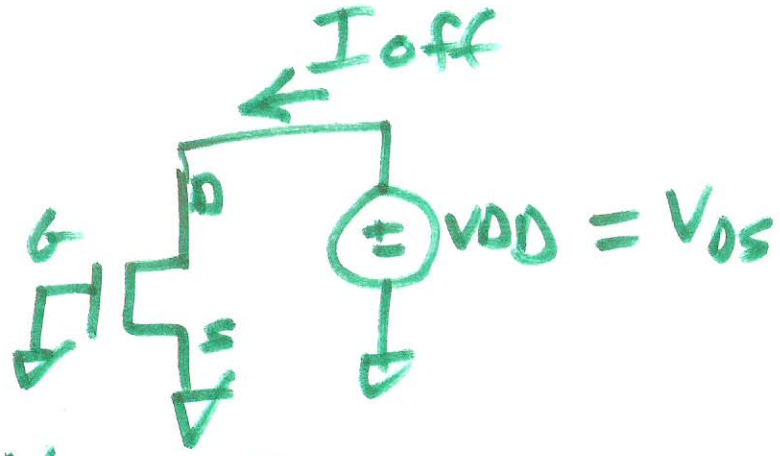
EE 421 / ECG 621

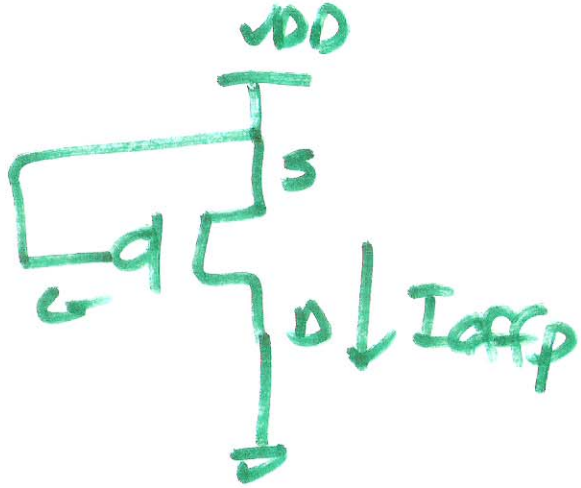
Lecture 13

Fall 2013

OCT. 9

A 6.9

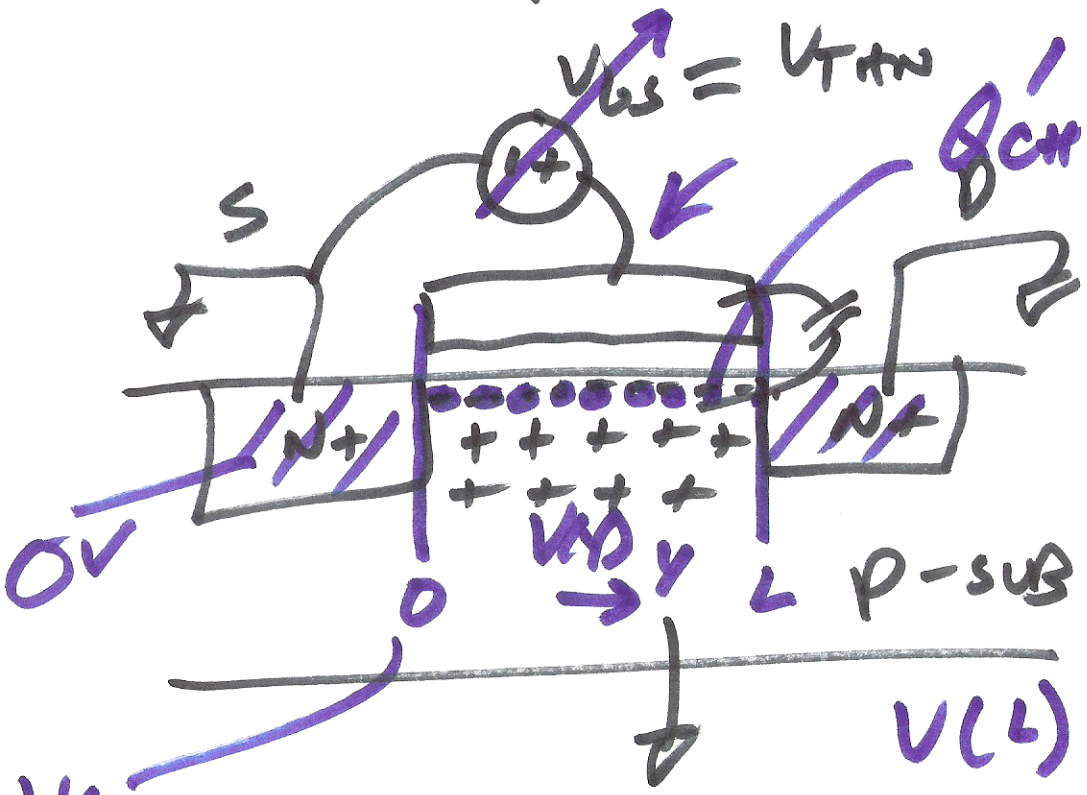




$V_S - V_D = V_{SD} = V_{DD}$

MOSFET operating in triode

$CV = Q$



$Q'_b = C'_{ox} \cdot V_{THN}$ ← charge for V_{THN}

$Q'_{ch} = C'_{ox}(V_{GS} - V(y))$ ← total charge

$Q'_I = Q'_{CH} - Q'_b$ the charge above V_{THN} to conduct I

$$Q_I'(Y) = C_{ox}'\left(V_{GS} - V(Y) - V_{THN}\right)$$

$$\mu_n = \frac{\text{Velocity}}{\mathcal{E}} \quad \frac{cm/s}{V/cm} \quad \frac{cm^2}{V \cdot s}$$

$$dR = \frac{1}{Q_I'(Y)\cdot \mu_n} \frac{dY}{W}$$

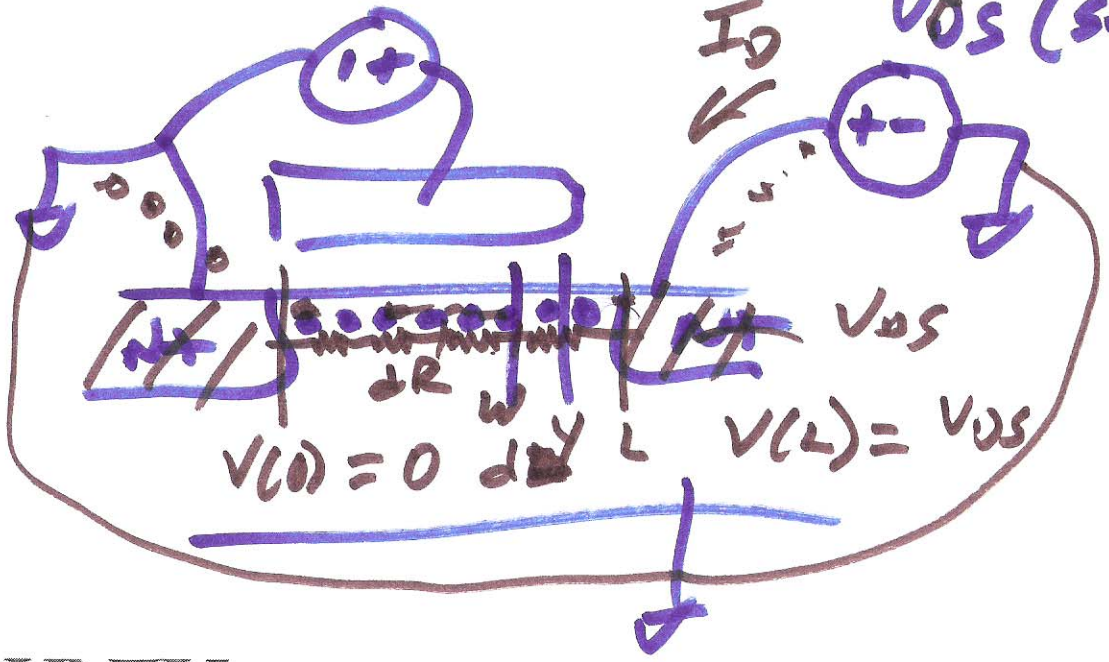
eff. sheet res.

$Q'(Y)$ $\frac{C}{\cancel{C}} \cdot \frac{cm^2}{V \cdot s}$

$= \frac{C/s}{V}$

$= \frac{A}{V} = \frac{1}{R}$

$V_{DS} > V_{THN}$



$$dV(Y) = dR \cdot I_D$$

$$dV(y) = \frac{1}{Q_I(y) \cdot \mu_n} \cdot \frac{dy}{W} \cdot I_D$$

$$I_D \cdot \int_0^L dy = \mu_n \cdot Q_I(y) \cdot dV(y) \cdot W$$

$$\int_0^L I_D \cdot dy = \int_0^{V_{DS}} W \mu_n C_{ox}' (V_{GS} - V(y) - V_{THN}) \cdot dV(y)$$

$$KP_N = \mu_n C_{ox}'$$

$$KP_P = \mu_p \cdot C_{ox}'$$

$V(L)$

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

$$I_D \cdot L = \int_0^{V_{DD}} W \cdot \mu_n C_{ox} \left[V_{GS} \cdot dV(y) - V(y) \cdot dV(y) - V_{THN} \, dV(y) \right]$$

$$I_D \cdot L = W \cdot \mu_N \cdot C_{ox} \cdot \left[\int_0^{V_{DS}} V_{GS} \cdot dV(y) - \int_0^{V_{DS}} V(y) \cdot dV(y) - \int_0^{V_{DS}} V_{THN} \cdot dV(y) \right]$$

$V_{GS} \cdot V_{DS}$

$\frac{1}{2} V_{DS}^2$

$V_{THN} \cdot V_{DS}$

Triode

$$I_D = \mu_N \cdot C_{ox} \cdot \frac{W}{L} \left[(V_{GS} - V_{THN}) V_{DS} - \frac{V_{DS}^2}{2} \right]$$

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5) $V_{GS} > V_{THN}$, $V_{DS} \leq V_{GS} - V_{THN}$

SATuration

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

$$I_D = \mu_n C_{ox}' \cdot \frac{W}{L}\left[(V_{GS}-V_{THN})(V_{GS}-V_{THN}) - \frac{(V_{GS}-V_{THN})^2}{2}\right]$$

$$\beta_N = \mu_n \cdot C_{ox}' \cdot \frac{W}{L}$$

$$= K_{PN} \cdot \frac{W}{L}$$

$$I_D = \mu_n \cdot C_{ox}' \cdot \frac{W}{L} \frac{(V_{GS} - V_{THN})^2}{2}$$

$$V_{GS} > V_{THN}$$

$$V_{DS} \geq V_{GS} - V_{THN}$$

SATuration

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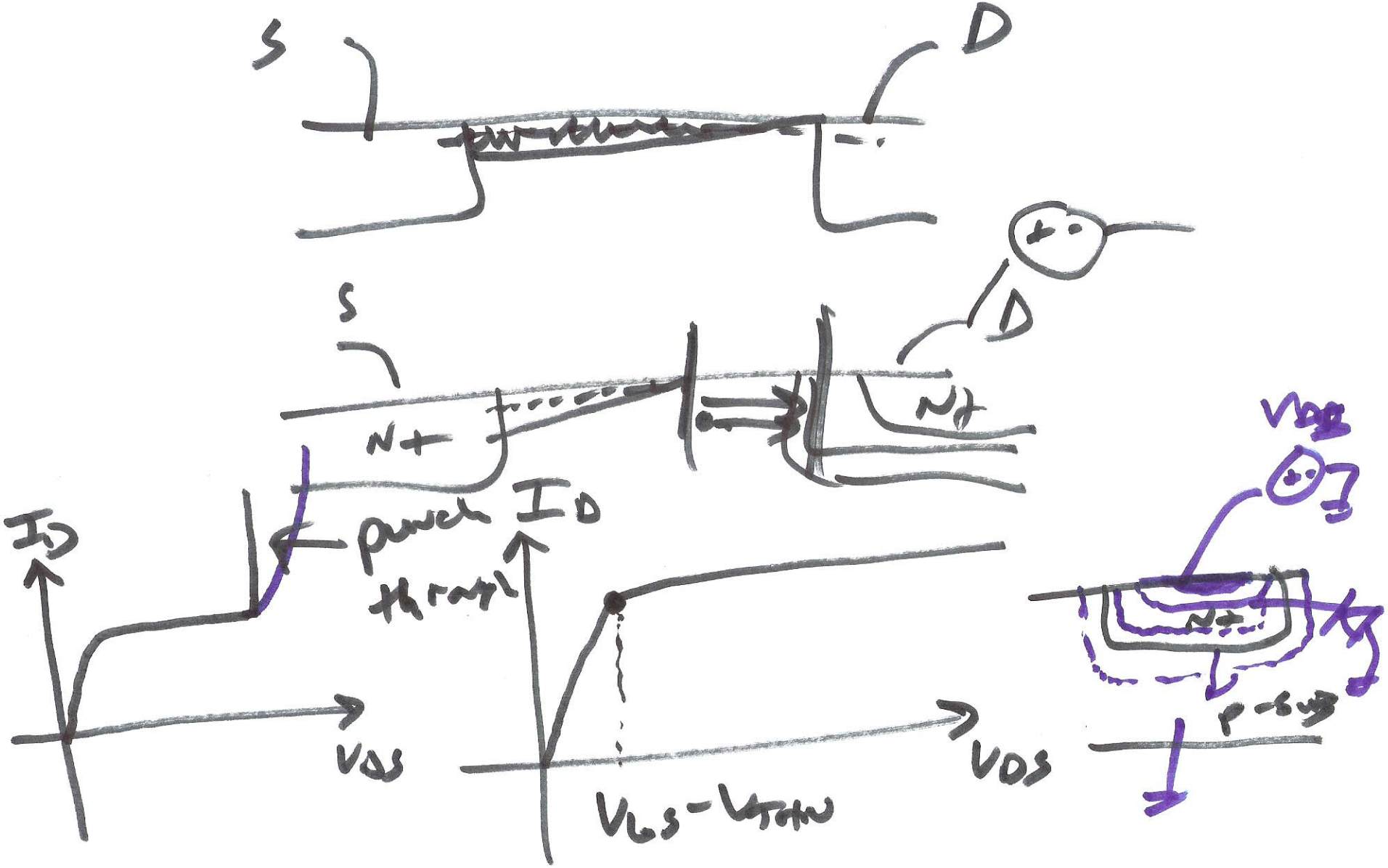
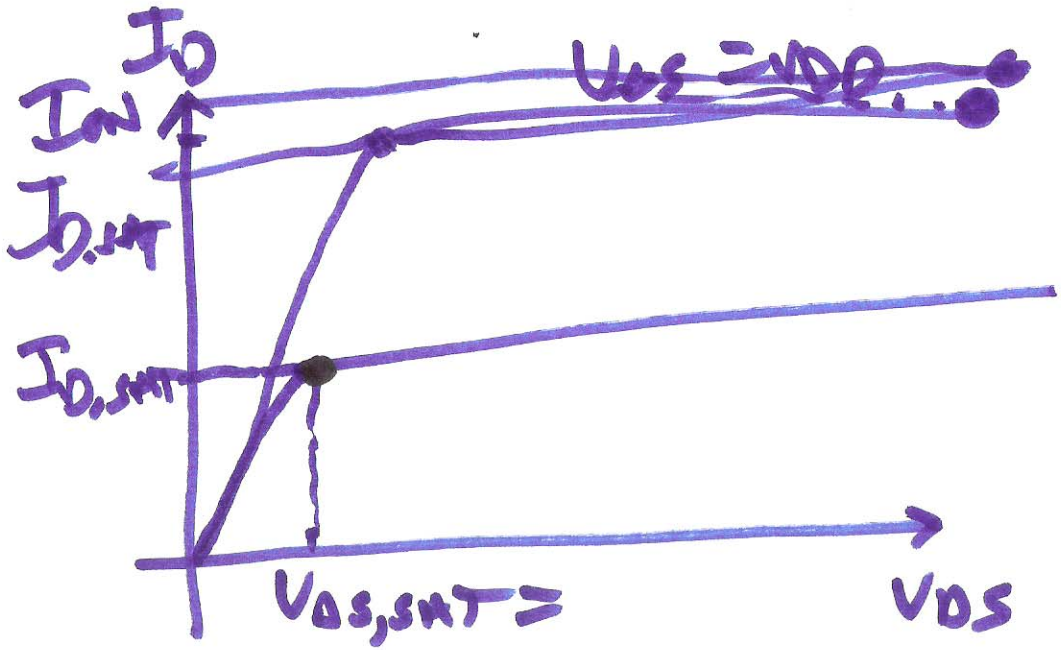
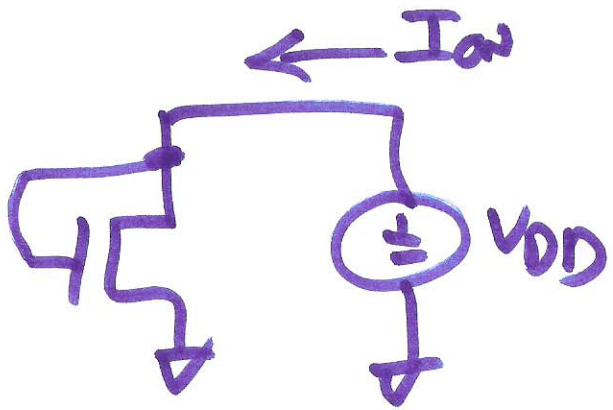
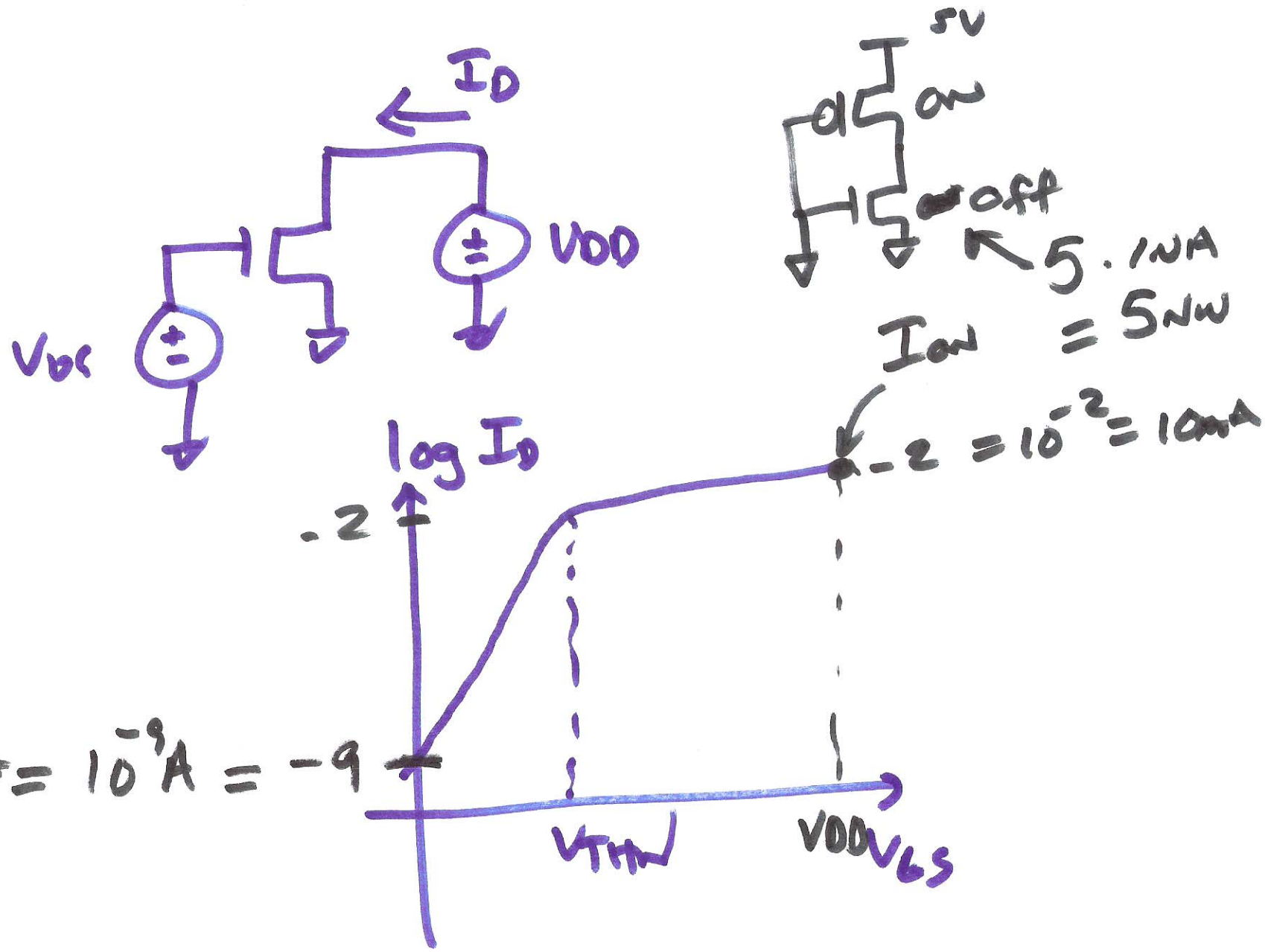

S
D
S
D
N+
N+
I_D
pinch
through
I_D
V_{DS}
$V_{GS}-V_{TH}$
V_{DS}
V_{GS}
N+
P-sub



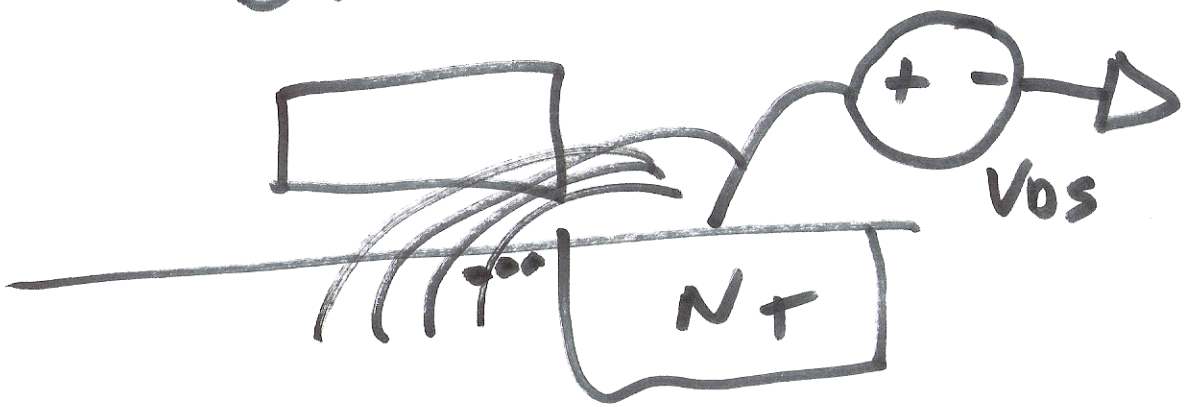


$I_{Drive} = I_{ON} \cdot W$

$\frac{mA}{\mu m}$

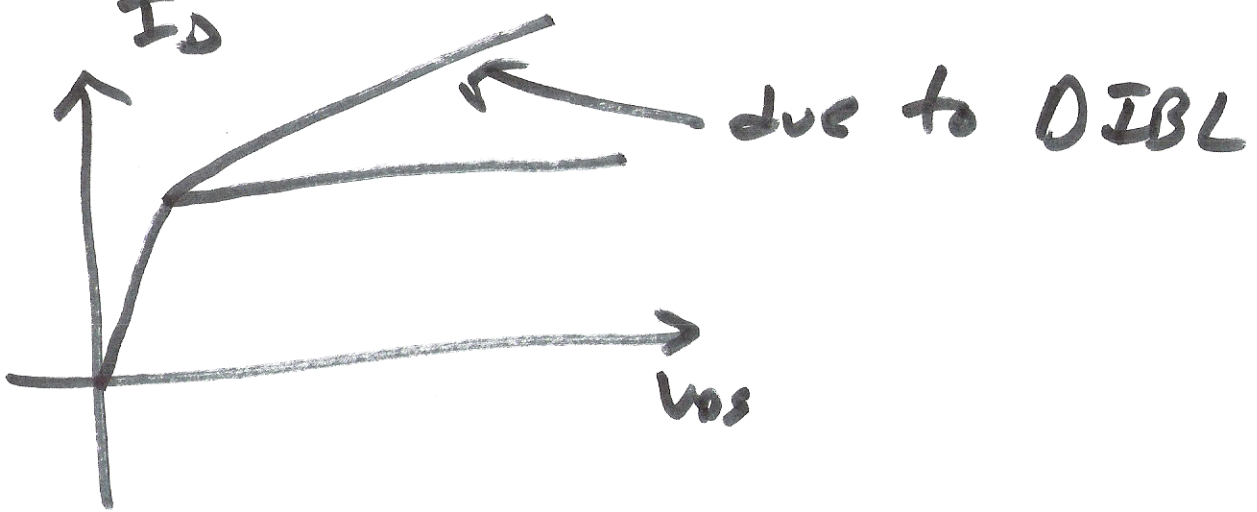

I_D
V_{DD}
V_{DC}
5V
on
off
5.1nA
I_{on} = 5nW
10^{-2} = 10mA
log I_D
-2
-9
1nA = 10^{-9}A = -9
V_{THN}
V_{DD}
V_{GS}

DIBL - Drain Induced Barrier Lowering (dibble)

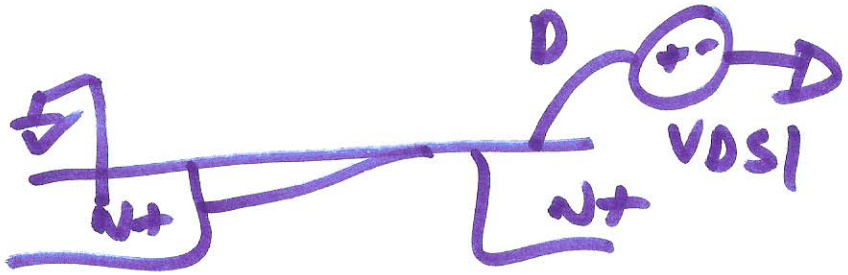


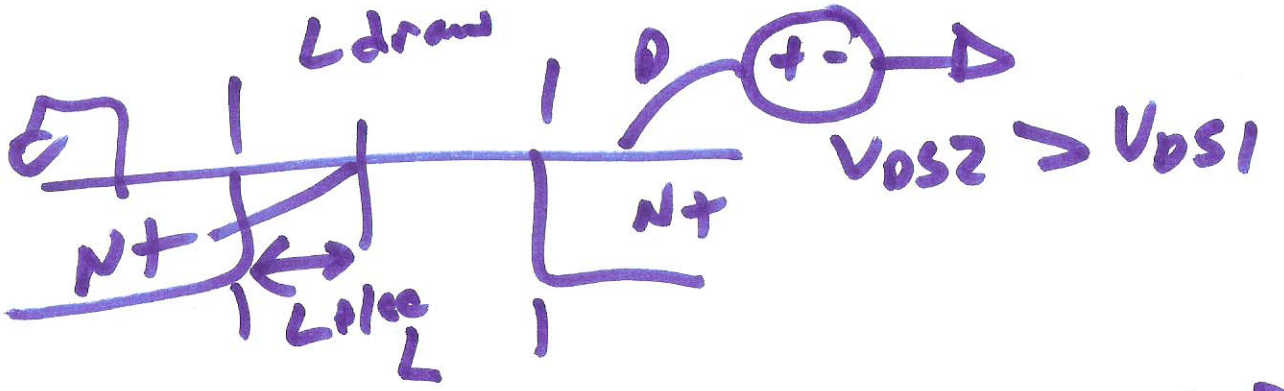
$$I_D = \frac{\beta_N}{2}\left(V_{GS} - V_{TH}\right)^2$$

$V_{DS}\uparrow$ $V_{TH}\downarrow$



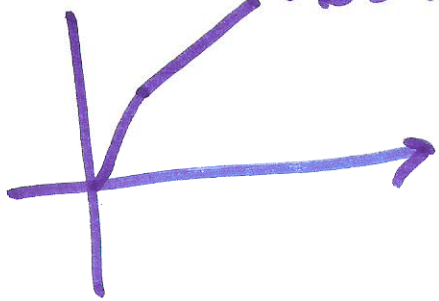
Channel length Modulation (CLM)





$$I_D = KP_N \cdot \frac{W}{L_{effective}} \left(V_{GS} - V_{TH_N}\right)^2$$

$V_{DS} \nearrow \quad L_{effective} \searrow \quad I_D \nearrow$



$$I_D = \frac{KP_n}{2} \cdot \frac{W}{L}\left(V_{GS} - V_{THN}\right)^2 \cdot \left(1 + \lambda\left(V_{DS_s} - V_{DS,SAT}\right)\right)$$

$$\lambda \rightarrow V^{-1}$$

$$I_D = I_{D,SAT} \cdot \left(1 + \lambda\left(V_{DS} - V_{DS,SAT}\right)\right)$$

$$I_{D,SAT} = \frac{KP_n}{2} \cdot \frac{W}{L}\left(V_{GS} - V_{THN}\right)^2$$