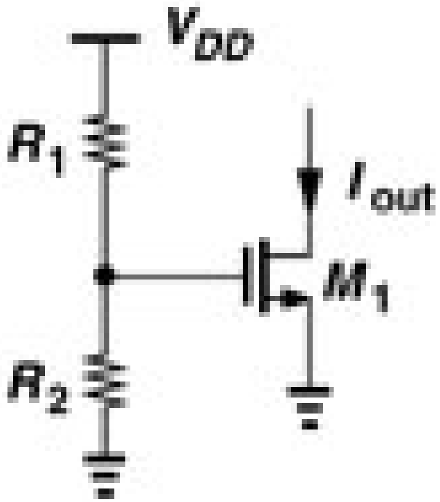
Lecture 4
IL2218 Analog electronics, advanced course

- Chapter 5
- Passive current mirrors
- Active current mirrors
- Examples

Current controlled by voltage V_{GS}



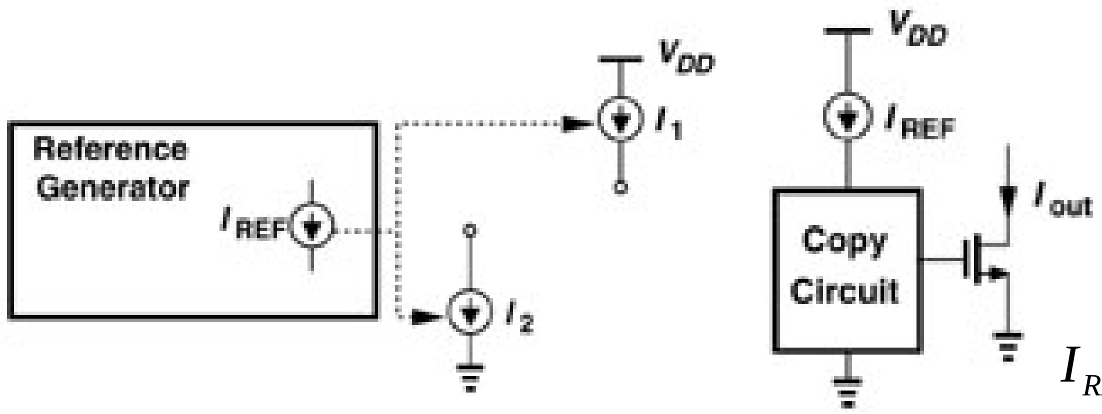
$$V_{GS} = \frac{R_2}{R_2 + R_1} V_{DD}$$

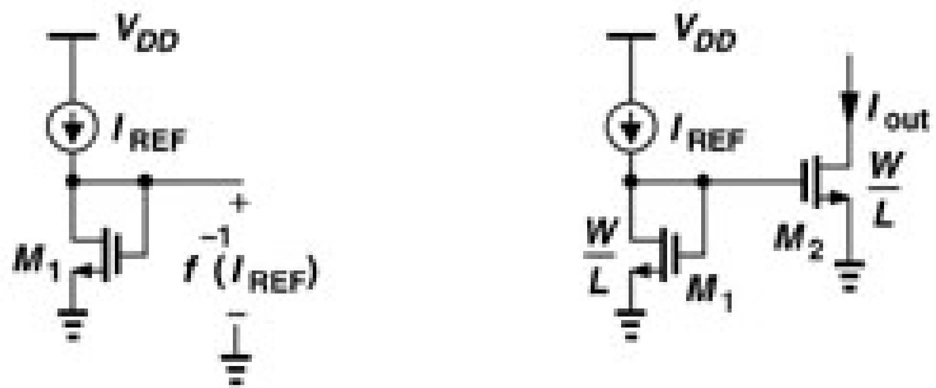
$$I_{OUT} \approx \frac{\mu_n C_{ox}}{2} \frac{W}{L} (V_{GS} - V_{TH})^2$$

Current is controlled by resistive divider

I_{out} is poorly defined because current is depending on process
V_{TH} and μ_n, that varies from wafer to wafer. They are also temperature dependent!

Reference currents





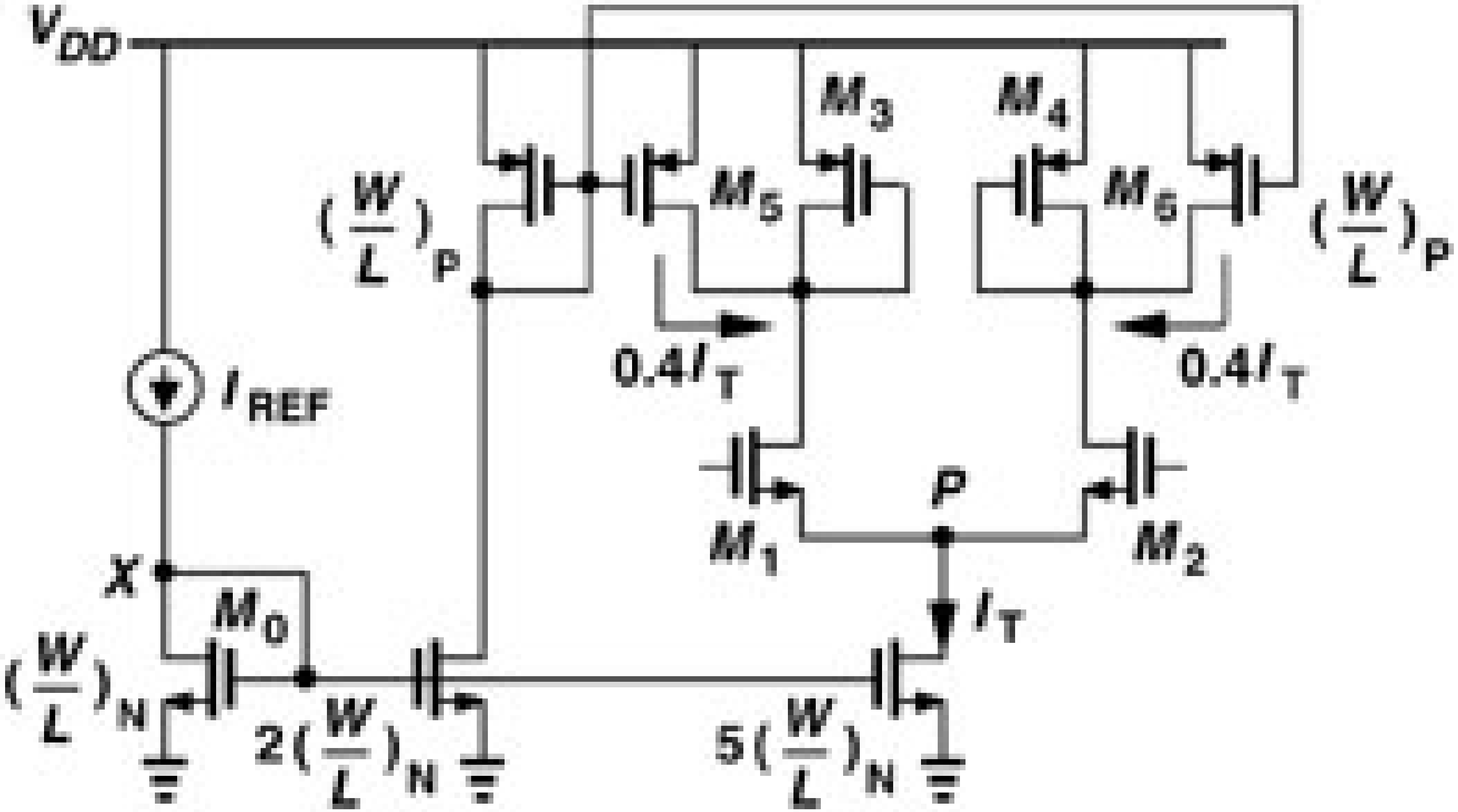
$$I_{REF} = \frac{\mu_n C_{ox}}{2}\left(\frac{W}{L}\right)_1 (V_{GS} - V_{TH})^2$$

$$I_{out} = \frac{\mu_n C_{ox}}{2}\left(\frac{W}{L}\right)_2 (V_{GS} - V_{TH})^2$$

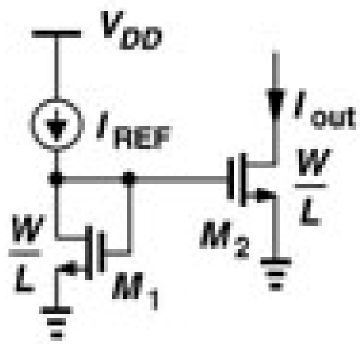
$$I_{out} = \frac{\left(\frac{W}{L}\right)_2}{\left(\frac{W}{L}\right)_1} I_{REF}$$

Precise copying of the current with no dependence on process and temperature

Use of current mirrors to bias amplifiers



Channel length modulation

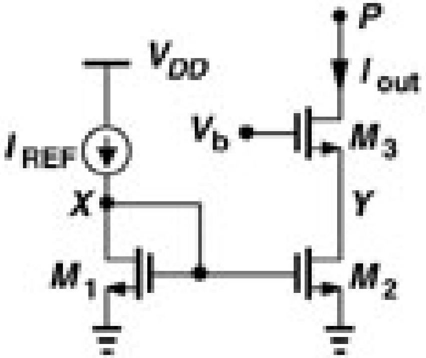


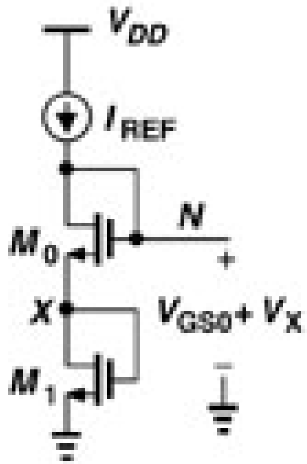
$$I_{REF} = \frac{\mu_n C_{ox}}{2}\left(\frac{W}{L}\right)_1 (V_{GS} - V_{TH})^2 (1 + \lambda V_{DS1})$$

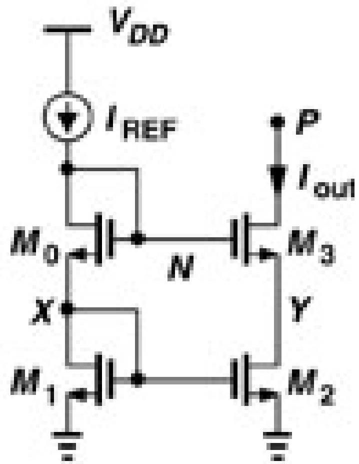
$$I_{out} = \frac{\mu_n C_{ox}}{2}\left(\frac{W}{L}\right)_2 (V_{GS} - V_{TH})^2 (1 + \lambda V_{DS2})$$

$$\frac{I_{out}}{I_{REF}} = \frac{\left(\frac{W}{L}\right)_2}{\left(\frac{W}{L}\right)_1} \frac{(1 + \lambda V_{DS2})}{(1 + \lambda V_{DS1})}$$

Cascode current mirror







$$V_N = V_{GS0} + V_X$$

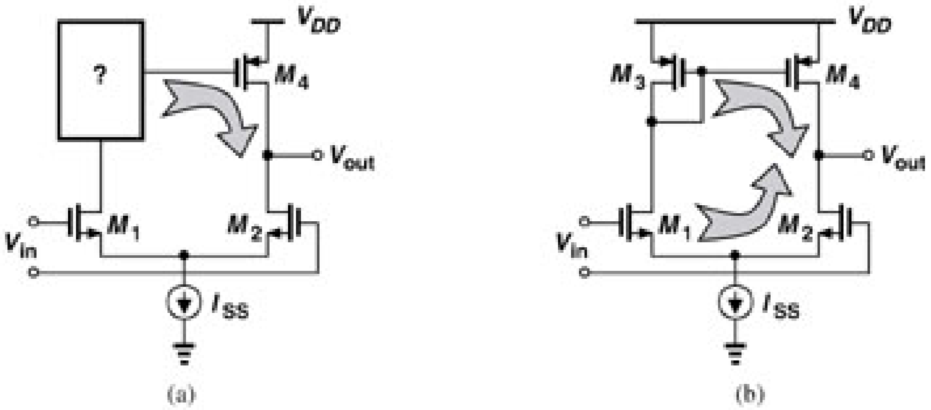
$$V_{GS0} + V_X = V_{GS3} + V_Y$$

If V_X equals V_Y then
I_{out} closely track I_{REF}

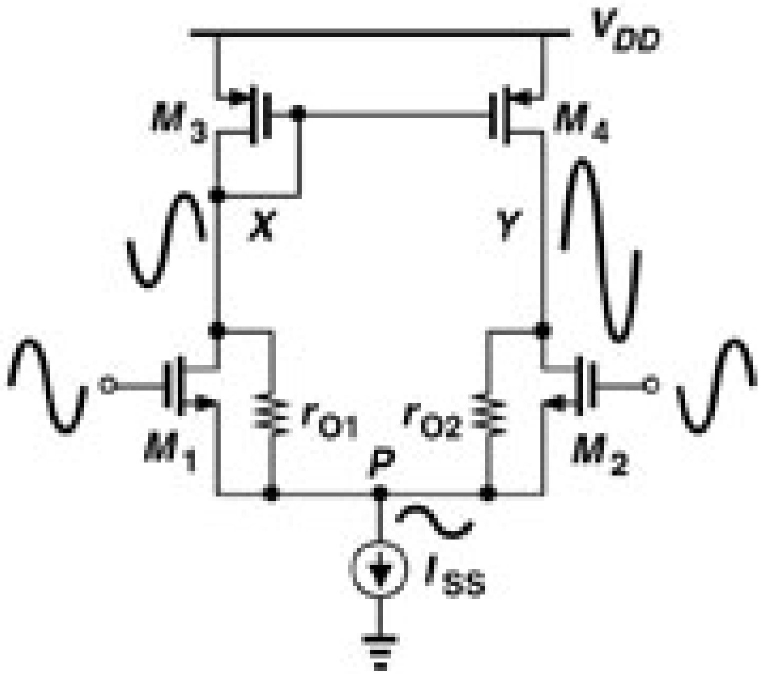
Current tracks with proper dimensions of transistors

$$\frac{\left(\frac{W}{L}\right)_3}{\left(\frac{W}{L}\right)_0} = \frac{\left(\frac{W}{L}\right)_2}{\left(\frac{W}{L}\right)_1}$$

Active current mirror

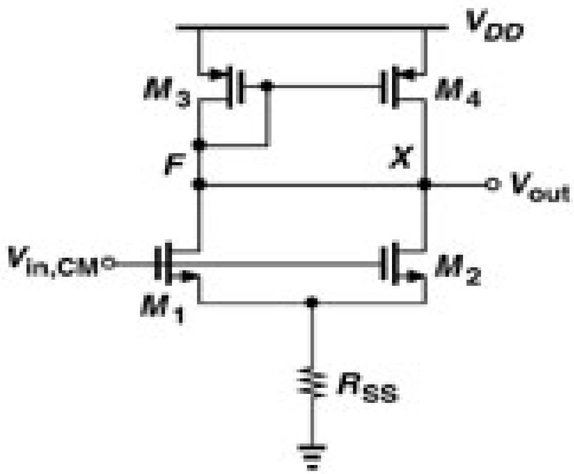


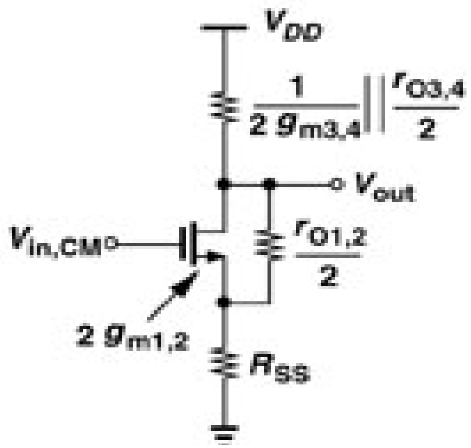
The current is mirrored over to the output side



Small signal gain?

Common mode properties





$$A_{CM} \approx \frac{-\frac{1}{2g_{m3,4}} \| \frac{r_{o3,4}}{2}}{\frac{1}{2g_{m1,2}} + R_{SS}} = \frac{-1}{1+2g_{m1,2}R_{SS}} \cdot \frac{g_{m1,2}}{g_{m3,4}}$$

$$CMRR = \left|\frac{A_{DM}}{A_{CM}}\right| \approx \frac{g_{m1,2}(r_{o1,2} \,//\, r_{o3,4})}{\frac{g_{m1,2}}{g_{m3,4}(1+2g_{m1,2}R_{SS})}} = g_{m3,4}(r_{o1,2} \,//\, r_{o3,4})(1+2g_{m1,2}R_{SS})$$