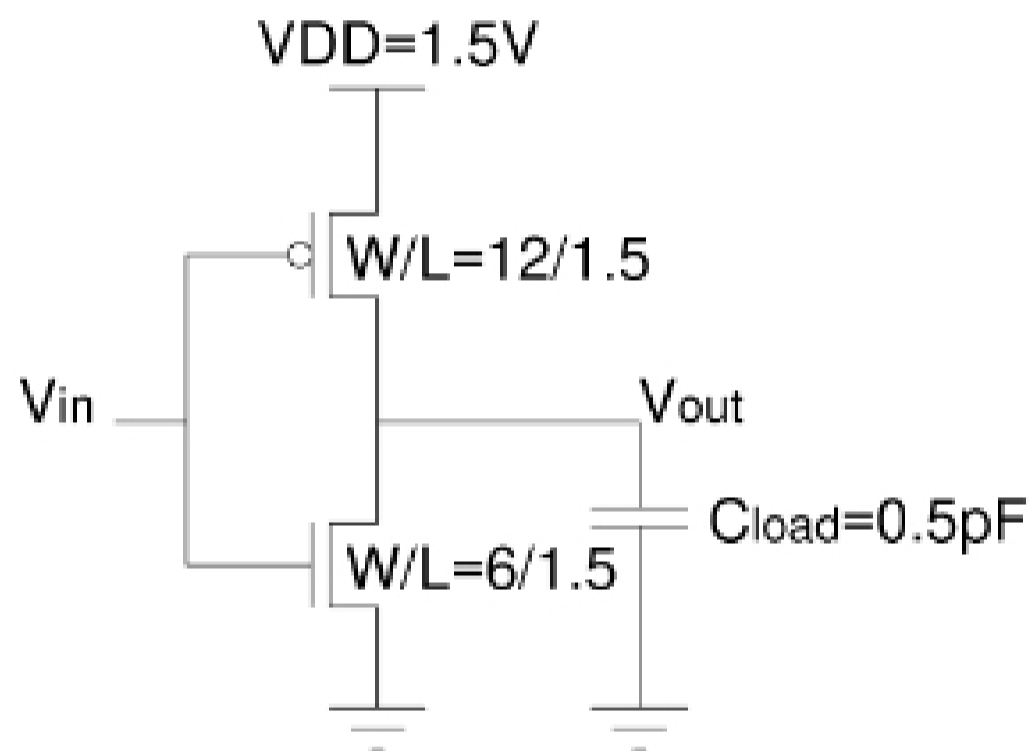


Massachusetts Institute of Technology  
 Department of Electrical Engineering and Computer Science  
 6.012  
 Microelectronic Devices and Circuits  
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 Due - March 23, 2007

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**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
$\mu$	220 $cm^2/Vs$	110 $cm^2/Vs$
$\lambda$	0.1 $V^{-1}$	0.1 $V^{-1}$
$T_{ox}$	15 nm	15 nm

• Dimensions of W and L are in  $\mu m$

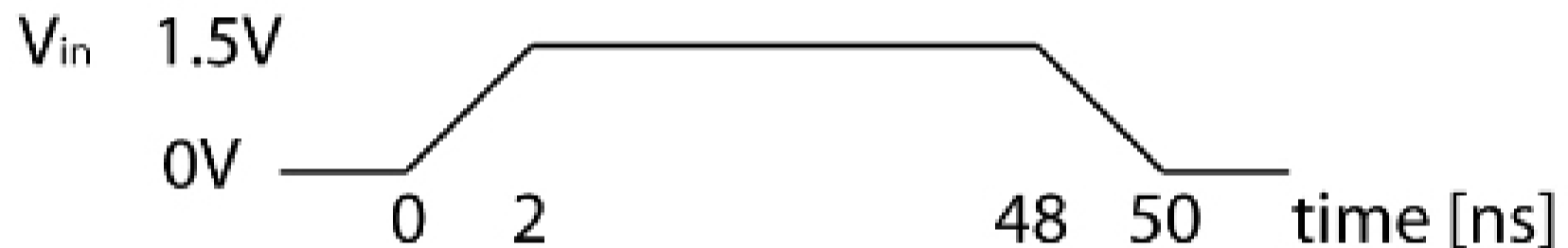
- Calculate  $V_M$ , the voltage midpoint.
- Calculate  $A_V$ , the voltage gain at  $V_{in}=V_M$ .
- Calculate  $N_{ML}$  and  $N_{MH}$ , the noise margin low and noise margin high.
- Calculate  $t_{PHL}$  and  $t_{PLH}$ , the propagation delay from high-to-low and propagation delay from low-to-high.

## 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
```

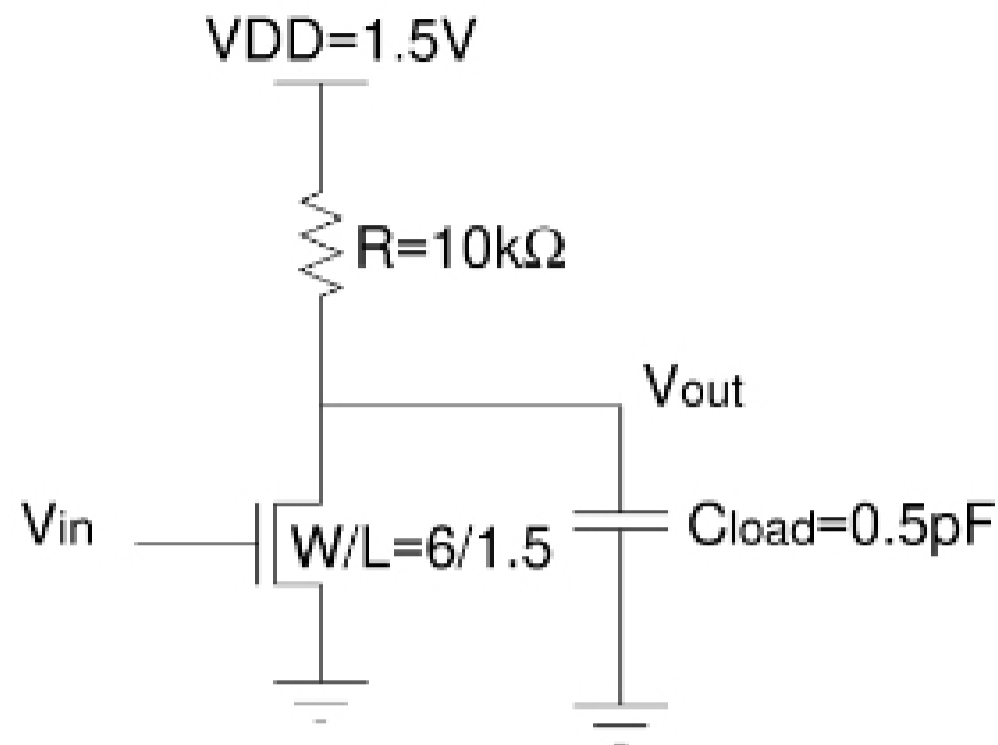
- Use the DC sweep on the input voltage to simulate transfer characteristics using SPICE. Compare  $V_M$ ,  $A_V$ ,  $N_{ML}$ ,  $N_{MH}$ , with the calculated results.
- Use the Pulse input to simulate an input waveform shown below using SPICE. Compare  $t_{PHL}$  and  $t_{PLH}$  with your hand calculations.



## 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  $V_{in} = V_M$ .

