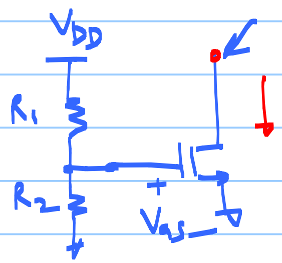
Note Title 2/5/2013

ECE 511 - Lecture 5

$f_T \propto \frac{V_{ov}}{L}$

$g_m r_o \propto \frac{L}{V_{ov}}$

* How to design stable current sources?



$I_{out} = \frac{k'_n}{2} \frac{W}{L} (V_{GS} - V_{THN})^2$

(initially $\lambda = 0$)

$$I_{out} = \frac{k'_n}{2} \cdot \frac{W}{L} \Big(\underbrace{\frac{R_2}{R_1 + R_2} \cdot V_{DD} - V_{THN}}_{V_{ov}} \Big)^2$$

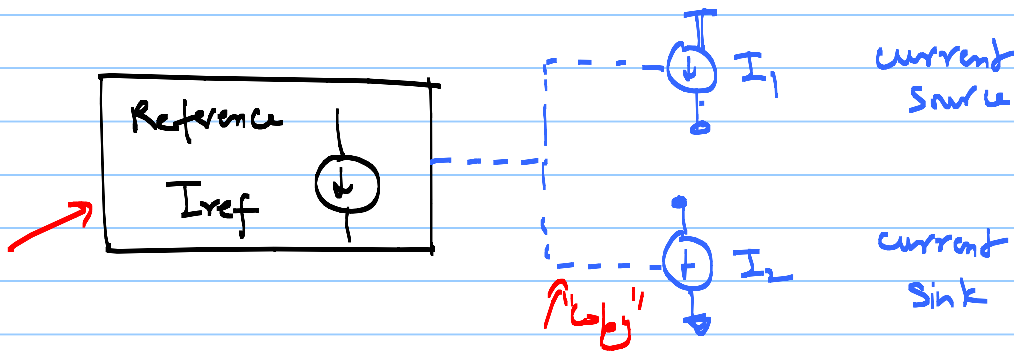
I_{out} depends upon $\rightarrow$ V_{DD}, T, μ_n, V_{THN}

$V_{ov} \rightarrow V_{DD}$ & V_{THN}

I_{out} is poorly defined

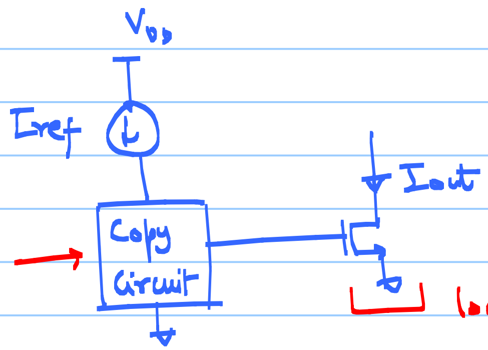
"precise"

$\underline{\underline{Sol^n}}$ Create a stable, "precise" reference generator, and "copy" the currents.



* How to generate copies of a reference current?

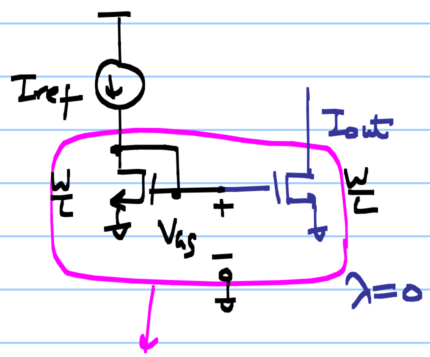
How do we get $I_{out} = I_{ref}$??



local current source

$$I_D = f(V_{GS}, V_{DS}) = f(V_{GS})$$

$$V_{GS} = f^{-1}(I_{ref})$$



$$I_{out} = \cancel{f}\left(\cancel{f^{-1}}(I_{ref})\right) = I_{ref}$$

Current Mirror

"matched transistors"

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

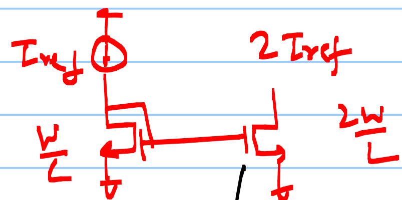
$$I_{ref} = \frac{1}{2} k P_n \left(\frac{W}{L}\right)_1 (V_{GS} - V_{THN})^2$$

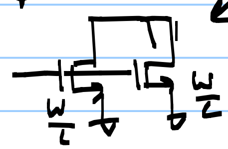
$$I_{out} = \frac{1}{2} k P_n \left(\frac{W}{L}\right)_2 (V_{GS} - V_{THN})^2$$

for same L

$$\frac{I_{out}}{I_{ref}} = \frac{(W/L)_2}{(W/L)_1} \Rightarrow \boxed{I_{out} = \left(\frac{W_2}{W_1}\right) I_{ref}}$$

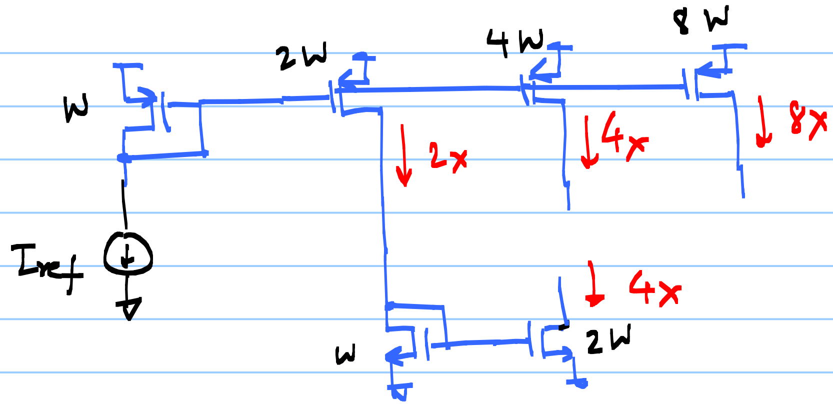
* copy and scale current by $\left(\frac{W}{L}\right)$ ratio





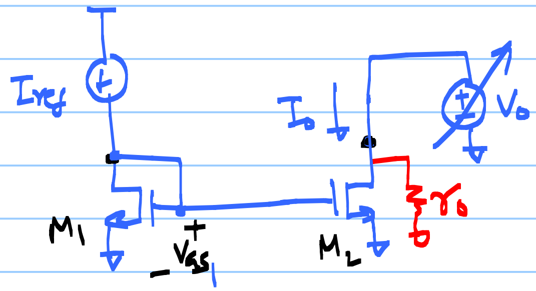
in short channel

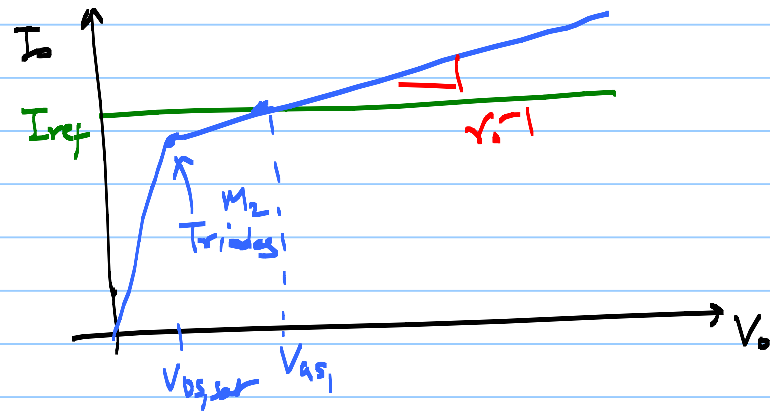
$\lambda = 0$



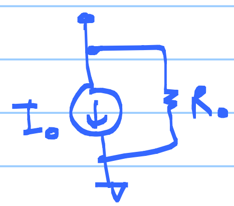
$\lambda > 0$

For M_2, $I_D = f(V_{GS}, \underset{\uparrow V_o}{V_{DS}})$



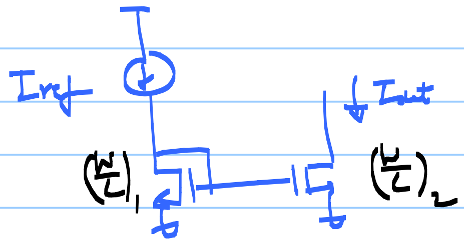


For precise matching $\Rightarrow$ $V_{DS_2} = V_{GS_1}$



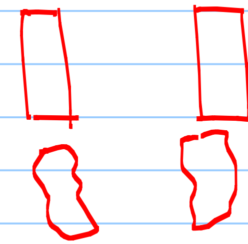
$\Rightarrow$ A good current source should have large "R_o"

Matching in current mirrors



$V_{THN_1} \neq V_{THN_2}$

$\left(\frac{W}{L}\right)$ mismatch



$$y = f(x_1, x_2, \ldots)$$

$$\Delta y = \left(\frac{\partial f}{\partial x_1}\right) \cdot \Delta x_1 + \left(\frac{\partial f}{\partial x_2}\right) \Delta x_2 + \cdots$$

sensitivity error (mismatch)

$$I_D = \frac{KP_n}{2}\left(\frac{W}{L}\right)\left(V_{GS} - V_{THN}\right)^2$$

$$\Delta I_D = \frac{\partial I_D}{\partial (W/L)} \cdot \Delta\left(\frac{W}{L}\right) + \frac{\partial I_D}{\partial (V_{GS}-V_{THN})} \cdot \Delta (V_{GS}-V_{THN})$$

$$= \frac{KP_n}{2} \cdot (V_{GS}-V_{THN})^2 \cdot \Delta\left(\frac{W}{L}\right) - KP_n \left(\frac{W}{L}\right)(V_{GS}-V_{THN}) \cdot \Delta V_{THN}$$

Normalize

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

$$\sigma_{(W/L)} \propto \frac{1}{\sqrt{WL}}$$

$$\sigma_{\Delta V_{THN}} \propto \frac{1}{\sqrt{WL}}$$

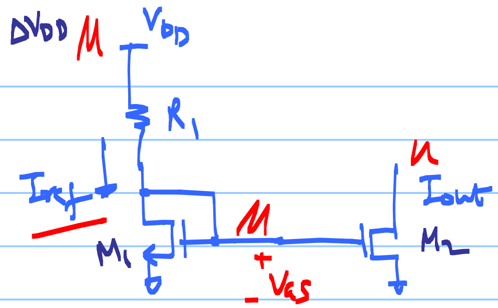
$$\sigma^2_{\frac{\Delta I_D}{I_D}} = \frac{\sigma^2_{\Delta (W/L)}}{(W/L)^2} + 4 \cdot \frac{\sigma^2_{\Delta V_{THN}}}{(V_{GS}-V_{THN})^2}$$

* To minimize the current mismatch

① Large "WL"

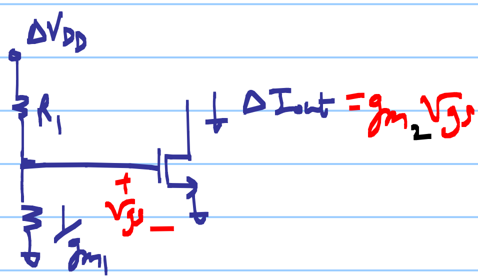
② Use larger V_{OV}

* How do we generate I_{ref}?



$\boxed{V_{DD}} \leftarrow$ Supply independent biasing

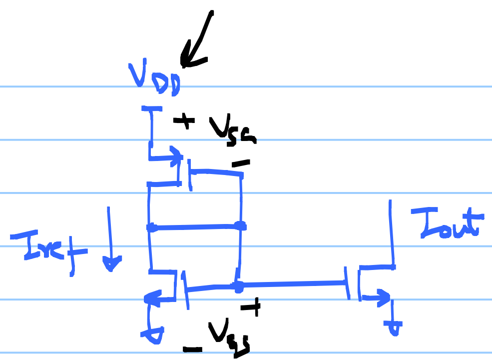
$T \leftarrow$ "BGR"



$$\Delta I_{out} = \frac{\Delta V_{DD}}{R_1 + 1/g_{m1}} \cdot \frac{(W/L)_2}{(W/L)_1}$$

"PSRR"

$$\Delta I_{out} = \frac{\Delta V_{DD}}{R_1 + 1/g_{m1}} \cdot \frac{1}{g_{m1}} \cdot g_{m2}$$



$V_{DD} = V_{GS} + V_{SG}$

Solve for I_{ref}

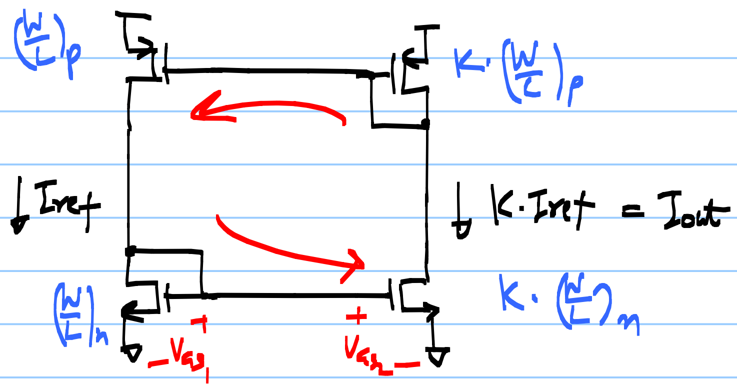
$$(V_{DD} - V_{THp} - V_{THN})^2 = I_{ref} \underbrace{\left(\sqrt{\frac{2}{\beta_p}} + \sqrt{\frac{2}{\beta_n}}\right)^2}_{K}$$

$$I_{ref} = \frac{1}{K} \cdot (V_{DD} - V_{THN} - V_{THp})^2$$

- How to Get rid of V_{DD} dependence??

$$\Delta I_{ref} = \frac{\Delta V_{DD}}{1/g_{mn} + 1/g_{mp}}$$

Assuming $\lambda = 0$



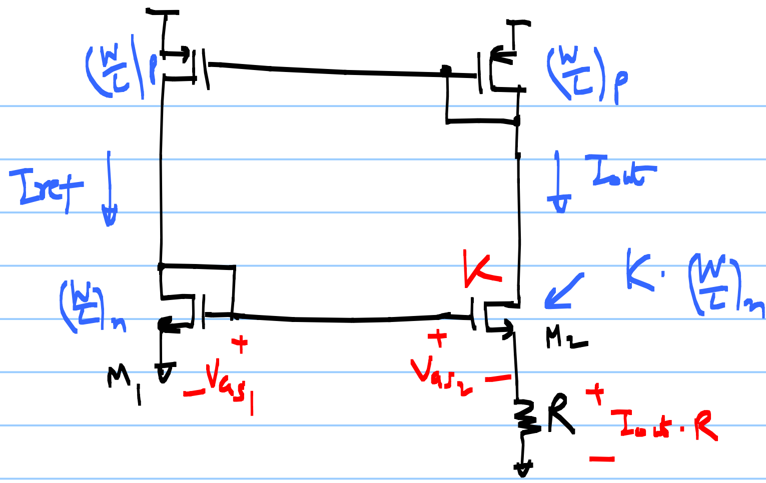
$I_{out} = K \cdot I_{ref}$

* ∵ I_{out} & I_{ref} feed from each other
  ↳ indep. of V_{DD}

* How do we set value of I_{ref}?

$\lambda = 0$

$I_{out} = I_{ref}$



* assume $V_{THN_1} = V_{THN_2}$

$$V_{GS_1} = V_{GS_2} + I_{out} \cdot R$$

$$\sqrt{\frac{2\, I_{out}}{KP_n \left(\frac{W}{L}\right)_1}} + \cancel{V_{THN_1}} = \sqrt{\frac{2\, I_{out}}{KP_n \left(\frac{W}{L}\right)_1 K}} + \cancel{V_{THN_2}} + I_{out} \cdot R$$

$$\sqrt{\frac{2\, I_{out}}{KP_n (W/L)}} \left(1 - \frac{1}{\sqrt{K}}\right) = I_{out} \cdot R \longrightarrow (1)$$

$I_{out} = \underset{\times}{0},\ \boxed{\frac{2}{KP_n\left(\frac{W}{L}\right)} \cdot \frac{1}{R^2}\left(1-\frac{1}{\sqrt{K}}\right)^2}$ ← independent of V_{DD}

Beta Multiplier Reference (BMR)

↳ 'Coz of K