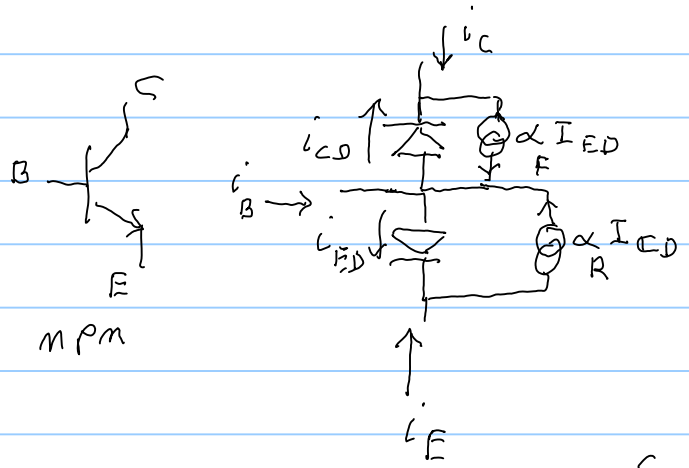
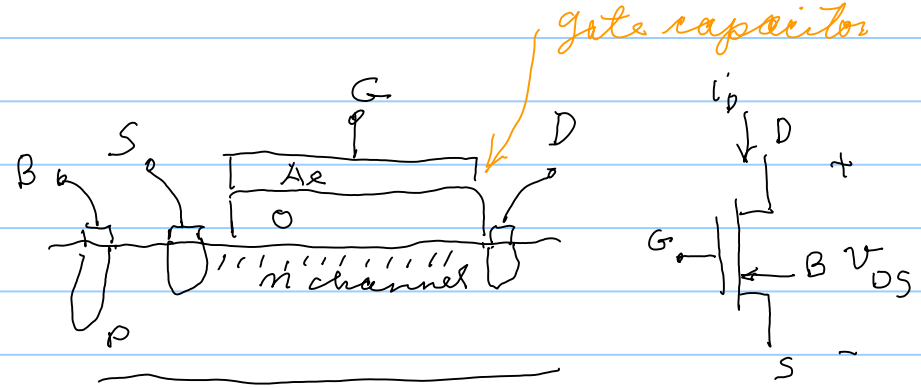
EE 303 H

09/15/15

Note Title 9/15/2015



$$\beta = \frac{\alpha}{1-\alpha}$$



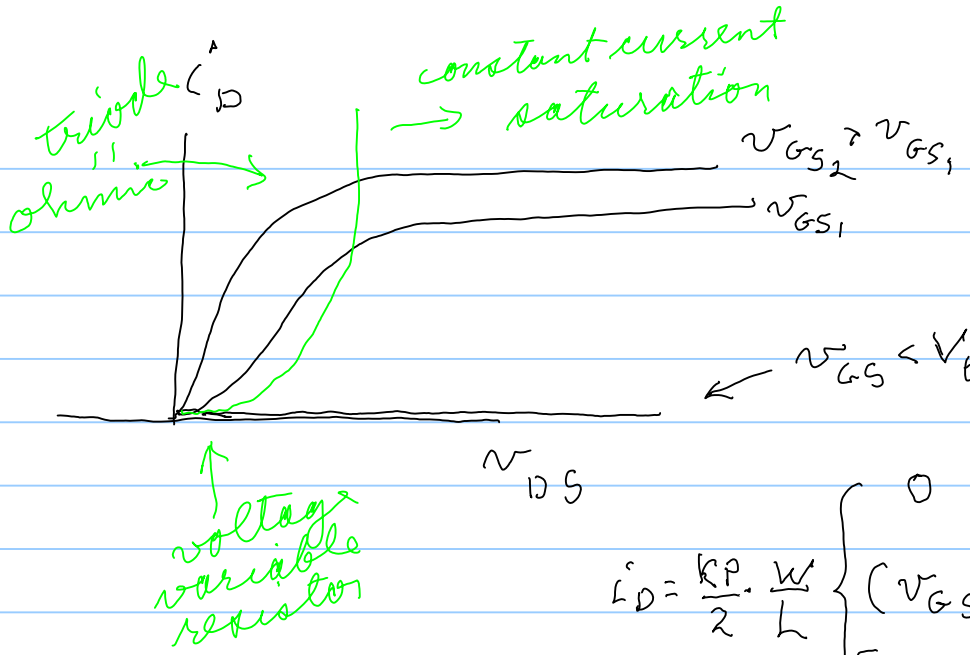
MOS = metal oxide silicon

B = bulk

S = source, D = drain

G = gate

NMOS $V_D > V_S$



$i_D = f(v_{GS}, v_{DS})$

$v_{GS} < V_{th} \Rightarrow i_D = 0$ cut-off

$$i_D = \frac{KP}{2}\cdot\frac{W}{L}\begin{cases} 0 & v_{GS} \le V_{th} \quad v_{DS} \ge 0 \quad \text{cut-off} \\ (v_{GS}-V_{th})^2(1+\lambda v_{DS}) & V_{th} \le v_{GS} \le v_{DS} \quad \text{sat} \\ \left[2(v_{GS}-V_{th})v_{DS} - v_{DS}^2\right](1+\lambda v_{DS}) & v_{GS} \ge v_{DS} \ge V_{th} \quad \text{ohmic} \end{cases}$$

$V_{th} = VTO$ if $v_{BS} = 0$

voltage controlled
VCCS if operate in saturation

$$i_D = I_D + \left.\frac{\partial i_D}{\partial v_{GS}}\right|_Q (v_{GS} - V_{GS}) + \left.\frac{\partial i_D}{\partial v_{DS}}\right|_Q (v_{DS} - V_{DS}) + \cdots$$

I_D, V_{GS}, V_{DS} = ~~bias~~ values = DC @ Q

$$i_d = i_D - I_D, \quad v_{gs} = v_{GS} - V_{GS}, \quad v_{ds} = v_{DS} - V_{DS}$$

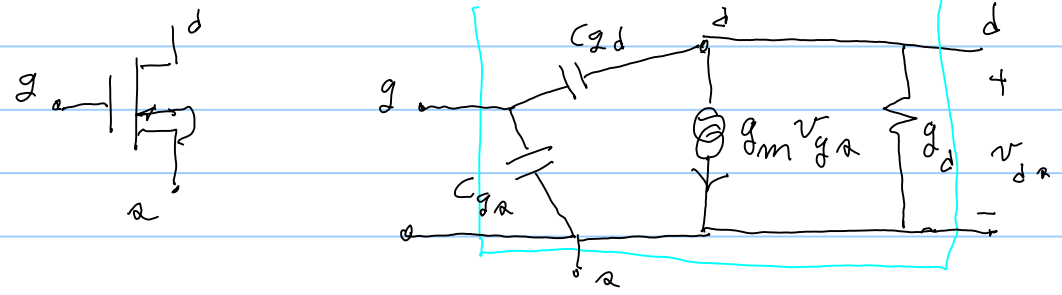
$$i_d = \left.\frac{\partial i_D}{\partial v_{GS}}\right|_Q v_{gs} + \left.\frac{\partial i_D}{\partial v_{DS}}\right|_Q v_{ds}$$

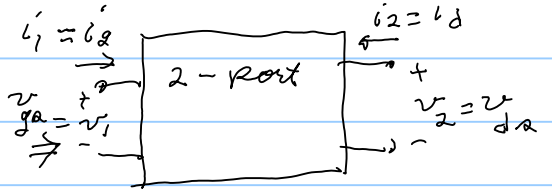
$$= g_m v_{gs} + g_d v_{ds}$$

$I_G = 0$, $i_g \Rightarrow$ see a capacitor

$$i_g = sC_{gs} v_{gs} + sC_{gd} v_{gd}$$

for B = S





$$\begin{bmatrix} i_1 \\ i_2 \end{bmatrix} = Y \begin{bmatrix} v_1 \\ v_2 \end{bmatrix}$$

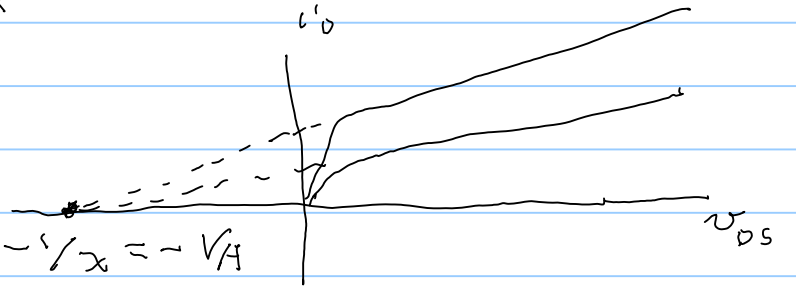
g_m = mutual conductance = $\left.\frac{\partial i_D}{\partial v_{GS}}\right|_Q$

Q is in saturation region $i_D = \frac{KP}{2}\frac{W}{L}\cdot(v_{GS}-VTO)^2(1+\lambda v_{DS})$

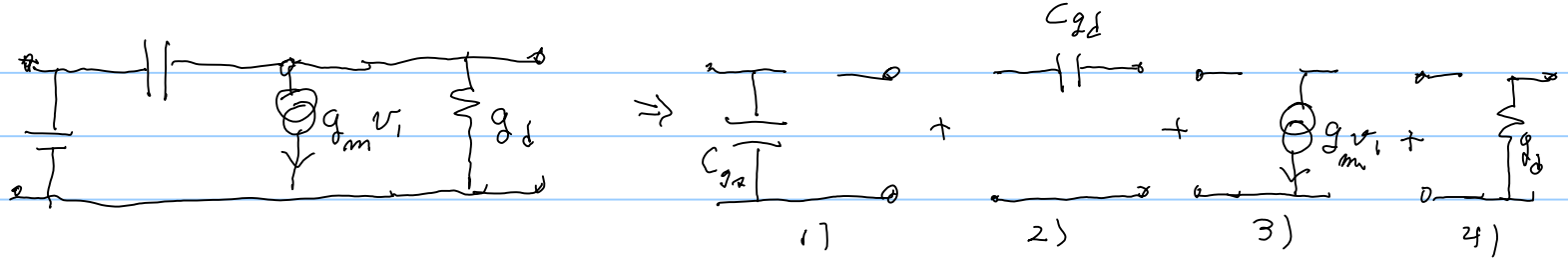
$$\left.\frac{\partial i_D}{\partial v_{GS}}\right|_Q = \left. 2\cdot\frac{KP}{2}\left(\frac{W}{L}\right)(v_{GS}-VTO)(1+\lambda V_{DS})\right|_Q = \left.\frac{2 i_D}{(v_{GS}-VTO)}\right|_Q = \frac{2 I_D}{(V_{GS}-VTO)} = g_m$$

$$\frac{\partial i_D}{\partial v_{DS}} = \lambda\left[\frac{KP}{2}\frac{W}{L}(v_{GS}-VTO)^2\right]\Big|_Q = \lambda\cdot\frac{I_D}{(1+\lambda V_{DS})} \approx \lambda I_D$$

$\lambda = 1/V_A$, V_A = Early voltage



The Y matrix



$$Y_1 = \begin{bmatrix} sC_{gs} & 0 \\ 0 & 0 \end{bmatrix}, \quad Y_2 = \begin{bmatrix} sC_{gd} & -sC_{gd} \\ -sC_{gd} & sC_{gd} \end{bmatrix}, \quad Y_3 = \begin{bmatrix} 0 & 0 \\ g_m & 0 \end{bmatrix}, \quad Y_4 = \begin{bmatrix} 0 & 0 \\ 0 & g_d \end{bmatrix}$$

$$Y_3 + Y_4 = \begin{bmatrix} 0 & 0 \\ g_m & g_d \end{bmatrix} \text{ when } s = 0 \Rightarrow \text{very low frequency } Y$$