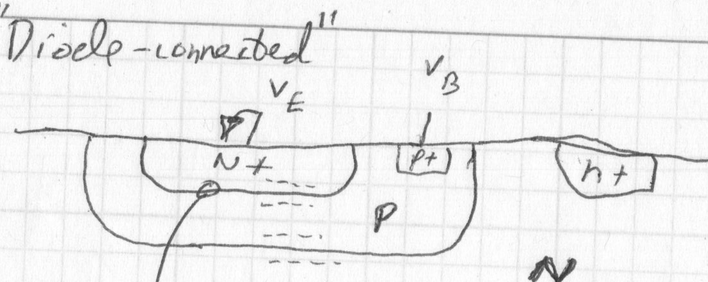
OH W11-12, F4-5

Device Models

BJT

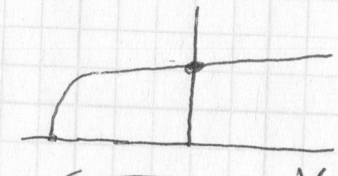
MOS

"Diode-connected"

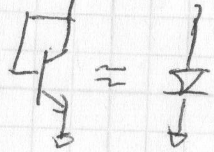



$I_e = I_s e^{V_{BE}/V_T}$

↑ mostly $e^-$ from emitter

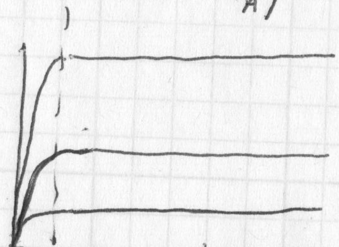



$V_{CB} = 0$



$I_c = I_s e^{V_{BE}/V_T}\left(1 + \frac{V_{CE}}{V_A}\right)$ if $V_{BE} >> V_T$

$V_{CE} > V_{CE,sat}$



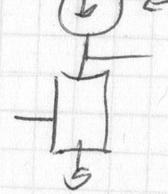

$V_A$ typically 10-100V for discretes

$g_m = \frac{\partial I_c}{\partial V_{BE}} = \frac{I_c}{V_T}$ very tough to do better

$g_o = \frac{\partial I_c}{\partial V_{CE}} = I_s e^{V_{BE}/V_T} \frac{1}{V_A} = \frac{I_c}{V_A} \frac{1}{1 + \frac{V_{CE}}{V_A}}$

$\approx \frac{I_c}{V_A}$

$r_o = \frac{1}{g_o} \approx \frac{V_A}{I_c}$

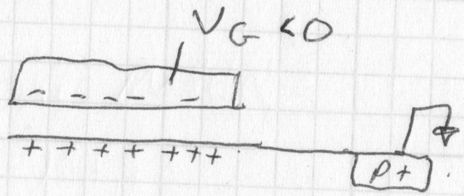



intrinsic gain

$A_{V,int} = -g_m R_o = -\frac{I_c}{V_T} \frac{V_A}{I_c} = \frac{-V_A}{V_T} \approx \begin{cases} 1,000 \\ 4,000 \end{cases}$

MOS capacitor

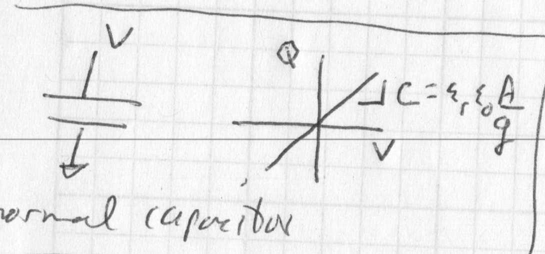
$V_G < 0$




accumulation

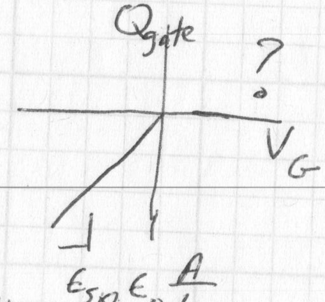
(ignoring flatband voltage)

p




$C = \varepsilon_r \varepsilon_0 \frac{A}{d}$

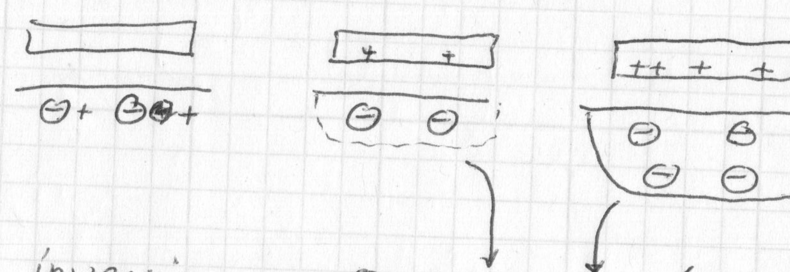
normal capacitor



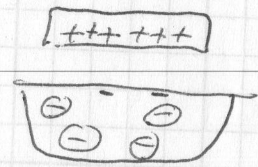

or other → $\varepsilon_{SiO_2} \varepsilon_0 \frac{A}{t_{ox}}$

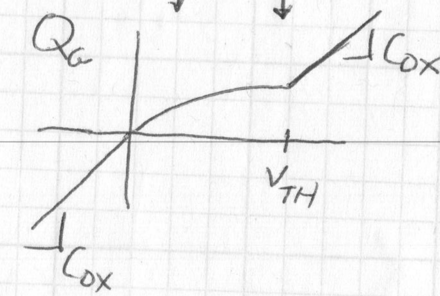
depletion

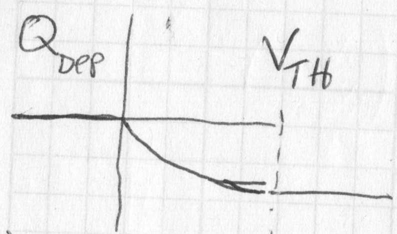
$V_G = 0$ $V_G > 0$

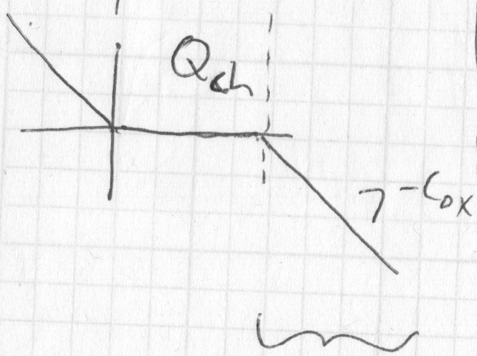



inversion



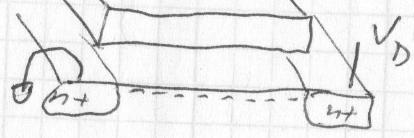



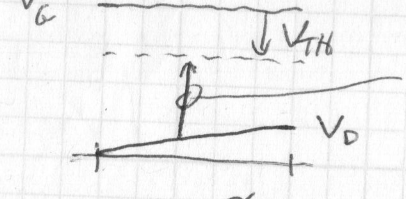

this is the part that does us some good

charge density in the channel is proportional to $V_{GS} - V_{TH}$

$\sigma_{CH} = C_{ox}(V_{GS} - V_{th})$

if $V_{GS} > V_{TH}$ and $V_{DS} < V_{GS} - V_{TH}$



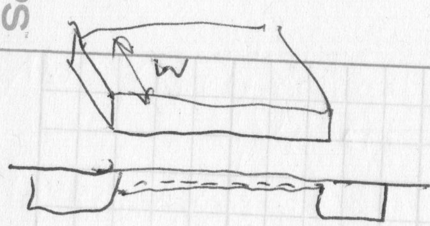




channel overdrive voltage

average is

$$\frac{(V_G - V_{TH}) + (V_G - V_{TH} - V_D)}{2}$$

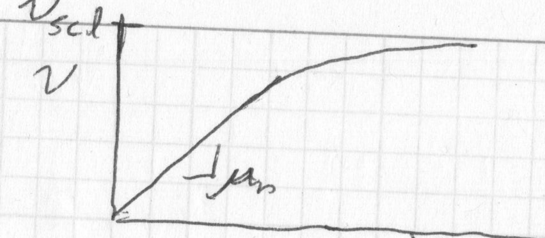
$$= V_{GS} - V_{TH} - \frac{1}{2} V_{DS}$$




$I_D = (\text{avg. charge per length})(\text{velocity in } x)$

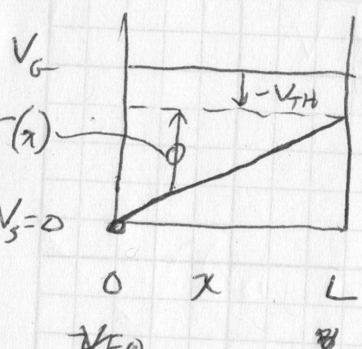
$\left(W C_{ox} \left(V_{GS} - V_{th} - \frac{1}{2} V_{DS}\right)\right) \; v$

$I_D = \mu_n C_{ox} \frac{W}{L} \left(V_{GS} - V_{th} - \frac{1}{2} V_{DS}\right) V_{DS}$




$E = \frac{V_{DS}}{L}$

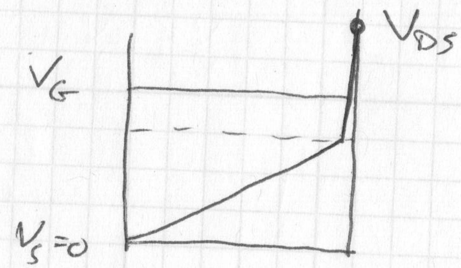
$v = \mu E = \mu_n \frac{V_{DS}}{L}$




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

no mobile charge at drain

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




$I_D = \frac{\mu_n C_{ox}}{2} \frac{W}{L} \left(V_{GS} - V_{TH}\right)^2 \left(1 + \lambda V_{DS}\right)$

add for continuity (non-physical)