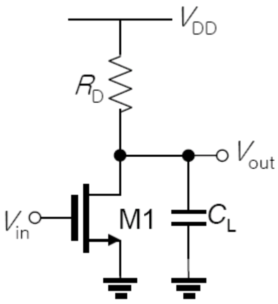
Quiz 11	Subject	Professor	Student ID#	Student Name	Score
Date: 2009.11.25	Microelectronics 2	Jong-Ho Lee			

1. Following figure depicts an inverter. Assume all op amps are ideal. Answer for the following questions.



$$I_{D,lin} = \mu_n C_{ox}\frac{W}{L}[(V_{GS}-V_{TH})V_{DS}-\frac{V_{DS}^2}{2}]$$

$$I_{D,sat} = \mu_n C_{ox}\frac{W}{2L}(V_{GS}-V_{TH})^2$$

(a) When the V_{in} is V_{DD}, V_{out} is very close to 0 V. In this case, calculate approximately the channel resistance of transistor M1. (3)

Answer)

When V_{in} is V_{DD}, M_1 is in a triode region. $[V_{DS1} < V_{GS1} - V_{TH1}]$

$$I_D \approx \mu_n C_{OX}\frac{W}{L}(V_{GS1}-V_{TH1})V_{DS1}$$

$$R_{on1} = \frac{V_{DS1}}{I_{D1}} = \frac{1}{\mu_n C_{ox}\frac{W}{L}(V_{GS1}-V_{TH1})}$$

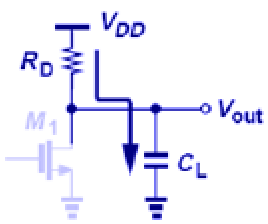
Therefore, When $V_{in} = V_{DD}$,

$$\boldsymbol{R_{on1} = \frac{1}{\mu_n C_{ox}\frac{W}{L}(V_{DD}-V_{TH1})}}$$

(b) An NMOS inverter drives a load capacitor C_L as depicted in above figure. Determine the time constant at output node when V_{out} goes from low to high. Assume R_D is 20 R_{on1}. Here R_{on1} is the channel resistance of transistor M1 when it is turned on. (4)

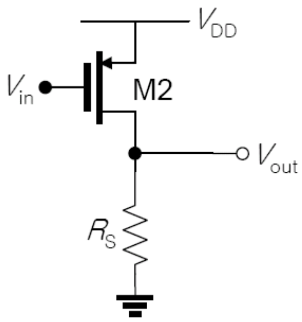
Answer)

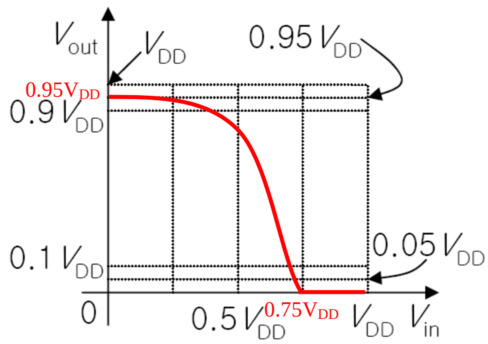
When the input to an NMOS inverter jumps from V_{DD} to 0, V_{out} goes from low to high.



$$\boldsymbol{\tau = R_D C_L = 20 R_{on1} C_L = \frac{20 C_L}{\mu_n C_{ox}\frac{W}{L}(V_{DD}-V_{TH1})}}$$

2. Using M2 and R_S below, we can implement an inverter. Plot schematically the voltage transfer characteristic of the inverter in the figure on the right side. Assume the threshold voltage of PMOS M2 is 0.25 V_{DD}. Assume R_S is 19×R_{on2}. (3)





Answer)

Assume V_{in} varies from V_{DD} to 0.

i) For $V_{DD} - |V_{TP}| < V_{in} \le V_{DD}$ $(0.75V_{DD} < V_{in} \le V_{DD})$,

M_2 remains off and $V_{out}=0$.

(logical ZERO)

ii) As V_{in} decreases less than $V_{DD} - |V_{TP}|$, M_2 turns on and V_{out} begins to rise. (M_2 is in a saturation region)

$$V_{out} = I_D R_s$$

$$= \frac{1}{2}\mu_p C_{ox}\frac{W}{L}R_s(V_{DD}-V_{in}-|V_{TP}|)^2$$

iii) As the input decreases further, V_{out} rises, eventually driving into the triode region for $V_{out} \ge V_{in} - |V_{TP}|$. $(V_{SD} \le V_{SG} - |V_{TP}|)$

As V_{in} decreases less than $V_{out} - |V_{TP}|$, V_{out} continues to rise, Reaching its highest level for V_{in}=0.

$$V_{out.max} = R_s I_{D,max}$$

$$= \frac{1}{2}\mu_p C_{ox}\frac{W}{L}R_s\left[2(V_{DD}-|V_{TP}|)(V_{DD}-V_{out,max})-(V_{DD}-V_{out,max})^2\right]$$

$$= \frac{19}{2}\mu_p C_{ox}\frac{W}{L}R_{on2}\left[2(V_{DD}-|V_{TP}|)(V_{DD}-V_{out,max})-(V_{DD}-V_{out,max})^2\right]$$

$$\approx 19(V_{DD}-V_{out,max})$$

$$\therefore V_{out,max} \approx 0.95V_{DD}$$

Use front side only