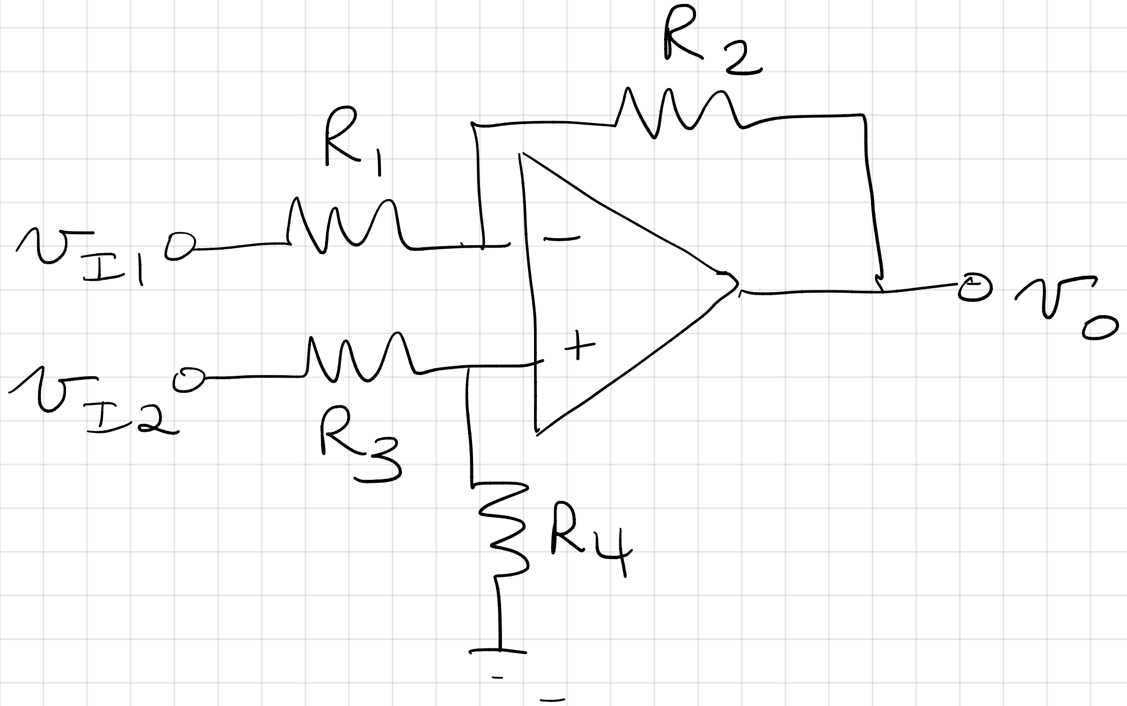
# Difference Amplifiers




$$A_{cm} = -\frac{R_2}{R_1} + \left(1 + \frac{R_2}{R_1}\right)\left(\frac{R_4}{R_3 + R_4}\right)$$

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$R_1 = R_3 = 2\,k\Omega$

$R_2 = R_4 = 200\,k\Omega$

$A_{cm} = 0$
↑
perfectly match resistors

$$A_d = \frac{R_2}{R_1} = \frac{200}{2} = 100\,\frac{V}{V} \text{ or } 40\,dB$$

$R_{id} = 2R_1 = 4\,k\Omega$ $\qquad R_o = 0$

$CMRR \rightarrow \infty$

$R_1 - R_4$ have 1% tolerance.

$$A_{cm} = -\frac{R_2}{R_1} + \left(1 + \frac{R_2}{R_1}\right)\left(\frac{R_4}{R_3+R_4}\right)$$

$$= \left(\frac{R_4}{R_3+R_4}\right)\left[-\frac{R_2}{R_1}\left(\frac{R_3+R_4}{R_4}\right) + \left(1+\frac{R_2}{R_1}\right)\right]$$

$$= \left(\frac{R_4}{R_3+R_4}\right)\left[-\frac{R_2}{R_1}\left(1+\frac{R_3}{R_4}\right) + \left(1+\frac{R_2}{R_1}\right)\right]$$

$$= \left(\frac{R_4}{R_3+R_4}\right)\left[\left(-\frac{R_2}{R_1} - \frac{R_3}{R_4}\frac{R_2}{R_1}\right) + \left(1+\frac{R_2}{R_1}\right)\right]$$

$$= \left(\frac{R_4}{R_3+R_4}\right)\left[1 - \frac{R_2}{R_1}\frac{R_3}{R_4}\right]$$

$$= \frac{1}{\frac{R_3}{R_4}+1}\left[1 - \frac{R_2}{R_1}\frac{R_3}{R_4}\right]$$

$$= \left( \frac{1}{\frac{R_3}{R_4} + 1} \right) \left( 1 - \frac{R_2}{R_1} \frac{R_3}{R_4} \right) \left( \frac{\frac{R_4}{R_3}}{R_4/R_3} \right)$$

$$= \frac{\left[ \frac{R_4}{R_3} - \frac{R_2}{R_1} \right]}{1 + \frac{R_4}{R_3}}$$

$R_1 = R_3 = 2\ k\Omega$

$R_2 = R_4 = 200\,k\Omega$

$200\,k\Omega \pm 1\%\,(200\,k\Omega)$

$200\,k\Omega\,(1 \pm .01)$

$2\,k\Omega\,(1 \pm .01)$

$$\frac{200(1-.01)}{2(1+.01)} \leq \frac{R_4}{R_3} \leq \frac{200(1+.01)}{2(1-.01)}$$

$$\frac{198}{2.02} \leq \frac{R_4}{R_3} \leq \frac{202}{1.98}$$

$$98.02 \le \frac{R_4}{R_3} \le 102.02$$

$$98.02 \le \frac{R_2}{R_1} \le 102.02$$

$$A_{cm} = \frac{\left[\frac{R_4}{R_3} - \frac{R_2}{R_1}\right]}{1 + \frac{R_4}{R_3}} \quad \begin{matrix} \leftarrow \text{large} \\ \\ \leftarrow \text{small} \end{matrix}$$

want to know the worst case $A_{cm}$

let $\frac{R_4}{R_3} = 98.02 \qquad \frac{R_2}{R_1} = 102.02$

$$A_{cm} = \frac{(98.02 - 102.02)}{1 + 98.02} = -0.04 \ V/V$$

$$|A_{cm}| = 0.04 \ \frac{V}{V} \qquad A_d = \frac{R_2}{R_1} = \frac{102.02}{\frac{V}{V}}$$

$$CMRR = 20 \log \left| \frac{A_d}{A_{cm}} \right|$$

$$= 20 \log \left| \frac{102.02}{.04} \right|$$

$$= 68.04 \text{ dB}$$