a) Common Mode voltage gain: (single-ended)

$$A_{cm} = \frac{V_o}{V_{cm}} = \frac{V_{o2}}{V_{s1}}\bigg|_{V_{s2}=V_{s1}} = -g_{m2}\pi_{D2}\left[1+g_{m1}\pi_s - g_{m1}\pi_s\right]\frac{1}{\Delta}$$

$$\boxed{A_{cm} \cong -\frac{g_m \pi_D}{1+2g_m\pi_s} = -\frac{1}{2}\frac{\pi_D}{\pi_s\left(1+\frac{1}{2g_m\pi_s}\right)}}$$

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

b) Differential Mode voltage gain: (single-ended)

$$A_d = \frac{V_o}{V_d} = \frac{V_{o2}}{V_{s1}}\bigg|_{V_{s2}=0} = g_{m1}\pi_s\, g_{m2}\pi_{D2}\frac{1}{\Delta}$$

$$\boxed{A_d \cong \frac{g_m\pi_s\, g_m\pi_D}{1+2g_m\pi_s} = \frac{1}{2}\frac{g_m\pi_D}{\left(1+\frac{1}{2g_m\pi_s}\right)}}$$

c) Common Mode Rejection Ratio:

$$\boxed{CMRR = \frac{|A_d|}{|A_{cm}|} \cong g_m\pi_s}$$

Numerical Example

$\pi_D = 39k\Omega$

$\pi_s = 18k\Omega$

$g_m = 4\times10^{-4}\frac{A}{V}$

$\Rightarrow$

$$\boxed{\begin{aligned} A_{cm} &\cong -1.01 \\ A_d &\cong 7.29 \\ CMRR &\cong 7.2 \end{aligned}}$$

Conclusion: To improve both A_d and CMRR we have to replace π_D and π_s by current sources! → active Loads