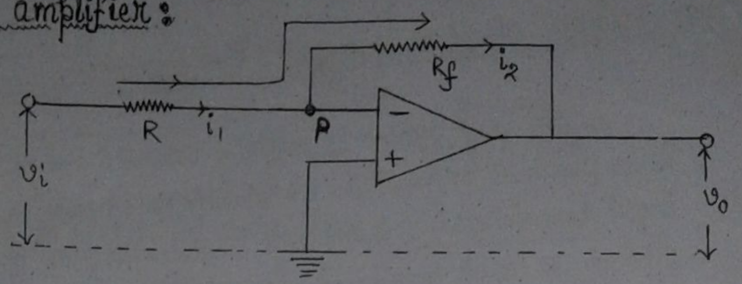
# Applications of OPAMP

## (1) Inverting amplifier :




* A basic inverting amplifier using OP-AMP is shown in figure. Since the gain of the OPAMP is very high, it is always operated under negative feedback condition. $R_f$ is the feedback resistance.

* An input voltage $v_i$ is applied at the inverting terminal across a resistance R and the non-inverting terminal is grounded.

Since open loop gain of an ideal OP-AMP is infinite,

$A \to \infty$

$\Rightarrow \dfrac{v_0}{0 - v_P} = \infty$

$\Rightarrow v_P = 0$ i.e the point P is virtual ground.

Since the input resistance of an OPAMP is ideally infinite, practically no current enters into the OP-AMP. Thus $i_1 = i_2$.

$$\Rightarrow \frac{v_i - 0}{R} = \frac{0 - v_0}{R_f}$$

$$\Rightarrow \boxed{\frac{v_0}{v_i} = -\frac{R_f}{R}}$$ i.e closed loop gain of the amp. $= -\frac{R_f}{R}$.

The negative sign indicates that the output is 180° out of phase with the input i.e the output voltage is inverted w.r.t. input voltage, hence the name "inverting amplifier".

## (2)* Phase shifter : V.U. 2003, 2007

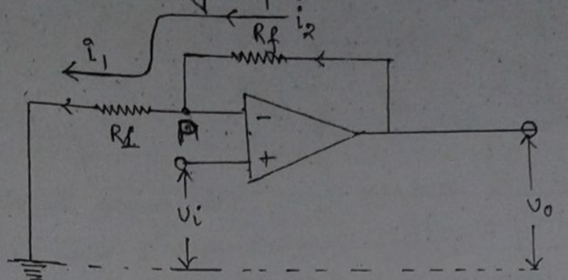
If the resistances R and $R_f$ are replaced by impedances $z$ and $z_f$ having equal magnitude ($|z| = |z_f|$) but different phases $\phi$ and $\phi_f$,

then $\dfrac{v_0}{v_i} = -\dfrac{|z_f|\, e^{j\phi_f}}{|z|\, e^{j\phi}} = (-1)\, e^{j(\phi_f - \phi)} = e^{j[\pi + (\phi_f - \phi)]}$

i.e inverting amplifier acts as phase shifter.

(2)

(3)* **Non-inverting amplifier :**




The circuit diagram of non-inverting amplifier using OP-AMP is shown in figure. Since the gain of the OP-AMP is very high, it is always operated under negative feedback condition. $R_f$ is the feedback resistance. An input voltage $v_i$ is applied at the non-inverting (+) terminal. The inverting terminal is grounded across a resistance $R_1$.

Since the open-loop gain of an ideal op-AMP is infinite.

i.e $A \to \infty$

$\Rightarrow A = \dfrac{v_o}{v_i - v_p} = \infty$

$\Rightarrow v_i - v_p = 0$

$\Rightarrow v_p = v_i$ i.e the point P is virtual ground.

Since the input resistance of the OP-AMP is ideally infinite, practically no current enters into the OP-AMP.

Thus $i_2 = i_1$

$$\Rightarrow \frac{v_o - v_i}{R_f} = \frac{v_i - 0}{R_1}$$

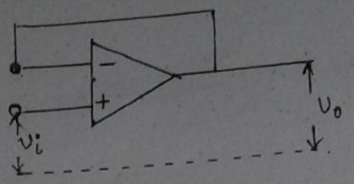
$$\Rightarrow v_o R_1 - v_i R_1 = v_i R_f$$

$$\Rightarrow v_o R_1 = v_i (R_1 + R_f)$$

$$\Rightarrow \boxed{\frac{v_o}{v_i} = 1 + \frac{R_f}{R_1}}$$

Obviously the circuit acts as a non-inverting amplifier.

## (4)* Unity gain follower or buffer : V.U - 2004

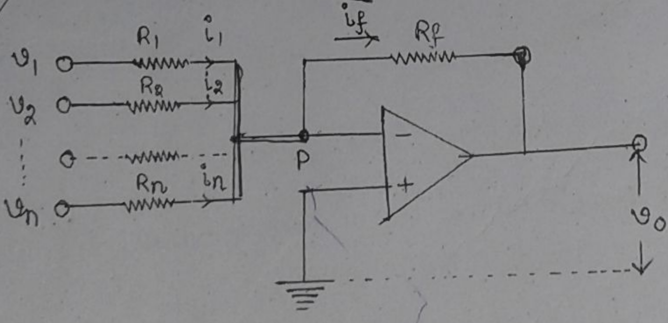



If we choose $R = \infty$ and/or $R_f = 0$ then ~~from~~ the closed loop gain of non inverting amplifier becomes $(A) = 1$ (unity).

If the non inverting terminal of an OP-AMP is (fed back) connected with the output with no feedback resistance and $R = \infty$ then the amplifier gain becomes unity i.e the amplifier acts as a voltage follower. Then the circuit is called unity gain buffer.

Use : It can be used as an impedance matching device between a high impedance source and a low impedance load.

## (5)* Adder or summing amplifier :

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(*)

Since the open loop gain of an ideal OP-AMP is infinite, the point P is virtual grounded i.e $v_P = 0$.

Since the input resistance of an OPAMP is ideally infinite, practically no current enters into the OP-AMP.

i.e $\quad i_1 + i_2 + \cdots + i_n = i_f$

$$\Rightarrow \frac{v_1 - 0}{R_1} + \frac{v_2 - 0}{R_2} + \cdots + \frac{v_n - 0}{R_n} = \frac{0 - v_0}{R_f}$$

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

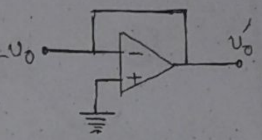
$$\Rightarrow \quad v_0 = -R_f\left(\frac{v_1}{R_1} + \frac{v_2}{R_2} + \cdots + \frac{v_n}{R_n}\right)$$

If $R_1 = R_2 = \cdots = R_n = R$ and also $R_f = R$

Then $\boxed{v_0 = -(v_1 + v_2 + \cdots + v_n)}$

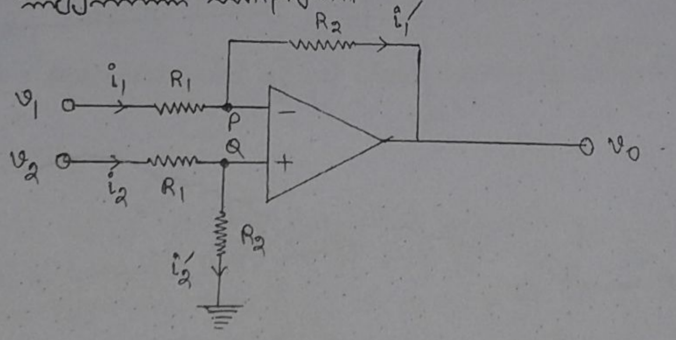
Thus output voltage is sum of the input voltages but of inverse phase. To remove the phase inversion the output is applied at the input of another inverting amplifier with unity gain. Then the output becomes,

$\boxed{v_0' = v_1 + v_2 + \cdots + v_n}$




which is act as adder or summing amplifier.

⑥* <u>Differential amplifier :</u>

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Since the open loop gain of an ideal OP-AMP is infinite,

$A \to \infty$

$$\Rightarrow \frac{v_0}{v_Q - v_P} = \infty$$

$$\Rightarrow v_P = v_Q = v \text{ (say)}$$

Since the input resistance of the OPAMP is ideally infinite, practically no current enters into the OP-AMP, Therefore $i_1 = i_1' \Rightarrow \frac{v_1 - v}{R_1} = \frac{v - v_0}{R_2}$ —— (1)

and $i_2 = i_2' \Rightarrow \frac{v_2 - v}{R_1} = \frac{v - 0}{R_2}$ —— (2).

Subtracting we get, $\frac{v_2 - v_1}{R_1} = \frac{v_0}{R_2}$.

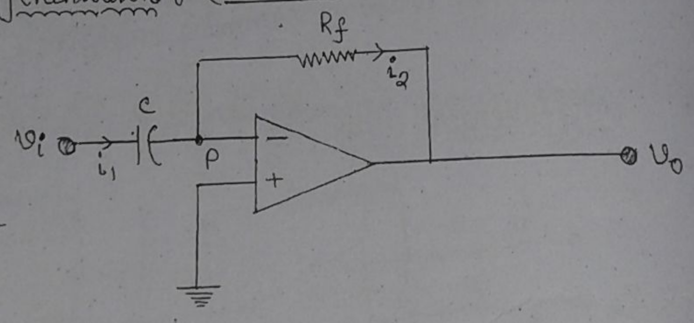
$$\Rightarrow \boxed{v_0 = \frac{R_2}{R_1}(v_2 - v_1)}.$$

Thus above circuit amplifies the difference of two input signals.

N.B. If we choose $R_1 = R_2$ then we get $\boxed{v_0 = v_2 - v_1}$

i.e the circuit acts as a subtractor.

(7) * Differentiator : (V.U. 2001)

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Since the open loop gain of an ideal op.AMP is infinite,

$A \to \infty$

$\Rightarrow \frac{v_0}{0 - v_P} = \infty$.

$\Rightarrow v_P = 0$, hence the point P is treated as virtual ground.

Since the input resistance of the OP-AMP is ideally infinite, practically no current enters into the OP-AMP,

i.e $i_1 = i_2$

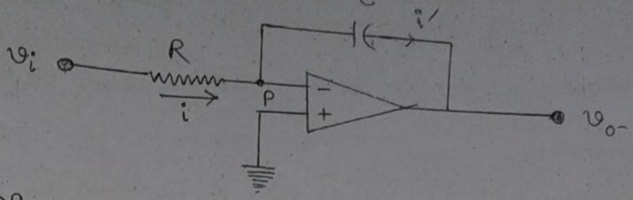
$\Rightarrow \frac{d}{dt}[c(v_i - 0)] = \frac{0 - v_0}{R_f}$ as charge across capacitor $q = c(v_i - 0)$

$\Rightarrow \quad c \cdot \frac{dv_i}{dt} = -\frac{v_o}{R_f}$

$$\Rightarrow \boxed{v_o = -cR_f \cdot \frac{dv_i}{dt}}$$

Which shows that the output voltage $v_o$ is proportional to the time derivative of the input voltage, the constant of proportionality being "$-cR_f$".

## (8)* Integrator :




If the position of resistor (R) and capacitor (c) are interchanged in differentiator circuit then the circuit is known as "integrator".

Since the open loop gain of an ideal OP-AMP is infinite,

$A \to \infty$

$\Rightarrow \frac{v_o}{0 - v_P} = \infty$

$\Rightarrow v_P = 0$, i.e the point P is virtual grounded.

Since the input resistance of the OP-AMP is ideally infinite, practically no current enters into the OP-AMP,

i.e $\quad i = i'$

$\Rightarrow \frac{v_i - 0}{R} = \frac{d}{dt}\left[(0 - v_o)c\right] \quad$ as $q = c(0 - v_o)$

$\Rightarrow \frac{v_i}{R} = -c\frac{dv_o}{dt}$

$$\Rightarrow \boxed{v_o = -\frac{1}{cR}\int v_i\,dt}$$

The circuit thus provides an output which is proportional to the time integral of input signal.