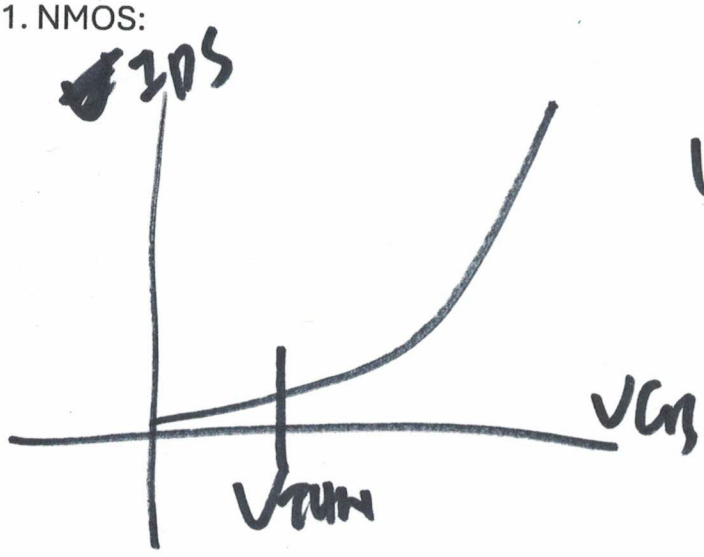
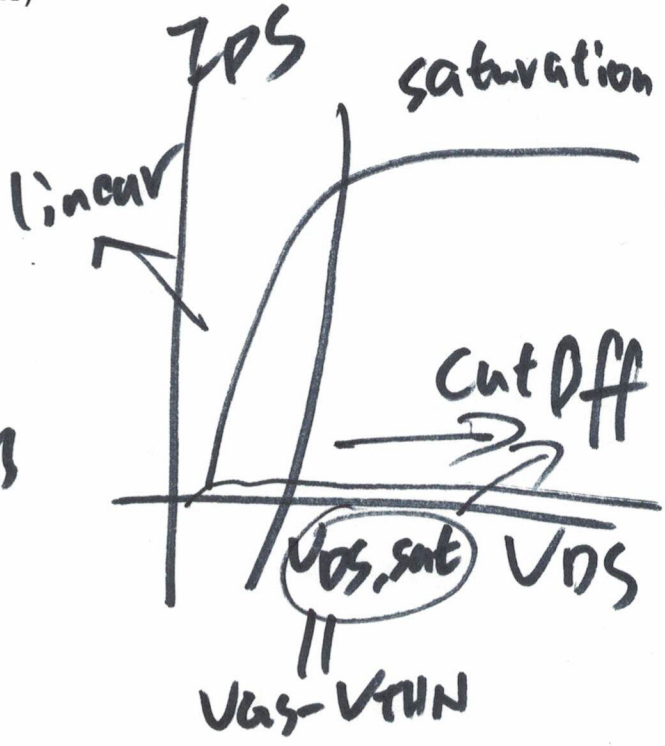
CE338 Quiz 4

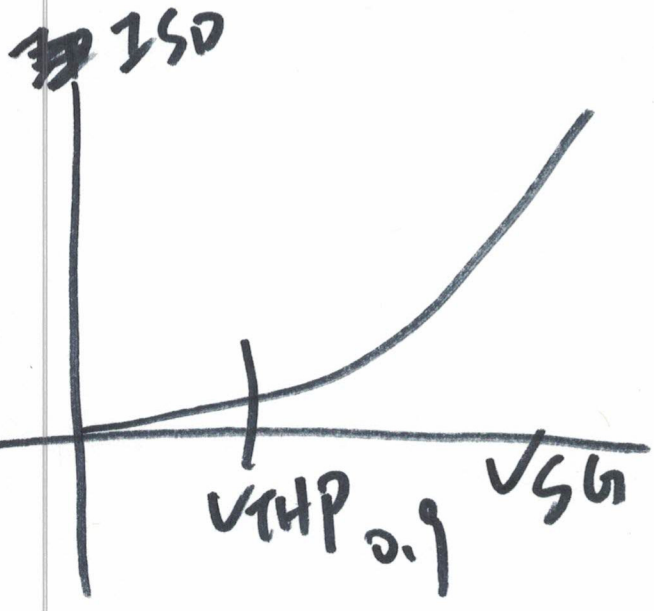
1. Sketch the two I-V curves of NMOS and PMOS. Label $V_{THN}$, $V_{THP}$, $V_{DS,sat}$, $V_{SD,sat}$, all three operating regions for each type of transistor, and explain which region has the highest channel resistance. (20 points)

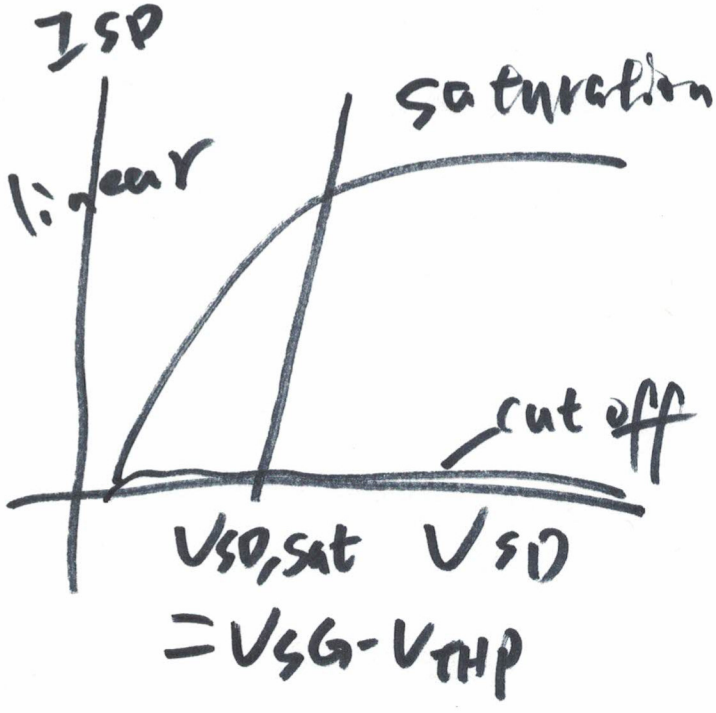
1. NMOS:

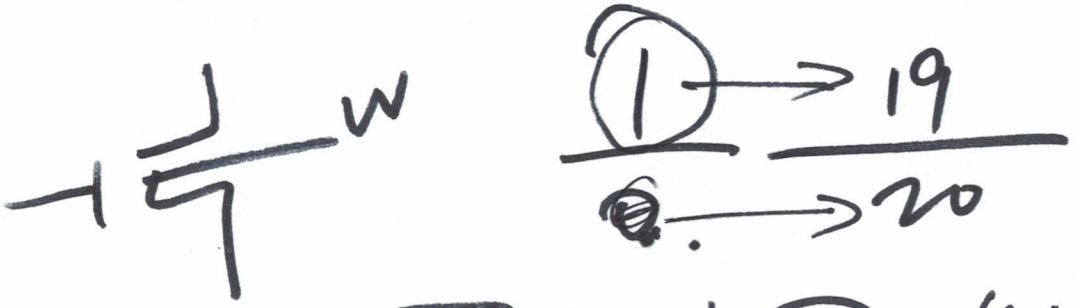


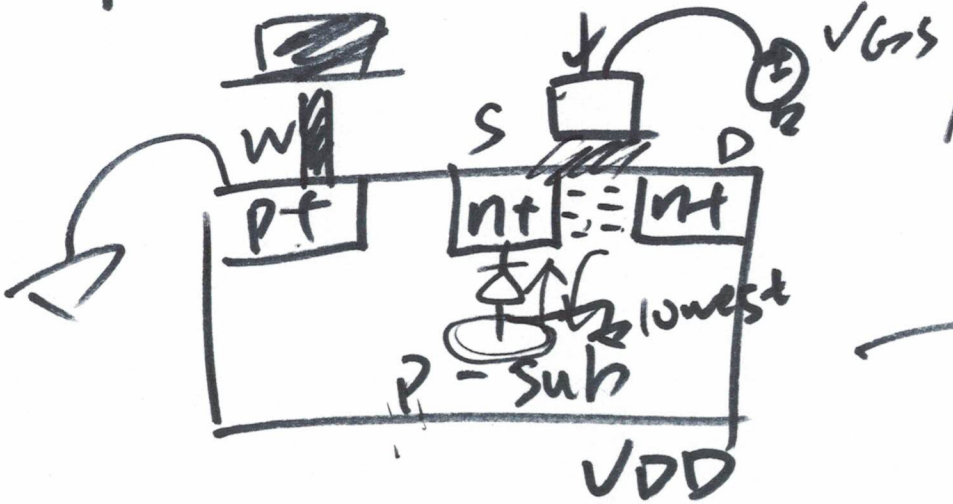




2. PMOS:

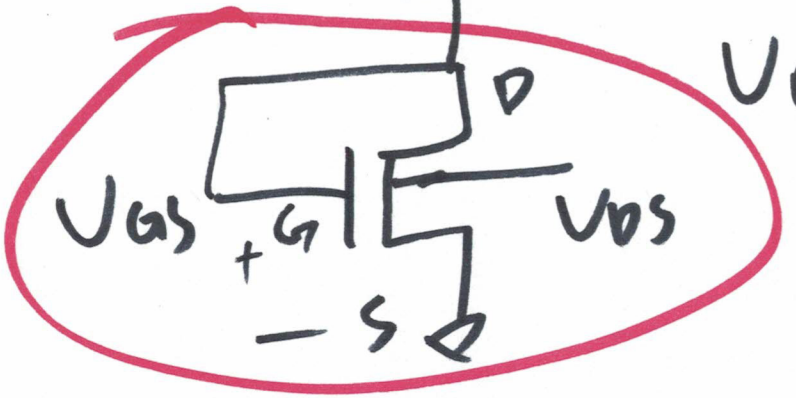


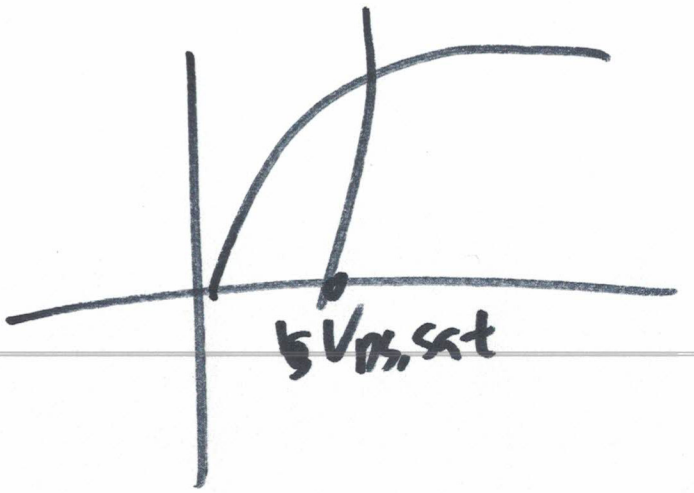







$V_{DS} > V_{DS,sat}$

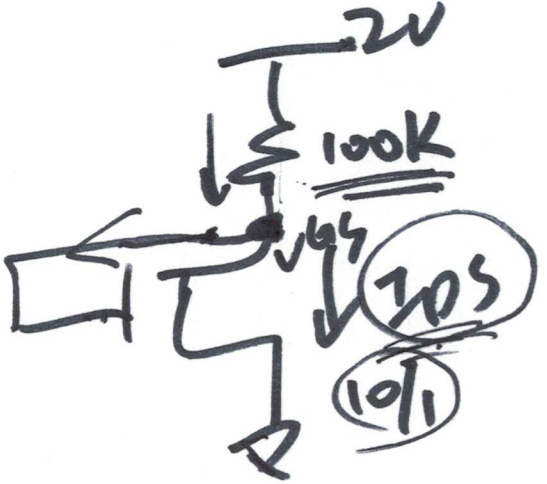



$V_{DS} > V_{DS,sat}$

$V_{GS} - V_{THN}$

$V_{DS}$

①





## Square Law Equation

$$I_{DS} = \frac{KP_n}{2}\frac{W}{L}(V_{GS} - V_{THN})^2$$

$$\frac{\beta_n}{2}(V_{GS} - V_{THN})^2$$

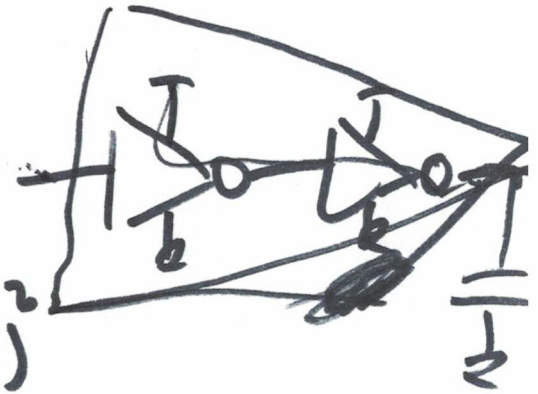
$$KP_n = \mu_n C_{OXn}$$

$\mu_n$: mobility of electrons

$C_{OXn}$: oxide layer unit capacitance

$$KP_n \cdot \frac{W}{L} = \beta_n$$

buffering



$$I_{DS} = \frac{KP_n}{2}\frac{W}{L}(V_{GS}-V_{TH})^2$$

$KP_n = 120\,\mu A/V^2$

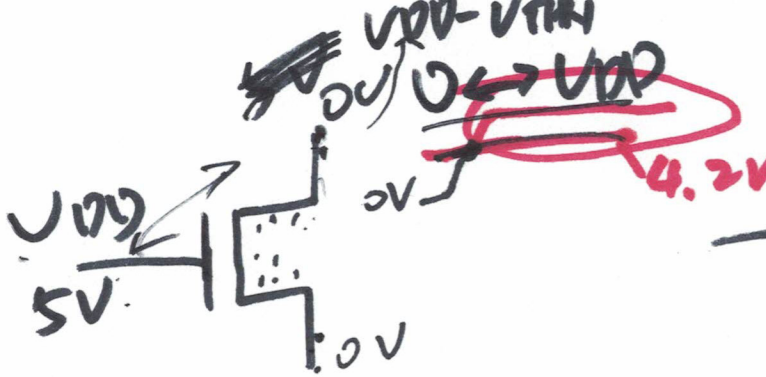
Saturation

$$I_{DS} = \frac{2-V_{GS}}{100K}$$

$$60V_{GS}^2 - 95V_{GS} + 36\times 4 = 0$$

$V_{GS} =$ 0.933V, ~~0.65V~~

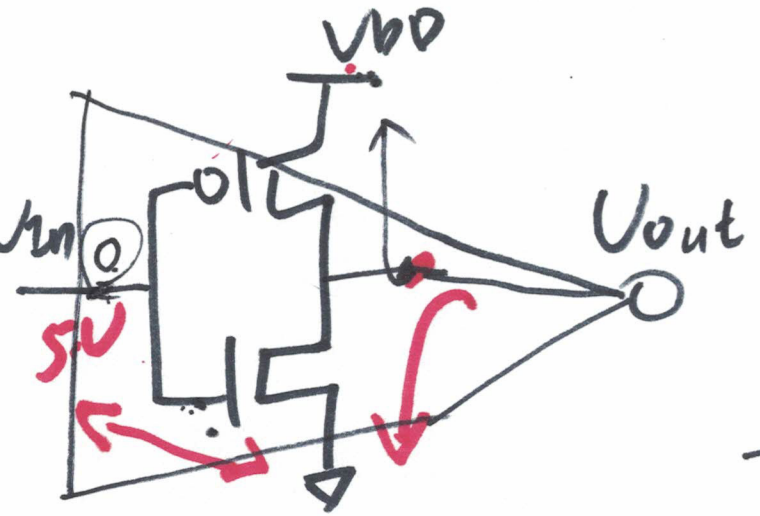
$V_{THN} = 0.8V$

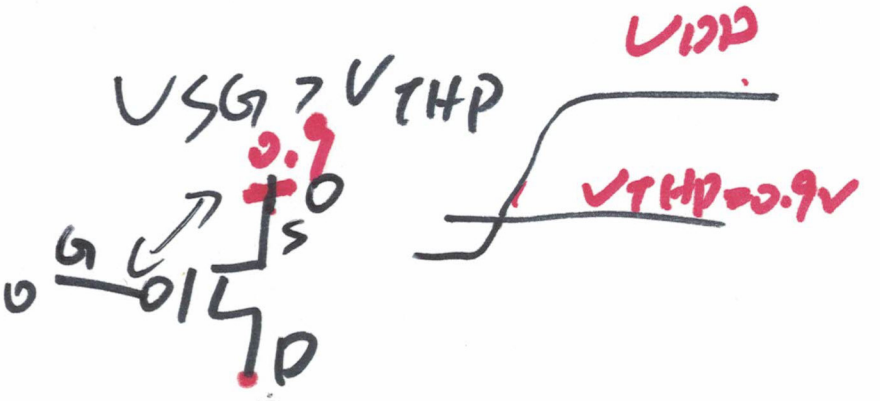



NMOS is good at passing 0's

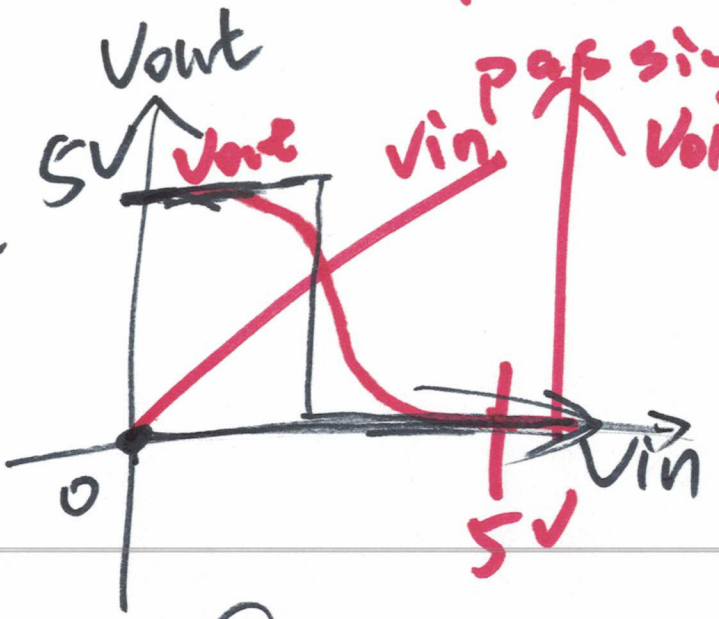
$V_{DD}-(V_{DD}-V_{tHN})$

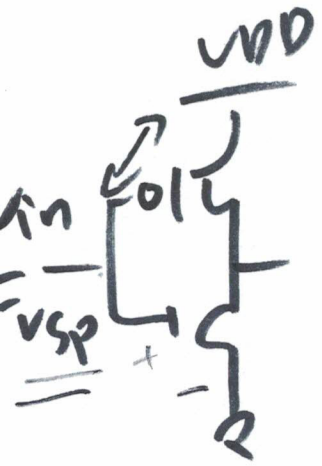
$= V_{tHN}$

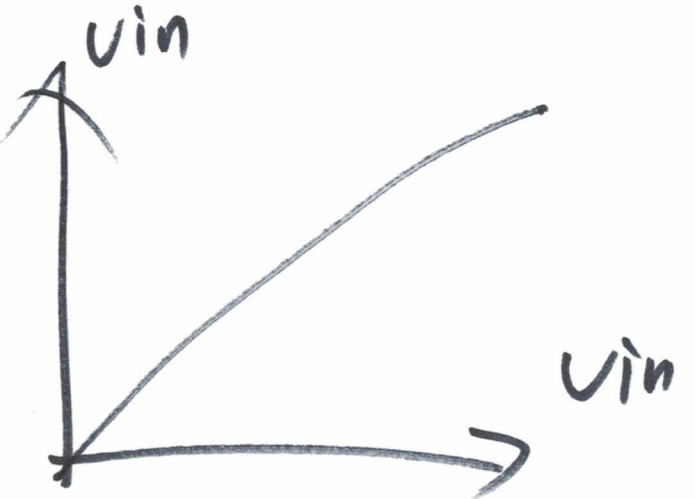


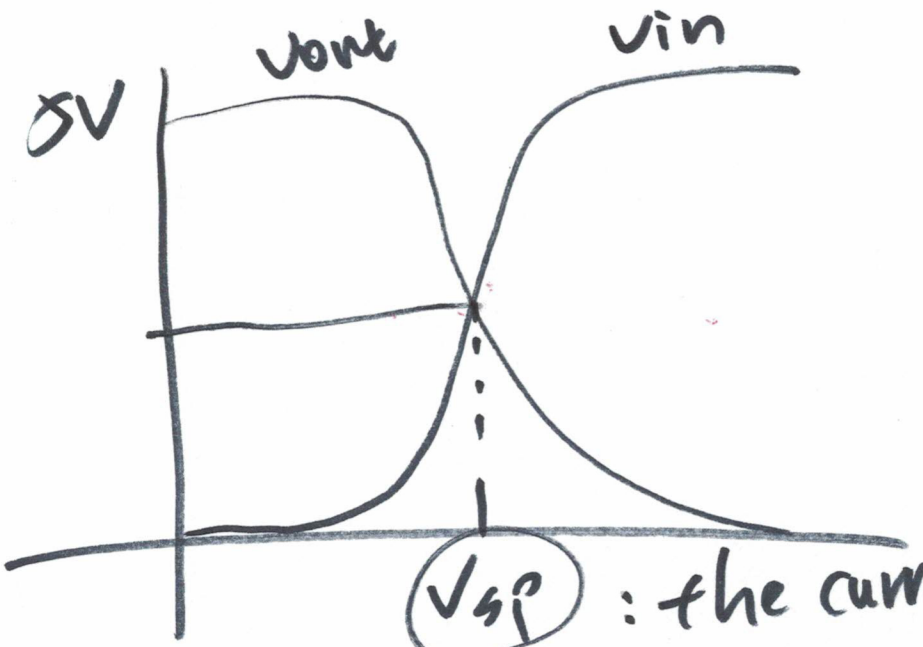




PMOS is good at passing 1's voltage VDD

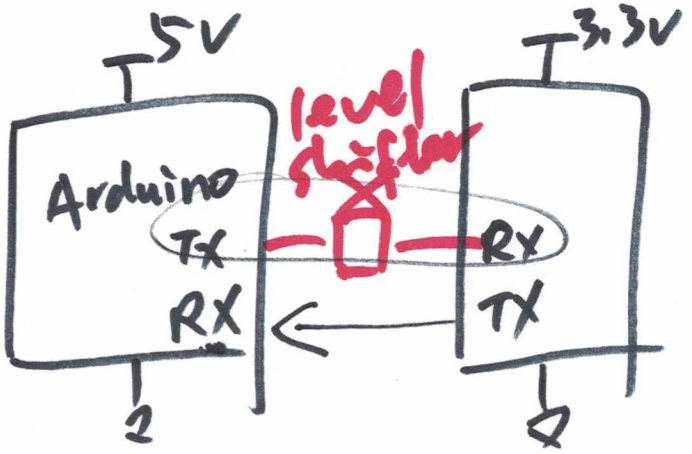


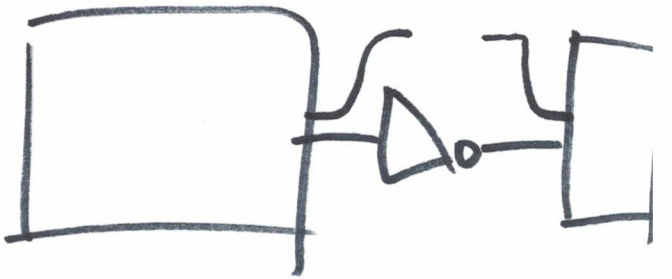



: the current in Pmos and Nmos Switching point are equal.



$$\frac{\beta_n}{2}(V_{GS}-V_{THN})^2 = \frac{\beta_p}{2}(V_{SG}-V_{THP})^2$$

$$\frac{\beta_n}{2}(V_{SD}-V_{THN})^2 = \frac{\beta_p}{2}(V_{DD}-V_{SD}-V_{THP})^2$$

$$\frac{\beta_n}{\beta_p} = \left(\frac{V_{DD}-V_{SD}-V_{THP}}{V_{SD}-V_{THN}}\right)^2$$

$$\sqrt{\frac{\beta_n}{\beta_p}} = \frac{V_{DD}-V_{SD}-V_{THP}}{V_{SD}-V_{THN}}$$

$$V_{SD} = \frac{\sqrt{\frac{\beta_n}{\beta_p}}V_{THN}+(V_{DD}-V_{THP})}{1+\sqrt{\frac{\beta_n}{\beta_p}}}$$