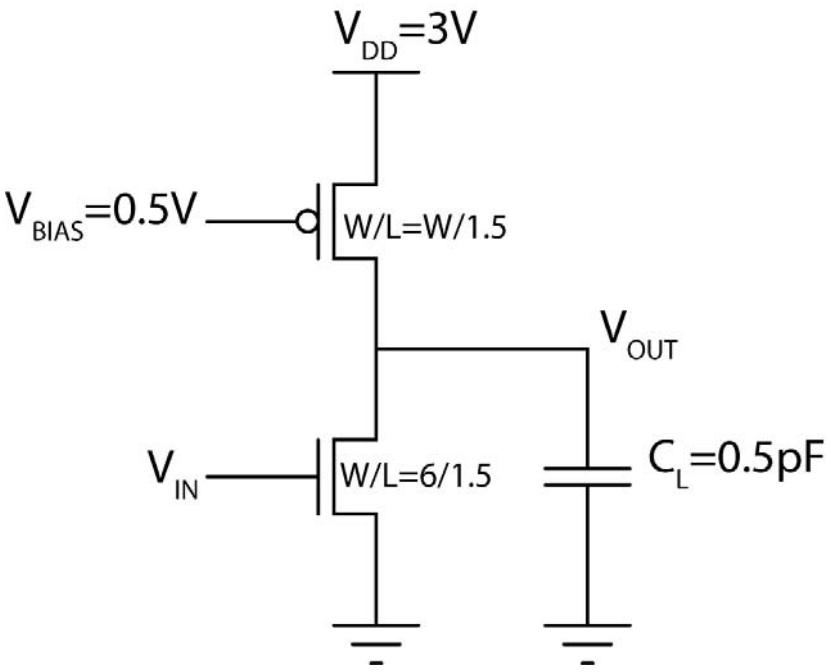
a) Use the DC sweep on the input voltage to simulate transfer characteristics using SPICE. Compare V_M, A_V, N_{ML}, N_{MH}, with the calculated results.
b) Use the Pulse input to simulate an input waveform shown below using SPICE. Compare t_{PHL} and t_{PLH} with your hand calculations.



Problem 3

Consider the circuit below, which consists of an NMOS device and PMOS current source load.

a) Calculate the width of the PMOS device so its saturation current is 50μA.
b) Calculate V_M, V_{OH}, V_{OL}. Remember, for hand calculations we assume $V_{OH}=V_{MAX}$, and $V_{OL}=V_{MIN}$.
c) Calculate the voltage gain of this circuit, when $V_{IN}=V_M$.
d) Calculate V_{OUT} when $V_{IN}=3$.



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