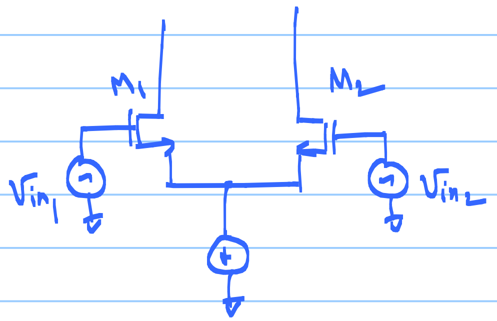
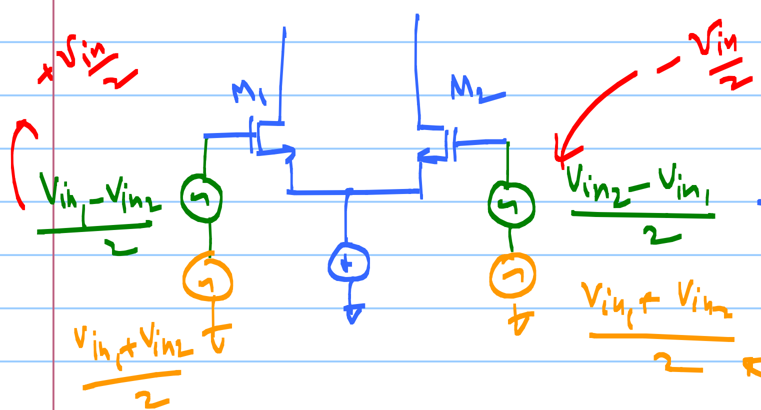
ECE 511 - Lecture 19

Note Title 4/4/2013



$$V_{in_1} = \left(\frac{V_{in_1} - V_{in_2}}{2}\right) + \left(\frac{V_{in_1} + V_{in_2}}{2}\right)$$

$$V_{in_2} = \frac{(V_{in_2} - V_{in_1})}{2} + \left(\frac{V_{in_1} + V_{in_2}}{2}\right)$$



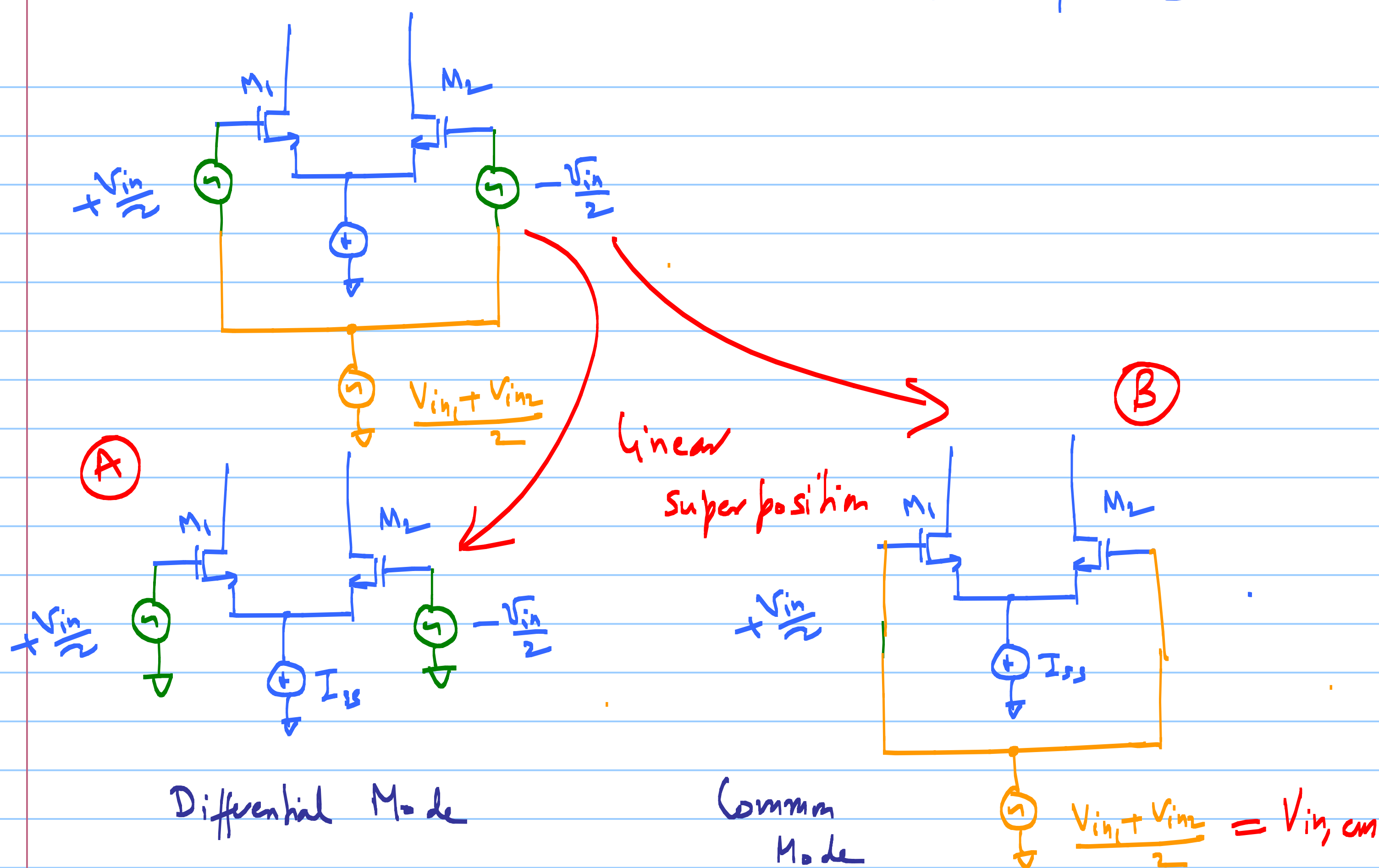
$$\frac{V_{in_2} - V_{in_1}}{2} = -\left(\frac{V_{in_1} - V_{in_2}}{2}\right) = -\frac{V_{in}}{2}$$

differential input signal

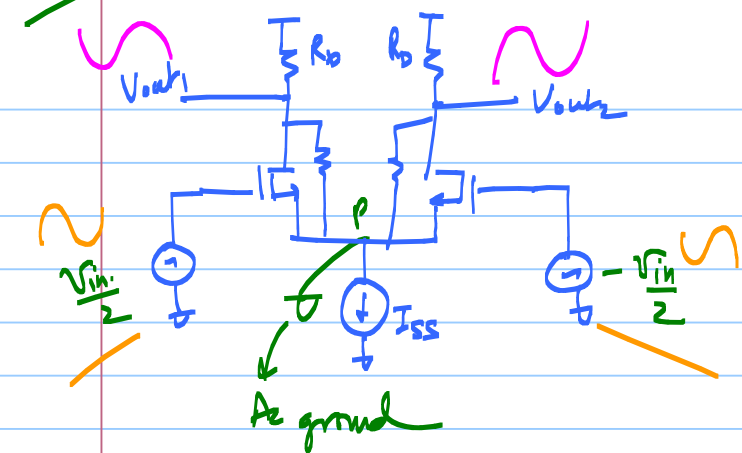
$$\frac{V_{in_1} + V_{in_2}}{2}$$

common-mode input signal

$V_{in} = V_{in_1} - V_{in_2}$



Example: DM circuit



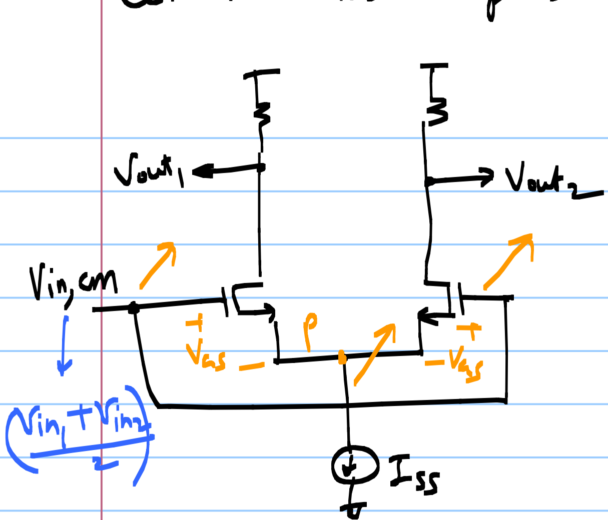
$$v_{out_1} = -g_m(R_D \| r_o)\frac{v_{in}}{2}$$

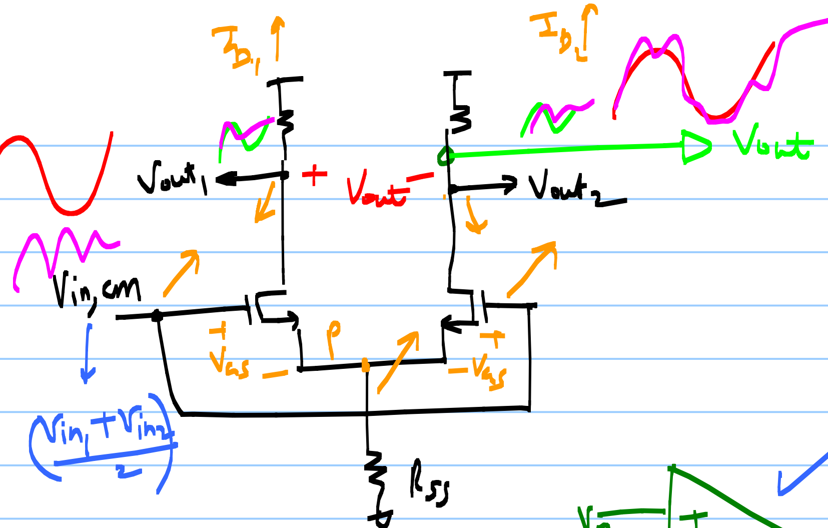
$$v_{out_2} = +g_m(R_D \| r_o)\frac{v_{in}}{2}$$

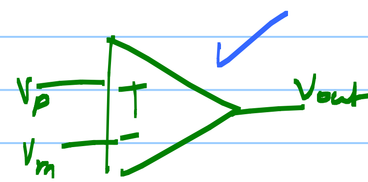
$$v_{out} = v_{out_1} - v_{out_2} = \boxed{-g_m(R_D \| r_o)}\, v_{in}$$

Differential mode gain → $A_{v,DM}$

Common-mode response:



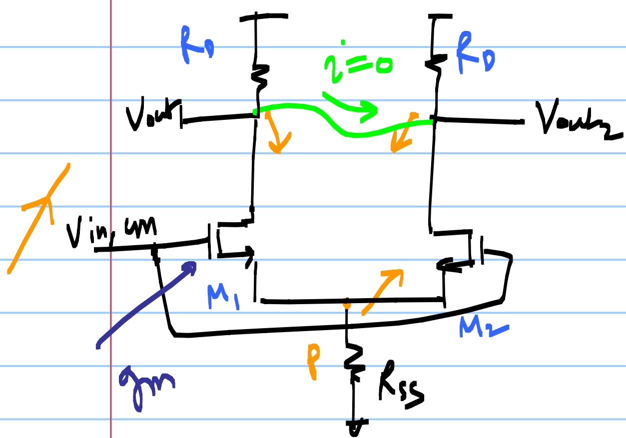


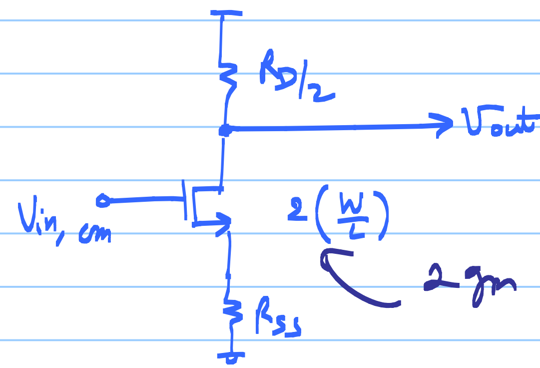


* Current source is not ideal

↳ CM variations will appear at the outputs

"CM Equivalent Circuit"





$$A_{v,CM} = \frac{v_{out}}{v_{in,cm}} = -\frac{\cancel{2}g_m}{1+2g_mR_{SS}} \cdot \frac{R_D}{\cancel{2}}$$

$$\boxed{A_{v,CM} = -\frac{g_mR_D}{1+2g_mR_{SS}}}$$

$$A_{v,CM} = -\frac{(g_m R_D)}{1 + 2g_m R_{SS}} \qquad R_{SS} \to \infty$$

Single-ended output

$$V_{out_1} = \underbrace{A_{v,DM}}_{-\frac{g_m}{2} R_D} \cdot \underbrace{V_{in}}_{V_{in_1} - V_{in_2}} + \underbrace{A_{v,CM}}_{-\frac{R_D/2}{\left(\frac{1}{2g_m}\right) + R_{SS}}} \cdot \underbrace{V_{in,cm}}_{\frac{V_{in_1} + V_{in_2}}{2}}$$

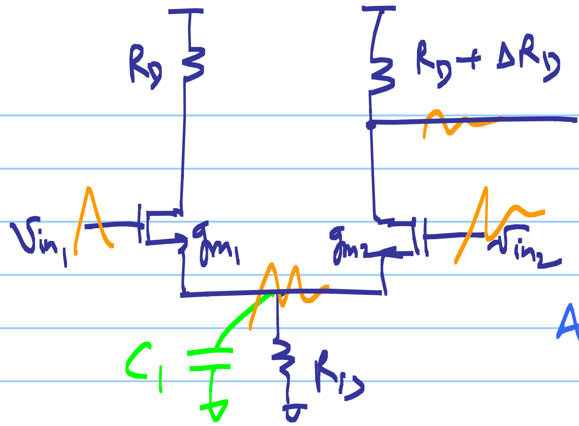
* We want large $A_{v,DM}$ and small $A_{v,CM}$ $\Rightarrow$ $R_{SS} \uparrow$ for rejecting CM disturbance

metric

$$CMRR = \left| \frac{A_{v,DM}}{A_{v,CM}} \right| = \frac{\frac{g_m R_D}{2}}{\frac{g_m R_D}{1+2g_m R_{SS}}} = \frac{1}{2} + g_m R_{SS} \simeq g_m R_{SS}$$

In a FD circuit $V_{out} = V_{out_1} - V_{out_2}$

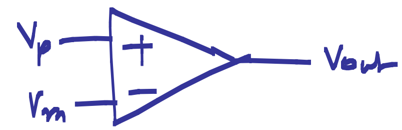
CMRR is irrelevant

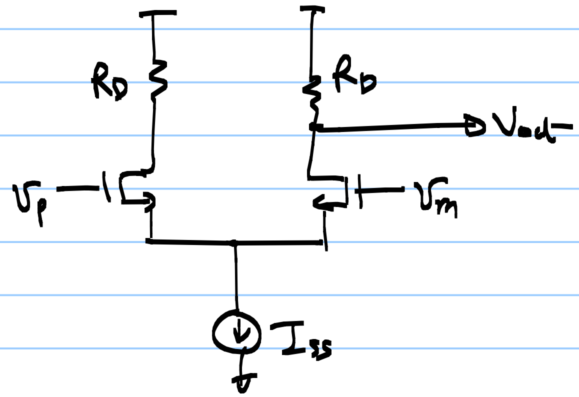


$g_{m_2} = g_{m_1} + \Delta g_m$

Asymmetry in the diff pair causes CM mode to appear as differential noise at the output

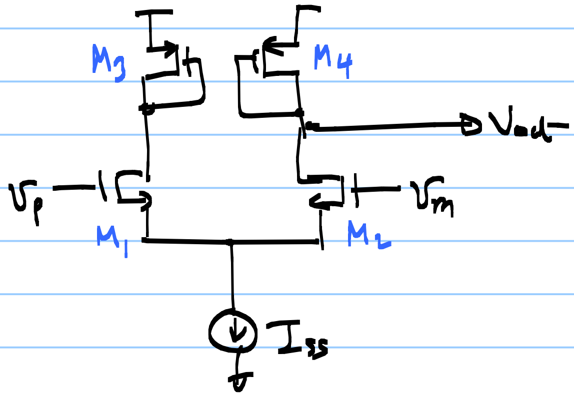
$$CMRR \simeq \left(\frac{g_m}{\Delta g_m}\right)\left(1 + 2 g_m R_{ss}\right) \longrightarrow \text{worse at high frequency}$$





$$A_{v,DM} = + \frac{g_m (R_D \| r_o)}{2}$$

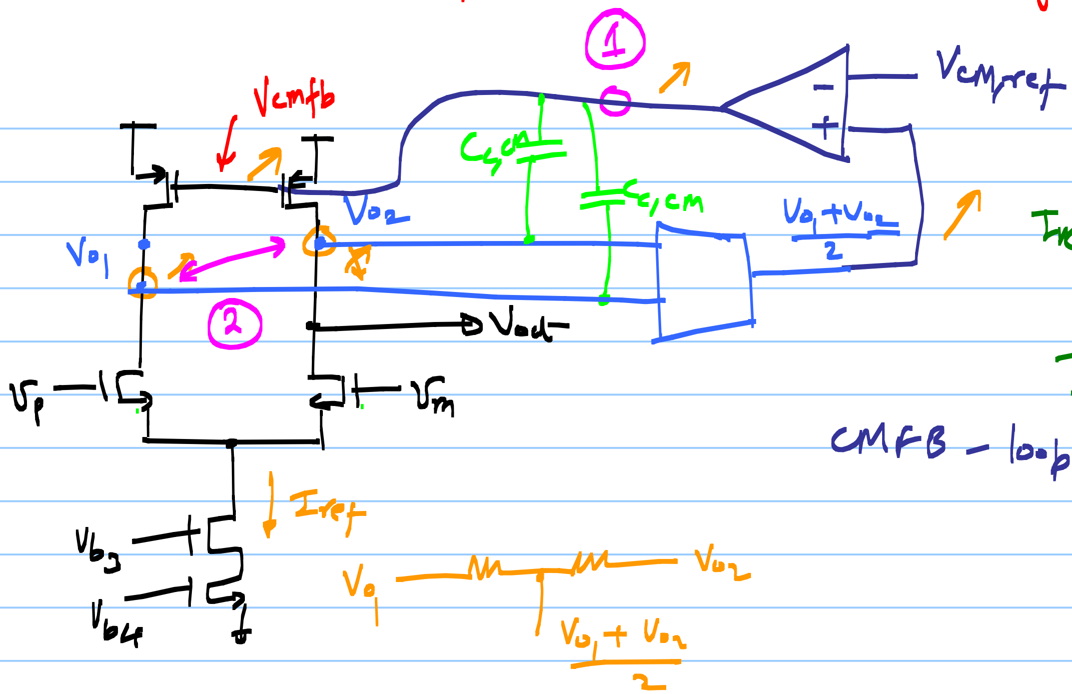
$$A_{v,CM} = - \frac{R_D/2}{\frac{1}{2g_m} + R_{SS}}$$

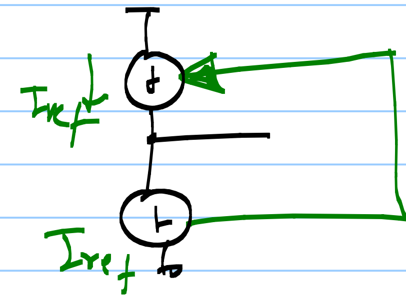


$$A_{v,DM} = + \frac{g_{m1,2}}{2} \left(\frac{1}{g_{m3,4}} \| r_{o2} \| r_{o3} \right)$$

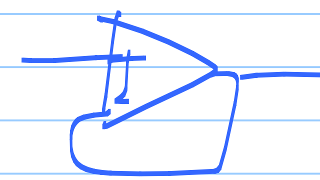
$$\simeq \frac{1}{2} \frac{g_{m1,2}}{g_{m3,4}}$$

* Output CM-level is undefined → BAD!





CMFB - loop



Dc level set to Vbiasp "By symmetry"