EE 421 / ECG 621

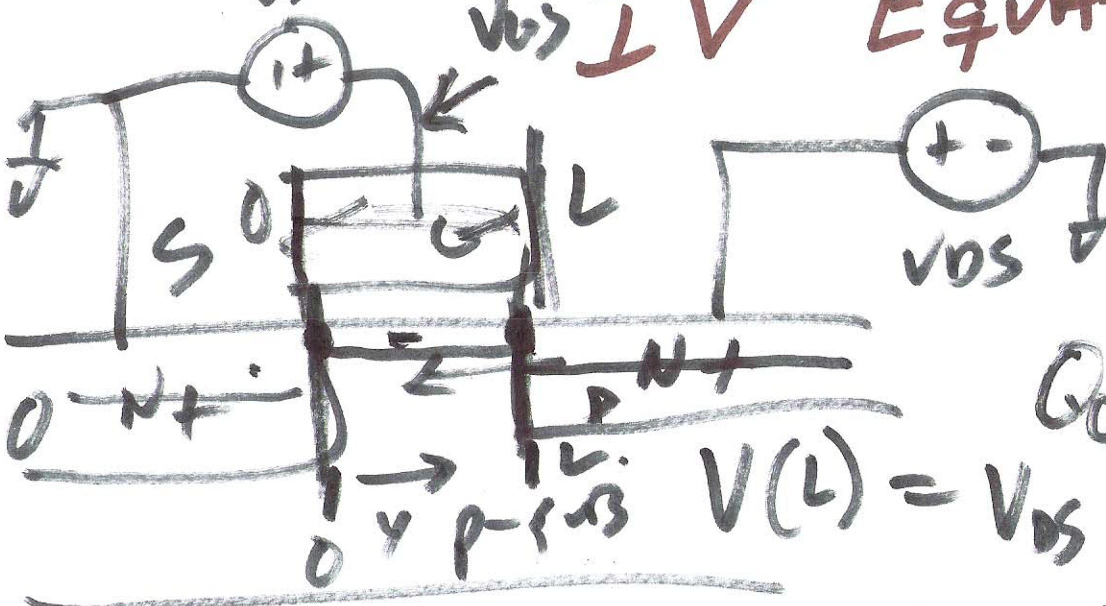
Digital IC Design

Oct. 22, 2014

IV Equations of MOSFETs

$$I_D = \frac{KP}{2}\frac{W}{L}(V_{GS} - V_{THN})^2$$

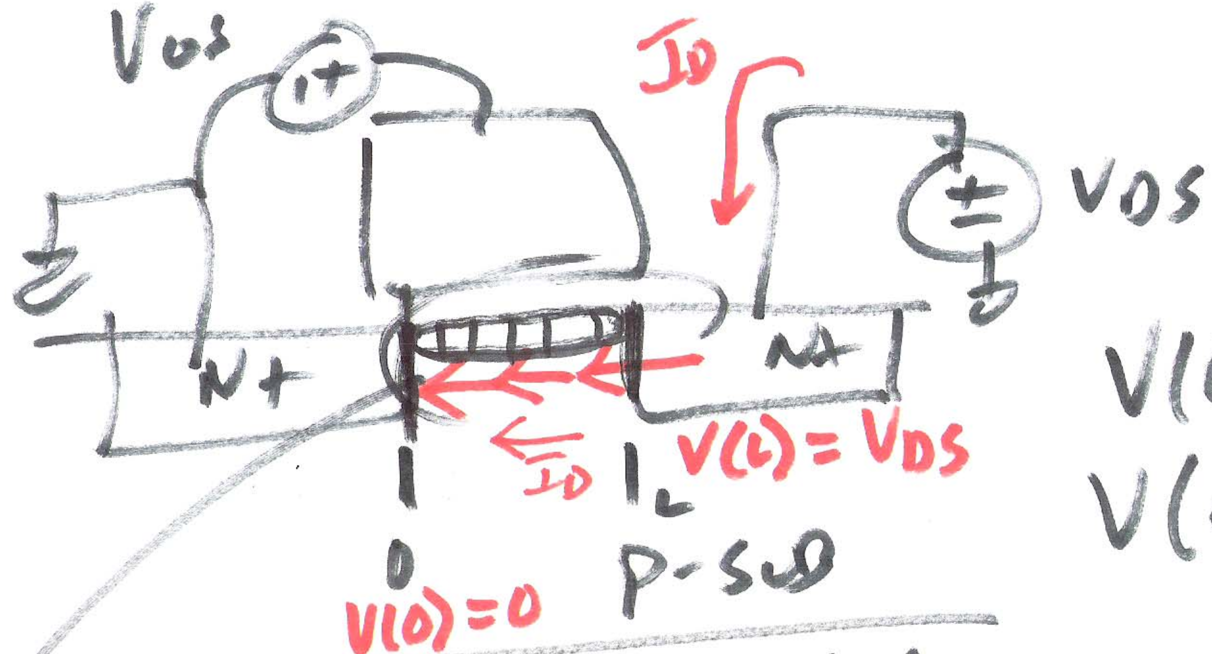
$V_{GS} \geq V_{THN}$



$$Q'_{CH}(y) = C'_{ox}(V_{GS} - V(y))$$

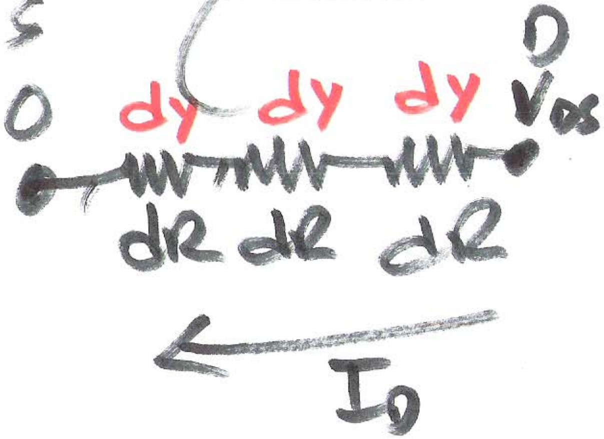
$$V(L) = V_{DS}$$

$$V(0) = 0$$



$V(0) = 0$

$V(L) = V_{DS}$



$$Q'_{CH} = C'_{ox}\left(V_{GS} - V(y)\right)$$

$$Q'_b = C'_{ox} V_{THN}$$

$$dV = I_D \, dR$$

$$\int_0^L dy = L$$

$$dR = R_{sheet} \cdot \frac{dy}{W}$$

$$\frac{1}{\mu_n\left(Q'_{CH} - Q'_b\right)}$$

Q'_I

$$\int_0^{V_{DS}} dV(y) = I_D\,dR = \int_0^L \frac{1}{\mu_n \cdot Q_I'(y)} \cdot \frac{dy}{W} \cdot I_D$$

$$I_D \cdot dy = \mu_n\, Q_I(y) \cdot W \cdot dV(y)$$

$$= \mu_n \cdot W \left(Q_{CH}'(y) - Q_b' \right) \cdot dV(y)$$

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

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

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

$$I_D = \mu_n C'_{ox}\frac{W}{L}\left((V_{GS}-V_{THN})V_{DS} - \frac{1}{2}V_{DS}^2\right)$$

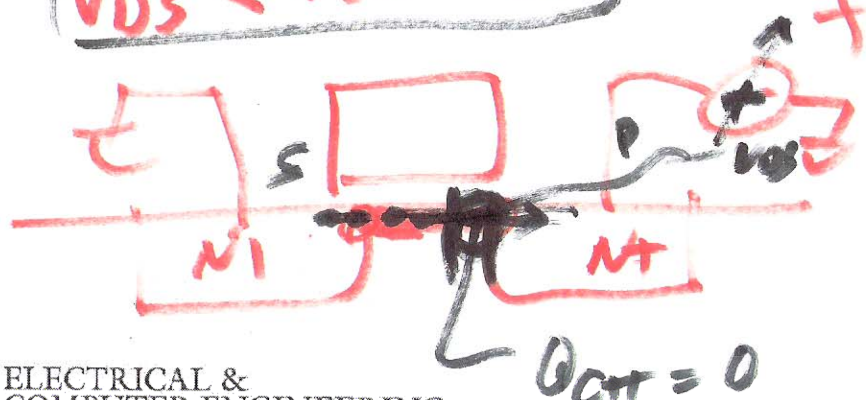
$(V_{GS} - V(y) - V_{THN})$

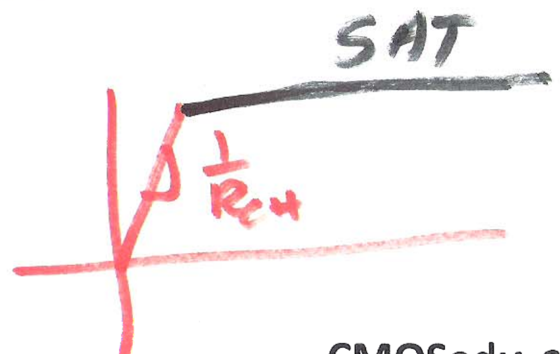
$V_{GS} > V_{THN}$

VDS

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

$V_{DS} < V_{GS} - V_{THN}$ for triode



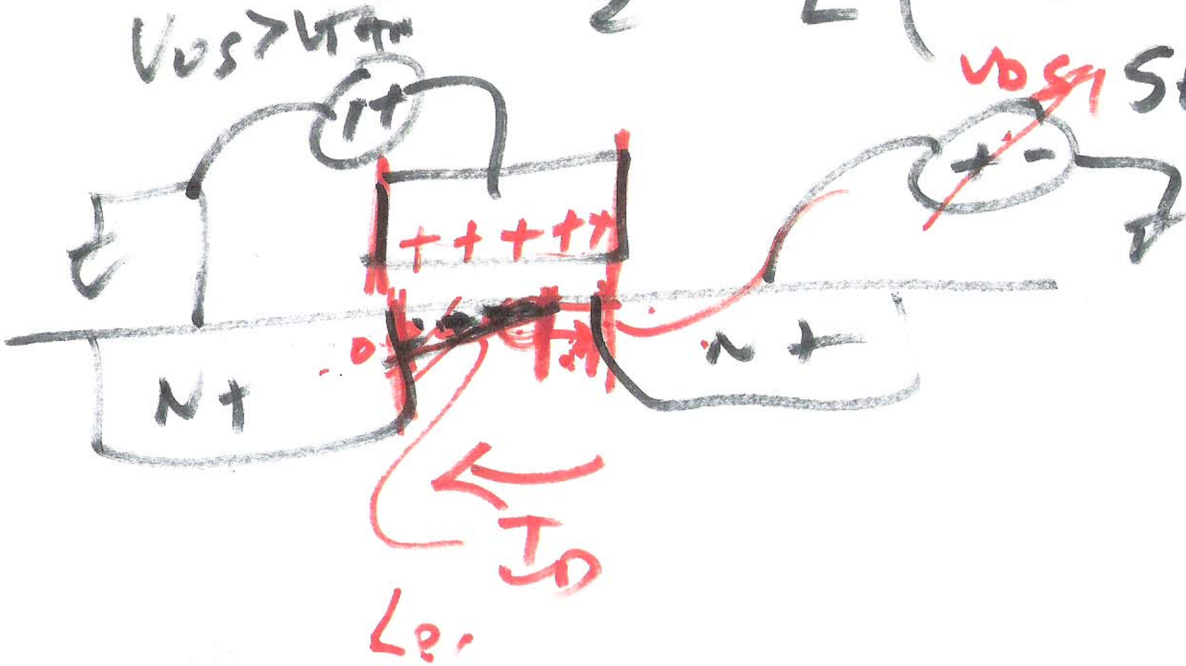


for SAT $V_{GS} > V_{THN}$, $V_{DS} \ge V_{GS} - V_{THN}$

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

$$= \frac{\mu_n C'_{ox}}{2}\cdot\frac{W}{L}\left(V_{GS}-V_{THN}\right)^2$$

SAturation!



for triode

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

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

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

$$KP_n = \mu_n C'_{ox}$$

$$\beta_n = \mu_n C'_{ox} \cdot \frac{W}{L} = KP_n \cdot \frac{W}{L}$$

for saturation

$$C'_{ox} = \frac{\epsilon_{ox}}{t_{ox}}$$

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

$$= \frac{KP_n \cdot W}{2 \quad L}(V_{GS} - V_{THN})^2$$

$$= \frac{\beta_n}{2}(V_{GS} - V_{THN})^2$$

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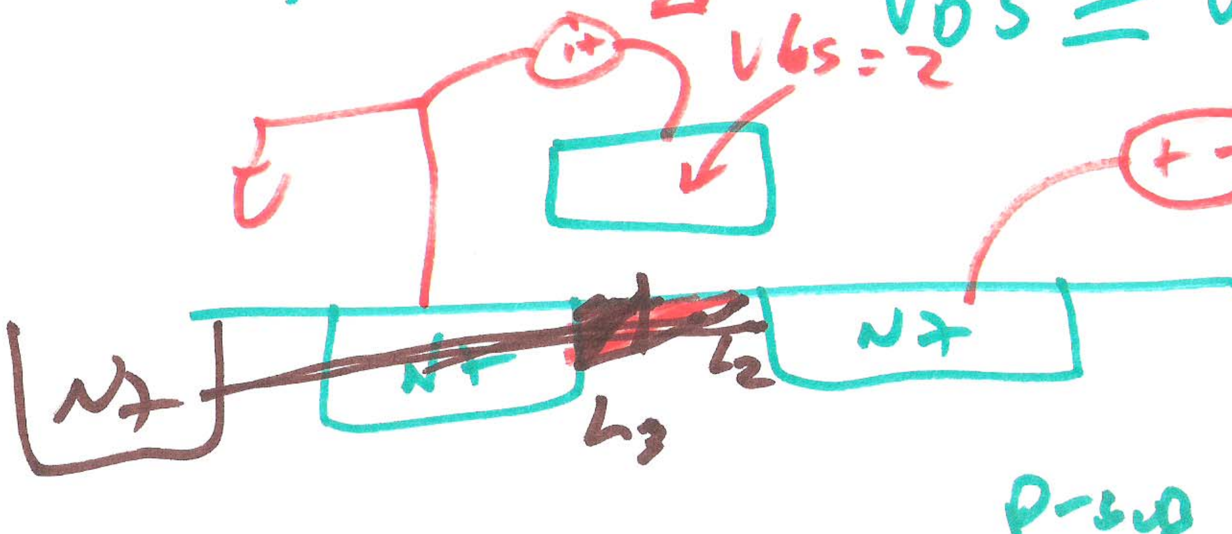
for saturation

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



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

$V_D - V_S \geq V_G - V_S$

$V_D \geq V_G - V_{THN}$ (2?, 2 − V_{THN}, .8)

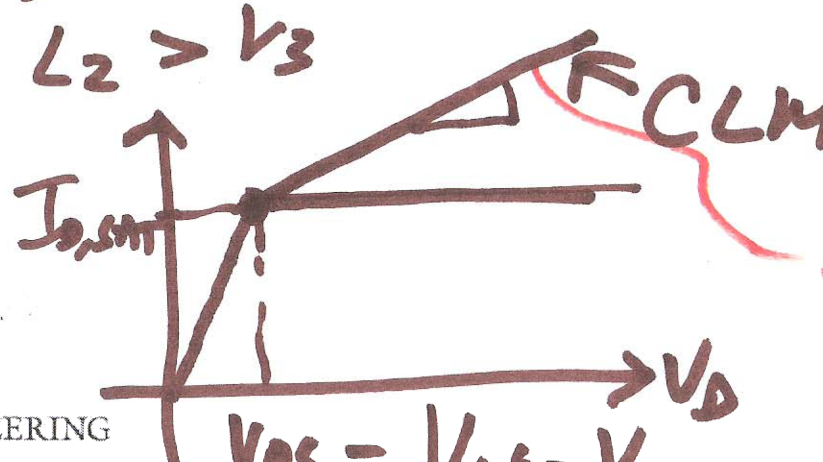
in saturation

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

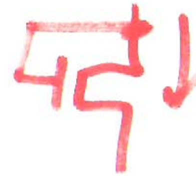
$L_2 > L_3$

$V_{GS} \leq V_{DS,SAT}$ triode

$V_{DS} \geq V_{DS,SAT}$ SAT



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



$\text{slope} = \frac{1}{\lambda I_{D,SAT}}$

$$I_D = \frac{\beta_N}{2}(V_{GS} - V_{THN})^2 (1 + \lambda(V_{DS} - V_{DS,sat}))$$

$\frac{\beta_N}{2}(V_{GS} - V_{THN})^2$ = $I_{D,sat}$

λ → channel length modulation parameter

units = $\frac{1}{V} = V^{-1}$

$$I_D = I_{D,sat}(1 + \lambda(\ \ ))$$