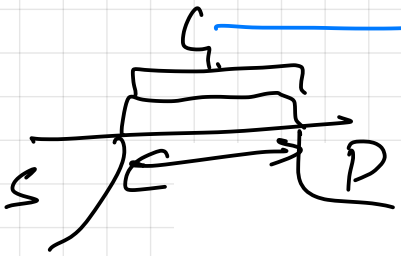
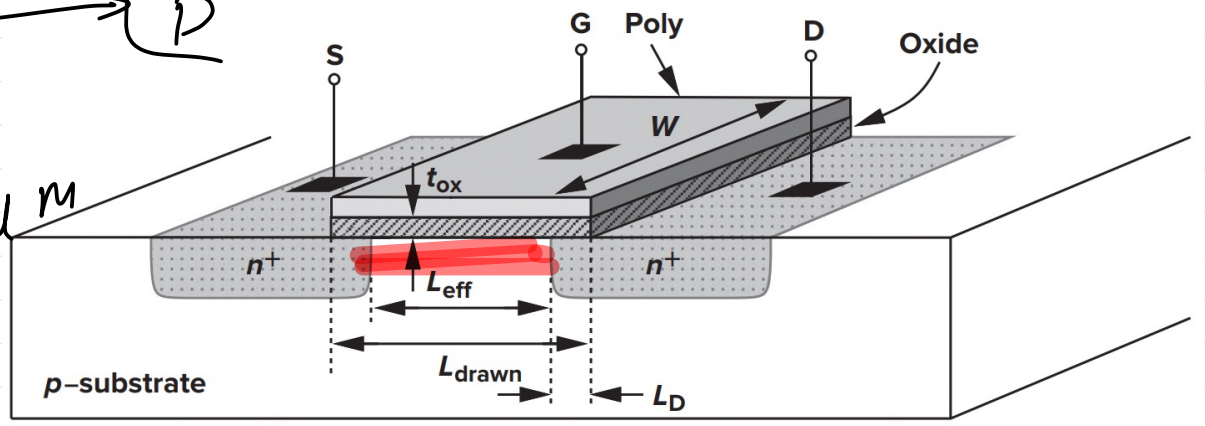
Lecture 2: NMOS Inverter

02/08/2022

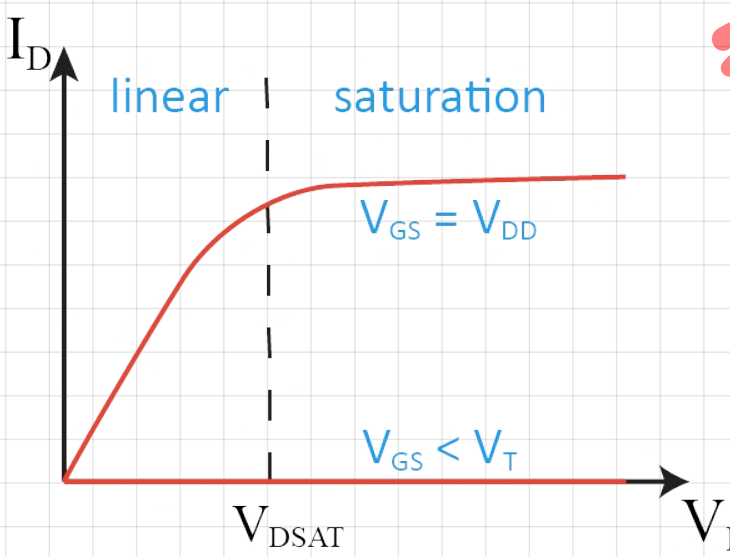
$L < 1\,\mu m$

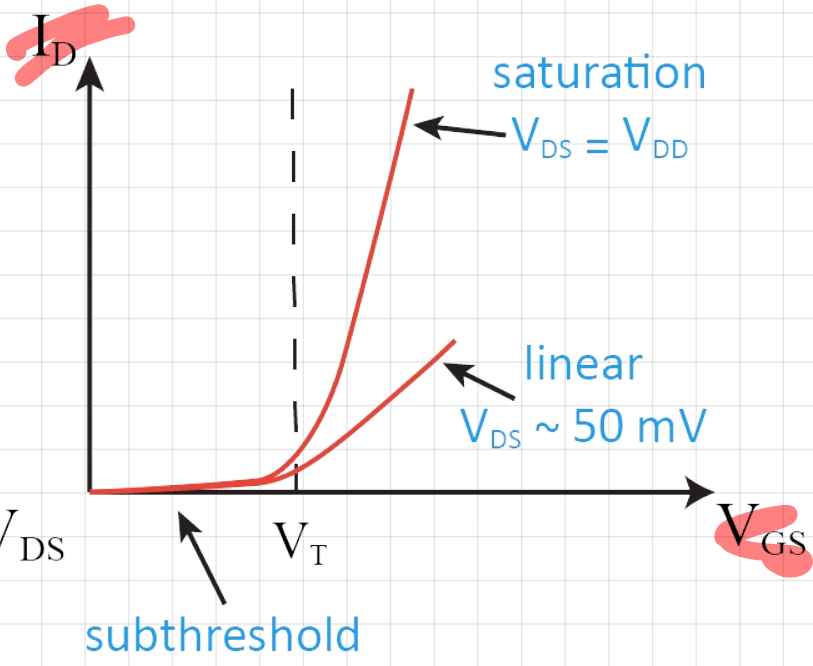


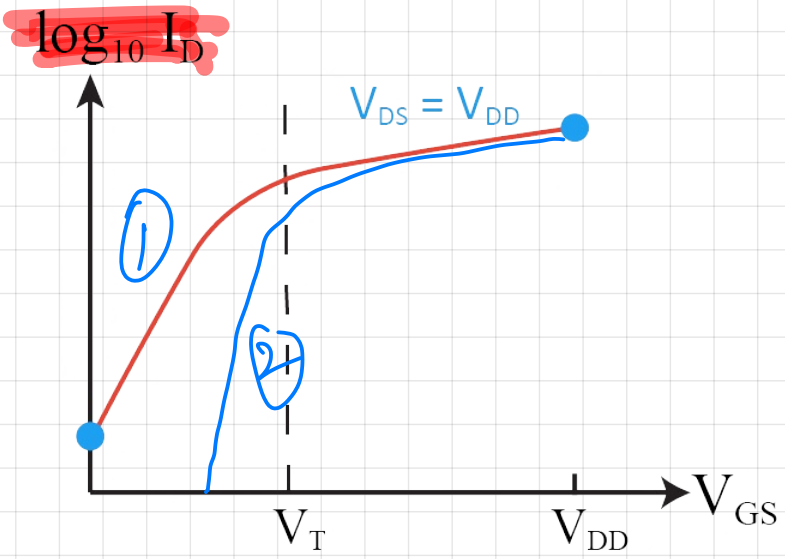
$L = 0.25\,\mu m$

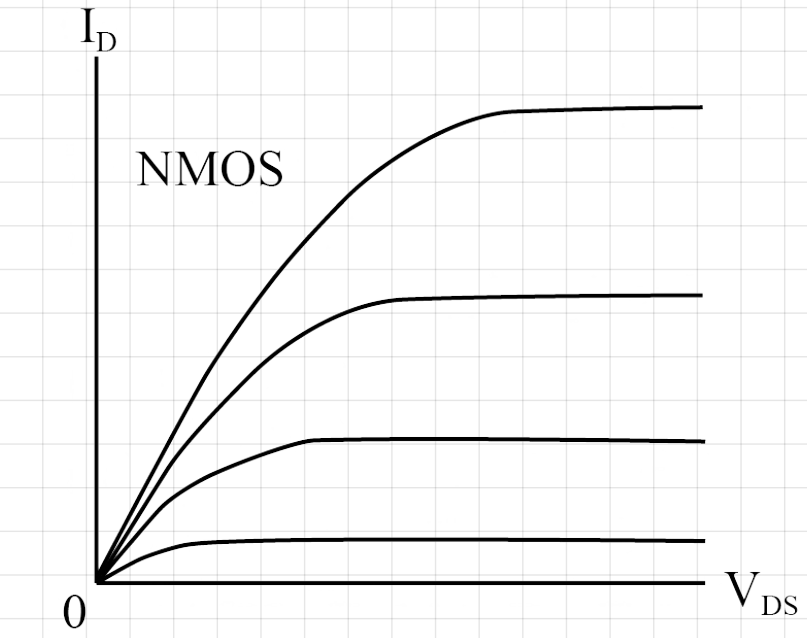


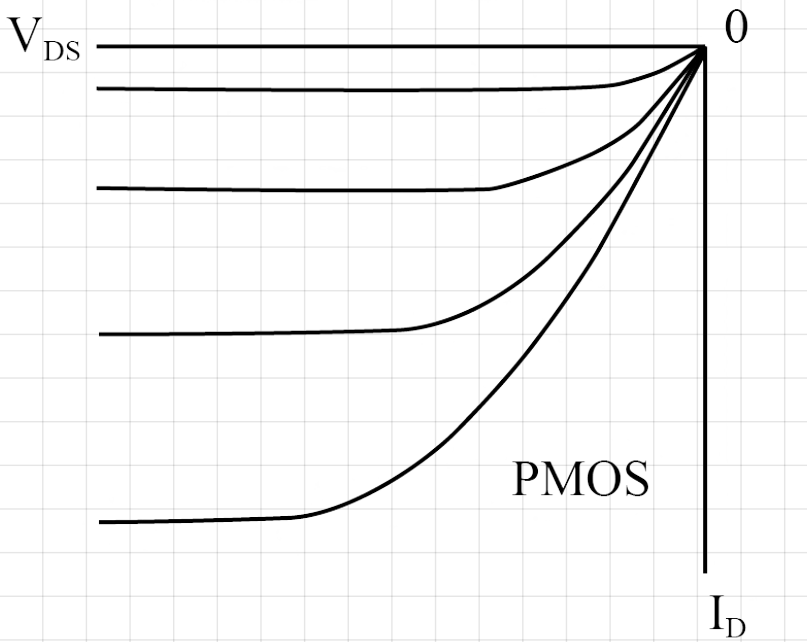
$$I_D = \mu C_{ox} \frac{W}{L} \left[(V_{GS} - V_T) V_{DS} - \frac{V_{DS}^2}{2} \right]$$





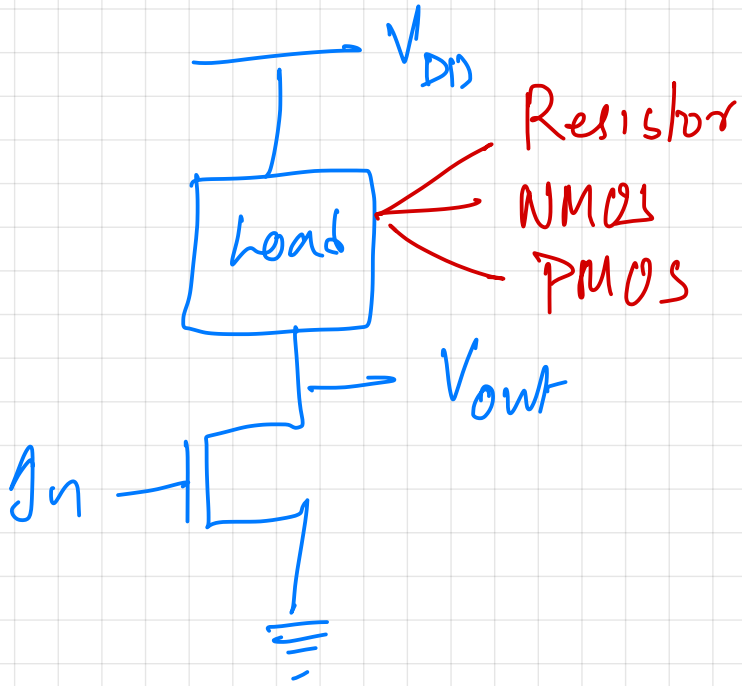


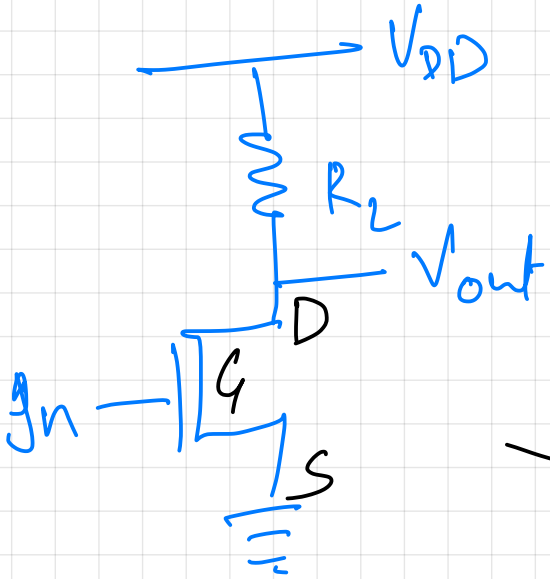

I_D
NMOS
0
V_{DS}


V_{DS}
0
PMOS
I_D

Logic Inverter

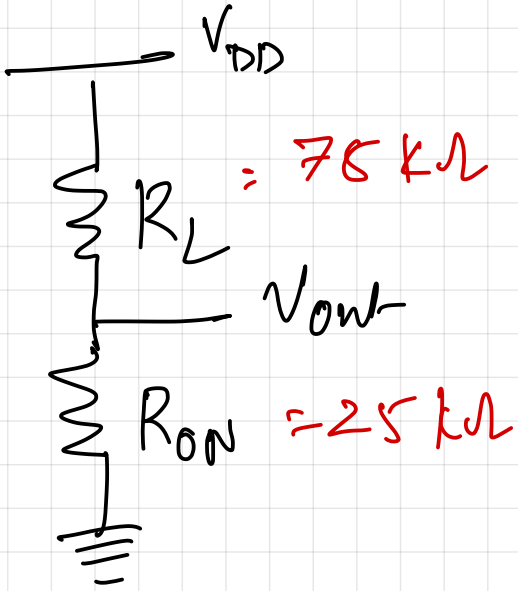
In	Out
0	1
1	0





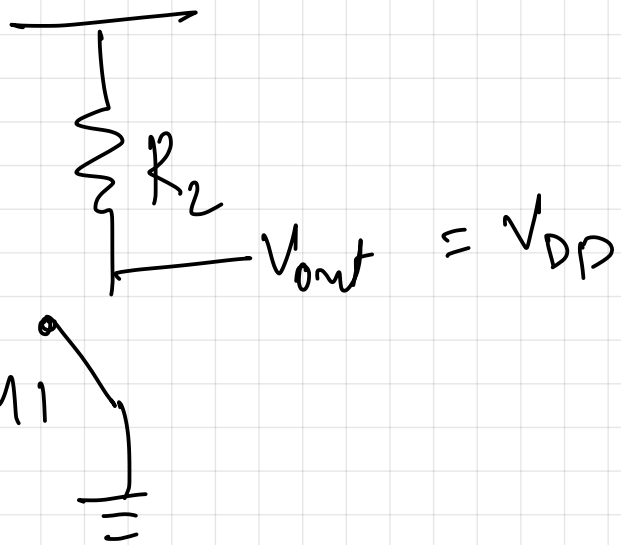
$V_{in} = V_{DD}$ $\quad V_{out} = ?\ 0$

$V_{in} = V_{DD}$



$V_{GS} = V_{DD} > V_{Th}$

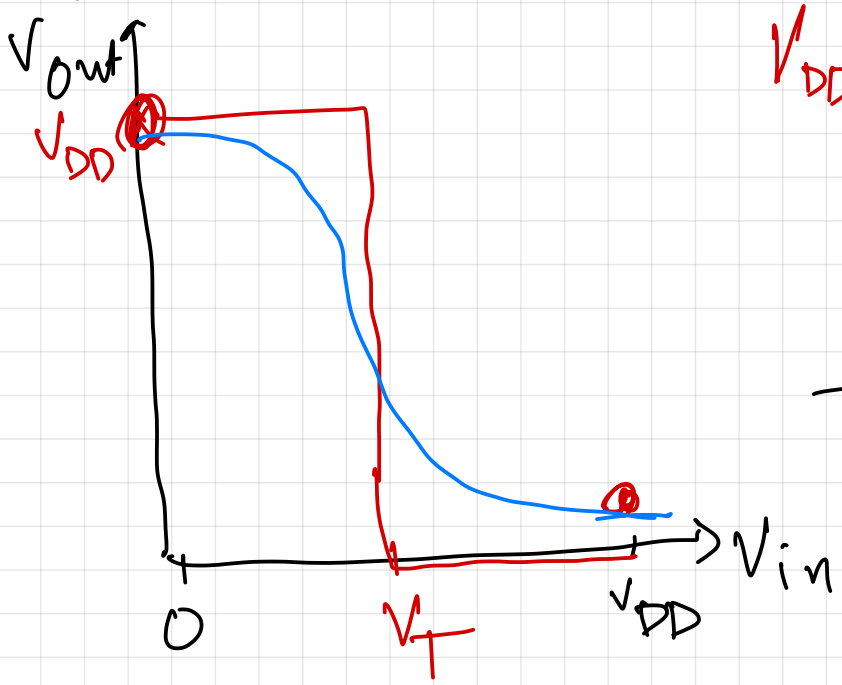
$V_{in} = 0$

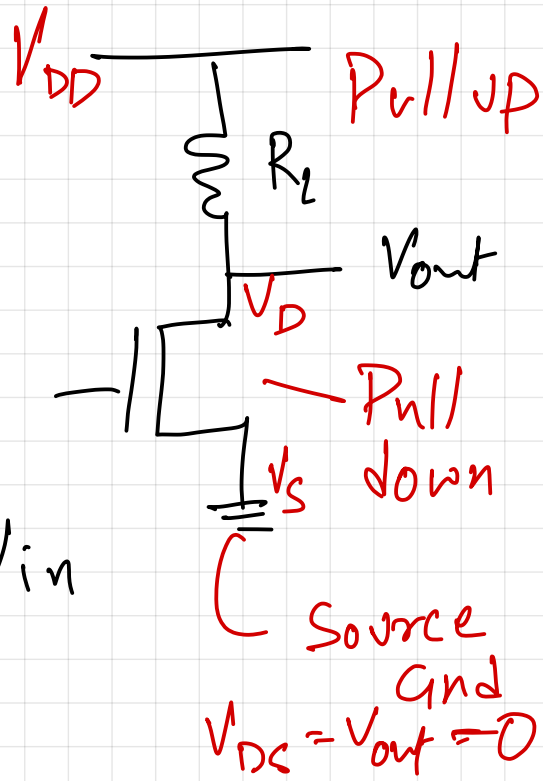


$$V_{out} = \frac{R_{ON}}{R_{ON} + R_{out}}$$

0.25 V

Voltage Transfer Characteristic (VTC)





$$\frac{V_{DD} - V_{out}}{R_L} = \mu C_{ox} \frac{W}{L} \left[(V_{GS} - V_T) V_{out} - \frac{V_{out}^2}{2} \right]$$

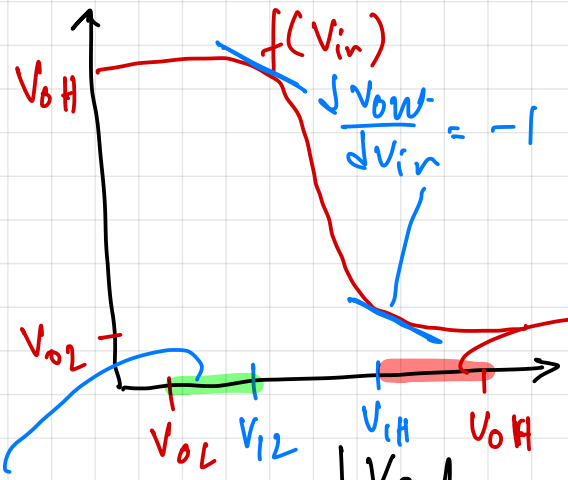
V_{GS}: $0 \rightarrow V_{DD}$

V_{OH} : Nominal high voltage

$5\,V \rightarrow 3.3\,V \rightarrow 2.5\,V - 1.8\,V$

$\rightarrow 1.1\,V$

V_{OL} : Nominal low voltage



$V_{OH} = f(V_{OL})$

$V_{OL} = f(V_{OH})$

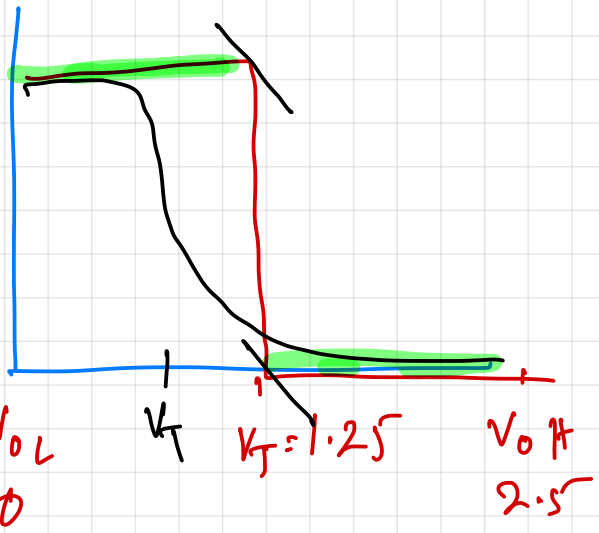
$V_{OL} \neq 0$

$NM_H = V_{OH} - V_{IH}$

Any voltage above V_{IH} will be treated as high

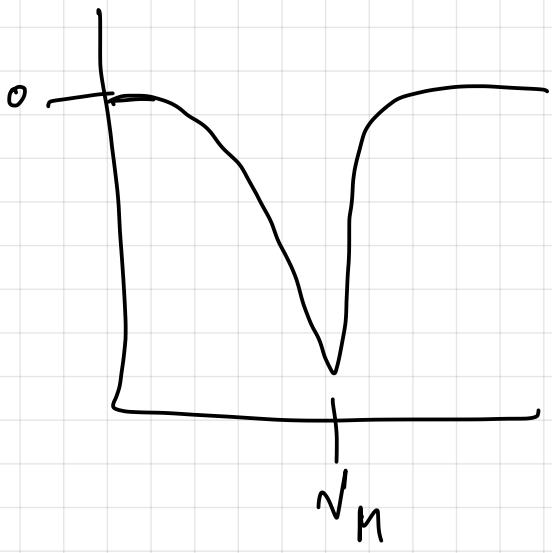
$NM_L = V_{IL} - V_{OL}$

$\text{gain} = \frac{dV_{out}}{dV_{in}}$



$NM_L = 1V$

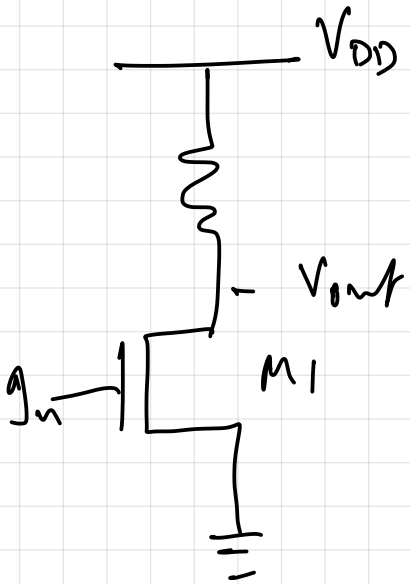
$NM_H = 4V$



$V_M = V_{out} = V_{IN}$

What happens when $R_L \uparrow$

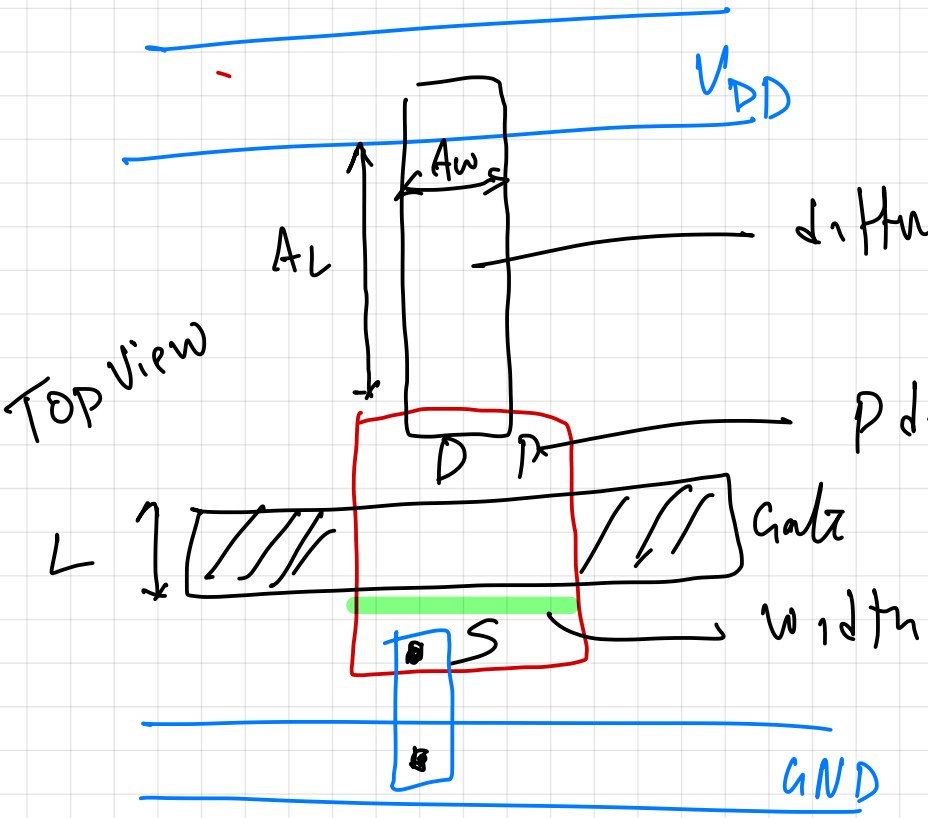
$$V_{OL} = \frac{R_{ON}}{R_{ON} + R_L}$$



$W \uparrow I_D \uparrow$ Pull down is stronger
VTC shifts left

$R_L \uparrow$ pull up weaker relative to pull down $\therefore$ VTC shifts left

$\sigma = n e \mu$



$10^{17}\ cm^{-3}$

$$R = R_D \cdot \frac{A_L}{A_W}$$

100's Ω

1000's Ω