08/08/2019

EE5311

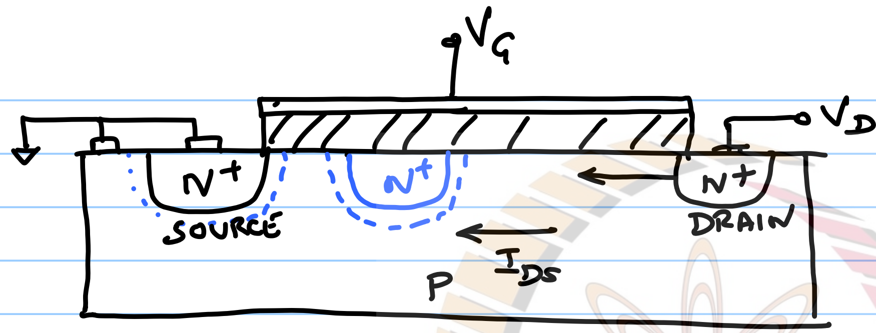
MODULE-1 : THE TRANSISTOR

SHORT CHANNEL EFFECTS (SCE)

1) CHANNEL LENGTH MODULATION (CLM) $\longrightarrow \dfrac{\Delta L}{L} = \lambda V_{DS}$

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

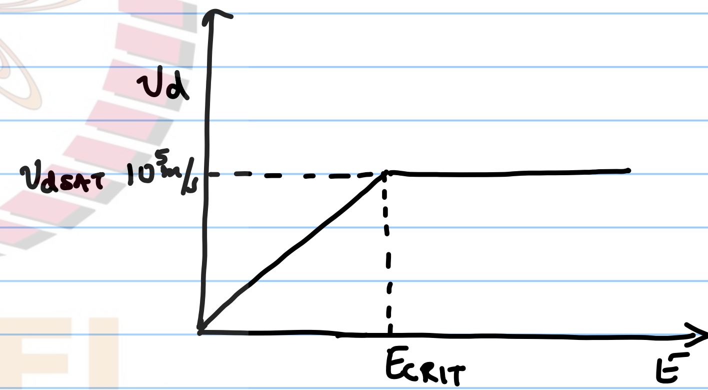
2) VELOCITY SATURATION :



$V_{DD} \downarrow$ WITH TECH

$$E = \frac{V_{DS}}{L}$$

v_d = drift vel $\leq 10^5$ m/s



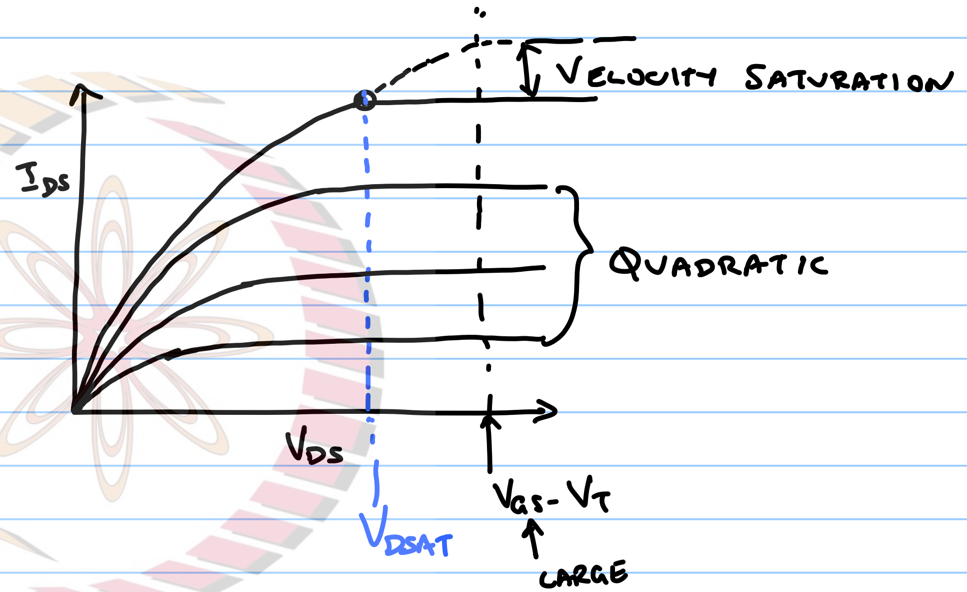
$$v_d = \mu_n E$$

$$v_{dSAT} = \mu_n \cdot \frac{V_{DSAT}}{L}$$

$$\therefore \quad V_{DSAT} = \frac{v_{DSAT} \cdot L}{\mu_n}$$

$V_{GS} \rightarrow$ SMALL ($>V_T$)

$V_{GS} \rightarrow$ LARGE



$$I_D = \begin{cases} 0 & V_{GS} < V_T \\ \mu_n C_{ox} \frac{W}{L} V_{DS}\left[(V_{GS}-V_T) - \frac{V_{DS}}{2}\right] & V_{DS} \leq V_{GS}-V_T \rightarrow \text{LINEAR (TRIODE)} \\ \frac{1}{2}\mu_n C_{ox} \frac{W}{L}(V_{GS}-V_T)^2 \rightarrow V_{DS} = V_{GS}-V_T & V_{DS} > V_{GS}-V_T \longrightarrow \text{(SATURATION)} \\ \mu_n C_{ox} \frac{W}{L} V_{DSAT}\left[(V_{GS}-V_T) - \frac{V_{DSAT}}{2}\right] & V_{DSAT} < V_{GS}-V_T \quad \text{(VEL SAT)} \end{cases}$$

Unified Current Model

$$I_D = \underbrace{\mu_n C_{ox}}_{K_n'} \frac{W}{L} V_{min}\left[(V_{GS}-V_T) - \frac{V_{min}}{2}\right](1+\lambda V_{DS})$$

$\lambda \to \frac{\Delta L}{L}$

$$V_{min} = \min(V_{GS}-V_T,\ V_{DS},\ V_{DSAT})$$

$V_{GS}-V_T \to$ SAT

$V_{DS} \to$ LIN

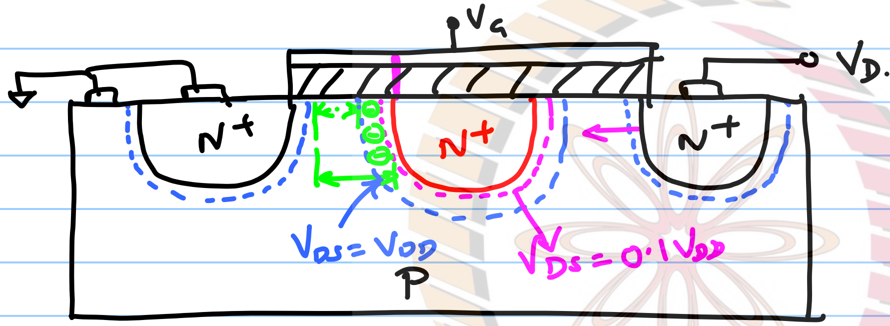
$V_{DSAT} \to$ VEL SAT.

$$V_{TH} = V_{TH0} + \gamma\left(\sqrt{|V_{SB}+2\phi_s|} - \sqrt{|2\phi_s|}\right)$$

5 PARAMETERS : $(K_n', V_{DSAT}, \lambda, V_{TH0}, \gamma) \leftarrow$ LEVEL 1 SPICE MODEL (TECHNOLOGY PARAMETERS)

$$K_n' = \mu_n C_{ox} = \mu_n \frac{\varepsilon_{ox}}{t_{ox}}$$

DRAIN INDUCED BARRIER LOWERING (DIBL)

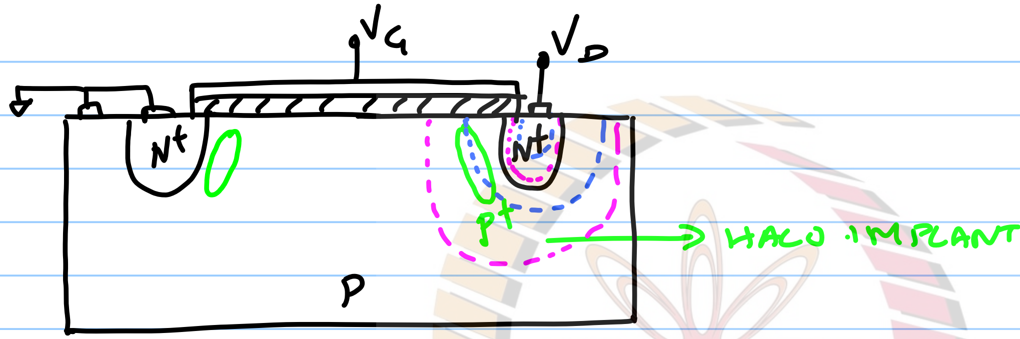


$V_{DS1} = 0.1\, V_{DD} \rightarrow V_{TH} = V_{TLIN}$

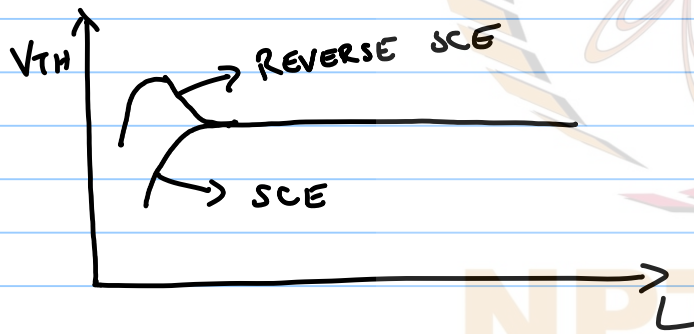
$V_{DS2} = V_{DD} \rightarrow V_{TH} = V_{TSAT}$

$$\eta = \text{DIBL} = \frac{V_{TLIN} - V_{TSAT}}{(V_{DD} - 0.1 V_{DD})}$$

$$V_{TH} = V_{TH0} + \gamma\left(\sqrt{|V_{SB} + 2\psi_s|} - \sqrt{|\psi_s|}\right) - \eta V_{DS}$$



V_G
V_D
N^+
N^+
p^+
HALO IMPLANT
P



V_{TH}
REVERSE SCE
SCE
L