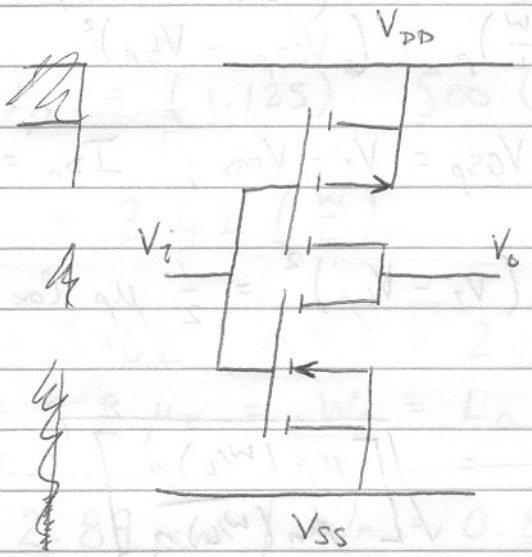
Q2 UE3003 SPR 2006 10/8/06

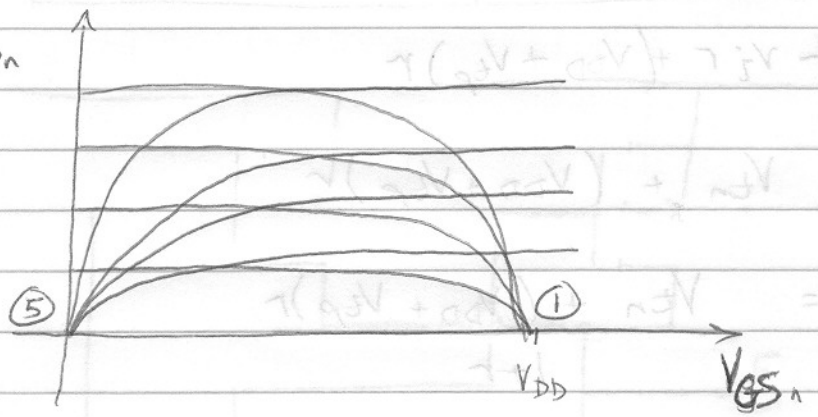
NOT gate

EXAM READY ANSWER

(a)



(b)

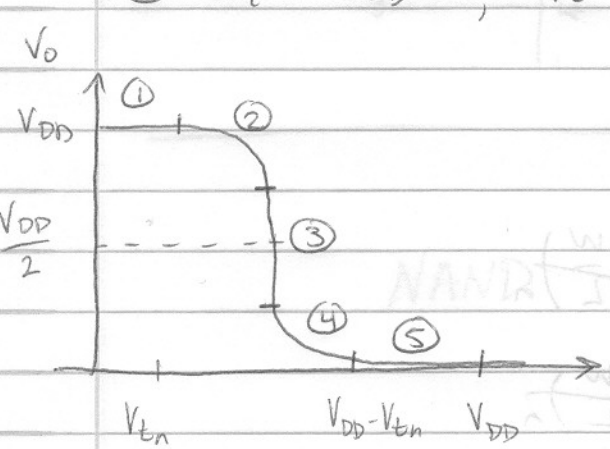


The operating point is given by the intersection of the curves

① $V_i = 0$, $V_o = V_{DD}$

⑤ $V_i = V_{DD}$, $V_o = 0$

(c)



① M_n cutoff, M_p triode

② M_n saturated, M_p triode

③ M_n saturated, M_p saturated

④ M_n triode, M_p saturated

⑤ M_n triode, M_p cutoff

(d) $I_{Dn} = \frac{1}{2}\mu_n C_{ox}\left(\frac{W}{L}\right)_n \left(V_{GSn} - V_{tn}\right)^2$

$I_{Dp} = -\frac{1}{2}\mu_p C_{ox}\left(\frac{W}{L}\right)_p \left(V_{GSp} - V_{tp}\right)^2$

$V_{GSn} = V_i$; $V_{GSp} = V_i - V_{DD}$; $I_{Dn} = -I_{Dp}$

$$\frac{1}{2}\mu_n C_{ox}\left(\frac{W}{L}\right)_n \left(V_i - V_{tn}\right)^2 = \frac{1}{2}\mu_p C_{ox}\left(\frac{W}{L}\right)_p \left(V_i - V_{DD} - V_{tp}\right)^2$$

$$-\left(\frac{V_i - V_{tn}}{V_i - V_{DD} - V_{tp}}\right) = \sqrt{\left[\frac{\mu_p (W/L)_p}{\mu_n (W/L)_n}\right]} = r$$

$$V_i - V_{tn} = -V_i r + (V_{DD} + V_{tp}) r$$

$$V_i (1+r) = V_{tn} + (V_{DD} + V_{tp}) r$$

$$V_i = V_{th} = \frac{V_{tn} + (V_{DD} + V_{tp}) r}{1+r}$$

(e) $$V_{th} = \frac{V_{DD}}{2} = 2.5 = \frac{0.7 + (5 + (-0.9))\, r}{1+r}$$

$$2.5(1+r) = 0.7 + 4.8r$$

$$2.5 + 2.5r = 0.7 + 4.8r$$

$$1.8 = 1.8r$$

$\boxed{r = 1.125}$, Then

$$\mu_p \left(\frac{W}{L}\right)_p = \mu_n \left(\frac{W}{L}\right)_n$$

$$175 \left(\frac{W}{L}\right)_p = 500 \left(\frac{W}{L}\right)_n$$

$$\left(\frac{W}{L}\right)_p = 2.86 \left(\frac{W}{L}\right)_n$$

$$\sqrt{\frac{\mu_p \left(W/L\right)_p}{\mu_n \left(W/L\right)_n}} = 1.125$$

$$175 \left(\frac{W}{L}\right)_p = (1.125)^2 \cdot 500 \left(\frac{W}{L}\right)_n$$

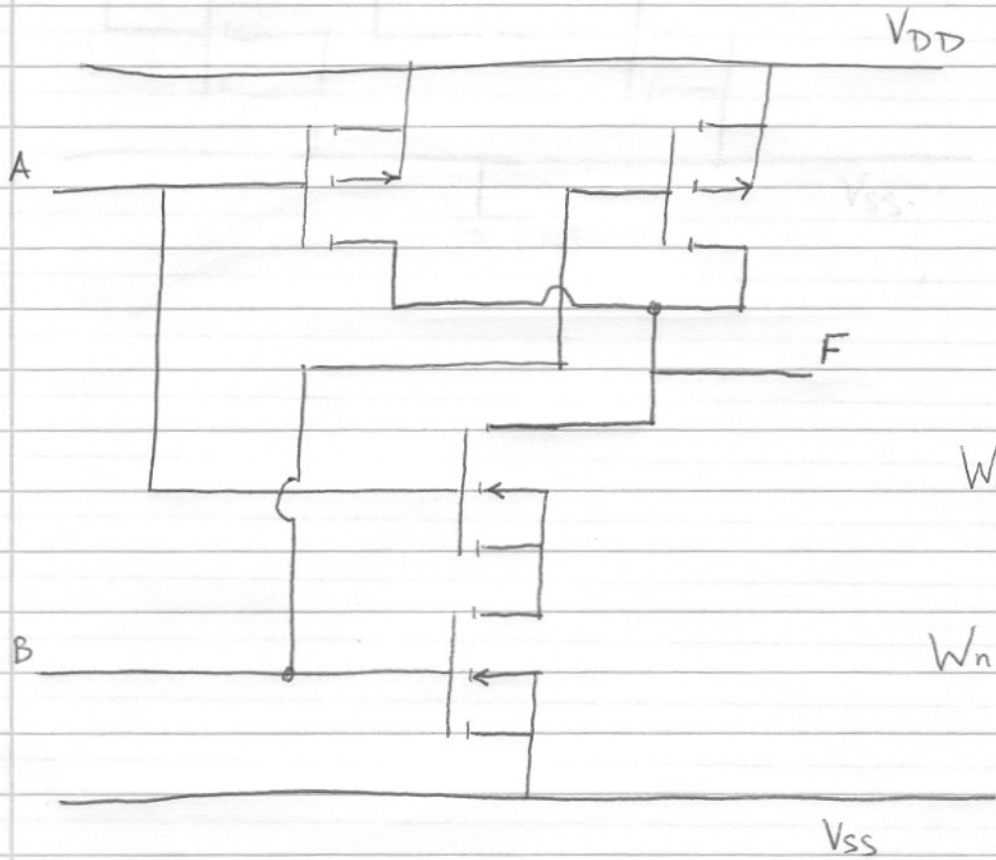
$$\left(\frac{W}{L}\right)_p = 3.62 \left(\frac{W}{L}\right)_n$$

Set $W_p = 3.62\,(0.8) = 2.893\,\mu m$

$L_p = 0.8\,\mu m = W_n = L_n$

$W_p = 2.89\,\mu m$	$W_n = 0.8\,\mu m$

(f)



$W_p = 2.89\,\mu m$

$W_n = 1.6\,\mu m$

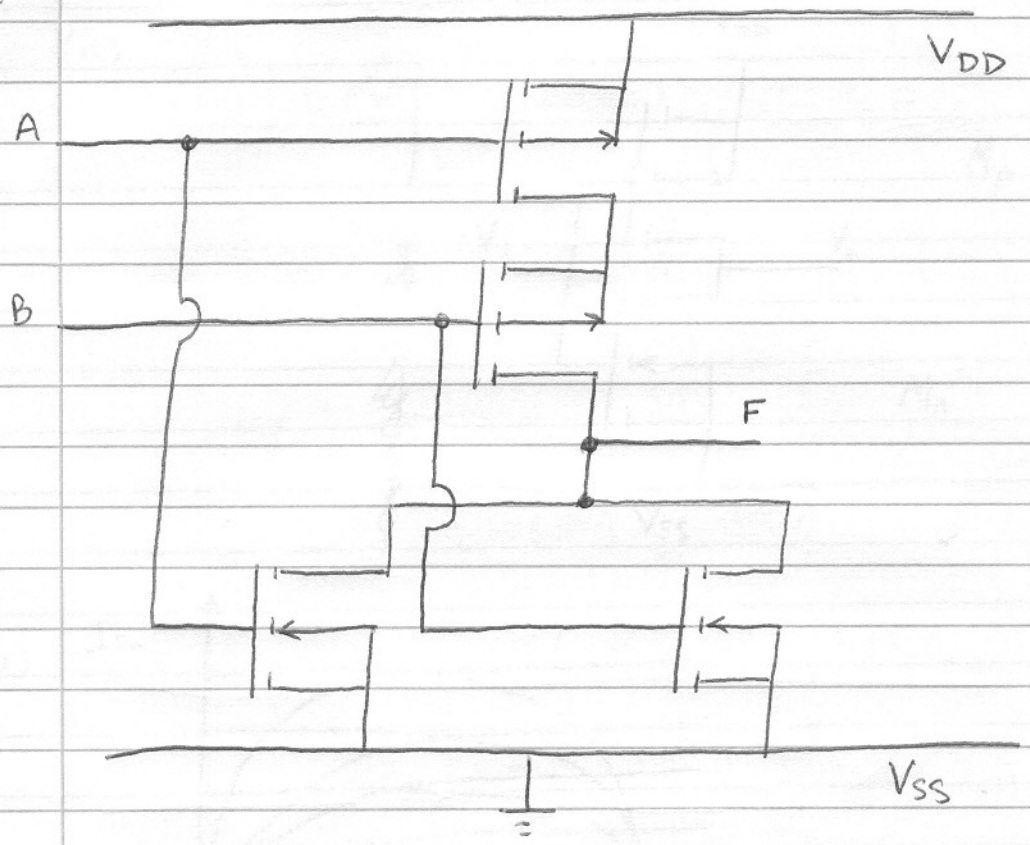
$W_n = 1.6\,\mu m$

compensates for effectively being twice as long!

NAND

(f) ALT.

Alternatively, may be asked for a NOR gate



twice as long effectively
→ need $2W_p$ for ea. of these to maintain $V_{th} = V_{DD}/2$