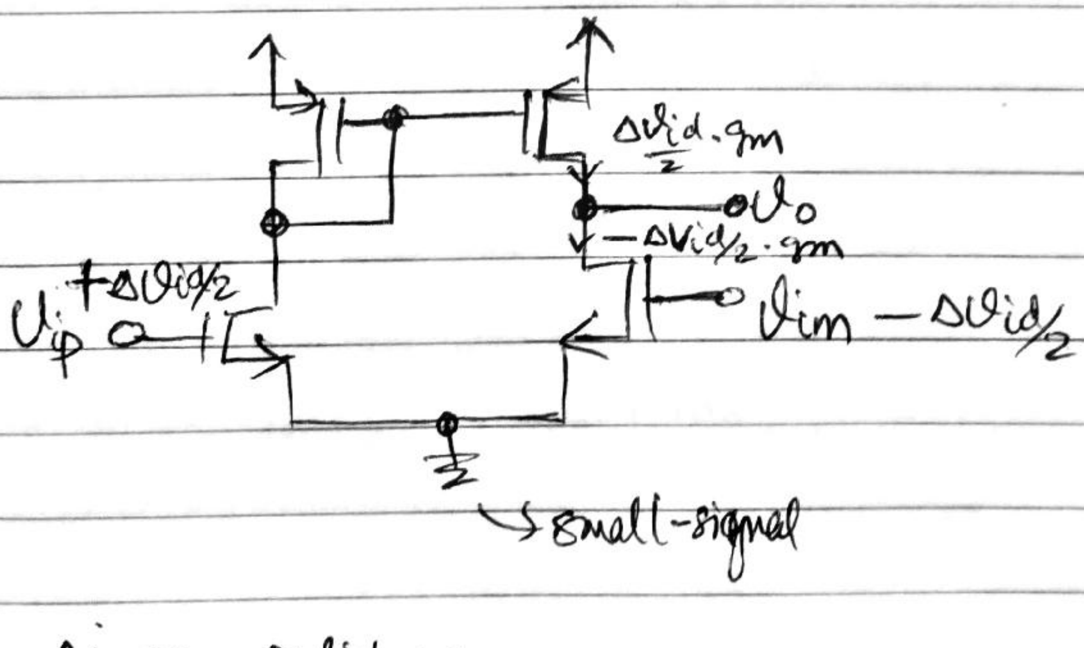
SMALL-SIGNAL GAIN OF DIFF-AMP.

Differential Gain:

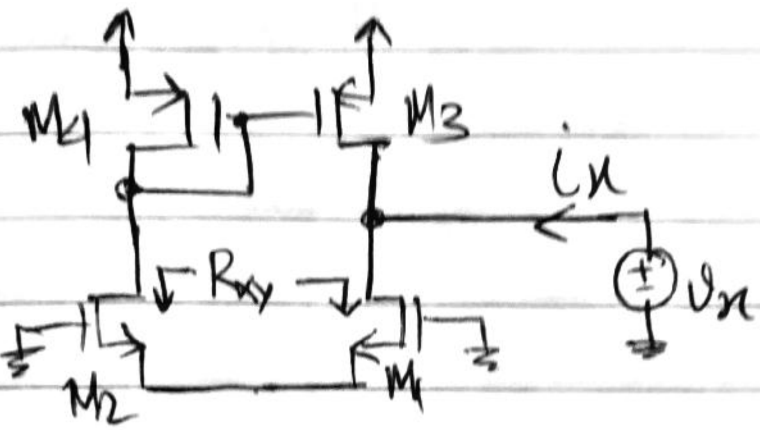
Instead of drawing the entire small-signal, we can find the effective small-signal differential G_m & output impedance R_{out} & gain is $G_m \cdot R_{out}$

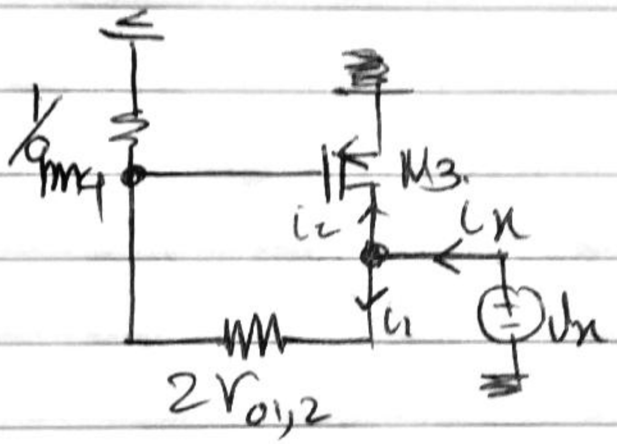
Since for pure diff signal, the coupled sources are constant, they look like small-signal ground.



$\Delta i_{out} = \Delta v_{id} \times g_m.$

Output Impedance





$$i_1 = \frac{v_x}{2r_{o1,2}}$$

$$i_2 = \frac{v_x}{2r_{o1,2}}$$

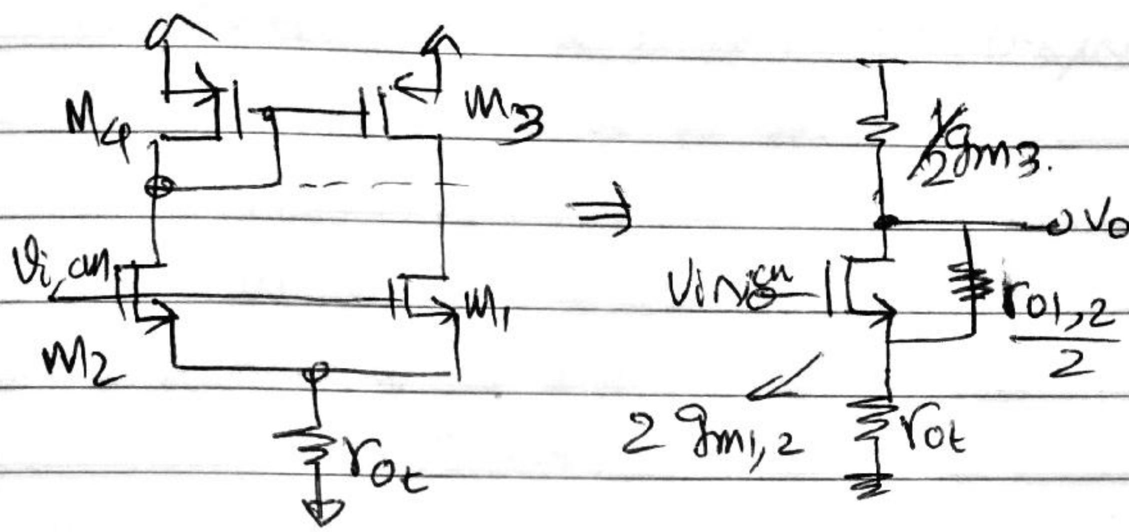
$$\therefore i_1 + i_2 = \frac{v_x}{r_{o1,2}}$$

$$i_x = i_1 + i_2 + i_3 = \frac{v_x}{r_{o1,2}} + \frac{v_x}{r_{o3}}$$

$$\therefore r_{out} \cong r_{o1,2} \parallel r_{o3}$$

$$\boxed{A_d = g_{m1,2} \times (r_{o1,2} \parallel r_{o3})}$$

Common-mode gain



$$A_{cm} \cong \frac{-1/2g_{m3,4}}{\frac{1}{2g_{m1,2}} + r_{ot}} = \frac{-1}{1+2g_{m1,2}\cdot r_{ot}} \frac{g_{m1,2}}{g_{m3,4}}$$

$$CMRR = \left|\frac{A_{DM}}{A_{CM}}\right| = g_{m1,2}\cdot(r_{o1,2} \| r_{o3,4}) \frac{g_{m3,4}(1+2g_{m1,2}r_{ot})}{g_{m1,2}}$$

$$\boxed{CMRR = (1+2g_{m1,2}r_{ot})g_{m3,4}(r_{o1,2} \| r_{o3,4})}$$