Ques 1: What is operational amplifier? Draw it using symbolic representation and explain the inverting and non-inverting mode.

Ans :-

- The operational amplifier, most commonly referred as 'op-amp'. was introduced in 1940s.
- In those days, it was used in the analog computers to perform a variety of mathematical operations such as addition, substraction, multiplication, etc. Due to its use in performing mathematical operations it have been given a name operational amplifier.
- With the help of IC op-amp, the circuit design becomes very simple. The variety of useful circuits can be built without the necessity of knowing about the complex internal circuitary.
- IC op-amps are inexpensive, take up less space and consume less power. The IC op-amp has become an integral part of almost every electronic circuit which uses linear integrated circuit.
- The op-amp is basically an excellent high gain d.c. amplifier.

- All the op-amps have minimum following five terminals :-

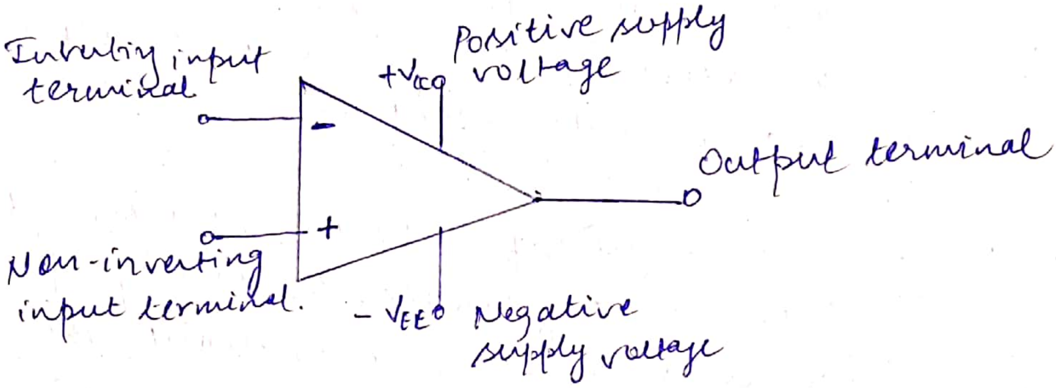
(i) The positive supply voltage terminal V_{CC} or $+V$.

(ii) The negative supply voltage terminal $-V_{EE}$ or $-V$

(iii) The output terminal

(iv) The inverting input terminal, marked as negative.

(v) The non-inverting input terminal, marked as +.

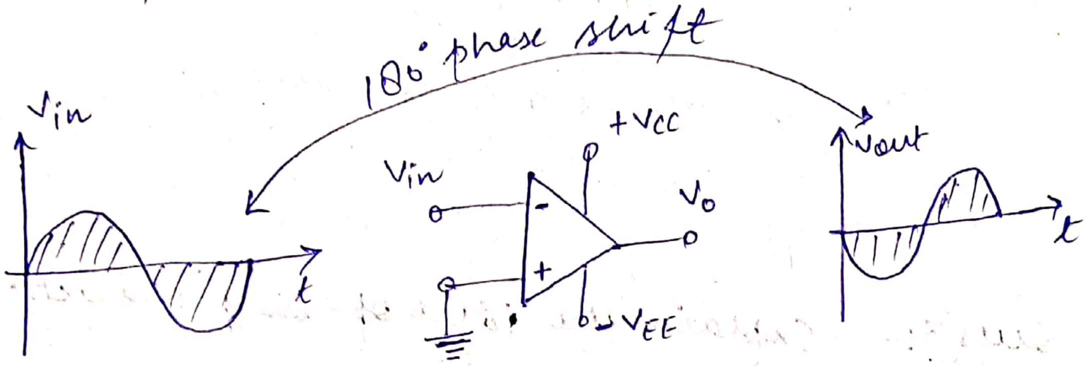


Op-amp symbol.

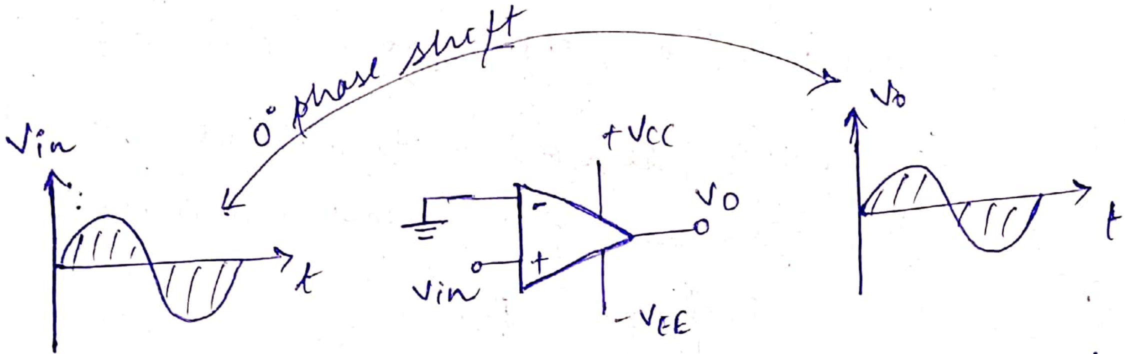
- The two input terminals are inverting and non-inverting input terminal.

- If the input is given at inverting input terminal, the output is 180° out of phase with the input phase.

while the input at non-inverting input terminal results in the same polarity (phase) output.



Input applied to inverting terminal.



input applied to non-inverting terminal.

Ques 2:- Explain why there is infinite bandwidth for Ideal op-amp.

Ans:- The range of frequency over which the amplifier performance is satisfactory is called it's bandwidth. The bandwidth of an ideal op-amp is infinite. This means the operating frequency range is from 0 to ∞. This ensures that the gain of the op-amp will be constant over the frequency range from d.c. (zero frequency) to infinite frequency. So op-amp can amplify d.c. as well as a.c. signals.

Ques 3:- Explain the ideal op-amp characteristics.

Ans:- The various characteristics of an ideal op-amp are as follows:-

(a) Infinite voltage gain: ($A_{OL} = \infty$)

- It is denoted as A_{OL}. It is the differential open loop gain and is infinite for an ideal op-amp.

(b) Infinite input impedance: ($R_{in} = \infty$)

The input impedance is denoted as R_{in} and is infinite for an ideal op-amp. This ensures that no current can flow into an ideal op-amp.

(c) Zero output ~~resistance~~ impedance ($R_o = 0$)

- The output impedance is denoted as R_o, and is 0 for an ideal op-amp. This ensures that the output voltage of the op-amps remains same, irrespective of the value of the load resistance connected.

(d) Zero offset voltage : ($V_{ios} = 0$)

- The presence of the small output voltage through $V_1 = V_2 = 0$ is called an offset voltage. It is 0 for an ideal op-amp. This ensures zero output for zero input signal voltage.

(e) Infinite Bandwidth : (BW = ∞)

- The range of frequency over which the amplifier performance is satisfactory is called its bandwidth. The bandwidth of an ideal op-amp is infinite. This means the operating frequency range is from 0 to ∞. This ensures that the gain of an op-amp will be constant over the frequency range from d.c (zero frequency) to infinite frequency. So op-amp can amplify d.c. as well as a.c. signals.

(f) Infinite CMMR : ($\rho = \infty$)

- The ratio of differential gain and common mode gain is defined as CMMR. Thus infinite CMMR of an ideal op-amp ensures 0 common mode gain. Due to this common mode noise output voltage is zero for an ideal op-amp.

(g) Infinite slew rate : (S = ∞)

. This ensures that the change in the output voltage occur simultaneous with the changes in the input voltage.

· The slew rate is important parameter of op-amp. when the input voltage applied is step type which changes ~~instaneou~~ instantaneously then the output must change rapidly as input changes. If output does not change with the same rate as input then there occurs distortion in the output. Such a distortion is not desirable.

· Infinite slew rate indicates that output changes simultaneously with the change in the input voltage.

(h) No effect of temperature :-

· The characteristics of op-amp do not change with temperature.

(i) · Power supply Rejection Ratio : (PSSR = 0)

· The power supply rejection ratio is defined as the ratio of the change in input offset voltage due to the change in supply voltage producing it, keeping other power supply voltage constant.

Characteristics	Symbol	Value
Open loop voltage gain	A_{OL}	∞
Input impedance	R_{in}	∞
Output impedance	R_o	0
offset voltage	V_{ios}	0
Bandwidth	B.W.	∞
CMRR	ρ	∞
Slew rate	S	∞
Power Supply Rejection Ratio	PSRR	0.

<u>Ans 4:-</u> Define :- (i) BW
(ii) PSRR
(iii) CMRR for an op-amp.

<u>Ans:-</u> (i) BW :- The range of frequency over which the amplifier performance is satisfactory is called the bandwidth (BW). The band-width of an idea op-amp is infinite.

(ii) <u>PSRR</u> :- The power supply rejection ratio is defined as the ratio of the change in input offset voltage due to the change in supply voltage producing it, keeping other power supply voltage constant. It is also called power supply sensitivity or supply voltage rejection ratio (SVRR).

(iii) CMRR for an ideal op-amp :- The ratio of differential gain and common mode gain is defined as CMRR. Thus infinite CMRR of an ideal op-amp ensures zero common mode gain. Due to this common mode noise, output voltage is zero for an ideal op-amp.

Ques 5 :- Explain ideal op-amp and find : derive the expression for
(a) Differential gain
(b) common mode gain
(c) common mode rejection ratio
(d) Voltage level and its saturating property

Ans :- ~~(a) Differential gain :-~~ An ideal op-amp is an amplifier which has the following characteristics :-

(i) Infinite voltage gain
(ii) Infinite input impedance
(iii) Zero output impedance
(iv) Zero offset voltage

(e) infinite bandwidth

(f) infinite CMRR

(g) infinite slew rate

(h) No effect of temperature

(i) zero power supply rejection ratio.

(a) Differential gain :- The gain with which differential amplifier amplifies the difference between two input signals is called differential gain (A_d).

The difference between the two inputs ($V_1 - V_2$) is generally called difference voltage and denoted V_d.

$$V_0 \propto (V_1 - V_2) \qquad \left[V_0 = \text{output voltage}\right]$$

$$\Rightarrow \quad V_0 = A_d (V_1 - V_2)$$

$$\Rightarrow \quad V_0 = A_d V_d$$

Hence, ~~voltage gain~~ differential can be expressed as $\boxed{A_d = \frac{V_0}{V_d}}$

(b) common mode gain :-

If we supply two input voltages which are equal in all the respects to the differential amplifier i.e. $V_1 = V_2$, then ideally the output voltage must be equal to 0.

- But the output voltage of the practical differential amplifier not only depends on the difference voltage but also depends on the average common level of the two inputs.

- Such an average level of the two input signal is called common mode signal denoted by V_c

$$\boxed{V_c = \frac{V_1 + V_2}{2}}$$

- The gain with which op-amp amplifies the common mode signal to produce output is called common mode gain (A_c).

$$\boxed{V_0 = A_c V_c} \Rightarrow \boxed{A_c = \frac{V_0}{V_c}}$$

(C) Common Mode Rejection Ratio :-

- The ability of op-amp to reject a common mode signal is expressed by a ratio called common mode rejection ratio.

- It is defined as the ratio of the differential voltage gain A_d to common mode voltage gain A_c.

- $$\text{CMRR or } \rho = \left| \frac{A_d}{A_c} \right|$$

- Ideally, the CMRR is 0.

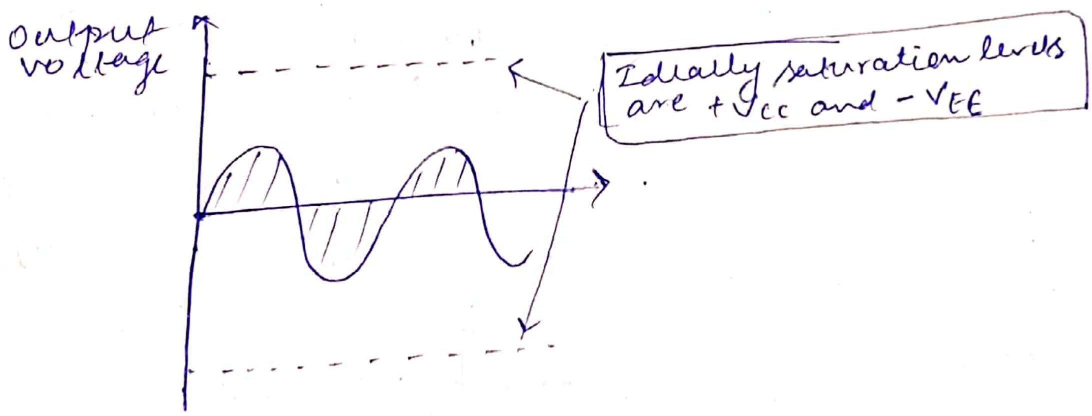
(d) voltage level and its saturation property :-

- The supply voltages of the op-amp are $+V_{CC}$ and $-V_{EE}$. These supply voltage levels decide the maximum output voltage levels of the op-amp.

- Practically the op-amp output saturates at the voltages slightly less than the supply voltages $+V_{CC}$ and $-V_{EE}$

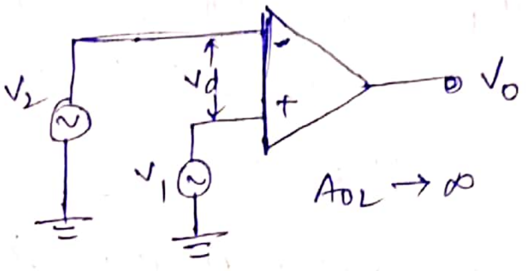
- Thus the output voltage of the op-amp can be driven to within 1 V of $+V_{CC}$ and $-V_{EE}$ before the output saturation takes place.

- This is called saturating property of the op-amp.



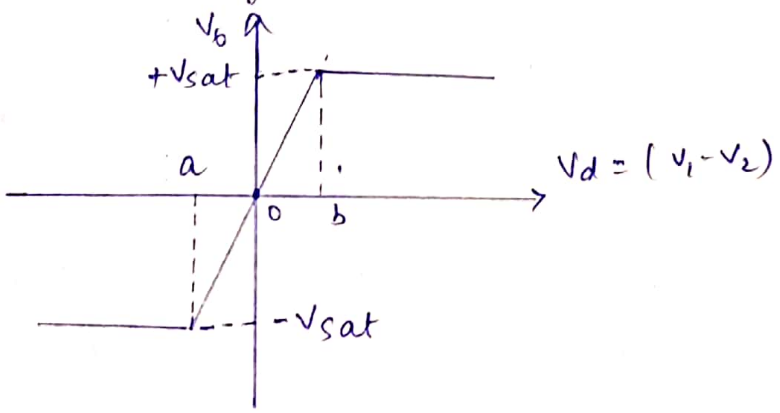
Ques 6:- Why is it necessary to reduce the gain of op-amp from its open loop value?

Ans:- • The simplest possible way to use an op amp is in the open loop mode.



• The d.c. supply voltages applied to the op-amp are V_{CC} and $-V_{EE}$ and the output varies linearly only between V_{CC} and $-V_{EE}$

• Since open loop gain A_{OL} is very large, the output voltage V_o is either at its positive saturation value or negative saturation value for very small values of V_d.



- Thus very small noise voltage present at the input also gets amplified due to its high open loop gain and op-amp gets saturated.

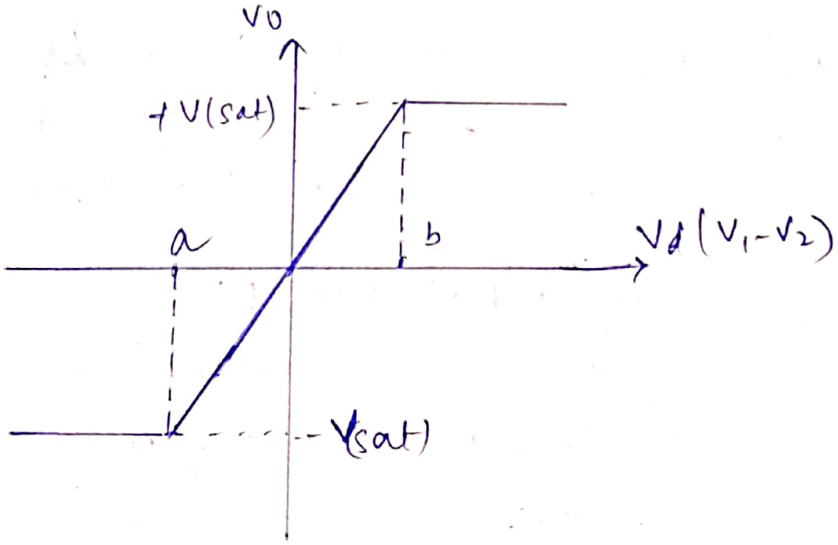
- From the graph it can be seen that for small range of input signal (from point a to b), it behaves linearly.

- This range is very small and practically due to high open loop gain, op-amp either shows $+V_{sat}$ or $-V_{sat}$ level.

- This indicates the inability of op-amp to work as a linear small signal amplifier in the open loop mode.

Ques 7:- Explain voltage transfer characteristics of open loop configuration of op-amp.

Ans :-



- The dc supply voltages applied to the op-amp are V_{CC} and $-V_{EE}$ and the output varies linearly only between V_{CC} and $-V_{EE}$.

- The open loop gain A_{OL} is very large, the output voltage V_o is either at its positive saturation voltage ($+V_{sat}$) or negative saturation voltage ($-V_{sat}$) for very small values of V_d.

- The very small noise voltage present at the input also gets amplified due to its high open loop gain and op-amp gets saturated.

- This range is very small and practically due to high open loop gain, op amp either shows $+V_{sat}$ or $-V_{sat}$ level.

Ques 8:- State the realistic assumptions related to the op-amps and state their uses.

Ans:- • We can make two assumptions which are realistic and simplify the analysis of op-amp circuits to a great extent.

1. Zero input current:
   - The current drawn by either of the input terminals (inverting and non-inverting) is zero.

2. Virtual Ground:-
   - This means the differential input voltage

Vd between the non-inverting and inverting input terminals is essentially zero

- Even if output voltage is few volts, due ~~to zero~~ large open loop gain of op-amp, the difference voltage Vd at the input terminals is almost 0.

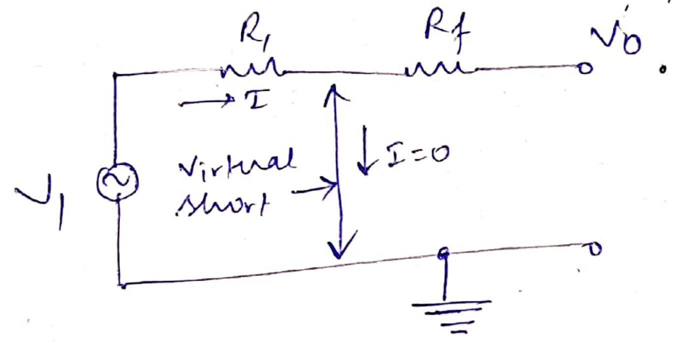
$$V_o = V_d A_{OL}$$

i.e. $V_d = \frac{V_o}{A_{OL}}$

= almost zero as A_{OL} is very very high

$\therefore V_d = (V_1 - V_2) = 0$

i.e. $\underline{V_1 = V_2}$.



Ques 9:- why an inverting amplifier is called scale changer? Derive the expression with the help of neat and clean circuit diagram.