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LINEAR INTEGRATED CIRCUITS

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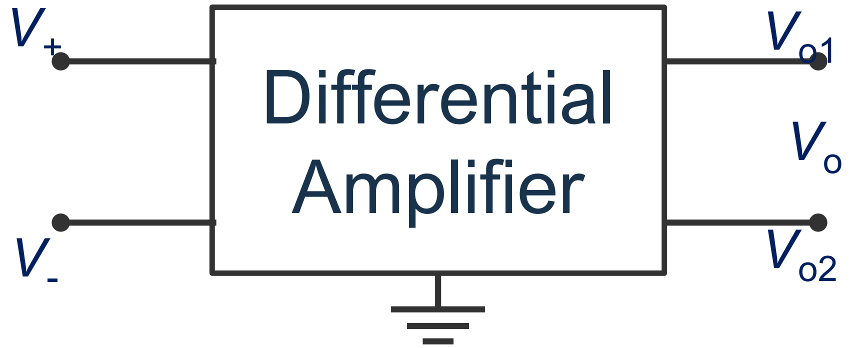
Part-02: Mathematical Analysis of OpAmp based Differential Amplifier

Differential Amplifier

A Differential Amplifier is a type of electronic amplifier that amplifies the difference between two input voltages. It also suppresses any common voltage (e.g. noise) present at both Inverting & Non-inverting input terminals.

Mathematically,

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



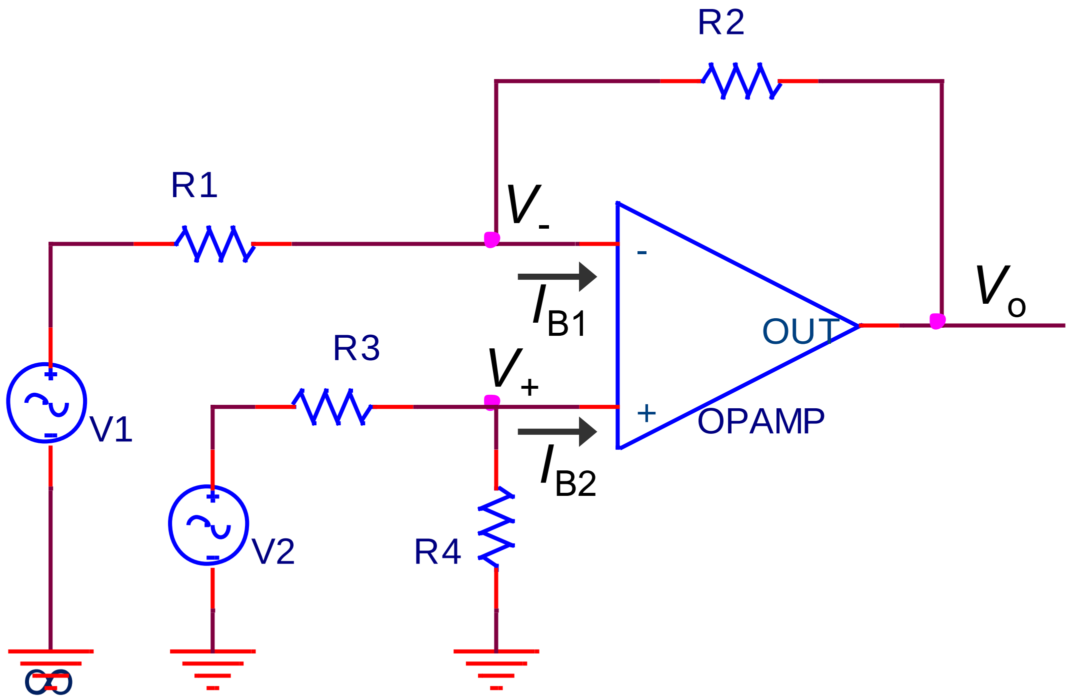
Important Features an OpAmp

- It has Infinite Differential Voltage Gain A_d

$$A_d = \frac{V_o}{V_+ - V_-} = \infty$$

$$V_+ - V_- = \frac{V_o}{A_d} \cong 0$$

$$V_+ = V_- \text{ (Virtually Short)}$$



- OpAmp has infinite Input Impedance $R_i = \infty$

$$I_{B1} = I_{B2} \cong 0$$

Output Voltage due to V_1 only

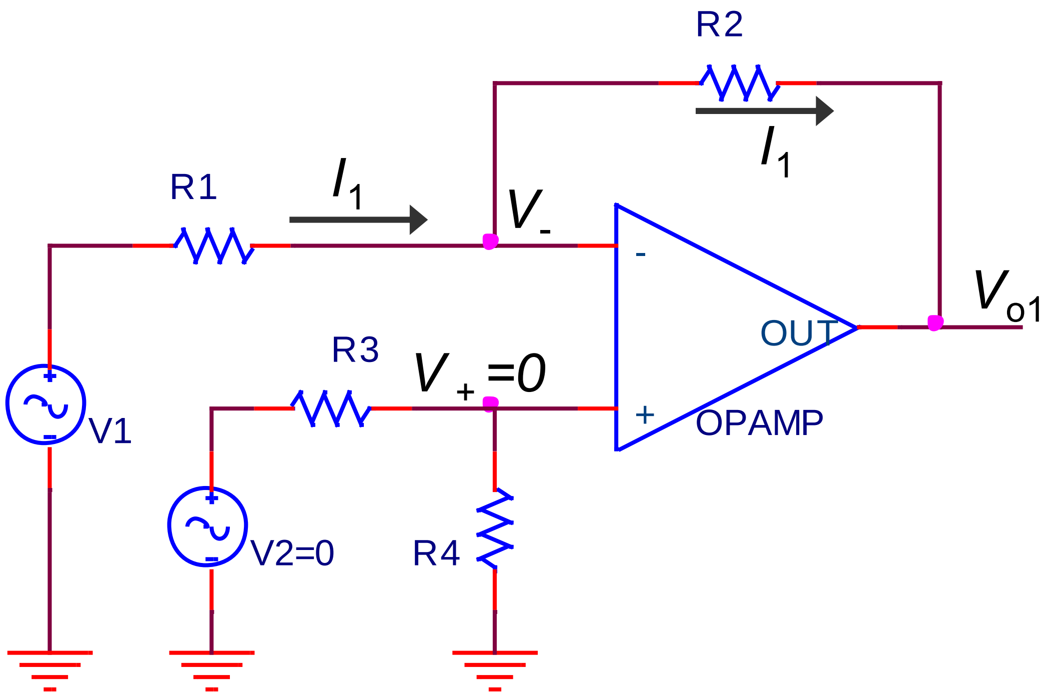
Superposition Theorem to determine V_o

Part 1: V_{o1} is output due to only input V_1

$$V_+ \cong V_- = 0$$

$$I_1 = \frac{V_1}{R_1}$$

$$V_{o1} = -R_2 I_1 = -\frac{R_2 V_1}{R_1}$$



Output Voltage due to V_2 only

Part2: Output is V_{o2} due to only input V_2

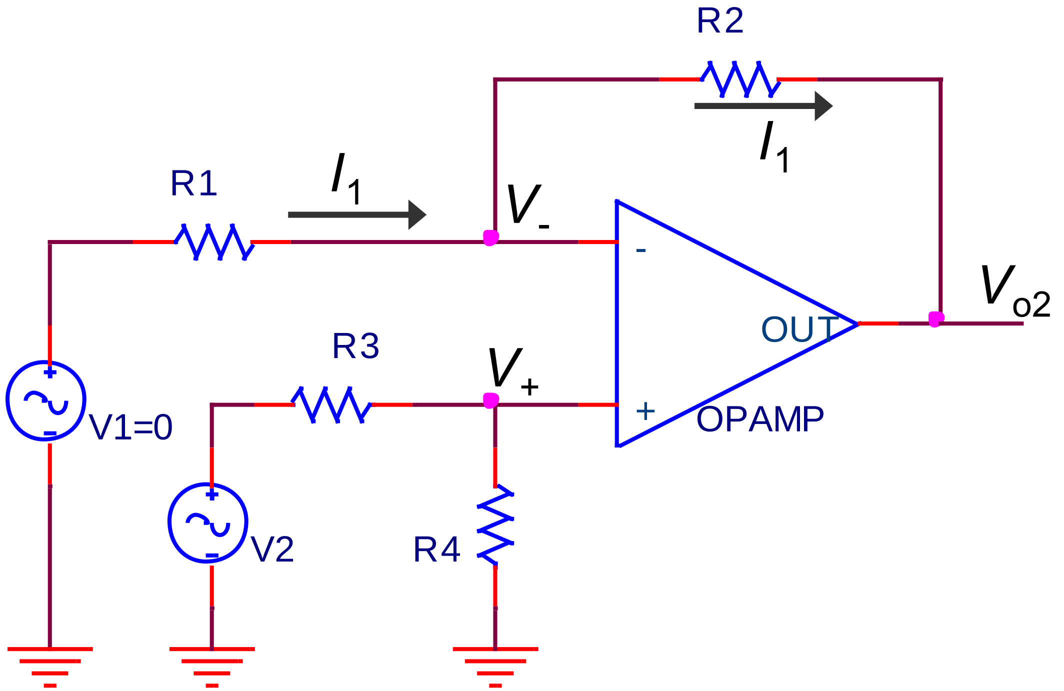
$$V_{o2} = -I_1(R_1 + R_2) \qquad (1)$$

$$V_- \cong V_+ = \frac{R_4}{R_3 + R_4} V_2$$

$$I_1 = \frac{0 - V_-}{R_1} = \frac{-R_4}{R_3 + R_4} V_2 \qquad (2)$$

From (1) and (2)

$$V_{o2} = \frac{-(R_1 + R_2)}{R_1} \frac{-R_4}{R_3 + R_4} V_2$$



Total Output Voltage due to V_{o1} and V_{o2}

From Superposition theorem Output Voltage

$$V_o = V_{o1} + V_{o2}$$

$$V_o = -\frac{R_2}{R_1}V_1 + \frac{R_1 + R_2}{R_1}\frac{R_4}{R_3 + R_4}V_2$$

Assume, $R_1 = R_3$ and $R_2 = R_4$

$$V_o = \frac{R_1 + R_2}{R_1}\frac{R_2}{R_1 + R_2}V_2 - \frac{R_2}{R_1}V_1$$

$$V_o = \frac{R_2}{R_1}(V_2 - V_1)$$