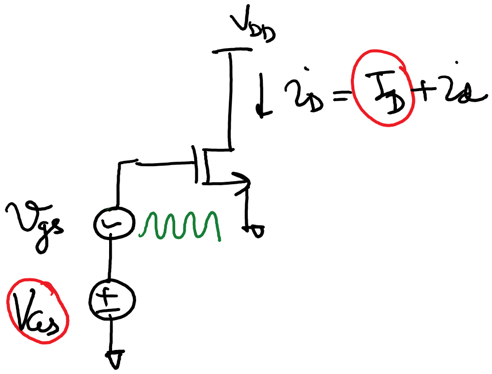
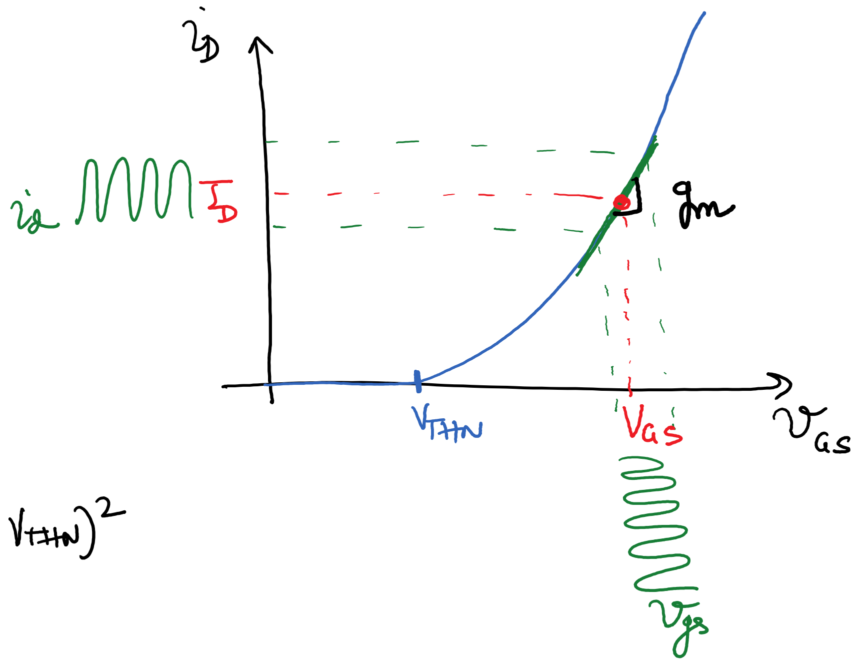
ECE 515- Lecture 2

Tuesday, August 28, 2018 11:15 AM





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

$$i_d = g_m v_{gs}$$

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

$$g_m = \underbrace{KP_n\cdot\frac{W}{L}}_{\beta_n}\underbrace{(V_{GS}-V_{THN})}_{V_{ov}} = \beta_n V_{ov} \longrightarrow (1)$$

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

$$= \beta_n\sqrt{\frac{2I_D}{\beta_n}}$$

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

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

$$\Rightarrow V_{GS}-V_{THN} = \sqrt{\frac{2I_D}{\beta_n}}$$

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

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

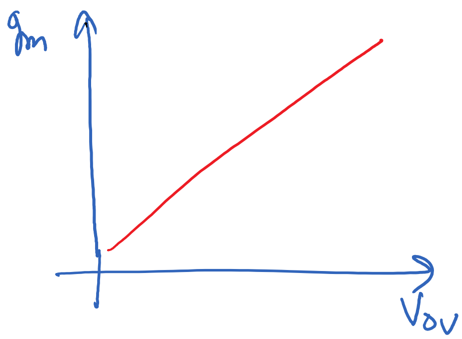
$$= \frac{2I_D}{(V_{GS} - V_{THN})^{\cancel{2}}} \cdot \cancel{(V_{GS} - V_{THN})}$$

$$\boxed{g_m = \frac{2I_D}{V_{OV}}} \rightarrow 3$$

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

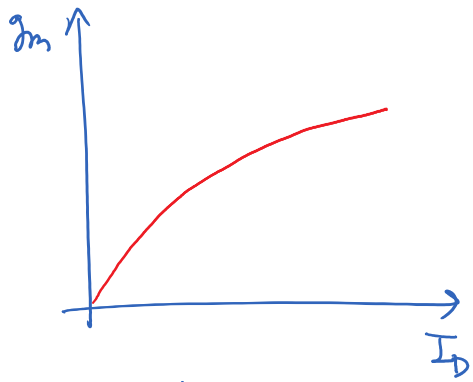
$$g_m = \sqrt{2 \beta I_D}$$

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



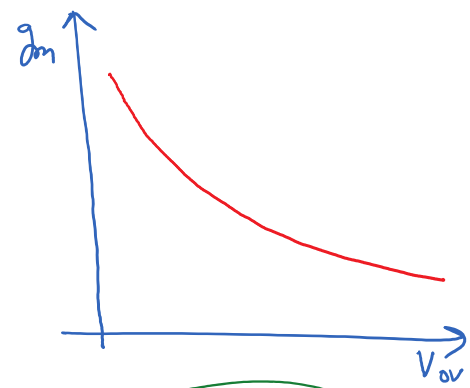
$\frac{W}{L} = \text{const}$

$\Rightarrow \beta = \text{const}$



$\frac{W}{L} = \text{const}$

$\Rightarrow \beta = \text{const}$



$I_D = \text{const}$

$\frac{W}{L}$ can vary

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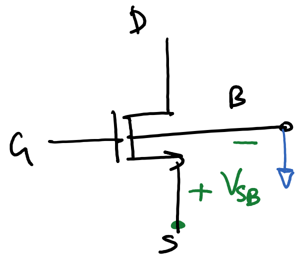
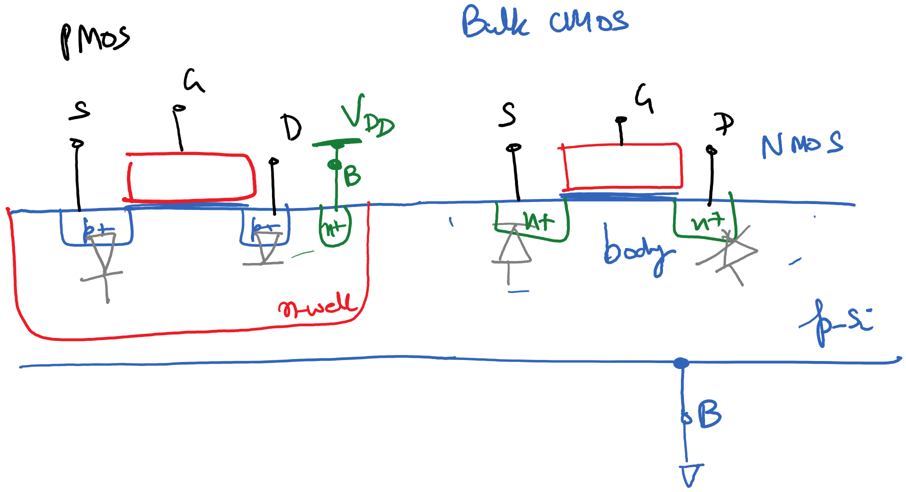
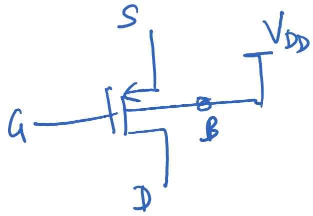
Body Effect :

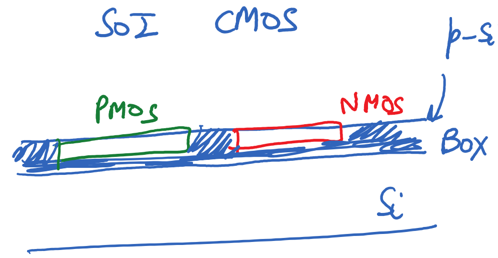


Bulk CMOS

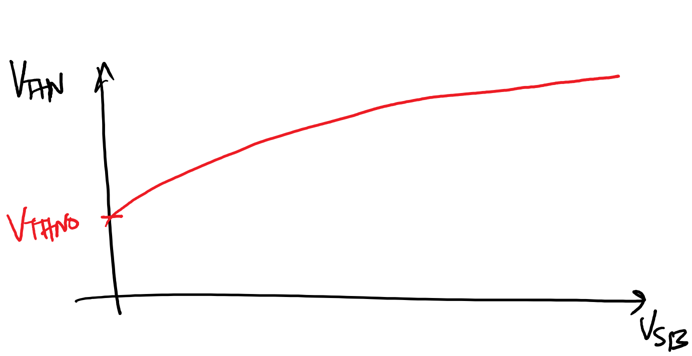




SOI CMOS

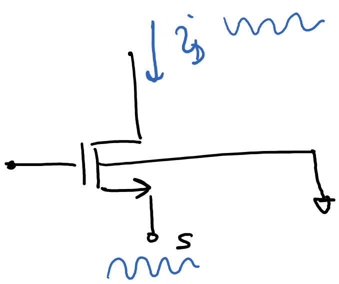


$$V_{THN}(V_{SB}) = V_{THN_0} + \gamma_n\left(\sqrt{2|V_{fp}|+V_{SB}} - \sqrt{2|V_{fp}|}\right)$$



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

$\Rightarrow I_D \downarrow$



body conductance

$$V_{THP}(V_{BS}) = V_{THP_0} + \gamma_p\left(\sqrt{2|V_{fn}|+V_{BS}} - \sqrt{2|V_{fn}|}\right)$$

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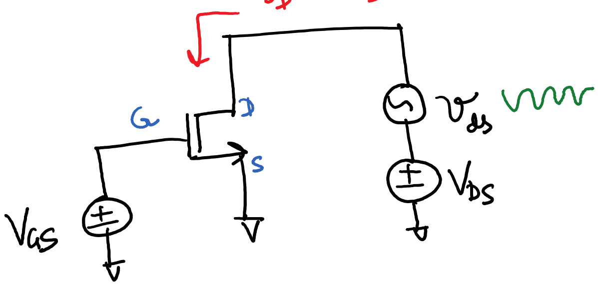
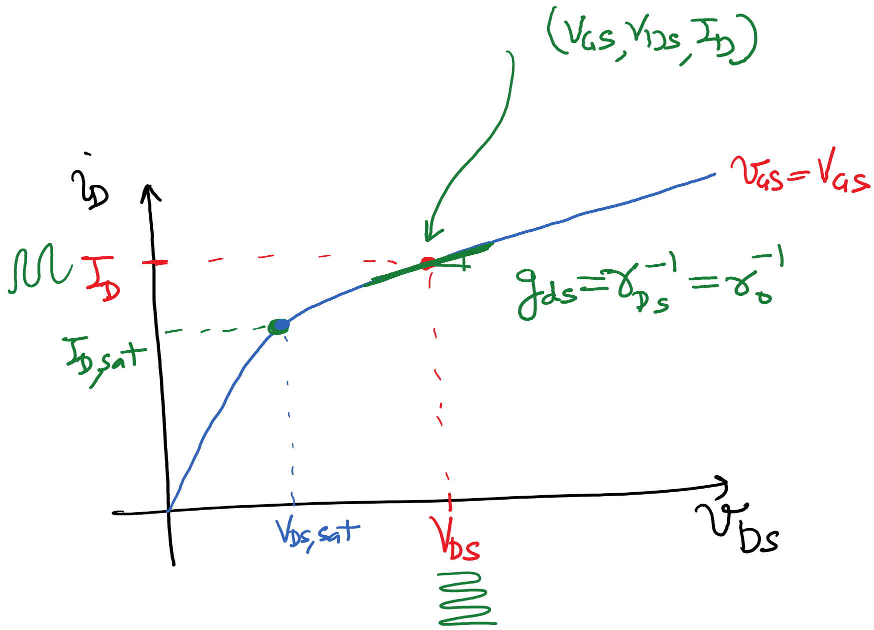
$i_D = I_D + i_d$



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



$$i_D = \frac{KP_n}{2}\frac{W}{L}(V_{GS} - V_{THN})^2 \cdot \underbrace{[1 + \lambda(v_{DS} - V_{DS,sat})]}_{\text{channel length modulation term}}$$

$$i_d = g_{ds}\, v_{ds} = \frac{v_{ds}}{r_o}$$

$$g_{ds} = r_o^{-1} = \left.\frac{\partial i_D}{\partial v_{DS}}\right|_{\substack{v_{DS} = V_{DS} \\ v_{GS} = V_{GS}}}$$

$$= \underbrace{\frac{KP_n}{2}\frac{W}{L}(V_{GS} - V_{THN})^2}_{I_{D,sat}} \cdot \lambda = \lambda I_{D,sat}$$

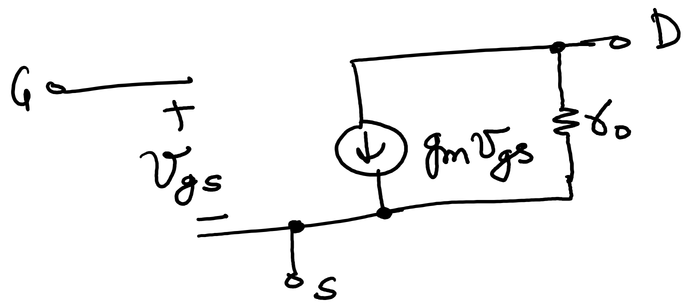
$$g_{DS} = r_o^{-1} = \lambda I_{D,sat}$$

$$\boxed{r_o = \frac{1}{\lambda I_{D,sat}}}$$

g_m, r_o

Small-signal model (thus far)

NMOS



Cadence Spectre

$$g_{DS} = g_o = r_o^{-1} = r_{DS}^{-1}$$

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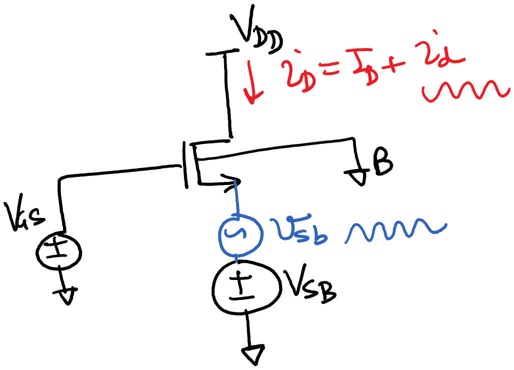
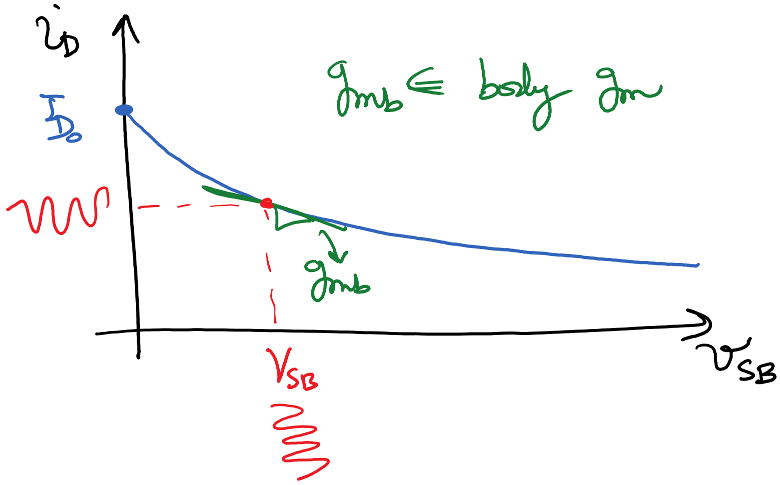
$V_{SB}\uparrow \Rightarrow V_{THN}\uparrow$
$\Rightarrow I_D \downarrow$

Body-Effect Transconductance:





$$i_D = f(v_{SB})$$

$$g_{mb} = \left.\frac{\partial i_D}{\partial v_{SB}}\right|_{v_{SB}=V_{SB}} = \frac{\partial}{\partial v_{SB}}\left[\frac{KP_n}{2}\frac{W}{L}(V_{GS}-V_{THN})^2\right]$$

$V_{THN} = g(v_{SB})$

$$= \underbrace{KP_n \cdot \frac{W}{L}(V_{GS}-V_{THN})}_{g_m} \cdot \left[-\frac{\partial V_{THN}}{\partial v_{SB}}\right]$$

$$\hookrightarrow g_{mb} = g_m \cdot \underbrace{\left[-\frac{\gamma}{2} \cdot \frac{1}{\sqrt{|2V_{fp}| + V_{SB}}} \right]}_{\eta}$$

$$\eta = \frac{-\gamma}{2\sqrt{2|V_{fp}| + V_{SB}}}$$

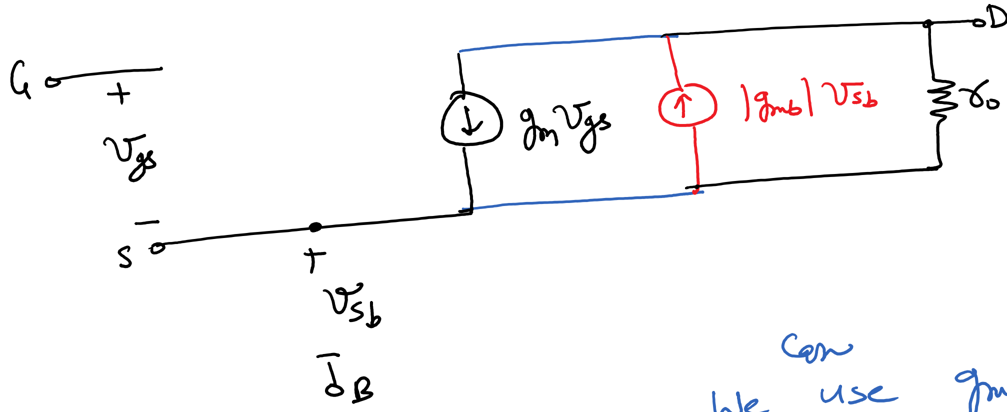
$$|\eta| < 1$$

$$g_{mb} = \eta g_m = -|\eta| g_m$$

↳ η describes the dependence of g_m on V_{SB}

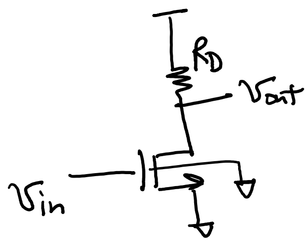
↳ The -ve sign indicates the opposing nature of $V_{SB} \uparrow$ on the drain current i_D

g_{mb} 'opposes' g_m

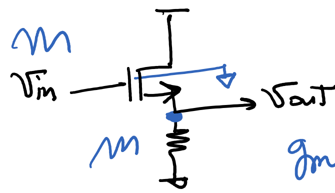


We can use g_{mb} wherever source is "wiggling"

Ex.



$$A_v = -g_m(r_o \| R_D)$$



g_{mb} is present here