Benha University
Faculty of Engineering at Shoubra

ELC301
Electronic Engineering

Lecture #6
Operational Amplifiers

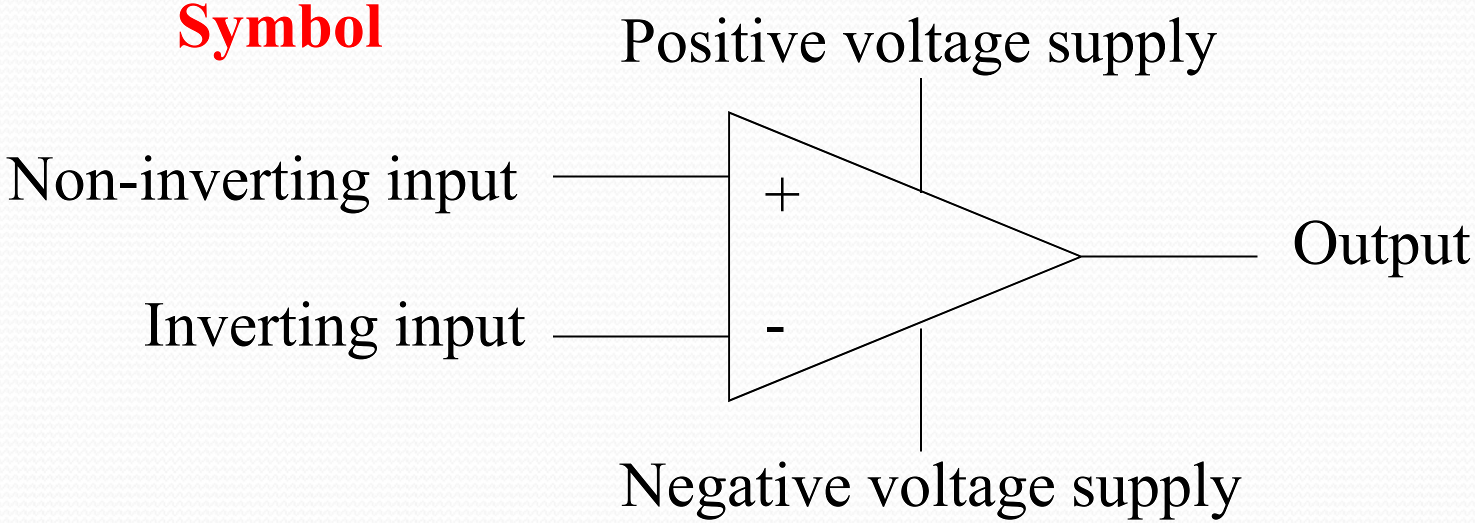
Instructor:
Dr. Moataz Elsherbini

Operational Amplifiers
&
Applications

- Basic Concepts
- The Inverting Amplifier
- Inverting Summer
- Non-inverting Amplifier
- Voltage Follower
- Subtracting Amplifier, Comparator
- integrator, Differentiator, phase shift oscillator

Op Amp

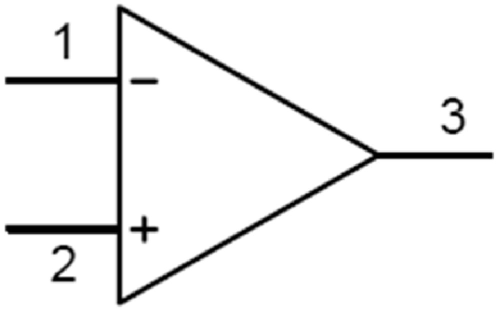
Symbol



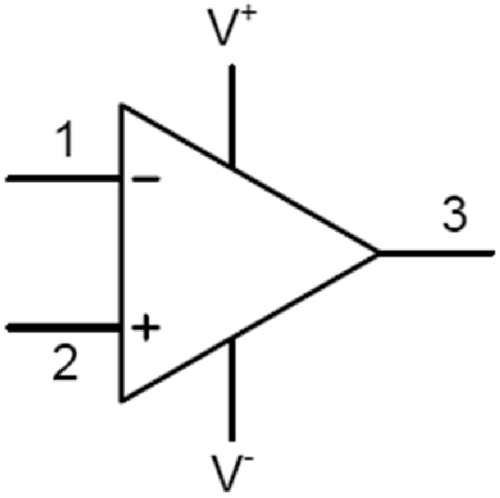
- At a minimum, op amps have 3 terminals: 2 input and 1 output.
- An op amp also requires dc power to operate. Often, the op amp requires both positive and negative voltage supplies (V+ and V-).

Op Amp

Symbol



op amp symbol
(we will use most often)



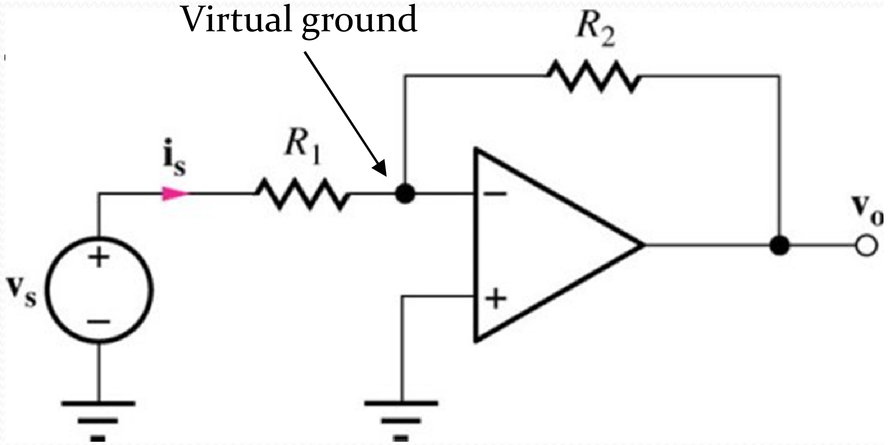
op amp symbol
with power supply connections

- One of the input terminals (1) is called an inverting input terminal denoted by '-'
- The other input terminal (2) is called a non-inverting input terminal denoted by '+'

Op Amp Applications

1-The Inverting Amplifier

- Feedback reduces the gain of op-amp
- The positive input is grounded.



$$V^+ = 0$$

$$V^+ = V^-$$

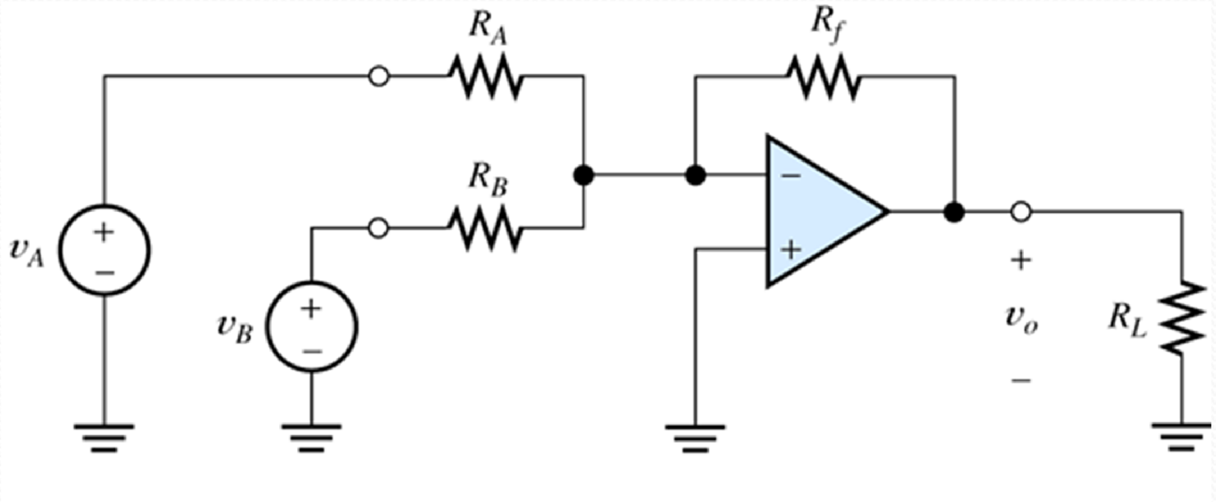
$$i_s = i_2$$

$$\frac{V_s - V^-}{R_1} = \frac{V^- - V_o}{R_2}$$

$$\frac{V_s}{R_1} = \frac{-V_o}{R_2}$$

$$\frac{V_o}{V_s} = \frac{-R_2}{R_1}$$

2-Inverting Summer



$$V_o = -(\frac{R_f}{R_A} V_A + \frac{R_f}{R_B} V_B)$$

3-Non-inverting Amplifier

$V^- = v_i$

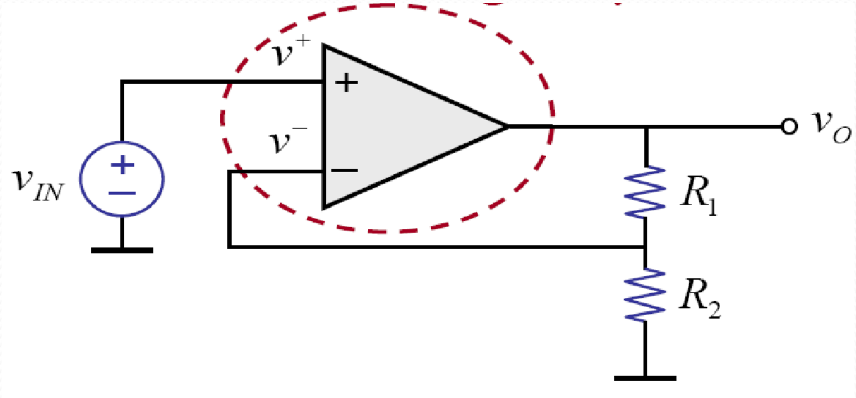
$V^+ = V^- = v_i$

$i_1 = i_2$

$$\frac{0 - V^+}{R_1} = \frac{V^+ - V_o}{R_2}$$

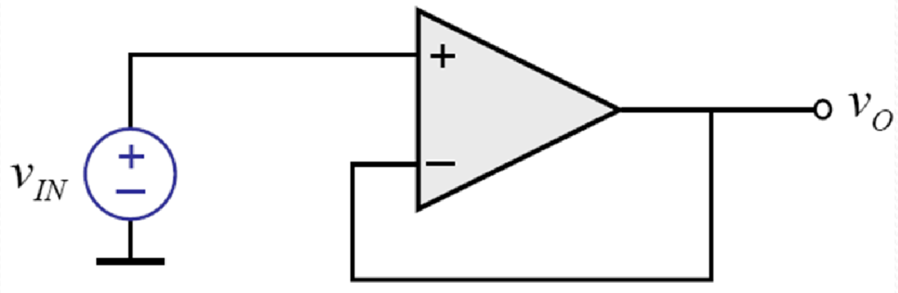
$$v_i(\frac{1}{R_1} + \frac{1}{R_2}) = \frac{V_o}{R_2}$$

$$\frac{V_o}{v_i} = R_2(\frac{1}{R_1} + \frac{1}{R_2})$$



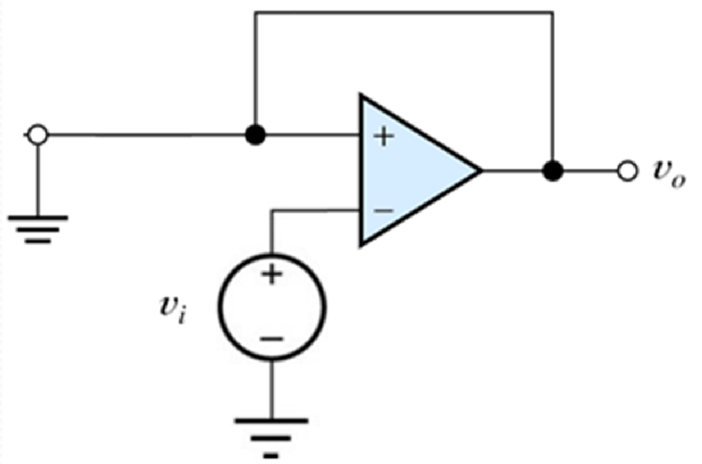
$$\frac{V_o}{v_i} = (1 + \frac{R_2}{R_1})$$

4- Unity Follower (Voltage Follower)



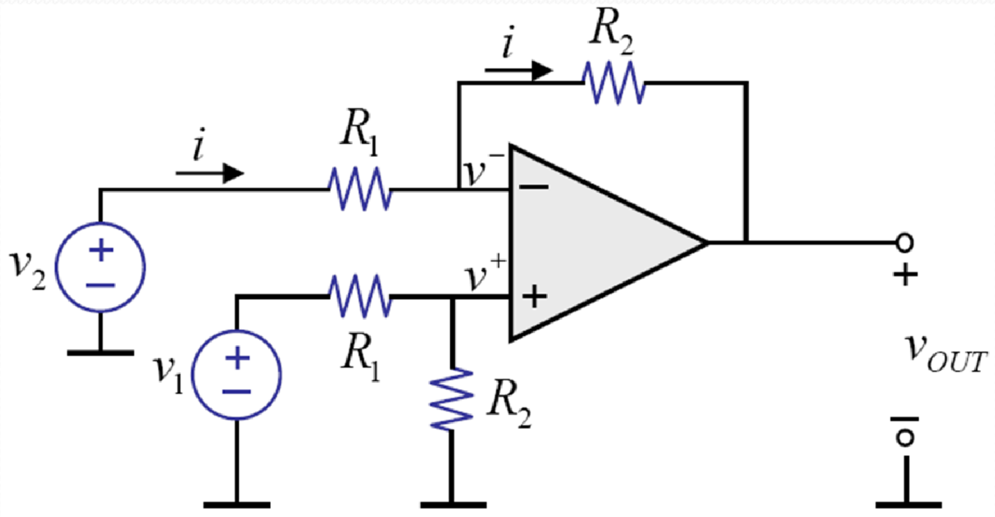
$$V^+ = v_i$$
$$V^+ = V^- = v_i$$
$$V^- = v_o$$
$$v_o = v_i$$

voltage gain = 1



$$V^- = v_i$$
$$V^+ = V^- = v_i$$
$$V^+ = v_o$$
$$v_o = v_i$$

5- Differential (Subtracting) Amplifier



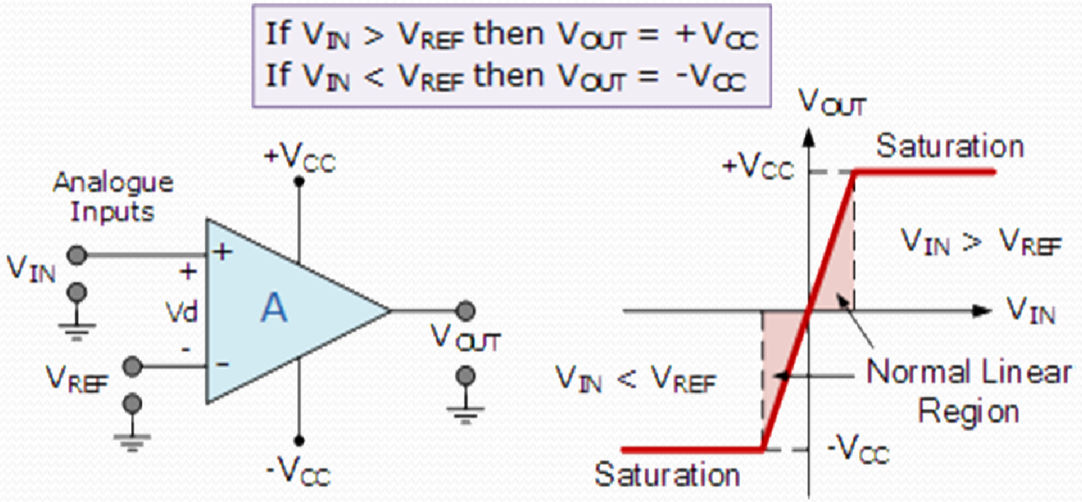
$$v_{out} = \frac{R_2}{R_1}(v_1 - v_2)$$

If $R_2 = R_1$

$$v_{out} = (v_1 - v_2)$$

6- Comparator

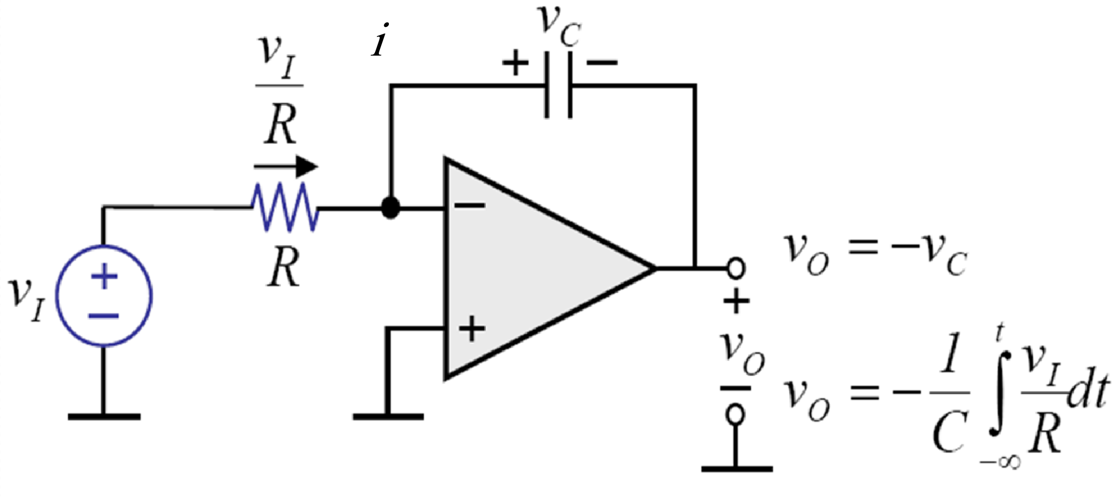
- Without feedback connection



- *if*

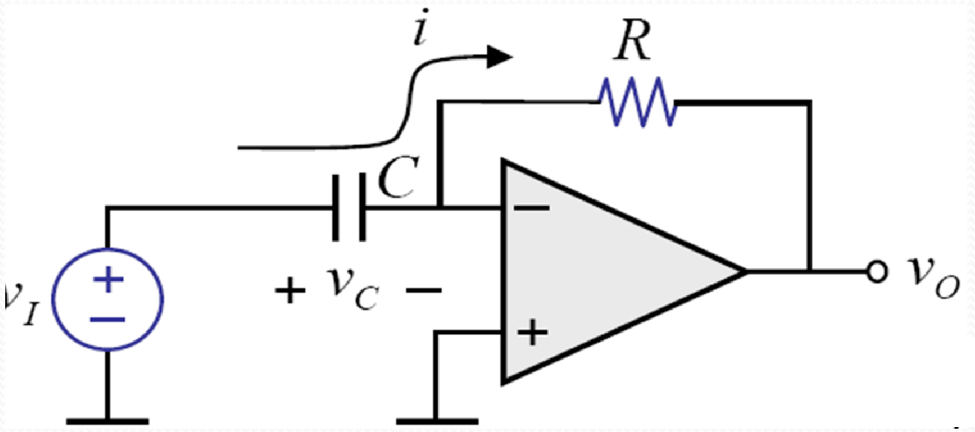
$$V_{IN} > V_{REF} \quad \text{Then } V_o = +V_{cc}$$
$$V_{IN} < V_{REF} \quad \text{Then } V_o = -V_{cc}$$

7- Integrator Amplifier



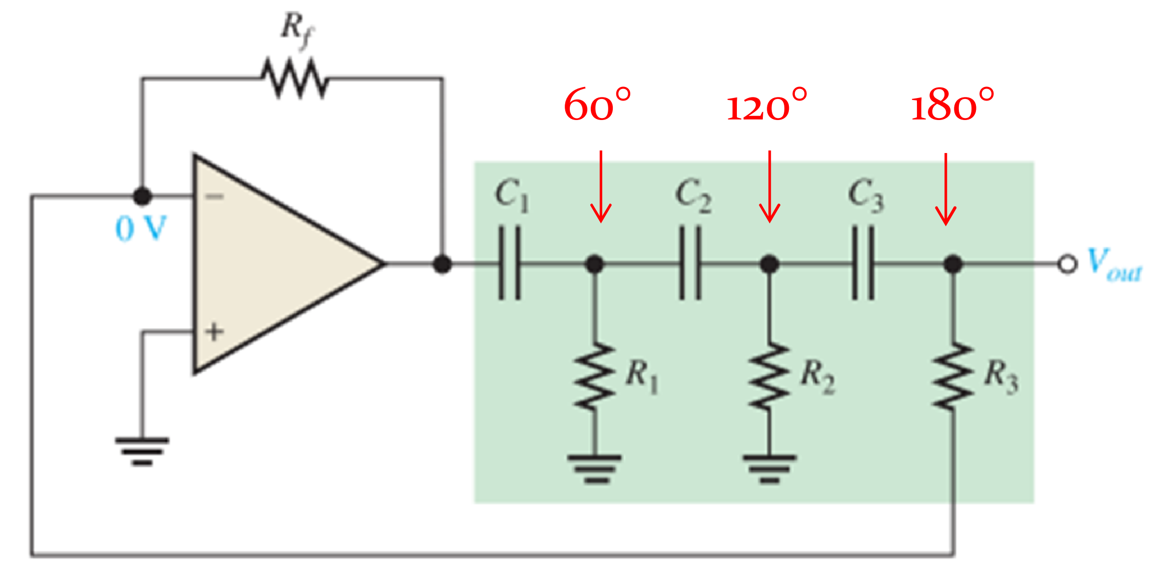
$$V_o = -\frac{1}{RC}\int v_I \, dt$$

8- Differentiator Amplifier



$$V_o = -RC\frac{d}{dt}v_I$$

9- The Phase-Shift Oscillator



$$B = \frac{1}{29}$$ where $B = R_3/R_f$.

$R_1 = R_2 = R_3 = R$ and $C_1 = C_2 = C_3 = C$.

$$f_r = \frac{1}{2\pi\sqrt{6}RC}$$