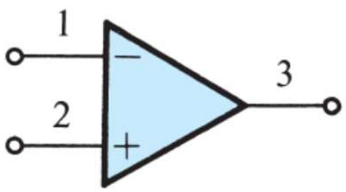
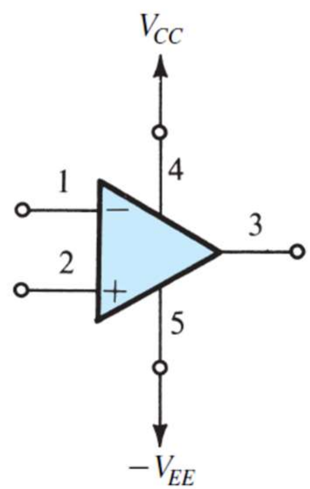
BASIC ELECTRONIC CIRCUITS

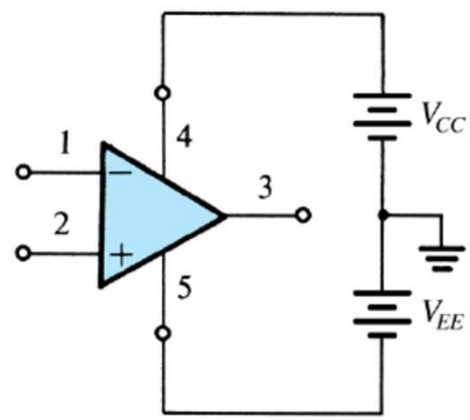
Amplifiers, and Op-Amps

The Ideal Op-Amp: terminals

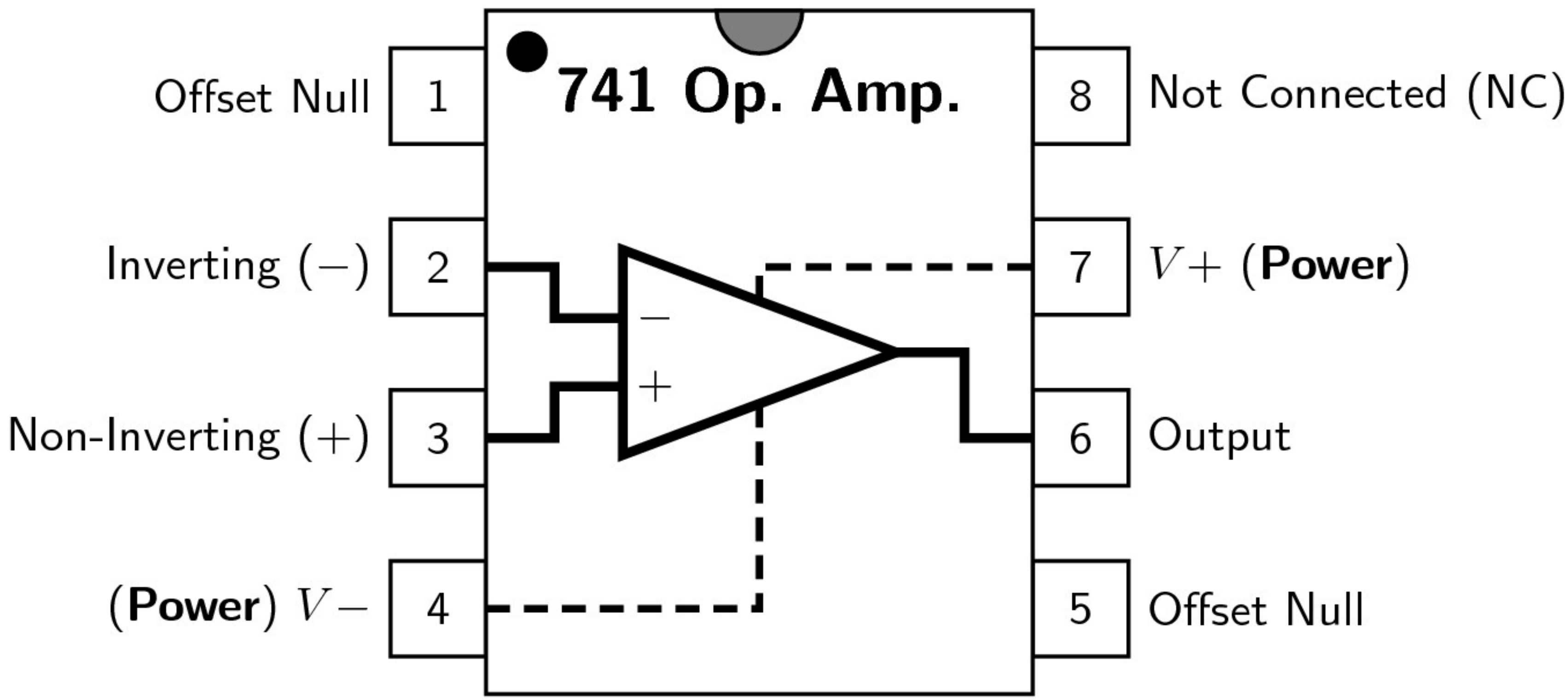
- 3 terminals: Two input and one output.
- No terminal of the op-amp package is physically connected to ground.





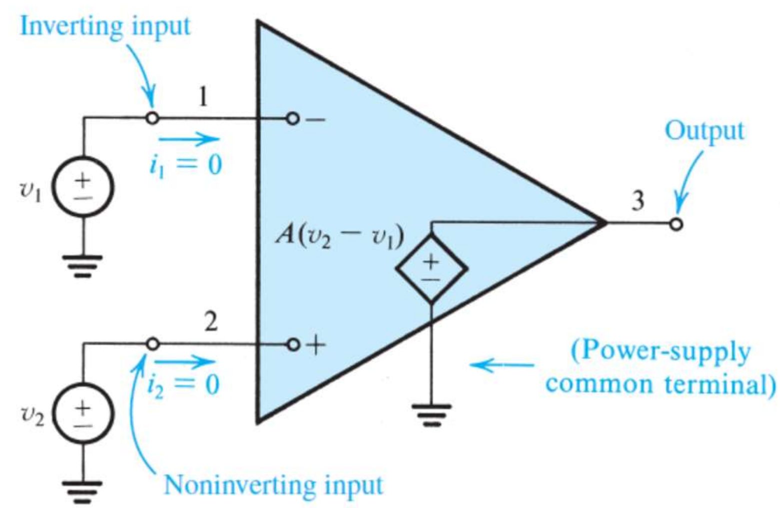


Pin configuration



Function and characteristics

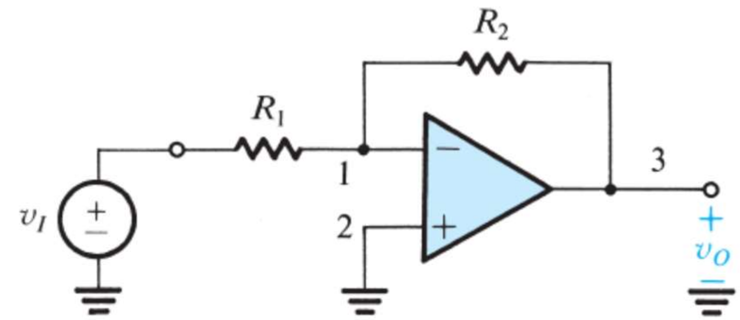
- Basic function is to sense the difference between the voltage signals applied at its input terminals.
  - Infinite input impedance
  - Zero output impedance
  - Zero common mode gain
  - Infinite open-loop gain A
  - Infinite bandwidth



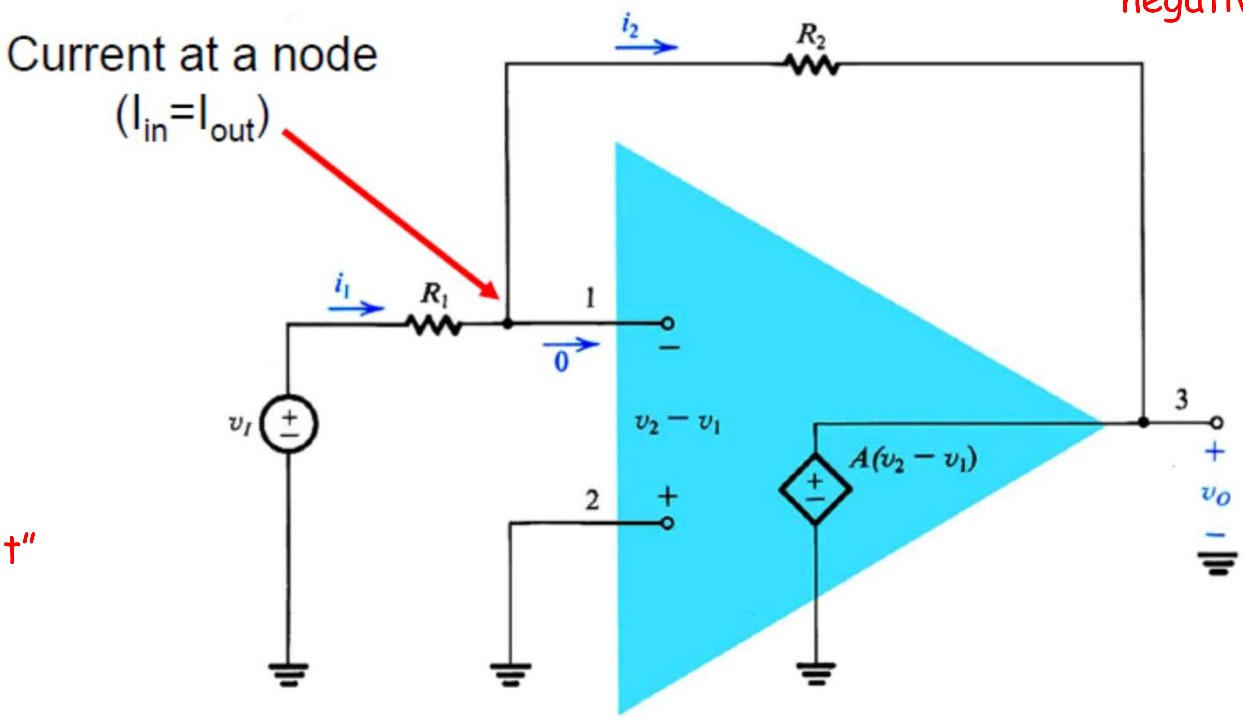
Equivalent Circuit (VCVS) model of the ideal OP-AMP

Differential input, single-ended output amplifier

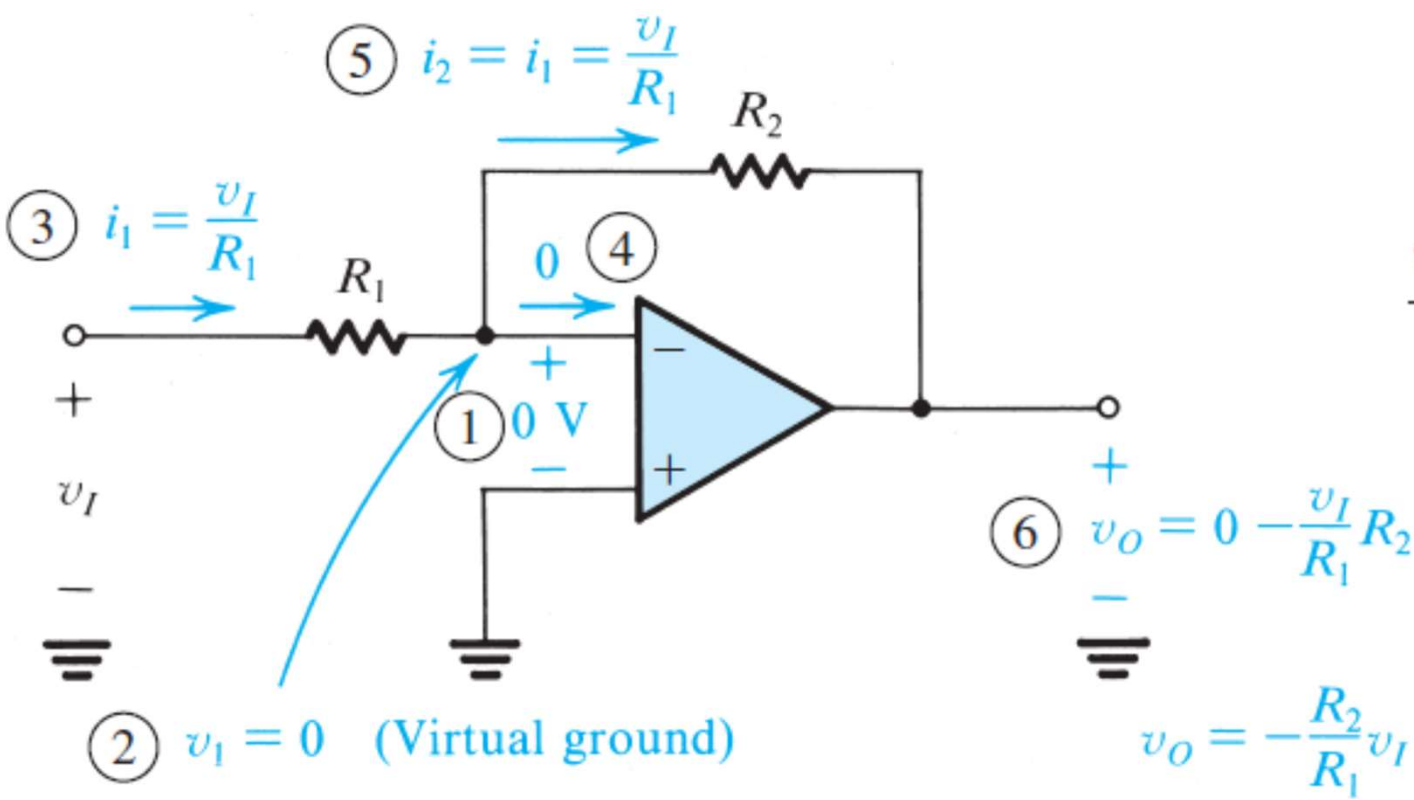
Inverting Configuration



"negative feedback"



"Virtual short Circuit"



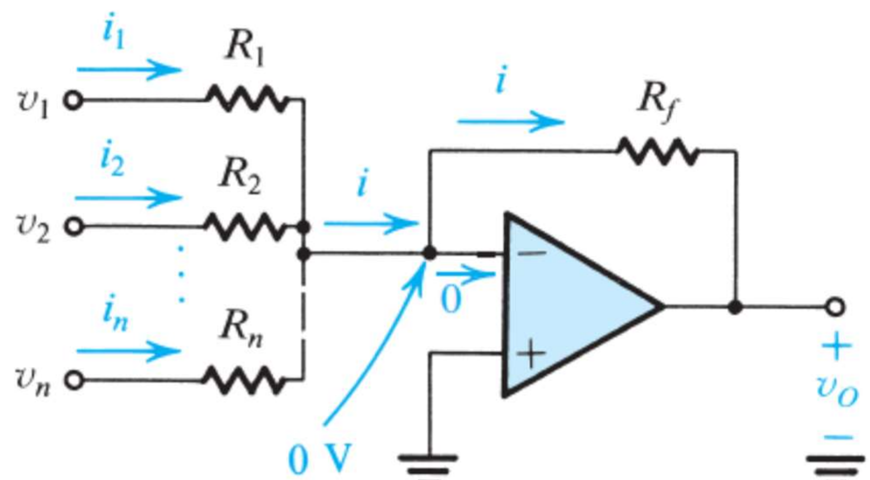
$$\frac{v_O}{v_I} = -\frac{R_2}{R_1}$$

Closed loop gain is independent of open-loop gain, entirely depends on the passive elements.

Application: The weighted Summer

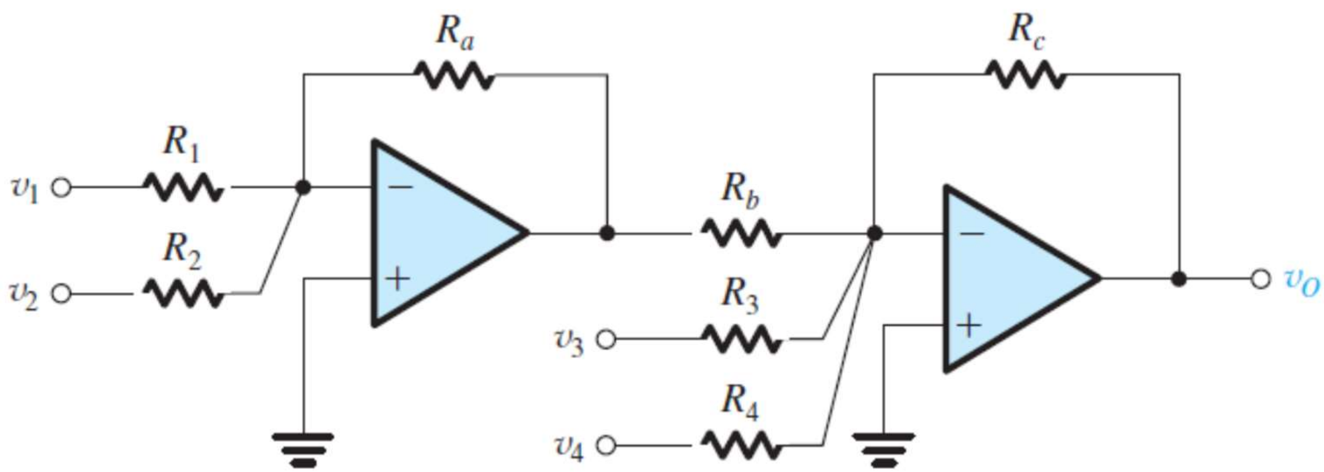
$$i = i_1 + i_2 + \cdots + i_n$$

$$v_O = 0 - iR_f = -iR_f$$



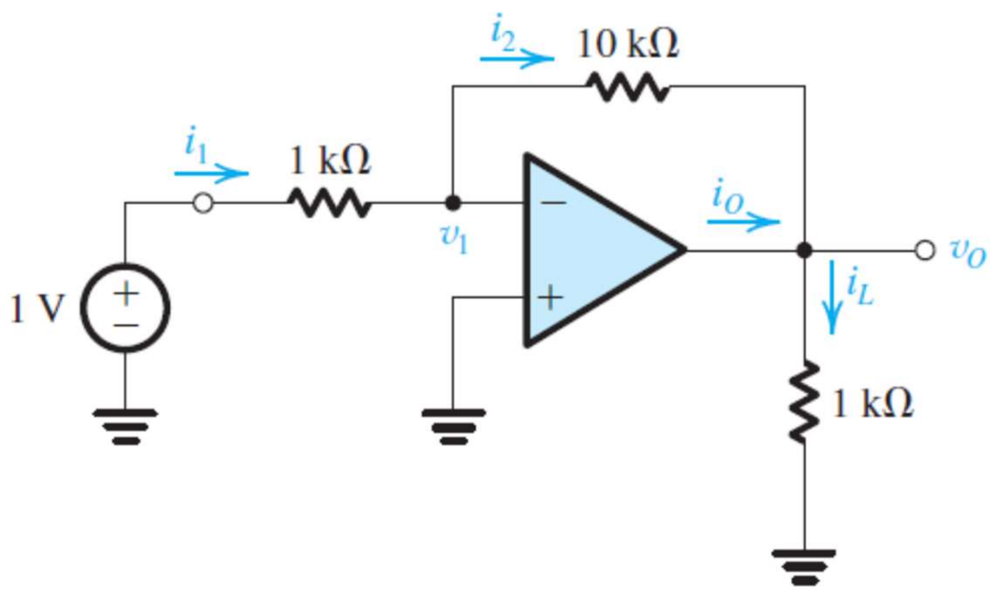
$$v_O = -\left(\frac{R_f}{R_1}v_1 + \frac{R_f}{R_2}v_2 + \cdots + \frac{R_f}{R_n}v_n\right)$$

Summing signals with opposite sign

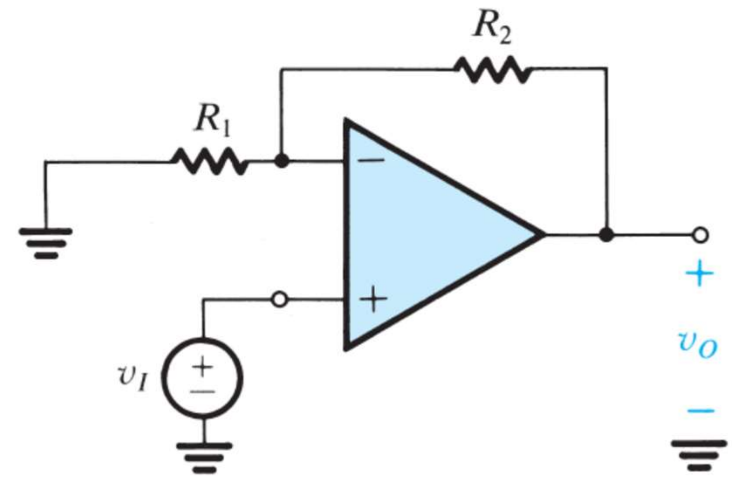


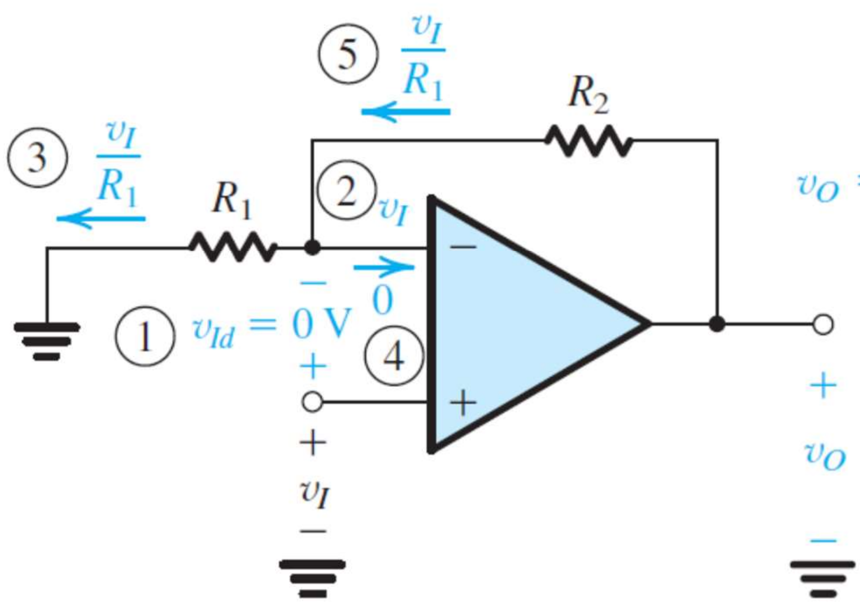
$$v_O = v_1\left(\frac{R_a}{R_1}\right)\left(\frac{R_c}{R_b}\right) + v_2\left(\frac{R_a}{R_2}\right)\left(\frac{R_c}{R_b}\right) - v_3\left(\frac{R_c}{R_3}\right) - v_4\left(\frac{R_c}{R_4}\right)$$

Determine the values of v_1, i_1, i_2, v_o, i_L, and i_o. Also determine the values of V_o/V_I, I_L/i_1 and power gain Po/Pi



Noninverting Configuration

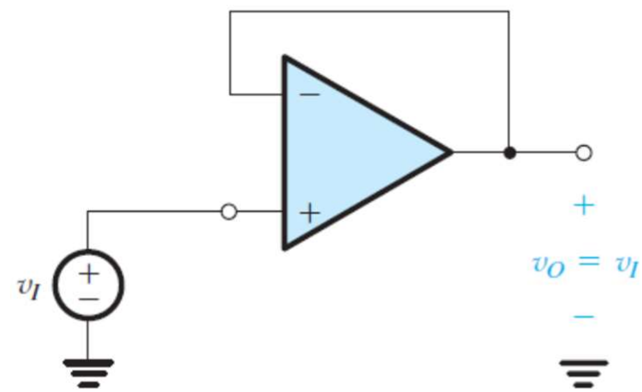


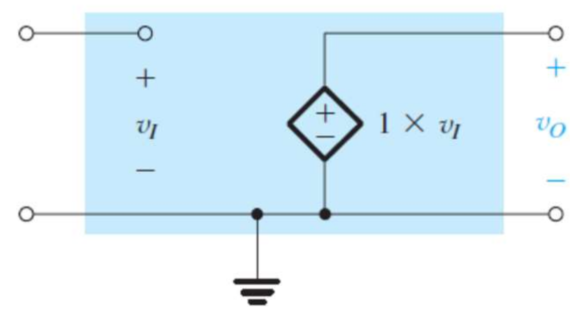


$$v_O = v_I + \frac{v_I}{R_1}R_2 = v_I\left(1 + \frac{R_2}{R_1}\right) \quad (6)$$

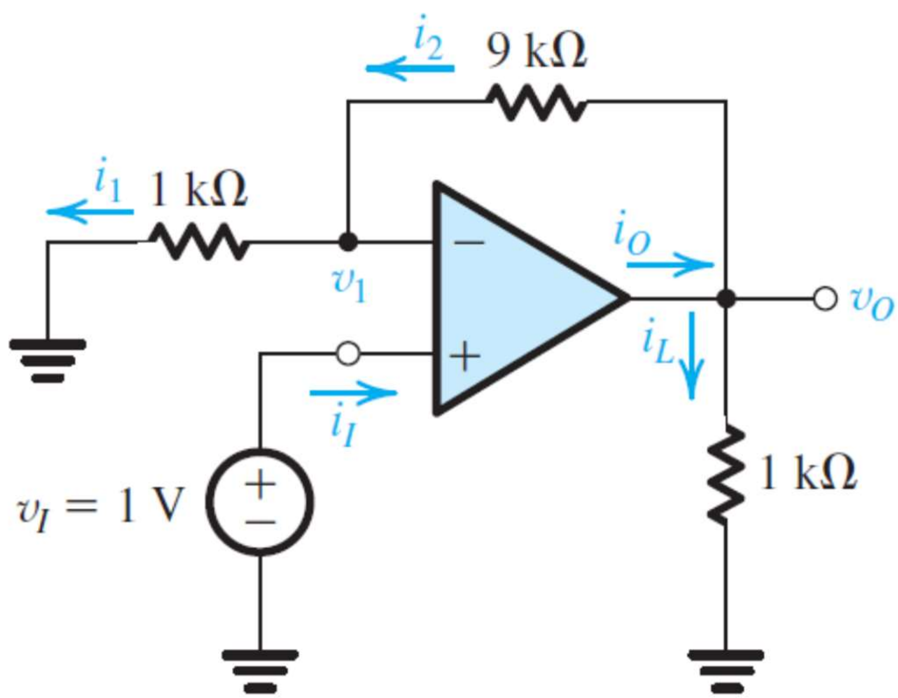
Application: Voltage follower

- High input impedance is a desirable feature of non inverting configuration.
- Unity-gain amplifier or Voltage follower.
- Used as an impedance transformer.



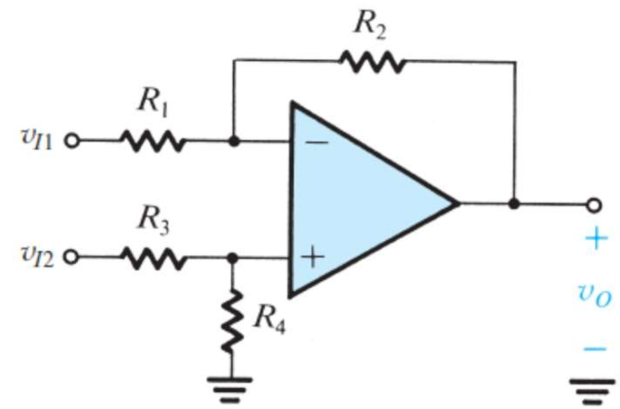


Determine the values of i_I, v_1, i_1, i_2, v_o, i_L, and i_o. Also determine the values of V_o/V_I, I_L/i_I and power gain P_L/P_I



Difference Amplifier

- Combination of inverting and noninverting configurations.



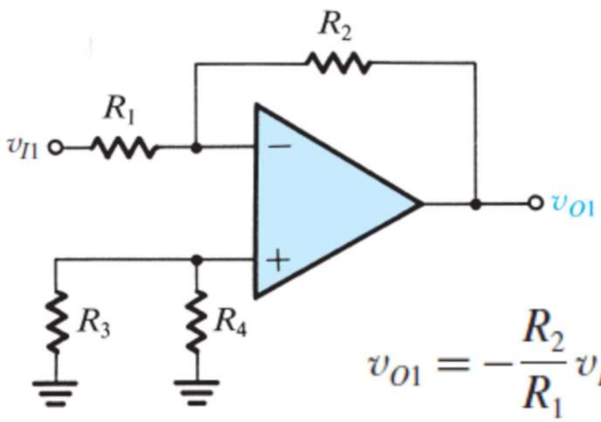
- Common mode signals need to be rejected, hence the magnitude of the inverting and noninverting must be same.

- Hence attenuate the gain of the +ve path from $(1+R_2/R_1)$ to R_2/R_1.

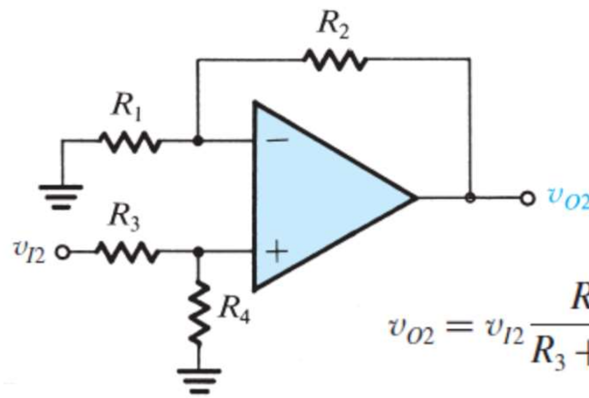
$$\frac{R_4}{R_4+R_3}\left(1+\frac{R_2}{R_1}\right)=\frac{R_2}{R_1}$$

$$\frac{R_4}{R_3}=\frac{R_2}{R_1}$$

- By Superposition:



$$v_{O1} = -\frac{R_2}{R_1} v_{I1}$$



$$\frac{R_4}{R_3} = \frac{R_2}{R_1}$$

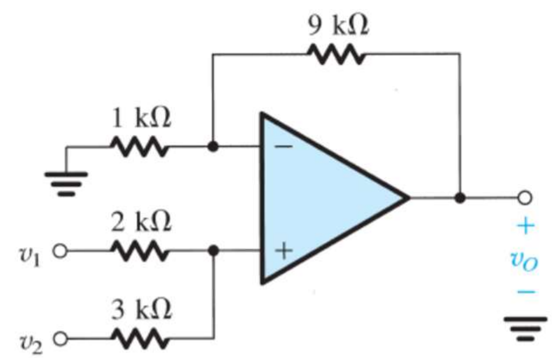
$$v_{O2} = v_{I2} \frac{R_4}{R_3 + R_4}\left(1 + \frac{R_2}{R_1}\right) = \frac{R_2}{R_1} v_{I2}$$

$$v_O = \frac{R_2}{R_1}(v_{I2} - v_{I1}) = \frac{R_2}{R_1} v_{Id}$$

$$A_d = \frac{R_2}{R_1}$$

$R_3 = R_1$ and $R_4 = R_2$

- Use superposition to determine Vo



$$v_O = 6v_1 + 4v_2$$

- If the 1K resistor is disconnected from the ground and connected to V3 , determine Vo.

$$v_O = 6v_1 + 4v_2 - 9v_3$$

- Design a non inverting amplifier with a gain of 2. At the maximum output voltage of 10 V the current in the voltage divider is to be 10 μ A.

$$v_0 = 10\ V$$

$$\frac{v_0 - v_1}{R_2} = 10\ \mu\text{A}$$

$$G = 2 = 1 + R_2/R_1$$

$$\frac{v_1}{R_1} = 10\ \mu\text{A}$$

$$R_1 = 0.5\ M\Omega$$

$$R_1 = R_2$$

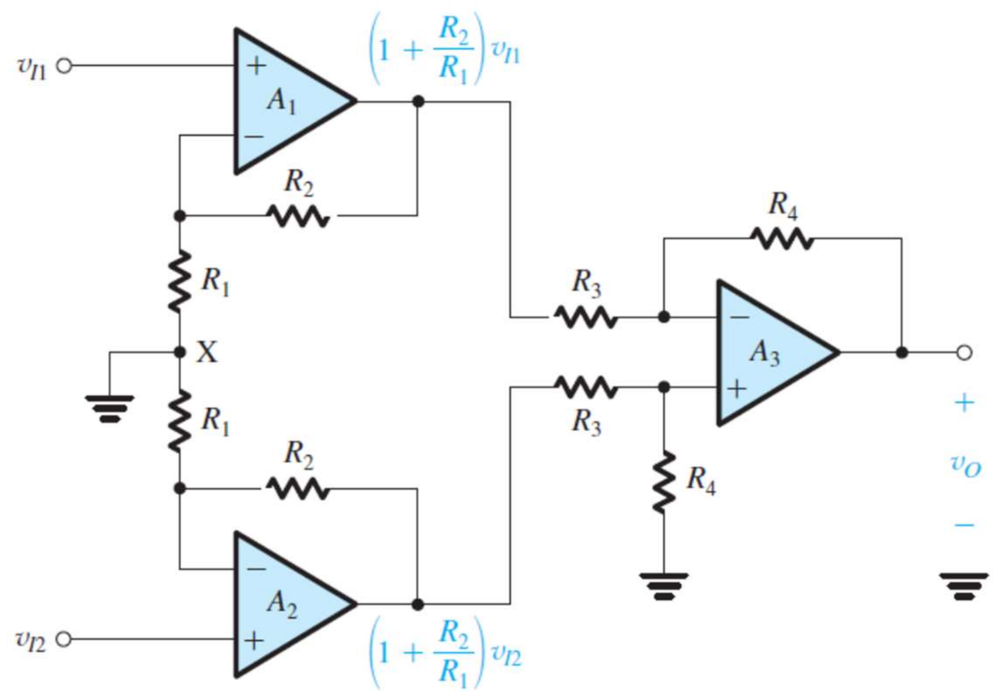
$$v_o = 2v_1$$

$$v_1 = 5\ V$$

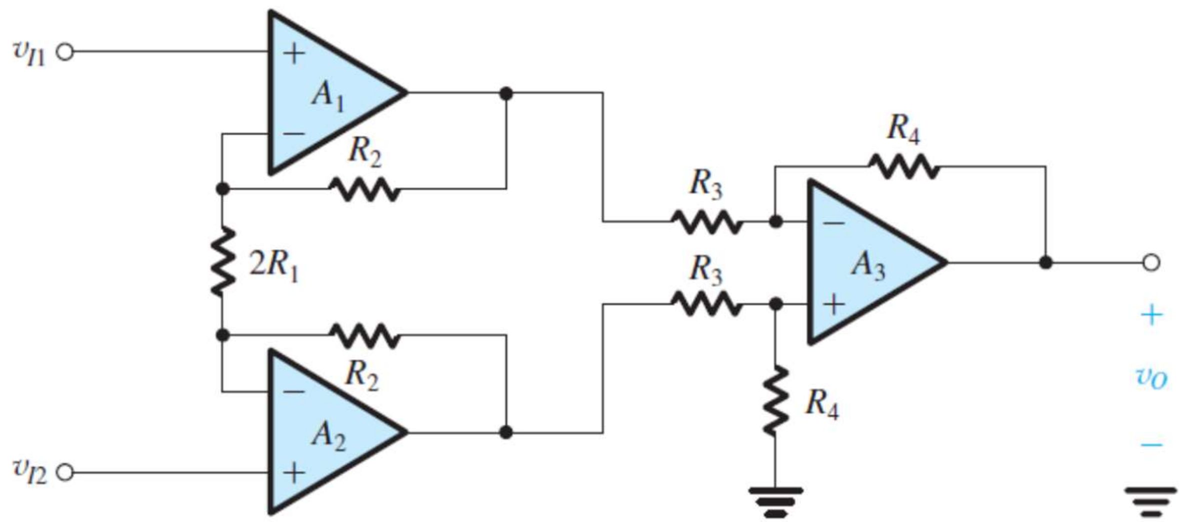
Instrumentation Amplifier

- To address the low input resistance of the difference amplifier.

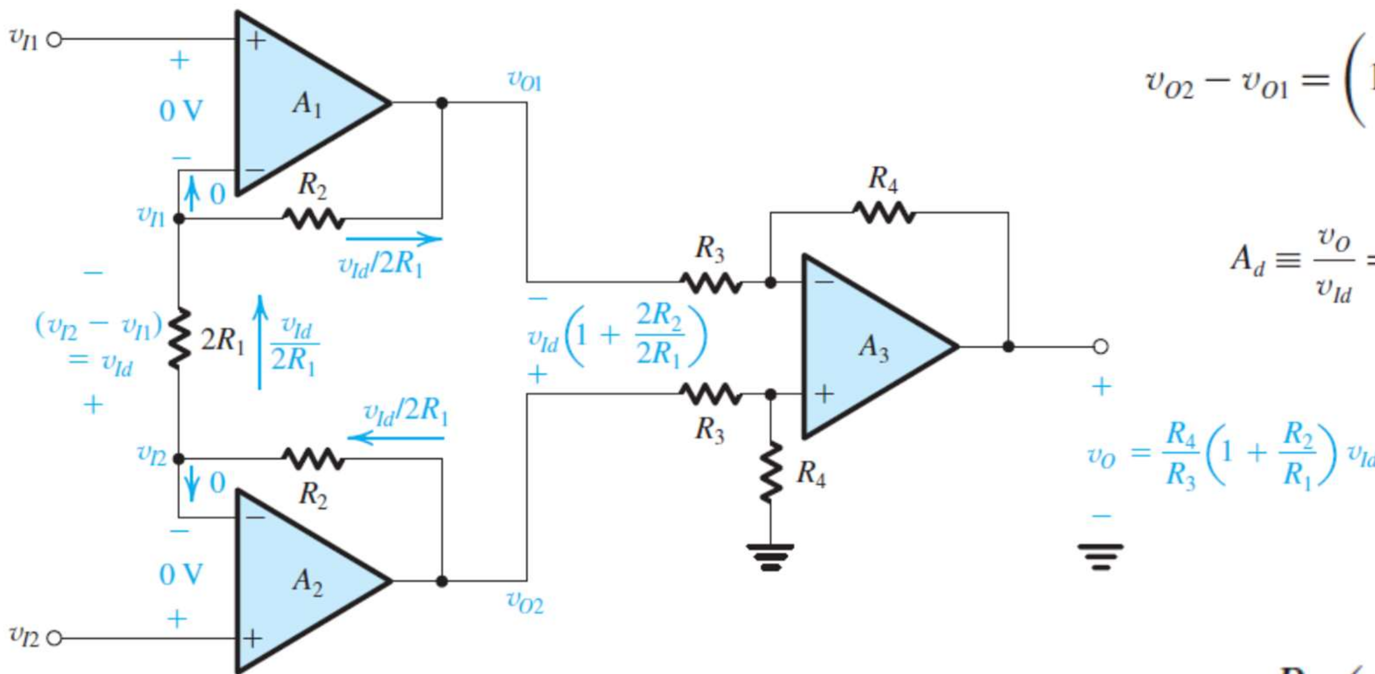
$$v_O = \frac{R_4}{R_3}\left(1 + \frac{R_2}{R_1}\right)v_{Id}$$



Instrumentation Amplifier



Instrumentation Amplifier



$$v_{O2} - v_{O1} = \left(1 + \frac{2R_2}{2R_1}\right) v_{Id}$$

$$A_d \equiv \frac{v_O}{v_{Id}} = \frac{R_4}{R_3}\left(1 + \frac{R_2}{R_1}\right)$$

$$A_d = \frac{R_4}{R_3}\left(1 + \frac{R_2 + R_2'}{2R_1}\right)$$