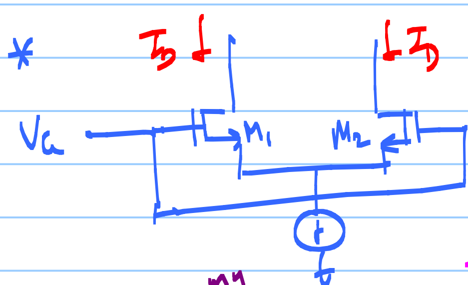
ECE 614 – Lecture 19

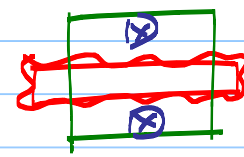
Note Title 11/8/2012

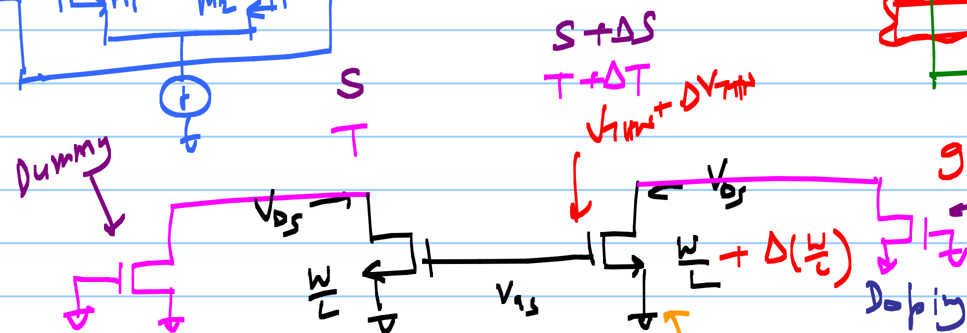
Mismatch and Offsets:

gain, BW etc.

N_D, N_A





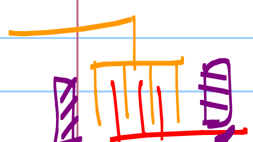


geometric variations

ΔW, ΔL

Doping level variations

ΔV_{THN}



Dummy

CMP $\Rightarrow$ unevenness

matched

$\mu_n C_{ox}$

Study of Mismatch

① Identify mechanisms leading to mismatch between devices

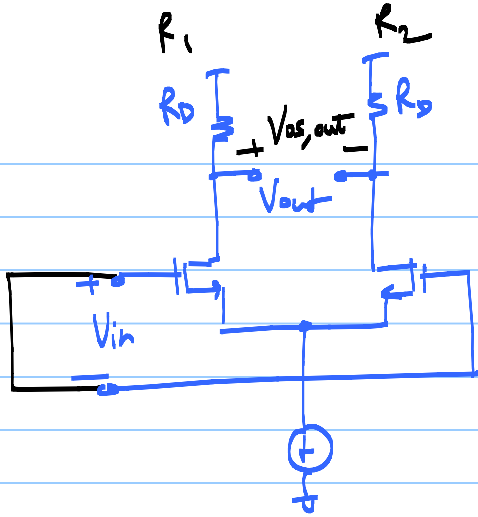
→ measurements and characterization by the foundry

⇒ ② analyze the effect of device mismatch upon circuits

Mismatch leads → $\boxed{\text{DC offsets}}$

→ finite even-order distortion (FD circuits also)

→ lower CM-rejection



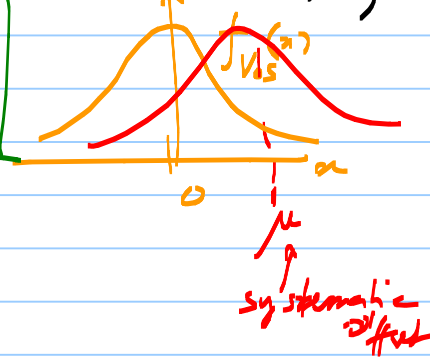
* with a DC offset

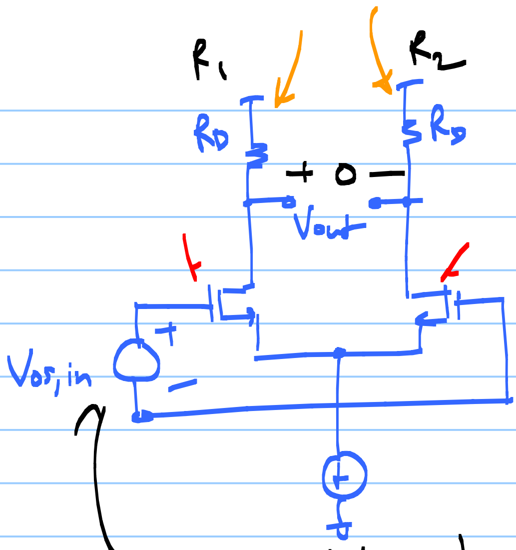
⇒ with $V_{in} = 0$

$V_{out} = V_{os,out}$

* It's more meaningful to specify the input-referred offset voltage ($V_{os,in}$)

$$\boxed{|V_{os,in}| = \frac{|V_{os,out}|}{|A_v|}}$$





$$|V_{os,in}| = \frac{|V_{os,out}|}{A}$$

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

$\mu_n C_{ox}$

$\frac{W}{L}$

V_{THN}

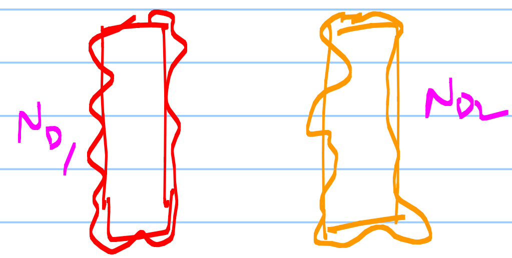
λ

I_D & $I_D + \Delta I_D$

$\frac{\Delta W}{W}$ & $\frac{\Delta L}{L}$

$$\frac{\Delta(W/L)}{(W/L)}$$

Large WL $\Rightarrow$ $\Delta(W/L)$ $\downarrow$



Geometric Variation

Pelgrom's paper:

$$\Delta V_{THN} = \frac{A_{V_{THN}}}{\sqrt{WL}} \qquad \sigma^2_{\Delta V_{THN}} \propto \frac{1}{WL}$$

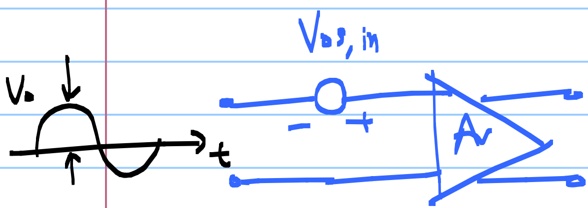
$$\Delta\left(\mu_n C_{ox} \frac{W}{L}\right) = \frac{A_K}{\sqrt{WL}} \qquad \sigma^2_{\Delta\beta} \propto \frac{1}{WL}$$

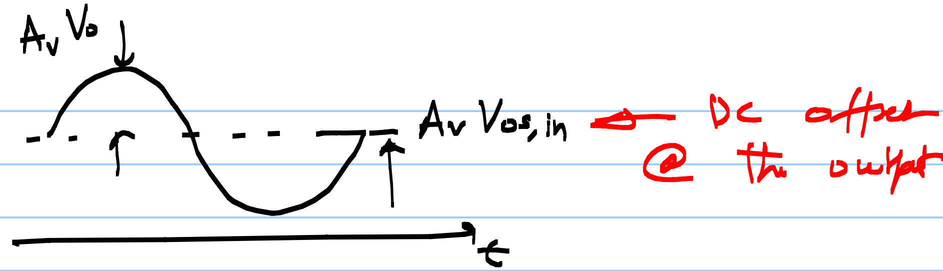
for large WL → variations experience "averaging"

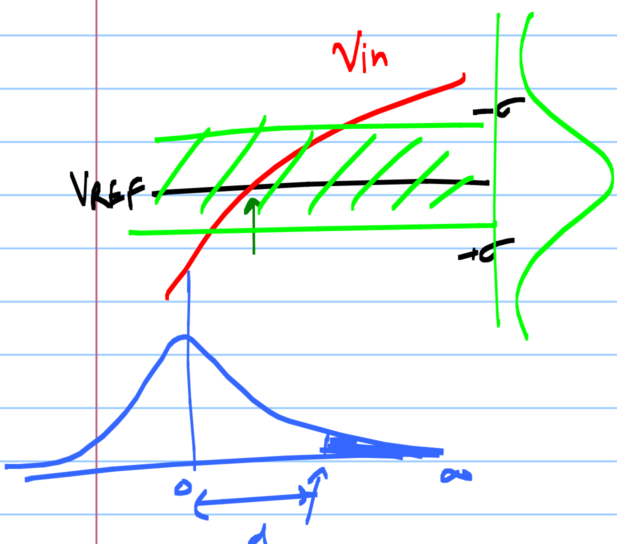
* C5 process : $L_{min} = 0.6\,\mu m$

$A_{VTHN} \approx \alpha \cdot t_{ox} = 10\,mV$ for a $t_{ox} = 100\,\mathring{A}$

$\frac{100\,\mu m}{0.6\,\mu m} \Rightarrow \sigma_{\Delta V_{THN}} = 1.4\,mV$



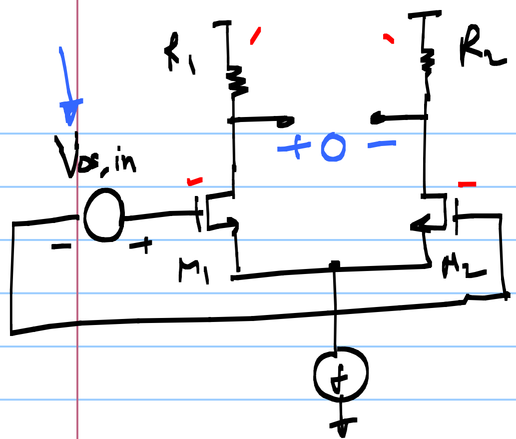




Here, the $V_{os,in}$ imposes a lower bound on the minimum $V_{in} - V_{ref}$ that can be easily detected.

$$P_E = Q\left(\frac{d}{\sigma}\right) = Q\left(\frac{|V_{in} - V_{ref}|}{\sigma_{V_{os,in}}}\right)$$

erfc



$V_{os,in} = V_{GS_1} - V_{GS_2}$

Left

$\left(\frac{W}{L}\right)_1 = \frac{W}{L}$

$V_{THN_1} = V_{THN}$

$R_1 = R_D$

$I_{D_1} = I_D$

$\lambda = \gamma = 0$

Right

$\left(\frac{W}{L}\right)_2 = \frac{W}{L} + \Delta\left(\frac{W}{L}\right)$

$V_{THN_2} = V_{THN} + \Delta V_{THN}$

$R_2 = R_D + \Delta R_D$

$I_{D_2} = I_D + \Delta I_D$

$V_{out} = 0$

$I_{D_1} R_1 = I_{D_2} R_2$

$\Rightarrow I_{D_1} \neq I_{D_2}$

$$V_{os,in} = V_{GS_1} - V_{GS_2}$$

$$= \sqrt{\frac{2 I_{D_1}}{\mu_n C_{ox} \left(\frac{W}{L}\right)_1}} + V_{THN_1} - \sqrt{\frac{2 I_{D_2}}{\mu_n C_{ox}\left(\frac{W}{L}\right)_2}} - V_{THN_2}$$

$$= \sqrt{\frac{2}{\mu_n C_{ox}}}\left[\sqrt{\frac{I_D}{W/L}} - \sqrt{\frac{I_D + \Delta I_D}{\frac{W}{L} + \Delta\left(\frac{W}{L}\right)}}\right] - \Delta V_{THN}$$

$$= \boxed{\sqrt{\frac{2 I_D}{\mu_n C_{ox} \frac{W}{L}}}}\left[1 - \sqrt{\frac{1 + \frac{\Delta I_D}{I_D}}{1 + \frac{\Delta (W/L)}{W/L}}}\right] - \Delta V_{THN} \rightarrow (1)$$

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

Assume $\frac{\Delta I_D}{I_D}$ & $\frac{\Delta (W/L)}{W/L} \ll 1$

$\varepsilon \ll 1 \Rightarrow \quad \sqrt{1+\varepsilon} \simeq 1 + \varepsilon/2$

$\left(\sqrt{1+\varepsilon}\right)^{-1} \simeq 1 - \varepsilon/2$

$$V_{os,in} = V_{ov}\left\{1 - \underline{\left(1+\frac{\Delta I_D}{2I_D}\right)\left[1-\frac{\Delta(W/L)}{2(W/L)}\right]}\right\} - \Delta V_{THN}$$

$$(I_D+\Delta I_D)(R_D+\Delta R_D) \simeq I_D R_D + R_D\Delta I_D + I_D \Delta R_D$$

$$\& \quad \left. I_{D_1}R_{D_1} = I_{D_2}R_{D_2} \right) \; V_{out}=0$$

$$\Rightarrow \quad \frac{\Delta I_D}{I_D} \simeq -\frac{\Delta R_D}{R_D}$$

$(V_{GS}-V_{THN})$

$$V_{os,in} = \frac{V_{ov}}{2}\left[\underset{P}{\frac{\Delta R_D}{R_D}} + \underset{P}{\frac{\Delta(W/L)}{(W/L)}}\right] - \underbrace{\Delta V_{THN}}$$

directly referred to the input

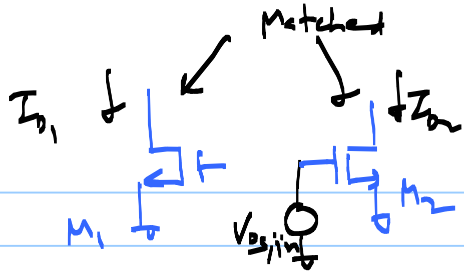
$$V_{OS,in} = \frac{V_{ov}}{2}\left[\frac{\Delta R_D}{R_D} + \frac{\Delta (W/L)}{(W/L)}\right] - \Delta V_{THN}$$

contribution of $\Delta(W/L)$ depends upon the V_{ov}

ΔV_{THN} is directly seen at the input

$E((\cdot)^2)$

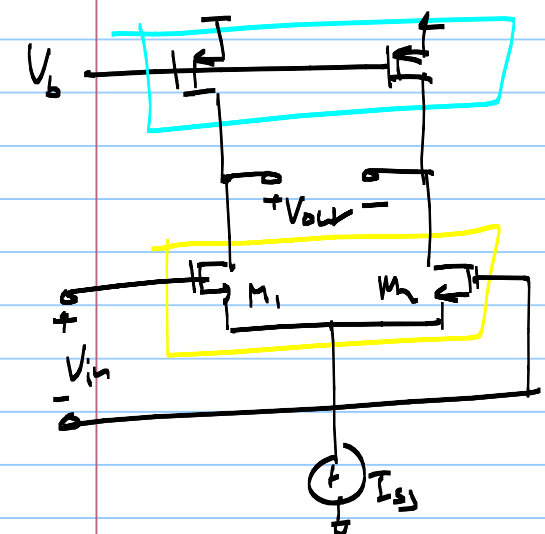
$$\sigma^2_{V_{OS,in}} = \left(\frac{V_{ov}}{2}\right)^2\left[\frac{\sigma^2_{\Delta R_D}}{R_D^2} + \frac{\sigma^2_{\Delta W/L}}{(W/L)^2}\right] + \sigma^2_{\Delta V_{THN}}$$

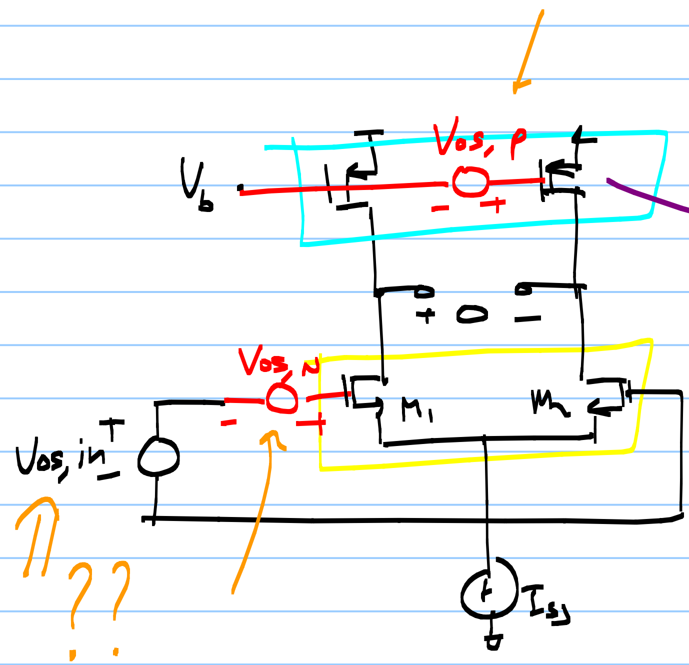


for $I_{D1} = I_{D2}$

$$\boxed{V_{os,in} = \frac{V_{ov}}{2}\left[\frac{\Delta (W/L)}{(W/L)}\right] + \Delta V_{TH}}$$

Ex.





$$\frac{g_{mp}\,\cancel{R_{out}}}{g_{mn}\,\cancel{R_{out}}}$$

$$V_{os,n} = \frac{(V_{GS}-V_{THN})}{2}\left[\frac{\Delta(W/L)}{(W/L)}\right]_N + \Delta V_{THN}$$

$$V_{os,p} = \frac{(V_{SG}-V_{THP})}{2}\left[\frac{\Delta(W/L)}{W/L}\right]_p + \Delta V_{THP}$$

from noise analysis results

$$V_{os,in} = V_{os,n} + V_{os,p}\left(\frac{g_{mp}}{g_{mn}}\right)$$

$$\boxed{\sigma^2_{V_{os,in}} = \sigma^2_{V_{os,N}} + \frac{g_{mp}^2}{g_{mn}^2}\cdot\sigma^2_{V_{os,p}}}$$

$f(V_{ov},\ W/L)$

$g_{mn}\uparrow,\ g_{mp}\downarrow$