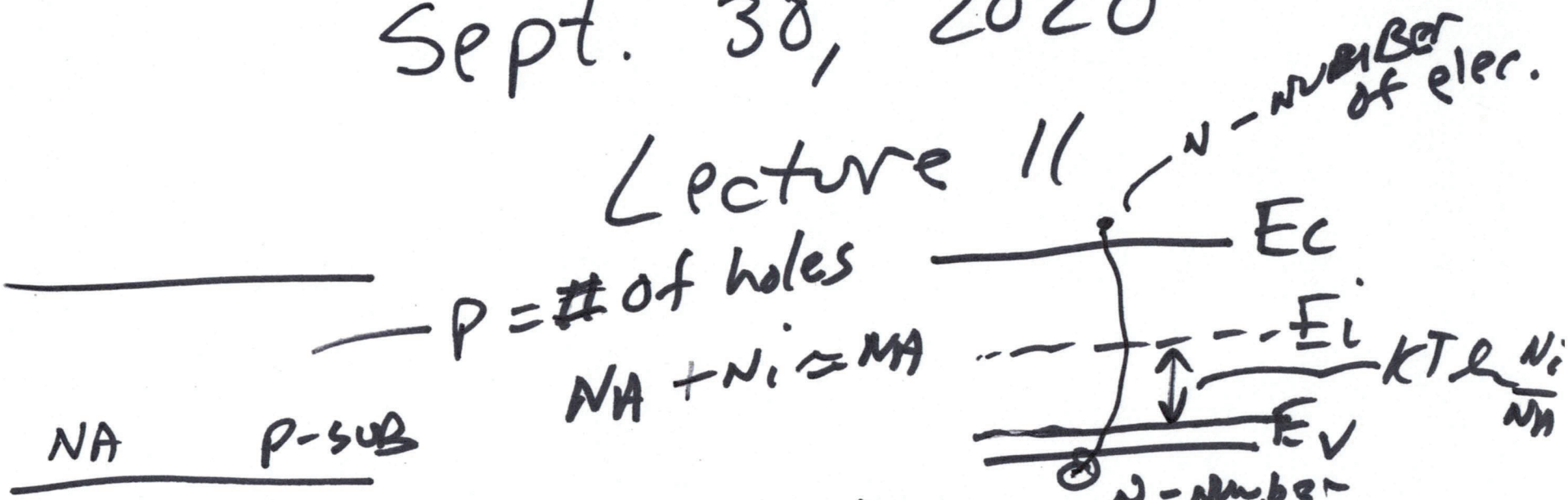
EE 421 / ECG 621

Digital IC Design

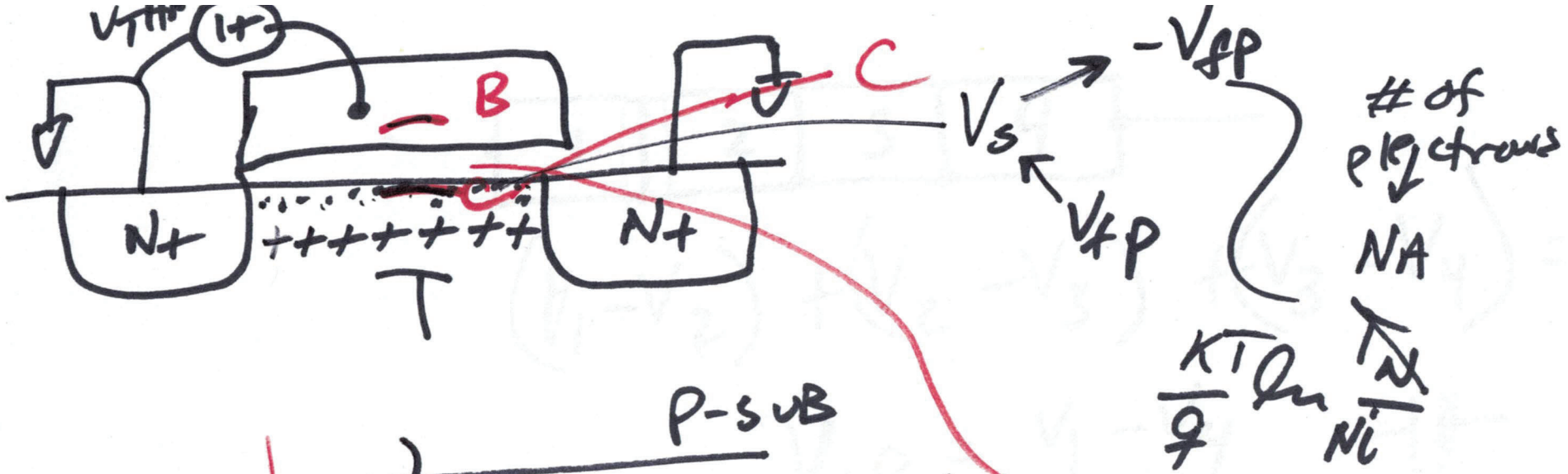
Sept. 30, 2020

Lecture 11



N_A = # of Acceptor atoms in substrate

Boron - 3 valence electrons



P-SUB

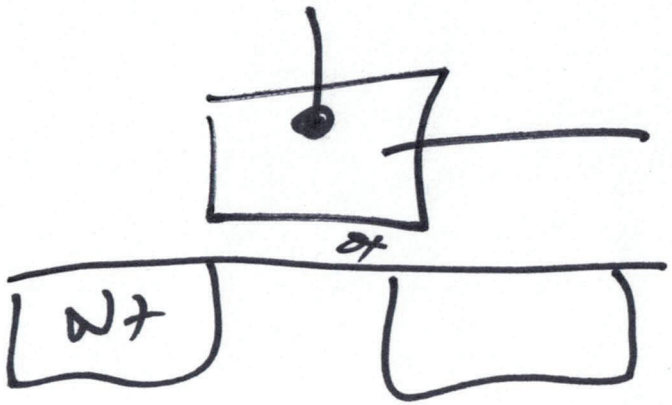
$$V_{fp} = \frac{KT}{q} \ln \frac{N_i}{N_A}$$

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

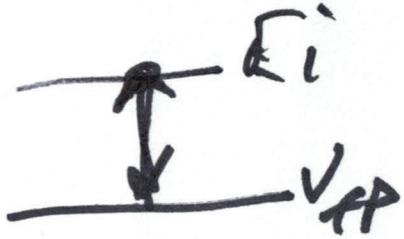
$$Q_{b0}' = \sqrt{2qN_A \cdot |-2V_{fp}|}$$

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

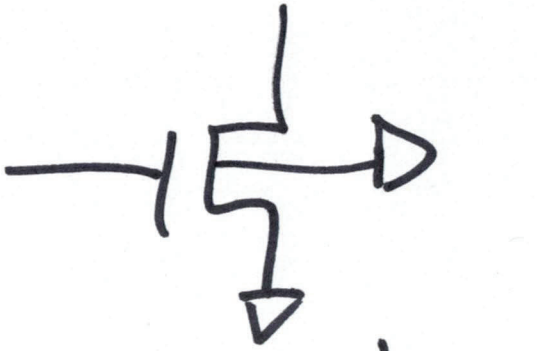
$$V_B = \underbrace{\frac{Q_b' - Q_{ss}'}{C_{ox}'}}_{B} - \underbrace{V_s}_{C} \Rightarrow \frac{Q_b'}{C_{ox}'} - 2V_{fp}$$

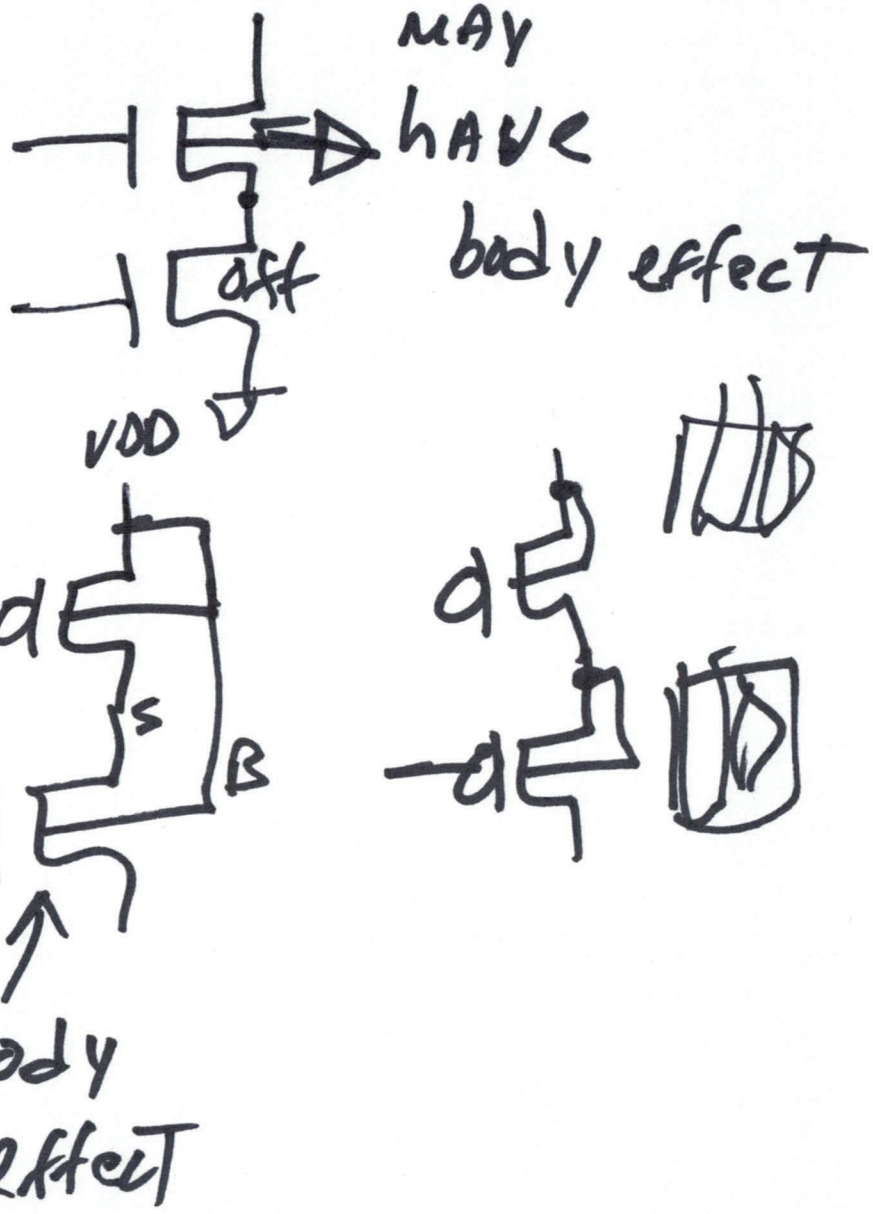


$$N_{D,Poly} = \frac{kT}{q} \ln \frac{N_{D,Poly}}{n_i}$$

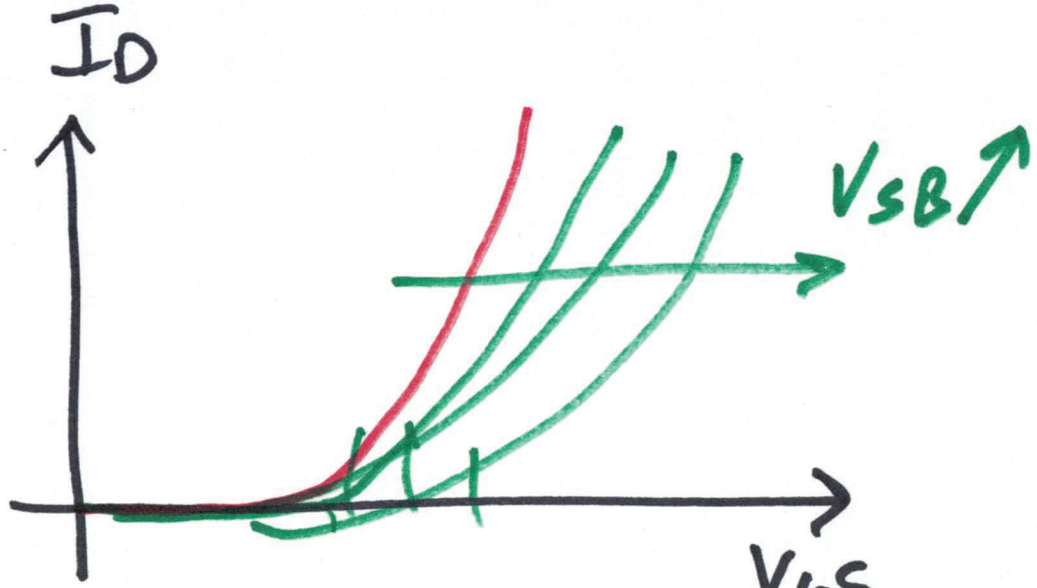


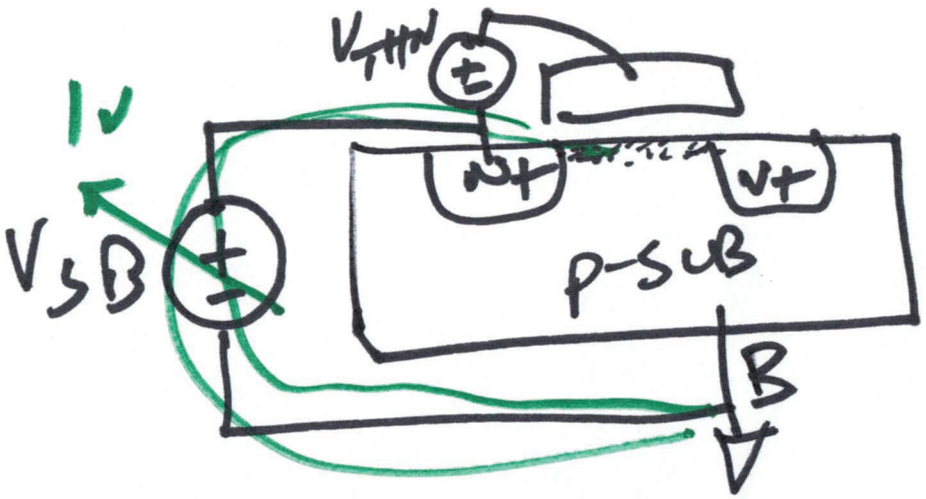
$$V_{ms} = \frac{kT}{q} \ln \frac{N_{D,Poly}}{n_i} - \frac{kT}{q} \ln \frac{N_i}{N_A}$$


NO body
effect

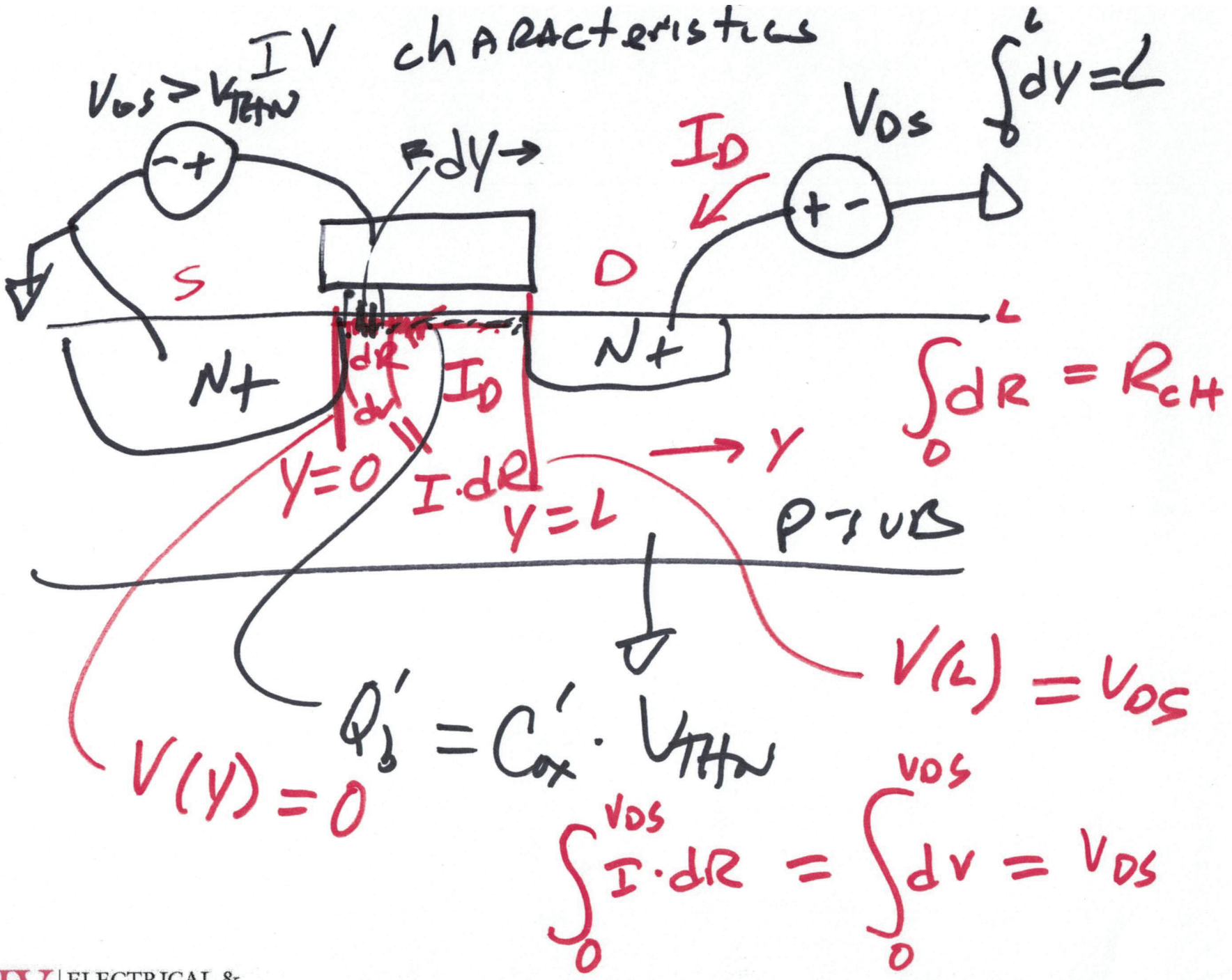

MAY
have
body effect
off
VDD
d
s
B
d
body
effect
d
d

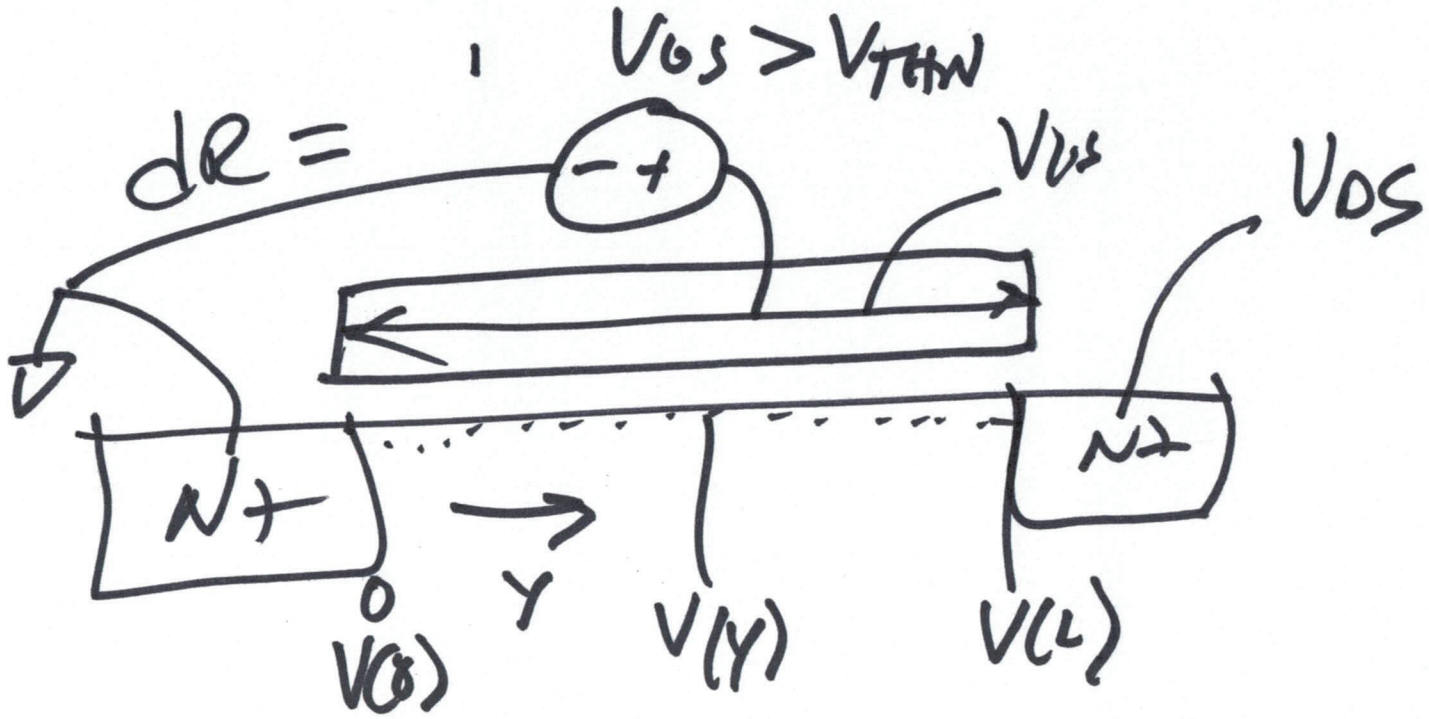
Body effecT





IV characteristics





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

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

$$Q_I' = Q_{CH}' - Q_b' = C_{ox}' \left(V_{GS} - V(y) - V_{THN} \right)$$

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

μ_N: mobility $\left(\frac{cm^2}{V \cdot s}\right)$ = $\frac{\text{speed}}{\text{electric field}}$

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

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

$$I_D \cdot L =$$

$KP_N = \mu_N \cdot C_{ox}'$

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

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

$$= W \mu_n C'_{ox} \left[\int_0^{V_{DS}} V_{GS} \cdot dV(y) - \int_0^{V_{DS}} V(y) dV(y) \right.$$

$$\left. - \int_0^{V_{DS}} V_{THN} \cdot dV(y) \right]$$

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

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

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

$$I_D \cdot L = W \mu_N C_{ox}' \left(V_{GS} V_{DS} - \frac{1}{2} V_{DS}^2 - V_{DS} V_{TH,N} \right)$$

$$I_D = \frac{W}{L} \mu_N C_{ox}' \left((V_{GS} - V_{TH,N}) V_{DS} - \frac{1}{2} V_{DS}^2 \right)$$

triode

$V_{GS} > V_{TH,N}$

$V_{DS} \leq V_{GS} - V_{TH,N}$

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

$$I_D = \frac{W}{L} \frac{\mu_N C_{ox}'}{2} \underbrace{\left(V_{GS} - V_{TH,N} \right)^2}_{= V_{DS}}$$

saturated