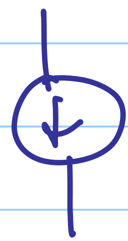
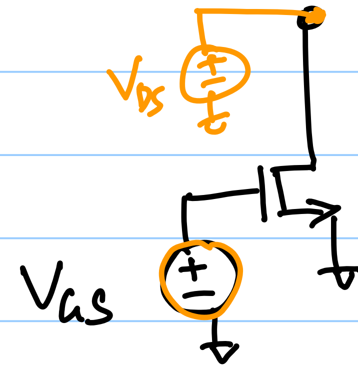
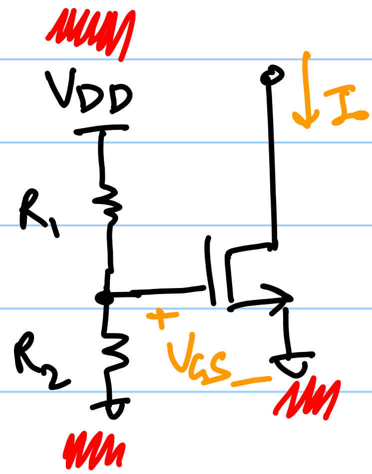
ECE 511 - Lecture 5

Note Title 1/29/2015





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

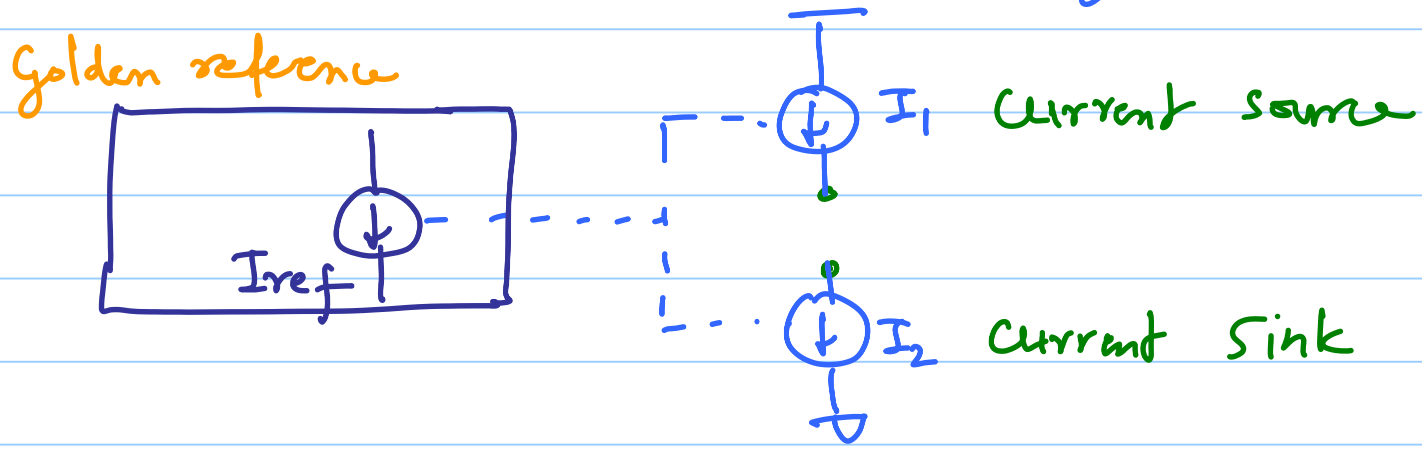


$$I_o = \beta\left(\frac{R_2}{R_1+R_2}V_{DD} - V_{THN}\right)^2$$

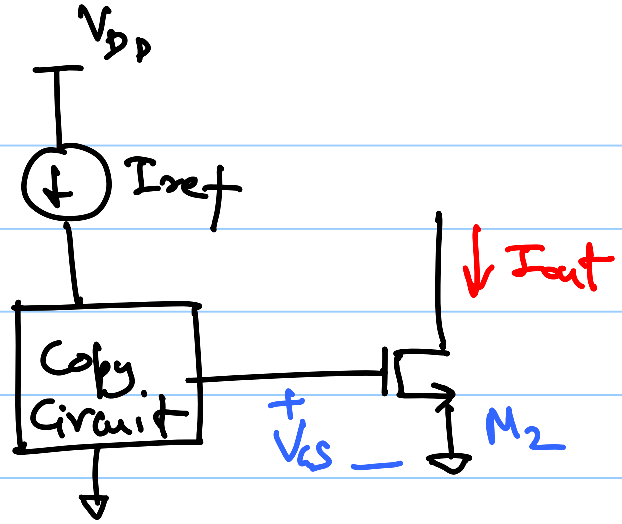
I_{out} depends upon → V_{DD}, process,

PVT-dependent

Sol^n: Create a stable "precise" reference generator and then copy the currents

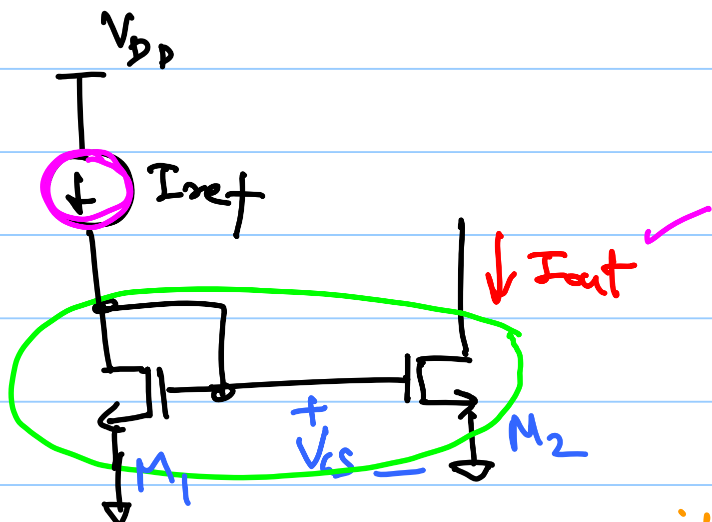


* first study the "copying" operation
later come back to precise reference



(assume $\lambda = 0$)

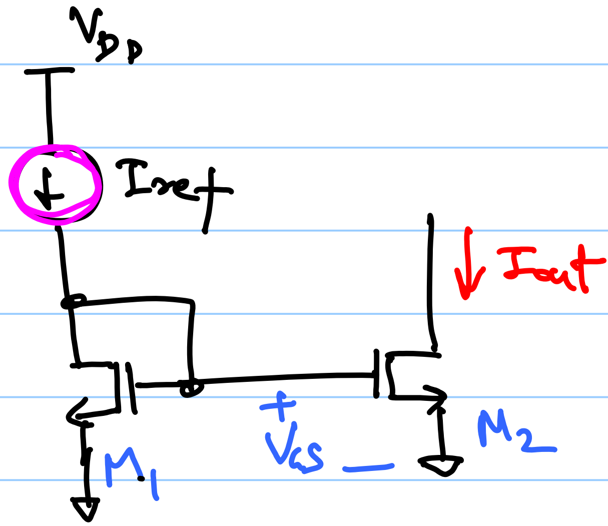
$$I_{DS} = f(V_{GS})$$



$$V_{GS} = \sqrt{\frac{2 I_{ref}}{\beta}} + V_{THN}$$

if no channel length modulation

$$I_{out} \triangleq I_{ref}$$



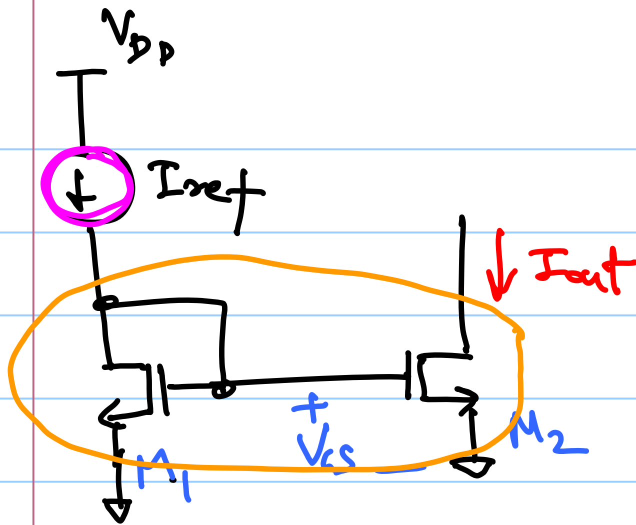
$\lambda = 0$

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

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

$$\frac{I_{out}}{I_{ref}} = \frac{(W/L)_2}{(W/L)_1}$$

$$= \frac{W_2}{W_1} \quad \text{for the same lengths}$$

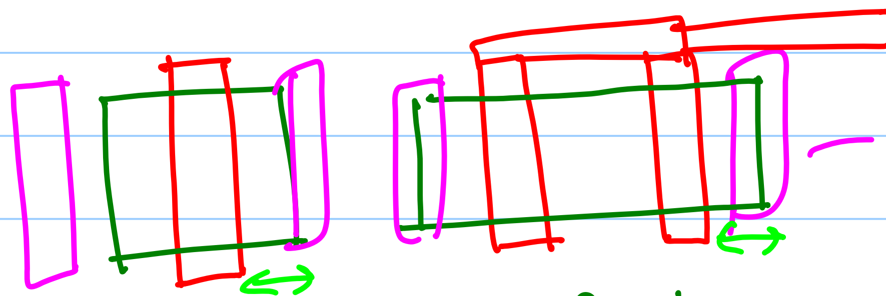


$\lambda = 0$

$$\frac{I_{out}}{I_{ref}} = \frac{W_2}{W_1}$$ for same L

current mirror

two devices should be perfectly "matched"



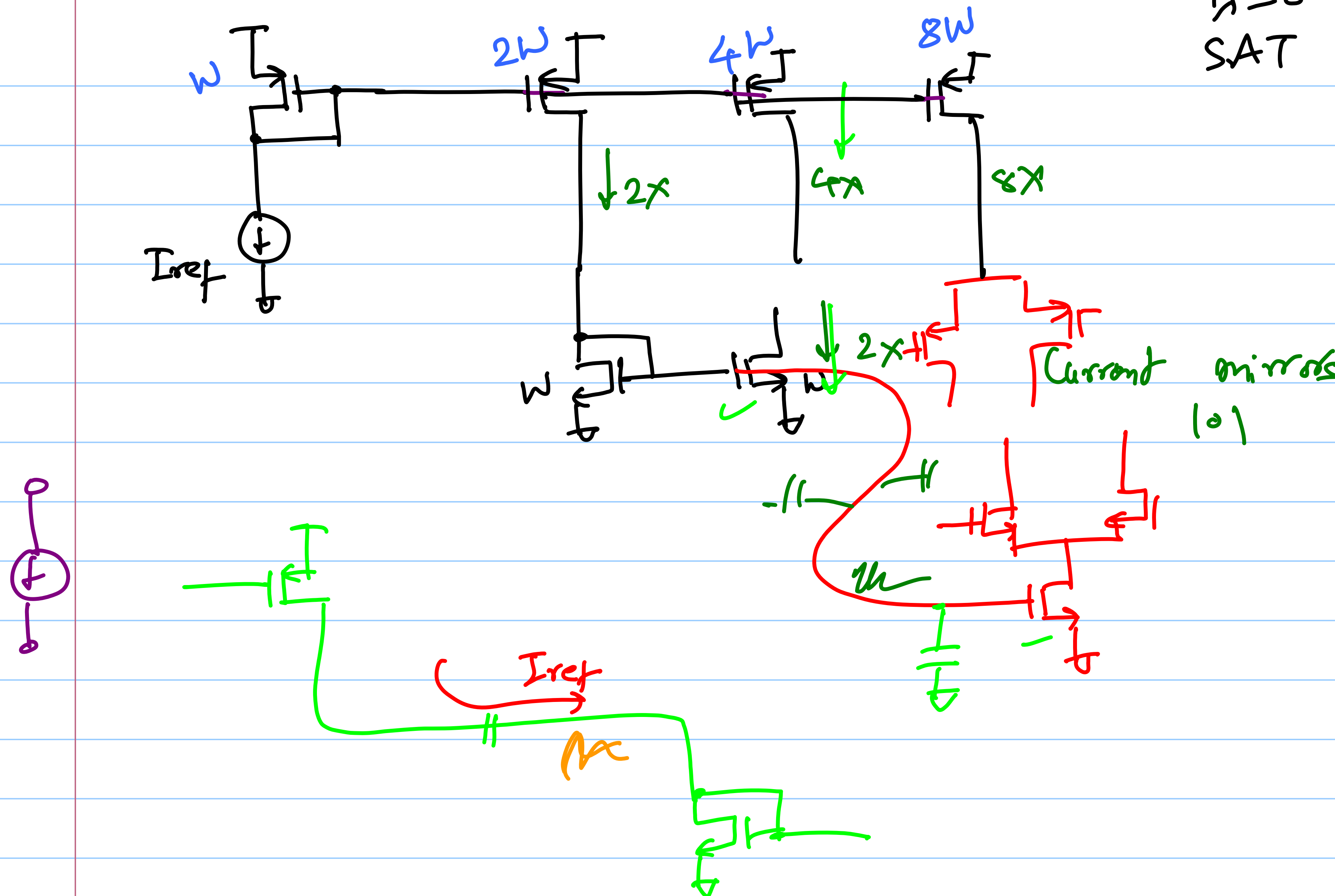
dummy poly

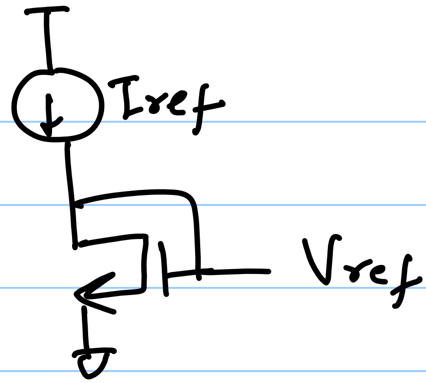
$2 \times \frac{10}{1}$

$$\frac{10}{1} = \frac{1.8\mu}{0.18\mu}$$

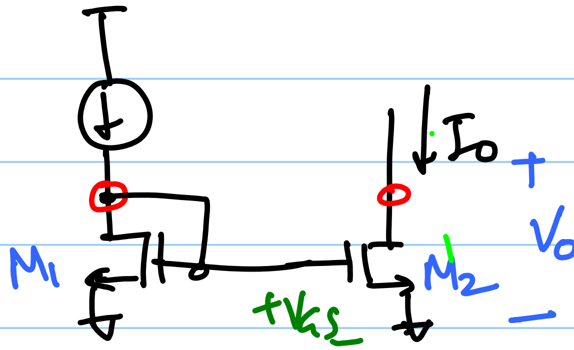
$\lambda = 0$

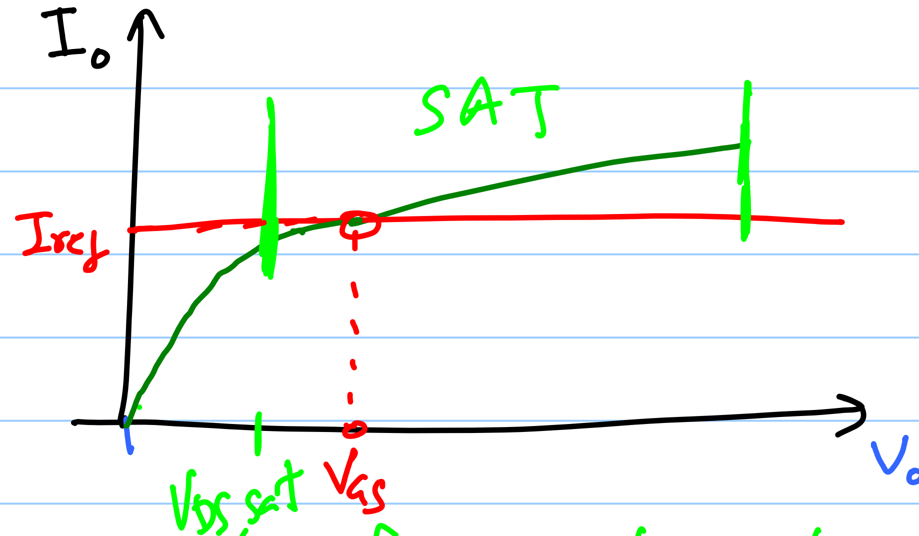
SAT



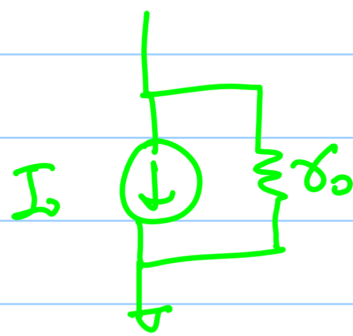

Iref
Vref

$\lambda \neq 0$

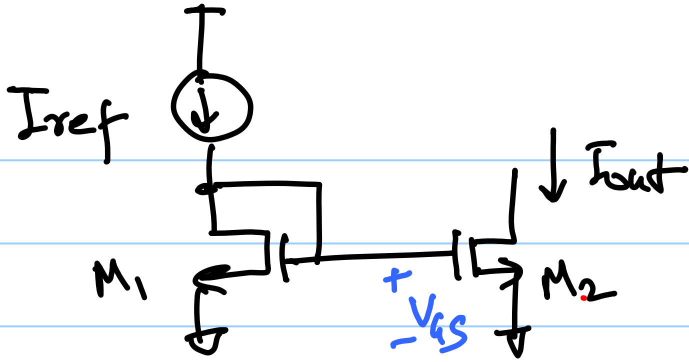




$V_{DS_2} = V_{DS_1} = V_{GS}$

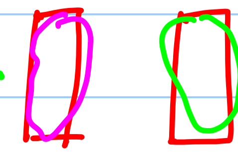


SAT



What can go wrong?

$\Delta(W/L)$, ΔV_{THN}



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

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

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

Sensitivity analysis

$$\Delta y \simeq \frac{\partial f}{\partial x_1} \cdot \Delta x_1 + \frac{\partial f}{\partial x_2} \Delta x_2 + \cdots$$

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

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

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

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

To minimize current mismatch

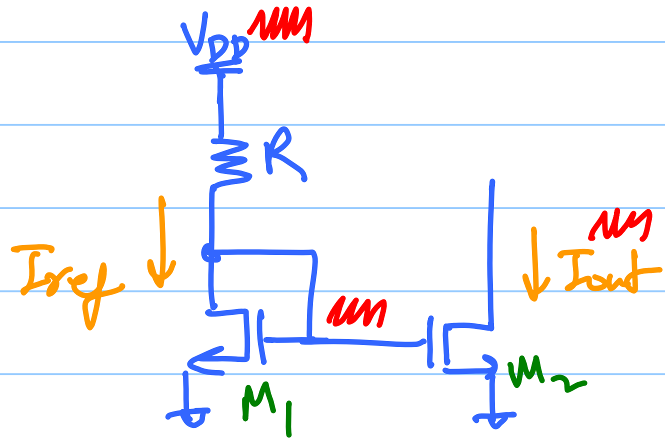
① V_{ov} should be large

② Large WL

$$y = x_1 - x_2$$

$$\sigma_y^2 = \sigma_{x_1}^2 + \sigma_{x_2}^2$$

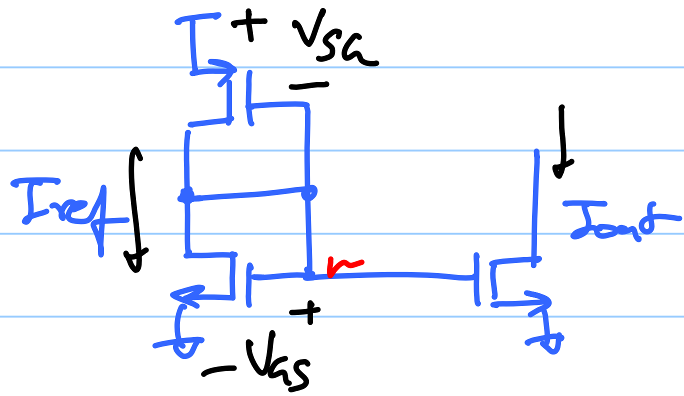
* How do we generate I_{ref}?



V_{DD} dependent X

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

supply noise sensitivity



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

$$= \sqrt{\frac{2 I_{ref}}{\beta_n}} + V_{THN} + \sqrt{\frac{2 I_{ref}}{\beta_p}} + V_{THP}$$

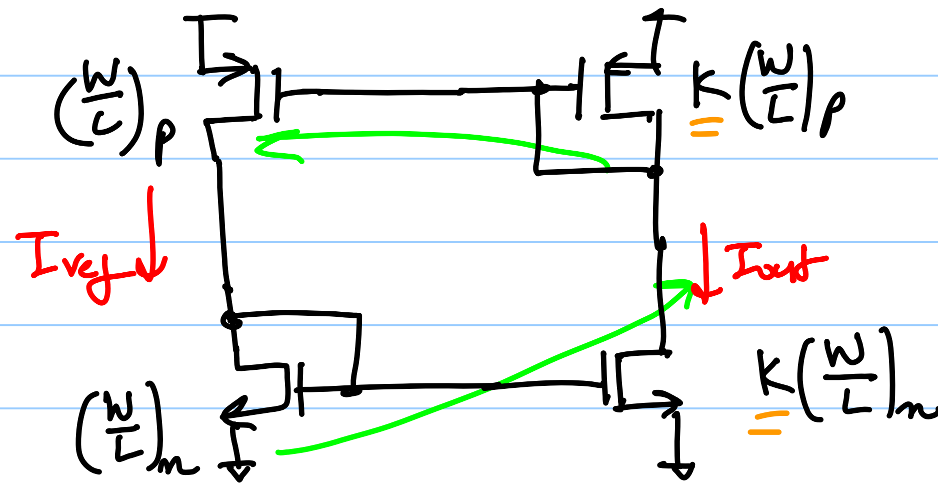
Solve for I_{ref}

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

Supply Independent Biasing

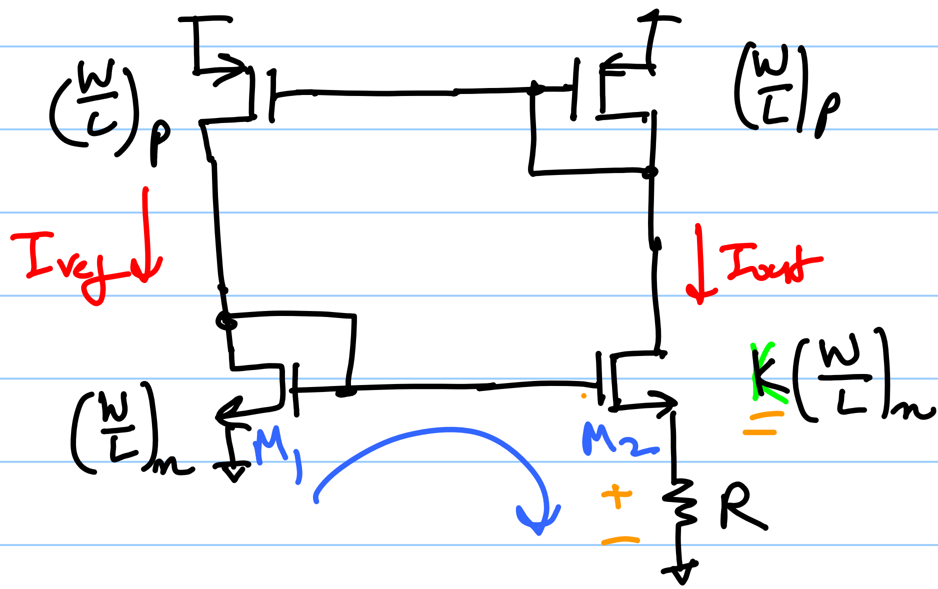
⇒ In order to get rid of V_{DD} sensitivity, the circuit must bias itself

⇒ I_{ref} must be derived from I_{out}



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

How do we set unique values for I_{ref} & I_{out}?



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

$$\sqrt{\frac{2I_{out}}{K'_n (W/L)_1}} + \cancel{V_{THN_1}} = \sqrt{\frac{2I_{out}}{K'_n (W/L)_2}} + \cancel{V_{THN_2}} + I_{out} \cdot R$$

$$\left(\frac{W}{L}\right)_2 = K \cdot \left(\frac{W}{L}\right)_1$$

* neglecting body-effect $V_{THN_1} = V_{THN_2}$

$I_{out} \triangleq I_{ref}$

" $\lambda = 0$ "

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

$$I_{out} = \begin{cases} \dfrac{2}{Kp_n\left(\frac{W}{L}\right)R^2}\left(1-\dfrac{1}{\sqrt{K}}\right)^2 \\ \underline{\underline{0}} \end{cases}$$

indep of V_{DD}