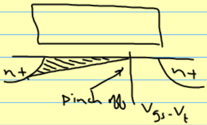
Simple Model Linear Region

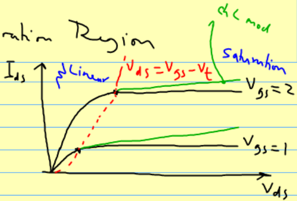
$$\int_0^L I_{ds} \cdot dx = \int_0^{V_{ds}} \mu_e C_{ox} \left(V_{gs} - V_t - V(x) \right) \cdot W \cdot dV(x)$$

$$I_{ds} = \mu C_{ox} \frac{W}{L} \left(\underbrace{(V_{gs} - V_t) \cdot V_{ds}}_{\approx \frac{1}{R_{ch}}} - \frac{1}{2} V_{ds}^2 \right)$$

what if $V_{ds} > V_{gs} - V_t$

Saturation Region





$$I_{ds}\Big|_{V_{ds}=V_{gs}-V_t} = \mu C_{ox}\frac{W}{L}\left((V_{gs}-V_t)\cdot(V_{gs}-V_t)-\frac{1}{2}(V_{gs}-V_t)^2\right)$$

$$I_{ds}\Big|_{V_{ds}=V_{gs}-V_t} = \mu C_{ox}\frac{W}{2L}(V_{gs}-V_t)^2$$

Channel Modulation

$$L_{real} = L - \xi \cdot V_{ds}$$

$$I_{ds} = \mu C_{ox} \frac{W}{2(L - \xi V_{ds})} \cdot (V_{gs} - V_t)^2$$

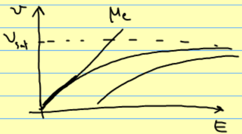
$$= \mu C_{ox} \frac{W}{2L} (V_{gs} - V_t)^2 \cdot \frac{1}{1 - \xi \frac{V_{ds}}{L}}$$

$$\left(1 + \frac{\xi}{L} V_{ds}\right)$$

λ

ch length
modulation
param

Velocity Sat



$$v = \begin{cases} v_{sat} & E > E_c \\ \dfrac{\mu_e E}{\left(1+\left(\frac{E}{E_c}\right)^n\right)^{1/n}} & E < E_c \end{cases}$$

$n=1$ for PMOS
$n=2$ for NMOS

$$I_{ds} = C_{ox}\left(V_{gs} - V_t - V(x)\right) \cdot \frac{\mu_e \frac{dV(x)}{dx}}{1 + \frac{dV_x}{dx} \cdot \frac{1}{E_c}} \cdot W$$

$$\int_0^L (\quad) dx = \int_0^{V_{ds}} (\qquad\qquad) dV(x)$$

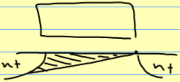
Velocity Sat Eq

$$I_{ds} = \mu_e C_{ox} \frac{W}{L}\left((V_{gs}-V_t)\cdot V_{ds} - \frac{1}{2}V_{ds}^2\right)\left(\frac{1}{1+\frac{V_{ds}}{E_c \cdot L}}\right)$$

extreme cases $L \longrightarrow \infty$ $K(V_{ds}) \Longrightarrow 1$ Long ch $K(V_{ds})$

$K(V_{ds}) < 1$ Short ch

Long ch



$V_{ds} = V_{dsat}$

$v = v_{sat}$

$E = E_c$

$$I_{ds} = C_{ox}\,(V_{gs} - V_t - V_{dsat}) \cdot v_{sat} \cdot W \quad ⊛$$

$I_{ds}\,⊛ = I_{ds}\,⊛⊛$ Solve for V_{dsat}

$$V_{dsat} = \frac{1}{1 + \frac{V_{gs} - V_t}{E_c L}} \cdot (V_{gs} - V_t)$$

$$= K\,(V_{gs} - V_t) \cdot (V_{gs} - V_t)$$