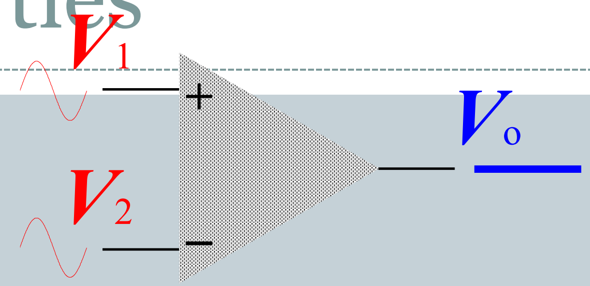
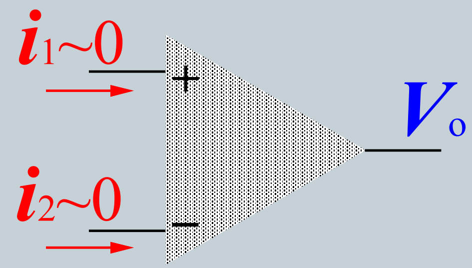
Op-Amp Properties

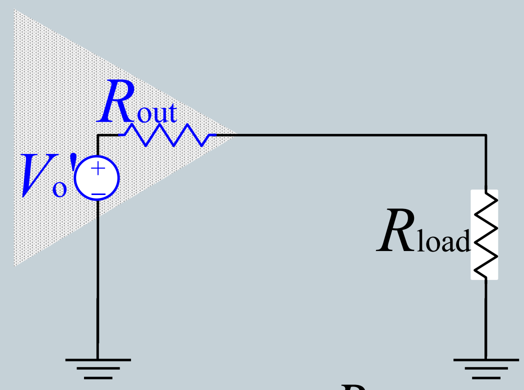
(1) Infinite Open Loop gain
- The gain without feedback
- Equal to differential gain
- Zero common-mode gain
- Pratically, G_d = 20,000 to 200,000



(2) Infinite Input impedance
- Input current i_i ~0A
- T-Ω in high-grade op-amp
- m-A input current in low-grade op-amp



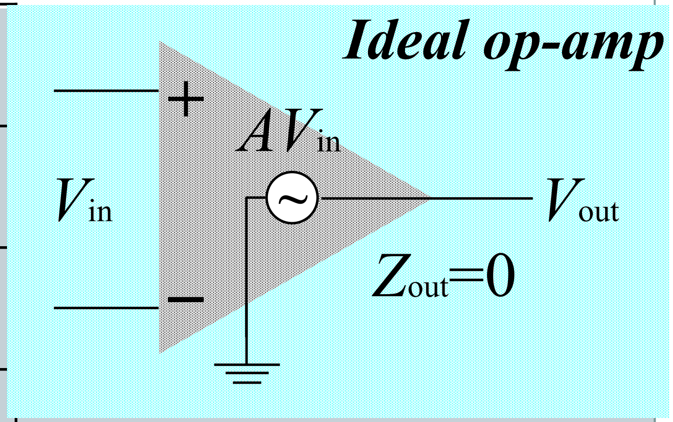
(3) Zero Output Impedance
- act as perfect internal voltage source
- No internal resistance
- Output impedance in series with load
- Reducing output voltage to the load
- Practically, R_{out} ~ 20-100 Ω

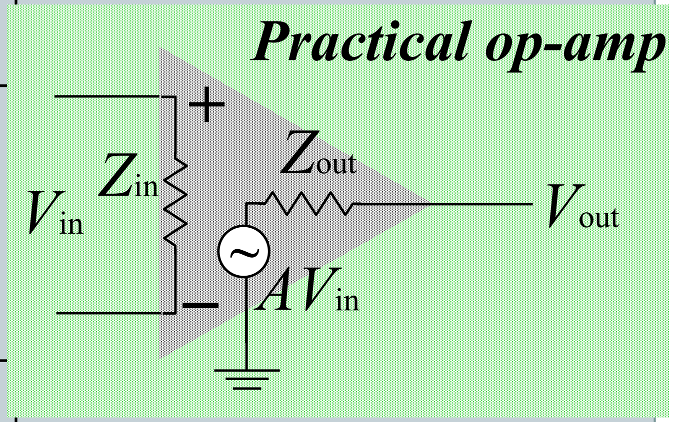


$$V_{load} = V_o' \frac{R_{load}}{R_{load} + R_{out}}$$

Ideal Vs Practical Op-Amp

	Ideal	Practical
Open Loop gain A	$\propto$	10^5
Bandwidth BW	$\propto$	10-100Hz
Input Impedance Z_{in}	$\propto$	>1MΩ
Output Impedance Z_{out}	0 Ω	10-100 Ω
Output Voltage V_{out}	Depends only on $V_d = (V_+ - V_-)$ Differential mode signal	Depends slightly on average input $V_c = (V_+ + V_-)/2$ Common-Mode signal
CMRR	$\propto$	10-100dB





Analysis Method :

Two ideal Op-Amp Properties:

(1) The voltage between V_+ and V_- is zero $V_+ = V_-$

(2) The current into both V_+ and V_- termainals is zero

For ideal Op-Amp circuit:

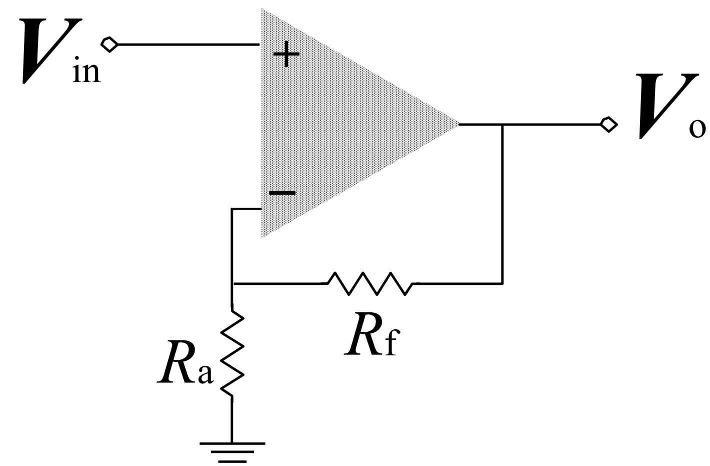
(1) Write the kirchhoff node equation at the noninverting terminal V_+

(2) Write the kirchhoff node eqaution at the inverting terminal V_-

(3) Set $V_+ = V_-$ and solve for the desired closed-loop gain

Non-inverting Amplifier

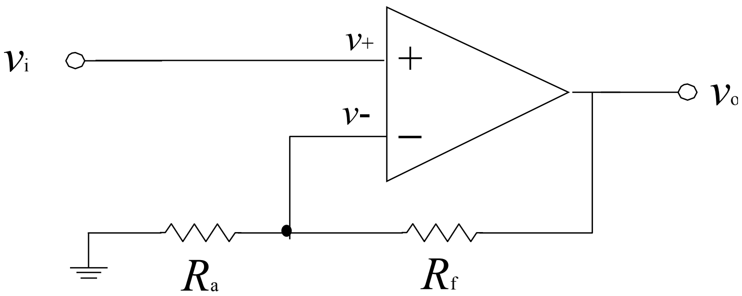
(1) Kirchhoff node equation at V_+ yields, $V_+ = V_i$



(2) Kirchhoff node equation at V_- yields, $\frac{V_- - 0}{R_a} + \frac{V_- - V_o}{R_f} = 0$

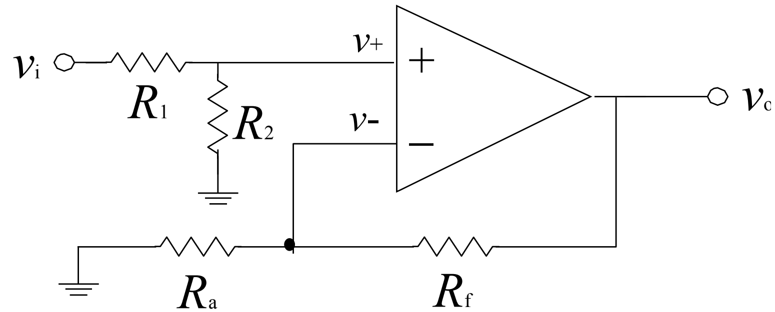
(3) Setting $V_+ = V_-$ yields

$$\frac{V_i}{R_a} + \frac{V_i - V_o}{R_f} = 0 \quad \text{or} \quad \frac{V_o}{V_i} = 1 + \frac{R_f}{R_a}$$



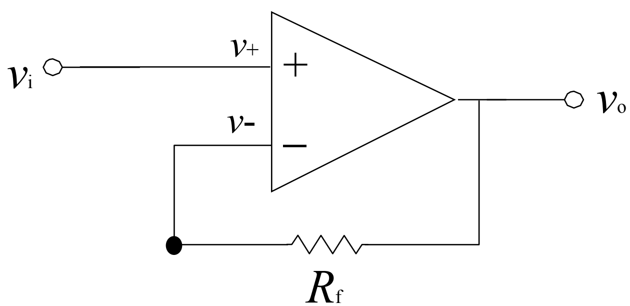
Noninverting amplifier

$$v_o = (1 + \frac{R_f}{R_a}) v_i$$



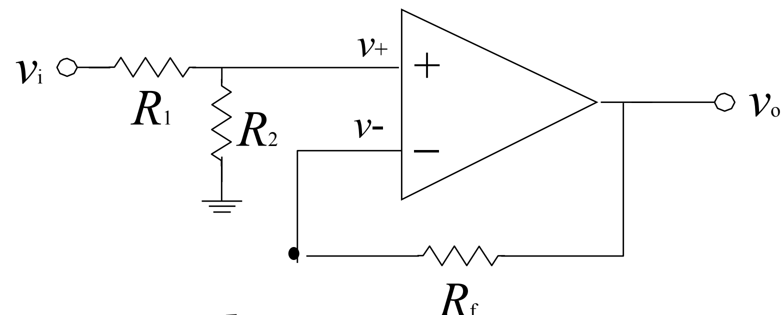
Noninverting input with voltage divide

$$v_o = (1 + \frac{R_f}{R_a})(\frac{R_2}{R_1 + R_2}) v_i$$



Voltage follower

$$v_o = v_i$$



Less than unity gain

$$v_o = \frac{R_2}{R_1 + R_2} v_i$$