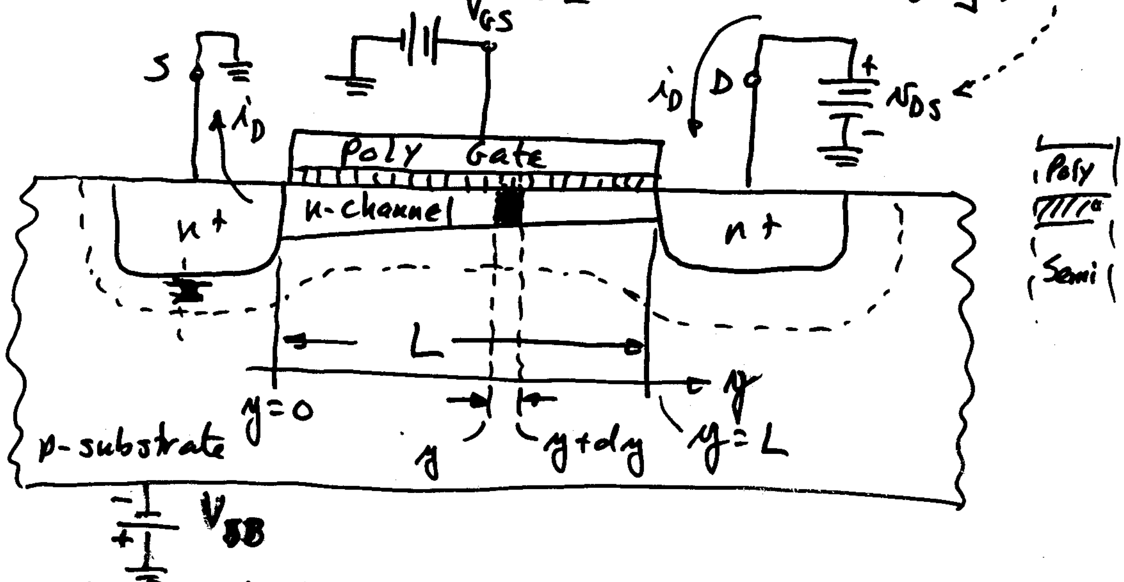
DEVELOPMENT OF LARGE-SIGNAL MODEL FOR MOSFET FOR SAH. EQ. AND FOR DSM TECHNOLOGY

SAH MODEL

$$i_D = \frac{k'}{2}\frac{W}{L}(v_{GS}-V_{TN})^2\ ,\quad v_{DS} \geq v_{GS}-V_T$$

$$* \quad i_D = k'\frac{W}{L}\left[(v_{GS}-V_{TN})v_{DS} - \frac{v_{DS}^2}{2}\right]\ ,\quad v_{DS} < v_{GS}-V_T$$



Note: $V(y)=0$ for $y=0$ and $V(y=L)=v_{DS}$

1.) Charge per unit area at point y in the channel is

$$q = Cv \longrightarrow Q_n(y) = C_{ox}\left[v_{GS}-V_T-v(y)\right]$$

2.) $i_{DS} = Q_n \times v \times W$ where v = carrier velocity

3.) Assume $v = \mu E_y = \mu \dfrac{dv(y)}{dy}$ $\dfrac{dv(y)}{dy}$

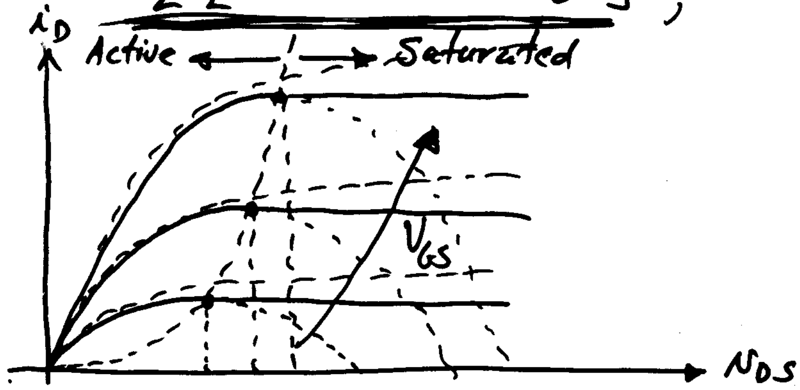
4.) $i_{DS} = i_D = C_{ox}\left[v_{GS}-v(y)-V_T\right]\mu E W$

$$\therefore\ i_D\,dy = \underbrace{\mu C_{ox}}_{k'} W\left[v_{GS}-v(y)-V_T\right]dv(y)$$

5.) $$\int_0^L i_D \, dy = k'W \int_0^{v_{DS}} \left[v_{GS} - v(y) - V_T \right] dv(y)$$

$$i_D L = k'W \left[(v_{GS} - V_T) v_{DS} - \frac{v_{DS}^2}{2} \right]$$

$$\underline{i_D = k' \frac{W}{L} \left[(v_{GS} - V_T) v_{DS} - \frac{v_{DS}^2}{2} \right]}, \quad v_{DS} < v_{GS} - V_T$$

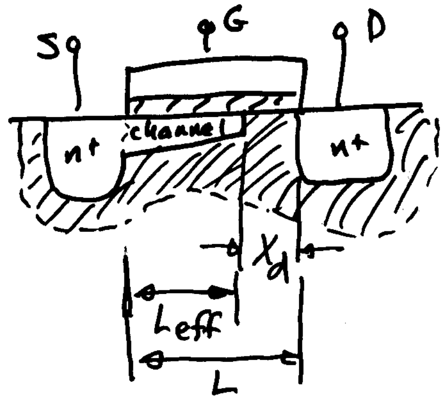


$$\frac{di_D}{\partial v_{DS}} = 0 \longrightarrow v_{DS} = v_{GS} - V_T = v_{DS}(sat)$$

6.) Saturation region model $(v_{DS} \geq v_{GS} - V_T)$

$$v_{DS} \leftarrow v_{GS} - V_T \implies i_D = \frac{k'W}{L} \left[(v_{GS} - V_T)(v_{GS} - V_T) - \frac{(v_{GS} - V_T)^2}{2} \right]$$

$$\underline{i_D = \frac{k'}{2} \frac{W}{L} (v_{GS} - V_T)^2}, \quad v_{DS} \geq v_{GS} - V_T$$



Channel Modulation

Assume saturation –

$L_{eff} = L - X_d$

$$i_D = \frac{k'}{2} \frac{W}{L_{eff}} (v_{GS} - V_T)^2$$

$$\frac{di_D}{dv_{DS}} = -\frac{k'W}{2L_{eff}^2} (v_{GS} - V_T)^2 \frac{dL_{eff}}{dv_{DS}} = -\frac{i_D}{L_{eff}} \frac{dL_{eff}}{dv_{DS}} = \frac{i_D}{L_{eff}} \frac{dX_d}{dv_{DS}}$$

$$\frac{di_D}{dv_{DS}} \equiv \lambda i_D \implies \lambda = \frac{1}{L_{eff}} \frac{dX_d}{dv_{DS}}$$

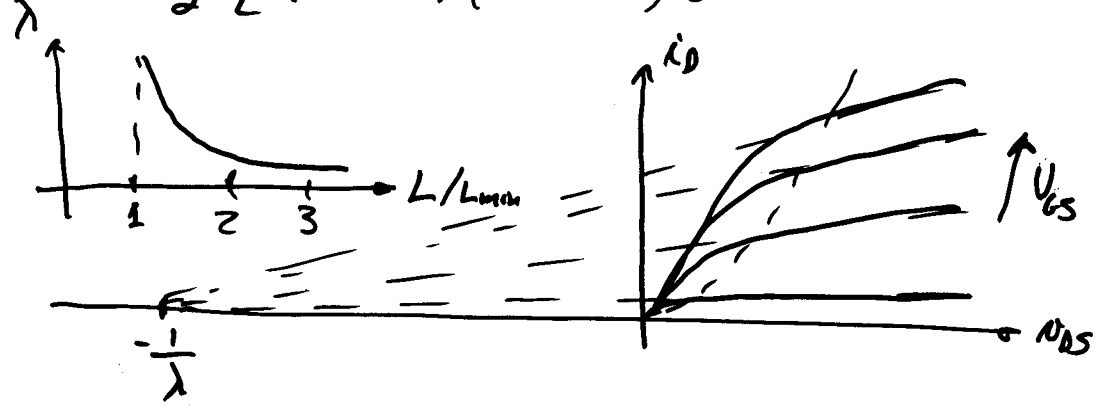
$$\therefore \; i_D(v_{DS}) = i_D(\lambda=0) + \left(\frac{d i_D}{d v_{DS}}\right) v_{DS} = i_D + \lambda i_D v_{DS}$$

$$i_D(v_{DS}) = i_D(1+\lambda v_{DS})$$

$$i_D = k' \frac{W}{L}\left[(v_{GS}-V_T)(v_{DS}) - \frac{v_{DS}^2}{2}\right](1+\lambda v_{DS}), \quad v_{DS} < v_{GS}-V_T$$

or

$$i_D = \frac{k'}{2}\frac{W}{L}(v_{GS}-V_T)^2(1+\lambda v_{DS}), \quad v_{DS} \geq v_{GS}-V_T$$



What about deep submicron technology (DSM)?

DSM effects?

1.) Strong vertical field

2.) Saturation of drift velocity.

$$v = \mu_e \frac{E_y}{1+\frac{E_y}{E_c}}, \quad E_y < E_c = \text{critical field}$$

$$v = v_{sat} = \frac{\mu_e E_c}{2}, \quad E_y \geq E_c$$

A redevelopment of previous eqs. gives,

Linear region:

$$i_{DS} = \frac{W}{L}\left(\frac{\mu_e C_{ox}}{1+\frac{v_{DS}}{E_c L}}\right)\left(v_{GS}-V_T-\frac{v_{DS}}{2}\right)v_{DS}\,(1+\lambda v_{DS})$$

Saturation Region:

$$i_{DS} = i_D = W C_{ox} (v_{GS} - V_T - v_{DS}) v_{sat} = W C_{ox} (v_{GS} - V_T - v_{DS}) \frac{\mu_e E_c}{2}$$

$$i_{DS} = \frac{W \mu_e C_{ox} E_c}{2} (v_{GS} - V_T - v_{DS})$$

What is $v_{DS}(sat.)$?

Equate the two currents (linear & sat.) and solve for $v_{DS}(sat)$

$$\frac{W}{L}\left(\frac{\mu_e C_{ox}}{1 + \frac{v_{DS}}{E_c L}}\right)\left(v_{GS} - V_T - \frac{v_{DS}}{2}\right) v_{DS} = \frac{W \mu_e C_{ox} E_c}{2} (v_{GS} - V_T - v_{DS})$$

$$\frac{\cancel{W \mu_e C_{ox} E_c}}{E_c L + v_{DS}}\left(v_{GS} - V_T - \frac{v_{DS}}{2}\right) v_{DS} = \frac{\cancel{W \mu_e C_{ox} E_c}}{2}(v_{GS} - V_T - v_{DS})$$

$$v_{GS} v_{DS} - V_T v_{DS} - \frac{v_{DS}^2}{2} = \frac{1}{2}(v_{GS} - V_T - v_{DS})(E_c L + v_{DS})$$

$$\Downarrow$$

$$v_{DS}\left[(v_{GS} - V_T) + E_c L\right] = E_c L (v_{GS} - V_T)$$

$$\therefore \quad v_{DS}(sat) = \frac{E_c L (v_{GS} - V_T)}{(v_{GS} - V_T) + E_c L}$$

Next write eq. for saturation

$$\therefore \quad i_{DS} = W C_{ox} (v_{GS} - V_T - v_{DS}) v_{sat} = W C_{ox}\left[v_{GS} - V_T - \frac{(v_{GS} - V_T) E_c L}{(v_{GS} - V_T) + E_c L}\right]$$

$$= W C_{ox} v_{sat}\left[\frac{(v_{GS} - V_T)^2}{(v_{GS} - V_T) + E_c L}\right] = \frac{W \mu_e E_c C_{ox}}{2}\left[\frac{(v_{GS} - V_T)^2}{(v_{GS} - V_T) + E_c L}\right]$$

when $v_{DS} > v_{DS}(sat.)$

or

$$i_{DS} = \frac{W \mu_e C_{ox} E_c}{2}\left[\frac{(v_{GS} - V_T)^2}{(v_{GS} - V_T) + E_c L}\right](1 + \lambda v_{DS})$$