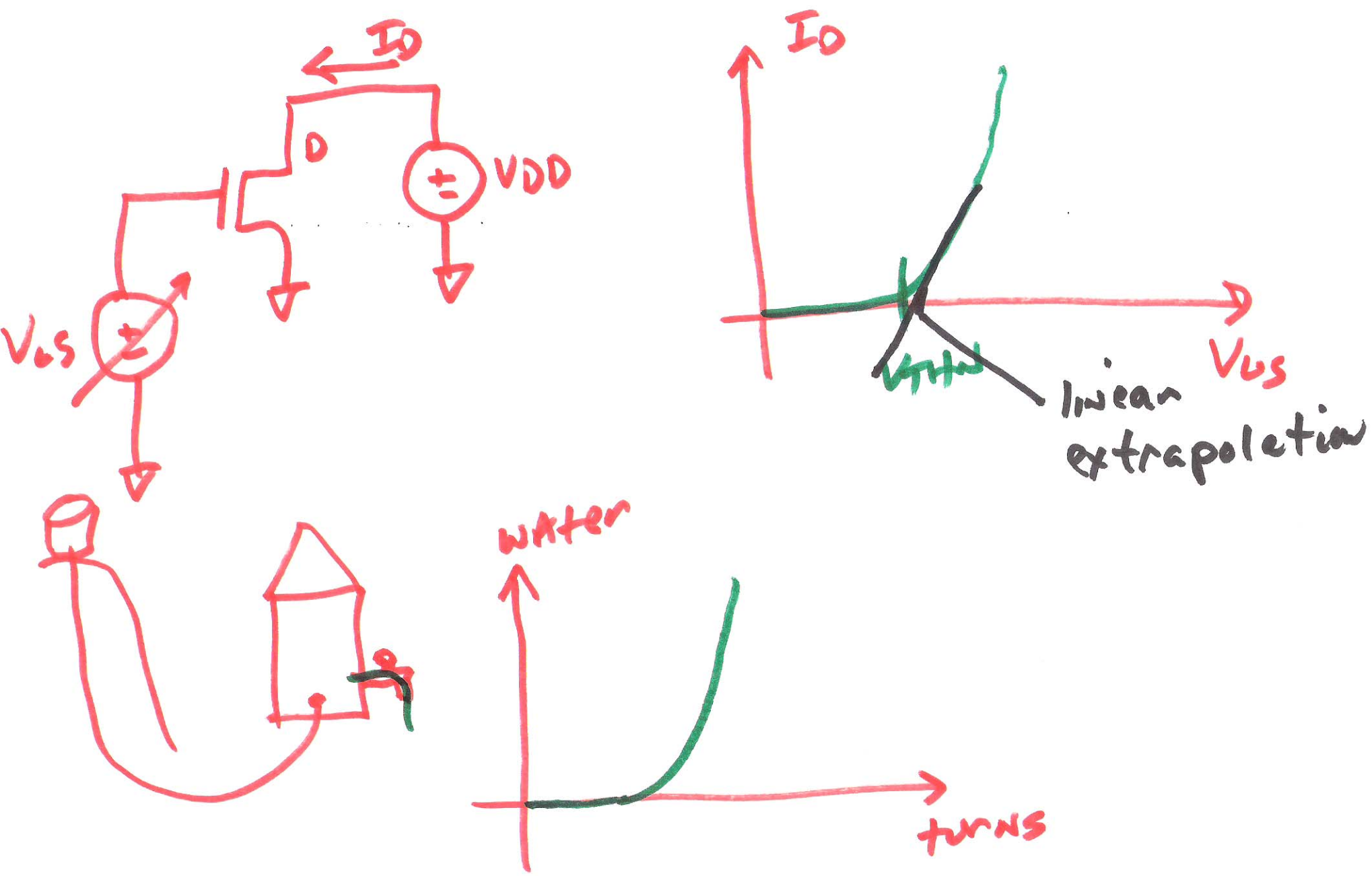
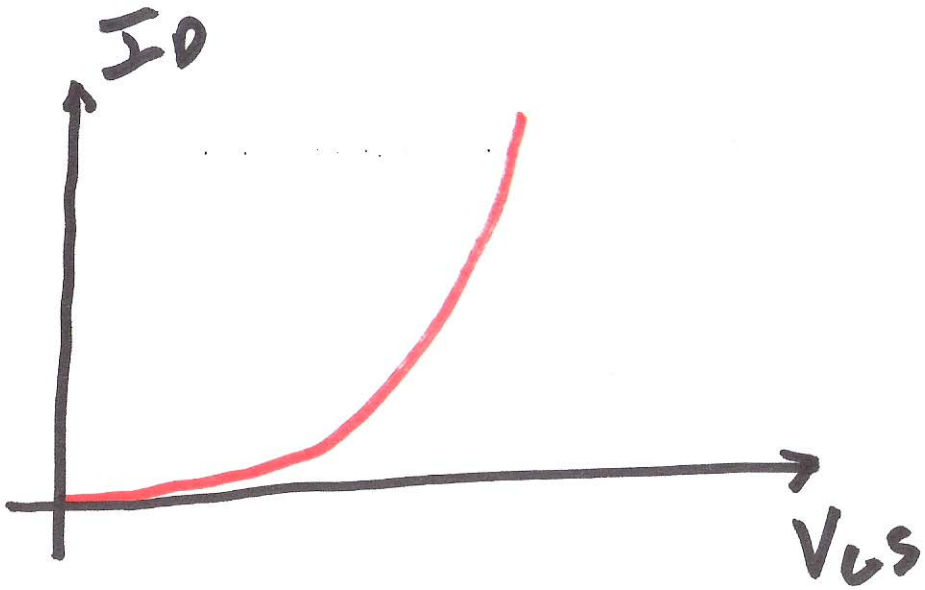

I_D
D
VDD
V_{DS}
I_D
V_{DS}
linear extrapolation
water
turns



$V_T \rightarrow \frac{KT}{q}$ $T \uparrow$ $V_T \uparrow$

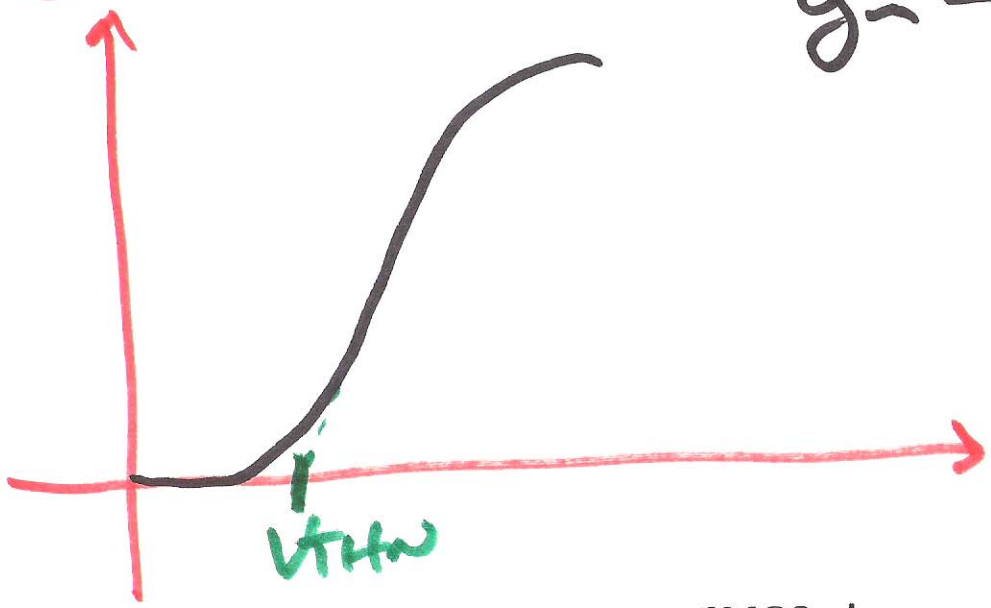
V_{THN} $T \uparrow$ $V_{THN} \downarrow$

V_{THP} $T \uparrow$ $V_{THP} \downarrow$

$\frac{\delta I_D}{\delta V_{GS}} = g_m$

$$g_m = \beta_N \cdot (V_{GS} - V_{THN})$$

$V_{GS} = V_{THN}$



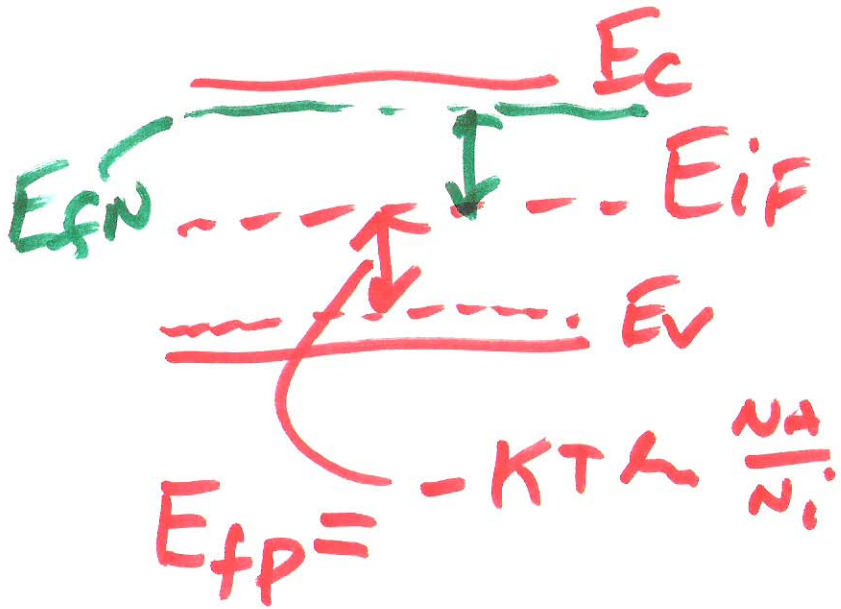
$$I_{D,SAT} = \frac{\mu_n \cdot \epsilon_{ox}}{2 t_{ox}} \cdot \frac{W}{L} \cdot (V_{GS} - V_{THN})^2$$

from Ch.6

$$V_{THN} = -V_{ms} - 2V_{fp} + \frac{Q'_{b0} - Q'_{ss}}{C'_{ox}}$$

$$Q'_{b0} = \sqrt{2 q N_A \epsilon_{Si} \cdot |-2V_{fp}|}$$

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



$$V_{ms} = V_b - V_{fp} = \frac{KT}{q} \ln \frac{N_{D,poly}}{N_i} - V_{fp}$$

3)

$$V_{THN} = \frac{-KT}{q} \ln \frac{N_{D,poly}}{N_i} + \frac{KT}{q} \ln \frac{N_A}{N_i} + \frac{Q_i' - Q_{ss}'}{C_{ox}}$$

$$\frac{\delta V_{THN}}{\delta T} = \frac{-K}{q} \ln \frac{N_{D,poly}}{N_i} + \frac{K}{q} \ln \frac{N_A}{N_i} + \frac{\delta Q_{B0}'/C_{ox}}{\delta T}$$

$$\ln e - \ln 1 = \frac{K}{q} \ln \frac{N_A}{N_{D,poly}} + \frac{Q_{B0}'}{C_{ox}' \cdot 2T}$$

$$\frac{\delta V_T}{\delta T} = \frac{\delta}{\delta T} \frac{KT}{q} = \frac{K}{q} =$$

$$0.085 \sim V/K^\circ$$

$$\frac{\delta V_{THN}}{\delta T} \simeq -\frac{K}{q} \ln \frac{N_{D,poly}}{N_A}$$

Long channel

$$\frac{\delta V_{THN}}{\delta T} \sim -1 \sim V/C^\circ$$

Short channel

$$\frac{\delta V_{THN}}{\delta T} \sim -.6 \frac{\sim V}{C^\circ}$$

$$TCV_{THN} = \frac{1}{V_{THN}} \cdot \frac{\delta V_{THN}}{\delta T}$$

$$V_{THN}(T) = V_{THN}(T_0 = 300K) \cdot (1 + TVC_{THN} \cdot (T - T_0))$$

see book

Mobility change with temp

$$\mu(T) = \mu(T_0) \cdot \left(\frac{T_0}{T}\right)^{1.5}$$

$$KP = \mu \cdot C_{ox}$$

$$KP(T) = KP(T_0) \cdot \left(\frac{T_0}{T}\right)^{1.5}$$

$$= KP(T_0) \cdot \left(\frac{T}{T_0}\right)^{-1.5}$$

$$\frac{\delta KP}{\delta T} = KP(T_0) \cdot (-1.5)\left(\frac{T_0}{T}\right)^{2.5} \cdot \frac{1}{T_0}$$

$$TKP = \frac{1}{KP}\frac{\delta KP}{\delta T} = \frac{-1.5}{T}$$

@ 300°K

$$TCKP = \frac{1}{KP} \cdot \frac{\delta KP}{\delta T} = \frac{-1.5}{300}$$

$$= -5000 \frac{ppm}{C^\circ}$$

$$= -0.005/C^\circ$$

$$KP(T) = KP^{(T_0)}(1 + TCKP(T - T_0))$$

$$= KP(T_0) \cdot \left(1 - 1.5 \cdot \left(\frac{T - T_0}{T}\right)\right)$$