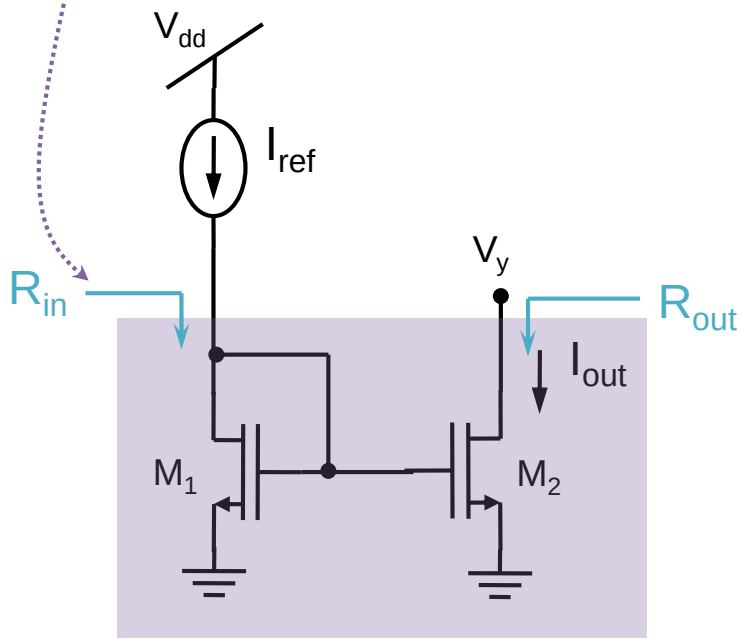
Last Lecture → Current Mirrors

- MOS Based

* Remember $I_D = \frac{K_n'}{2}\frac{W}{L}(V_{GS} - V_{th})^2(1 + \lambda V_{DS})$

* Assume $\mu_{01} = \mu_{02}$, $V_{th_1} = V_{th_2}$ } M_1 & M_2 matched transistors!



$$\left(W/L\right)_2 = N \cdot \left(W/L\right)_1$$

DC Behavior

$$\frac{I_{out}}{I_{ref}} = \frac{\left(W/L\right)_2}{\left(W/L\right)_1}\frac{(1 + \lambda V_{ds2})}{(1 + \lambda V_{ds1})}$$

Gain error due to channel length modulation!

$\lambda = 0$

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

AC Behavior

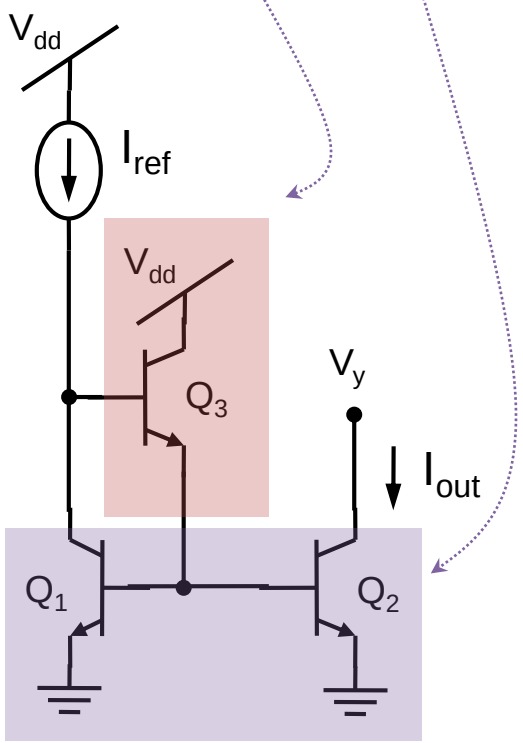
$$R_{in} = \frac{1}{g_{m1}}$$

$$R_{out} = r_{02}$$

$$A_i \approx \frac{\left(W/L\right)_2}{\left(W/L\right)_1}$$

Last Lecture → Current Mirrors

- **BJT Based**
- **β Compensation**



$$A_{E2} = N \cdot A_{E2}$$

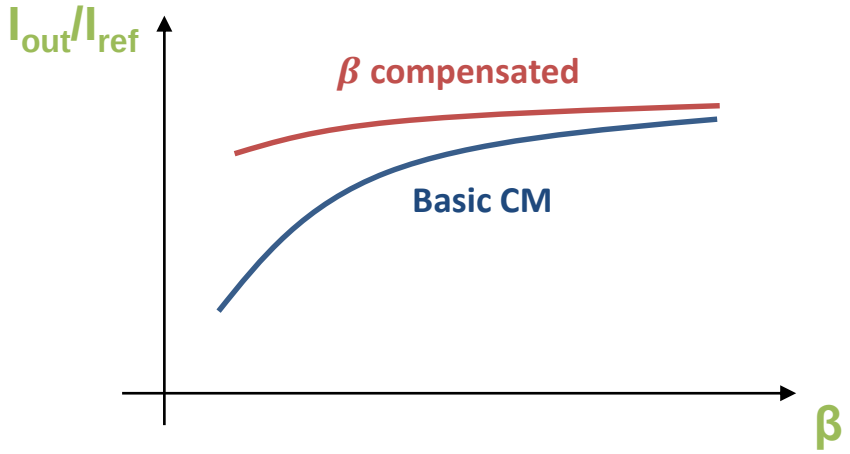
DC Behavior

$$\frac{I_{out}}{I_{ref}} = N \frac{1}{\left(1 + \frac{N+1}{\beta(\beta+1)}\right)}$$

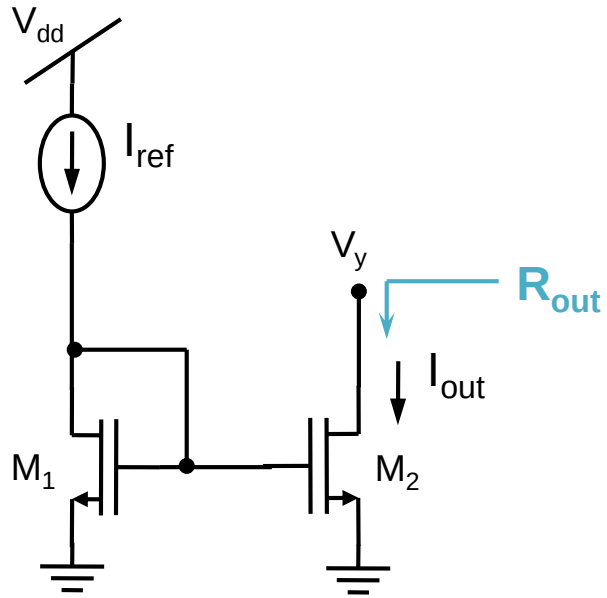
Beta effective is much larger!

$$\beta = \infty \Rightarrow \frac{I_{out}}{I_{ref}} \approx \frac{A_{E2}}{A_{E1}} = N$$

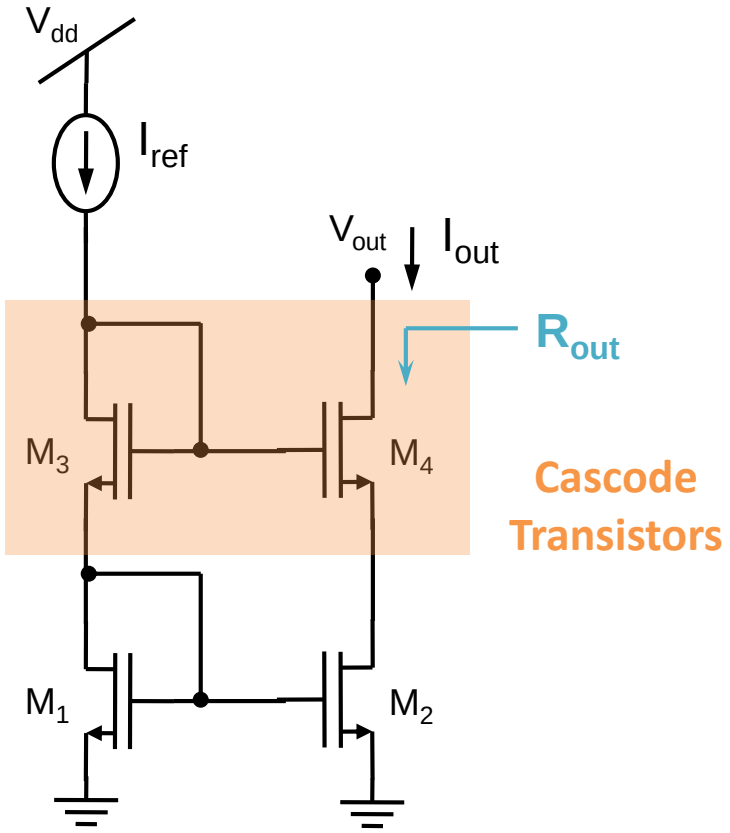
Comparison



Cascode Current Mirror



$$\frac{I_{out}}{I_{ref}} = \frac{(W/L)_2}{(W/L)_1}\frac{(1+\lambda V_{ds2})}{(1+\lambda V_{ds1})}$$



$$(W/L)_2 = N \cdot (W/L)_1$$

$$(W/L)_4 = N \cdot (W/L)_3$$

* Assume matched transistors!

DC Behavior

$$V_{GS3} = V_{GS4}$$

$$\therefore V_{DS1} = V_{DS2}$$

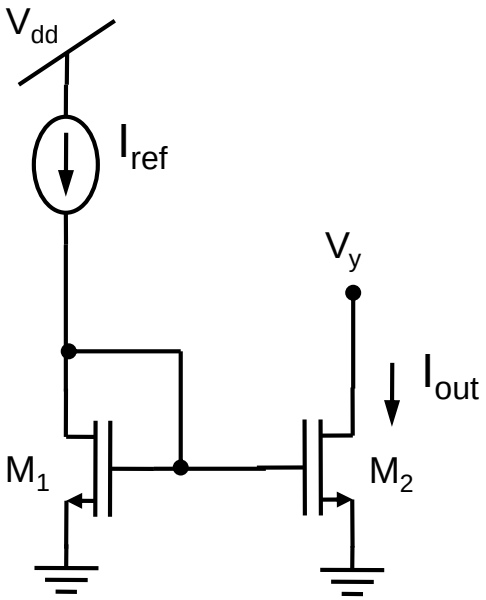
$$\therefore \frac{I_{out}}{I_{ref}} = \frac{(W/L)_2}{(W/L)_1}$$

AC Behavior

$$R_{in} = \frac{1}{g_{m1}} + \frac{1}{g_{m3}}$$

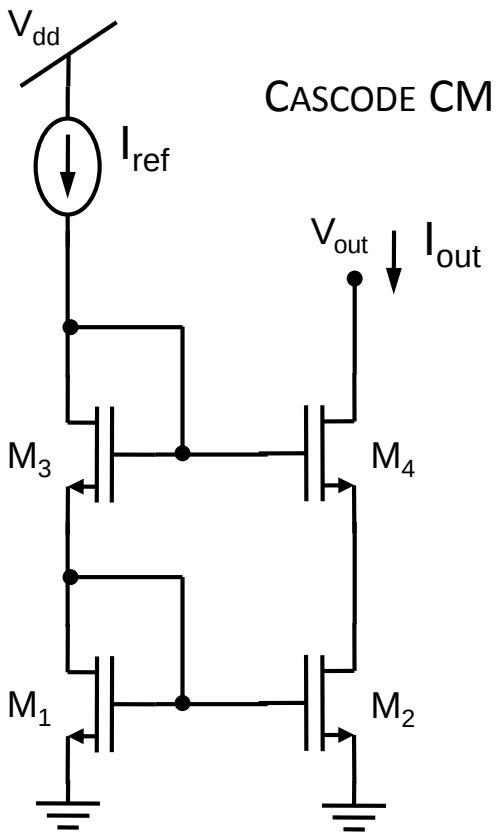
$$R_{out} = r_{04}(1 + g_{m4}r_{02})$$

nMOS Current Mirrors



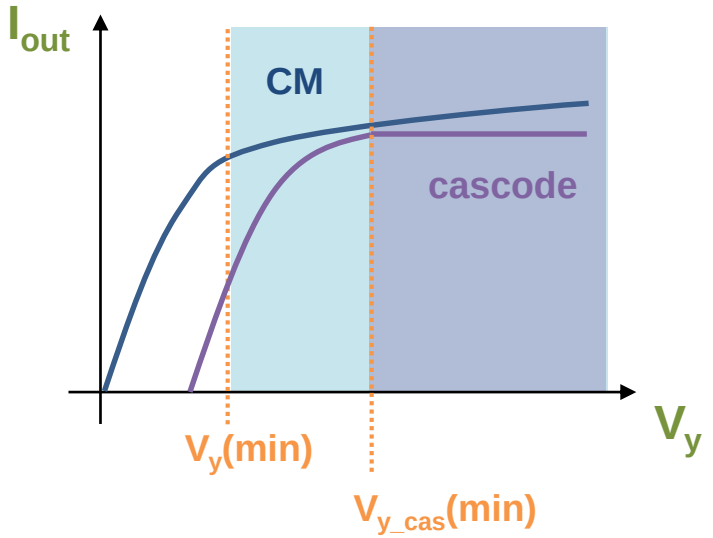
BASIC CM

$$\frac{I_{out}}{I_{ref}} = \frac{W_2/L_2}{W_1/L_1}\frac{(1+\lambda V_y)}{(1+\lambda V_x)}$$



CASCODE CM

$$\frac{I_{out}}{I_{ref}} = \frac{W_2/L_2}{W_1/L_1}$$



$$R_{out} = r_{02}$$

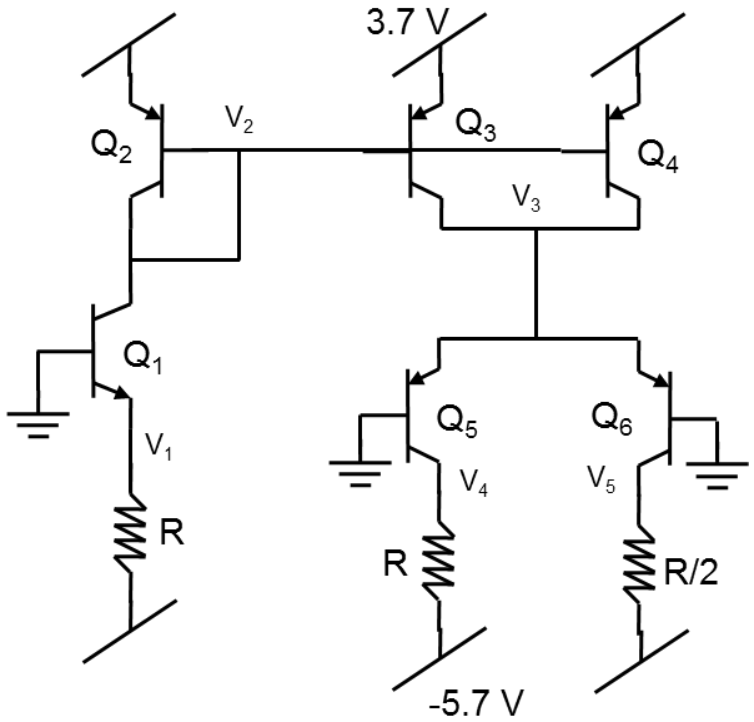
$$R_{out} = r_{04}(1 + g_{m4}r_{02})$$

Problem P7.60

For the circuit below, assuming matched transistors, $|V_{be}| = 0.7$ and $\beta = \infty$, find I, V_1, V_2, V_3, V_4, and V_5 for

a) R = 10kΩ

b) R = 100kΩ.



Problem P7.71

For the circuit below, assuming all transistors to be matched with current gain β,

a) **Assuming β =∞ find I_{01} and I_{02} in terms of I_{ref}**
b) **Use this idea to design a circuit that generates currents of 01.mA, 0.2mA, and 0.4mA, using a reference current source of 0.7mA.**
c) **What are the actual values of the current generated for β =50?**