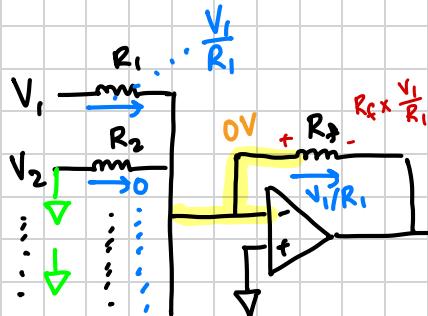


IDEAL OP-AMP LIMITATIONS

① Limited output swing $\Rightarrow V_o$ cannot go above V_{DD} or below $-V_{DD}$

② Limited input voltage

- Absolute voltage rating
- $V_f \approx V_-$ Input Common Mode Voltage $\frac{V_f + V_-}{2}$
- RRI \Rightarrow Rail to Rail Input

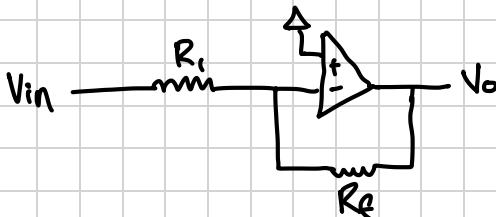


V_o due to V_1 alone

$$= -\frac{R_f}{R_1} V_1 = -\frac{R_f}{R_1} \frac{V_1}{R_1}$$

True output

$$\begin{aligned} &= -\frac{R_f}{R_1} V_1 - \frac{R_f}{R_2} V_2 - \frac{R_f}{R_3} V_3 + \dots \\ &= -R_f \sum_{i=1}^n \frac{1}{R_i} V_i \end{aligned}$$



Node Analysis

$$\frac{V_{in} - V_-}{R_1} = \frac{V_- - V_o}{R_f}$$

~~$V_- = 0$~~

$$\frac{V_-}{R_f} + \frac{V_-}{R_1} = \frac{V_{in}}{R_1} + \frac{V_o}{R_f}$$

$$V_o = A(V_+ - V_-)$$

$$(R_f + R_1) V_- = R_f V_{in} + R_1 V_o$$

$$V_+ = 0$$

$$V_- = \frac{R_f}{R_f + R_1} V_{in} + \frac{R_1}{R_f + R_1} V_o$$

$$V_o = A(0 - \frac{R_f}{R_f + R_1} V_{in} - \frac{R_1}{R_f + R_1} V_o)$$

Feedback

$$V_o \left(1 + A \frac{R_1}{R_f + R_1}\right) = -A \frac{R_f}{R_f + R_1} V_{in}$$

$$V_o = \frac{-A \frac{R_f}{R_f + R_1}}{1 + A \frac{R_1}{R_f + R_1}} V_{in}$$

CONTROL SYSTEMS

