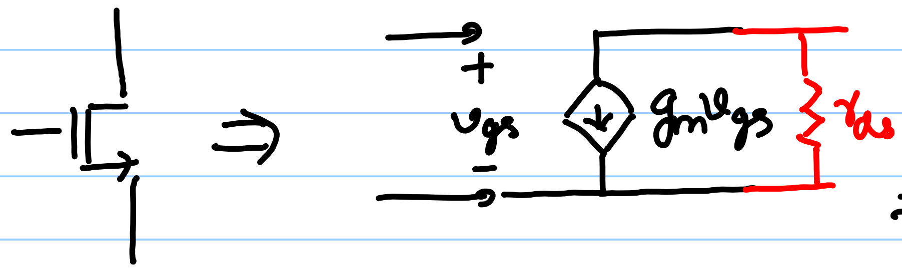
Note Title: lecture # 23

23-09-2021

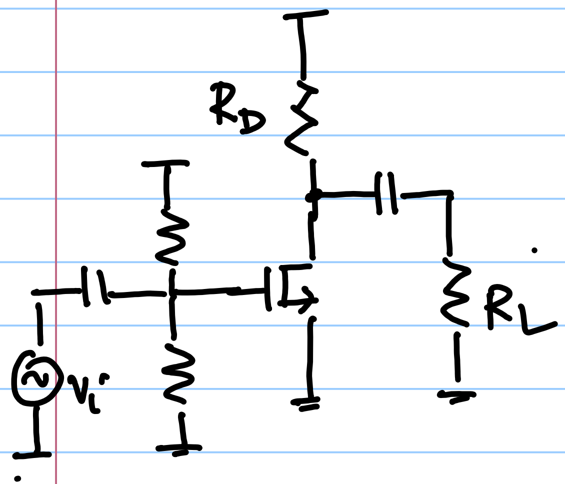


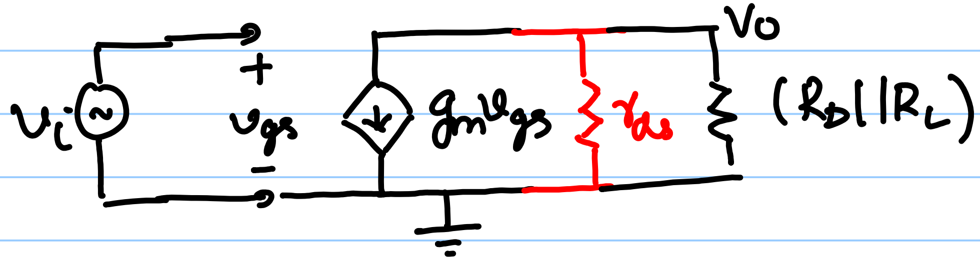
$$I_{DS} = \frac{\mu_n C_{ox}}{2} \frac{W}{L} (V_{gs}-V_{tn})^2 (1+\lambda V_{DS})$$

$$\frac{1}{r_{ds}} = \frac{\partial I_{DS}}{\partial V_{DS}} = \frac{\mu_n C_{ox}}{2} \frac{W}{L} (V_{gs}-V_{tn})^2 \cdot \lambda \checkmark$$

$$= \frac{\lambda I}{(1+\lambda V_{DS})} \approx \lambda I$$

$$r_{ds} = \frac{1}{\lambda I}$$



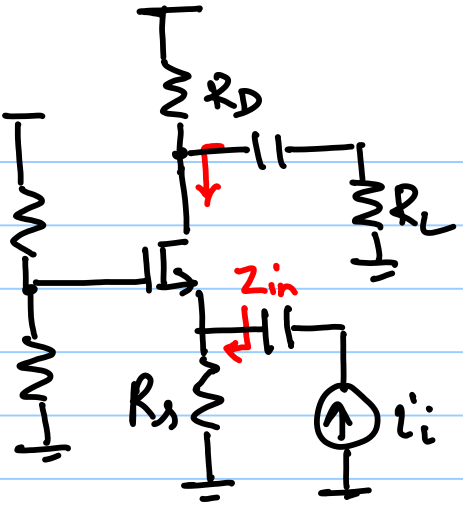


$$\frac{v_o}{v_i} = -g_m (r_{ds} || R_D || R_L) \xrightarrow{(R_D||R_L) \to \infty} \frac{v_o}{v_i} = -g_m r_{ds}$$

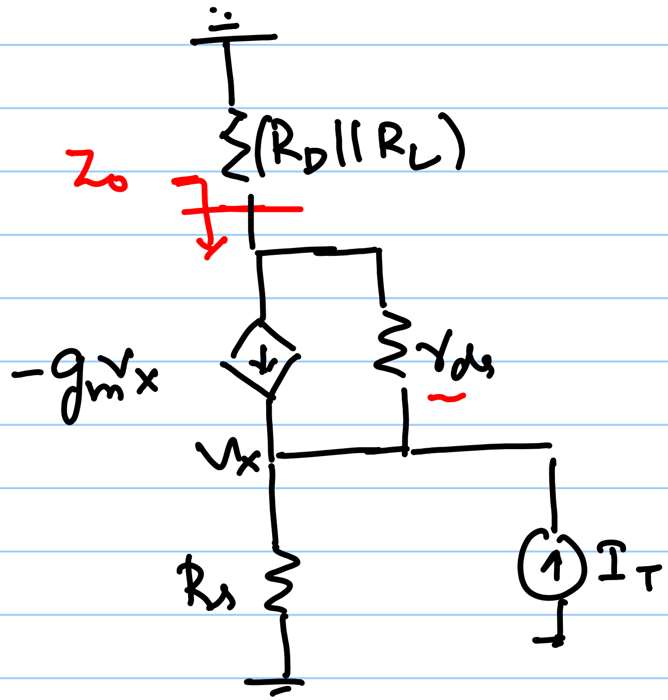
$$\frac{V_o}{V_i} = -g_m r_{ds} = -\frac{\mu_n C_{ox} \frac{W}{L} (V_{gs}-V_{tn}) (1+\lambda V_{DS})}{\frac{\mu_n C_{ox}}{2} \frac{W}{L} (V_{gs}-V_{tn})^2 \cdot \lambda}$$

$$= -\frac{(1+\lambda V_{DS})}{\lambda \cdot (V_{gs}-V_{tn})}$$

$(V_{gs}-V_{th}) \downarrow$ → Increase Gain.



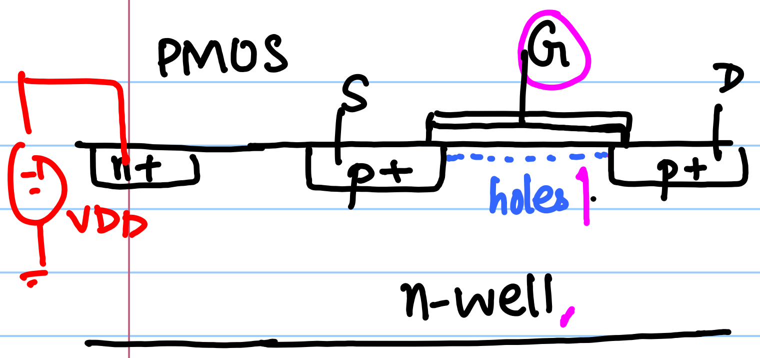
$Z_{in} = \left(\frac{1}{g_m} \| R_s\right)$

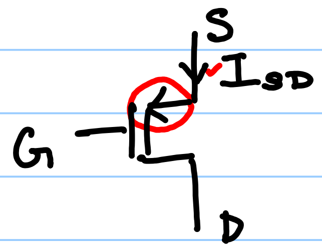


$Z_{in} = \frac{V_x}{I_T}$

n | p+

PMOS





- $V_{SG} - |V_{thp}| < 0 \Rightarrow I_{SD} = 0$

V_{thp} is -ve

- $V_{SG} - |V_{thp}| > 0$ & $V_{SD} < V_{SG} - |V_{thp}|$

$$I_{SD} = \mu_p C_{ox} \frac{W}{L}\left[(V_{SG} - |V_{thp}|)V_{SD} - \frac{V_{SD}^2}{2}\right]$$

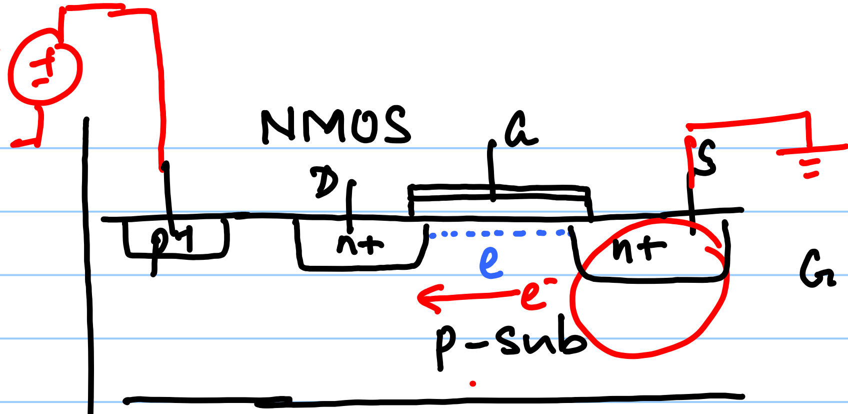
MOSFET in linear region

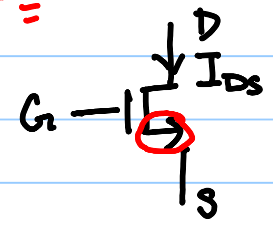
- $V_{SG} - |V_{thp}| > 0$ & $V_{SD} \geq V_{SG} - |V_{thp}|$

$$I_{SD} = \frac{\mu_p C_{ox}}{2} \frac{W}{L} (V_{SG} - |V_{thp}|)^2 (1 + \lambda V_{SD})$$

$\mu_p < \mu_n$

NMOS





- $V_{GS} - V_{thn} < 0 \Rightarrow I_{DS} = 0$

V_{thn} is +ve

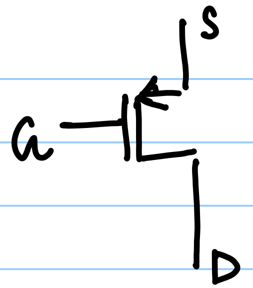
- $V_{GS} - V_{thn} > 0$ & $V_{DS} < V_{GS} - V_{thn}$

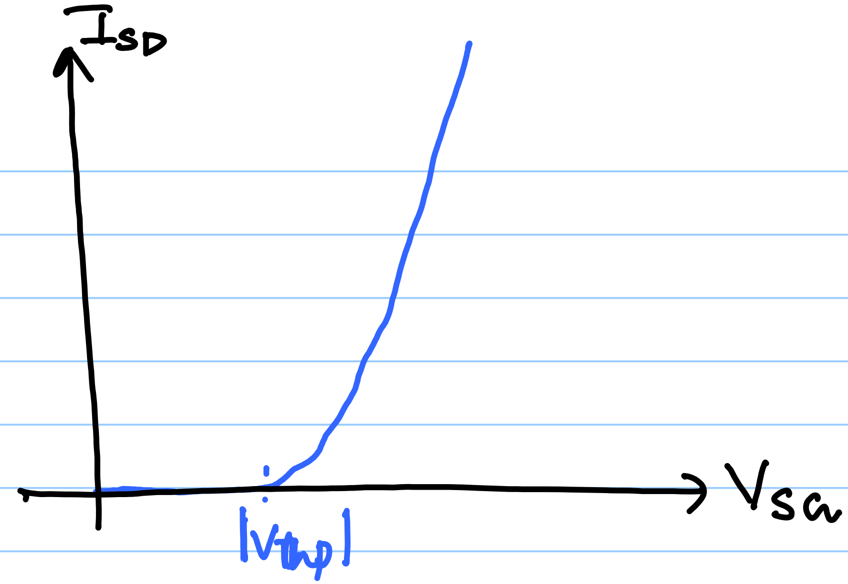
$$I_{DS} = \frac{\mu_n C_{ox}}{2} \frac{W}{L}\left((V_{GS} - V_{th})V_{DS} - \frac{V_{DS}^2}{2}\right)$$

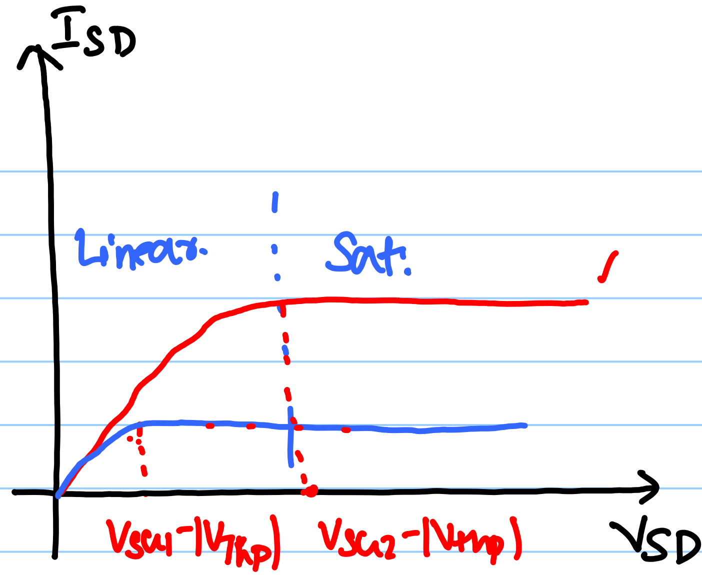
MOSFET is in linear region

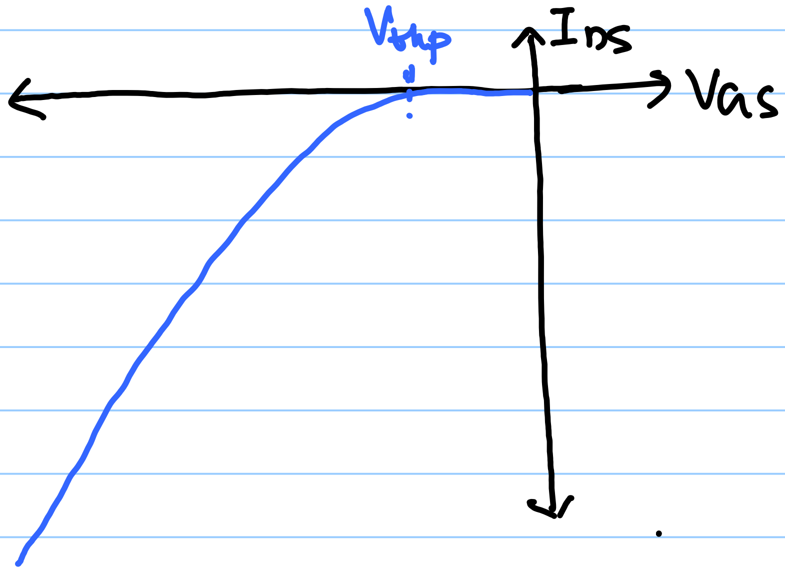
- $V_{GS} - V_{tn} > 0$ & $V_{DS} \geq V_{GS} - V_{thn}$

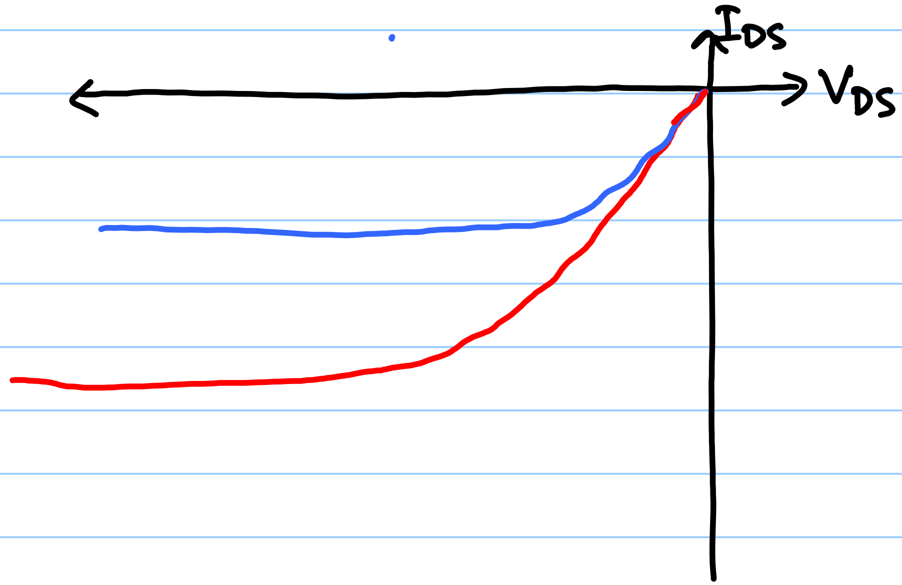
$$I_{DS} = \frac{\mu_n C_{ox}}{2} \frac{W}{L} (V_{GS} - V_{tn})^2 (1 + \lambda V_{DS})$$

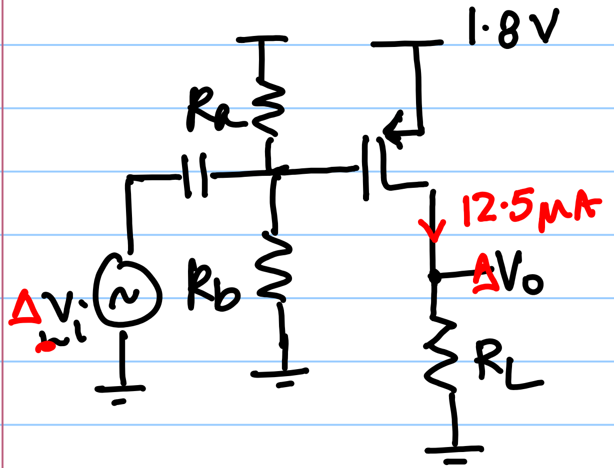

G
S
D


I_{SD}
V_{SG}
$|V_{thp}|$


I_{SD}
Linear
Sat.
$V_{SG1}-|V_{thp}|$
$V_{SG2}-|V_{thp}|$
V_{SD}


V_{thp}
I_{DS}
V_{GS}


I_{DS}
V_{DS}



- $V_{thp} = -0.7V$, $\mu_p C_{ox} = 50\ \mu A/V^2$, $\frac{W}{L} = 20$
- $V_G = 0.6V$
- MOSFET in sat

$V_{SG} - |V_{thp}| = 1.8 - 0.6 - |-0.7| = 0.5V$

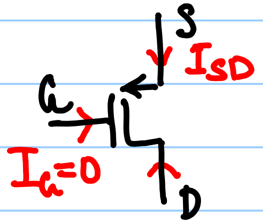
$$I_{SD} = \frac{\mu_p C_{ox}}{2} \frac{W}{L} (V_{SG} - |V_{thp}|)^2$$

$$= \frac{50\ \mu A/V^2}{2} \times 20 \times 0.5^2$$

$$= 50\ \mu A/V^2 \times 0.25\ V^2$$

$$= 12.5\ \mu A$$

$1mA \downarrow_{D}^{S} \longrightarrow 0.9mA \downarrow_{D}^{S} = 1mA \downarrow_{D}^{S} + 0.1mA \uparrow_{D}^{S}$



$$I_{SD} = \frac{\mu_p C_{ox}}{2} \frac{W}{L} (V_S - V_G \uparrow - |V_{thp}|)^2$$

$$\frac{\partial I_{SD}}{\partial V_G} = \mu_p C_{ox} \frac{W}{L} (V_S - V_G - |V_{thp}|) (-1)$$

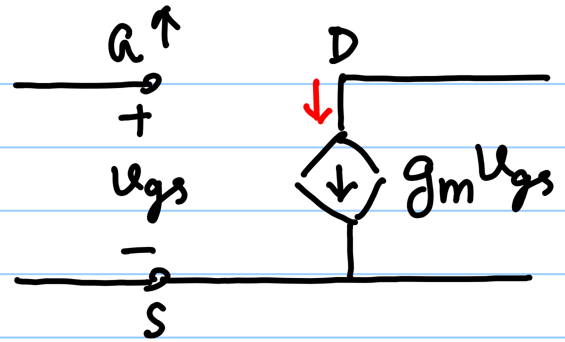
$$\Delta V_G \longrightarrow \Delta I_{SD} = \mu_p C_{ox} \frac{W}{L} (V_{SG} - |V_{thp}|) (-\Delta V_G)$$

$$\Delta I_{DS} = \underbrace{\mu_p C_{ox} \frac{W}{L} (V_{SG} - |V_{thp}|)}_{g_m} \Delta V_G$$

$$\frac{\partial I_{SD}}{\partial V_{SG}} = \underbrace{\mu_p C_{ox} \frac{W}{L} (V_{SG} - |V_{thp}|)}_{g_m}$$

$$\Delta I_{SD} = g_m \cdot \Delta V_{SG}$$

$$\Delta I_{DS} = g_m (-\Delta V_{SG}) = g_m \cdot \Delta V_{GS} = \Delta I_{DS}.$$



PMOS / NMOS small signal model is same.