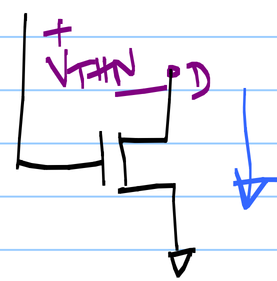
ECE 511 - Lecture 2

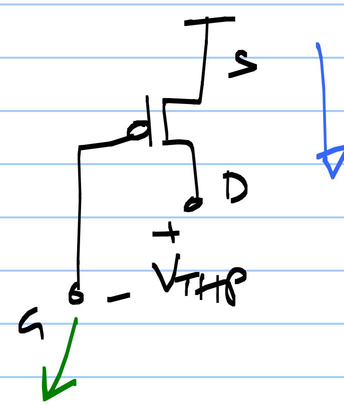
Note Title 1/24/2011

SAT

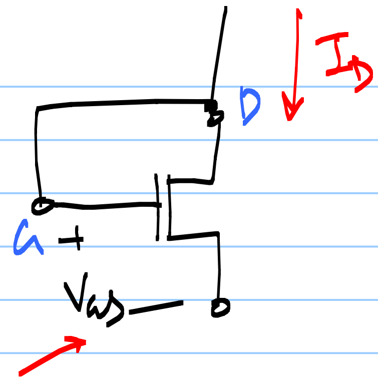
$V_{DS} > V_{GS} - V_{THN}$ NMOS

$V_{SD} > V_{SG} - V_{THP}$ PMOS





DIODE CONNECTED MOSFET



$$I_D = f(V_{GS}, \cancel{V_{DS}})$$

$$V_G = V_{DS}$$

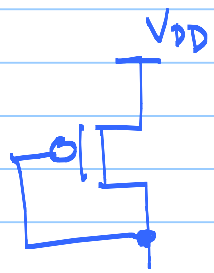
$$I_D = f(V_{GS})$$

g - D connected

Diode Connected MOSFET

$$V_{DS} > V_{GS} - V_{THN}$$

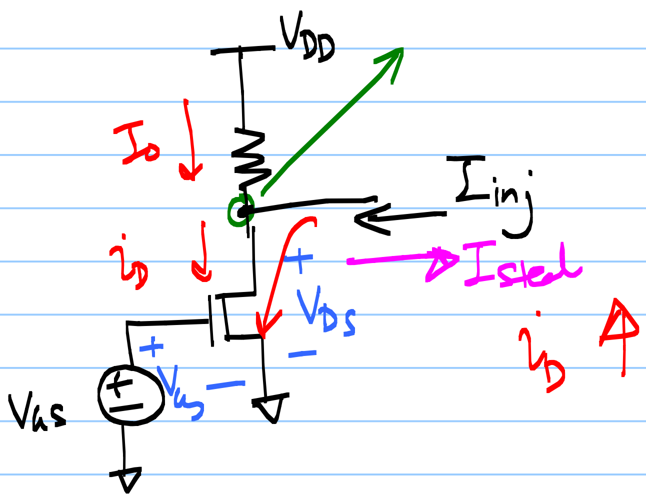
$$V_{GS} > V_G - V_{THN} \quad \text{(Always)}$$



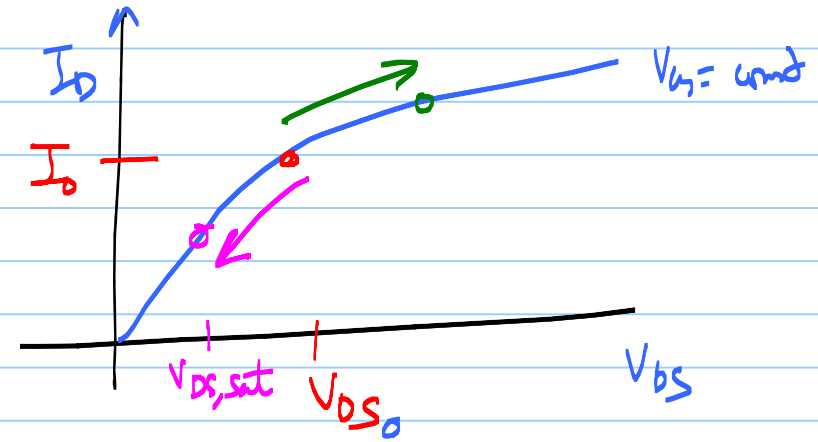
$$I_D = \frac{\beta n}{2}(V_{GS} - V_{THN})^2$$

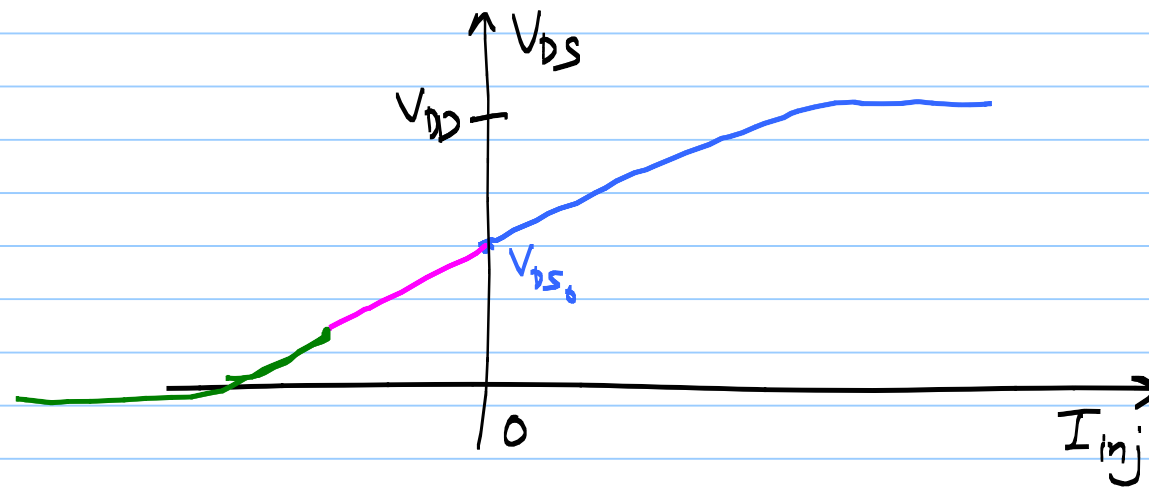
* Always in "SATURATION"

$$\boxed{V_{OV} = V_{GS} - V_{THN} \triangleq V_{DS,sat} \leftarrow \text{OVERDRIVE}}$$



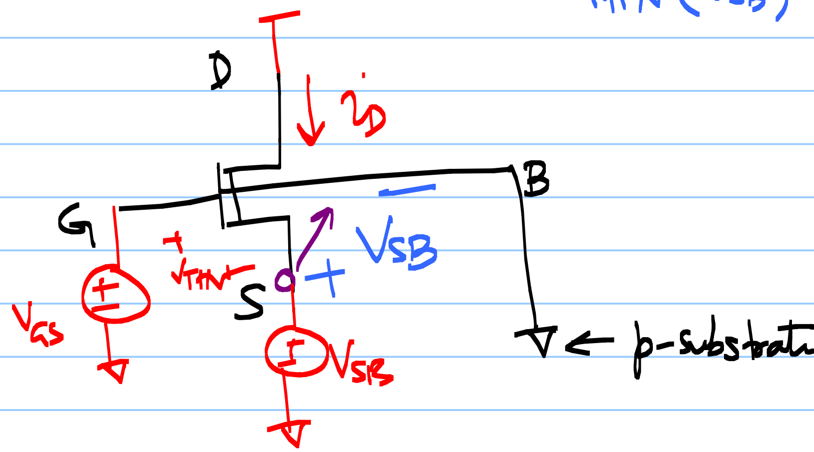
V_{DS} ↑

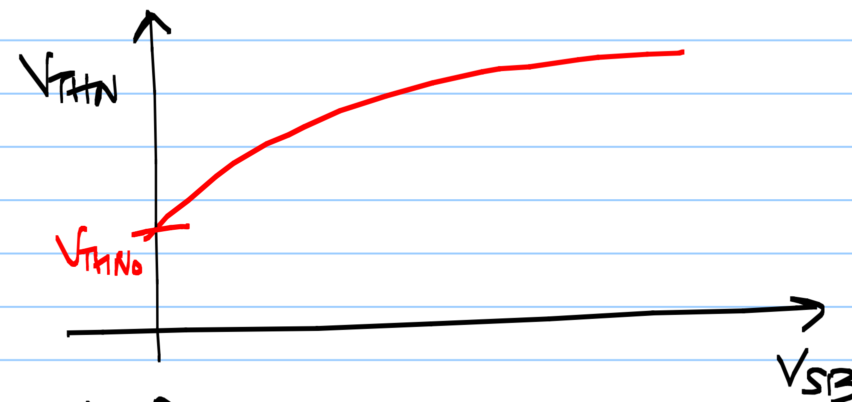




Body Effect:

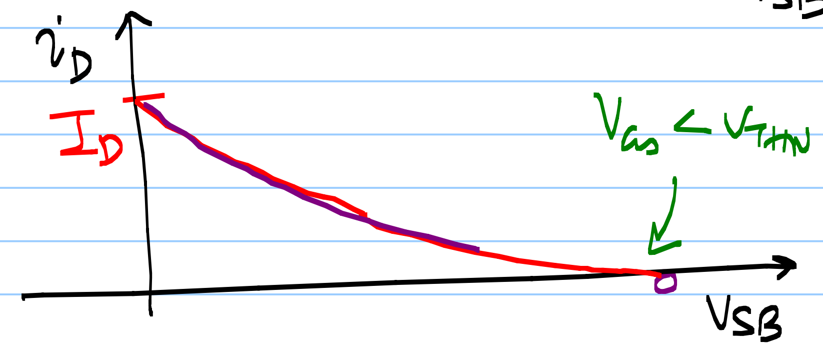
$$V_{THN}(V_{SB}) = V_{THN0} + \gamma_n\left(\sqrt{2|V_{fp}| + V_{SB}} - \sqrt{2|V_{fp}|}\right)$$





$V_{SB} \uparrow \Rightarrow V_{THN} \uparrow$

$\Rightarrow i_D \downarrow$

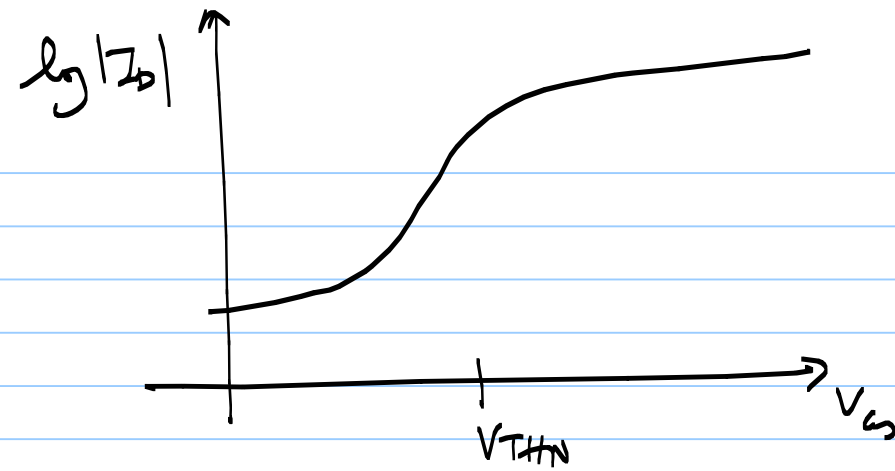


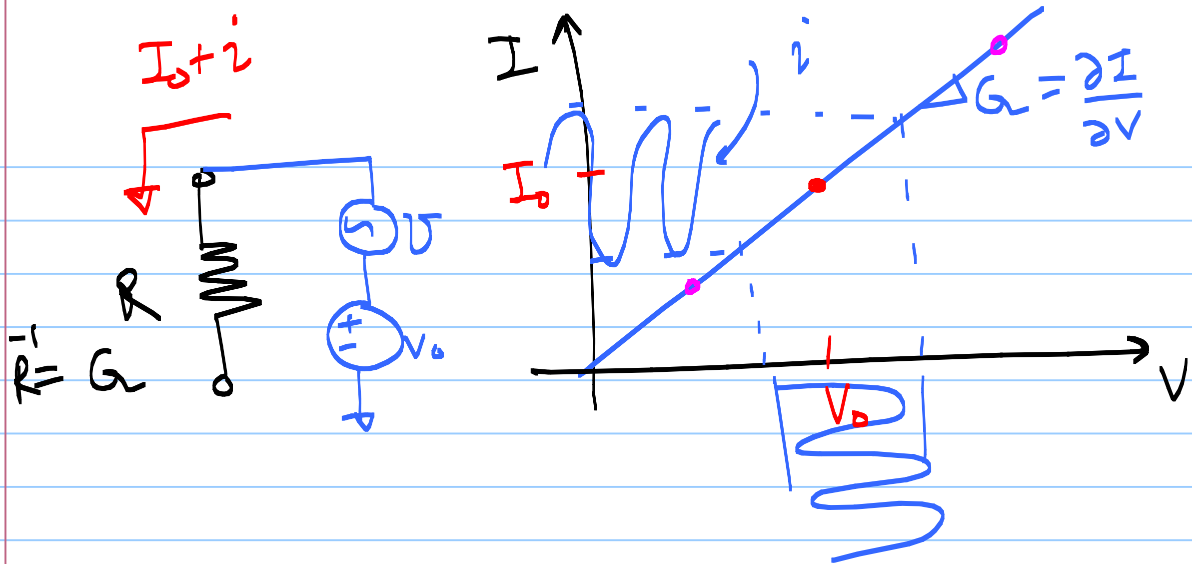
Subthreshold Region

$$I_D = I_{D0} \cdot \frac{W}{L} e^{\frac{V_{GS} - V_{THN}}{n V_T}} \leftarrow V_{DS}$$

$$I_D \propto e^{V_{OV}/nV_T}$$

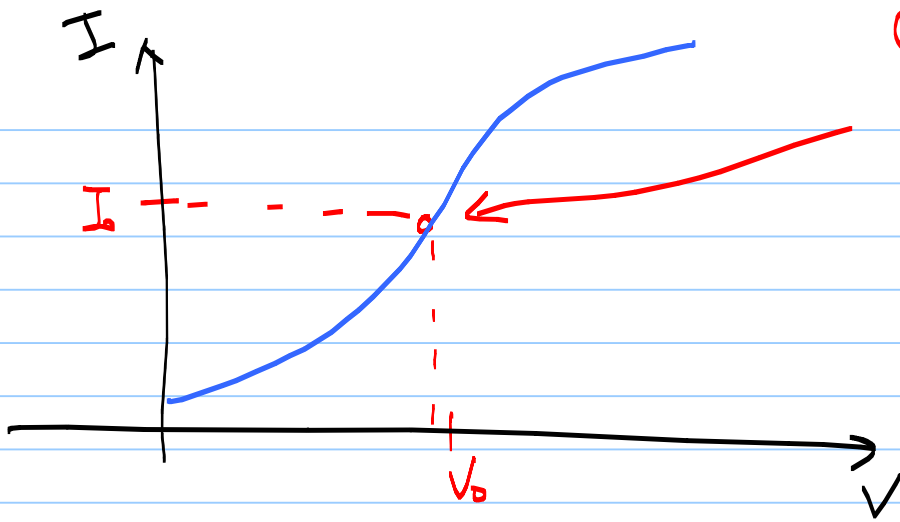
" EKV model "





"Bias"

Linear Device



Q-point

Bias point

DC operating point

$I = f(V)$

$$I = f(V) \qquad V \rightarrow \underline{V_0} + \underline{v}$$

$$\underset{(I_0 + i)}{I} = f(V_0) + \frac{f'(V_0)}{\lfloor 1}\underbrace{(V - V_0)}_{v} + \cancel{\frac{f''(V_0)}{\lfloor 2}}\underbrace{(V - V_0)^2}_{v^2} + \cancel{\frac{f'''(V_0)}{\lfloor 3}\underbrace{(V - V_0)^3}_{v^3}} + \cdots$$

As signal 'v' is sufficiently small

$v^2, \; v^3 \leftarrow$ neglect

$$I = \underbrace{f(V_o)}_{I_o} + \underbrace{f'(V_o)}_{g}\, v$$

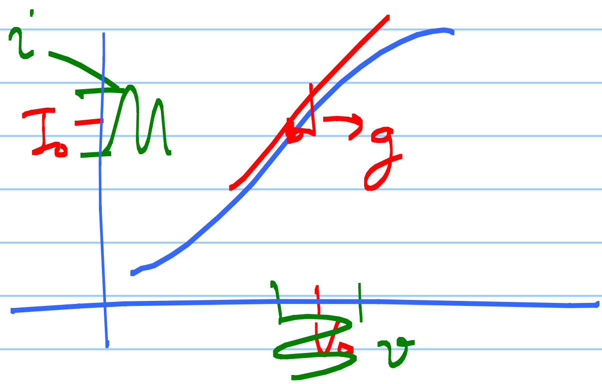
$g \longrightarrow$ Small Signal conductance

$$\underbrace{I - I_o}_{} = g \cdot v$$

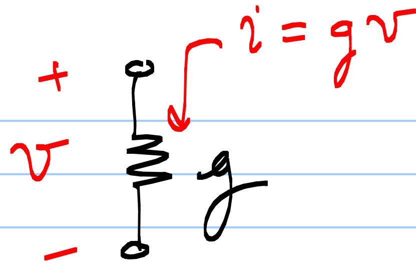
$$\boxed{i = g \cdot v}$$

$$g = \left.\frac{dI}{dV}\right|_{V=V_o}$$

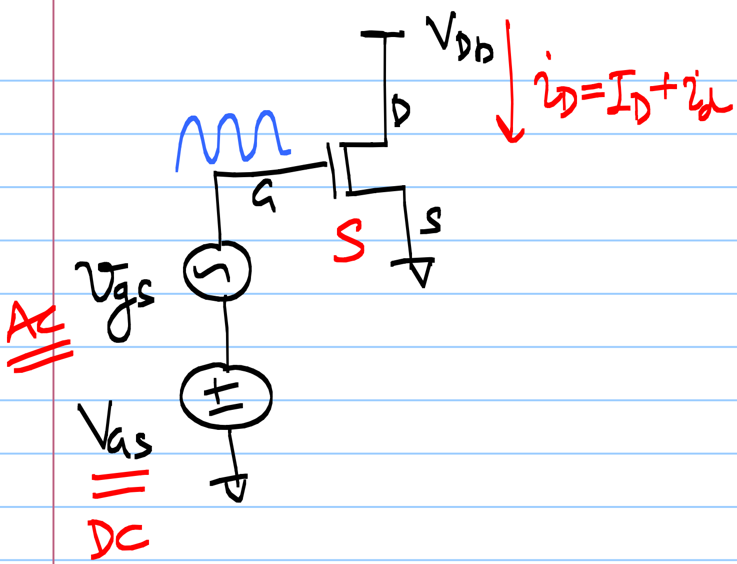
Small signal parameter is found at the Bias point



$i = g \cdot v \longleftarrow$ linearized around Bias point



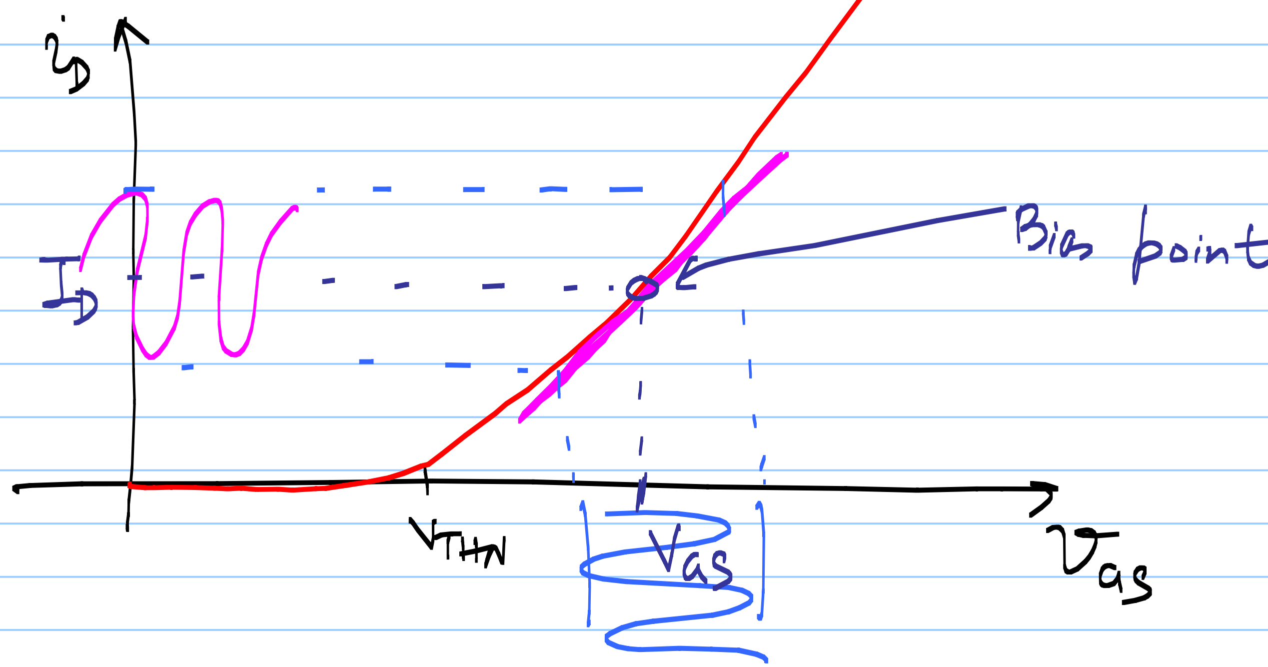
$$\boxed{i = g_1 v} + \underbrace{g_2 v^2 + g_3 v^3 + \cdots}_{\text{distortion terms}}$$



$$\underset{\text{Total}}{v_{GS}} = \underset{\text{DC}}{V_{GS}} + \underset{\text{AC}}{v_{gs}}$$

$$i_D = I_D + i_d$$

$\boxed{\text{Neglect CLM}}$



$$i_D = \frac{K P_n}{2} \frac{W}{L} (v_{GS} - V_{THN})^2$$

$$I_D + i_d = \frac{K P_n}{2} \frac{W}{L} (V_{GS} + v_{gs} - V_{THN})^2$$

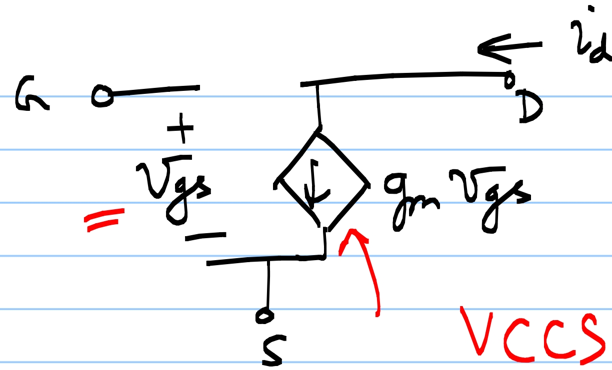
g_m = transconductance

$$i_d = g_m \cdot v_{gs}$$

$$g_m = \left.\frac{\partial i_D}{\partial v_{GS}}\right|_{v_{GS}=V_{GS}} = \left.\frac{K P_n}{\cancel{2}} \frac{W}{L} \cdot \cancel{2} (v_{GS} - V_{THN})\right|_{v_{GS}=V_{GS}}$$

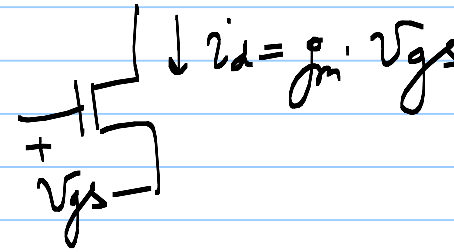
$$\boxed{g_m = K P_n \cdot \frac{W}{L} (\underbrace{V_{GS} - V_{THN}}_{V_{OV}})}$$

$$i_d = g_m \cdot v_{gs}$$



VCCS

(incomplete model)



$$g_m = \underbrace{K P_n' \cdot \frac{W}{L}}_{\beta_n} (V_{GS} - V_{THN})$$

$$g_m = \beta_n (V_{GS} - V_{THN}) \longrightarrow (1)$$

$$= \sqrt{2 \beta_n I_D} \longrightarrow (2)$$

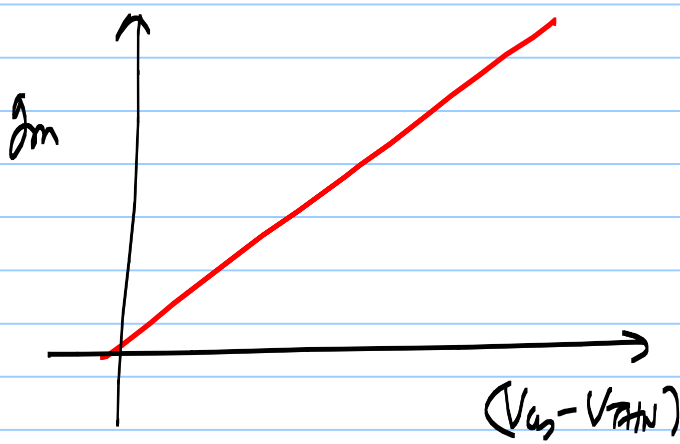
$$= \frac{2 I_D}{(V_{GS} - V_{THN})} \longrightarrow (3)$$

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

$$(V_{GS} - V_{THN}) = \sqrt{\frac{2 I_D}{\beta_n}} \longrightarrow (2)$$

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

$$g_m = \beta_n (V_{GS} - V_{THN})$$

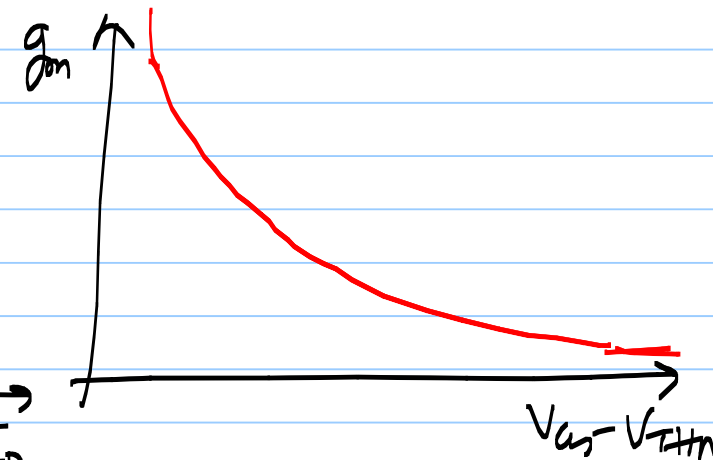


$\frac{W}{L}$ constant

$$g_m = \sqrt{2 \beta I_D}$$

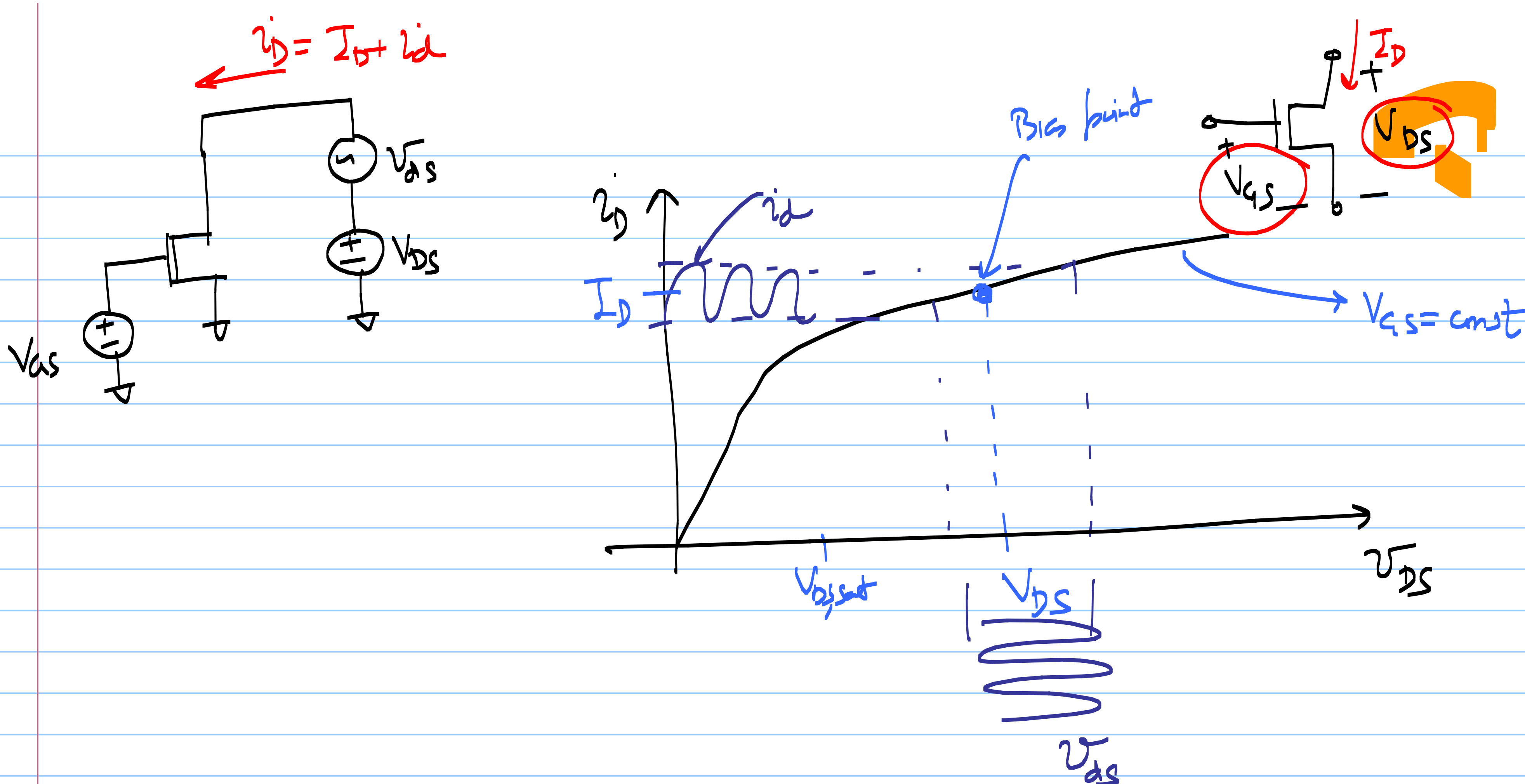
$\frac{W}{L}$ constant

$$g_m = \frac{2 I_D}{V_{GS} - V_{THN}}$$



I_D constant

$xy = c$



$i_D = I_D + i_d$
v_{ds}
V_{DS}
V_{GS}
i_D
i_d
I_D
Bias point
V_{DS}
V_{GS}
$V_{GS} = \text{const}$
v_{DS}
$V_{DS,sat}$
V_{DS}
v_{ds}

$$\underbrace{i_D}_{I_D + i_d} = \frac{K P_n}{2} \frac{W}{L} (V_{GS} - V_{THN})^2 \left[1 + \lambda \left(\underbrace{v_{DS}}_{V_{DS} + v_{ds}} - V_{DS,sat} \right) \right]$$

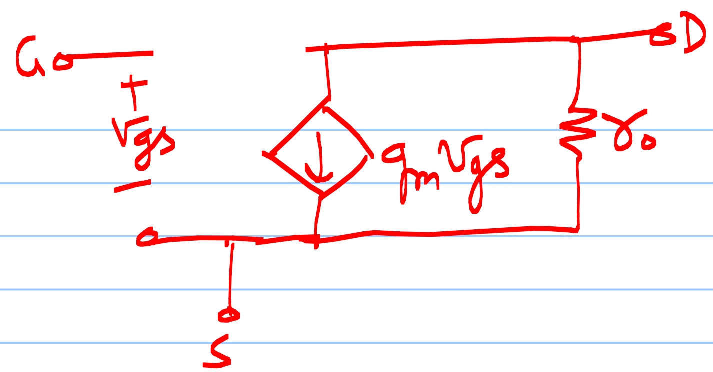
output conductance g_o, g_{DS}

$$i_d = g_o \cdot v_{ds} = \frac{v_{ds}}{r_o}$$

output resistance

$$g_o = r_o^{-1} = \left. \frac{\partial i_D}{\partial v_{DS}} \right|_{\substack{v_{DS} = V_{DS} \\ V_{GS} = \text{const}}} = \lambda \cdot I_{Dsat}$$

$$\boxed{r_o = \frac{1}{\lambda I_{Dsat}}}$$


G
D
+
v_{gs}
−
$g_m v_{gs}$
r_o
S