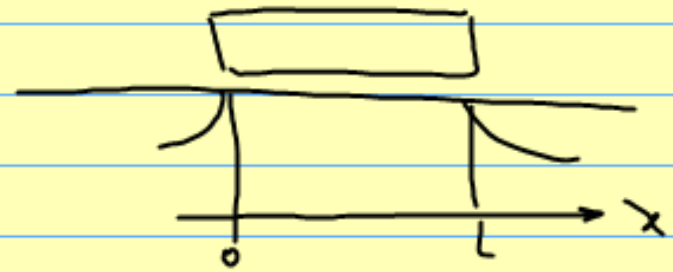
Subthreshold Leakage

$I_c \sim e^{V_{BE}/V_T}$ $\quad V_T = kT/q \sim 26mV$ (Room temp)

diffusion coeff

$I_{ds} = W \cdot D \cdot \frac{dQ_e}{dx}$



$D = \mu C_{dep} \left(\frac{kT}{q}\right)^2$

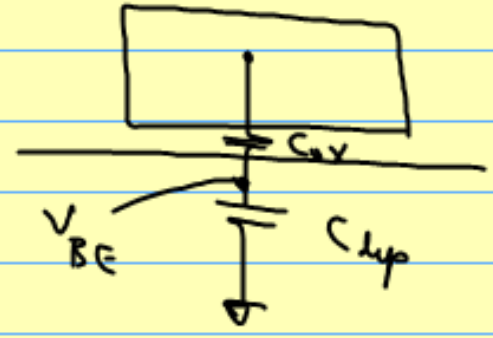
$I_{ds} \approx W \cdot D \frac{Q(L) - Q(0)}{L}$

at location L $\quad \approx e^{\frac{V_{BC}}{V_T}} - e^{V_{BE}/V_T}$

$\approx e^{V_{BE}/V_T} \left(1 - e^{\frac{V_{BC} - V_{BE}}{V_T}}\right)$ — V_{EC} : V_{ds}

Sub-thr Leakage

$$I_{ds} \propto e^{V_{BE}/V_T}\left(1-e^{-V_{ds}/V_T}\right)$$

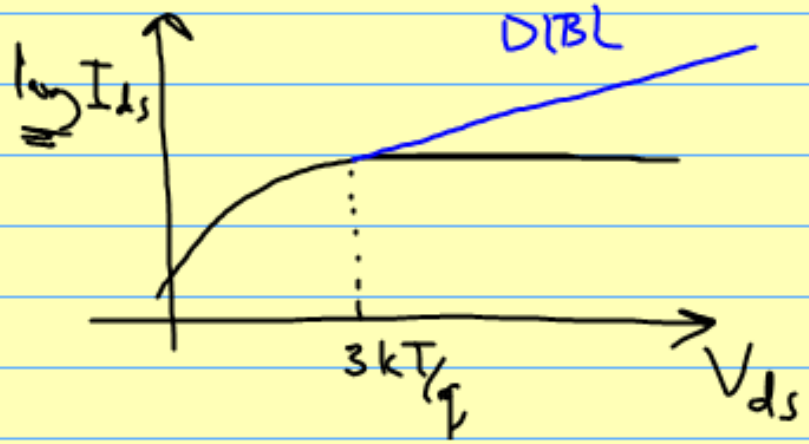


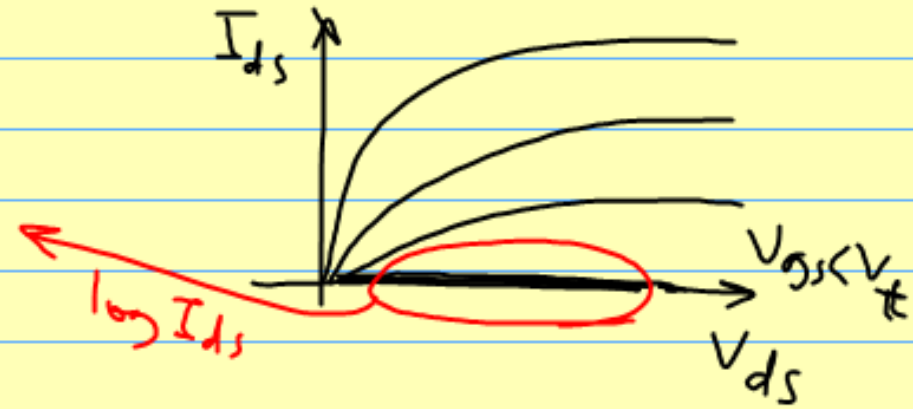
$$V_{BE} = \frac{C_{ox}}{C_{ox}+C_{dep}}\left(V_{gs}-V_T\right)$$

$$= \frac{V_{gs}-V_T}{\underbrace{1+\frac{C_{dep}}{C_{ox}}}_{m}} = \frac{V_{gs}-V_T}{m}$$

$$I_{ds} \propto e^{\frac{V_{gs}-V_T}{mV_T}}\left(1-e^{-V_{ds}/V_T}\right)$$

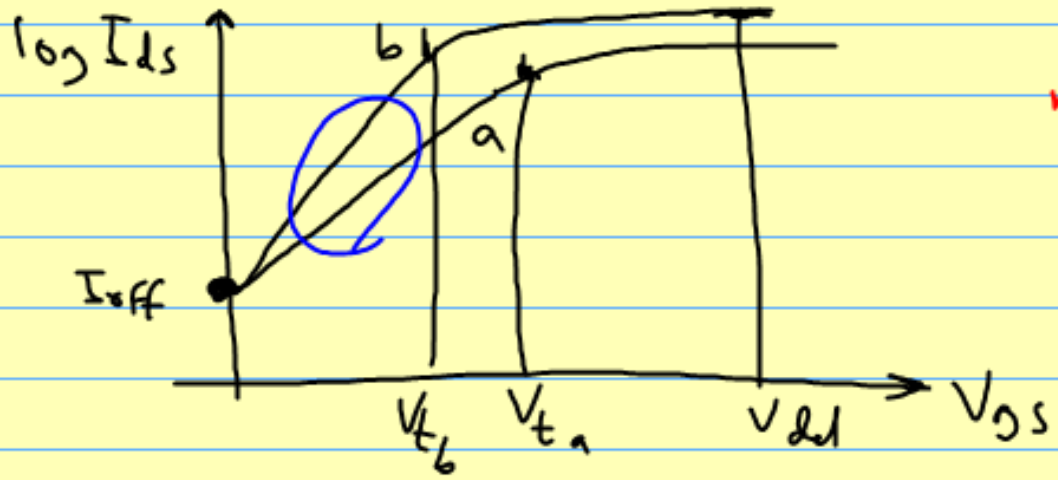
Leakage (fixed V_{gs})





$$e^{\frac{V_{gs}-V_T}{mV_T}}\left(1-e^{-V_{ds}/V_T}\right) \qquad V_{ds} > 3\,kT/q$$

Leakage (fixed V_{ds})

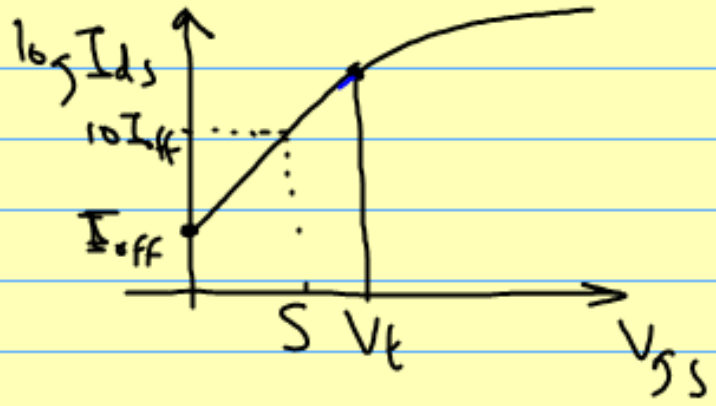


made $I_{off_a} = I_{off_b}$

I_{off} same (tech, device size)

for $V_{gs} > V_{t_{a,b}}$ b better

Sub thr swing (S)



ideal case $m=1$ ($C_{dep}=0$)

$S = 1 \times 26\,mV \times \ln 10 \sim 60\,mV/dec$

typical $m \simeq 1.3$

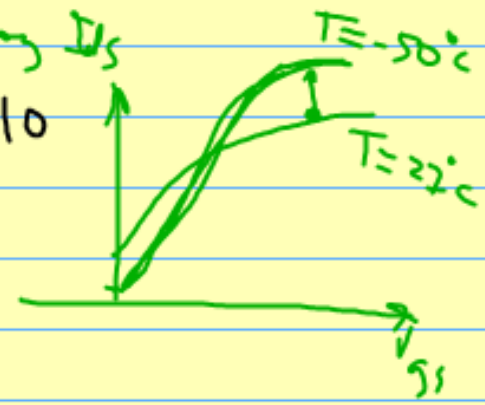
$S = 80\,mV/dec$

worst $T = 110°C$

$S = 100\,mV/dec$

$$I_{off} = A\, e^{\frac{0-V_T}{mkT/q}}$$

$$10\, I_{off} = A\, e^{\frac{S-V_T}{mkT/q}}$$

$$10 = e^{\frac{S}{mkT/q}} \Longrightarrow S = m \frac{kT}{q} \ln 10$$

$$m = 1 + \frac{C_{dep}}{C_{ox}}$$