IIT ROORKEE

NPTEL ONLINE CERTIFICATION COURSE

Microelectronics: Devices to Circuits

Small Signal Operation and Differential Amplifiers

SUDEB DASGUPTA

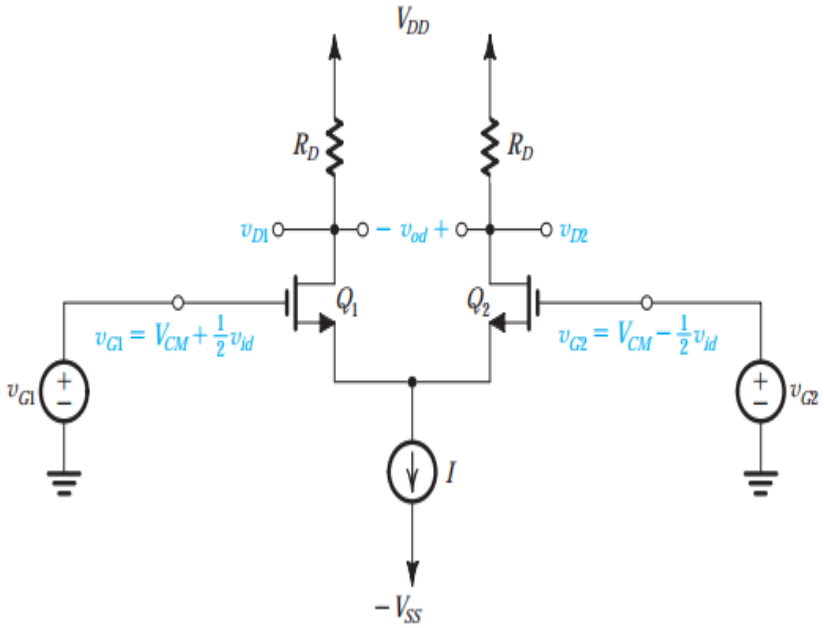
DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

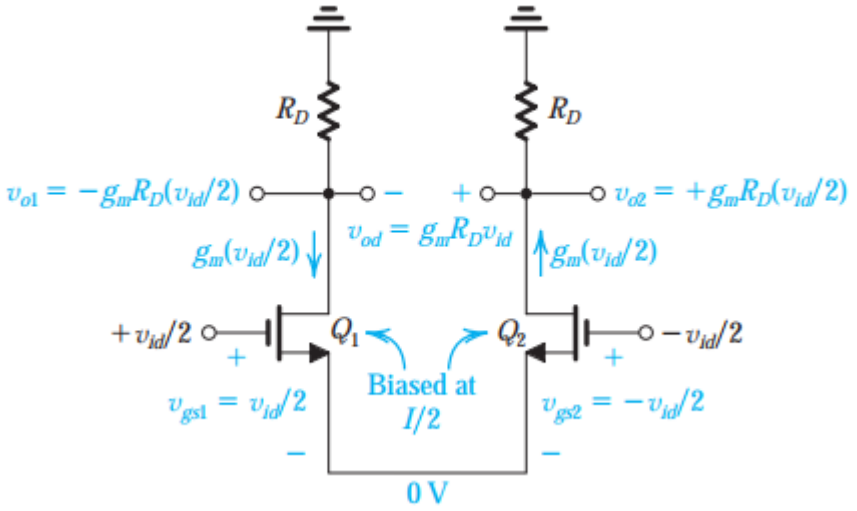


Outline

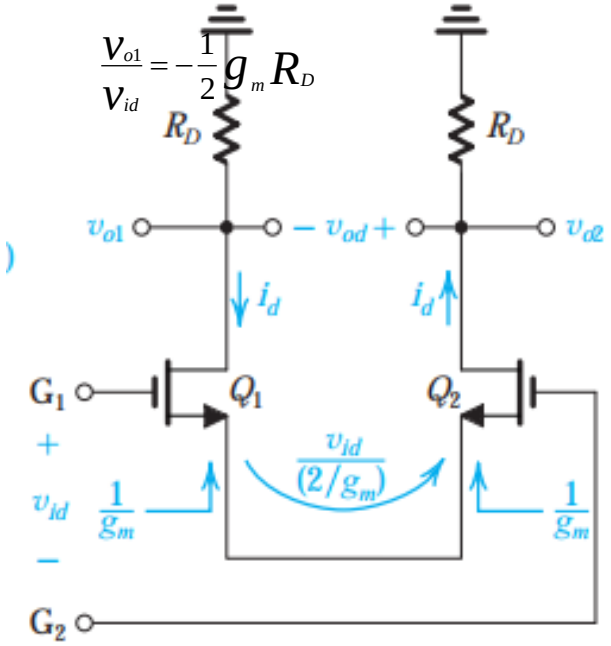
- Small Signal Operation of MOS Differential Pair
- The Differential Half Circuit
- Differential Amplifier with current source load
- Cascode Differential Amplifier
- Common mode gain and common-mode rejection ratio
- Effect of R_D mismatch
- Effect of g_m mismatch
- Recapitulation

Small Signal Operation of MOS Differential Pair





Source: Microelectronics Circuits, Sedra and Smith, Fifth edition



$$v_{G1} = V_{CM} + \frac{1}{2} v_{id}$$

$$v_{G2} = V_{CM} - \frac{1}{2} v_{id}$$

$$v_{O1} = -g_m \frac{v_{id}}{2} R_D$$

$$v_{O2} = +g_m \frac{v_{id}}{2} R_D$$

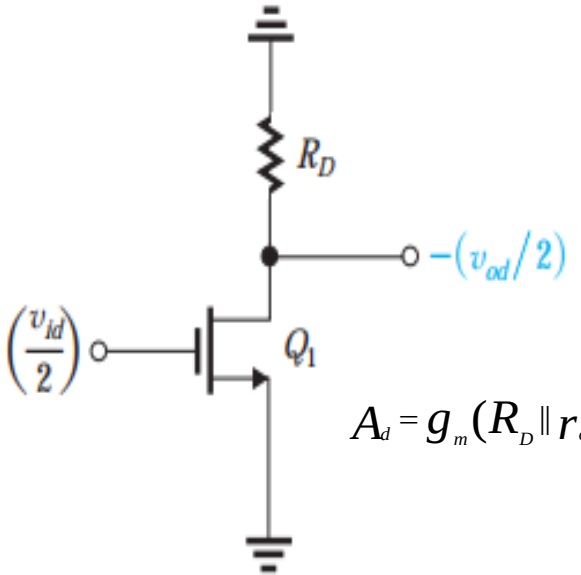
$$\frac{v_{o1}}{v_{id}} = -\frac{1}{2} g_m R_D$$

$$\frac{v_{o2}}{v_{id}} = \frac{1}{2} g_m R_D$$

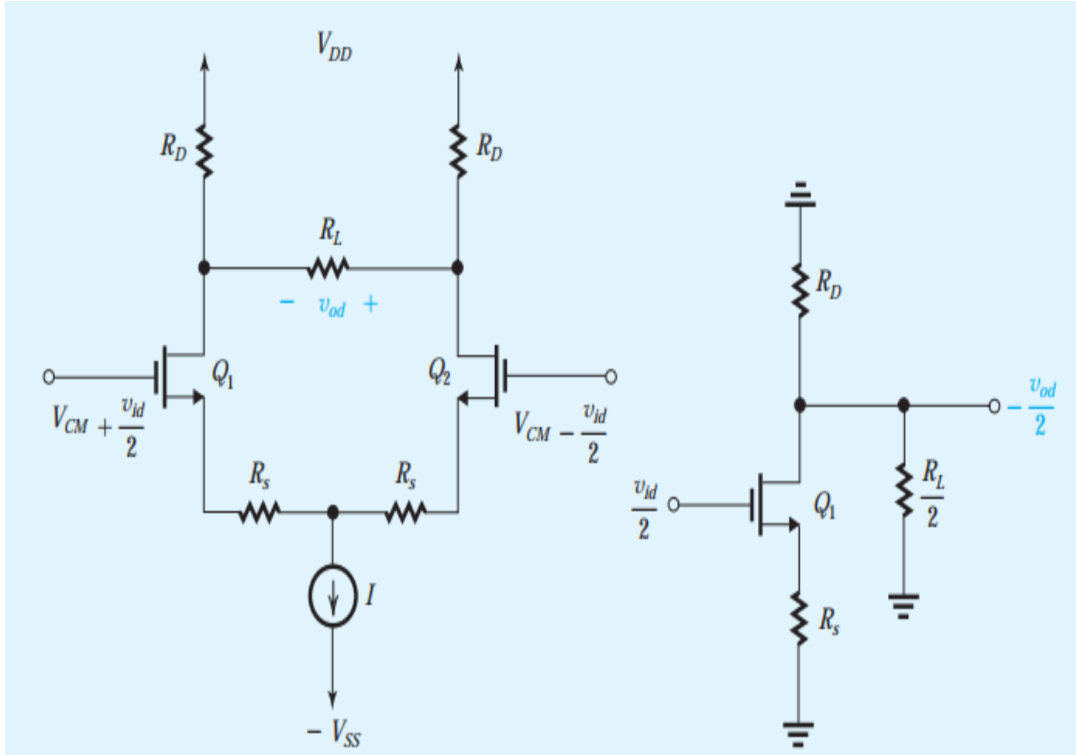
$$A_d = \frac{v_{o1} - v_{o2}}{v_{id}} = g_m R_D$$

Source: Microelectronics Circuits, Sedra and Smith, Fifth edition

The Differential Half Circuit

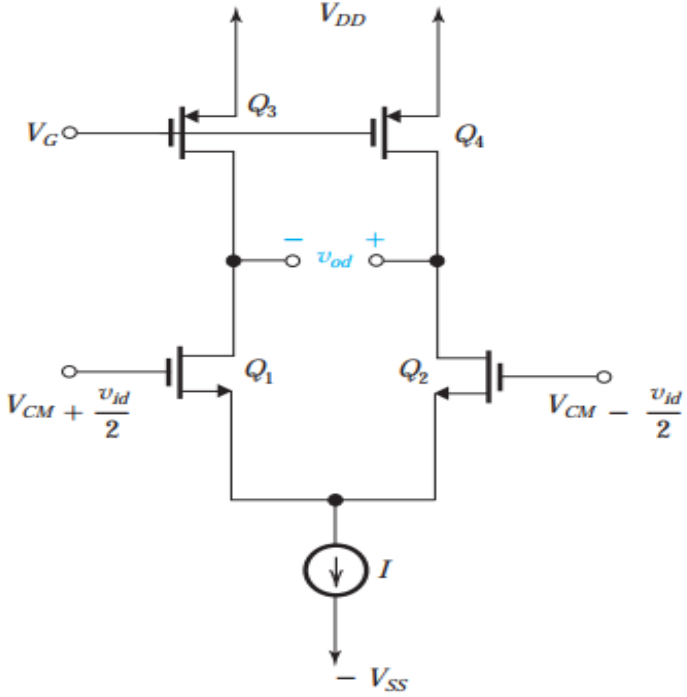


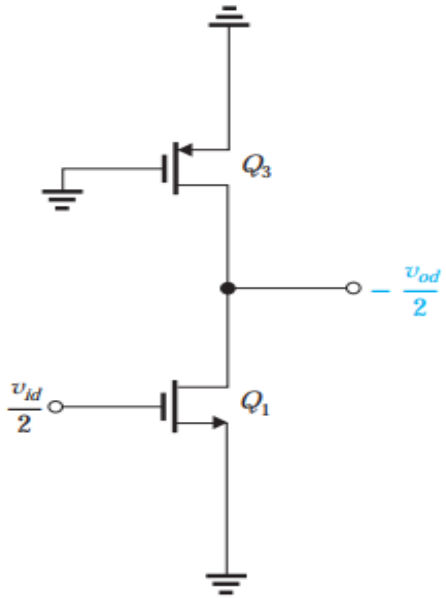
$$A_d = g_m(R_D \| r_o)$$



Source: Microelectronics Circuits, Sedra and Smith, Fifth edition

Differential Amplifier with current source load

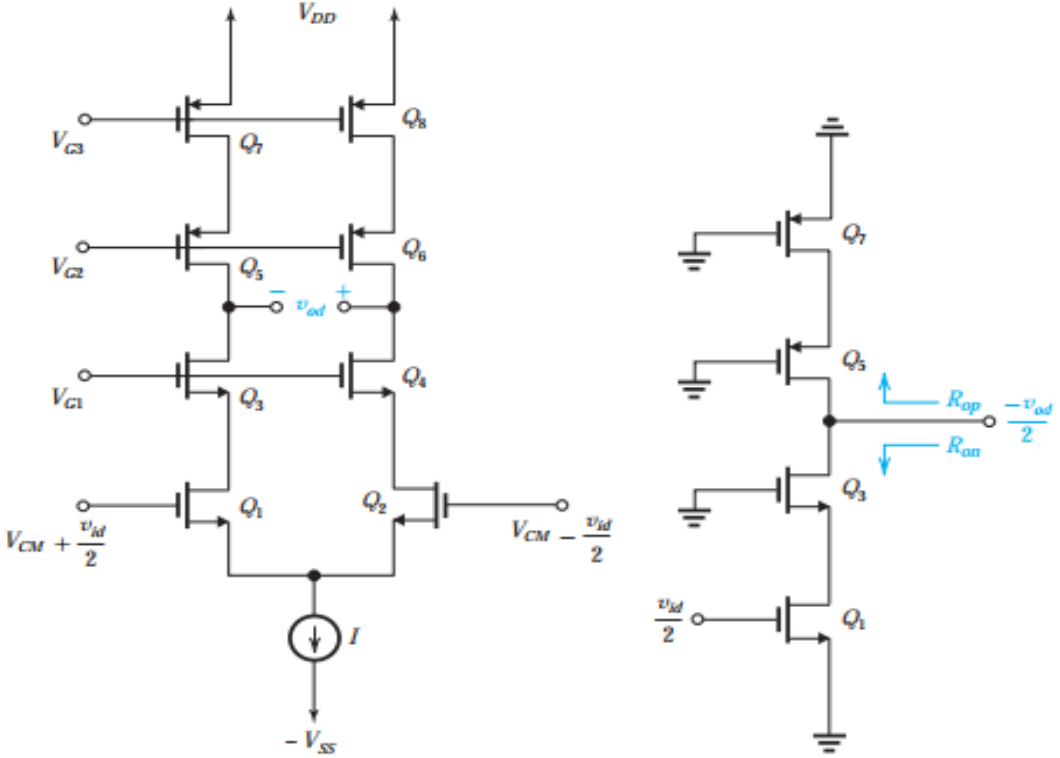




$$A_d = g_{m1}\left(r_{o1} \parallel r_{o3}\right)$$

Source: Microelectronics Circuits, Sedra and Smith, Fifth edition

Cascode Differential Amplifier



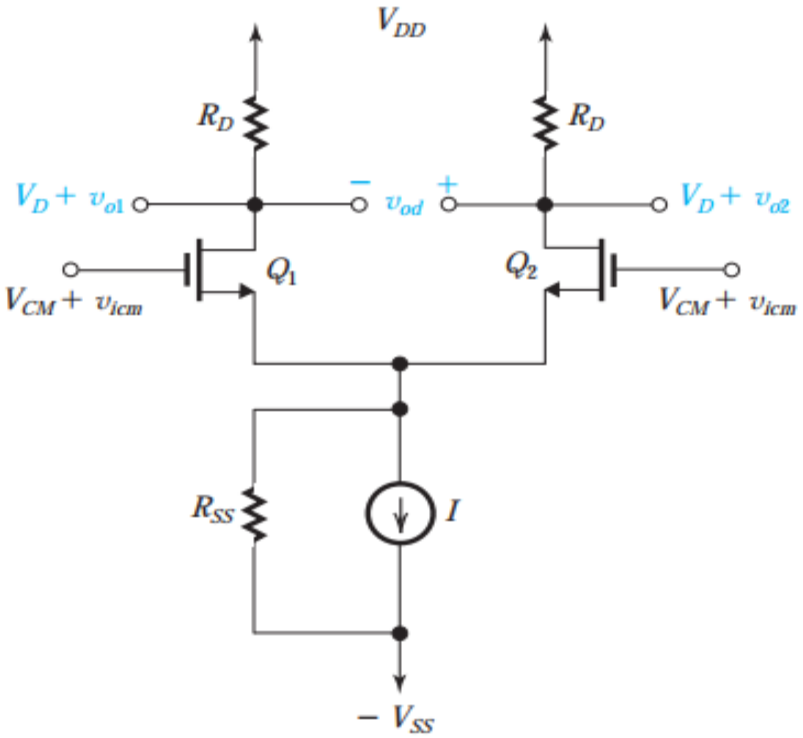
$$A_d = g_{m1}(r_{on} \parallel r_{op})$$

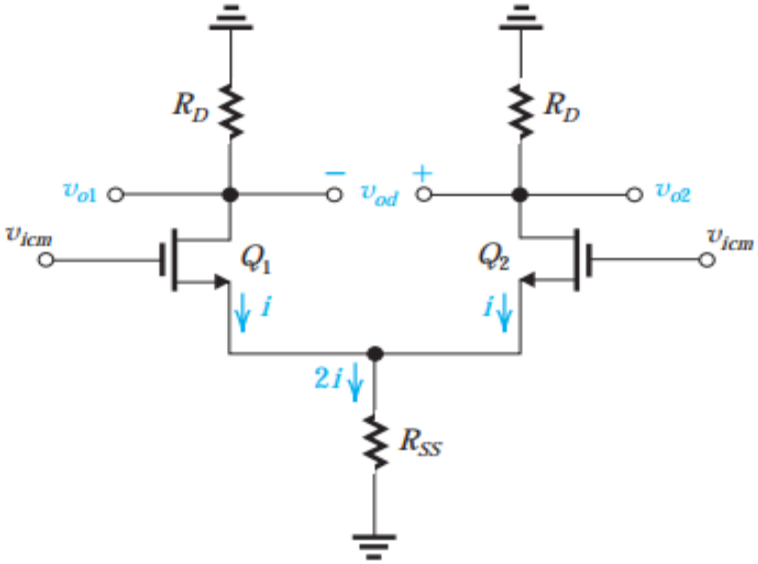
$$R_{On} = (g_{m3} r_{o3}) r_{o1}$$

$$R_{Op} = (g_{m5} r_{o5}) r_{o7}$$

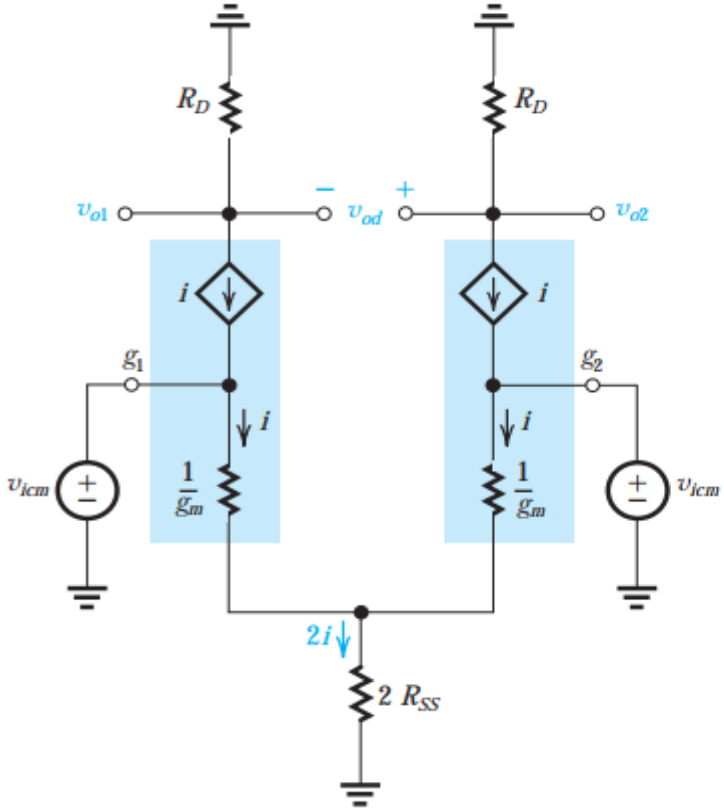
Source: Microelectronics Circuits, Sedra and Smith, Fifth edition

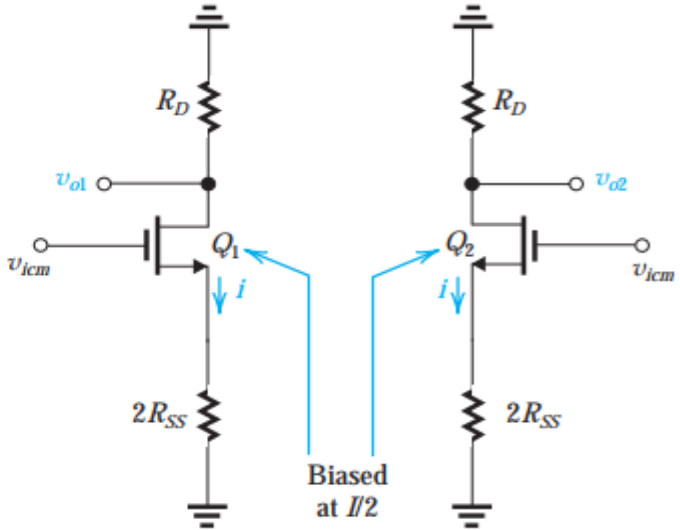
Common mode gain and common-mode rejection ratio





Source: Microelectronics Circuits, Sedra and Smith, Fifth edition





Source: Microelectronics Circuits, Sedra and Smith, Fifth edition

$$v_{icm} = \frac{i}{g_m} + 2i R_{SS}$$

$$\frac{v_{o1}}{v_{icm}} = \frac{v_{o2}}{v_{icm}} = -\frac{R_D}{2R_{SS}}$$

$$i = \frac{v_{im}}{\frac{1}{g_m} + 2R_{SS}}$$

Assume $2R_{SS} >> \frac{1}{g_m}$

$$v_{o1} = v_{o2} = -R_D i$$

$$v_{od} = v_{o2} - v_{o1} = 0$$

$$v_{o1} = v_{o2} = -\frac{R_D}{\frac{1}{g_m} + 2R_{SS}} v_{icm}$$

Source: Microelectronics Circuits, Sedra and Smith, Fifth edition

Effect of R_D mismatch

If mismatch in R_D is ΔR_D $v_{o1} = -\frac{R_D}{2R_{SS}} v_{icm}$ $v_{o2} = -\frac{R_D + \Delta R_D}{2R_{SS}} v_{icm}$

$$v_{od} = v_{o2} - v_{o1} = -\frac{\Delta R_D}{2R_{SS}} v_{icm} \qquad A_{cm} = -\frac{\Delta R_D}{2R_{SS}}$$

$$CMRR = \frac{2 g_m R_{SS}}{\Delta R_D / R_D}$$

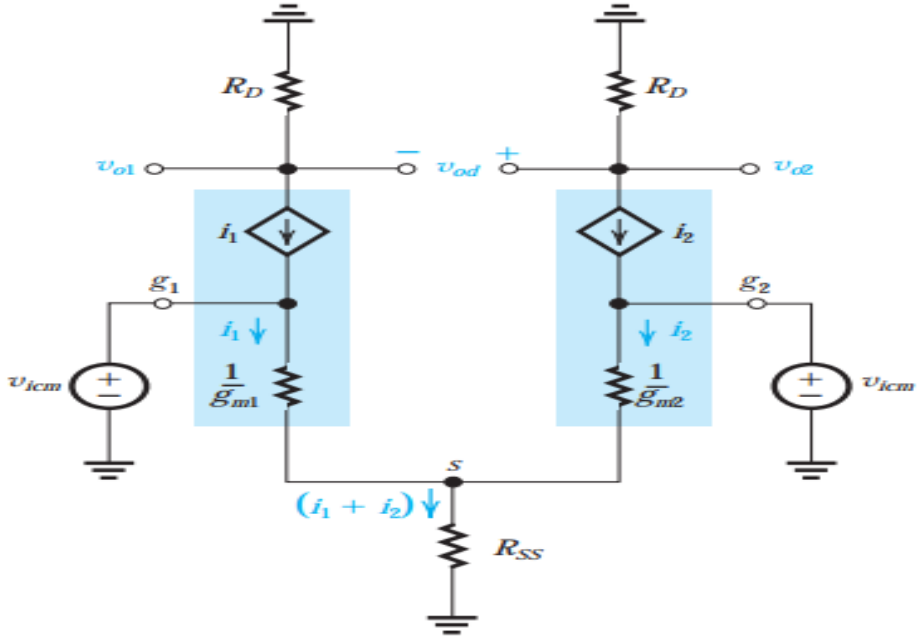
Source: Microelectronics Circuits, Sedra and Smith, Fifth edition

Effect of g_m mismatch

If mismatch in g_m is Δg_m

$$CMRR = \frac{2 g_m R_{SS}}{\Delta g_m / g_m}$$

$$g_{m1} = g_m + \frac{1}{2}\Delta g_m \qquad g_{m2} = g_m - \frac{1}{2}\Delta g_m$$



Source: Microelectronics Circuits, Sedra and Smith, Fifth edition

Recapitulation

- Small signal circuit analysis helps to calculate the differential gain, common –mode gain, common mode rejection ratio.
- The CMRR for the MOSFETs diff-amp is also a strong function of output resistance of the constant current source.
- The CMRR can be increased by increasing the output resistance of the current source.
- The CMRR can be increased by using the casocde current mirror.

Source: Microelectronics Circuits, Sedra and Smith, Fifth edition

Thank You