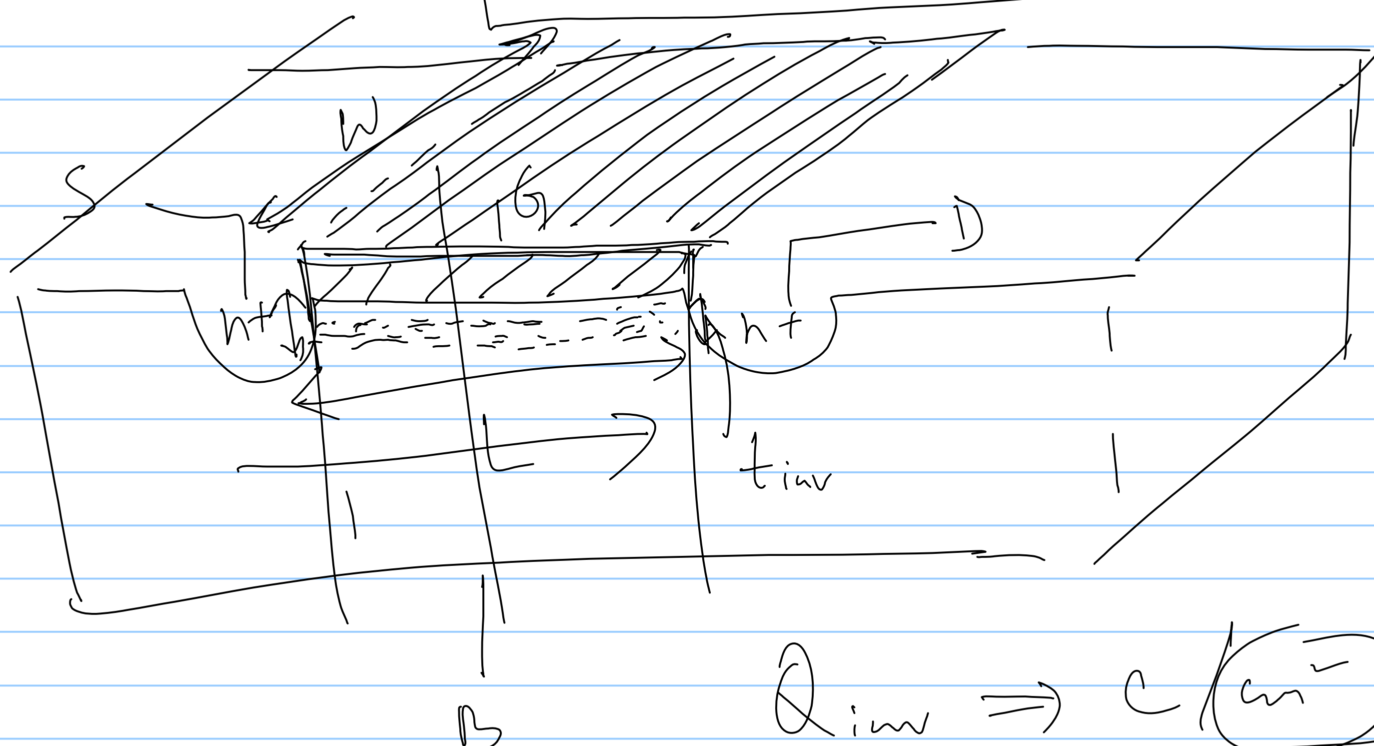
Drain Current in MOSFET

11/11/2014

$$Q_{inv} = -\boxed{C_{ox}\left[V_{GS} - V_{TH} - V_x\right]}$$



Gate Area = W.L

Capacitance $\Rightarrow$ F/cm²

Charge $\Rightarrow$ C/cm²

$Q_{inv} \Rightarrow$ C/cm²

Volume of the inversion layer $\Rightarrow W \cdot L \cdot t_{inv}$

Total inversion charge. $Q_{inv}^{Total} = q n \cdot \underline{W \cdot L} \cdot t_{inv}$

Coulomb.

$Q_{inv} = Q_{inv}^{Total} / W \cdot L$

C/cm^2

$$\boxed{Q_{inv} = q n \cdot t_{inv}}$$

Drain current in MOSFET is due to drift.

$$I_d = A n q \mu_n \mathcal{E}$$

$$= W \cdot \boxed{t_{inv} \cdot n q} \, \mu_{ns} \left(-\frac{dV_x}{dx} \right)$$

surface mobility of electrons

Surface mobility < Bulk mobility

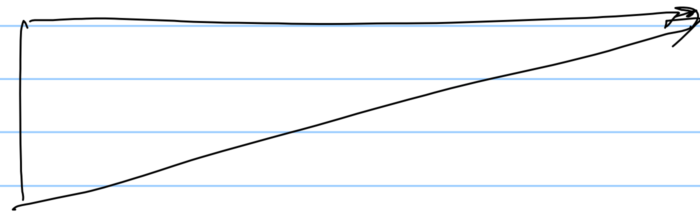
$$I_d \, dx = \left(-t_{inv} \, n q \right) W \mu_{ns} \, dV_x$$

$$\int_0^L \underline{\underline{I_d}}\, dx = \int_0^{V_{DS}} W \mu_{ns} C_{ox} \left[V_{GS} - V_{TH} - V_x \right] dV_x$$

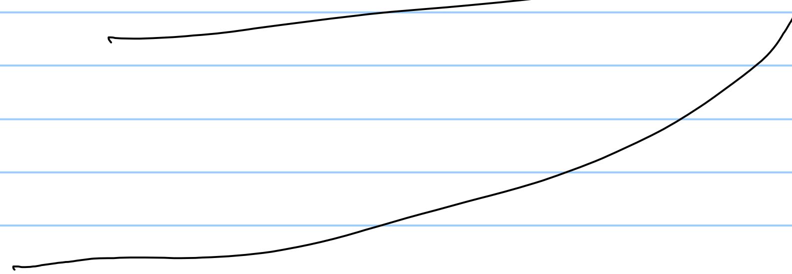
$$\Rightarrow I_d \cdot L = W \cdot \bar{\mu}_{ns} C_{ox} \left[(V_{GS} - V_{TH}) V_{DS} - \frac{V_{DS}^2}{2} \right]$$

$$\Rightarrow \boxed{I_d = \bar{\mu}_{ns} \frac{W C_{ox}}{L} \left[(V_{GS} - V_{TH}) V_{DS} - \frac{V_{DS}^2}{2} \right]}$$

$$\frac{Q_{dep}}{C_{ox}} = -\frac{\sqrt{q N_a 2 \varepsilon_{Si} (2\phi_F + V_x)}}{C_{ox}}$$



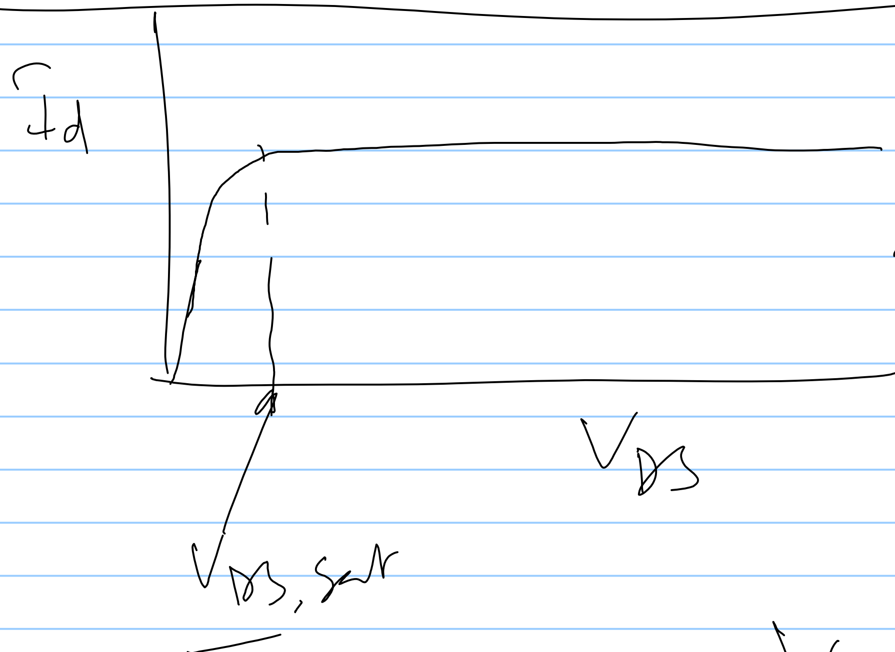
$Q_{inv}(x) \downarrow$ as $x \uparrow$

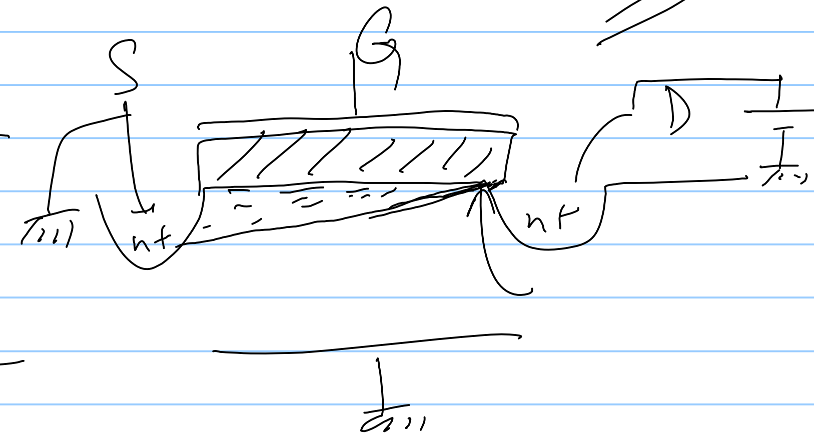


$Id \neq f(x)$

$\Sigma \uparrow$ as $x \uparrow$

$$\boxed{I_d = \bar{\mu}_{ns} \frac{W C_{ox}}{2} \left[(V_{GS} - V_{TH}) \underline{\underline{V_{DS}}} - \frac{V_{DS}^2}{2} \right]}$$





$V_{GC} > V_{TH}$

$\underline{\underline{V_{GC}}} = V_{TH} \Rightarrow Q_{inv} = 0$

$V_{GD} = V_{TH} \Rightarrow Q_{inv}$ at $x = L$ is zero.

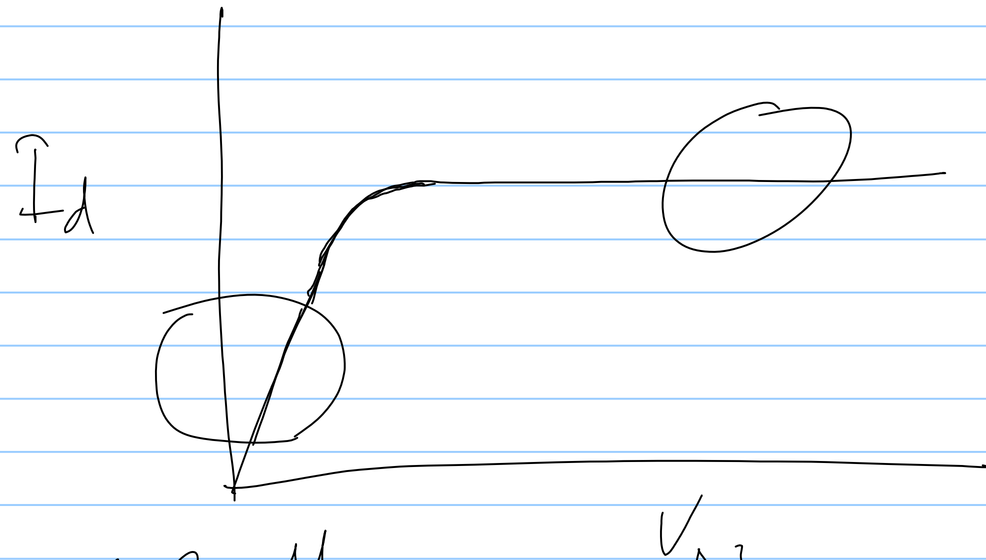
$V_{GS} - V_{DS} = V_{TH}$

$\Rightarrow \boxed{V_{DS,sat} = V_{GS} - V_{TH}} \rightarrow Q_{inv}$ at $x = L$ is zero (pinch-off condition)

At $\boxed{\underline{V_{DS}} = V_{DS,sat} = V_{GS} - V_{TH}}$

$$I_d = \bar{\mu}_{ns} \frac{W C_{ox}}{L} \left[(V_{GS} - V_{TH})^2 - \frac{(V_{GS} - V_{TH})^2}{2} \right]$$

$$\boxed{I_d = \frac{\bar{\mu}_{ns} W C_{ox}}{2L} (V_{GS} - V_{TH})^2}$$



If V_{DS} is very small

$$I_d \cong \mu_n \frac{W C_{ox}}{L} \left[(V_{GS} - V_{TH}) V_{DS} \right]$$

$$I_d = f(V_{GS}, V_{DS})$$

$$g_m = \left.\frac{\partial I_D}{\partial V_{GS}}\right|_{V_{DS}}$$

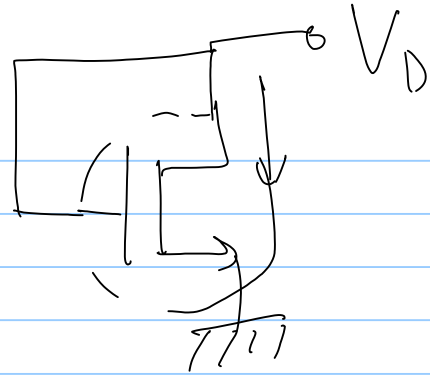
$$g_{ds} = \left.\frac{\partial I_D}{\partial V_{DS}}\right|_{V_{GS}}$$

In saturation

$$g_m = \frac{\bar{\mu}_{ns} W C_{ox}}{\cancel{2} L} \cdot \cancel{2}(V_{GS} - V_{TH})$$

In linear region

$$g_{ds} = \frac{\bar{\mu}_{ns} W C_{ox}}{L}(V_{GS} - V_{TH})$$



$I_D = 2mA$ when $V_{DS} = 2V$

$I_D = ?$ when $V_{DS} = 4V$

$V_{TH} = 1V$

$V_{GD} = 0$

$V_{GS} = 2V$, $V_{TH} = 1V$

$V_{DS} = 2V$

$V_{DS} > V_{GS} - V_{TH}$

$$I_d = \frac{\mu_n W C_{ox}}{2L}(V_{GS} - V_{TH})^2$$

$$\frac{I_{d2}}{I_{d1}} = \frac{3^2}{1^2} = 9$$