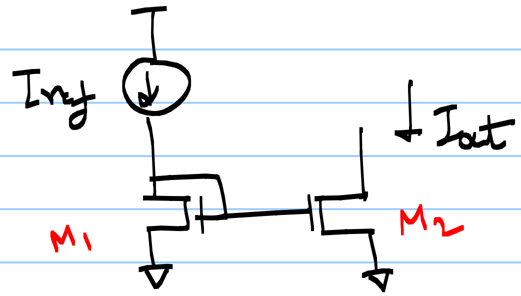
ECE 5411 – Lecture 7

Note Title 2/9/2011

Fig 20.4



$\Delta\left(\frac{W}{L}\right)$, ΔV_{THN}

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

Δx_1 , Δx_2

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

multivariable
Taylor Series

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

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

$$\Delta V_{THN}$$

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

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

normalize for comparism

$$\delta_{I_D} = \frac{\Delta I_D}{I_D} = \frac{\Delta(W/L)}{\underbrace{W/L}} - \frac{2\,\Delta V_{THN}}{\underbrace{(V_{GS} - V_{THN})}}$$

* To minimize current mismatch

↳ larger overdrive ($V_{GS} - V_{THN}$)

* big problem in Sub-V_T designs.

* with CMOS scaling

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

$\underline{\underline{\frac{\delta(W/L)}{(W/L)}}}$ is larger for smaller devices

↳ could use larger devices ✱

Effect Channel length modulation

$(\lambda > 0)$

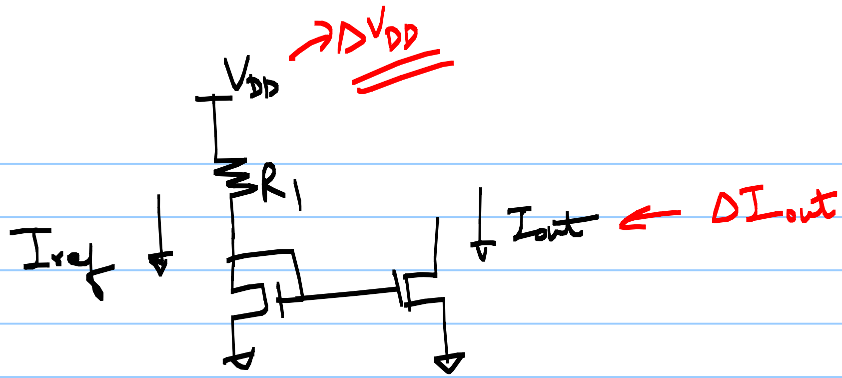
$$\frac{I_{D_2}}{I_{D_1}} = \frac{(W/L)_2}{(W/L)_1} \cdot \frac{1 + \lambda (V_{DS_2} - V_{DS_1,sat})}{1 + \lambda (V_{DS_1} - V_{DS_2,sat})}$$

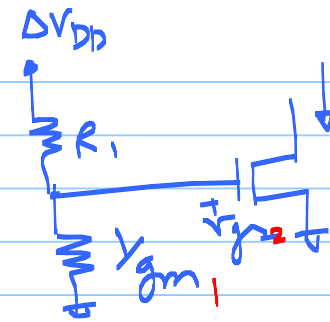
If $V_{DS_2} \neq V_{DS_1} = V_{GS}$

↳ current mismatch

↳ dominant source of mismatch

"Ac picture"



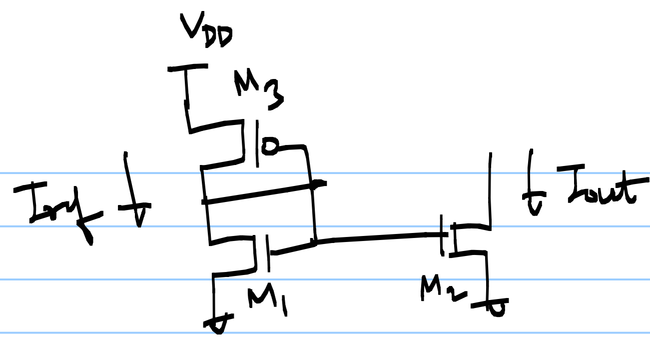


$$\Delta I_{out} = g_{m_2} \cdot v_{gs_2}$$

$$\Delta I_{out} = \frac{\Delta V_{DD}}{R_1 + 1/g_{m_1}} \cdot \left(\frac{g_{m_2}}{g_{m_1}}\right) = \boxed{\frac{\Delta V_{DD}}{R_1 + 1/g_{m_1}} \cdot \frac{(W/L)_2}{(W/L)_1}}$$

$$\frac{100 \times 10^{-3}}{10 \times 10^{3}}$$

$\underline{10\ \mu A}$



$$V_{DD} = V_{GS_1} + V_{SG_3}$$

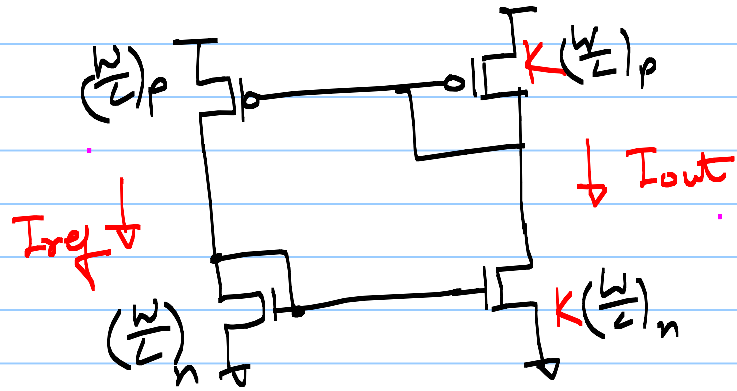
$$V_{DD} = \sqrt{\frac{2I_{ref}}{\beta_n}} + V_{THN} + \sqrt{\frac{2I_{ref}}{\beta_p}} + V_{THP}$$

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

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

$\Rightarrow$ I_{ref} must be derived from I_{out}

$(\lambda = 0)$



$\cancel{I_{out} = I_{ref}}$

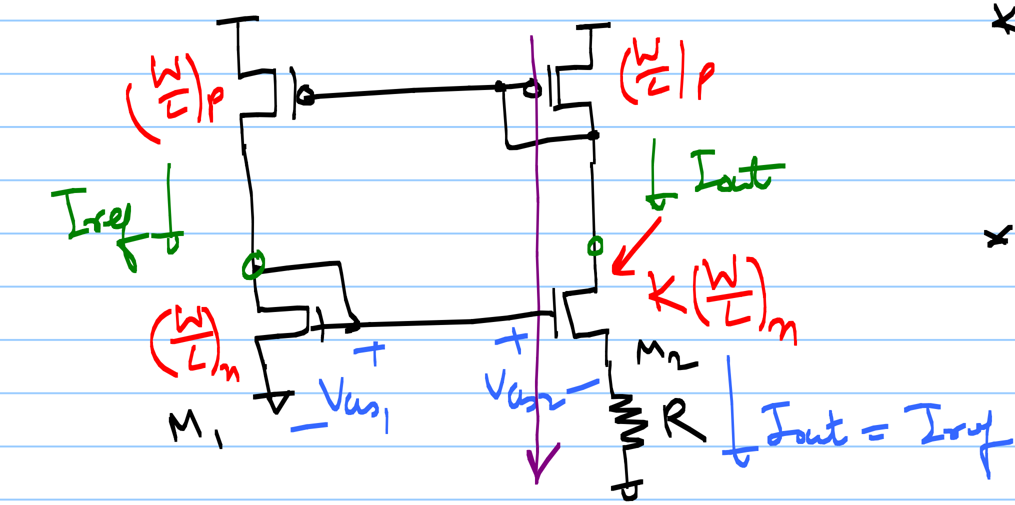
$I_{out} = K \cdot I_{ref}$

Since both I_{ref} & I_{out} feed from a current source, both are independent of V_{DD}.

This circuit can sustain any value of I_{ref}.

* How do we set the values of I_{ref} & I_{out}.

↳ add some constant to the circuit.



* PMOS devices force $I_{ref} = I_{out}$

* R decreases V_{GS} of M_2
  ↳ increase width of M_2 by K-times.

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

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

* neglect body effect → keep this in mind

$$\sqrt{I_{out}}\left[\sqrt{\frac{2}{k\,k'_n(W/L)_1}}\left(1-\frac{1}{\sqrt{k}}\right)\right] = I_{out}\cdot R$$

Solve for $I_{out} = I_{ref} = \begin{cases} 0, & \text{degenerate solution} \\ \boxed{\dfrac{2}{k\,k'_n(W/L)_1}\cdot\dfrac{1}{R^2}\left(1-\dfrac{1}{\sqrt{k}}\right)^2} \end{cases}$

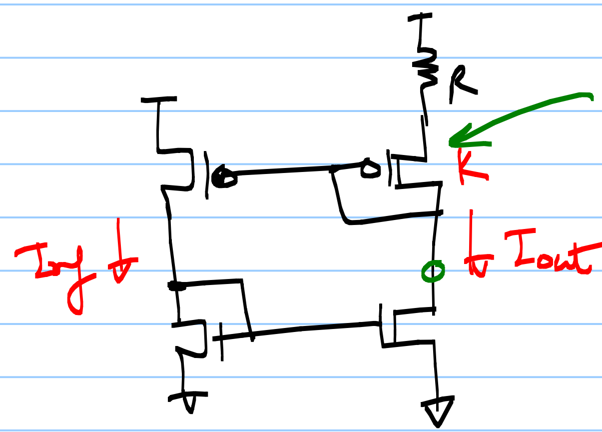
* $V_{THN_1} \neq V_{THN_2}$ leads to some error

* Supply independent biasing
* Beta multiplier reference (BMR)
* not Temperature independent

Let $K=4$

$$I_{ref} = \frac{\cancel{2}}{\cancel{2}KP_n\left(\frac{W}{L}\right)_1}\cdot\frac{1}{R^2}\left(\frac{1}{4}\right)$$

*



tie Body to source

* For $\lambda > 0$
  - ↳ lead to some V_{DD} dependence
  - ↳ use longer 'L' devices

$\lambda \propto \frac{1}{L}$

+ for lower sensitivity to V_{DD} noise

↳ use a locally regulated V_{DD} for generating $I_{ref} = I_{out}$.

See Fig 20.10

Fig 20.16