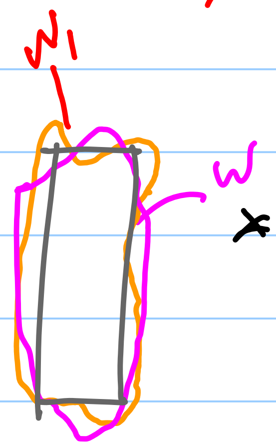
ECE 614 – Lecture 20

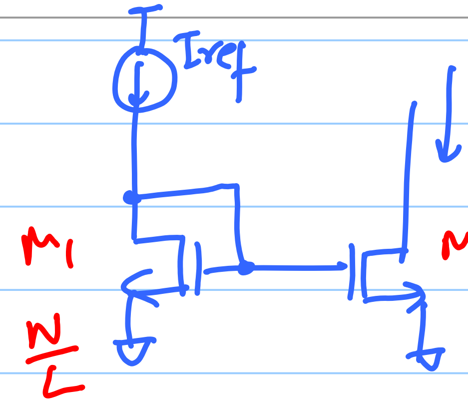
Note Title 10/30/2014

Mismatch:

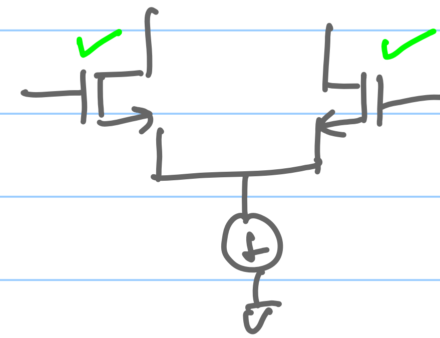
① ΔW, ΔL



photolith induced geometric variation

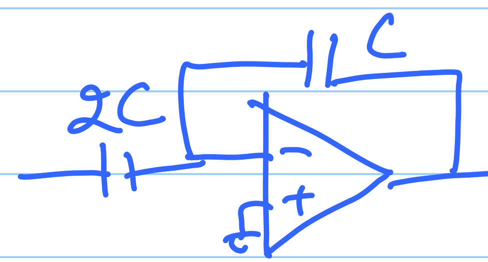


$V_{DS_1} \neq V_{DS_2}$



② ΔV_{THN} → doping levels, tox variation

process gradient

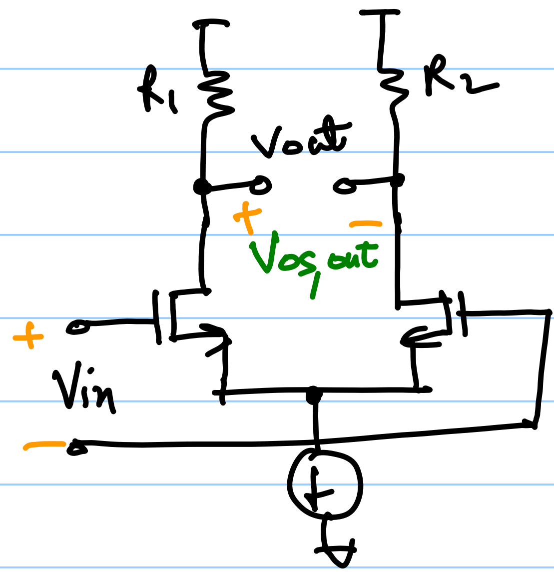


Mismatch leads to ⇒ DC offsets ✓

↳ finite even-order distortion in FD circuits

↳ lower CM rejection

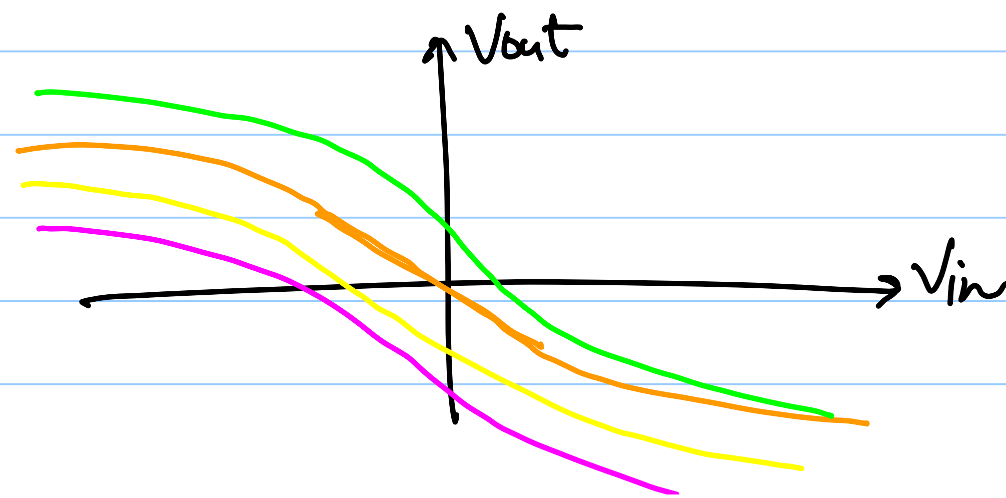
DC offsets:

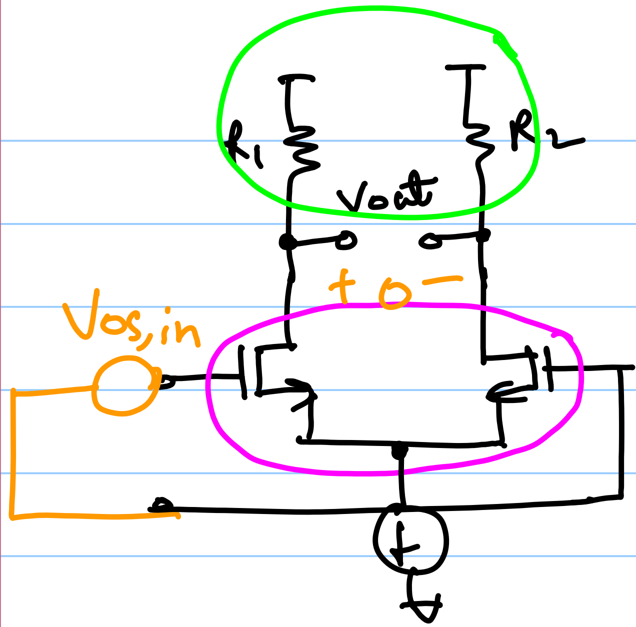


Ideally $V_{in} = 0$, $V_{out} = 0$

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

random but fixed quantity





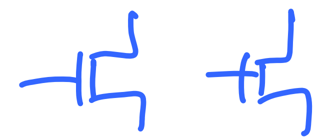
* It's more meaningful to specify the input-referred offset voltage

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

input that forces the output to zero

$V_{os,in} \Rightarrow$ random
zero mean
σ_{os}

Pelgrom's paper

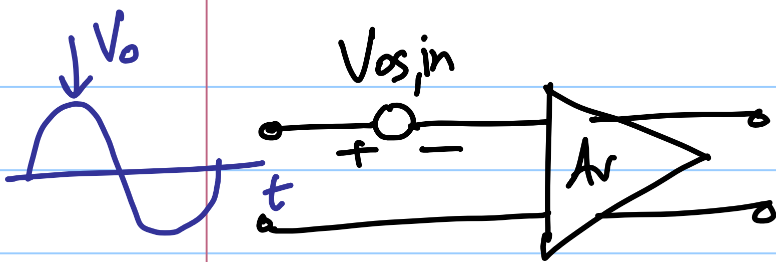


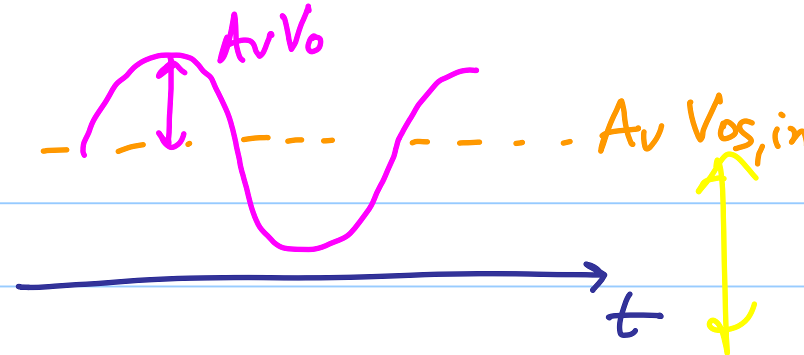
$$\sigma_{\Delta V_{THN}} = \frac{A_{VTHN}}{\sqrt{WL}}$$

Area

$$\sigma_{\Delta\left(\mu_n C_{ox} \frac{W}{L}\right)} = \frac{A_K}{\sqrt{WL}}$$

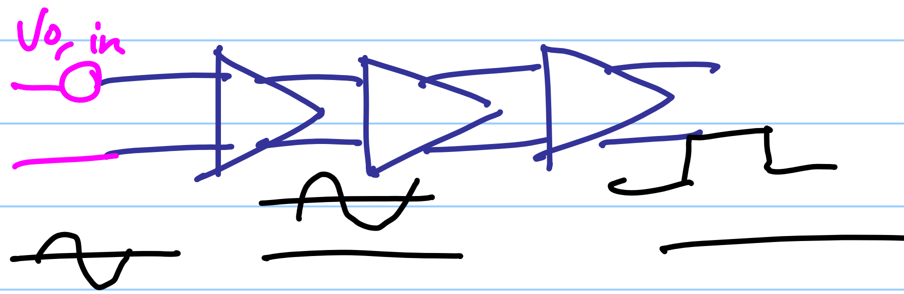
more mismatch as $W, L \downarrow$





* output contains amplified $V_{os,in}$

1 Direct coupled amplifier stages

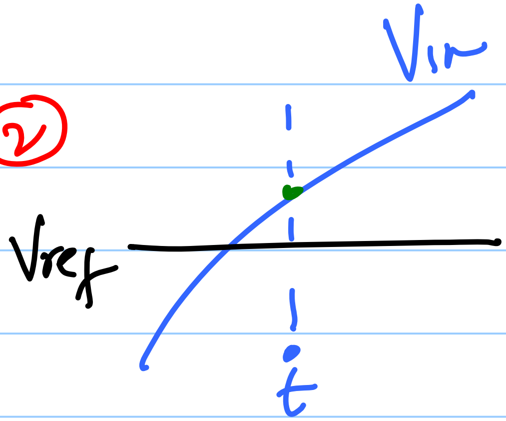


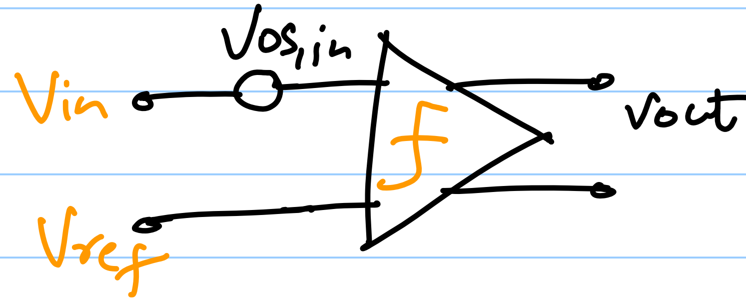
60dB gain

The offset can saturate the later stages

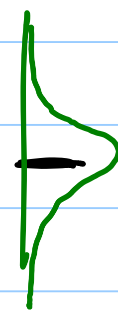
$\Rightarrow$ need to cancel offset

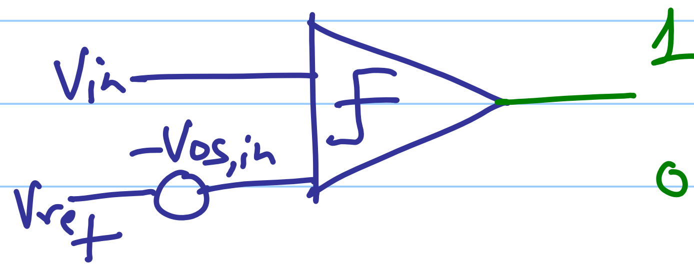
2





$\Downarrow$

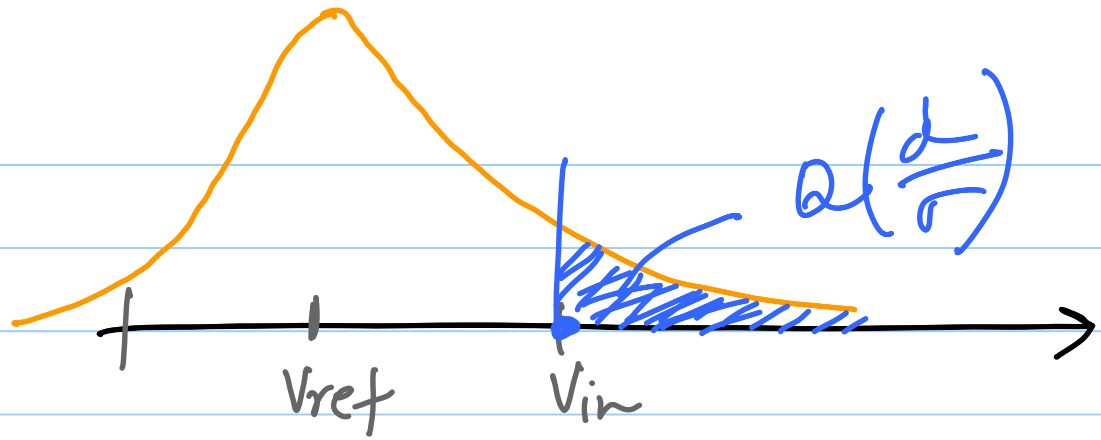




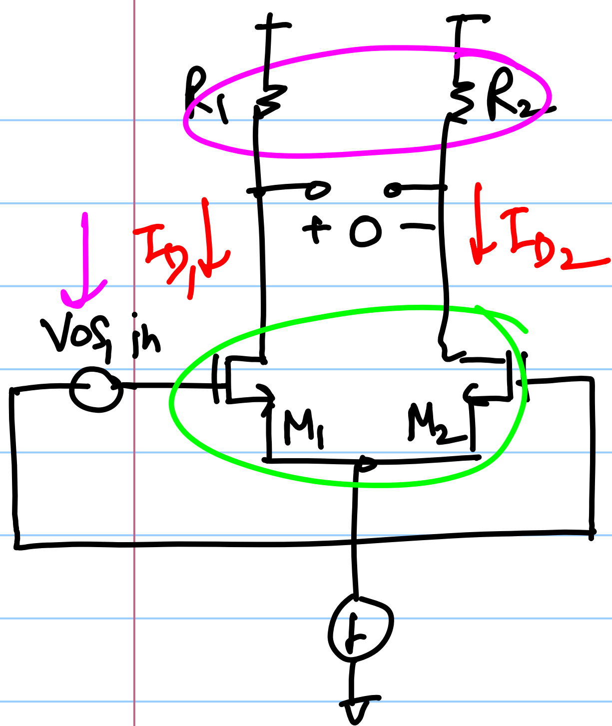
Comparator will make errors

$$p_E = Q\left(\frac{d}{\sigma}\right)$$

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



Vref
Vin
$Q\left(\frac{d}{\sigma}\right)$



$V_{THN_1} = V_{THN}$ $\quad$ $V_{THN_2} = V_{THN} + \Delta V_{THN}$

$\left(\frac{W}{L}\right)_1 = \frac{W}{L}$ $\quad$ $\left(\frac{W}{L}\right)_2 = \frac{W}{L} + \Delta\left(\frac{W}{L}\right)$

$R_1 = R_D$ $\quad$ $R_2 = R_D + \Delta R$

for $V_{out} = 0 \Rightarrow I_{D_1} R_1 = I_{D_2} R_2$

We know, $I_{D_1} \neq I_{D_2}$

Let $I_{D_1} = I_D$ & $I_{D_2} = I_D + \Delta I_D$

$\boxed{\lambda = \gamma = 0}$

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

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

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

$$\sqrt{1+\epsilon} \simeq 1+\frac{\varepsilon}{2}$$

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

$$\Rightarrow$$

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

$$I_{D_1}R_{D_1} = I_{D_2}R_{D_2} \quad \because \quad V_{out} = 0$$

$$\Rightarrow \frac{\Delta I_D}{I_D} = -\frac{\Delta R_D}{R_D}$$

sign is irrelevant

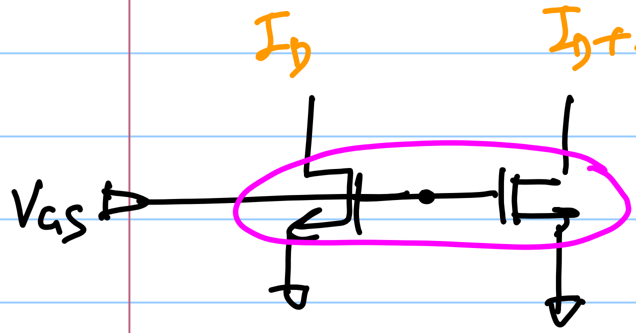
$$V_{os,in} = \frac{V_{ov}}{2}\left[\frac{\Delta R_D}{R_D} + \frac{\Delta(W/L)}{W/L}\right] - \Delta V_{THN}$$

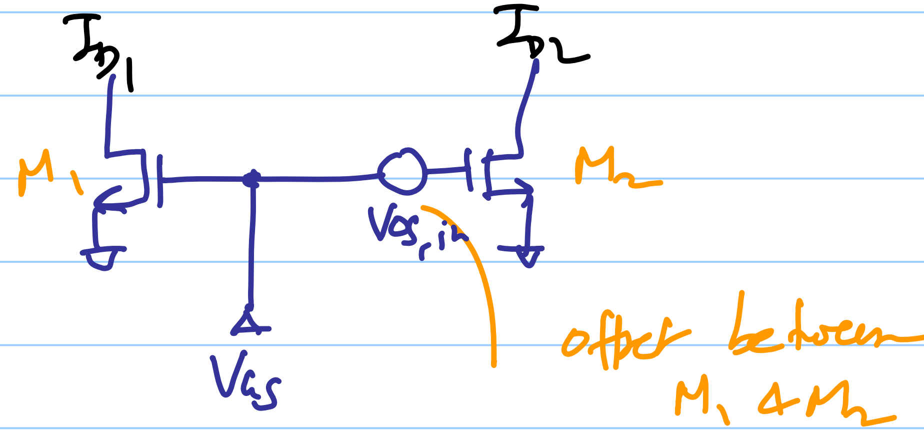
offset depends on device mismatches & biasing condition $V_{ov} = V_{GS} - V_{THN}$

① ΔV_{THN} is directly refered to the input

② Contribution of ΔR_D & $\Delta(W/L)$ increases with V_{ov}

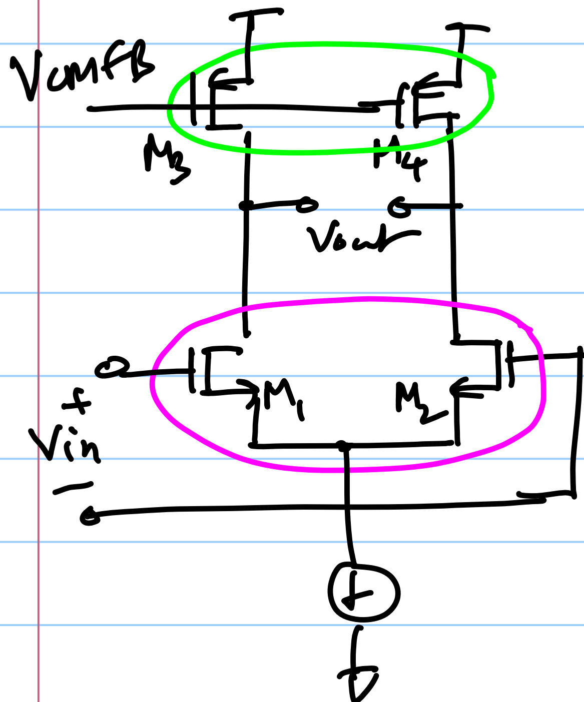
$$\sigma^2_{V_{os,in}} = \left(\frac{V_{ov}}{2}\right)^2\left[\underbrace{\frac{\sigma^2_{\Delta R_D}}{R_D^2}}_{\text{sensitivity}} + \underbrace{\frac{\sigma^2_{\Delta(W/L)}}{(W/L)^2}}_{\text{sensitivity}}\right] + \sigma^2_{\Delta V_{THN}}$$

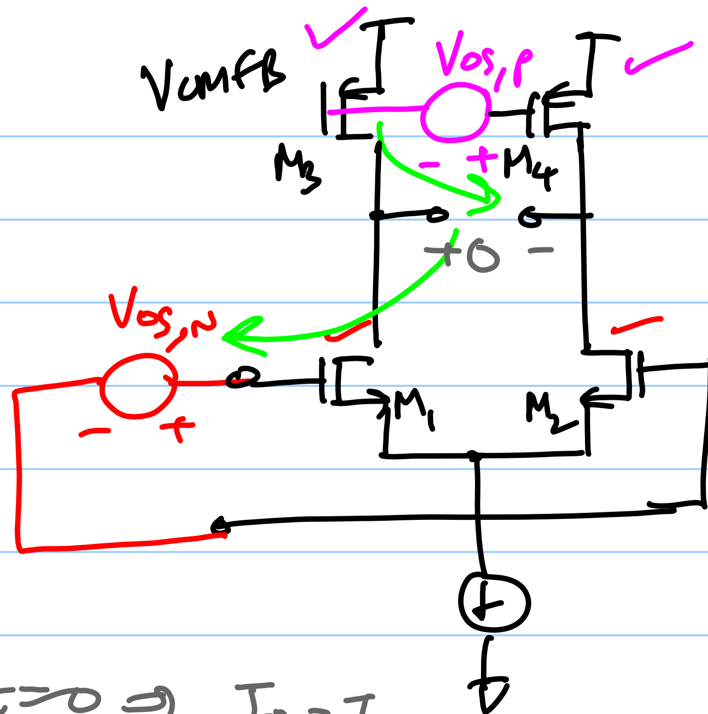




for $I_{D1} = I_{D2}$

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





for $V_{out} = 0 \Rightarrow I_{D_1} = I_{D_2}$

$I_{D_3} = I_{D_4}$

for a diff-pair with $I_{D_1} = I_{D_2}$

$$V_{os,N} = \frac{V_{ov_n}}{2}\left[\frac{\Delta(W/L)}{W/L}\right]_n + \Delta V_{THN}$$

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

from tricks used in noise analysis

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

$$\sigma^2_{V_{os,in}} = \sigma^2_{V_{os,n}} + \left(\frac{g_{mp}}{g_{mn}}\right)^2 \sigma^2_{V_{os,p}}$$

$f(V_{ov,n}, \Delta V_{THN})$

$f(V_{ov,p}, \Delta V_{THP})$

reduce by $WL \uparrow$, $V_{ov} \downarrow$

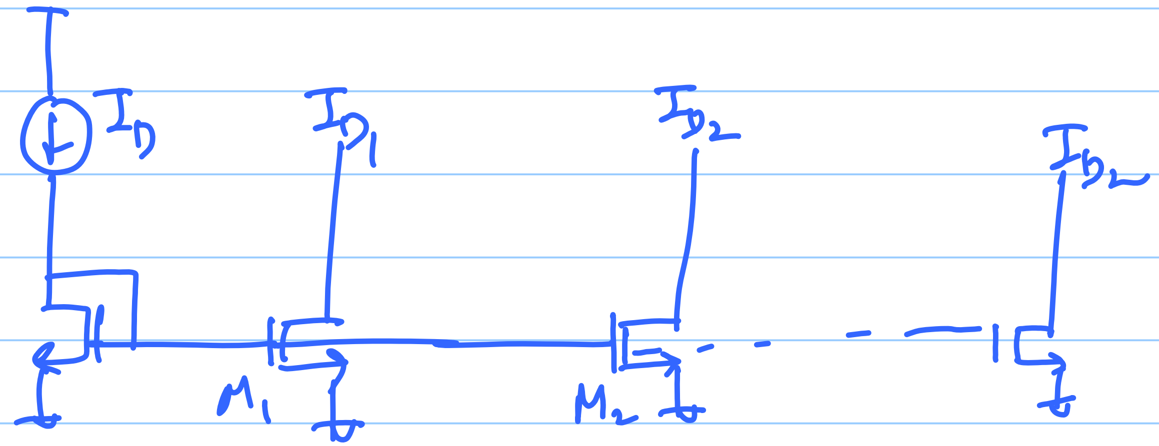
max g_{mn}

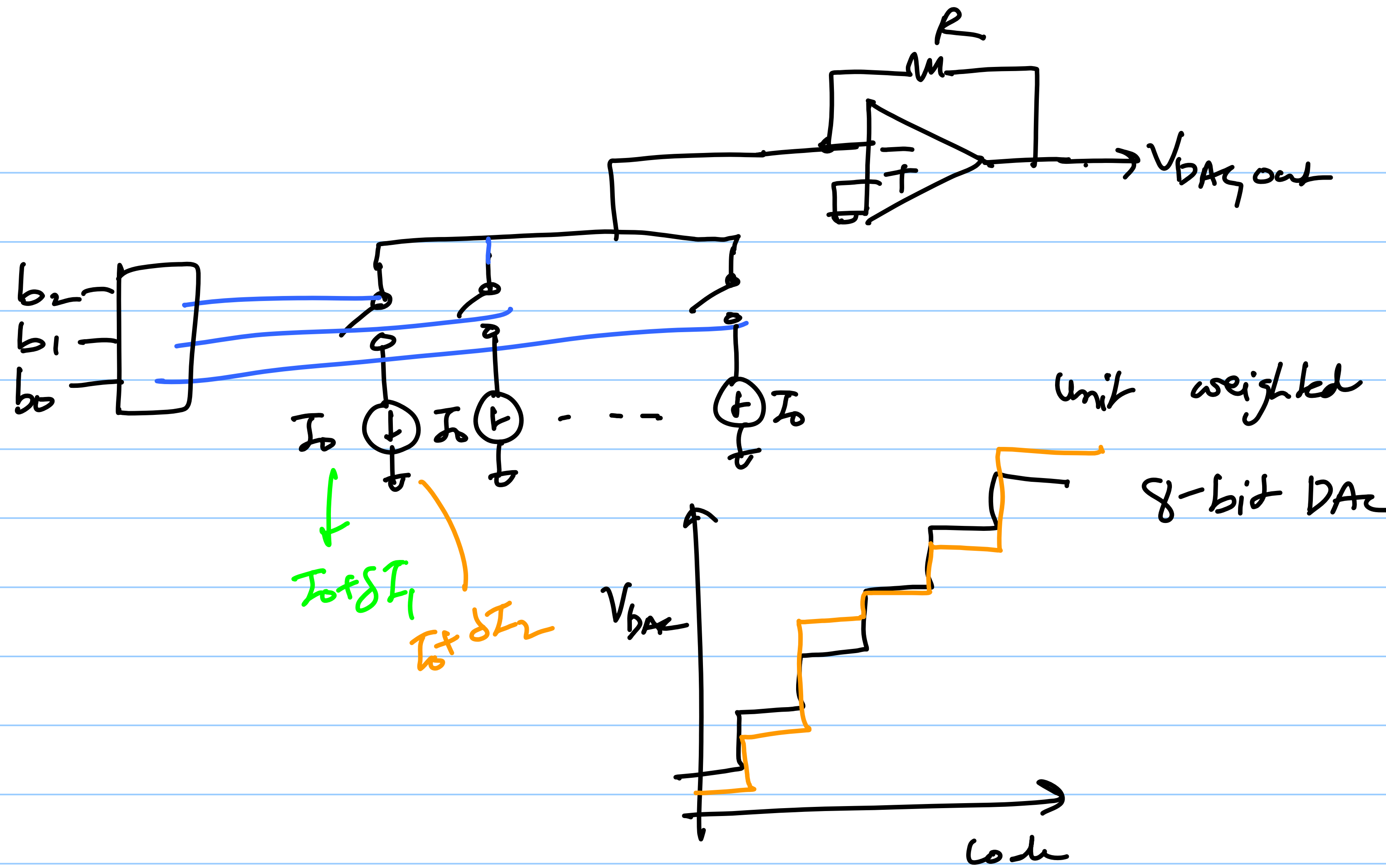
min g_{mp}

"Monte-Carlo simulation"

ADE-XL

Current Sources :




R
$V_{DAC,out}$
b_2
b_1
b_0
I_0
I_0
I_0
$I_0 + \delta I_1$
$I_0 + \delta I_2$
unit weighted
8-bit DAC
V_{DAC}
code

current mismatch

$$\frac{\Delta I_D}{I_D} = \frac{\Delta(W/L)}{W/L} - \frac{2\,\Delta V_{THN}}{(V_{GS}-V_{THN})}$$

to minimize $\frac{\Delta I_D}{I_D}$ → maximize V_{ov}

& use large Area