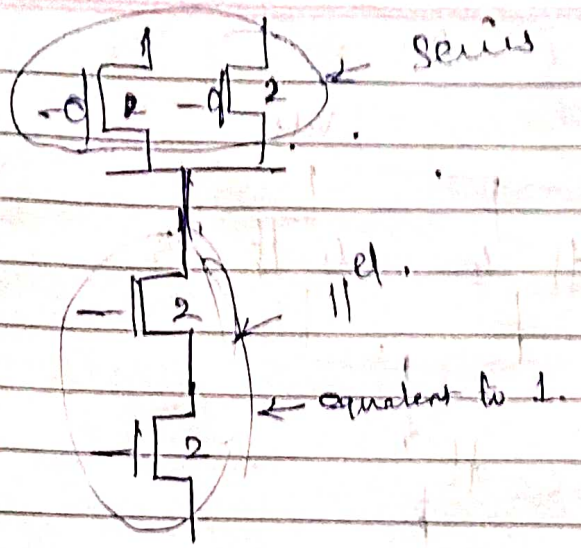
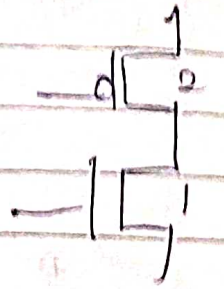
(1) 2 i/p NAND gate $\overline{A \cdot B}$



unit cell.



Series → how many series connection × unit cell value.

$\parallel^{el}$ → each $\parallel^{el}$ connection is equivalent to unit cell.

Pull down.

$$\left(\frac{W}{L}\right)_{eq\,A/B} = 1$$

$$1 = \frac{1}{\left(\frac{1}{W} + \frac{1}{W}\right)} = \frac{1}{\frac{2}{W}}$$

$$\left(\frac{W}{L}\right) = 2$$

Pull ~~down~~ up

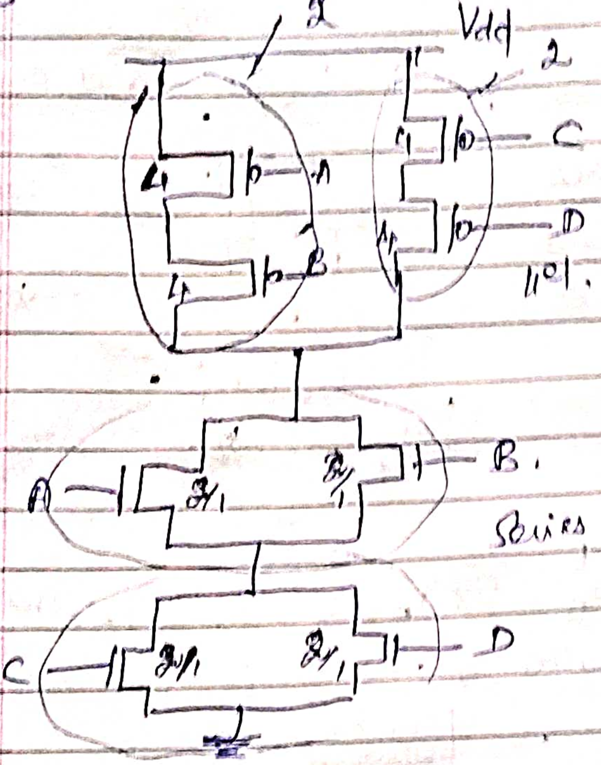
$$\left(\frac{W}{L}\right)_{eq} = \frac{1 \times W_{p.inv}}{1}$$

$$\left(\frac{W}{L}\right)_{eq} = 1 \times 2$$

$$\left(\frac{W}{L}\right)_{eq\,A/B} = 2.$$

OAI 22

(2) $F = \overline{(A+B)\cdot(C+D)}$



NMOS

(+) $||^{el}$

(·) series

PMOS

(+) series

(·) $||^{el}$.

$4+8$ — $2/1$ logical sizing

NMOS:

$(2 * 2/1) + (2 * 2/1)$

$= 4 + 4 = 8$

PMOS:

$(2 * 4/1) + (2 * 4/1)$

$8 + 8 = 16$

$16 + 8$ — $2/1$ size

PD

$= 2 \times W_{n,inv}$

$(W/L)_{equ} = 2 \times 1 = 2$

$(W/L)_A = (W/L)_B = 2$

$(W/L)_C = (W/L)_D = 2$

$$(W/L)_{equ} = \frac{1}{(L/W)+(L/W)} = \frac{1}{2L/W}$$

$$1 = \frac{1}{2L/W} = \frac{W}{L} = 2$$

another way for $(W/L)_{eq}$.

logical effort

$(C_{in})_{AB} = 6$

for AB $= 2+4$

$= 6/3$

PU

$(W/L)_{A,B} = 2$ $\qquad (W/L)_{C,D} = 2$.

logical effort for

$(C_{in})_{CD} = 6$ $\quad C_D = 2+4$

$= 6/3$

$(6/3, 6/3)$

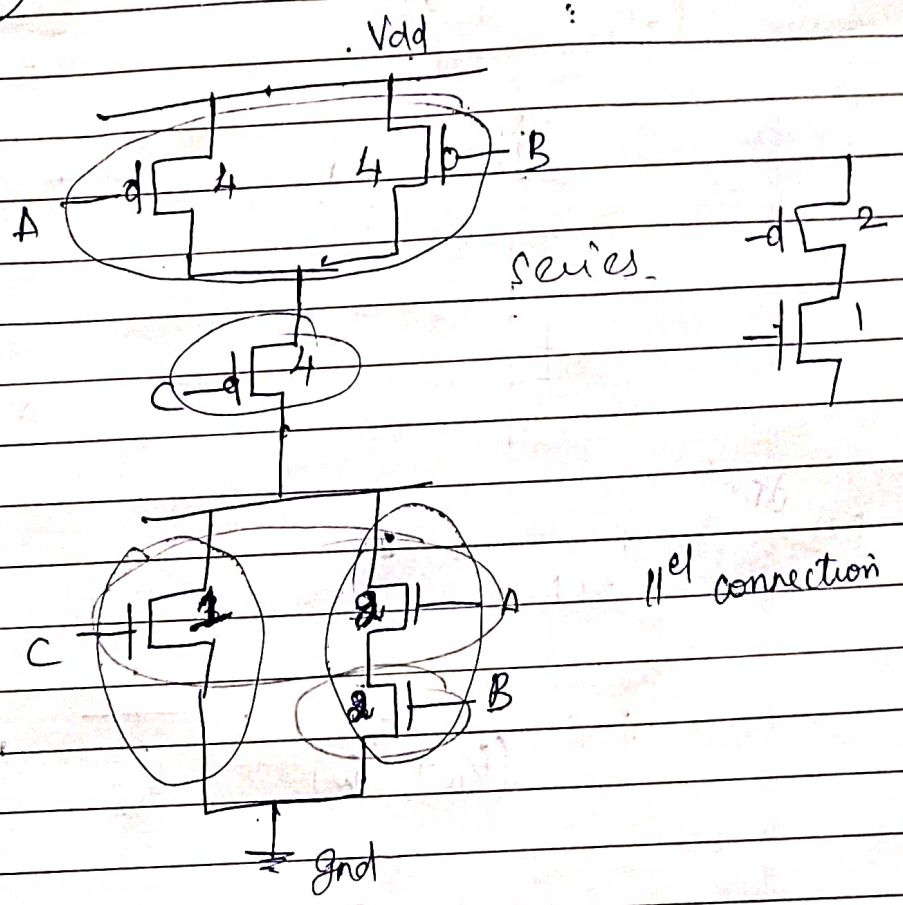
$(W/L)_p = W_{p,inv} = 2$.

$$2 = \frac{1}{(L/W)+(L/W)} = 2 = \frac{1}{\frac{2L}{W}}$$

$\frac{W}{L} = 4$

DATE: PAGE:

(3) $F = \overline{A.B + C}$



Pull down

$\left(\frac{W}{L}\right)_C = 1$

$\left(\frac{W}{L}\right)_{AB} = 1$

$\frac{1}{\left(\frac{1}{W}\right) + \left(\frac{1}{W}\right)} = 1$

$\frac{1}{\frac{2}{W}} = 1$

$\frac{W}{L} = 2.$

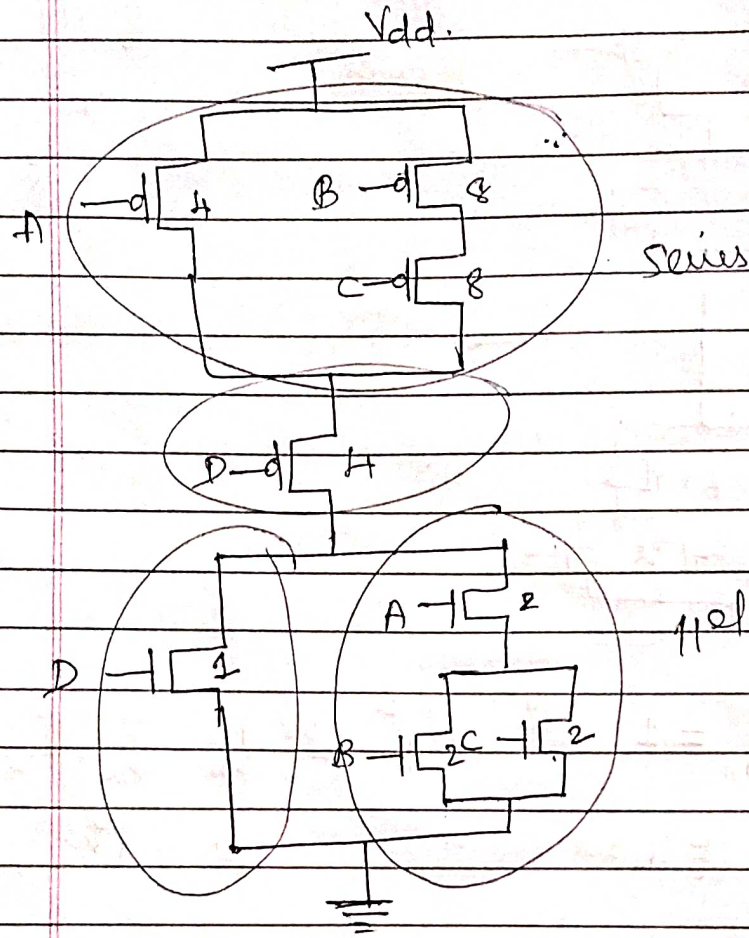
Pull up

2 → series connection

$\left(\frac{W}{L}\right)_{AB} = \left(\frac{W}{L}\right)_C = 4$

$\left(\frac{W}{L}\right)_{eqn} = 2 \times W_{pinv} \Rightarrow 2 \times 2 = 4$

(4) $f = \overline{D + A \cdot (B + C)}$



Pull down $\left(\frac{W}{L}\right)_D = \left(\frac{W}{L}\right)_{ABC} = 1$

$\left(\frac{W}{L}\right)_{ABC} = 1 = \frac{1}{\left(\frac{1}{W}\right) + \left(\frac{1}{W}\right)} = 2\,\frac{W}{L}$

$\left(\frac{W}{L}\right)_A = 2 \quad \left(\frac{W}{L}\right)_{BC} = 2$

B & C ⇒ 11 el connection

$\left(\frac{W}{L}\right)_B = \left(\frac{W}{L}\right)_C = 2$

Pull up

$2 \times 2 \Rightarrow 4$

$\left(\frac{W}{L}\right)_{ABC} = 4 \quad \left(\frac{W}{L}\right)_D = 4$

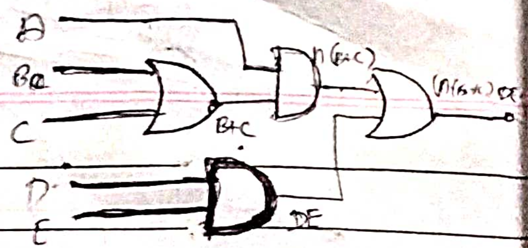
$4 = \frac{1}{\left(\frac{1}{W}\right) + \frac{1}{W}}$

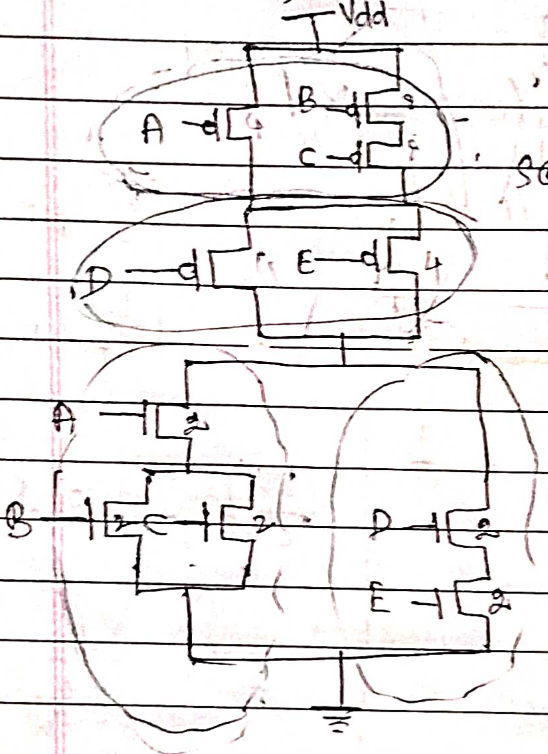
$\left(\frac{W}{L}\right)_{ABC} \Rightarrow \left(\frac{W}{L}\right)_A$ 11 el with $\left(\frac{W}{L}\right)_{BC}$ $\left(\frac{W}{L}\right)_B = 8$

$\left(\frac{W}{L}\right)_A = 4$ & $\left(\frac{W}{L}\right)_{BC} = 4$ $\left(\frac{W}{L}\right)_C = 8$

(A) (6)

$\overline{A(B+C)+DE}$





A BC DE

$6/3$, $10/3$, $6/3$

$5 \times 2 = 10$

$6 \times 3 = 12 + 16$

(38)

12
16
28

24

$\left(\frac{W}{L}\right)_{AD} = 2 \left(\frac{W}{L}\right)_{BCDE} = 2$

$2 \times 3 = \frac{1}{\frac{3L}{W}}$

pull do

Pd :-

$\left(W/L\right)_{ABC} = 1$ $\left(W/L\right)_{DE} = 1$

$1 = \frac{1}{(L/W)_A + (L/W)_{BC}}$ $1 = \frac{1}{(L/W)_A + (L/W)_B}$

$= \frac{1}{\frac{2L}{W}}$

$\frac{1}{\left(\frac{2L}{W}\right)} = 1$ $\frac{W}{L} = 2$

$(W/L$

$(L/W)_A = 2 = \left(\frac{L}{W}\right)_{BC}$

$BC \rightarrow \parallel^{el}$ $\left(\frac{L}{W}\right)_B = (L/W)_C = 2$

pull u

PU $\left(W/L\right)_{ABC}$ series $\left(W/L\right)_{DE} \Rightarrow$ 2 series connecti

$4 = \frac{1}{2L/W}$ $8 = \frac{W}{L}$

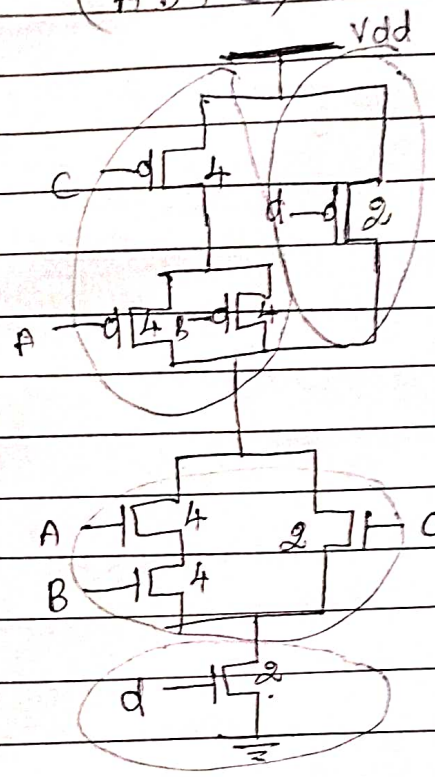
$2 \times 2 \Rightarrow 4 \Rightarrow \left(W/L\right)_{DE} = 4 = \left(\frac{W}{L}\right)_{ABC}$

$4 = \frac{1}{L/W + L/W}$

$\left(W/L\right)_D = 4$ $\left(W/L\right)_E = 4$ $= \left(\frac{W}{L}\right)_A = \left(\frac{W}{L}\right)_{BC} = 4$

(6)

$(AB+C)D$



11 el

series

Pull down $(W/L)_{ABC}$ series with $(W/L)_d$.

$2 \times 1 = 2$

$(W/L)_d = 2$ $\quad (W/L)_{ABC} = 2$

AB are 11^{el} with C

$(W/L)_{AB} = 2$ $\quad (W/L)_C = 2$

$2 = \frac{1}{(1/W)_A + (1/W)_B} = 2 = \frac{W}{2L} \Rightarrow W/L = 4$

$(W/L)_A = (W/L)_B = 4$

Pull up $(W/L)_{ABC} = 2$ & $(W/L)_D = 2$

$(W/L)_C$ is series with $(W/L)_{AB}$.

$(W/L)_C = (W/L)_{AB} \Rightarrow 2 = \frac{1}{\frac{1}{W} + \frac{1}{W}} \Rightarrow \frac{W}{L} = 4$

$8 = \frac{W}{L}$

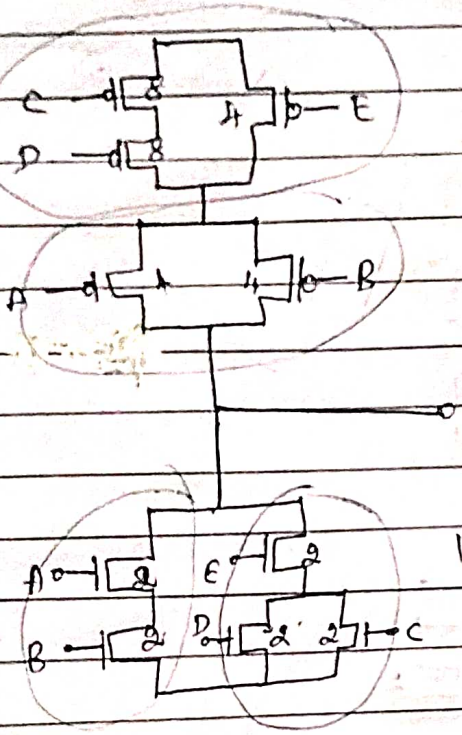
$\frac{1}{W}$

$(W/L)_C = (W/L)_{AB} = 4$ A & B are 11^{el}; so

$(W/L)_A = (W/L)_B = 4$

(4) $AB + (C+D)E$

8 4 2 1
0 1 1 1
7
8 - 1



Pull down

$\left(\frac{W}{L}\right)_{AB} = 1 \quad \left(\frac{W}{L}\right)_{CDE} = 1 = \left(\frac{W}{L}\right)_{AB} = \frac{1}{\frac{1}{4W} + \frac{1}{4W}}$

$\left(\frac{W}{L}\right)_A$ & $\left(\frac{W}{L}\right)_B$ are series $\quad 2 = \left(\frac{W}{L}\right)_A = \left(\frac{W}{L}\right)_B$

$\left(\frac{W}{L}\right)_{CD}$ & $\left(\frac{W}{L}\right)_E$ are in series.

$\left(\frac{W}{L}\right)_{CD} = 2 \quad \left(\frac{W}{L}\right)_E = 2$

C & D are 11^{el} $\quad \left(\frac{W}{L}\right)_C = \left(\frac{W}{L}\right)_D = 2$

Pull up: 2 series connection

$2 \times 2 = 4$

$\left(\frac{W}{L}\right)_{AB} = 4 \quad \left(\frac{W}{L}\right)_{CDE} = 4$

CD are 11^{el} with E.

$\left(\frac{W}{L}\right)_{CD} = 4 \quad \left(\frac{W}{L}\right)_E = 4$

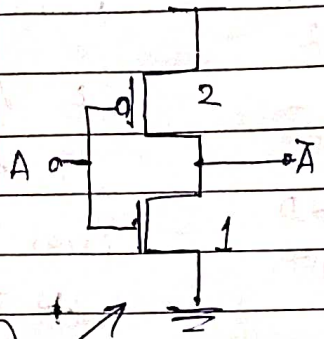
C & D are series,

$\left(\frac{W}{L}\right)_{CD} = 4 = \frac{1}{\frac{1}{4W} + \frac{1}{4W}} = 8$

$\left(\frac{W}{L}\right)_C = \left(\frac{W}{L}\right)_D = 8$

OAI 221

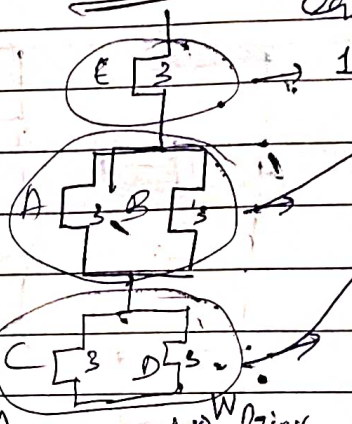
Unit CMOS Inverter:



$\left(\frac{W}{L}\right)_p = 2$

$\left(\frac{W}{L}\right)_n = 1$

NMOS



$\left(\frac{W}{L}\right)_{eq} = 3 \times W_{n_{inv}}$

$= 3 \times 1 = 3$

$(W/L)_E = 3$

$(W/L)_A = (W/L)_B = 3$ & $(W/L)_C = (W/L)_D = 3$

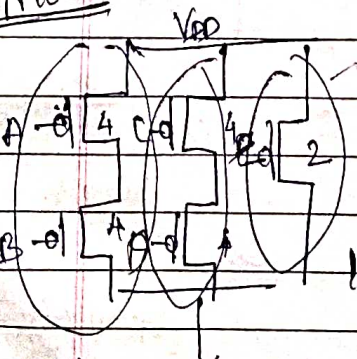
How many number of NMOS paths are connected in series.

don't consider about "el" connection

$$\left(\frac{W}{L}\right)_{eq} = \frac{1}{(1/W)+(1/W)+(1/W)} = \frac{1}{3\,L/W}$$

$$1 = \frac{1}{3L/W} \Rightarrow \left(\frac{W}{L}\right)_{equ} = 3$$

PMOS



3 Path of pmos are connected in series

$\left(\frac{W}{L}\right)_p = W_{p_{inv}}$

$= 2$

"el"

How many pmos paths are connected in "el".

$\left(\frac{W}{L}\right)_{eq_{A,B}} = 2 = \left(\frac{W}{L}\right)_{equ\,C,D} = \left(\frac{W}{L}\right)_{eq_E}$

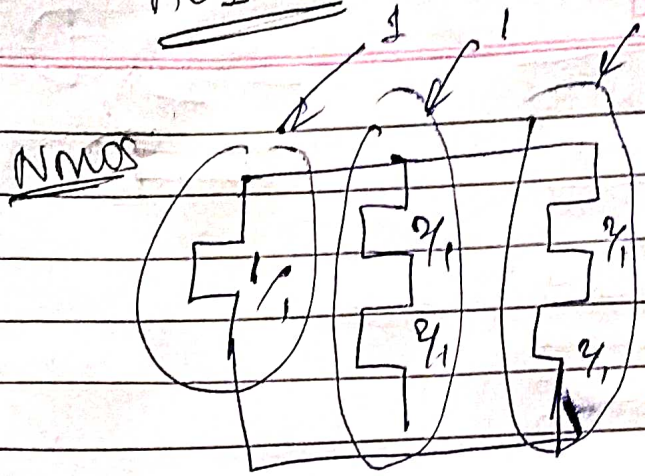
$\left(\frac{W}{L}\right)_{equE} = 2 = \frac{1}{L/W}$

$$2 = \frac{1}{1/W + 1/W} = \frac{1}{2L/W}$$

$4 = \left(\frac{W}{L}\right)$

$\left(\frac{W}{L}\right)_A = \left(\frac{W}{L}\right)_B = 4$; $\left(\frac{W}{L}\right)_C = \left(\frac{W}{L}\right)_D = 4$; $\left(\frac{W}{L}\right)_E = 2$

AOI 221



4:01

$\left(\frac{W}{L}\right)_p = 2$

$\left(\frac{W}{L}\right)_n = 1$

$\left(\frac{W}{L}\right)_{eq\,A,B} = 1$

$1 = \frac{1}{\frac{L}{W} + \frac{L}{W}}$

$1 = \frac{1}{\frac{2L}{W}}$

$2 = \left(\frac{W}{L}\right) =$

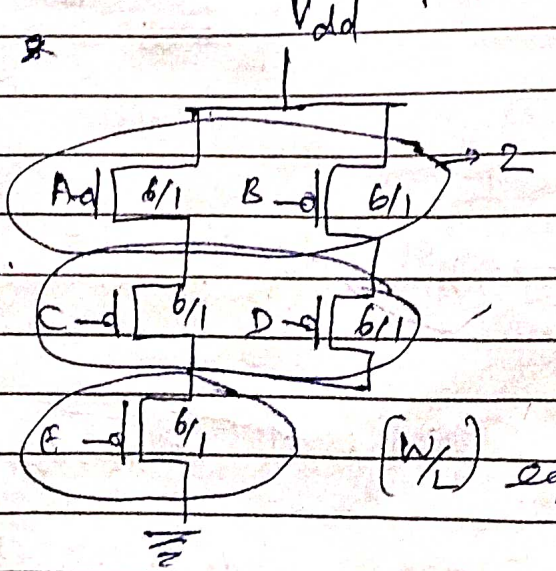
$\left(\frac{W}{L}\right)_{eq\,C,D} = 1$

$1 = \frac{1}{2\frac{L}{W}}$

$2 = \frac{W}{L}$.

PMOS

$\left(\frac{W}{L}\right)_E = 1 \times$



series
3 paths.

$\left(\frac{W}{L}\right)_{eq} = 3 \times W_{p,inv}$

$= 3 \times 2$

$= 6$

$\left(\frac{W}{L}\right)_{eq\,AB} = \left(\frac{W}{L}\right)_{eq\,CD} = \left(\frac{W}{L}\right)_E = 6$

$\left(\frac{W}{L}\right)_{eq}$