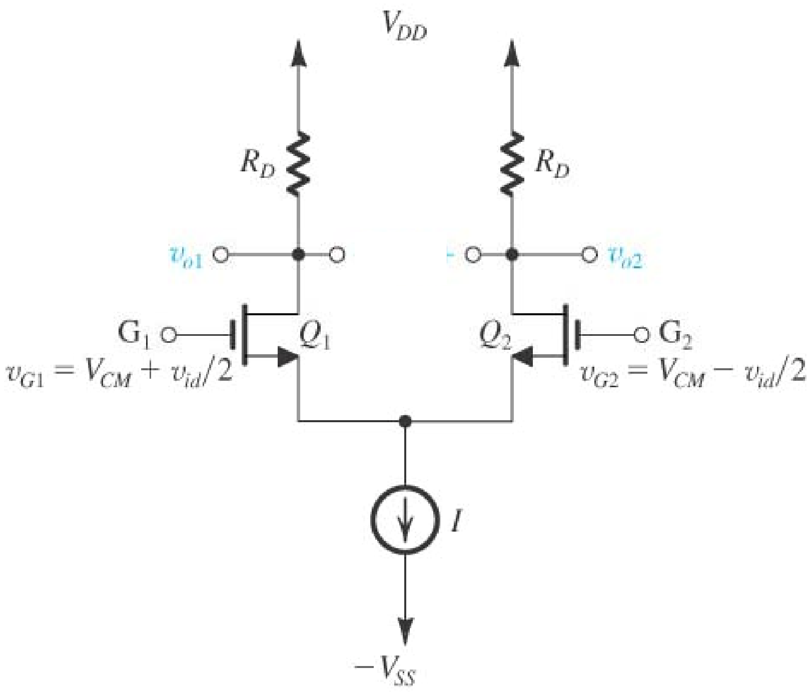
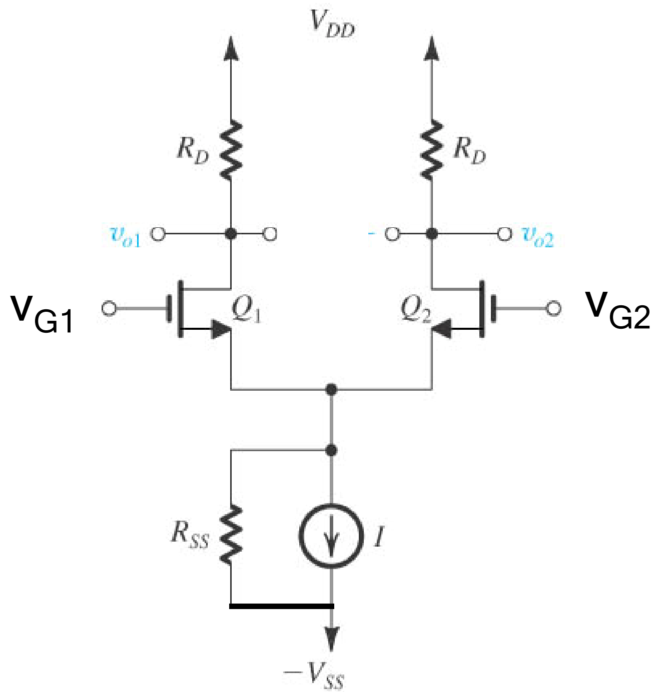
Lect. 29: MOS Differential Amplifiers(2)

Non-Ideal effects

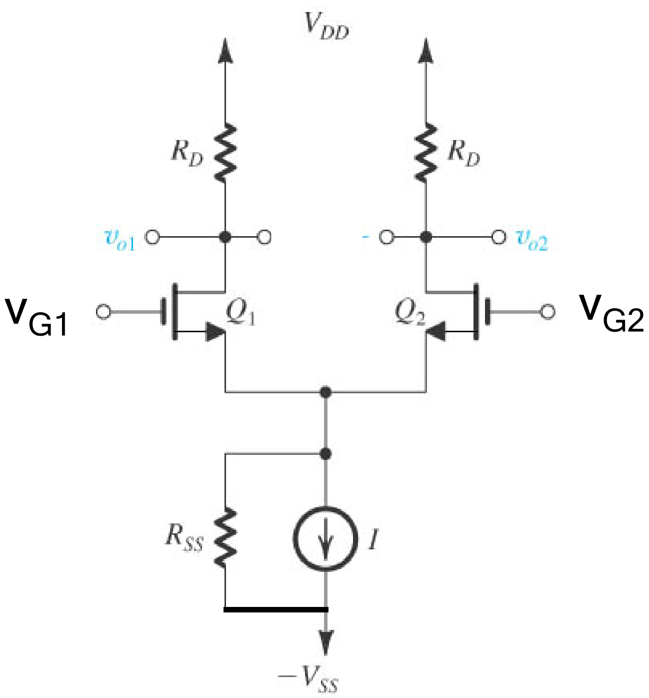


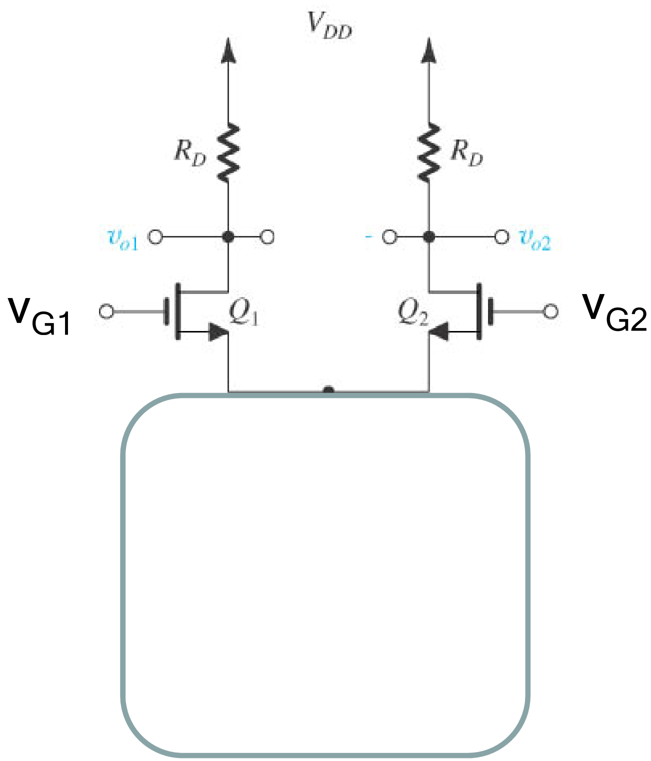


What if the current source is NOT ideal?

Lect. 29: MOS Differential Amplifiers(2)

Make it left-right symmetric



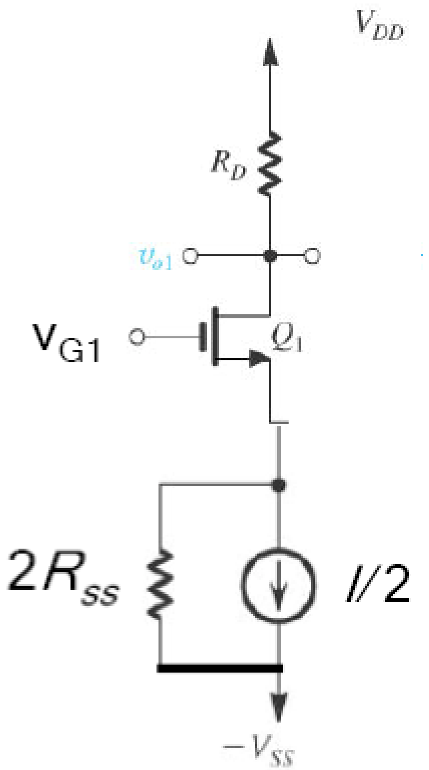


CM response?

DM response?

Lect. 29: MOS Differential Amplifiers(2)

Any difference?



Without R_{ss}, v_{G1} does affect v_{o1} in CM

With R_{ss} ➔ Common-Source with source resistance

$$\frac{v_{o1}}{v_{G1}} = ?$$

(Ingoring r_o)

$$v_{o1} = -g_m v_{gs} R_D$$

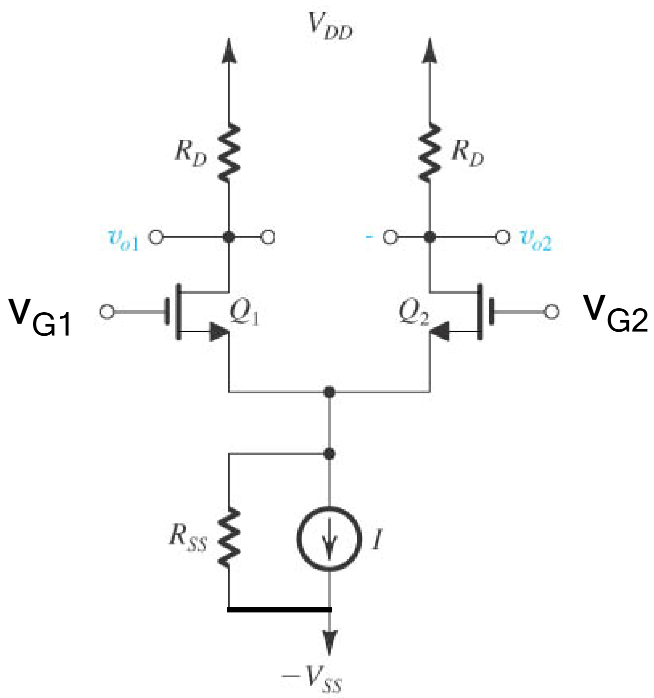
$$v_{gs} = v_{G1} - g_m v_{gs}(2R_{SS})$$

$$v_{gs} = \frac{v_{G1}}{1+2g_m R_{SS}}$$

$$\frac{v_{o1}}{v_{G1}} = -\frac{g_m R_D}{1+2g_m R_{SS}} \sim -\frac{R_D}{2R_{SS}}$$

With non-ideal current source, v_{G1} does affect v_{o1} in CM ➔ But v_{o1}-v_{o2} = 0

Lect. 29: MOS Differential Amplifiers(2)



But if we take output as v_{o1}-v_{o2}
R_{ss} doesn't affect the output

CMRR (Common-Mode Rejection Ratio)= $\left|\dfrac{A_d}{A_{cm}}\right|$

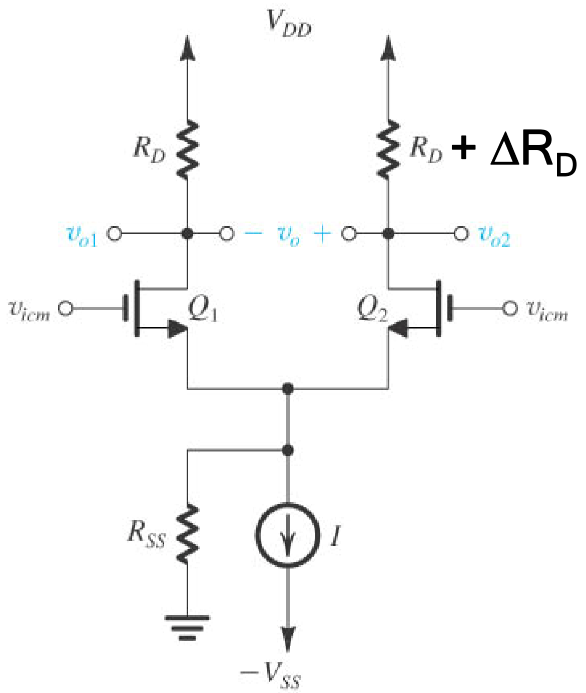
$$A_d = \frac{v_{od}}{v_{id}} = -g_m R_D \ \text{(Ignoring } r_o\text{)}$$

$$A_{cm} = \frac{v_{od}}{v_{icm}} = \frac{v_{o1} - v_{o2}}{v_{icm}} = 0$$

$$\text{CMRR} = \infty$$

Lect. 29: MOS Differential Amplifiers(2)

What if R_D's are NOT matched?



Assuming $\Delta R_D << R_D$

➔ Use results obtained for symmetric CM and DM.

CM (small signal)

$$v_{o1} \sim -\frac{R_D}{2R_{ss}} \cdot v_{icm}, \quad v_{o2} \sim -\frac{R_D + \Delta R_D}{2R_{ss}} \cdot v_{icm}$$

$$v_{o1} - v_{o2} \sim \frac{\Delta R_D}{2R_{ss}} \cdot v_{icm} \qquad \therefore A_{cm} = \frac{v_{o1} - v_{o2}}{v_{icm}} \sim \frac{\Delta R_D}{2R_{ss}}$$

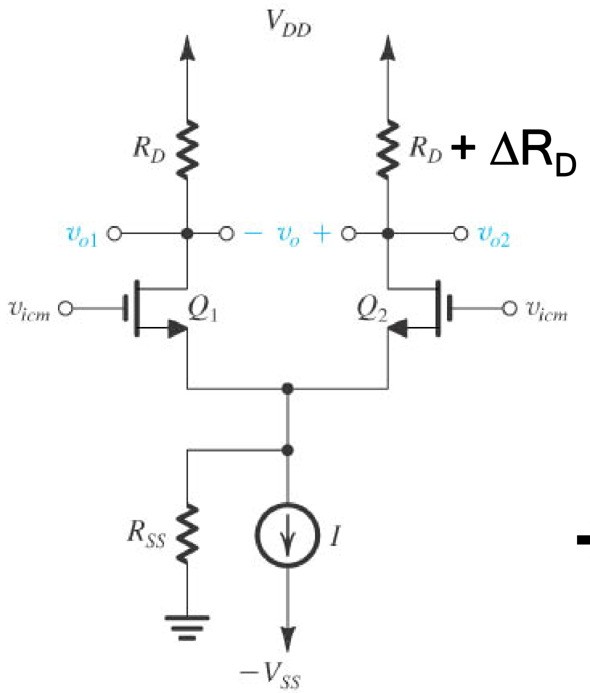
➔ CM gain

Assuming DM gain does not get affected

$$A_d \sim -g_m R_D$$

Lect. 29: MOS Differential Amplifiers(2)

What if R_D's are NOT matched?



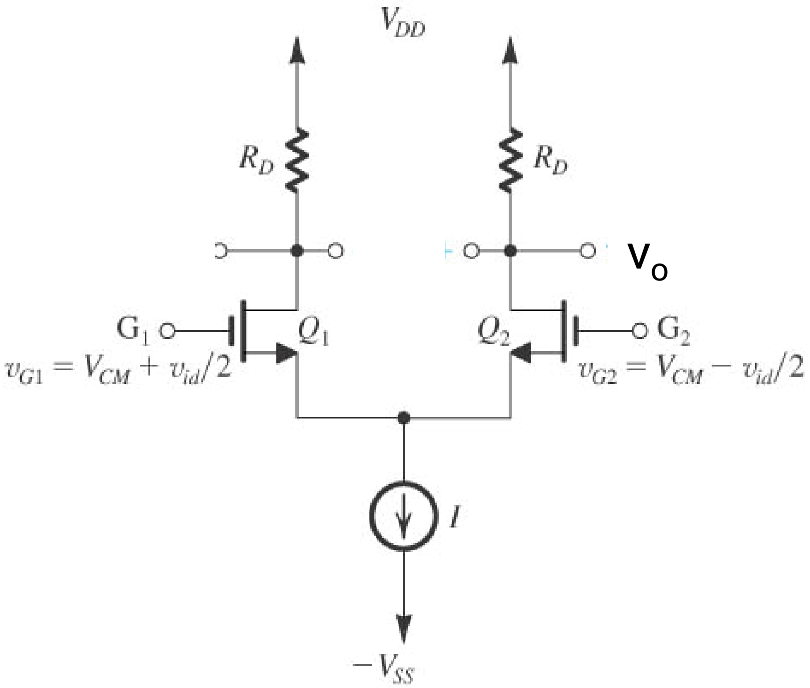
CMRR(Common-mode rejection ratio)= $\left|\frac{A_d}{A_{cm}}\right| \sim \frac{g_m R_D}{\frac{\Delta R_D}{2R_{ss}}}$

Any mismatches in differential pair causes finite CMRR

➔ Common-mode input affects output difference

Lect. 29: MOS Differential Amplifiers(2)

What if we want to have single-ended output?



For DM,

$$\frac{v_o}{-v_{id}/2} = -g_m R_D$$

$$\therefore A_d = \frac{v_o}{v_{id}} = \frac{g_m R_D}{2} \quad (\text{ignoring } r_o)$$

For CM,

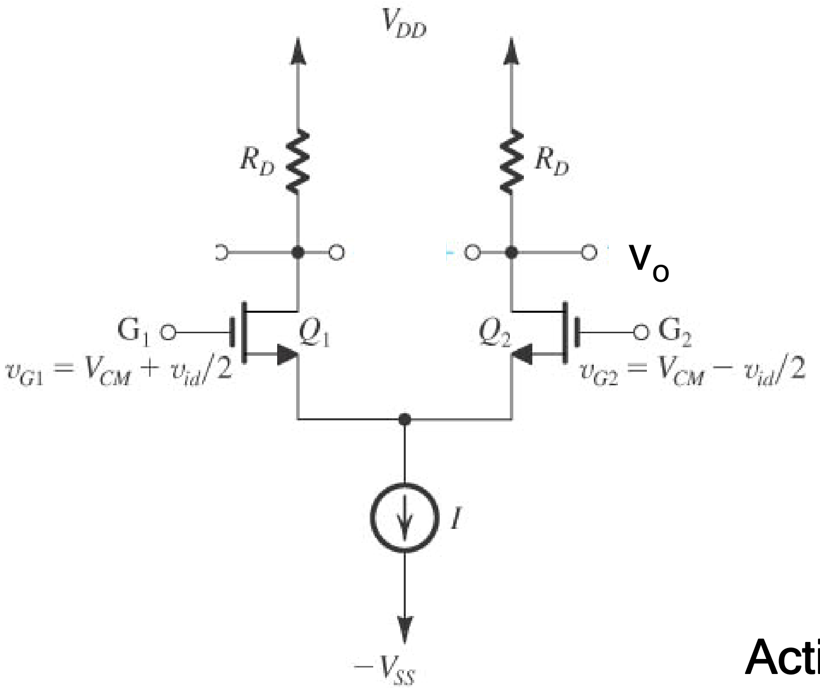
$$\frac{v_o}{v_{cm}} \sim -\frac{R_D}{2R_{ss}}$$

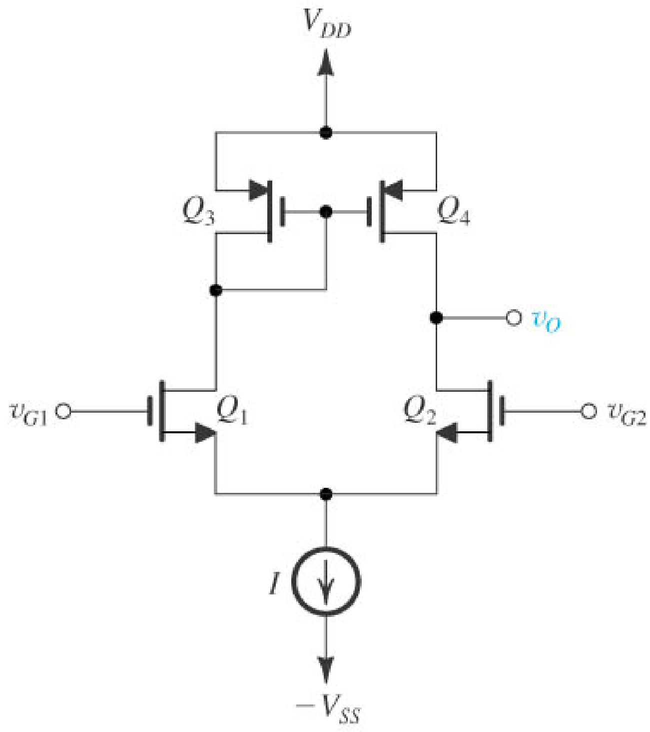
$$\text{CMRR} \sim \frac{\frac{g_m R_D}{2}}{\frac{R_D}{2R_{ss}}} = g_m R_{ss}$$

Finite CMRR for single-ended output

Lect. 29: MOS Differential Amplifiers(2)

Can we do better?



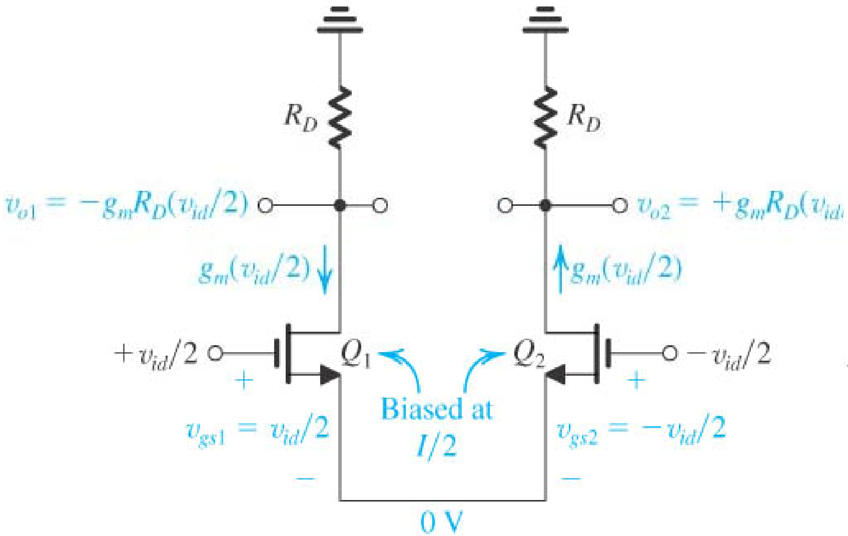


(a)

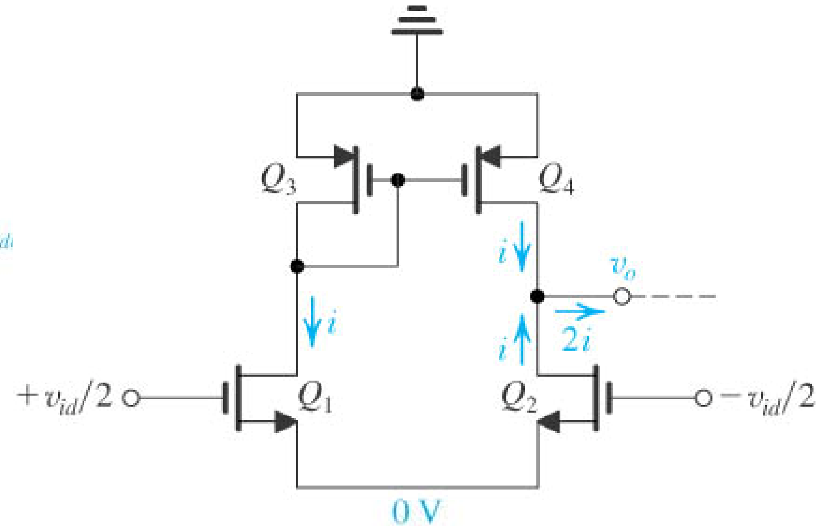
Active-loaded (current mirror) MOS differential pair

No resistors ➔ small size, better matching

Lect. 29: MOS Differential Amplifiers(2)



$$\frac{v_{o2}}{v_{id}} = \frac{g_m(R_D \| r_o)}{2}$$



Assuming symmetry $\frac{v_o}{v_{id}} = \frac{g_m(r_{on} \| r_{op})}{2}$

But detailed analysis (Razavi 10.6.2) can show

$$\frac{v_o}{v_{id}} = g_m(r_{on} \| r_{op})$$

Factor of 2 improvement due to current mirror!