Operational Amplifier(OPAMP)

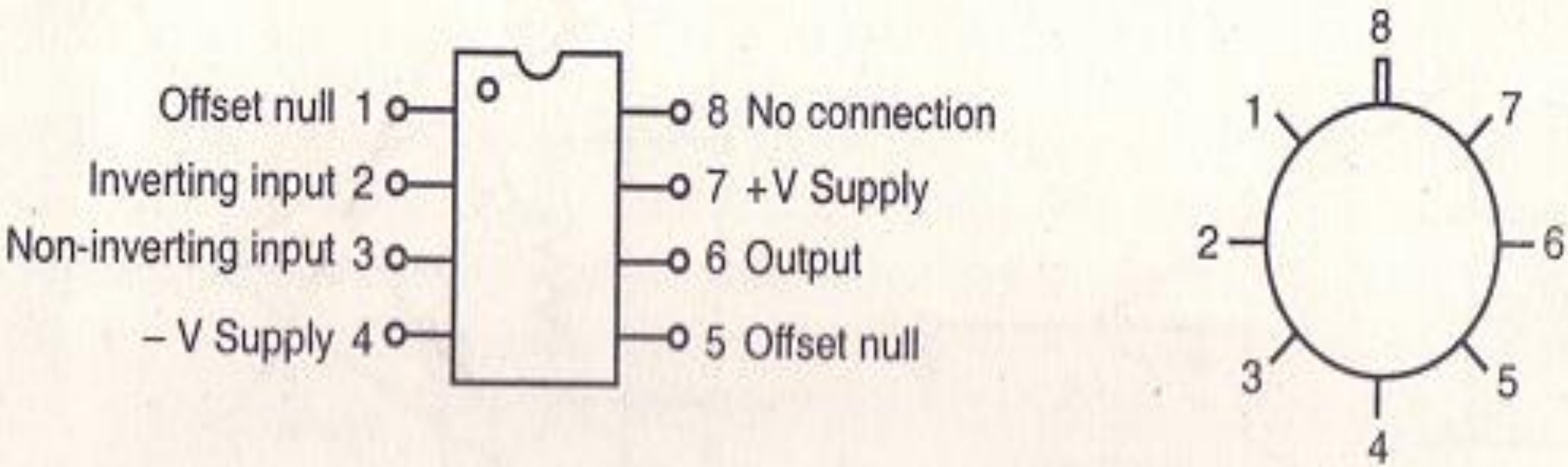
Operational amplifier is a direct-coupled amplifier used to perform wide variety of linear and some nonlinear operations which is usable in the frequency range from 0 to few MHz.

(TOAL No of Slides is 14)

Some features of OPAMP

- OPAMP was designed to perform mathematical operations such as summation, subtraction, multiplication, differentiation, integration etc. in analog computer.
- OPAMP can also be used for the purpose of solution of simultaneous linear algebraic equation as well as differential equation.
- Now a days OPAMPs are available almost all in IC forms having comparatively low price.
- Many useful circuits can be designed using OPAMP and so this has become very popular in electronic industry.

Pin Diagram & Circuit symbol of OPAMP



(a)

(b)

Fig. 1: Pin diagram of an OP AMP
(a) in DIP package
(b) metal case package

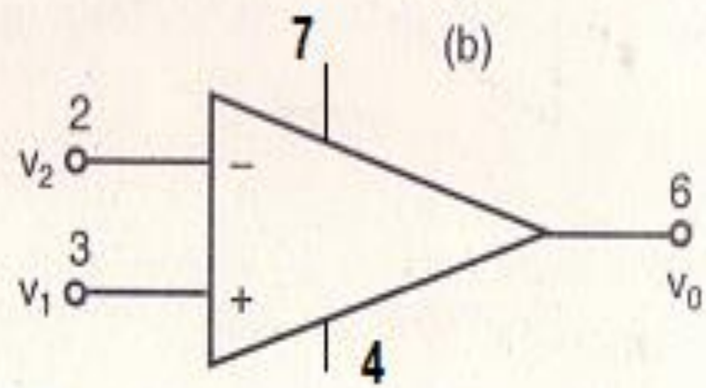


Fig. 2: Circuit symbol of OP AMP

Characteristics of ideal OPAMP

- Open loop voltage gain is infinite
- Input impedance is infinite
- Output impedance is zero
- Bandwidth is infinite
- Perfect balance i.e, ouput is zero when two input voltage are equal.
- Characteristics do not drift with temperature
- **Common mode rejection ratio** is infinite
- **Slew rate** is infinite

Deviations of practical amplifier from ideal one

In practical OPAMP

- Open Loop Voltage gain is not infinite
- Input impedance is not infinite
- CMRR is not infinite
- Output is not zero even if two input voltages are identical. The voltage which should be applied between the input terminals to balance the amplifier is called **input offset voltage**. where as the **input offset current** is the difference between the two bias currents entering into the input terminals of balanced amplifier and **input bias current** is the average of two separate currents entering the input terminals of a balanced amplifier.

Applications of OPAMP

OPAMP can be used both in inverting mode and non inverting mode. However OPAMP can be used for designing

i) Scale changer
ii) Phase Shifter
iii) Unity gain follower
iv) Adder
v) Subtractor
vi) Differential amplifier
vii) Integrator
viii) Differentiator

Inverting Amplifier

- Op-amp are almost always used with a negative feedback:
  - Part of the output signal is returned to the input with negative sign
  - Feedback reduces the gain of op-amp
  - Since op-amp has large gain even small input produces large output, thus for the limited output voltage (lest than V_{CC}) the input voltage v_x must be very small.
  - Practically we set v_x to zero when analyzing the op-amp circuits.

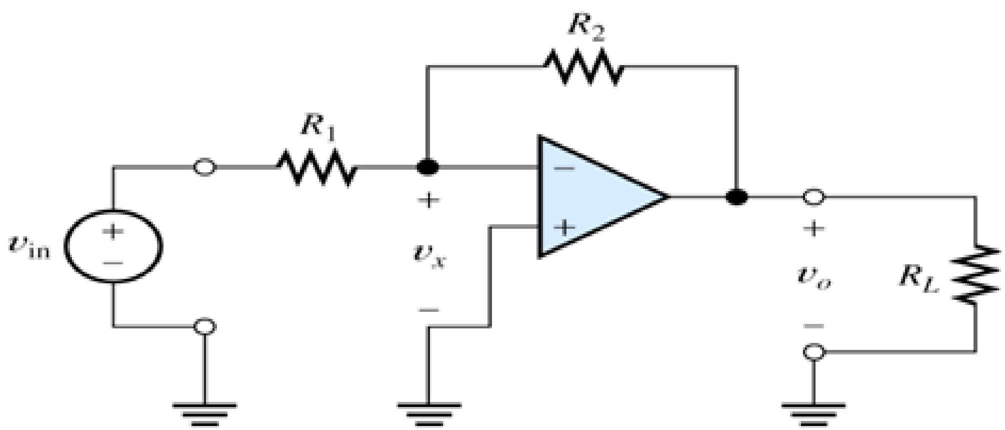


Fig.3: The inverting amplifier.

with $v_x = 0$ $\quad i_1 = v_{in} / R_1$

$i_2 = i_1$ and

$v_o = -i_2 R_2 = -v_{in} R_2 / R_1$

so

$A_v = v_o / v_{in} = -R_2 / R_1$ ……………(1)

Scale changer and Phase Shifter

- From (1) , $$v_0 = -\frac{R_2}{R_1} v_s = -k v_s$$

i.e the circuit multiplies the input by –k and so such circuit can be treated as scale changer.

If , R_1 and R_2 is replaced by impedances z_1 and z_2 and they are chosen in such a way that they have equal magnitude but different phase then

$$\frac{v_0}{v_s} = -\frac{Iz_2Ie^{j\varphi_2}}{Iz_2Ie^{j\varphi_1}} = e^{j(\pi+\varphi_2-\varphi_1)}$$

Where $\varphi_1$and $\varphi_2$are respectively the phase angles of z_1 and z_2.Thus the OPAMP can shift the phase of input voltage by the angle $\pi+\varphi_2-\varphi_1$

Non Inverting Amplifier

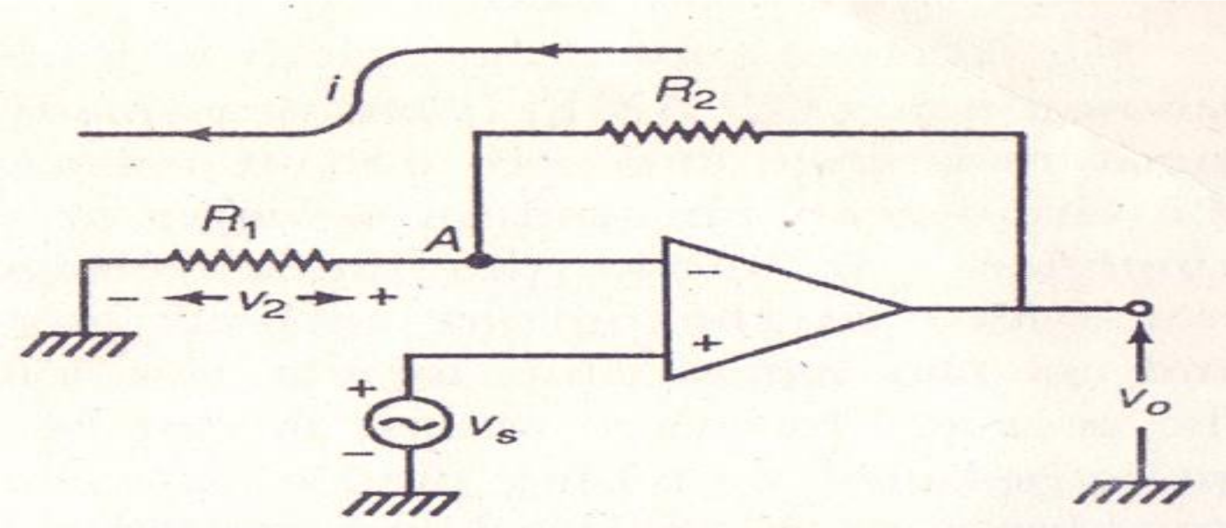


Fig.4 : Non-inverting OP AMP

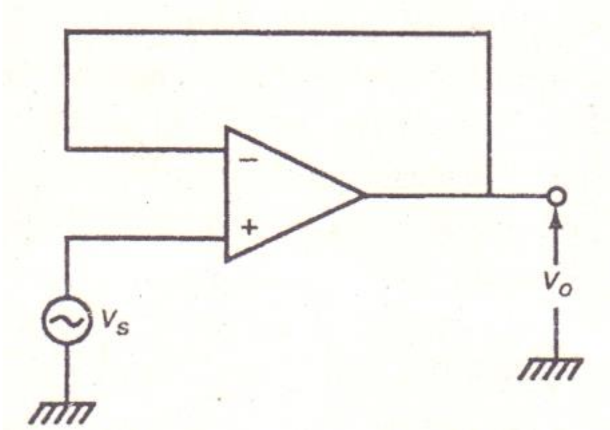
Here signal is applied in non-inverting terminal. Since gain $A \to \infty$

There is a virtual short at the input terminals and so,

$$\frac{v_0 - v_2}{R_2} = \frac{v_2 - 0}{R_1}$$

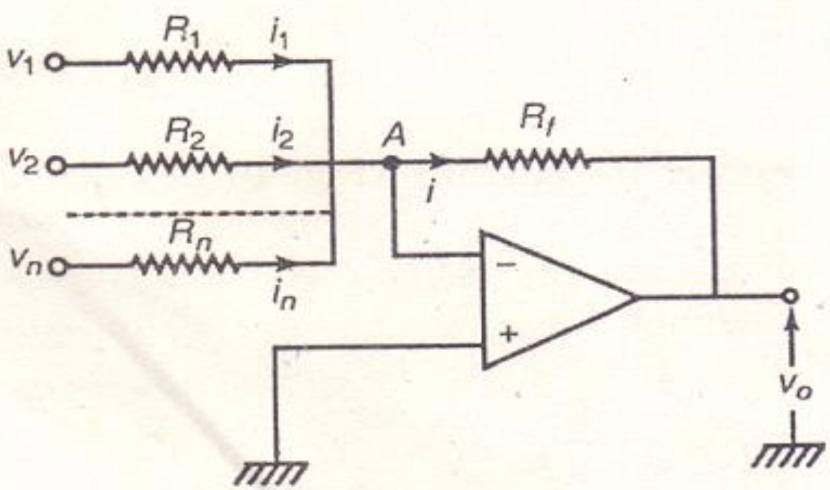
$$or, \frac{v_0}{v_s} = \frac{v_0}{v_2} = 1 + \frac{R_2}{R_1} \qquad \text{.........(1)}$$

Unity gain follower



From eq (2)it is found that the closed loop gain becomes unity if we choose $R_1 = \infty$ and/or .$R_2 = 0$. The amplifier then acts a voltage follower i.e, a non-inverting amplifier with unity gain.

OPAMP as Adder



Adder using OP AMP

Since the point A may by treated as virtual ground we can write

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

or
$$\frac{v_1}{R_1} + \frac{v_2}{R_2} + \cdots + \frac{v_n}{R_n} = -\frac{v_0}{R_f}$$

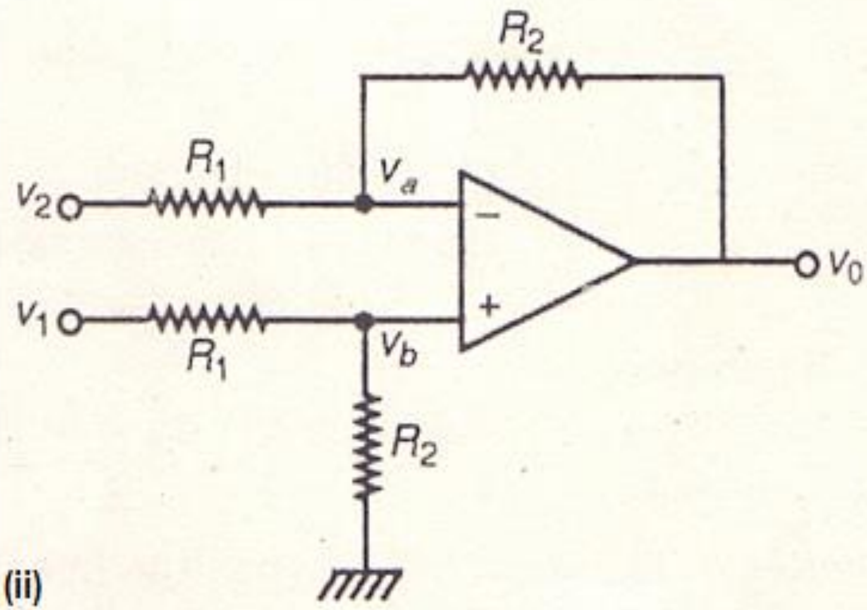
$$\therefore \quad v_0 = -\left(\frac{R_f}{R_1} v_1 + \frac{R_f}{R_2} v_2 + \cdots + \frac{R_f}{R_n} v_n\right)$$

If $R_1 = R_2 = \cdots = R_n$ then

$$v_0 = -\frac{R_f}{R_1}(v_1 + v_2 + \cdots + v_n)$$

Thus the output is proportional to the algebraic sum of the inputs.

OPAMP used for difference of two signals



Differential amplifier

In this circuit

$$\frac{v_2 - v_a}{R_1} = \frac{v_a - v_0}{R_2} \quad \text{.......(i)}$$

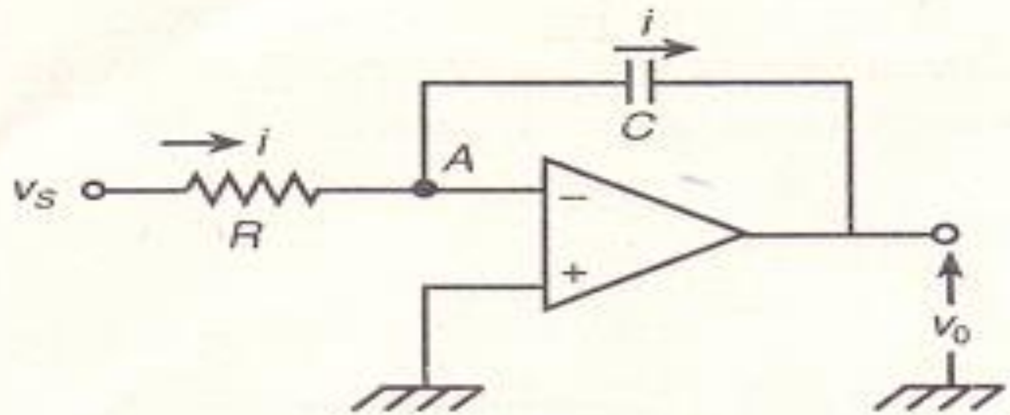
$$\frac{v_1 - v_b}{R_1} = \frac{v_b - 0}{R_2} \quad \text{.......(ii)}$$

Putting $v_a = v_b$ and subtracting Eq. **(i) from (ii)**

we get, $$v_0 = \frac{R_2}{R_1}(v_1 - v_2)$$

Thus the circuit amplifies the difference of two input signals.

OPAMP as Integrator



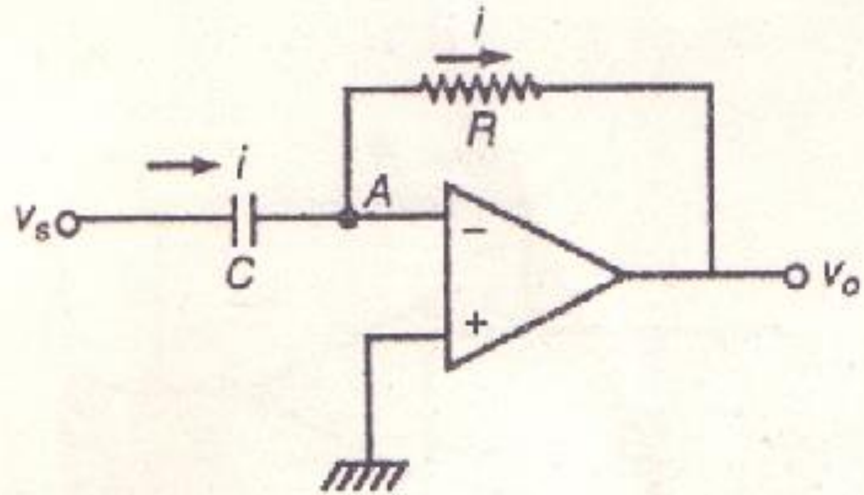
In this circuit $$i = \frac{v_s - 0}{R} = \frac{dq}{dt} = -\frac{d}{dt}(Cv_0)$$

where we take $q = C(0 - v_0)$ as the instantaneous charge on the capacitor.

Hence the output voltage $$v_o = -\frac{1}{CR}\int v_s dt + K$$

where the integration constant K depends on the inital condition i.e., the initial capacitor voltage.

OPAMP as differentiator



In this circuit $$i = \frac{dq}{dt} = \frac{d}{dt}(Cv_s) = \frac{0 - v_0}{R}$$

where we take $q = Cv_s$ as the instantaneous charge on the capacitor.

Therefore, $$v_o = -CR\frac{dv_s}{dt}$$