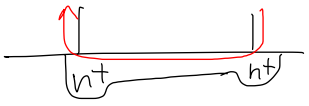
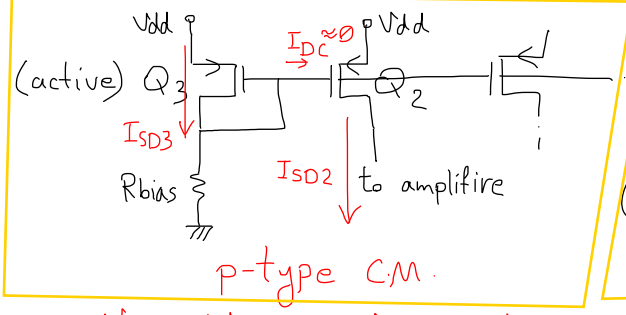
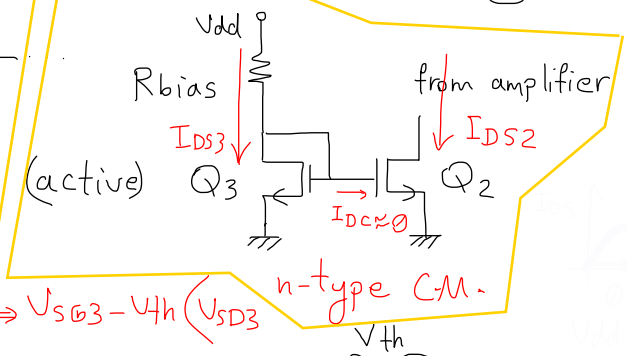
* Current Mirrors (DC Analysis):







$V_{G3} = V_{D3} \Rightarrow V_{SG3} = V_{SD3} \Rightarrow V_{SG3} - V_{th} (V_{SD3}$

for pmos Q3 :

$$I_{SD3} = \frac{1}{2}\mu_p C_{ox}\frac{W_3}{L_3}\left(V_{SG}-V_{th}\right)^2\left[1+\lambda\left(V_{SD}-\underbrace{\left(V_{SG}-V_{th}\right)}_{V_{th}}\right)\right] \Rightarrow \text{find} \begin{cases} V_{SG3} \\ I_{SD3} \end{cases}$$

KVL: $V_{dd} = V_{SG3} + R_{bias}\cdot I_{SD3}$

Q_2 operate in active:

$$\frac{I_{SD2}}{I_{SD3}} = \frac{\cancel{\frac{1}{2}\mu_p C_{ox}}\frac{W_2}{L_2}\cancel{\left(V_{SG2}-V_{th}\right)^2}\left[1+\lambda\left(V_{SD2}-\left(V_{SG2}-V_{th}\right)\right)\right]}{\cancel{\frac{1}{2}\mu_p C_{ox}}\frac{W_3}{L_3}\cancel{\left(V_{SG3}-V_{th}\right)^2}\left[1+\lambda V_{th}\right]}$$

$$\frac{I_{SD2}}{I_{SD3}} = \frac{\frac{W_2}{L_2}}{\frac{W_3}{L_3}} \times \frac{\overbrace{1+\lambda\left(V_{SD2}-\left(V_{SG2}-V_{th}\right)\right)}^{\text{ignore}}}{\underbrace{1+\lambda V_{th}}_{\text{ignore}}}$$

this term generate some error in mapping the current and for $\lambda \approx 0$ disappears

$V_{dd}=3V$, $V_{SD2}\approx 1.5V$, $V_{th}=0.5V$, $V_{SG2}=1V$

$\lambda = 0.01\left[\frac{1}{V}\right]$

$r_{ds} = \frac{1}{\lambda \cdot I_{DS}}$

for nmos Q3 :

$$I_{DS3} = \frac{1}{2}\mu_n C_{ox}\frac{W_3}{L_3}\left(V_{GS3}-V_{th}\right)^2\left[1+\lambda V_{th}\right] \Rightarrow \text{find} \begin{cases} V_{GS3} \\ I_{DS3} \end{cases}$$

KVL: $V_{dd} = R_{bias}\cdot I_{DS3} + V_{GS3}$

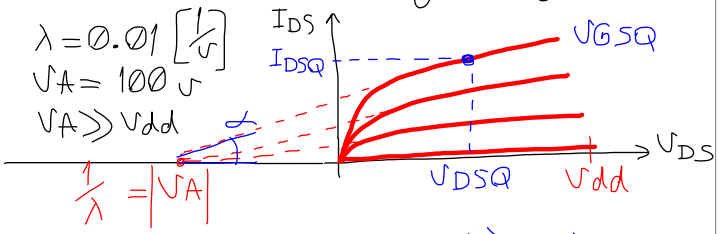
$$\frac{I_{DS2}}{I_{DS3}} = \frac{\frac{W_2}{L_2}}{\frac{W_3}{L_3}} \times \frac{1+\lambda\left(V_{DS2}-\left(V_{GS2}-V_{th}\right)\right)}{1+\lambda V_{th}}$$

λ: Early voltage

$\lambda = 0.01\left[\frac{1}{V}\right]$

$V_A = 100\,V$

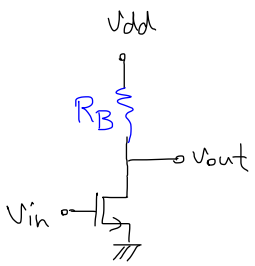
$V_A \gg V_{dd}$

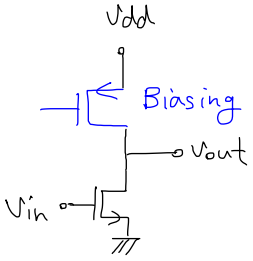


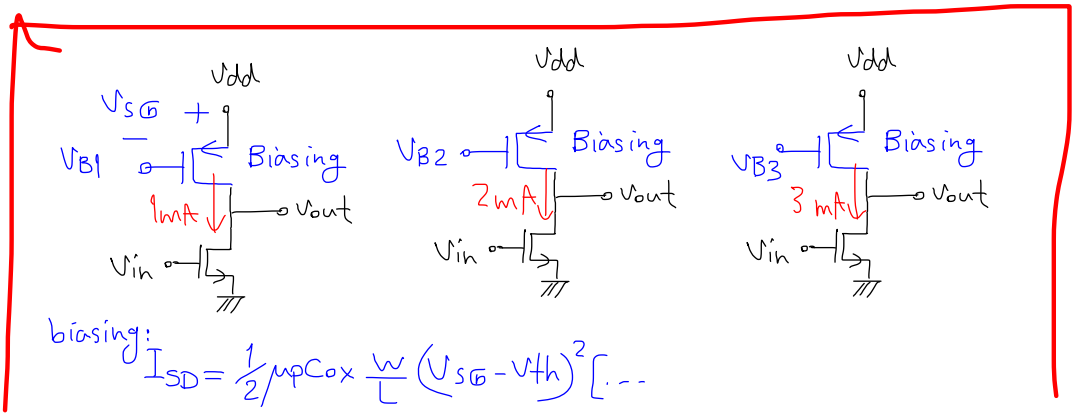
$$\tan\alpha = \frac{I_{DSQ}}{V_A + \cancel{V_{DSQ}}}, \begin{cases} V_A \gg V_{dd} \\ V_{DSQ} < V_{dd} \end{cases}$$

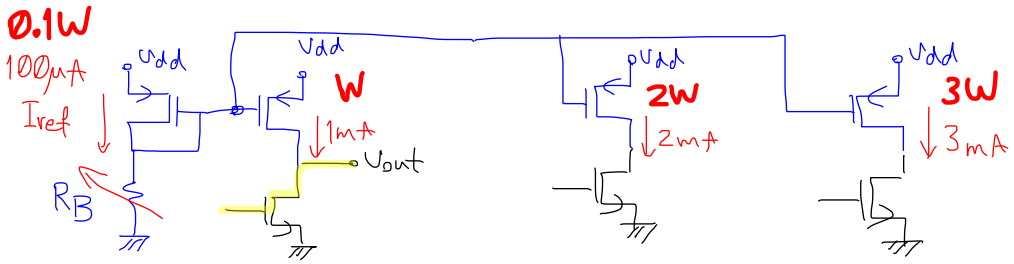
ignore

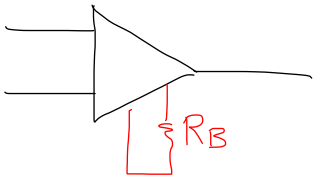
$$\frac{I_{DSQ}}{V_A} = \frac{1}{r_{ds}} = \lambda \cdot I_{DSQ} \Rightarrow \lambda = \frac{1}{V_A}$$

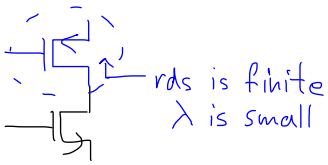

Vdd
RB
Vout
Vin

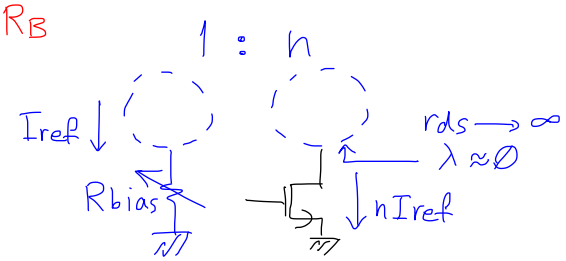

Vdd
Biasing
Vout
Vin


Vdd
VSG
VB1
Biasing
1mA
Vout
Vin
VB2
2mA
VB3
3 mA
biasing:
ISD = 1/2 μpCox W/L (VSG - Vth)^2 [...


0.1W
100μA
Iref
RB
Vdd
W
1mA
Vout
2W
2mA
3W
3mA

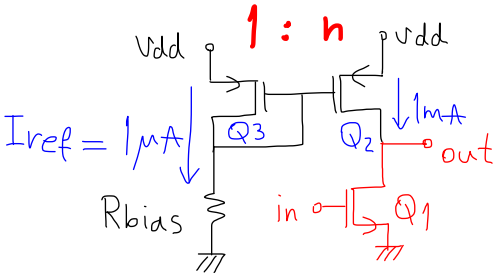

RB


rds is finite
λ is small


1 : n
Iref
Rbias
rds → ∞
λ ≈ 0
nIref

✳ Current Mirror (AC analysis):

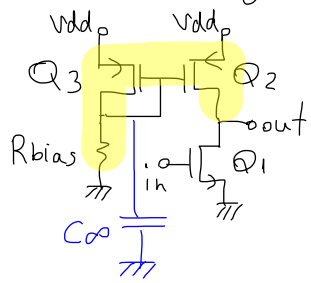
$L_2 = L_3 = 45\,nm$

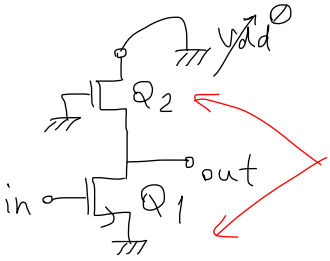


$$\frac{I_{SD2}}{I_{SD3}} \approx \frac{\frac{W_2}{L_2}}{\frac{W_3}{L_3}} \Rightarrow \frac{1mA}{1\mu A} = \frac{W_2}{W_3}$$

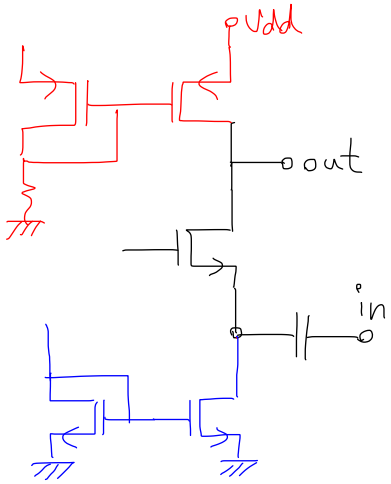
✳Gate of Q_2 mainly has a DC voltage and during AC analysis is considered as ground

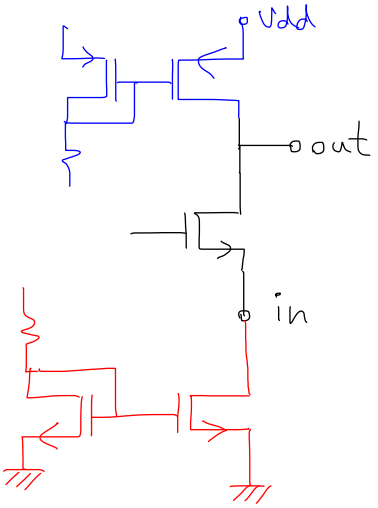
→ AC analysis





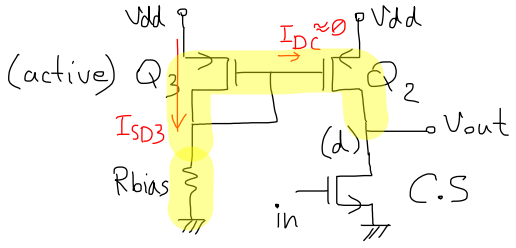
replace Q_1 and Q_2 with small-signal model

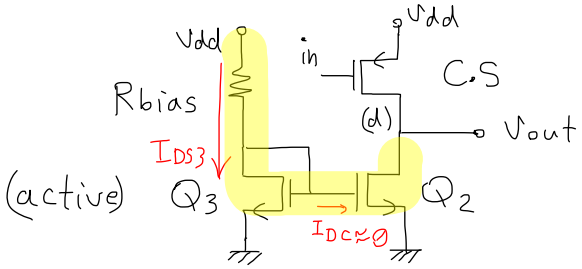




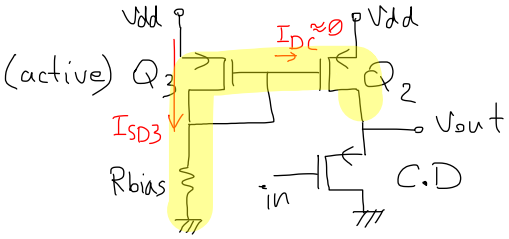
* Current Mirrors (in Circuit):

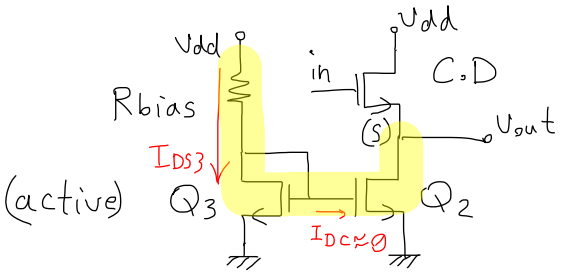
Common Source



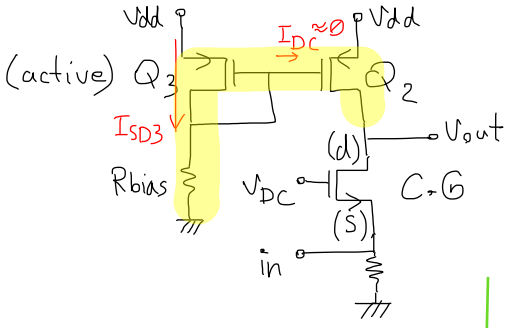


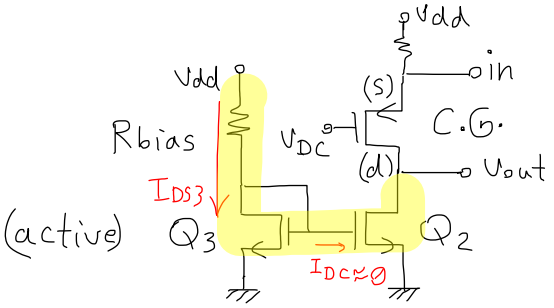
Common Drain

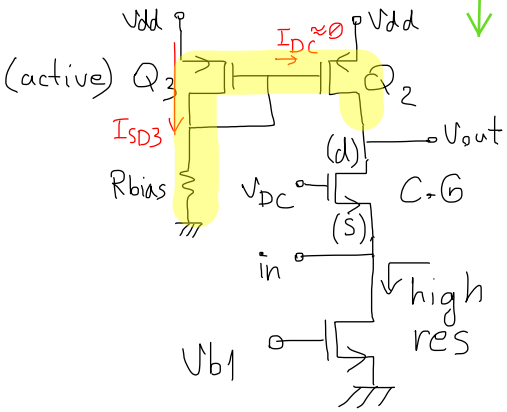


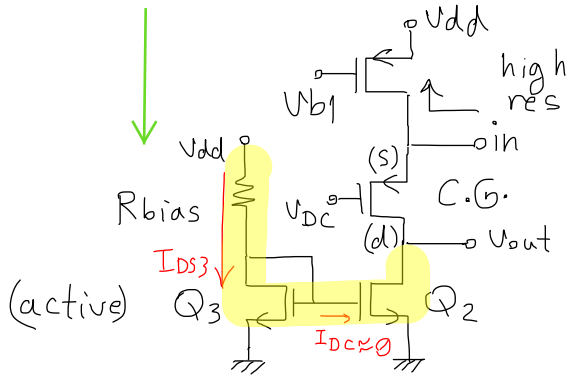


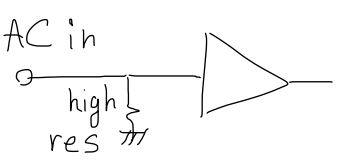
Common Gate

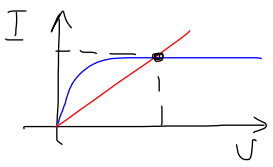




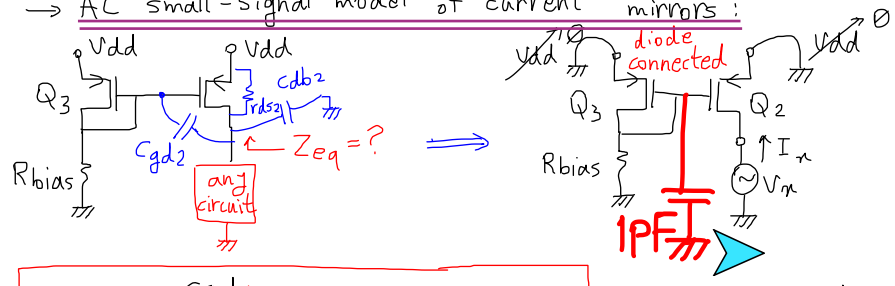




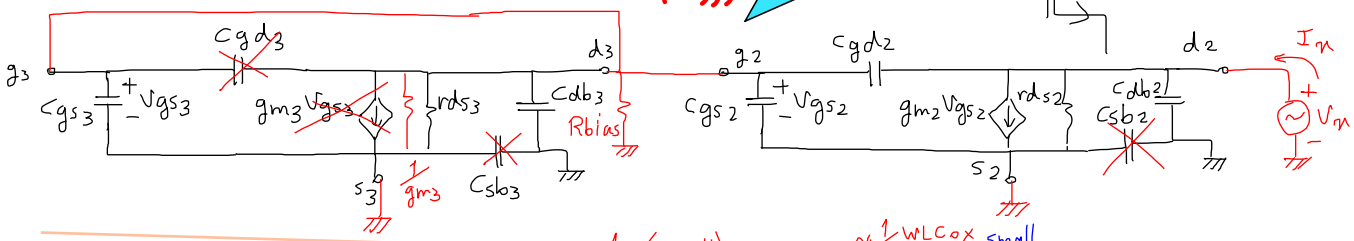




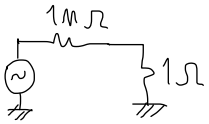
→ AC small-signal model of current mirrors:



$V_{gs} + \Big\downarrow g_m V_{gs} \equiv \frac{1}{g_m}$



$g_m r_{ds} \gg 1 \Rightarrow \frac{1}{g_m} \ll r_{ds}$ (small, large)

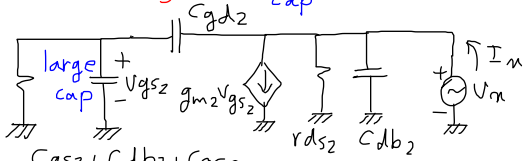


$V_{gs2} = V_x \dfrac{\text{small impedance}}{\text{large impedance} + \text{small impedance}}$

$V_{gs2} \approx 0$

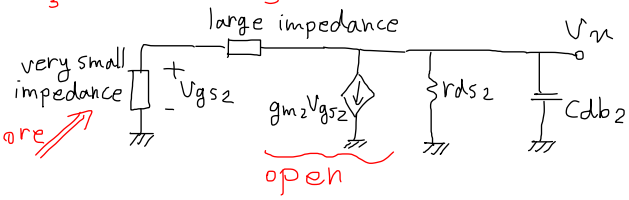
$\approx \frac{1}{g_{m3}}$ (small) $\quad R_{bias} \| \frac{1}{g_{m3}} \| r_{ds3}$

$\approx \frac{1}{3} WLC_{ox}$ small cap

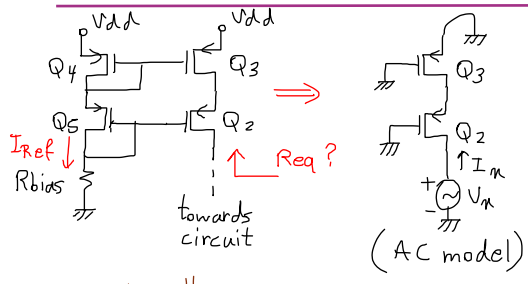


$C_{gs3} + C_{db3} + C_{gs2}$

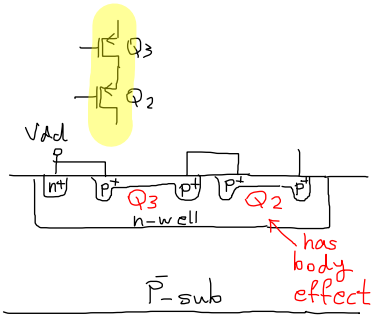
$\frac{2}{3} WLC_{ox}$ $\quad \frac{2}{3} WLC_{ox}$

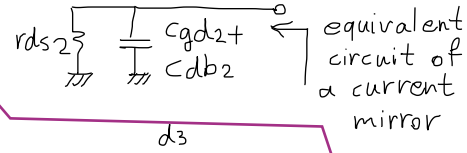


→ how to increase resistance of a current mirror:

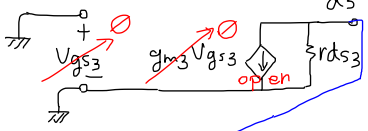


use one n-well



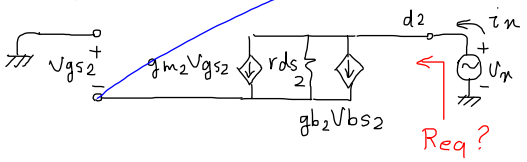


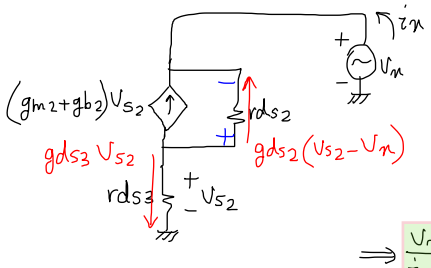
equivalent circuit of a current mirror



$V_{gs2} = V_{g2} - V_{s2} = -V_{s2}$

$V_{bs2} = V_{b2} - V_{s2} = -V_{s2}$





KCL(S2): $(g_{m2}+g_{b2})V_{s2} + g_{ds3}V_{s2} + g_{ds2}(V_{s2} - V_x) = 0$

$i_x = g_{ds3} V_{s2}$

$\Rightarrow V_{s2}\left[g_{m2}+g_{b2}+g_{ds3}+g_{ds2}\right] = V_x\left[g_{ds2}\right]$

$\Rightarrow \dfrac{V_x}{i_x} = \dfrac{g_{ds3}+g_{ds2}+g_{m2}+g_{b2}}{g_{ds2}\, g_{ds3}} \approx g_{m2} r_{ds2} r_{ds3}$