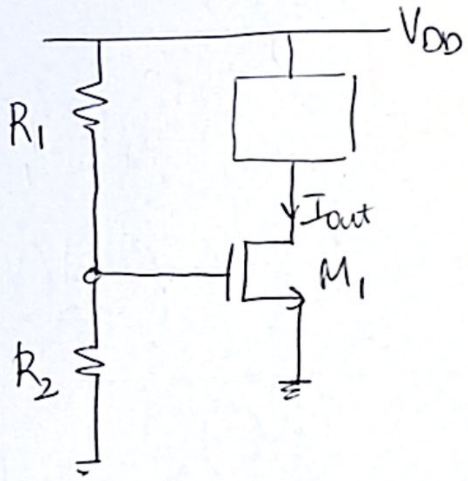
Lec 20 Current Mirrors / Biasing

Biasing

> We want to bias transistors such that the bias point is independent of Process, Voltage, Temp, (PVT).

Simplest implementation (without voltage sources).

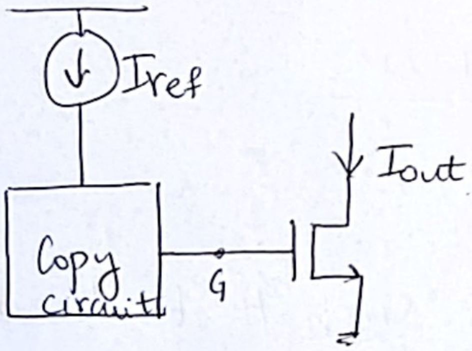


$$I_{out} = \frac{1}{2}\mu_n C_{ox}\frac{W}{L}\left(\frac{R_2}{R_1+R_2}V_{DD} - V_T\right)^2$$

μ_n ↑ Temp. — V_{DD} ↑ Supply — V_T ↑ Temp, Process

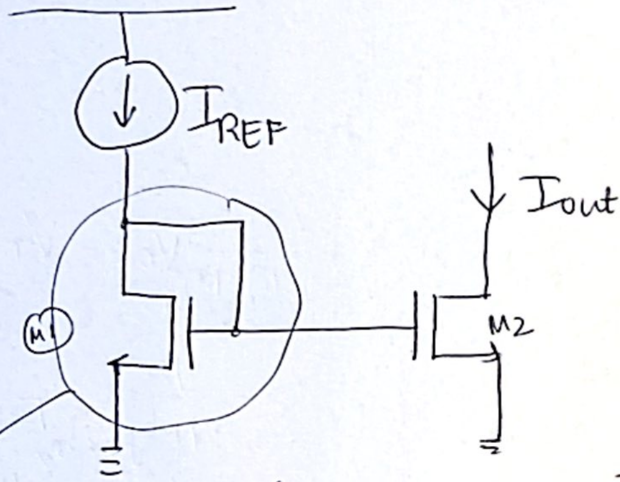
> Even if V_G is precise, I_{out} can vary!

> I_{REF} "exists" → How do we copy this, i.e how to make $I_{out} = K\, I_{REF}$?



Ignoring CLM

$$I_{out} = f(V_{GS}) \Rightarrow V_{GS} = f^{-1}(I_{out})$$



Diode connected ⇒ always saturation or OFF

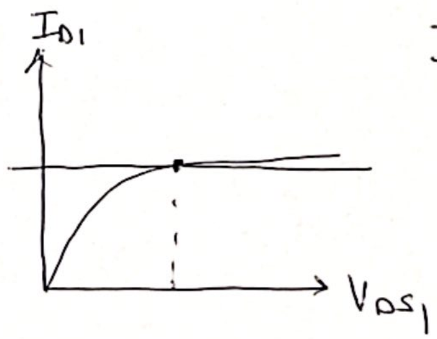
NMOS current mirror

$$I_{REF} = \frac{1}{2}\mu_n C_{ox}\left(\frac{W}{L}\right)_1 (V_{GS}-V_T)^2$$

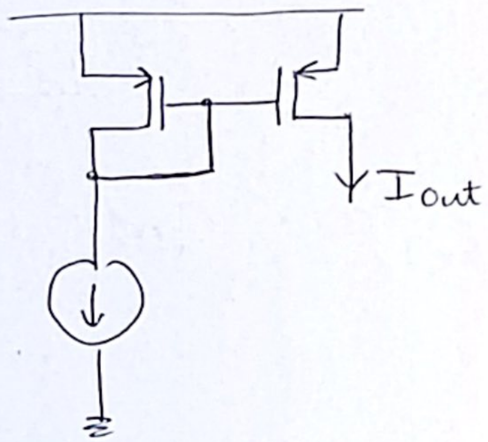
$$I_{out} = \frac{1}{2}\mu_n C_{ox}\left(\frac{W}{L}\right)_2 (V_{GS}-V_T)^2$$

$$\Rightarrow \boxed{I_{out} = \frac{(W/L)_2}{(W/L)_1} I_{REF}}$$

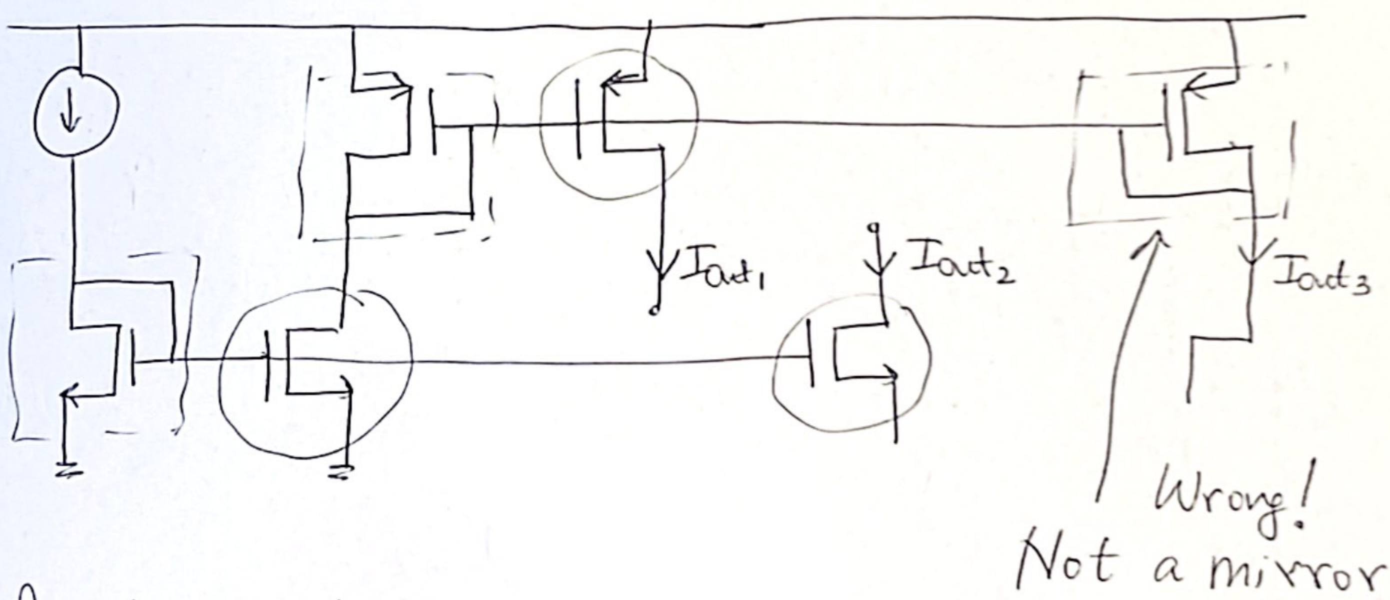
Independant of PVT.



PMOS current mirrors



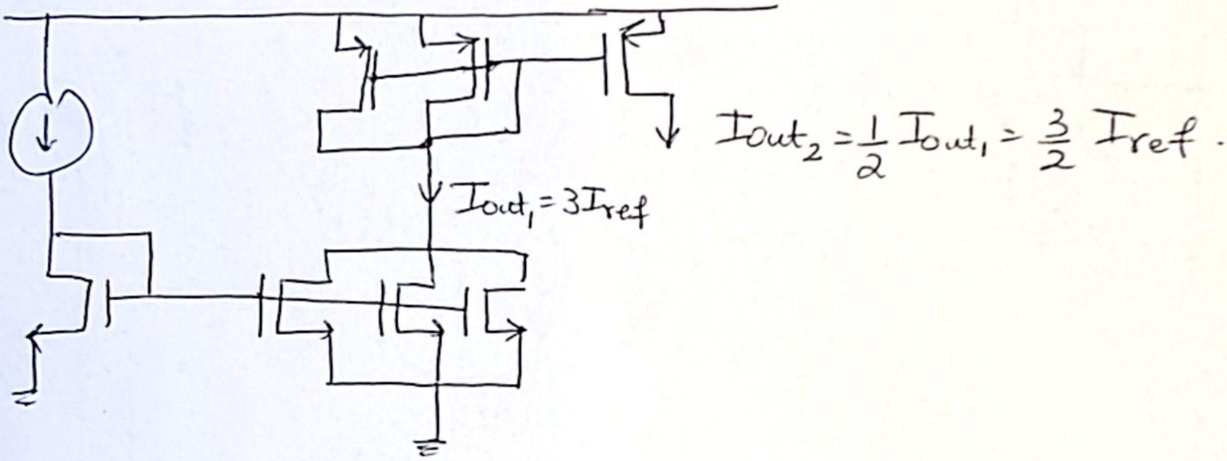
Combining



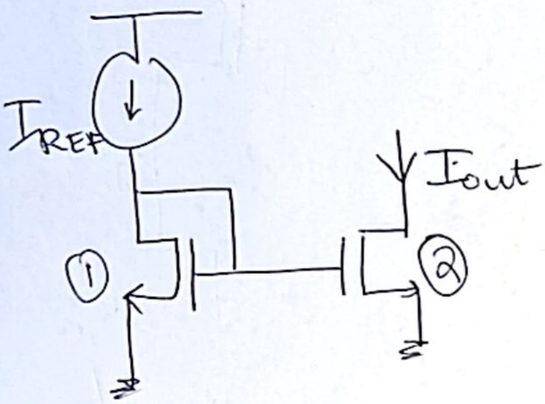
Implementation

> Mirror transistors are sized equally & copied, to prevent mismatches due to effective dimensions.

> To get non integer current copying, use 2 levels with $\frac{q}{p}$.



Including channel length modulation



$$I_{D1} = \frac{1}{2}\mu_n C_{ox}\left(\frac{W}{L}\right)_1 (V_{GS}-V_{TH})^2(1+\lambda V_{DS1})$$

$$I_{D2} = \frac{1}{2}\mu_n C_{ox}\left(\frac{W}{L}\right)_2 (V_{GS}-V_{TH})^2(1+\lambda V_{DS2})$$

$$\Rightarrow \frac{I_{D2}}{I_{D1}} = \frac{\left(\frac{W}{L}\right)_2}{\left(\frac{W}{L}\right)_1} \cdot \frac{1+\lambda V_{DS2}}{1+\lambda V_{DS1}}$$

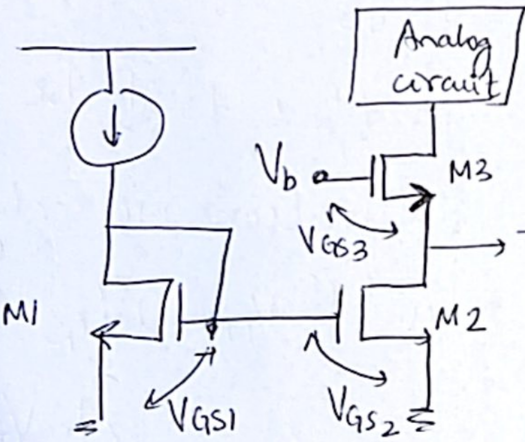
$V_{DS2} \rightarrow$?

$V_{DS1} \rightarrow V_{GS}$

We want $V_{DS1} = V_{DS2}$

Try making $V_{DS1} = V_{DS2}$

> We want $V_{DS2} \leftarrow V_{DS1}$ & also remain independent of any external influence

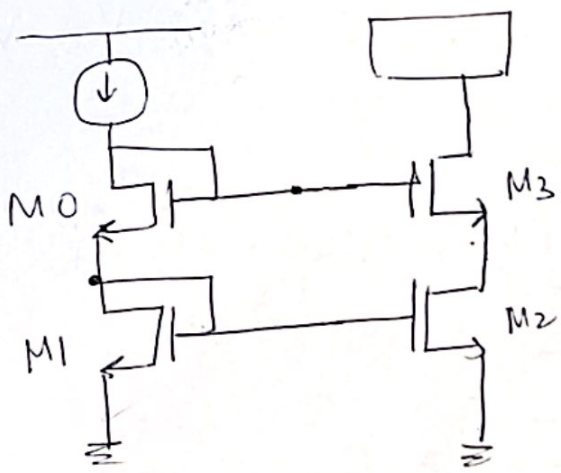


→ This node is "shielded.

We want $V_{DS1} = V_{DS2}$

$$\underbrace{V_b - V_{GS3}}_{V_{DS2}} = \underbrace{V_{GS1}}_{V_{DS1}}$$

$\Rightarrow V_b = V_{GS1} + V_{GS3}$ but I don't want to bias with voltage source. How do I generate $2 \times V_{GS}$?

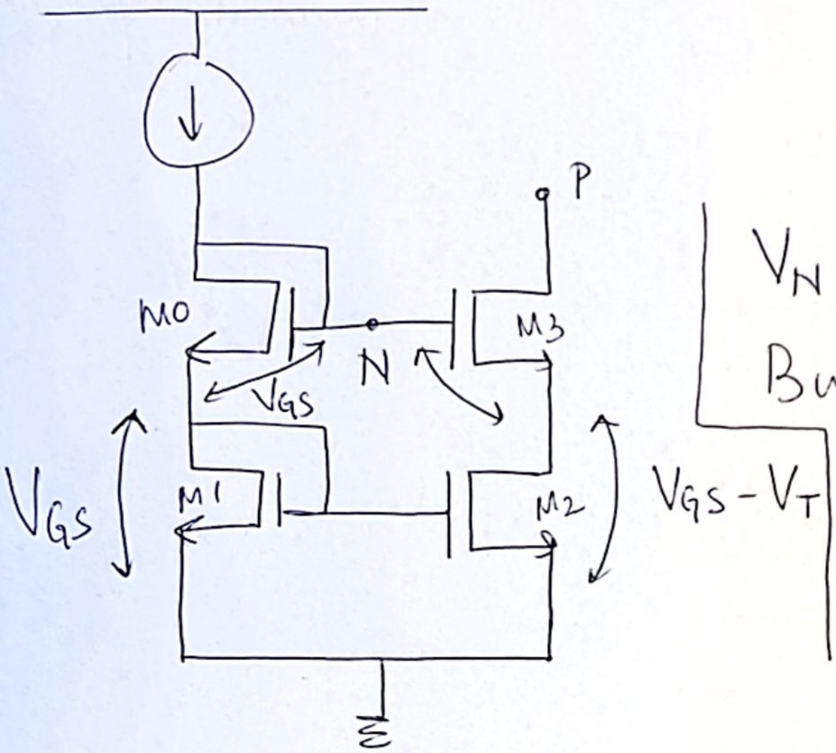


→ Cascode Current Mirror

$V_{GS0} = V_{GS3} \Rightarrow$ we have $V_{DS2} = V_{DS1}$.

→ $\frac{W_3}{W_0} = \frac{W_2}{W_1}$ for nonequal mirroring.

> This consumes too much headroom!



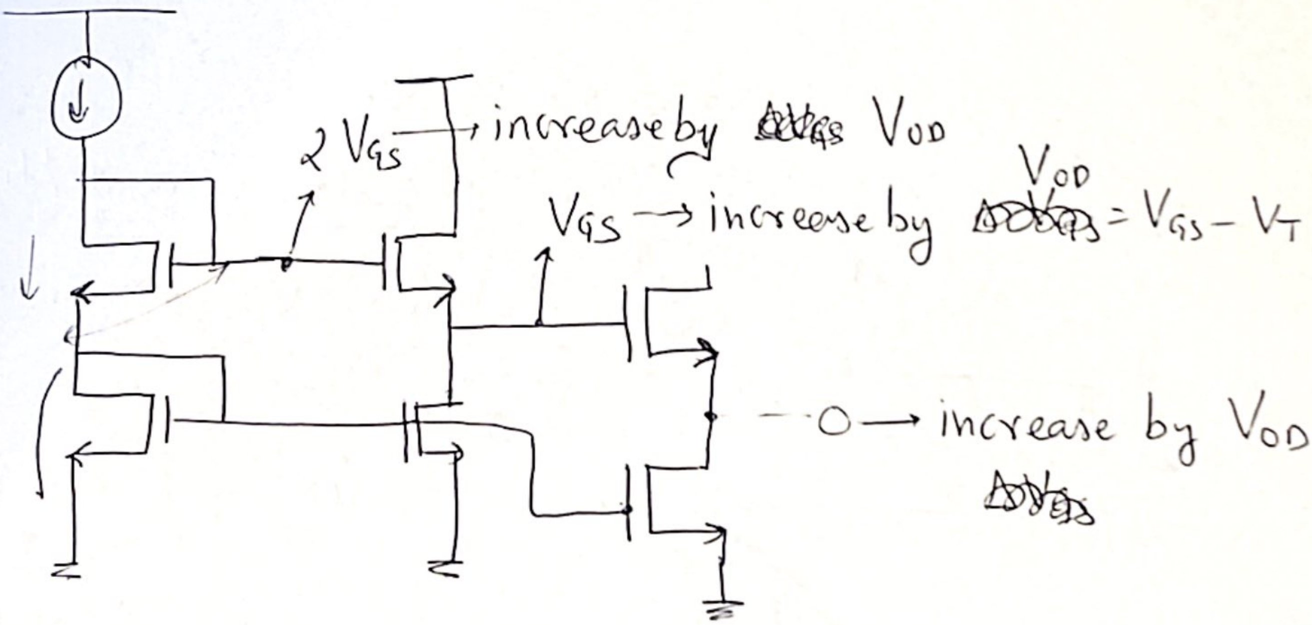
$V_N = 2V_{GS}$

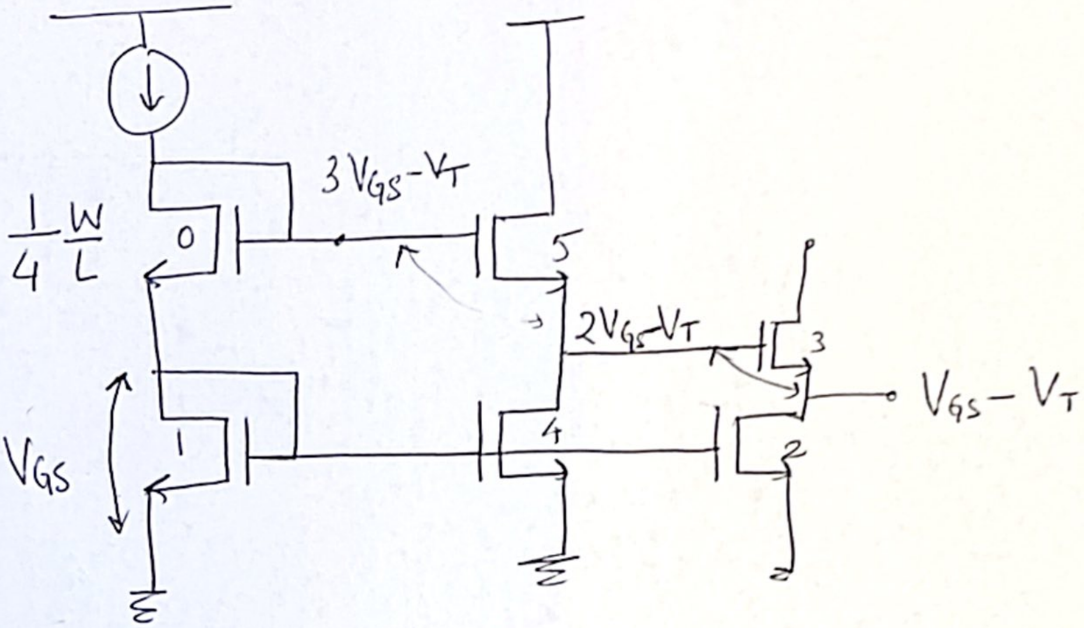
But for M_2 & M_3 to be in saturation we only need $V_N = 2V_{GS} - V_T$.

⇒ There is an extra V_T

$V_P = 2V_{GS} - V_T$ but it only needs to $2V_{GS} - 2V_T$.

How can we drop another V_T?





$$V_{OD} = V_{GS} - V_T = \sqrt{\frac{I_D}{\frac{1}{2}\mu_n C_{ox}\frac{W}{L}}} \Rightarrow \text{if } \frac{W}{L} \text{ is } \frac{1}{4} \Rightarrow V_{OD} = 2\times$$

$$V_{G3_0} = V_T + 2\left[V_{GS} - V_T\right]$$

$$= 2V_{GS} - V_T \Rightarrow V_{DS_2} = V_{GS} - V_T \,!$$
