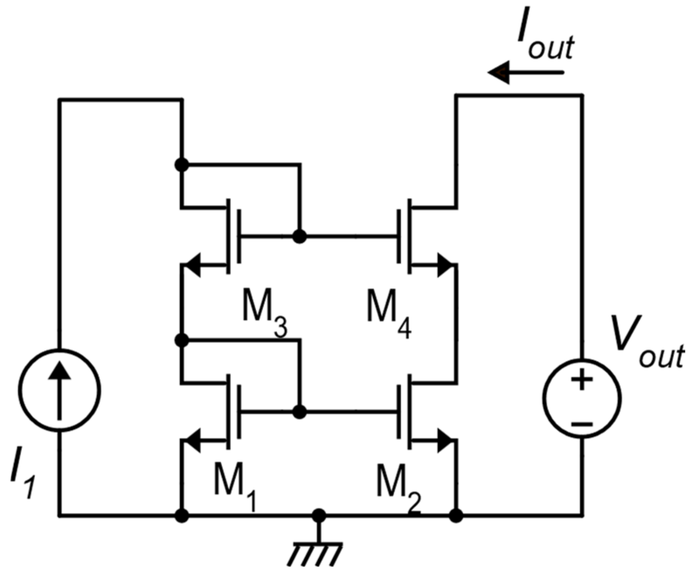
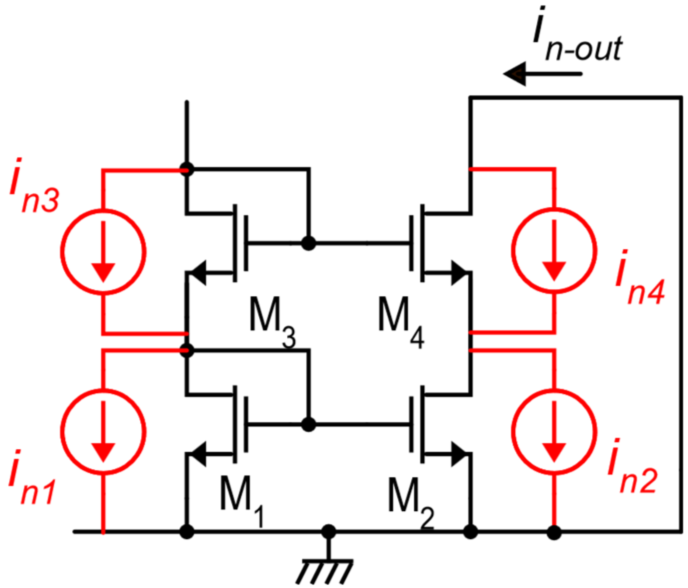
Noise in cascode current mirrors



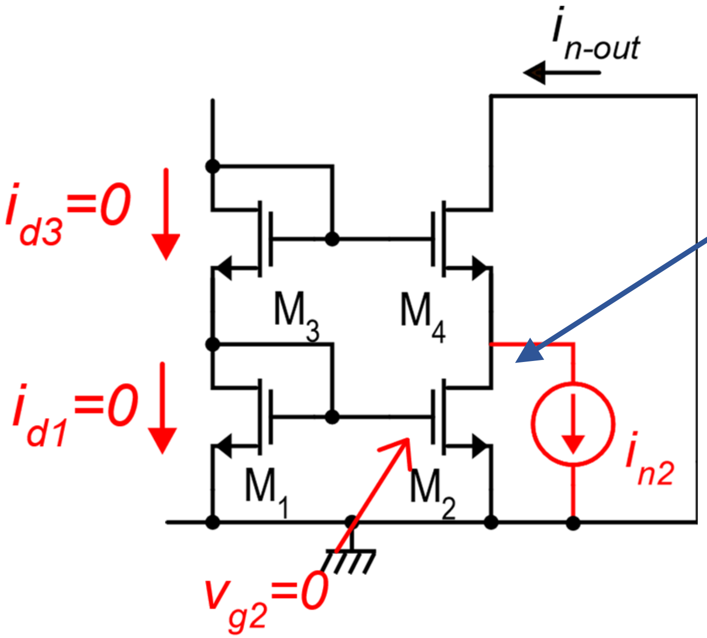
Standard cascode current mirror

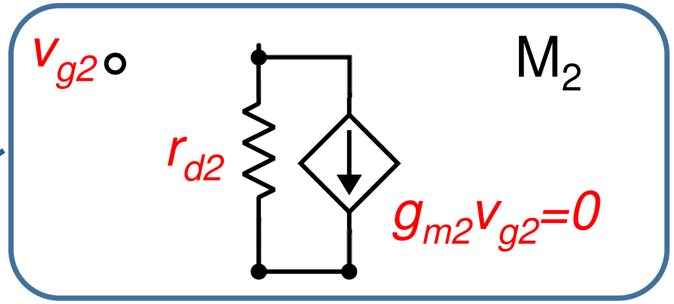


Small signal circuit with noise current sources

In these slides, the analysis of the output noise will be performed neglecting parasitic capacitances, then the results will be applicable in a frequency range where the response is the same as that exhibited at dc (f=0).

Current i_{n2}



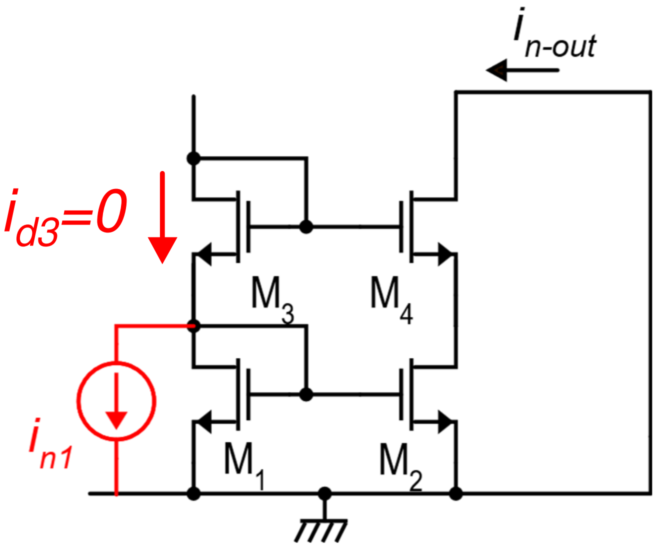


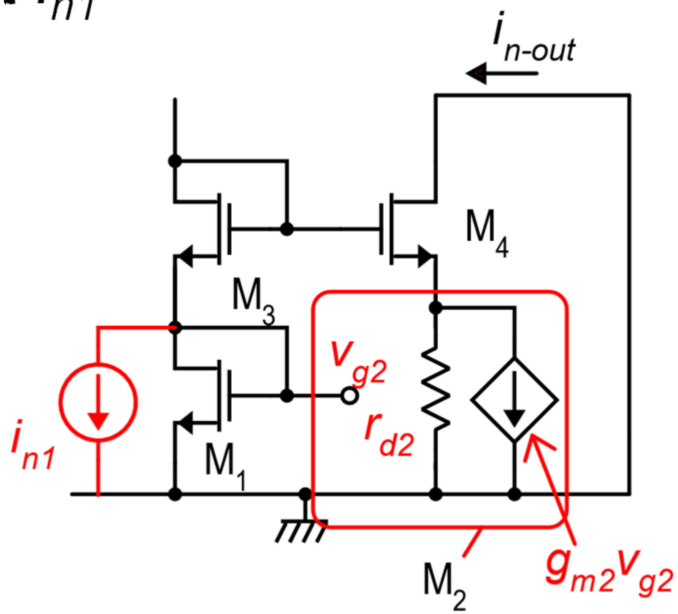
i_{n2} is applied at the input of a common gate stage (M_4) and reaches the output terminal of the mirror through a gain:

$$A_{I-CG}(0) = \frac{g_{m-cg} r_s}{1 + g_{m-cg} r_s} = \frac{g_{m4} r_{d2}}{1 + g_{m4} r_{d2}} \cong 1$$

$$i_{n-out}(i_{n2}) \cong i_{n2}$$

Current i_{n1}



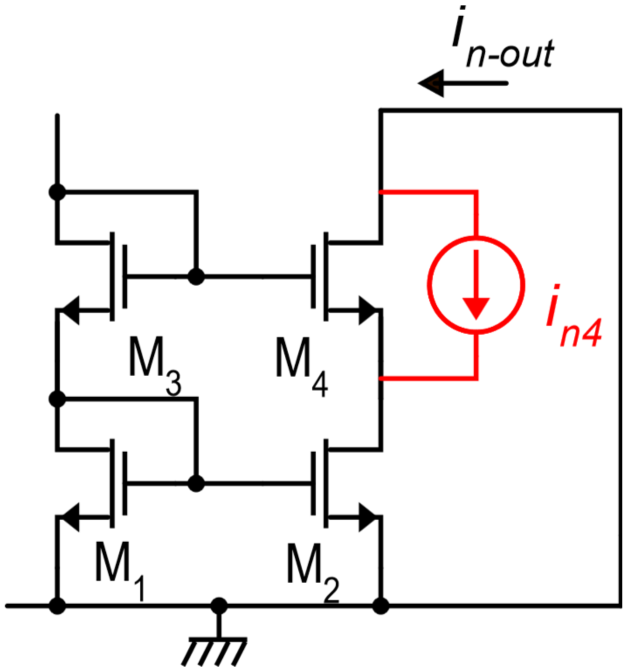


$$i_{n-out}\left(i_{n1}\right)=A_{I-CG}\left(0\right)g_{m2}v_{g2}\cong g_{m2}v_{g2}$$

$$v_{g2}=-i_{n1}\frac{1}{g_{m1}}$$

$$i_{n-out}\left(i_{n1}\right)\cong -i_{n1}\frac{g_{m2}}{g_{m1}}=-k_M i_{n1}$$

Current i_{n4}

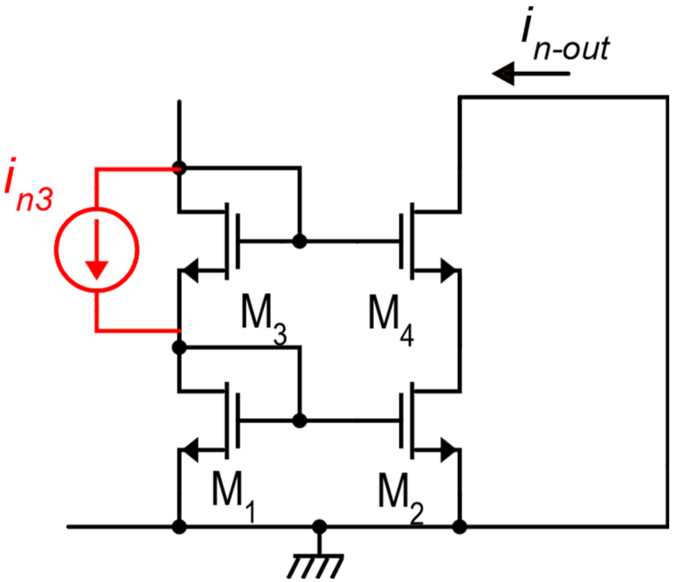


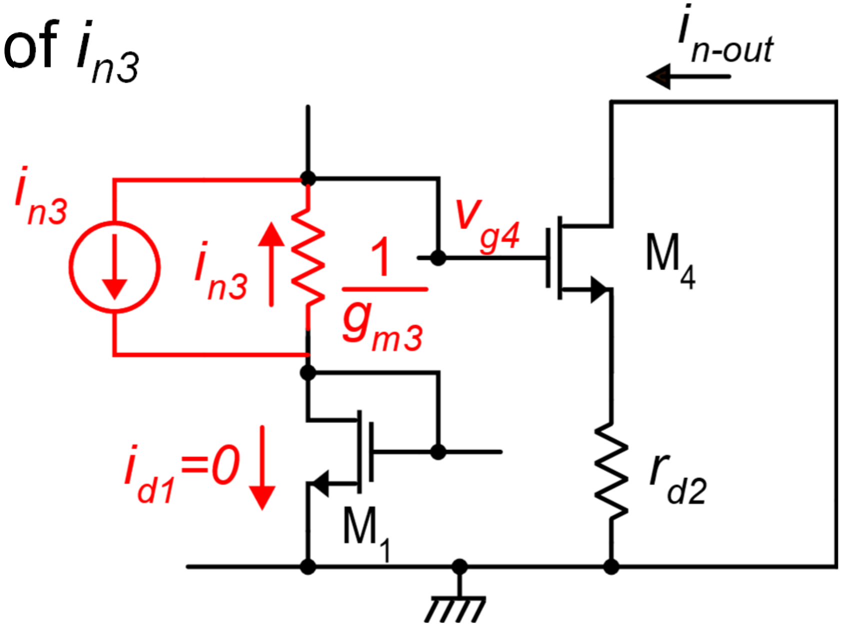
i_{n4} is the noise source of the MOSFET that forms the common gate stage. We can apply the transfer function between this current and in-out that we have already calculated for the CG stage (at dc):

$$i_{n-out} = i_{n4} \frac{1}{1 + r_s g_{m-cg}} \cong \frac{i_{n4}}{g_{m4} r_{d2}}$$

In dc and at low frequencies, the CG device give a negligible contribution compared to the effect of $\boldsymbol{i_{n1}}$ and $\boldsymbol{i_{n2}}$

Effect of i_{n3}

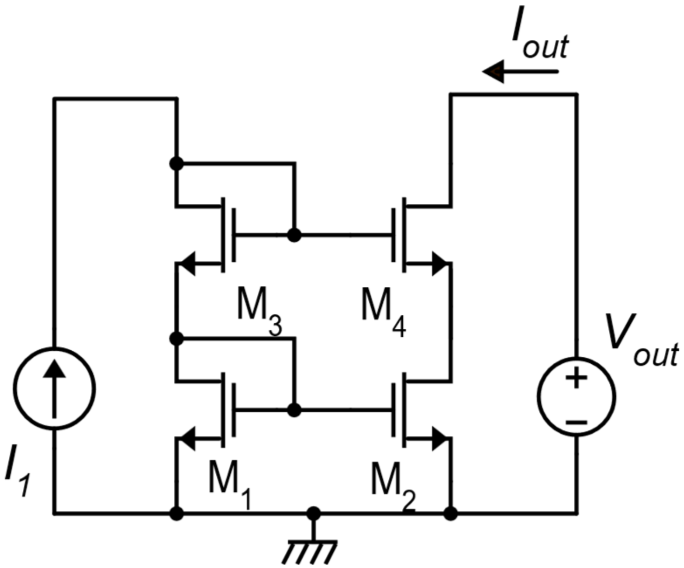




$$v_{g4} \cong -i_{n3}\frac{1}{g_{m3}} \qquad i_{d4} = g_{m4}v_{gs4} = g_{m4}\left(v_{g4} - i_{d4}r_{d2}\right) \qquad i_{d4} = g_{m4}\frac{v_{g4}}{1+g_{m4}r_{d2}}$$

$$i_{d4} = i_{n-out} = -\frac{i_{n3}}{g_{m3}}g_{m4}\frac{1}{1+g_{m4}r_{d2}} \cong -\frac{g_{m4}}{g_{m3}}\frac{i_{n3}}{g_{m4}r_{d2}} = -\frac{i_{n3}}{g_{m3}r_{d2}}$$

In summary



M_1, M_2: practically the same effect as in the simple mirror:

$$i_{n-out}\left(i_{n2}\right) \cong i_{n2}$$

$$k_M = A_I\left(0\right) = \frac{\beta_2}{\beta_1}$$

$$i_{n-out}\left(i_{n1}\right) \cong -k_M i_{n1}$$

M_3, M_4: their contribution to the output noise current is equal to their noise currents divided by a factor $\boldsymbol{g_m r_d}$ and, generally, **can be neglected**

$$i_{n-out}\left(i_{n4}\right) \cong \frac{i_{n4}}{g_{m4} r_{d2}} \qquad i_{n-out}\left(i_{n3}\right) \cong -\frac{i_{n3}}{g_{m3} r_{d2}}$$