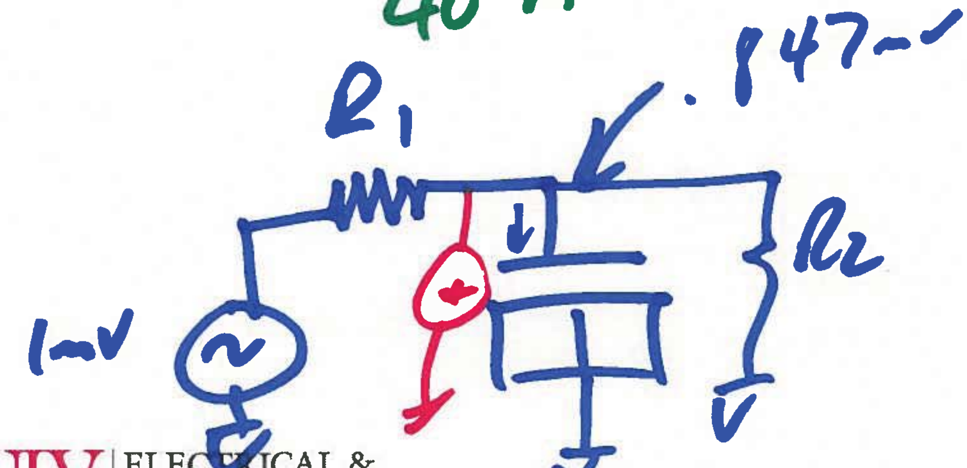
EE 421/ECG 621
Digital IC Design

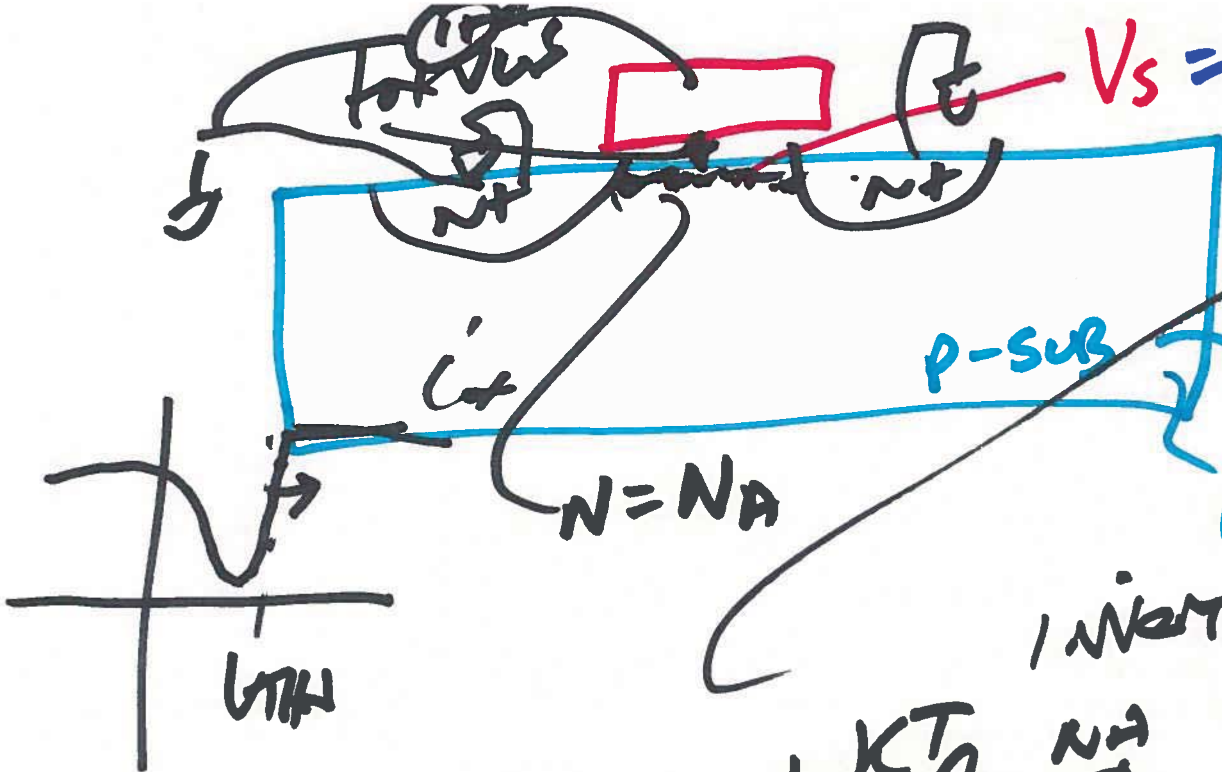
Lecture 12 OCT. 3, 2018

$$C'_{ox} = \frac{\varepsilon_o \cdot \varepsilon_{ox}}{t_{ox}} = \frac{\varepsilon_{ox} \cdot 8.85\ aF/\mu m}{\mu m} = \frac{aF}{\mu m^2}$$

$$40\ \text{Å} = 40 \times 10^{-10} = 4\ nm = 0.004\ \mu m$$



$$.847 = 1 \cdot \frac{R_2}{R_1 + R_2}$$



$V_S = -\frac{kT}{q}\ln\frac{N_A}{n_i}$ (ACC)

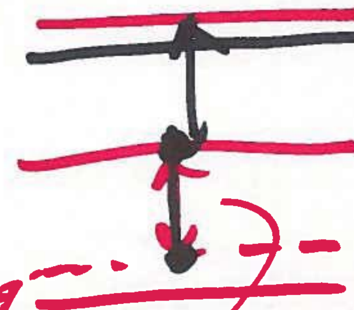
$V_S = 0$ (INT)

N_A, $\frac{\text{Atoms}}{cm^3}$

$P = N_A$

INVERTED

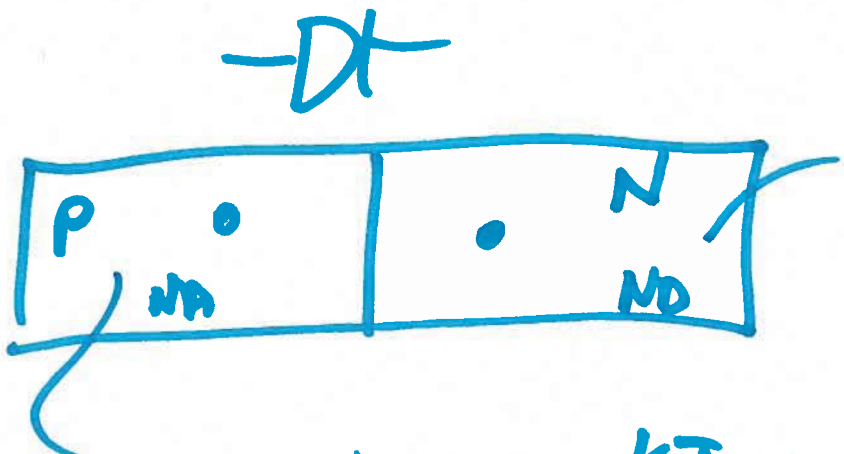
$$V_S = +\frac{kT}{q}\ln\frac{N_A}{n_i}$$



$-\frac{kT}{q}\ln\frac{N_A}{n_i}$

$$Q_b' = \sqrt{2qN_A\varepsilon_{si}\left|-2V_{fp}+V_{SB}\right|}$$

CONTACT potentials

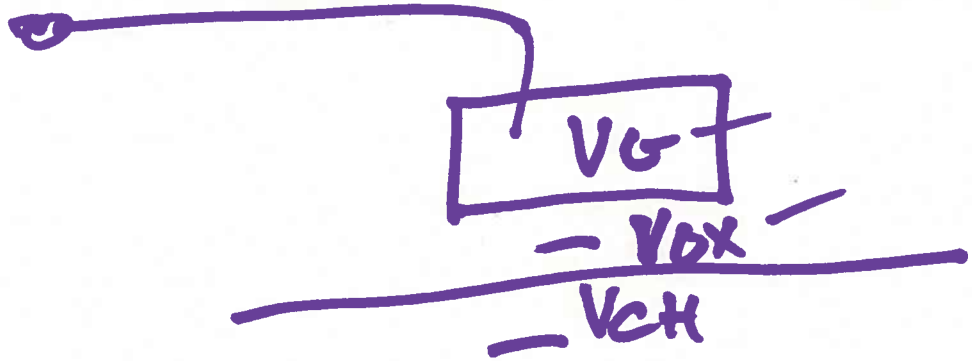


$$\frac{kT}{q}\ln\frac{N_D}{N_i}$$

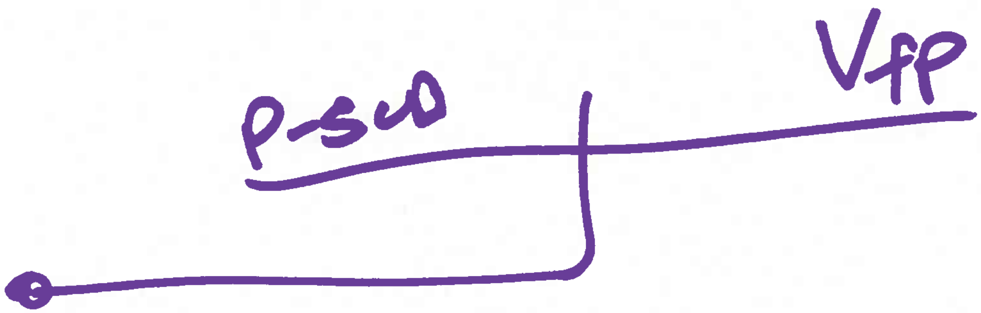
$$-\frac{kT}{q}\ln\frac{N_A}{N_i} = \frac{kT}{q}\ln\frac{N_i}{N_A}$$

$$\frac{kT}{q}\ln\frac{N_D}{N_i} - \frac{kT}{q}\ln\frac{N_i}{N_A}$$

contact potential $= \frac{kT}{q}\ln\frac{N_D N_A}{N_i}$



$$\frac{KT}{q}\ln\frac{N_{D,poly}}{N_i}$$

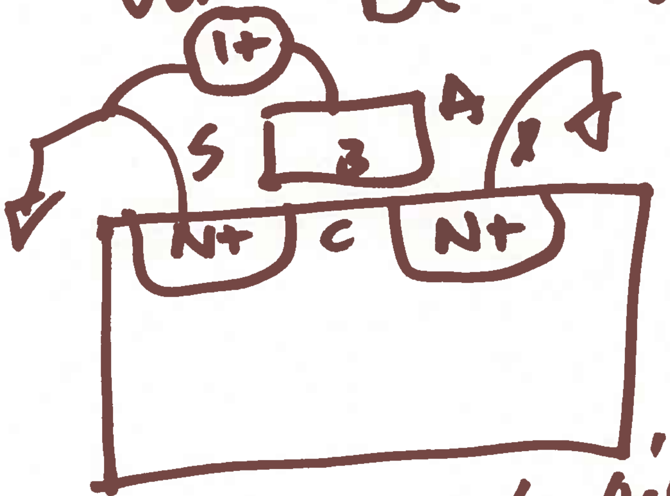


$$V_G - \cancel{V_{ox}} + \cancel{V_{ox}} - \cancel{V_{CH}} + \cancel{V_{CH}} - V_{FP}$$

Contact potential $= V_G - V_{FP} = V_{ms}$

$V_{GS} = V_{THN}$

Deriving threshold voltage

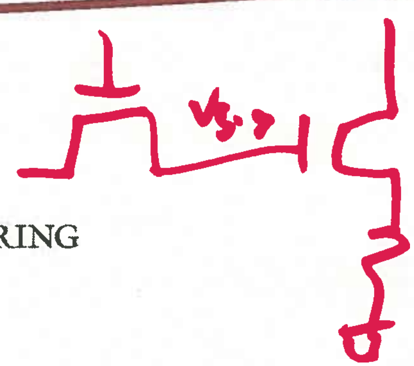


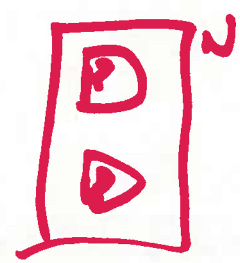
$$V_{BC} = \frac{Q_b'}{C_{ox}'}$$

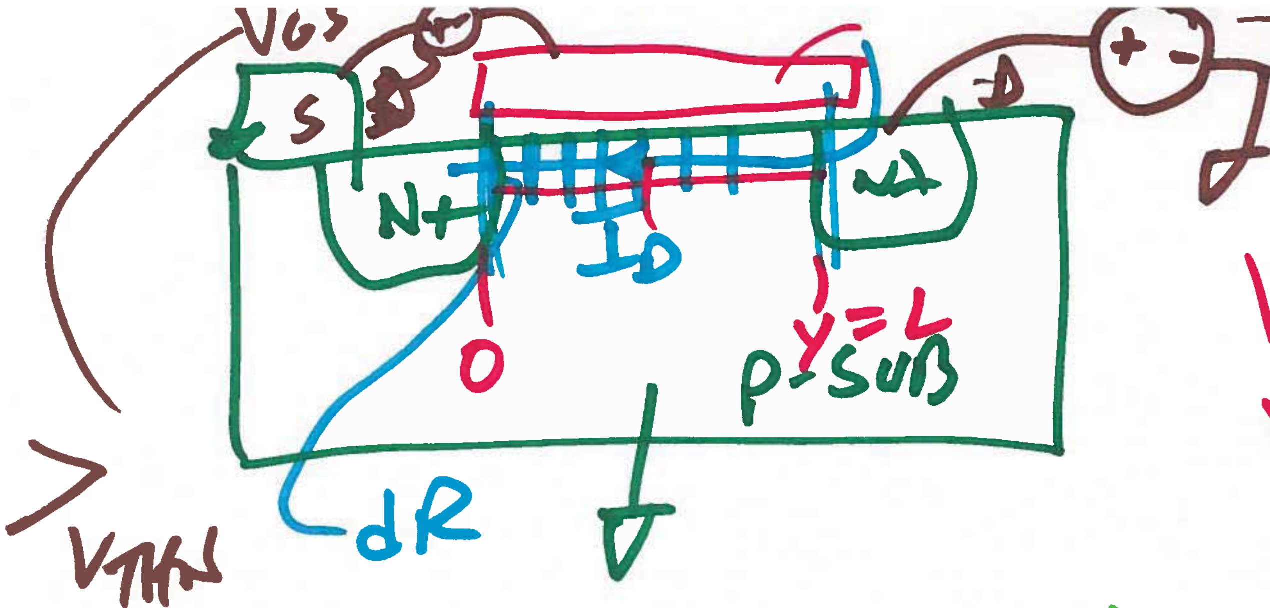
I_D vs. V_{DS}

$$V_B = \frac{Q_b' - Q_{ss}'}{C_{ox}'} - 2V_{fp}$$

$$\boxed{V_{THNO} = \frac{Q_b' - Q_{ss}'}{C_{ox}'} - 2V_{fp} - V_{ms}}$$







$$V(0) = 0$$
$$V(L) = V_{DS}$$

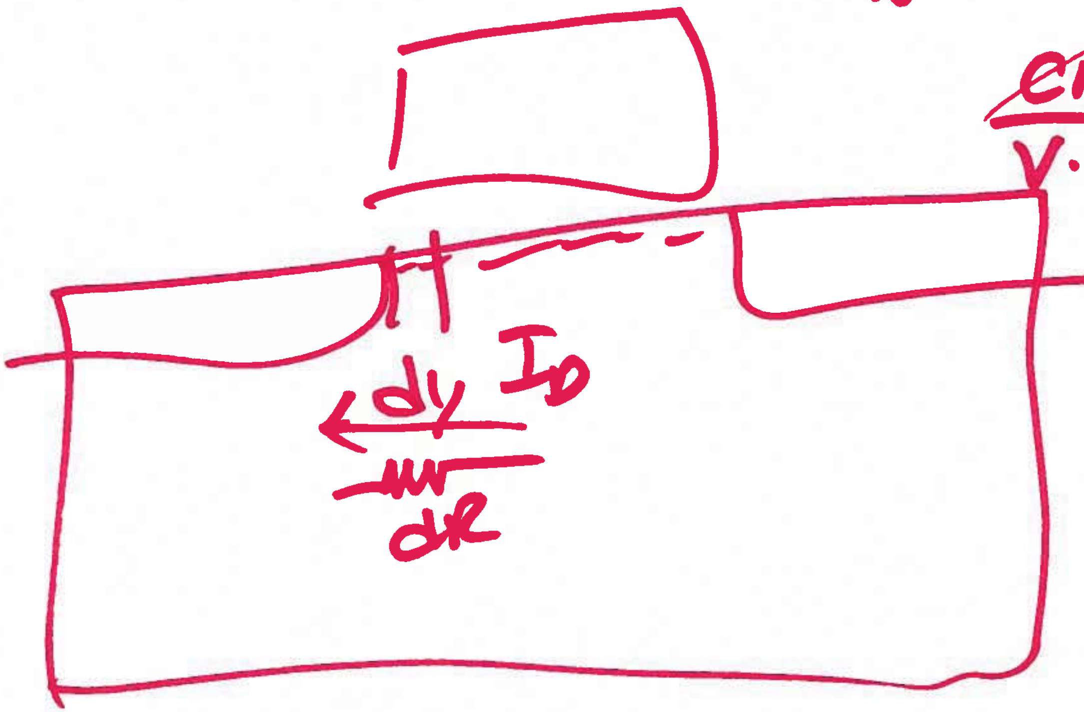
$$\int \underbrace{I_D \cdot dR}_{dV} \quad (V_{GS} - V(y)) \cdot C'_{ox} = Q'_{CH}$$

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

Charge available to conduct current

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

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



$$\frac{\cancel{cm^2}}{V \cdot s} \cdot \frac{\text{colums}}{\cancel{cm^2}}$$

$$\frac{1}{\frac{\text{colums}}{Vs}}$$

$$\frac{V}{\text{colums}/s} = \frac{V}{I} = r = R$$

$$dV(y) = \frac{I_D \cdot dy}{W \cdot \mu_N \cdot Q_I'}$$

$$Q_I' = C_{ox}'(V_{GS} - V(y) - V_{TH})$$

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

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

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

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

$$\frac{I\cdot L}{C'_{ox}}=W\cdot\mu_n\left[\int_0^{V_{DS}} V_{GS}\cdot dV(y)-\int_0^{V_{DS}} V(y)\,dV(y)-\int_0^{V_{DS}} V_{THN}\cdot dV(y)\right]$$

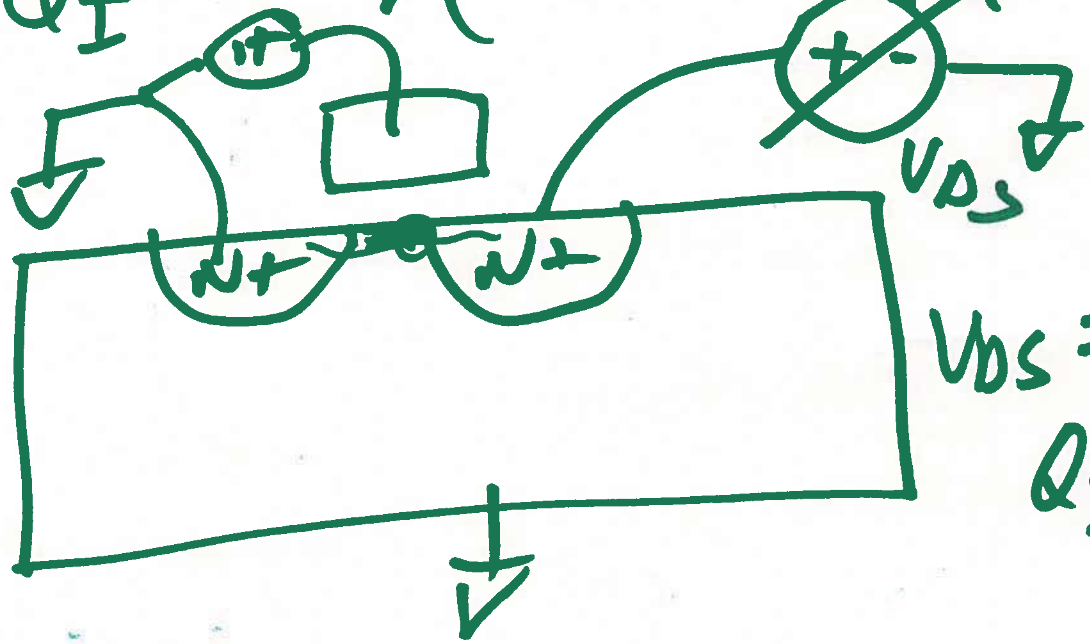
$$\frac{I\cdot L}{C'_{ox}}=W\mu_n\left[V_{GS}\cdot V_{DS}-V_{THN}\cdot V_{DS}-\frac{1}{2}V_{DS}^2\right]$$

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

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

Triode
linear
ohmic

$$Q'_I = C'_{ox}\left(V_{GS} - V_{THN} - \overset{V_{DS}}{V(y)}\right)$$



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

$Q'_I = 0$

SATURATION

$$\boxed{V_{DS} \geq V_{GS} - V_{THN}, \quad V_{GS} \geq V_{THN}}$$

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

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

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

SAT