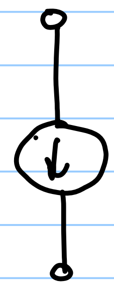
ECE 511 – Lecture 6

Note Title 2/6/2014

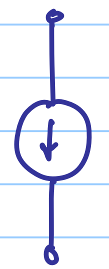
Current Mirrors :



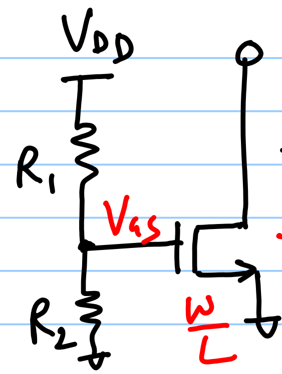
Current sources

* are used widely in circuit design

* How to design stable current sources.



VCCS



$\lambda = 0$

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

→ depends V_{DD}, process (V_{THN}), Temp

Temperature Dependence

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

$$\frac{\partial V_{THN}}{\partial T} \simeq -\frac{k}{q}\ln\left(\frac{N_{D,\,poly}}{N_A}\right) \simeq -1\,mV/^\circ C$$

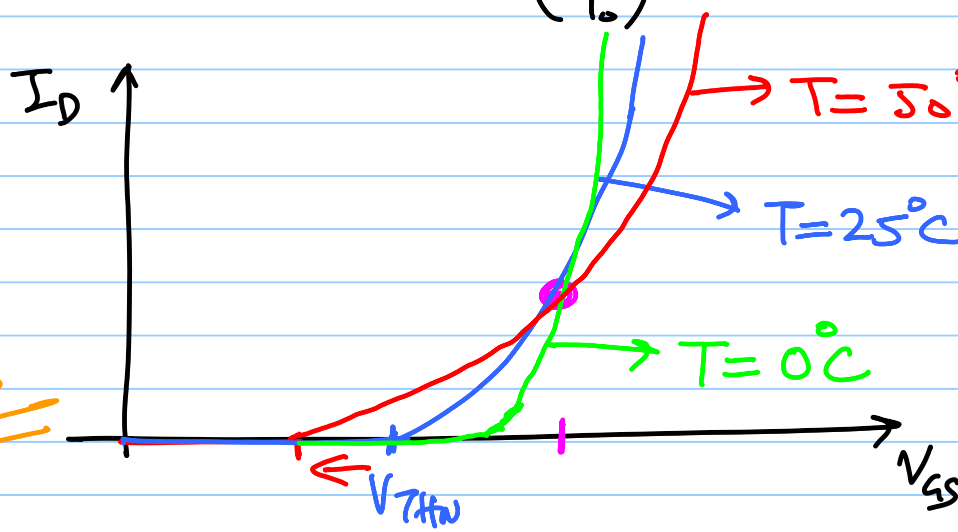
$$KP_n(T) = KP_n(T_0)\left(\frac{T}{T_0}\right)^{-3/2}$$

$T\uparrow \Rightarrow$ $\underline{\underline{V_{THN}\downarrow}}$ $\boxed{\underline{KP_n\downarrow}}$

CMOS

Fig 9.29

9.30

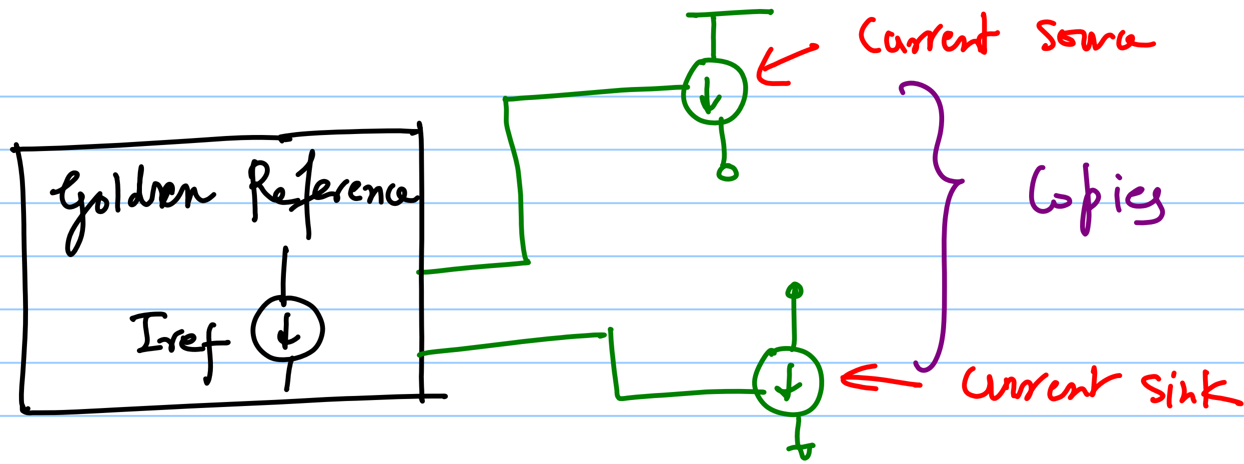


DC sweep over V_{GS}

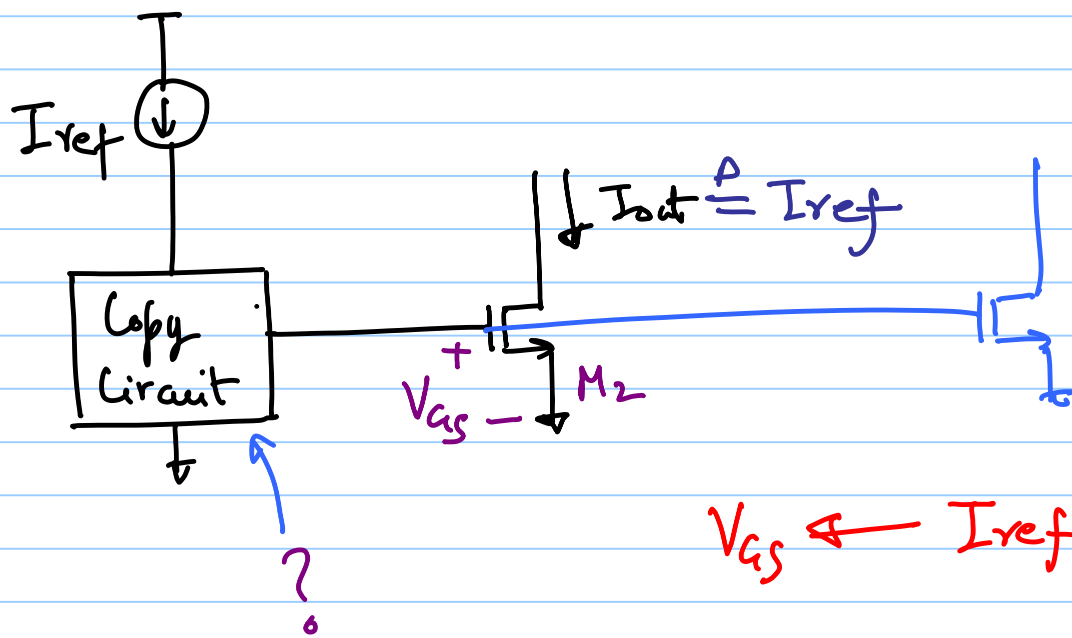
parametric sweep

Temperature

Solⁿ



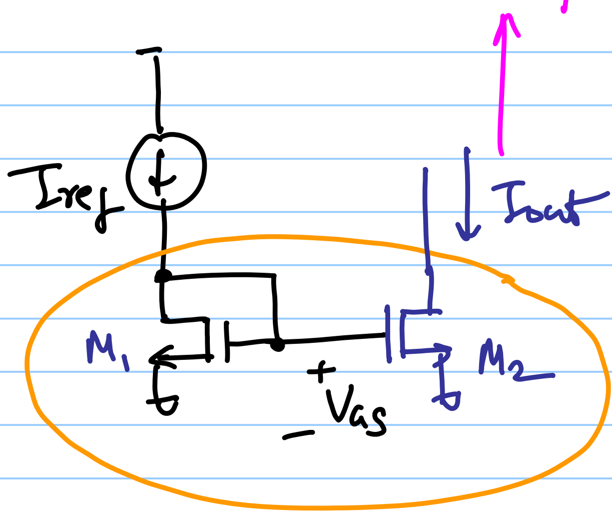
* How to generate copies of a reference current?



How to assure that $I_{out} = I_{ref}$?

$V_{GS} \leftarrow I_{ref}$

$\lambda = 0$



Current Mirror

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

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

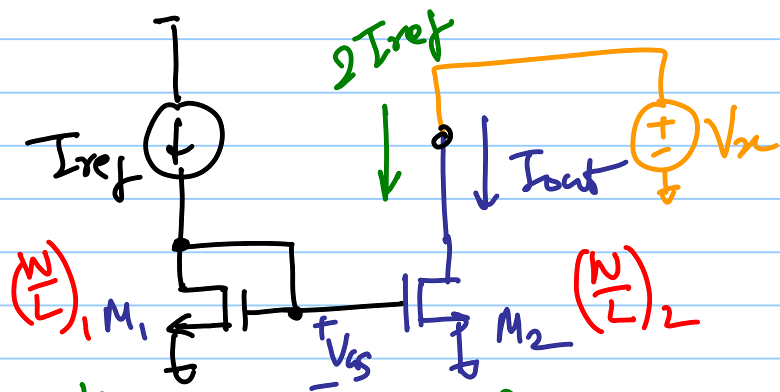
$$\Rightarrow \quad V_{GS} = f^{-1}(I_{ref}) \leftarrow \text{independent of } V_{DS}$$

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

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

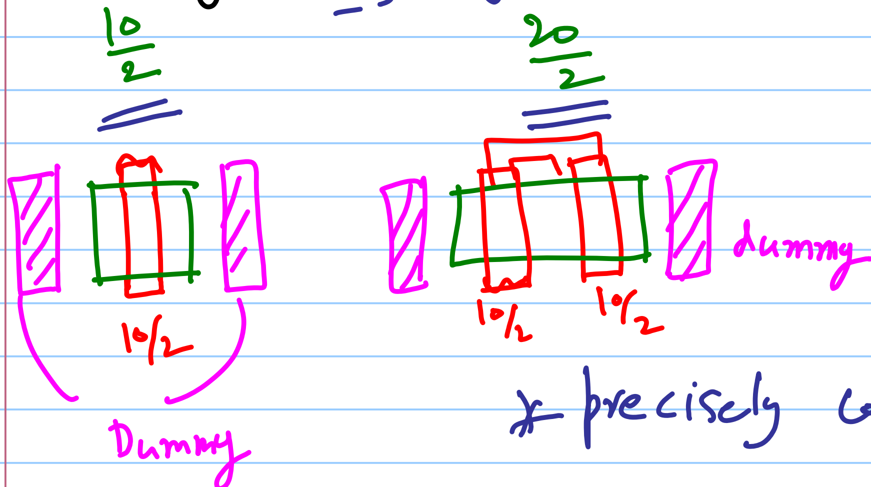
$$= I_{ref}, \quad \text{assuming } \lambda = 0$$

$\boxed{\lambda = 0}$



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

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

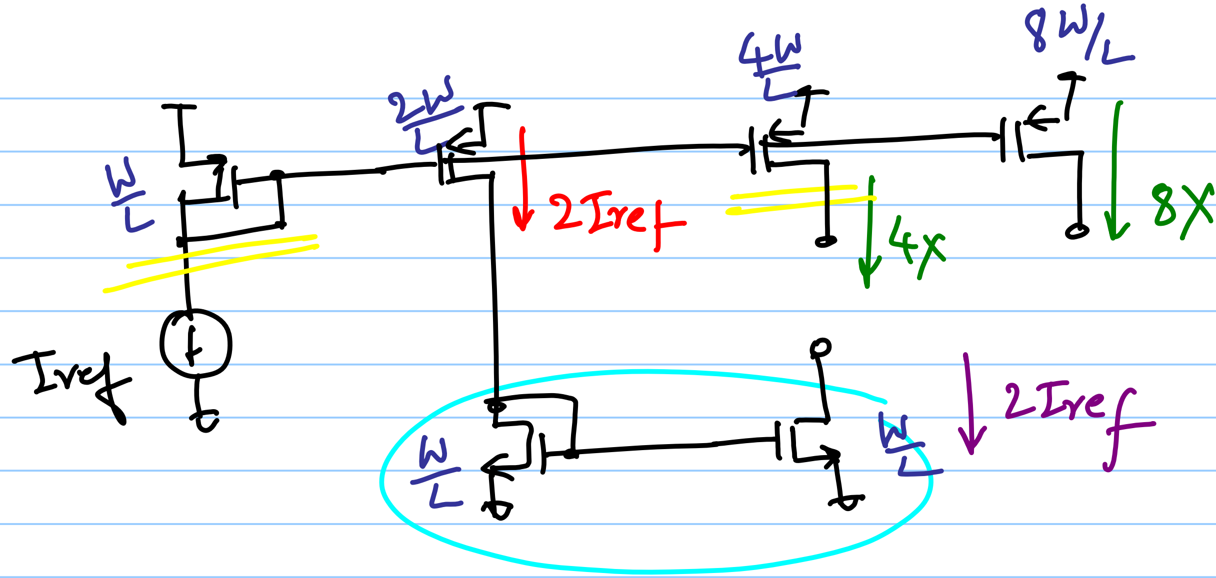


$$\frac{I_{out}}{I_{ref}} = \frac{(W/L)_2}{(W/L)_1} = \frac{W_2}{W_1}$$

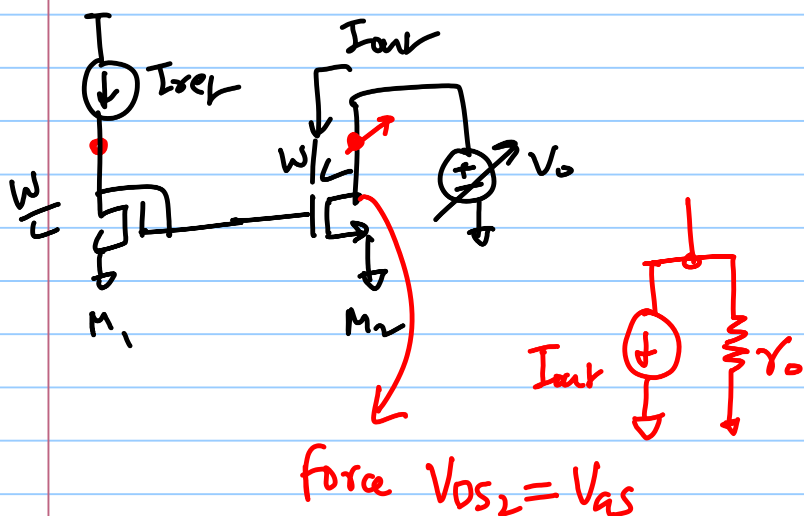
Let $L_1 = L_2$

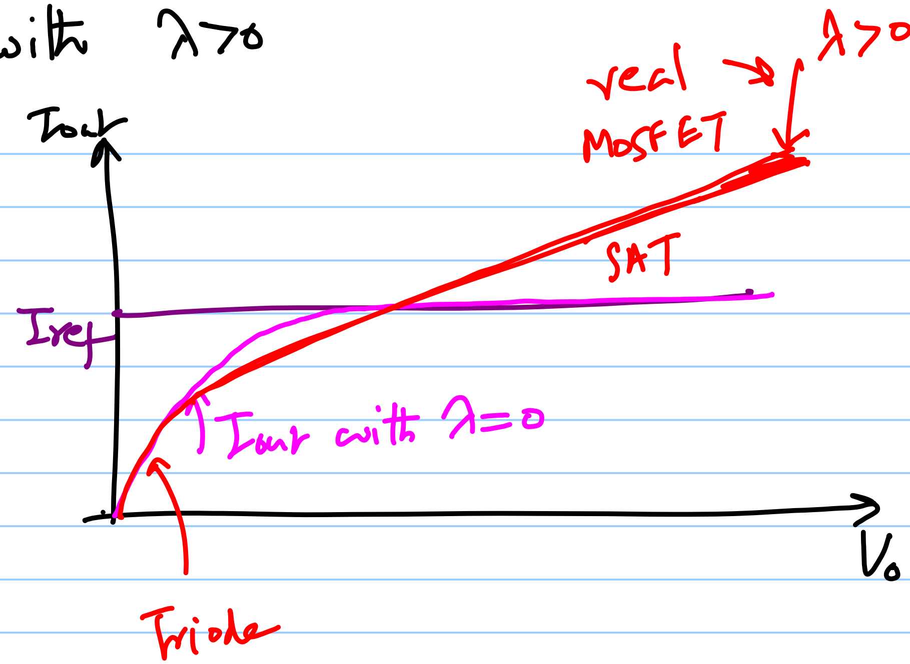
* precisely copy and scale currents by W ratio

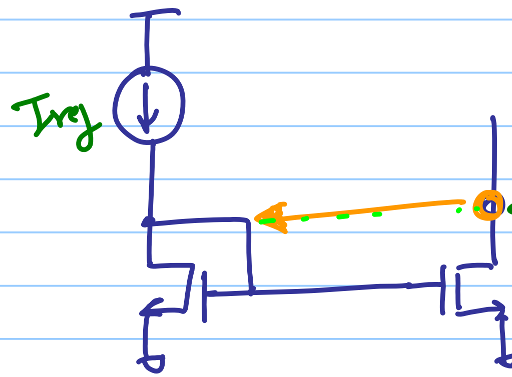
$\boxed{\lambda = 0}$



* Now, what happens with $\lambda > 0$

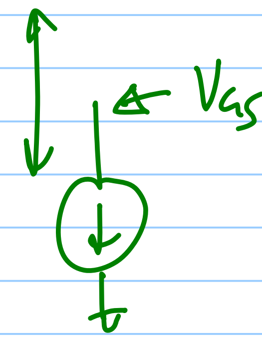




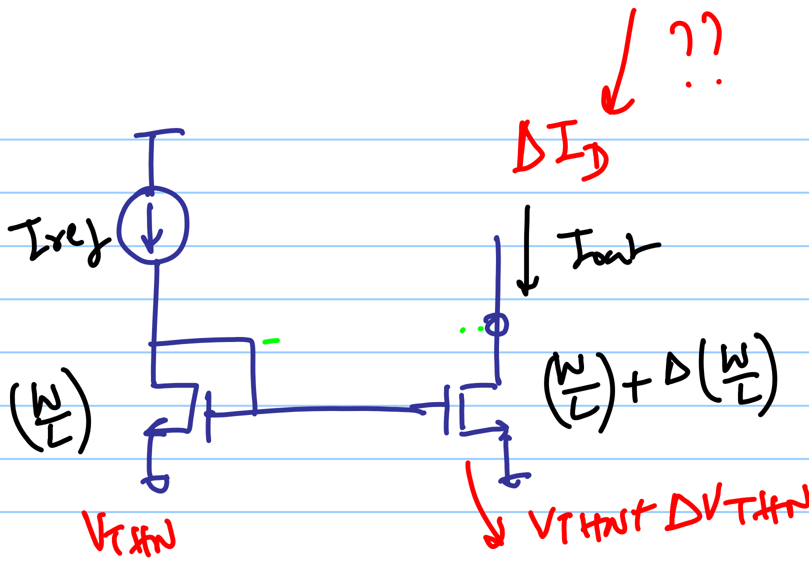


$I_{out} \triangleq I_{ref}$

$V_{DS_2} = V_{GS}$



$\underline{\underline{\lambda = 0}}$



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

$$\Delta y = \underbrace{\frac{\partial f}{\partial x_1}} \Delta x_1 + \underbrace{\frac{\partial f}{\partial x_2}} \Delta x_2 + \cdots$$

Sensitivity

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

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

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

% mismatch $\boxed{\dfrac{\Delta I_D}{I_D} = \dfrac{\Delta (W/L)}{W/L} - 2\dfrac{\Delta V_{THN}}{(V_{GS}-V_{THN})}}$

gaussian

$$Y = X_1 \pm X_2$$

$$\sigma_Y = \sqrt{\sigma_{X_1}^2 + \sigma_{X_2}^2}$$

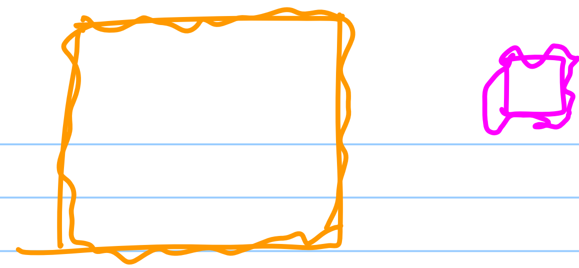
To minimize $\left(\dfrac{\Delta I_D}{I_D}\right)$

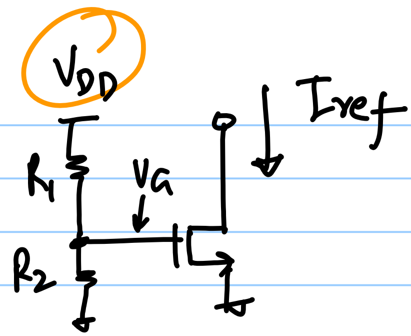
1. Large V_{ov}
2. Large WL

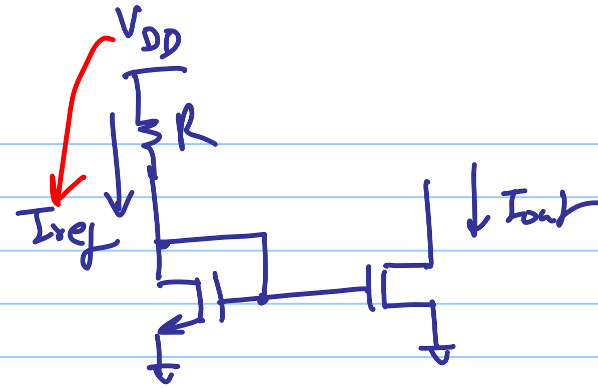
Monte-Carlo Analysis

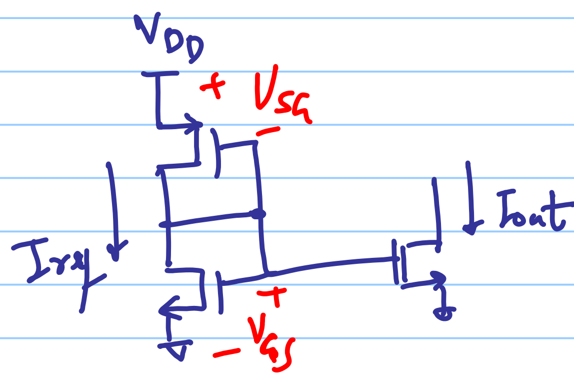
$$\sigma_{\Delta V_{THN}} = \frac{A_{V_{THN}}}{\sqrt{WL}}$$

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




VDD
R1
VG
R2
Iref

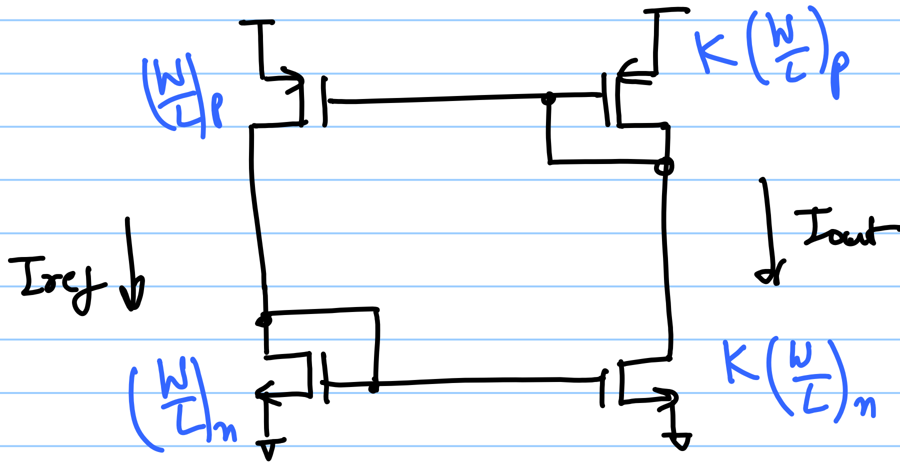

VDD
R
Iref
Iout


VDD
+
VSG
−
Iref
Iout
+
VGS
−

Supply Independent Biasing

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

$$I_{ref} \longrightarrow I_{out}$$

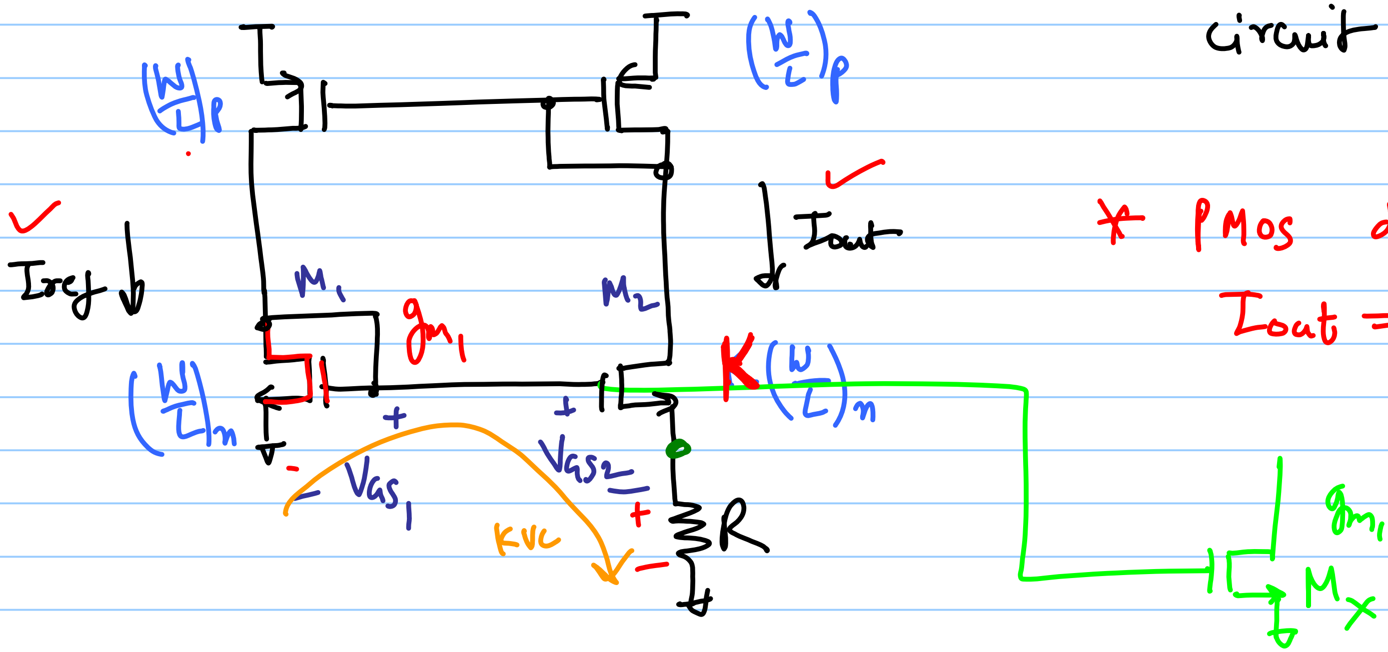


$I_{out} = K \cdot I_{ref}$ $\quad (\lambda = 0)$

$\downarrow$

both are indep of V_{DD}.

* Add a 'constant' to the circuit



* PMOS devices set

$I_{out} = I_{ref}$ $(\lambda = 0)$

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

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

* neglect body effect

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

$$I_{out} = 0, \quad \frac{2}{KP_n\left(\frac{W}{L}\right)} \cdot \frac{1}{R^2}\left(1-\frac{1}{\sqrt{K}}\right)^2$$

$$\boxed{I_{out} = \boxed{0}, \quad \frac{2}{\beta_n R^2}\left(1-\frac{1}{\sqrt{K}}\right)^2}$$

* Beta Multiplier Circuit (BMR)

* Constant "g_m" bias Circuit

$$g_{m_1} = \sqrt{2\beta I_{out}} = \frac{2}{R}\left(1-\frac{1}{\sqrt{K}}\right)$$

independent of V_{DD}

Varies Temp