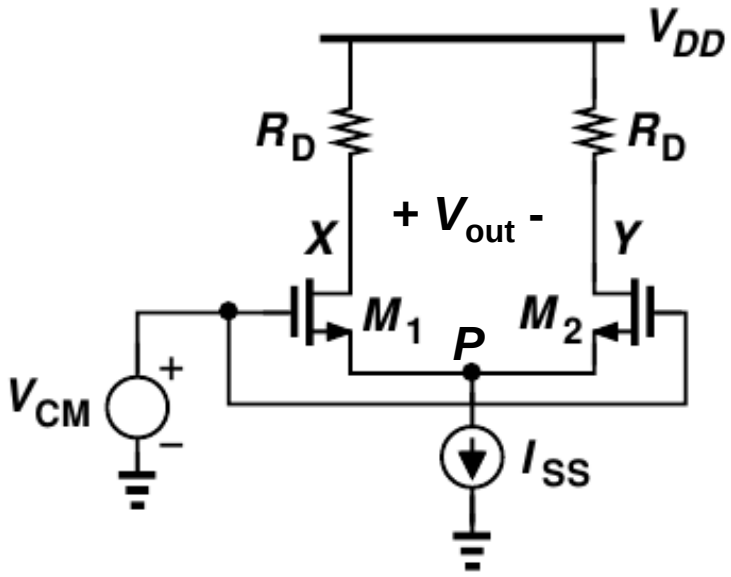
Can Input V_{CM} be Completely Rejected?

- In practice, input V_{CM} variation may not be completely rejected.



Even V_{CM} is changed

➔ $I_{D1} = I_{D2} = I_{SS}/2$ are kept unchanged

➔ $V_X = V_Y$ are kept unchanged

➔ V_{out} is not affected

∵ V_P can be adjusted!

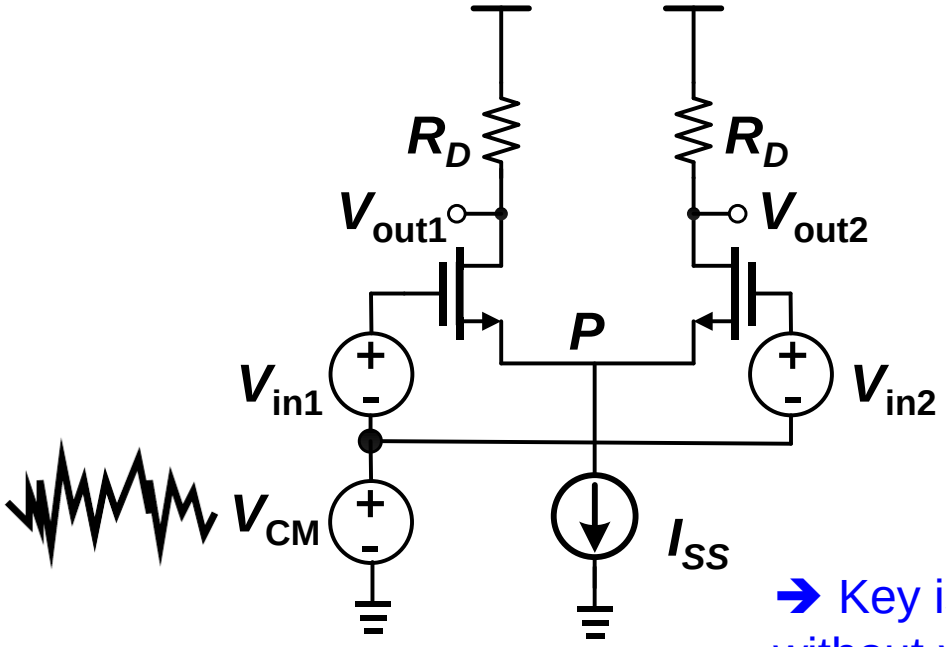
Common Mode Rejection

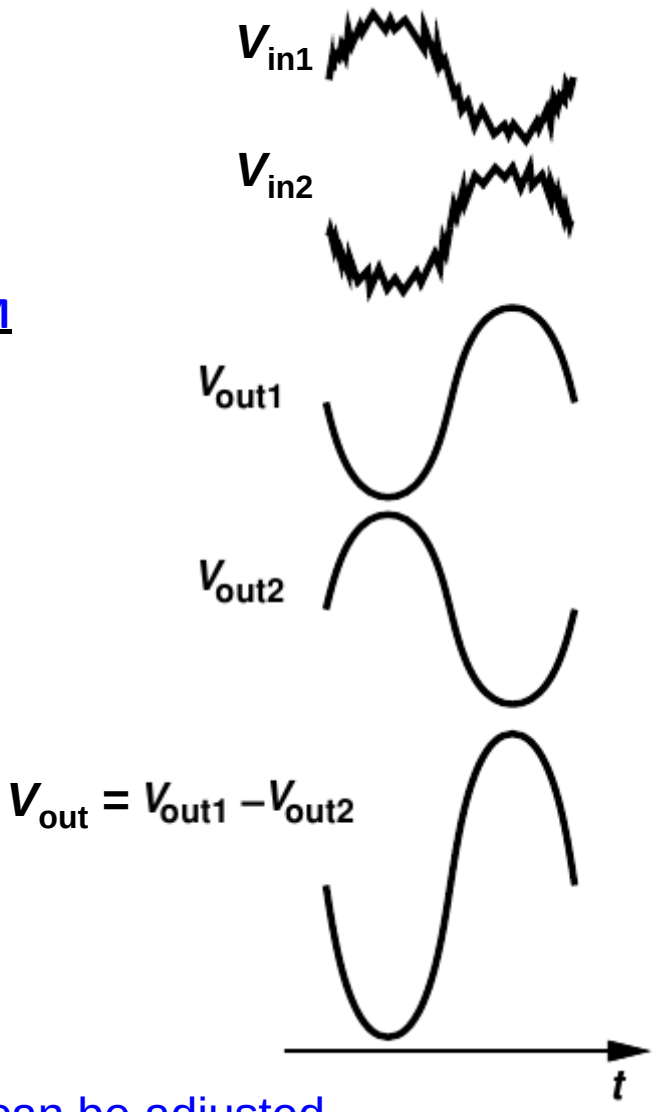
Hanwool Jeong

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Quantifying How Well Common Mode is Rejected!

- In the ideal case, output CM does not change at all even with input CM variation.
- Defining common-mode gain $A_{CM} = \frac{\Delta V_{out,CM}}{\Delta V_{in,CM}}$ and its value is 0 for the ideal case.

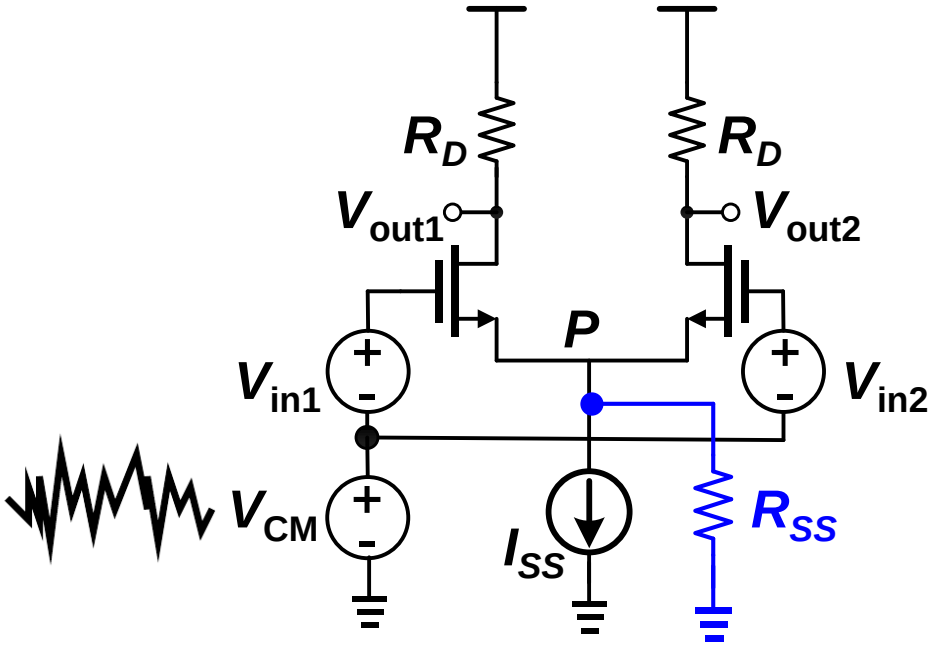


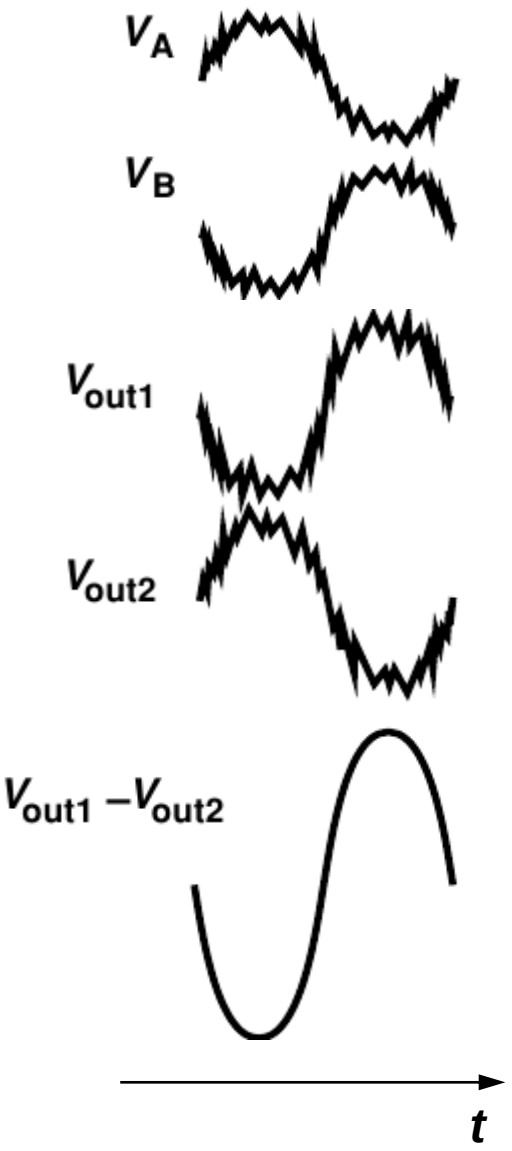


➔ Key is that P can be adjusted without varying bias currents.

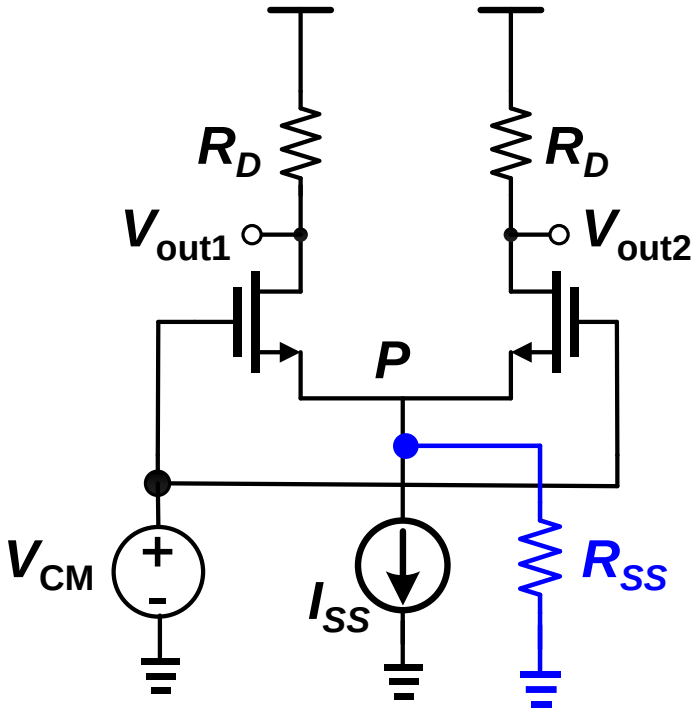
Non-ideality (1) ; What if P Change Incurs Bias Current Change

- I_{SS} is non-ideal current source ➔ Finite R_{out}
- V_{CM} change ➔ P change ➔ I_{D1} & I_{D2} change
  - In large signal, $V_{out,CM}$ is changed.
  - In small signal, g_m is changed while g_m for M_1 & M_2 are same



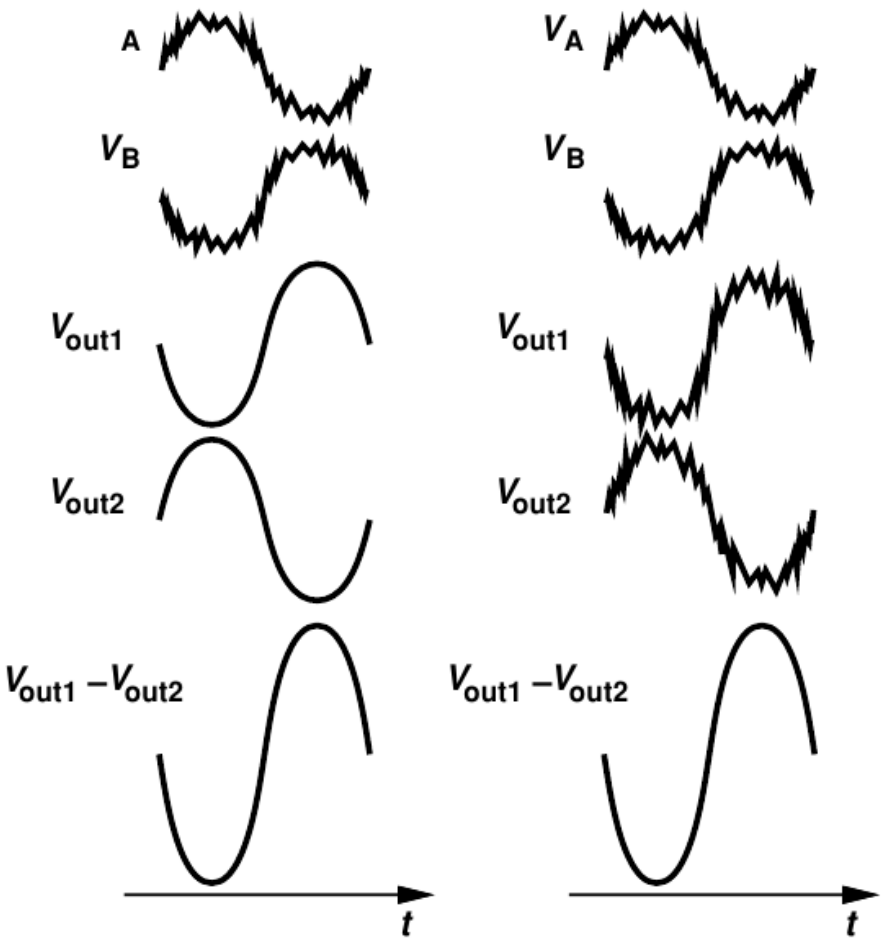


Common-mode Gain for Non-ideal Current Source



$$A_{CM} = \Delta V_{out,CM}/\Delta V_{in,CM} = \frac{-g_m R_D}{1+2g_m R_{SS}}$$

Anyway V_{out} is Unchanged!

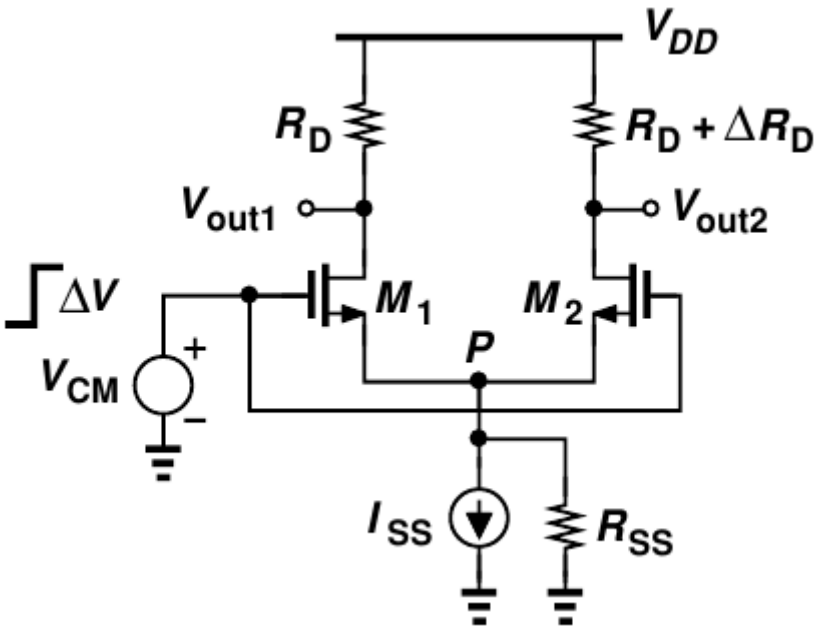


- Is there any non-idealities that result in differential output V_{out} change?
- In that case, how can we quantify the goodness of common-mode rejection?

➔ Is there any metric that quantifies small-signal output robustness to input CM variation?

Non-ideality (2); Asymmetry

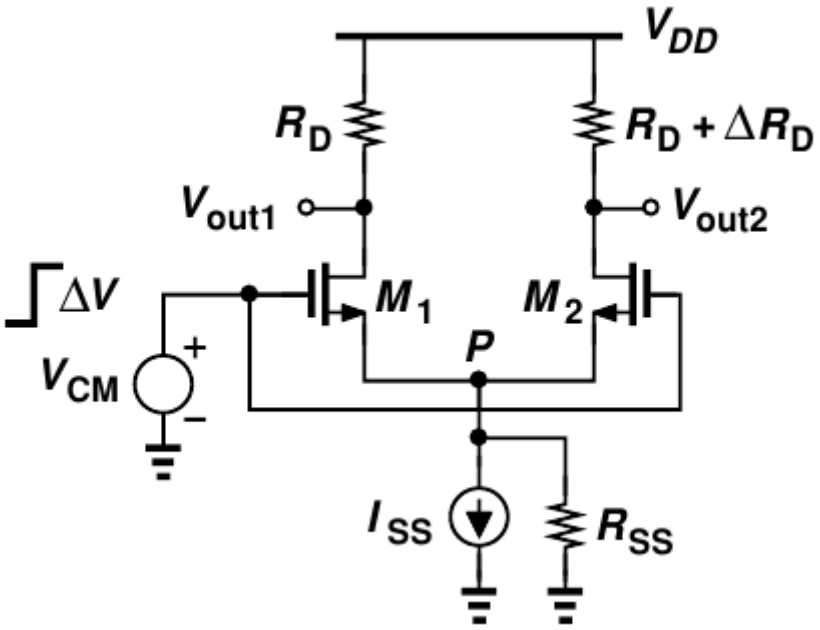
- In this case, there is an asymmetry at loads.



$$\begin{aligned}\Delta V_{out} &= \Delta V_{out1} - \Delta V_{out2} \\ &= \Delta I_D R_D - \Delta I_D (R_D + \Delta R_D) \\ &= -\Delta I_D \cdot \Delta R_D \\ &= -\frac{\Delta V_{CM}}{\frac{1}{g_m} + 2R_{SS}} \Delta R_D\end{aligned}$$

We observe differential output is changed by VCM change

Common Mode to Differential Mode Conversion, A_{CM-DM}



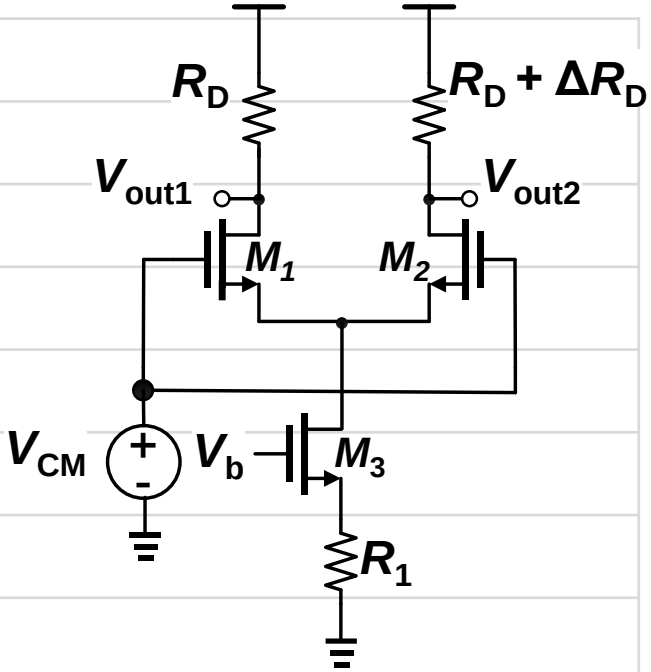
$$A_{\text{CM-DM}} = \left| \frac{\Delta V_{out}}{\Delta V_{CM,input}} \right|$$

$$= \frac{\Delta R_D}{\frac{1}{g_m} + 2R_{SS}}$$

$$A_{CM-DM} \approx \frac{\Delta R_D}{2R_{SS}}$$

Example 10.27

Determine A_{CM-DM} for the circuit shown in Fig. 10.46. Assume $\lambda = 0$ for M_1 and M_2.



CMRR,
Common-mode Rejection Ratio

- CM-DM conversion cannot be simply quantified by A_{CM-DM}.
- If circuit provides a large differential gain, A_{DM}, then relative corruption at the output is small.
- Thus, we define common-mode rejection ratio (CMRR) as

$$\text{CMRR} = \frac{A_{DM}}{A_{CM-DM}}$$

Example 10.28

Calculate the CMRR of the circuit in Fig. 10.46. Assume that load mismatch effect is negligible for A_{DM}.

