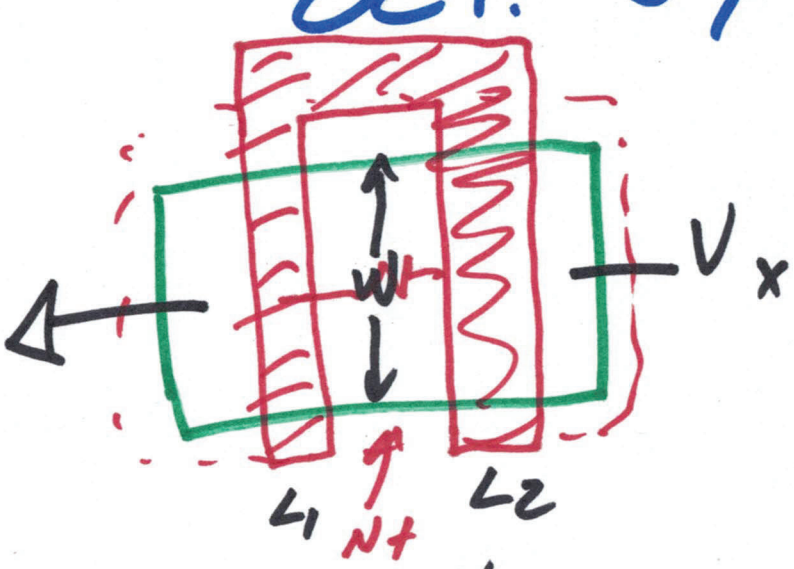
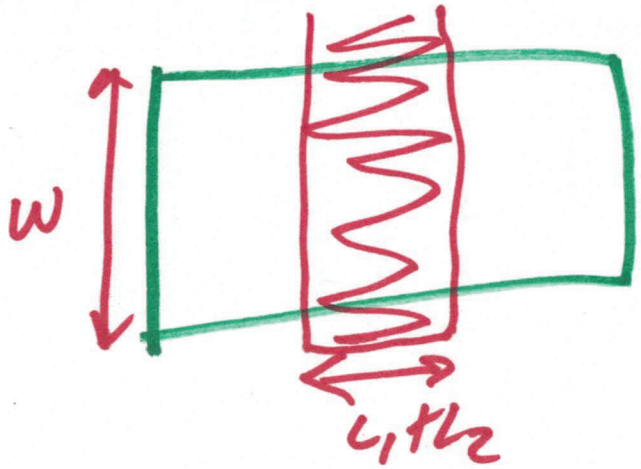
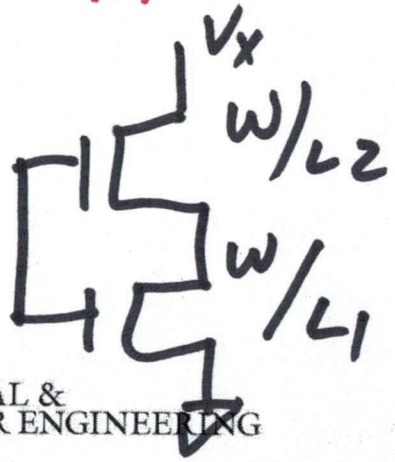
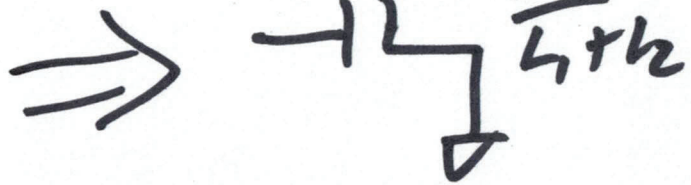
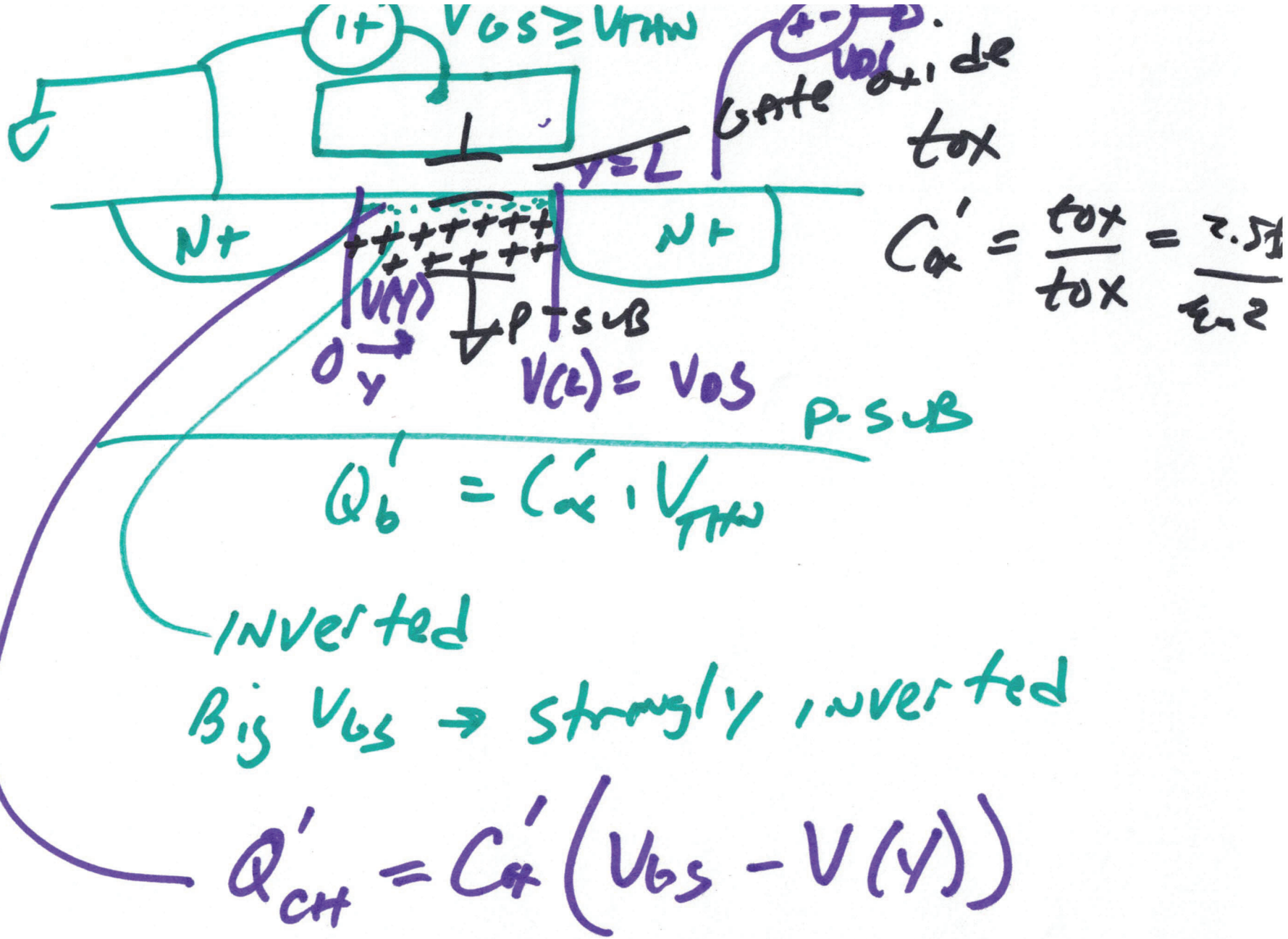
EE 421 / ELG 621
Digital IC Design
OCT. 5, 2020











$$C_{ox}' = \frac{t_{ox}}{t_{ox}} = \frac{3.5}{t_{ox}}$$

$$Q_b' = C_{ox}' \cdot V_{THN}$$

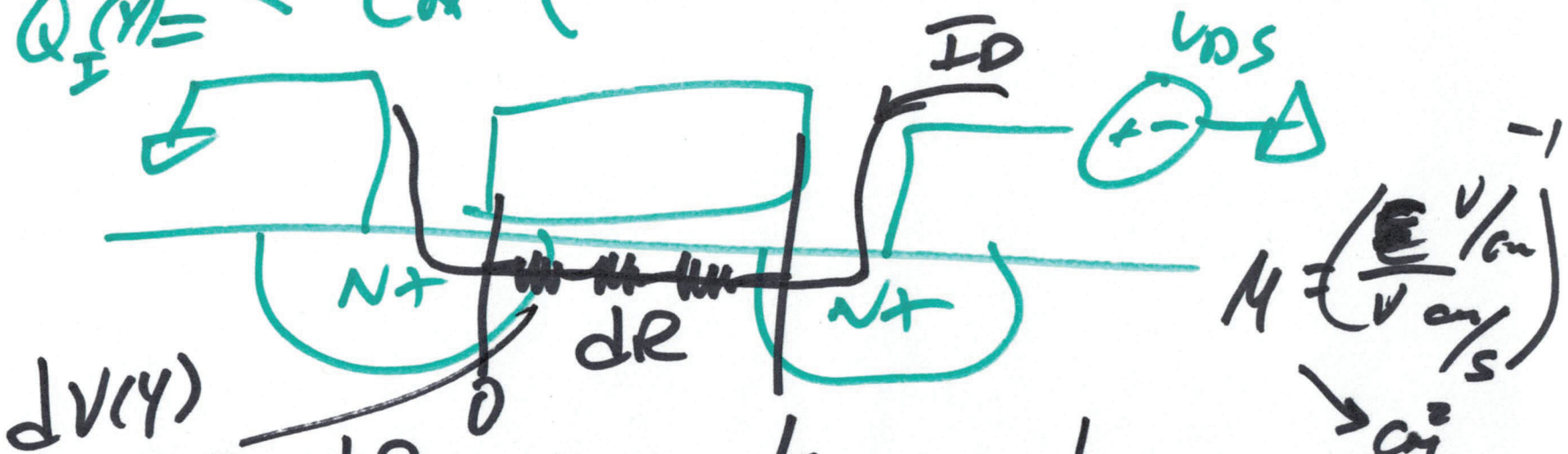
By V_{GS} → strongly inverted

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

$$Q_I'(y) = Q_{CH}'(y) = Q_b'$$

↑ inverted channel to conduct current

$$Q_I'(y) = C_{ox}' \cdot (V_{GS} - V(y) - V_{THN})$$



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

$$dR = \frac{dy}{W} \cdot \frac{1}{Q_I'(y) \cdot \mu_n}$$

$$\mu = \left(\frac{E}{V_{GS}}\right)^{-1} \rightarrow \frac{cm^2}{Vs}$$

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

$$I_d \cdot dy = W \cdot Q_I'(y) \cdot \mu_n \cdot dV(y)$$

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

$V_{GS} > V_{THN}$

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

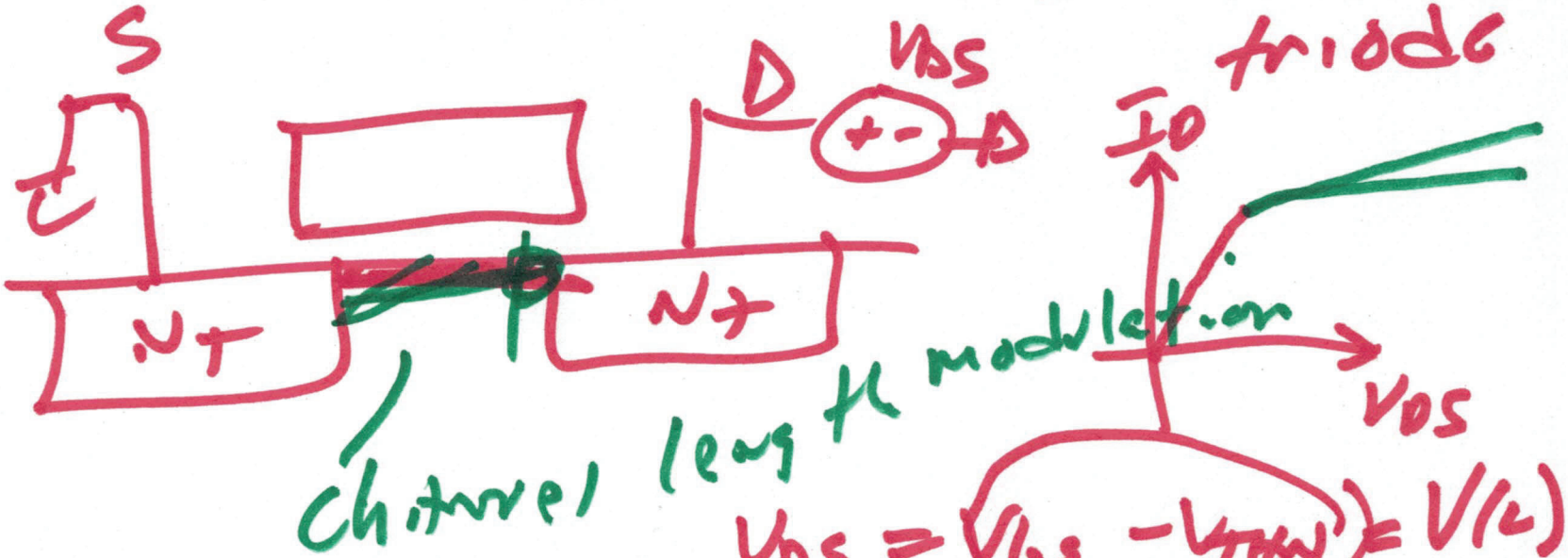
$$I_d \cdot L = W \mu_n C_{ox}' \left(V_{GS} \cdot V_{DS} - V_{THN} \cdot V_{DS} - \frac{1}{2} V_{DS}^2 \right)$$

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

triode

$$V_{DS} \geq V_{THN} \quad \& \quad \underline{V_{DS} \leq V_{GS} - V_{THN}}$$

triode



$$V_{DS} = (V_{GS} - V_{THN}) = V(L)$$

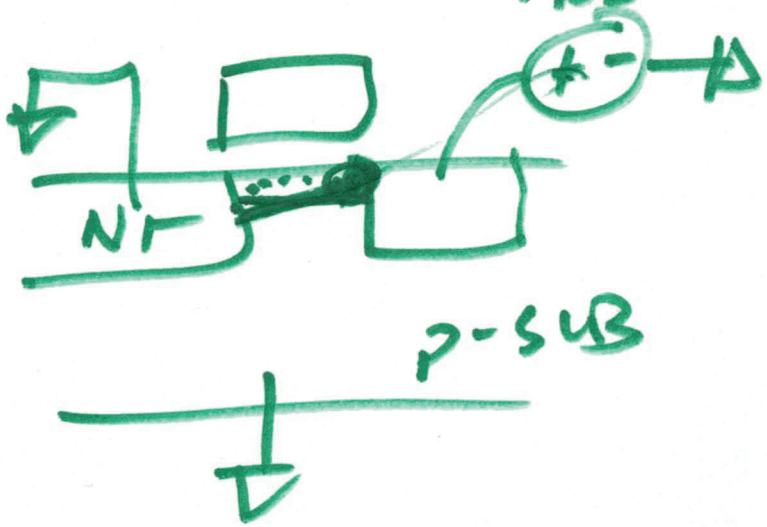
$$Q_I' = C_{ox}' \cdot (V_{GS} - V(y) - V_{THN})$$

$$Q_I' \rightarrow 0$$

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

$$x^2 - \frac{1}{2}x^2 = \frac{1}{2}x^2$$

$$I_D = \frac{W}{L} \underbrace{\frac{\mu_n \cdot C_{ox}'}{2}}_{K_{PN}} (V_{GS} - V_{TH})^2$$



$V_{GS} > V_{TH}$

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

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

$$I_D = \frac{W}{L_{elec}} \cdot \frac{\mu_n C_{ox}}{2} (V_{GS} - V_{TH})^2$$

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

$V_{DS,SAT} =$

$V_{GS} - V_{TH}$

L_{elec}

I_D

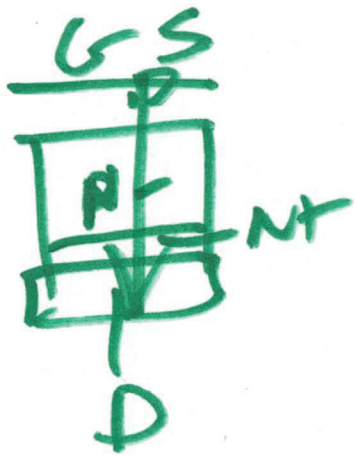
V_{DS}

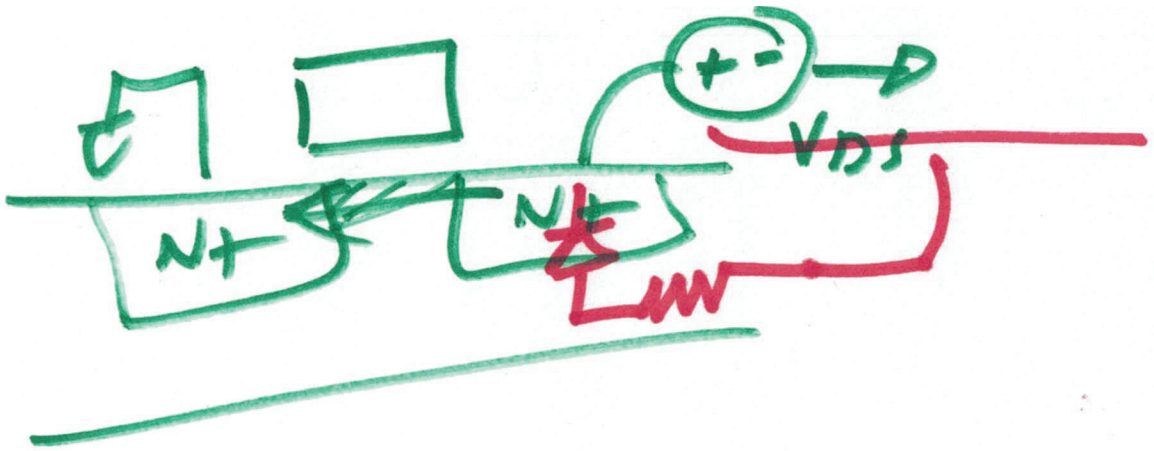
Breakdown

punch through

$\lambda (V_{DS} - V_{DS,SAT})$

channel modulation factor, $\frac{1}{V_A}$

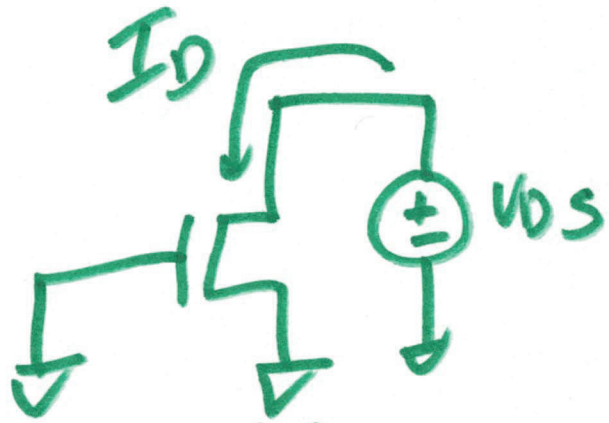



+
-
V_{DS}
N+
N+

ON / Off currents

off current measured

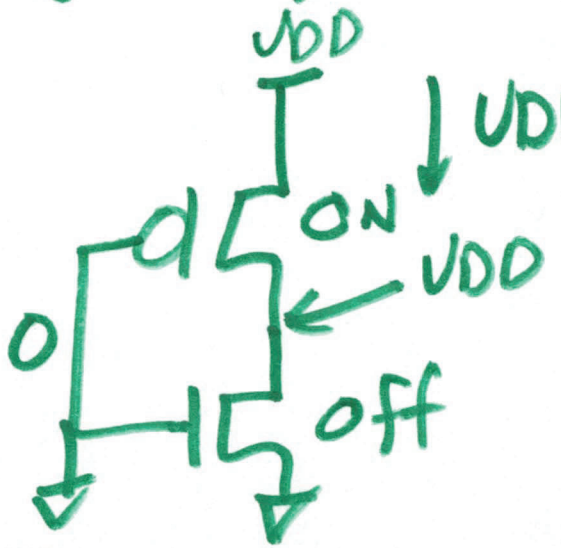
$V_{DS} = VDD$ & $V_{GS} = 0$

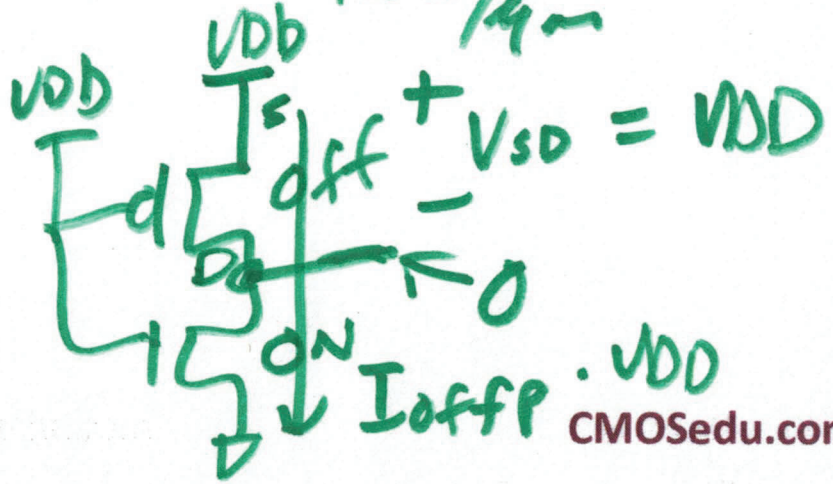


$I_D = I_{D,Off} \cdot W$

100 nA/μm

10 nA/μm





ON

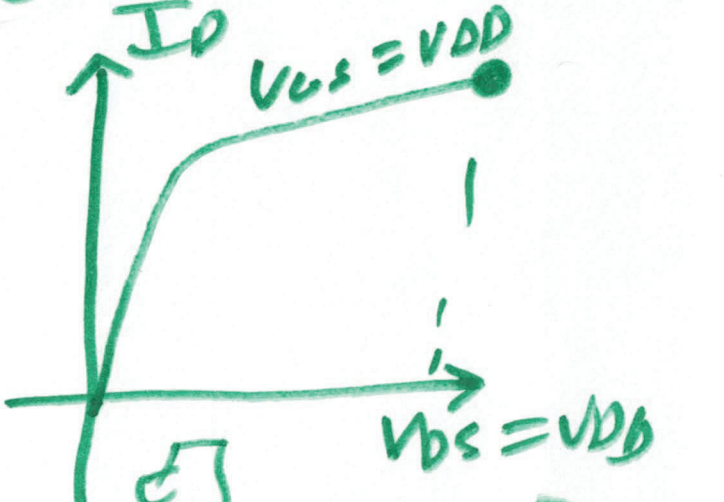
drive current
ON current

VDD

VDD

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

$\mu A/\mu m$



off current