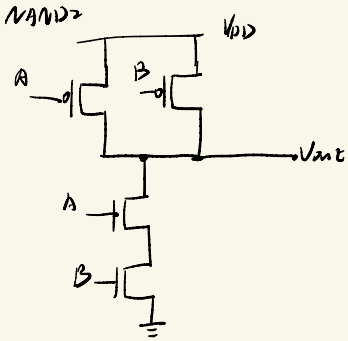
2.3



(a) $k_{peq} = 2k_p$ $\quad k_{neq} = \frac{1}{2}k_n$.

$$k_R = \frac{k_{neq}}{k_{peq}} = \frac{k_n}{4k_p} = \frac{1}{4}$$

$$V_{th} = \frac{V_{T0,n} + 2\sqrt{\frac{1}{k_R}} \cdot (V_{DD} - |V_{T0,p}|)}{1 + 2\sqrt{\frac{1}{k_R}}}$$

$$= \frac{0.53 + 2 \times \frac{1}{2} \times (1.2 - 0.51)}{1 + 2 \times \frac{1}{2}}$$

$$= 0.61\,V$$

(b) 两输入同时跳变: $k_{neq} = 50\,\mu A/V^2$. $k_{peq} = 200\,\mu A/V^2$

① t_{pHL}: $\dfrac{C_{Load}\,\Delta V}{I_{average,fall}}$

$$I_{average,fall} = \frac{1}{2}\left(I_1(V_{in} = 1.2V, V_{out} = 1.2V) + I_2(V_{in} = 1.2V, V_{out} = 0.6V)\right)$$

$V_{in} = 1.2V$. NMOS 饱和.

$$I_1 = \frac{1}{2} k_{neq} (V_{GS} - V_{TH})^2$$

$$= \frac{1}{2} \times 50 \times 10^{-6} \times (1.2 - 0.53)^2 = 1.12225 \times 10^{-5} A$$

$V_{out} = 0.6V$. $\quad V_{GS} - V_{TH} = 1.2 - 0.53 = 0.67V$.

$V_{DS} = 0.6V < V_{GS} - V_{TH}$.

线性区

$$I_2 = \frac{1}{2} k_{neq} (2(V_{GS} - V_{TH}) V_{DS} - V_{DS}^2)$$

$$= \frac{1}{2} \times 50 \times 10^{-6} \times (2 \times 0.67 \times 0.6 - 0.6^2) = 1.11 \times 10^{-5} A$$

$I_{average.fall} = 1.116125 \times 10^{-5} A$

$$t_{pHL} = \frac{C_{load} \, \Delta V}{I_{average.fall}} \approx 10.75 \, ns$$

$$t_{pLH} = \frac{C_{load} \, \Delta V}{I_{average.rise}}$$

$$I_{average.rise} = \frac{1}{2}(I_1(V_{in} = 0V, V_{out} = 0V) + I_2(V_{in} = 0V, V_{out} = 0.6V))$$

$V_{in} = 0V$, $V_{out} = 0V$, $\quad V_{DS} = -V_{DD}$. 2管子饱和区

$$I_1 = \frac{1}{2} k_{peq} (V_{GS} - V_{TMP})^2$$

$= \frac{1}{2} \times 200 \times 10^{-6} \times (0 - 1.2 + 0.51)^2$

$= 4.761 \times 10^{-5} A$

$V_{out} = 0.6V$, $V_{DS} = 0.6 - 1.2 = -0.6V$

$V_{GS} - V_{TH} = 0 - 1.2 + 0.51 = -0.69V < V_{DS}$

饱和区

$I_2 = \frac{1}{2} k_{peq} (2(V_{GS} - V_{TH}) V_{DS} - V_{DS}^2)$

$= \frac{1}{2} \times 200 \times 10^{-6} \times (2 \times 0.69 \times 0.6 - 0.6^2)$

$= 4.68 \times 10^{-5} A$

$I_{average,rise} = 4.7205 \times 10^{-5} A$

$t_{pLH} = \frac{C_{load} \Delta V}{I_{average,rise}} = 2.5421 ns$

底部 nmos gate V_{DD} 时，顶部 nmos 断路

13 不动 (V_{DD}) A 跳变，

在计算 t_{pHL} 时，仍与上面情况一样，$t_{pHL} = 10.75 ns$

在计算 t_{pLH} 时，由于其中一个保持 J 导通，所以只计算一个，相当于 $k_{peq} = k_p = 100 \mu A/V^2$

相当于 $I_{average,rise}$ 减半

t_{pLH} 翻倍，$t_{pLH} = 5.0842 ns$

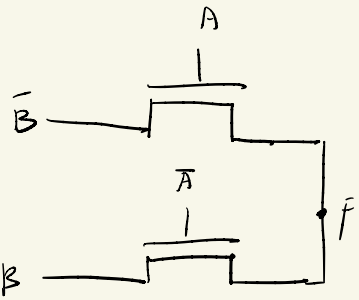
顶部 nmos gate 保持 V_{DD}. 下方 跳变

相当 A 保持 V_{DD}, B跳变

在计算 t_{pHL} 时, 仍与上面情况一样, $t_{pHL} = 10.75\ ns$

计算 t_{pLH} 时, 与第二种情况一致, $t_{pLH} = 5.0842\ ns$

7.11

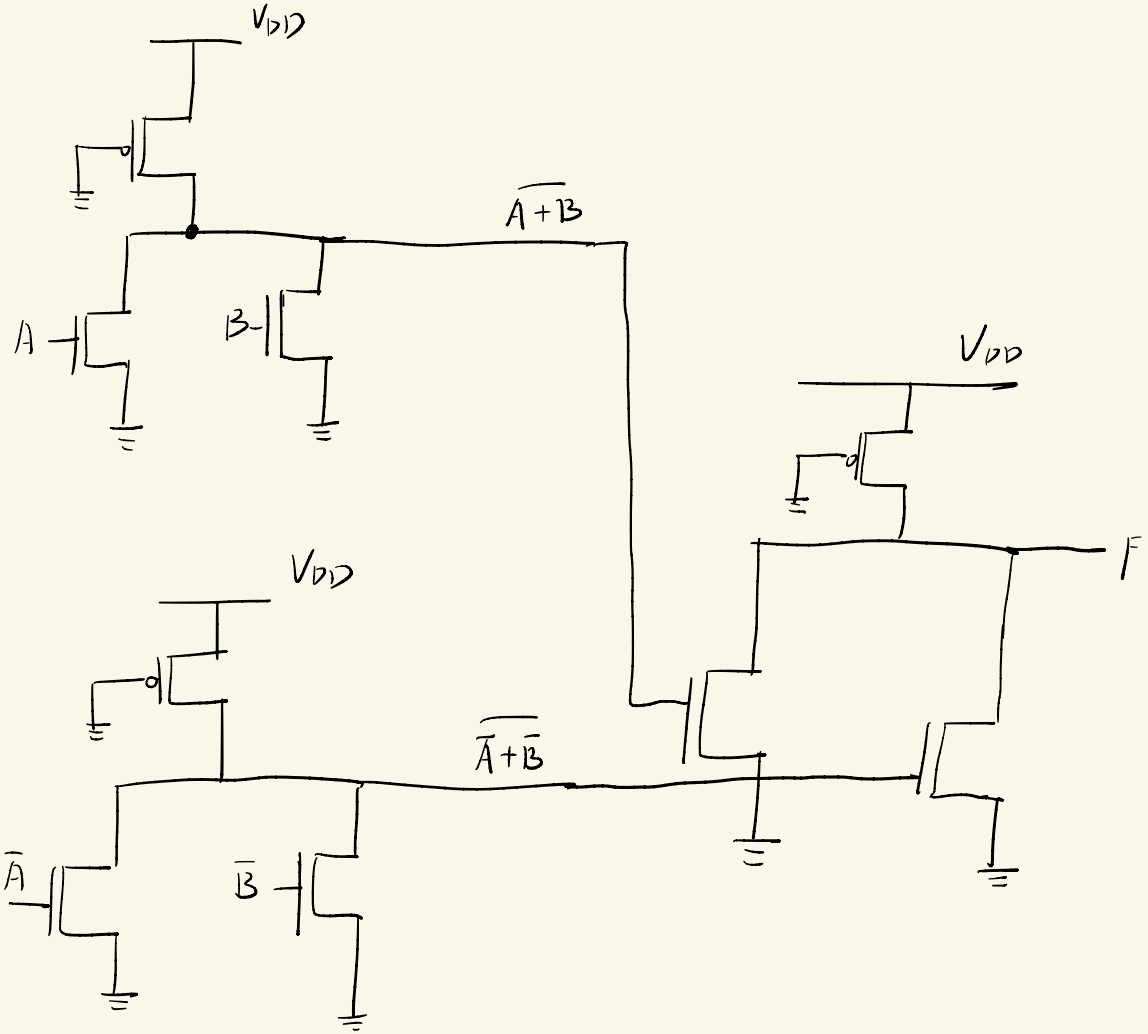


(a) $F = A\bar{B} + \bar{A}B = A \oplus B$

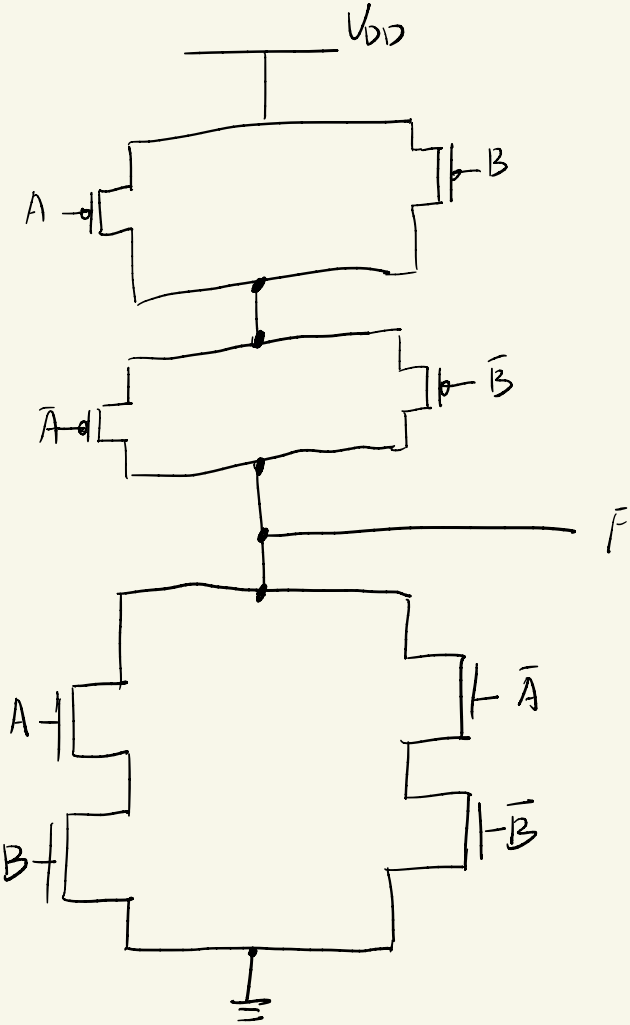
(b) 用 NOR 实现 $F = (A+B)(\bar{A}+\bar{B})$

$$= \overline{\overline{A+B} + \overline{\bar{A}+\bar{B}}}$$

pseudo nmos:



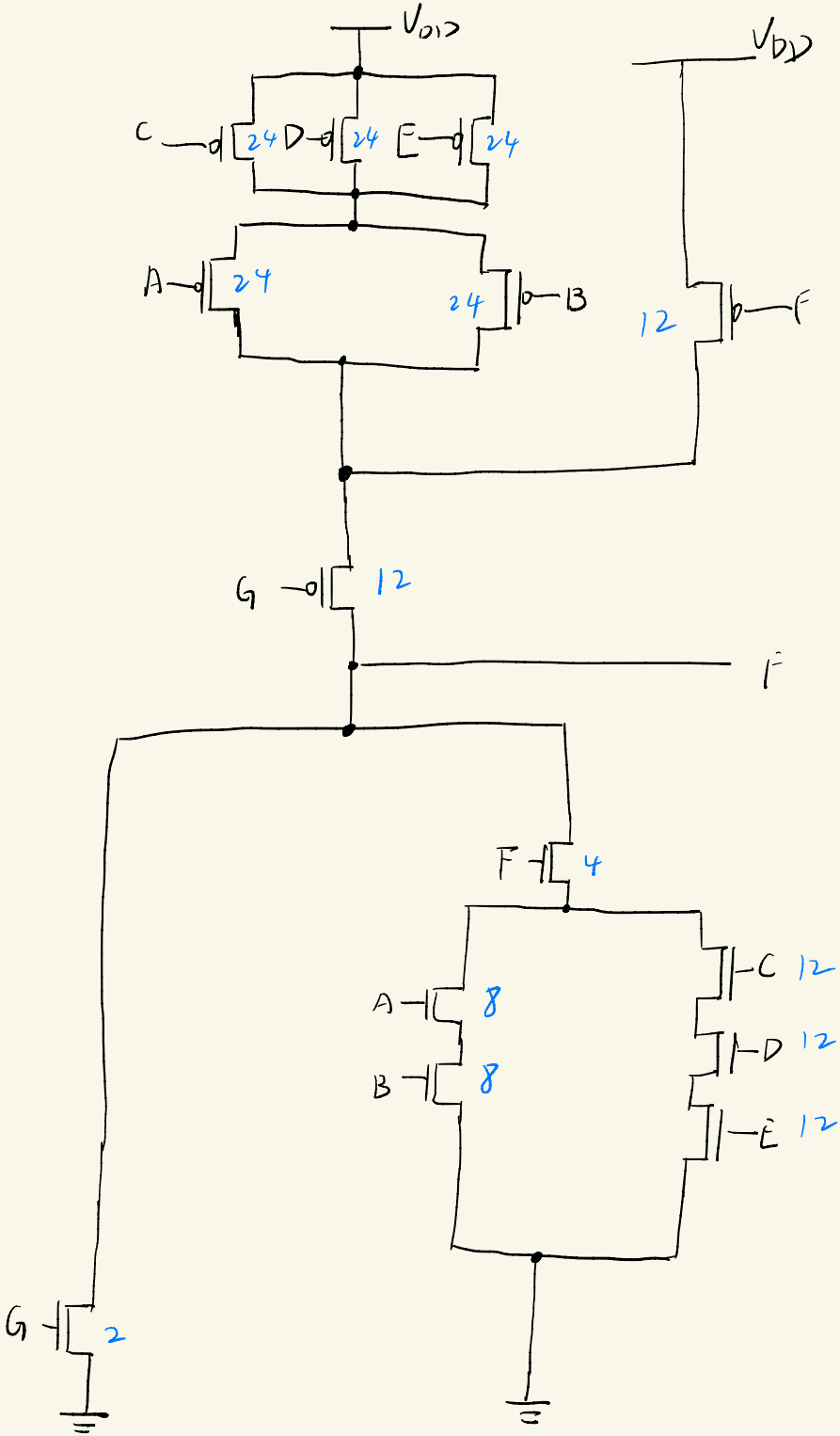
(C) AOI



1. $X = ((\bar{A}+\bar{B})(\bar{C}+\bar{D}+\bar{E})+\bar{F})\bar{G}$ 用互补CMOS实现

$$X = \overline{\left(\left(\overline{\bar{A}+\bar{B}} + \overline{\bar{C}+\bar{D}+\bar{E}}\right)\cdot F\right)+G}$$

$$X = \overline{G + F\cdot(AB+CDE)}$$


VDD
VDD
C
24
D
24
E
24
A
24
24
B
12
F
G
12
F
F
4
A
8
B
8
C
12
D
12
E
12
G
2

要求驱动能力：NMOS $\frac{W}{L}=2$，　　PMOS $\frac{W}{L}=6$

下拉网络中：$G=2$，　$F=4$　　$A=B=4\times2=8$　　$C=D=E=4\times3=12$

上拉网络中：$G=F=6\times2=12$，　任一通路　$12\times2=24$

最好的上拉信号：上拉的有支路都导通．ABCDEFG 都为 0

最好的下拉信号：下拉的有支路都导通：ABCDEFG 都为 1

最坏的上拉信号：只有某一路导通：　G、F 为 0，　$(\bar{A}+\bar{B})\cdot(\bar{C}+\bar{D}+\bar{E})=0$

或 $G=0$、$F=1$、　$A=0$、$B=1$，　C、D、E 中有且只有 1 个为 0

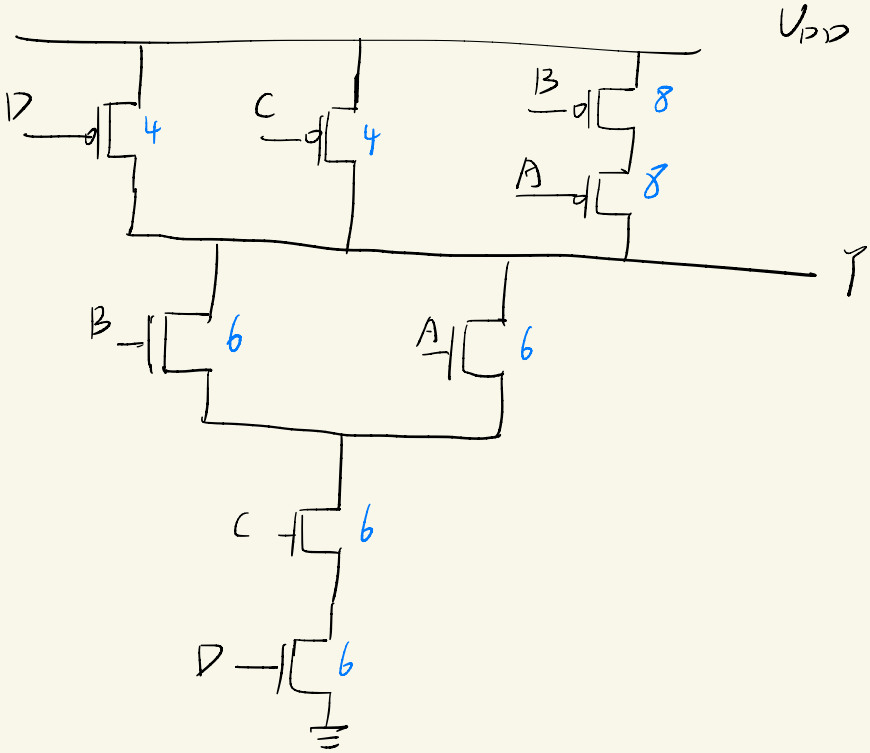
或 $G=0$，$F=1$，　$A=1$　$B=0$．　C、D、E 中有且只有 1 个为 0

最坏的下拉信号：只有某一路导通：　$G=1$，
- $F=0$．　A、B、C、D、E 任意
- $F=1$，
  - A、B 不同时为 1
  - C、D、E 不同时为 1

或 $G=0$，$F=1$，
- $A=B=1$，　C、D、E 至少有 1 个为 0
- $C=D=E=1$，　A、B 至少有 1 个为 0

2.

(1) $Y = \overline{(A+B)CD}$



(2)

最坏的 tpHL：只有一条支路导通 并由 D 实现跳变，A、B 之间电容

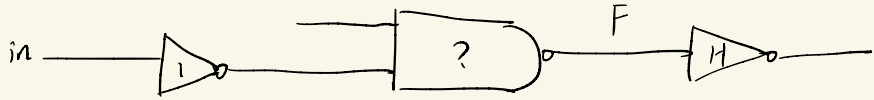
(ABCD) 0110 → 1011

或 1010 → 0111

tpLH：由D实现跳变

0111 → 0110

3.



二、输入 NAND门

设 NAND2尺寸为 X

$$t_{inv.1} = t_{inv.intr} + \text{logic_effort_invert} \frac{X}{1}$$

$$t_{nand} = t_{nand.intr} + \text{logic_effort_xNAND} \cdot \frac{H}{X}$$

R寸为1的反相器，逻辑努力为 1.　　NAND为 $\frac{4}{3}$

$$t_p = t_{inv.intr} + t_{nand.intr} + X + \frac{4}{3}\frac{H}{X}$$

$$\frac{\partial t_p}{\partial x} = 1 + \frac{4}{3}H\left(-\frac{1}{x^2}\right) = 0$$

$$x^2 = \frac{4}{3}H$$

$$x = \sqrt{\frac{4}{3}H}$$

如果是 K输入 NAND，则 逻辑努力：$\frac{K+2}{3}$

$$\frac{\partial t_p}{\partial x} = 1 + \frac{x+2}{3} \cdot H\left(-\frac{1}{x^2}\right) = 0$$

$$x = \sqrt{\frac{k+2}{3} \cdot H}$$