Operational Amplifier Unit-3

Op-amp:- It is an Analog IC (Integrated circuit) whose IC No is :-

741C

74 → TTL Logic family → (Transistor-Transistor Logic)

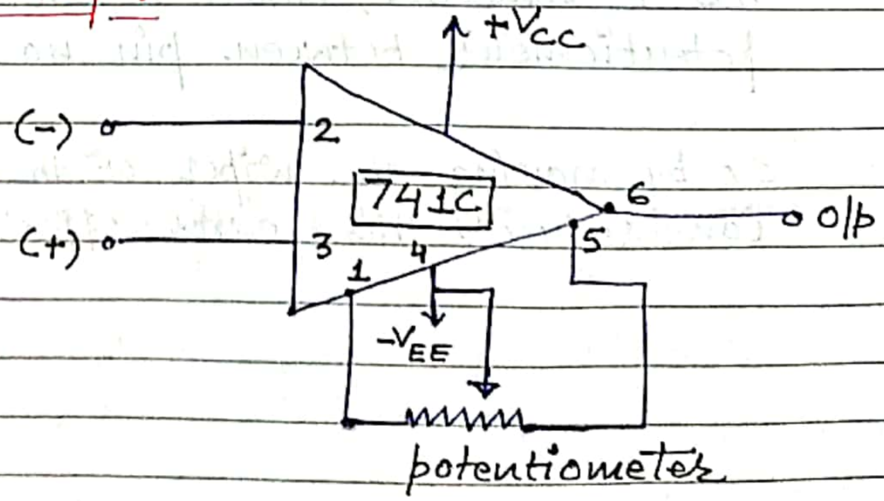
C → Commercial

→ op-amp is composed of 2 words: op, amp.

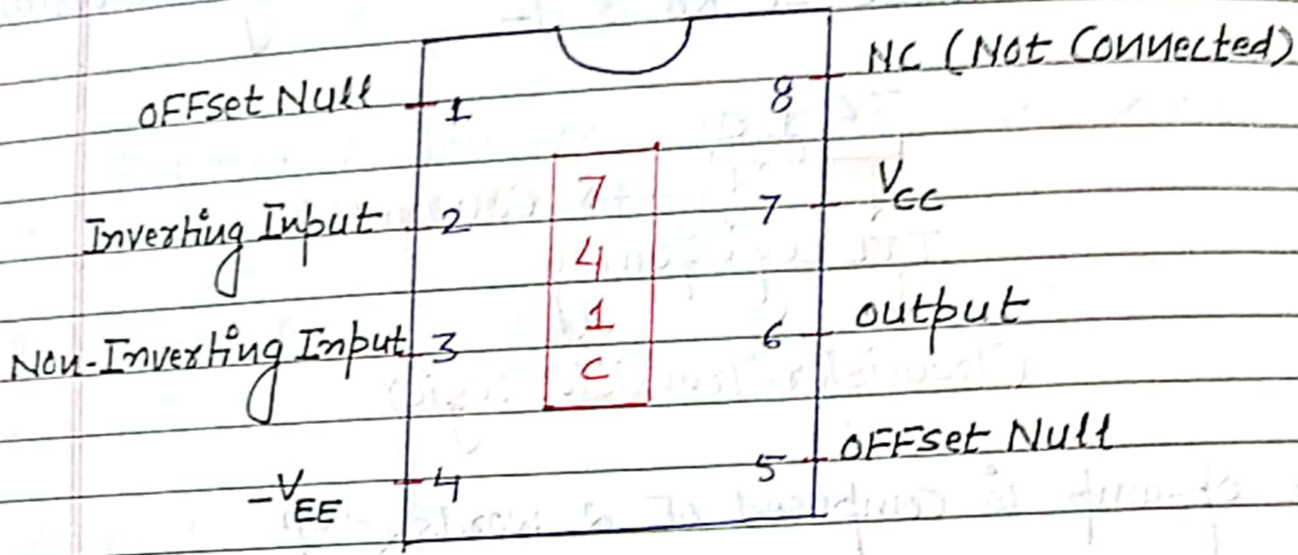
→ Op means operational ; with the help of op-amp we can perform mathematical operationals like addition, substraction, Integration, log, antilog etc.

→ Amp means Amplifier ; with the help of op-amp, we can amplify the signals as well.

Symbol of op-amp:-



Pin Configuration of op-amp :-



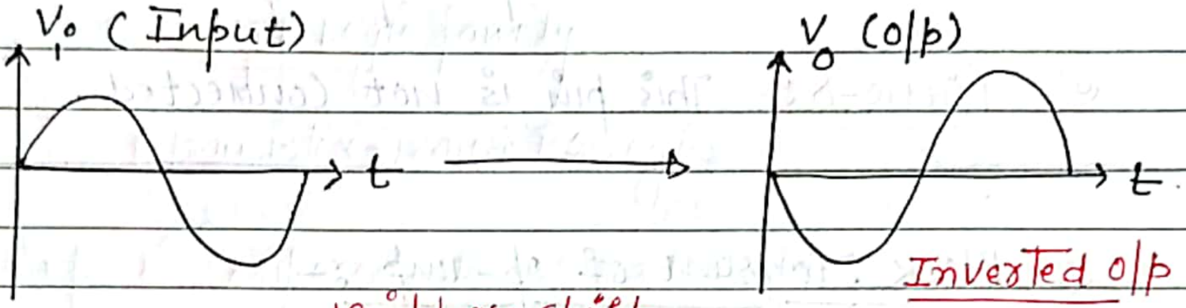
① **Pin No : 1 & 5 :-** These are known as offset null pins. Ideally when Input is zero ($V_p = 0$), output should also be zero ($V_0 = 0$), but due to fluctuations or spark or short circuiting or atmospheric disturbances, some error output voltage is produced even when Input $V_p = 0$.

This error voltage is called as offset voltage and has to removed, which is done by placing a potentiometer between pin no 1 and 5.

So by moving the wiper of the potentiometer, we can reduce this error offset voltage to zero.

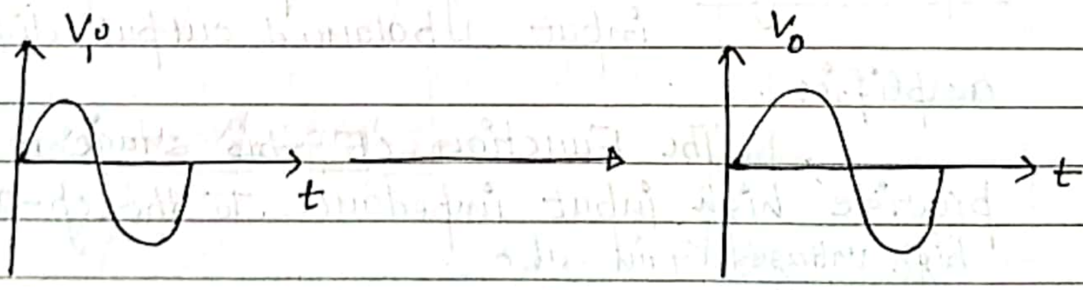
(2) Pin no 2 :- (Inverting Input pin) :-

If input is applied at pin no-2, we get amplified output at pin 6, but there is a phase shift of 180° between input and output.



180° phase shift between I/p & o/p

(3) Pin no 3 :- (Non-Inverting pin) :- If input is applied at pin no-3, we get amplified o/p at pin no-6 but there is no phase shift between input and o/p. means input and o/p both are in same phase.



Zero phase shift between I/p & o/p

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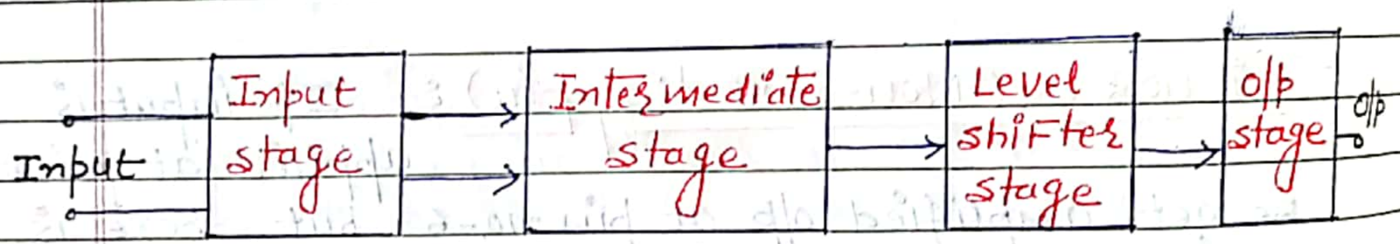
④ Pin no - 4, 7 :- These are the supply pins which are used to supply voltage to op-amp.

⑤ Pin no - 6 :- This pin is used to take the output of the op-amp.

⑥ Pin no - 8 :- This pin is not connected.

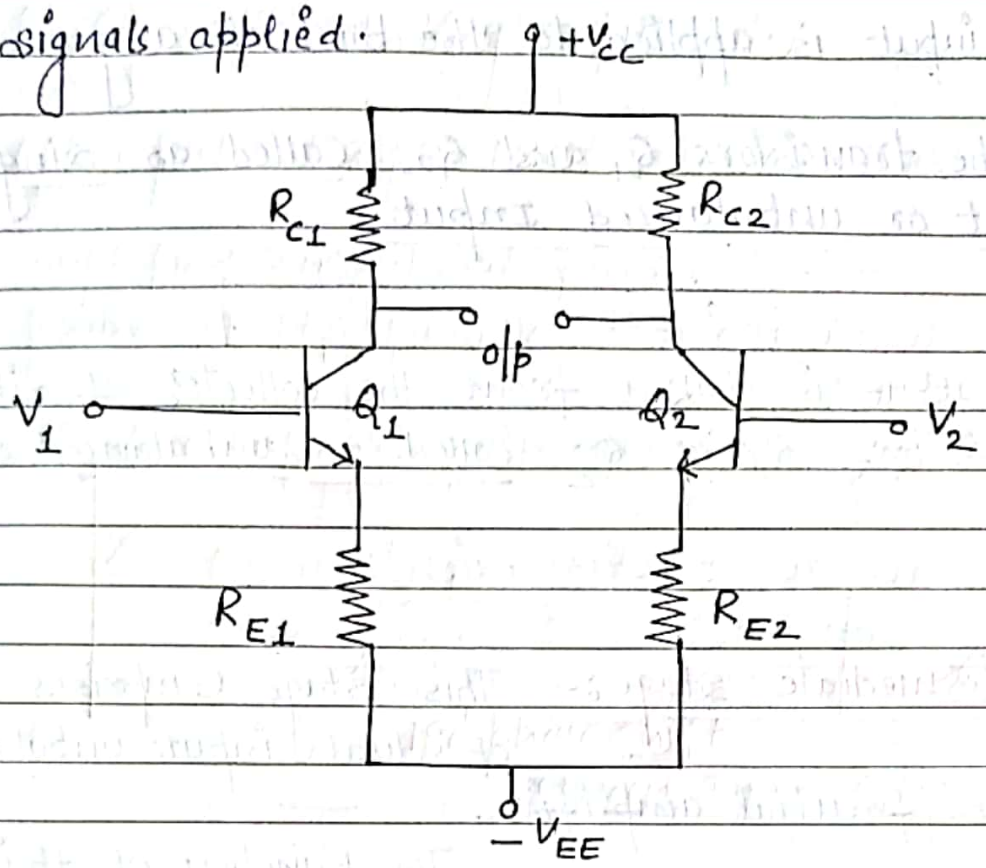
* Block Diagram of op-amp :-



① Input stage :- This stage comprises of dual input balanced output differential amplifier.

The Function of this stage is to provide high input impedance to the op-amp and high voltage Gain also.

Note :- Differential Amplifier :- A differential amplifier is a ckt which amplifies only the diffrence of two input signals applied.



→ Q_1, Q_2 are matched transistors ie their β is absolutely same (ideally). Input and output characteristics are also same.

$$\therefore \boxed{V_0 = A\,|V_1 - V_2|}$$

→ Since the input is given to the base of both the transistors hence named dual Input or balanced I/p.

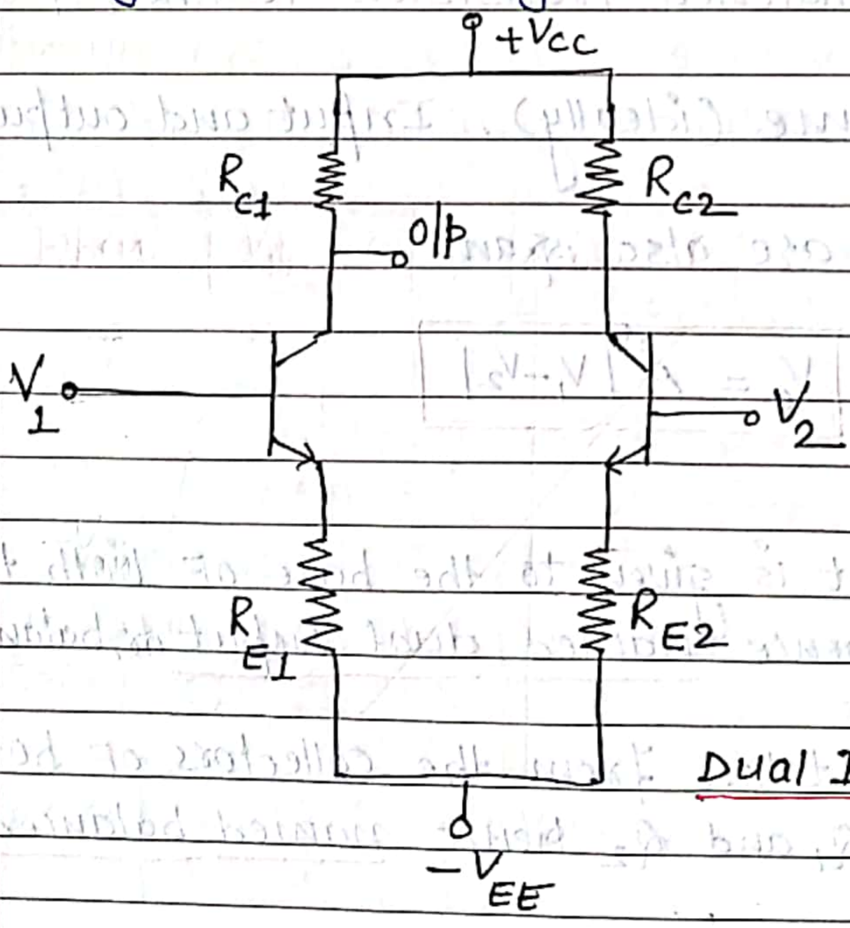
→ As the o/p is taken from the collectors of both the transistors Q_1 and Q_2 hence named balanced o/p.

→ If input is applied to the base of any one of the transistors Q_1 or Q_2, called as single input or unbalanced input.

→ IF output is taken from the collector of either transistors Q_1 or Q_2, called as unbalanced o/p.

② Intermediate stage :- This stage comprises of dual input unbalanced o/p differential amplifier.

The Function of this stage for providing rest of the voltage gain.



Dual Input Unbalanced o/p.

(3) Level shifter :- This stage Comprises of emitter follower using Constant Current source.

IF an unwanted d.c. signal is introduced in the ckt during amplification then the function of level shifter is to shift that d.c. level to ground either by pushing it or pulling it to ground level.

(4) Output stage :- This stage Comprises of Complimentry push pull amplifier.

The Function of this stage is to provide low output resistance.

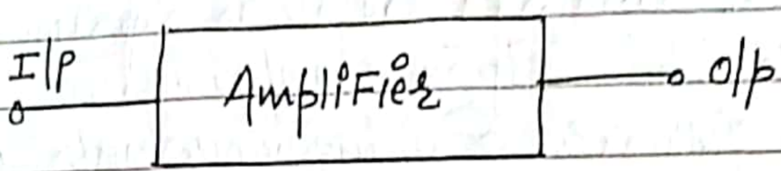
Configuration of op-amp :-

(1) open Loop Configuration :- open Loop Configuration means there is no Feedback between input and output. Practically op-amp is not used in open loop Configuration due to -

(1) Very high voltage gain which leads to distortion present in amplified output signal.

(2) Band width is very small.

(3) Gain is not Constant and Varies with temp and power supply.



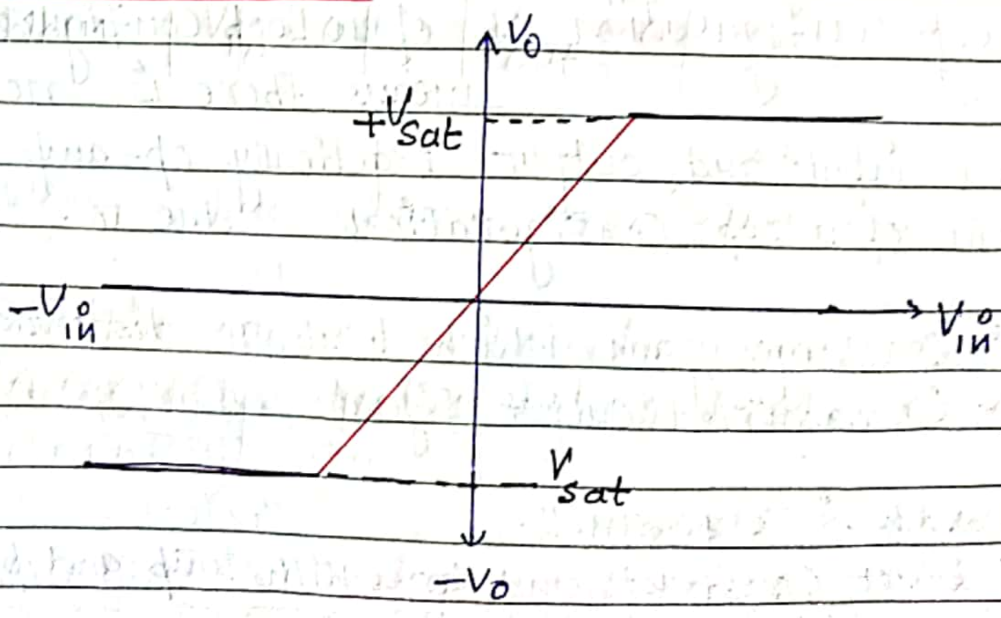
No Feedback Present

$\boxed{V_0 = A|V_1 - V_2|}$ where

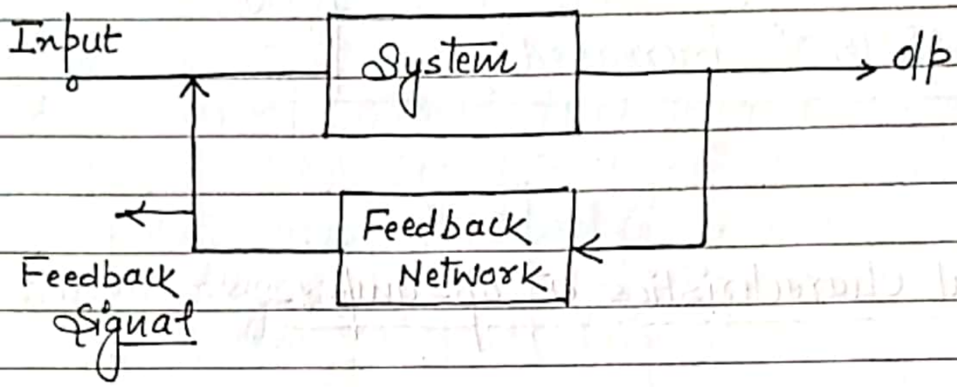
A = Open Loop Gain

Ideal Voltage Transfer Curve :- The maximum and minimum limit that an op-amp can amplify the input signal is $+V_{sat}$ and $-V_{sat}$.

* $+V_{sat}$ & $-V_{sat}$ Values are provided by the manufacturer which is equal to supply voltages $+V_{cc}$ and $-V_{EE}$.



(2) **Closed Loop Configuration :-** In Closed Loop Configuration, Feedback is present between input and o/p.



Types OF Feedback :-

(1) **(+Ve) Feedback :- (Positive Feedback)**

In positive Feedback, input signal and feedback signal are OF same phase, this is known as Regenerative Feedback and is used in Oscillators.

(2) **Negative Feedback :-** In this, there is a phase shift OF 180° between input signal and Feedback signal. It is also known as De-generative Feedback.

It is Commonly used in AmpliFiers.

Advantages of (-ve) Feedback :-

(1) It reduces and stablizes Voltage Gain.

(2) It reduces distortion at o/p signal.

(3) Bandwidth is increased.

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* Ideal Characteristics of op-amp :-

① open Loop Gain $\boxed{A = \infty}$:- This characteristics tells that an infinitesmialey small input signal can be amplified to such a level that it can be used For practical applications.

② When $\boxed{V_{in} = 0}$, $\boxed{V_{out} = 0}$:-

Ideally when input is zero, o/p should also be zero but due to sparks, Fluctuations atmospheric disturbances, short Circuiting, output appears even when Input is zero.

This error voltage is called as offset voltage which can be zero by using pin no 1 and 5 of op-amp.

(3) Input Resistance $\boxed{R_i = \infty}$:-

This condition should be satisfied so that internal circuit of op-amp should not draw any amount of current from the source and all the current should flow to the output of op-amp to provide high gain and to avoid loading effect.

(4) Output Resistance $\boxed{R_o = 0}$:- output resistance should be zero so that all the amplified current should be available at the output.

(5) Bandwidth $\boxed{BW = \infty}$:- Bandwidth is defined as the range of frequencies over which the device gives optimum performance.

→ This property tells that signal of least frequency to a signal of maximum freq. gets amplified.

(6) Common Mode Rejection Ratio ($CMRR = \infty$) :-

It is defined as the ratio of differential gain to the common mode gain.

$$\boxed{CMRR = \frac{A_d}{A_{CM}}}$$

OR

$$\boxed{\underset{\substack{\downarrow \\ \text{decibels}}}{CMRR \text{ in } db} = 20\log_{10} \frac{A_d}{A_{CM}}}$$

Where $A_d \longrightarrow$ Diffrential Gain

$A_{CM} \longrightarrow$ Common mode Gain

(7) Slew Rate ; $\boxed{SR = \infty}$:-

Slew Rate is defined as the maximum rate of change of output voltage with respect to time.

$$\boxed{S.Rate = \frac{\Delta V}{\Delta t}} \quad \text{Volts}/\mu sec$$

* Higher the Value of S.Rate, better will be the performance of op-amp

(8) Power supply Rejection Ratio :- (PSRR = 0)

It is defined as the ratio of change in input offset voltage to change in supply voltage.

$$\boxed{PSRR = \frac{\Delta V_{ios}}{\Delta V}}$$ unit $\mu V/volt$

* It is also known SVRR (supply voltage Rejection Ratio). Ideally PSRR should be zero but practically it should be as small as possible.

(9) Input offset voltage V_{ios} :-

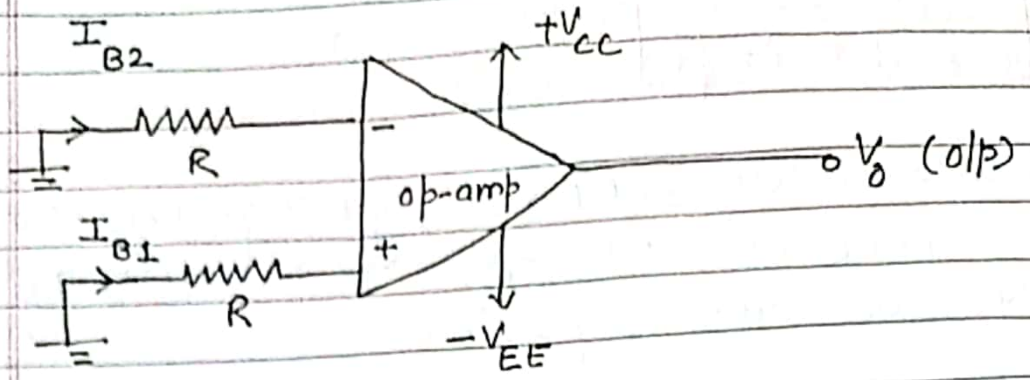
Ideally when $V_{in} = 0$, V_{out} should also be zero, but practically it is not so due to unavoidable unbalances inside the op-amp.

→ So we have to apply a small differential voltage at the input of the op-amp to make o/p voltage zero, which is called as Input offset voltage.

It is of the order of few mV range.

(10) Input bias current (I_B) :-

Input bias current I_B is the average of the currents flowing into the two input terminals of the op-amp ie I_{B1} and I_{B2}.



⇒ Input bias Current $\boxed{I_B = \frac{I_{B1} + I_{B2}}{2}}$

→ Ideally I_{B1} and I_{B2} must be zero but due to finite value of input resistance R_i, they do exist.

(ii) **Input offset Current :- (I_{ios})**

The algebric diffrence between the currents flowing into the inverting and non-inverting terminals of op-amp is called as Input offset current.

$$\boxed{I_{ios} = |I_{B1} - I_{B2}|}$$

Where I_{B1} = Current flowing into the non-inverting input

I_{B2} = Current Flowing into the inverting terminal.

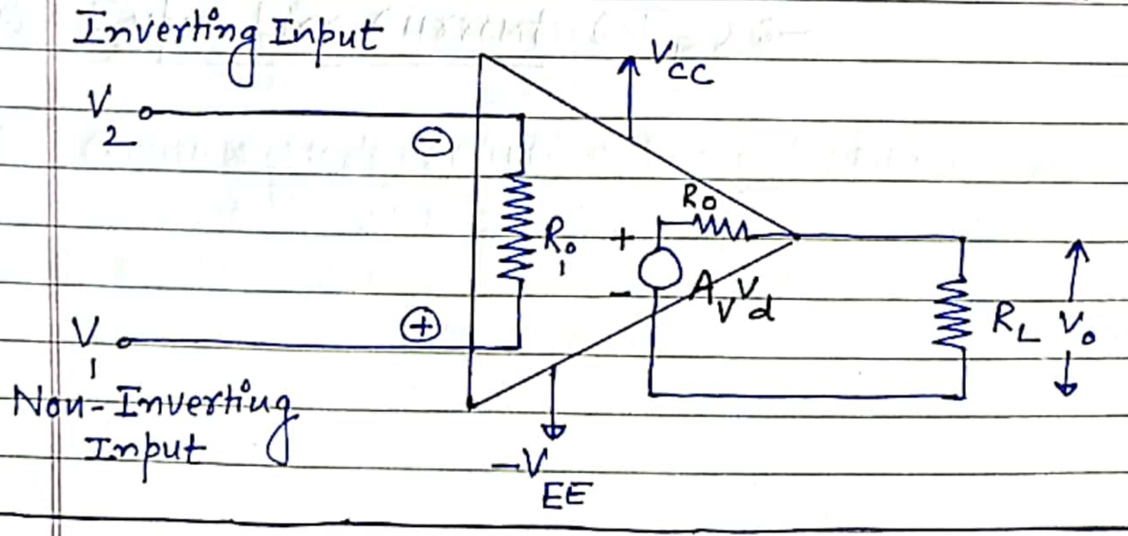
* Ideally, the input offset current must be zero but due to the unequal currents I_{B1} and I_{B2} flowing into the input terminals of the op-amp, input offset current exists.

*

Note :- The input offset current will give rise to a finite output voltage even when the input voltage is zero, that's why input offset current should be reduced to lowest possible value.

Equivalent ckt of op-amp :-

* $R_0 \rightarrow$ o/p Resistance
$R_i \rightarrow$ I/p Resistance.



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Modes OF Differential Ampr :- op-amp Consists OF differential Ampr. Differential amplifier operates in 2 modes :-

① Differential Mode ② Common mode

→ One OF the Common features OF diffrential ampr is its ability to Cancel out or reject Certain types OF undesired Voltage signals. Such undesired signals are referred to as 'NOISE'.

The noise signal appears equally at both inputs OF the circuit. means that any undesired noise signal which appear in polarity or common to both input terminals will be rejected or Cancelled out at the diffrential amplifier. output.

→ In diffrential Amplifier, the Common signal (NOISE) to both the inputs V_1 and V_2 will not effect on output.

→ The o/p depends on diffrential Input V_d $(|V_1 - V_2|)$ and the average OF two inputs Called as Common mode input V_{CM} $\left[\left|\frac{V_1+V_2}{2}\right|\right]$

① **Differential Mode :-** In Differential mode, o/p V_0 depends on differential input V_d which is multiplied by differential gain A_d.

$$\therefore \boxed{V_0 = V_d A_d} \quad \text{Where} \quad \boxed{V_d = |V_1 - V_2|}$$

② **Common Mode :-**

In Common mode, output V_0 depends on Common input V_{CM} which is multiplied by A_{CM} (Common mode Gain).

$$\therefore \boxed{V_0 = A_{CM} V_{CM}} \quad \text{Where} \quad \boxed{V_{CM} = \left|\frac{V_1 + V_2}{2}\right|}$$

Hence Total output

$$\boxed{V_0 = A_d V_d + A_{CM} V_{CM}}$$

* CMRR Can be defined as the ratio of differential gain to the Common mode Gain.

$$\boxed{CMRR = \frac{A_d}{A_{CM}}}$$

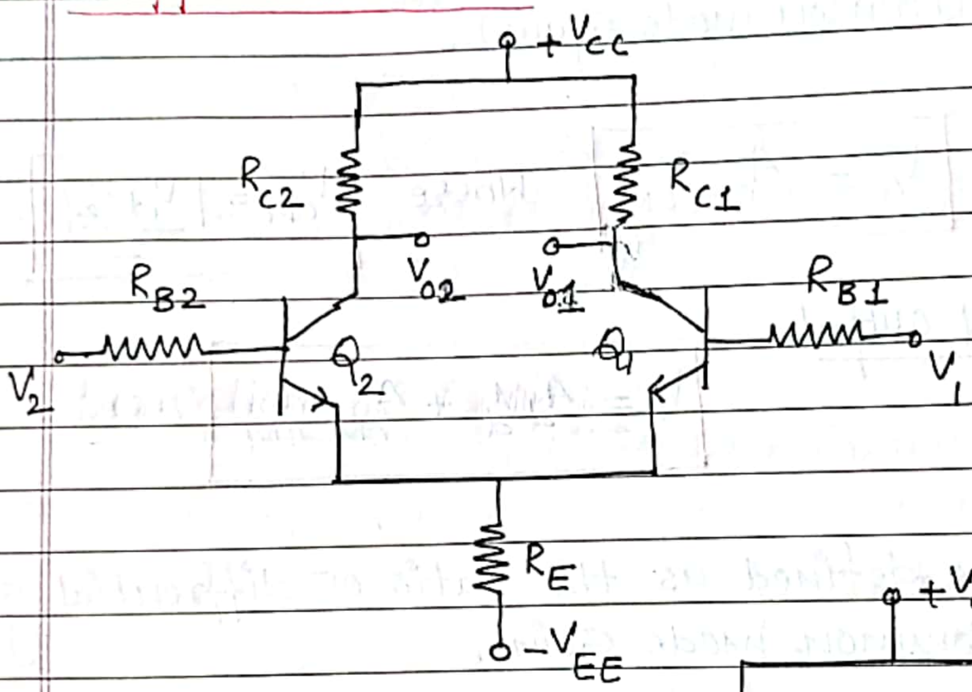
→ We Want To amplify the differential input V_d but don't want to amplify the Common signal i.e noise, so A_{CM} should be as small as possible and Ideally should be zero.

∴ $\boxed{CMRR = \infty}$ which is one of the ideal characteristics of op-amp.

Circuit Diagram of Differential Ampr using BJT :-

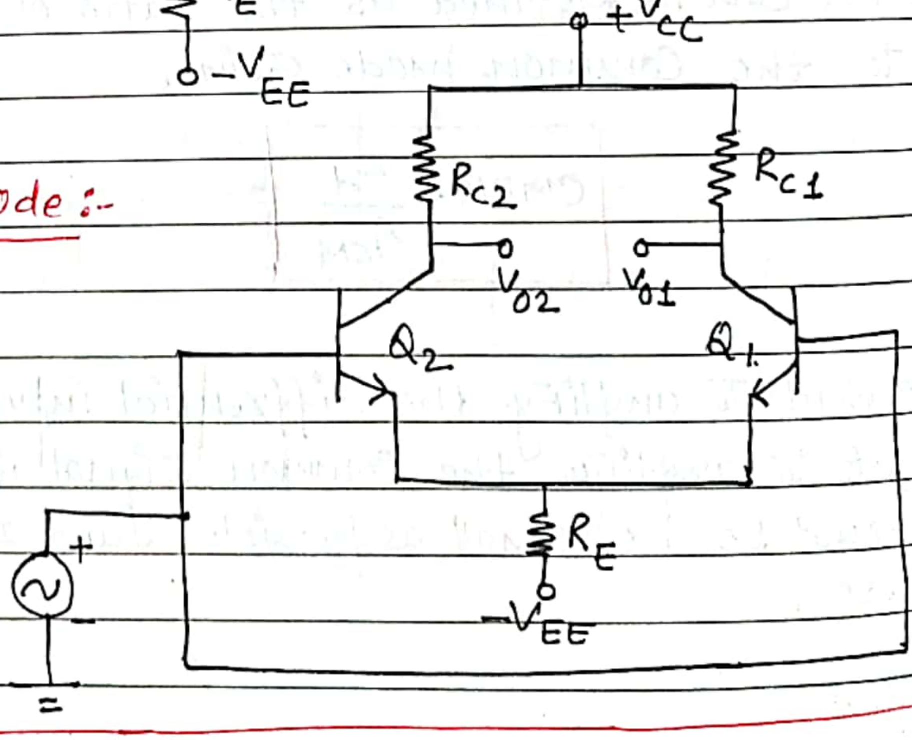
As Differential Ampr operates in 2 modes so below are the ckt diagrams of differential Ampr in 2 modes :- (using BJT)

① Differential Mode :-



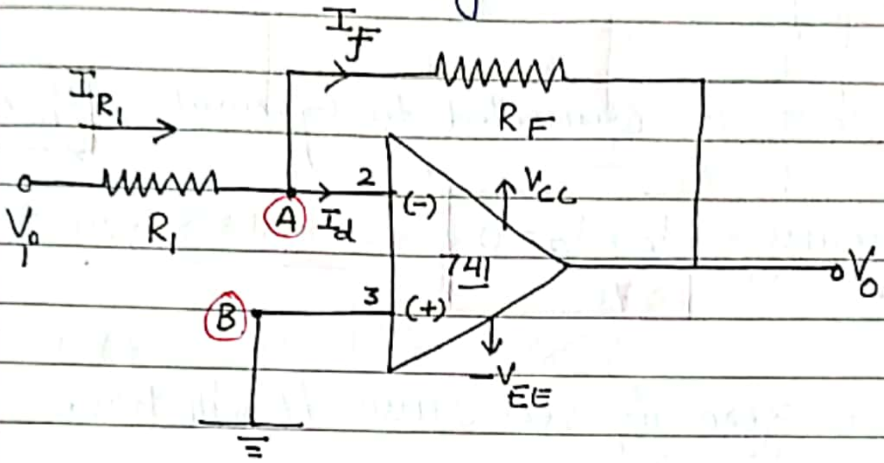
② Common Mode :-

Common Signal to both Inputs terminals, $V_{in} = V_{CM}$



op-amp As Inverting Amp^r :-

When input is applied to the inverting terminal of an op-amp, it is called as Inverting op-amp.



Concept of Virtual Ground :-

Ideally, open Loop Gain $A = \infty$

$$\boxed{A = \frac{V_0}{|V_d|}}$$

Where V_d is the diffrence between two inputs of the op-amp

$$\therefore \boxed{A = \frac{V_0}{|V_A - V_B|}}$$

V_A = Voltage At node A

V_B = Voltage At node B

For $A = \infty$

$|V_A - V_B| = 0$

$\boxed{V_A = V_B}$

Since Node B is connected to Ground $\therefore \boxed{V_B = 0}$

That means $\boxed{V_A = V_B = 0}$

→ V_A is not zero in real sense, it will have some potential but it is proven to be at ground.

This is the Concept of Virtual Ground.

Derivation of Gain :-

Applying KCL at node A.

$I_{R_1} = I_d + I_f$

→ For an ideal op-amp, input resistance $\boxed{R_i = \infty}$

therefore $\boxed{I_d = 0}$

$\therefore \boxed{I_{R_1} = I_f}$

$$\frac{V_i - V_A}{R_1} = \frac{V_A - V_0}{R_F}$$

but $\boxed{V_A = 0}$, From Virtual Ground Concept

$$\frac{V_i}{R_1} = -\frac{V_0}{R_F}$$

$$\boxed{A_f = \frac{V_0}{V_i} = \frac{-R_F}{R_1}}$$

Where

A_f = closed Loop Gain | Feedback gain

(-ve) sign indicates that there is a phase shift of 180° between input and output.

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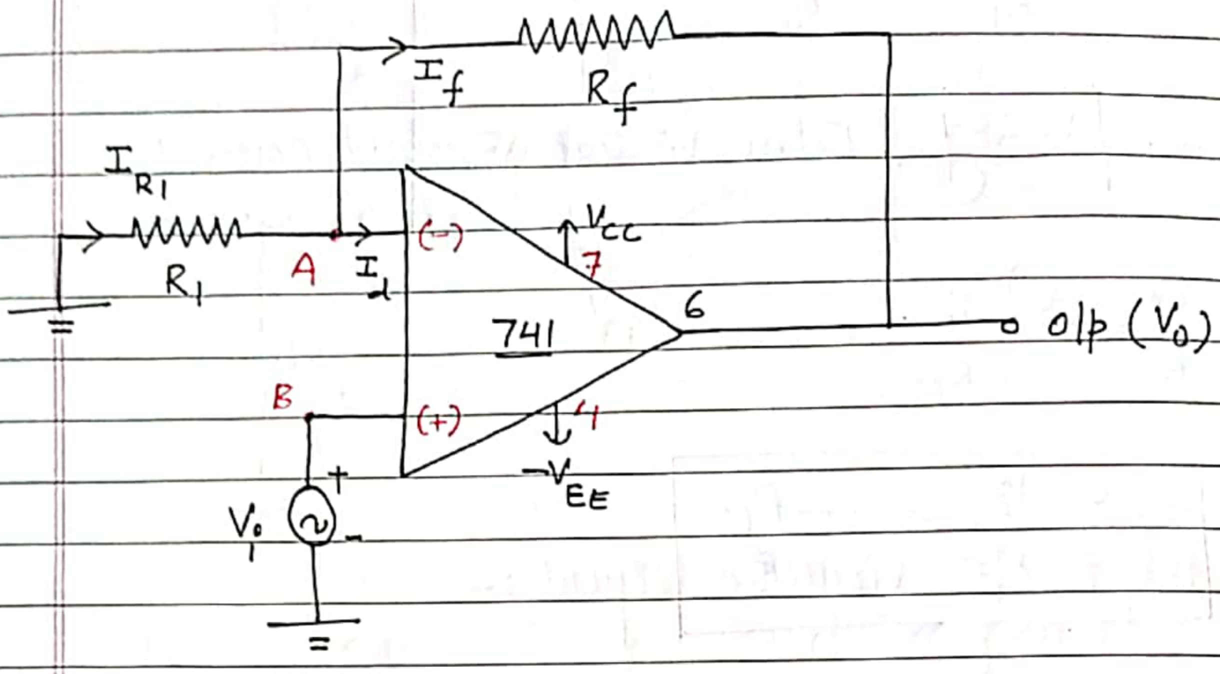
op-amp AS Non-Inverting Amp^r :-

When Input is applied to Non-Inverting terminal of an op-amp, It is called as Non-Inverting op-amp.



→ Ideally, open Loop Gain $A = \infty$

$$A = \frac{V_o}{|V_d|} = \frac{V_o}{|V_A - V_B|}$$

→ Where

V_A & V_B are the 2 Inputs of op-amp.

→ For $\boxed{A = \infty}$, $|V_A - V_B| = 0$

$$\therefore \boxed{V_A = V_B}$$

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But $V_B = V_{i}$ $\therefore$ $\boxed{V_A = V_B = V_{i}}$ From Virtual Short ckt Concept.

Derivation of Gain A_F :- Apply KCL at node A :-

$$I_{R1} = I_d + I_f$$

but $\boxed{I_d = 0}$ b'coz $\boxed{r_i = \infty}$ For an ideal op-amp

$$\therefore \quad I_{R1} = I_f$$

$$\frac{0 - V_A}{R_1} = \frac{V_A - V_0}{R_f}$$

$$\frac{-V_A}{R_1} = \frac{V_A}{R_f} - \frac{V_0}{R_f}$$

But $\boxed{V_A = V_B = V_{i}}$

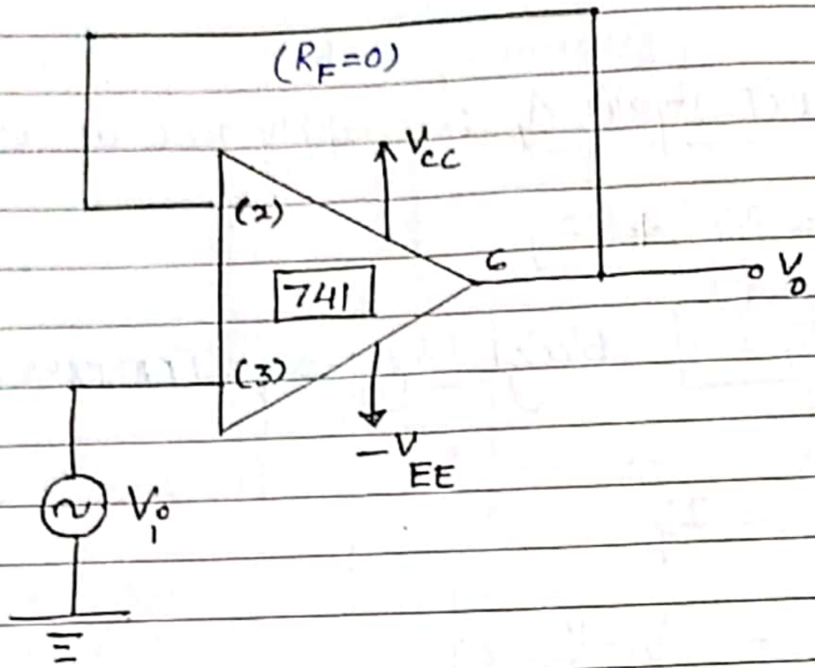
$$\therefore \quad \frac{-V_{i}}{R_1} = \frac{V_{i}}{R_F} - \frac{V_0}{R_F}$$

$$\frac{V_0}{R_F} = \frac{V_{i}}{R_F} + \frac{V_{i}}{R_1} \Rightarrow \frac{V_0}{R_F} = V_{i}\left[\frac{1}{R_F} + \frac{1}{R_1}\right]$$

$$\therefore \quad \boxed{A_F = \frac{V_0}{V_{i}} = 1 + \frac{R_F}{R_1}}$$

Proved

op-amp As voltage Follower :- | unity Gain Buffer :-



→ Let us Consider Non-Inverting Configuration of op-amp.

→ IF $\boxed{R_1 = \infty}$, $\boxed{R_F = 0}$ in an non-inverting op-amp then it becomes voltage Follower, then- We know -

→ Gain $\boxed{A_F = 1 + \frac{R_F}{R_1}}$ OF non-inverting op-amp

→ put $R_1 = \infty$ & $R_F = 0$

$$\boxed{A_F = 1}$$

As the gain of Voltage Follower is unity ∴ It is also known as Unity Gain Buffer.

$\rightarrow$ As $A_F = 1$

$\downarrow$

$$\frac{V_0}{V_{0_1}} = 1 \Rightarrow \therefore \boxed{V_0 = V_{0_1}}$$

Since o/p voltage follows the input voltage, therefore it is also called as Voltage Follower.

Features of Voltage Follower :-

1) closed Loop Gain $A_F = 1$

2) Very high input resistance

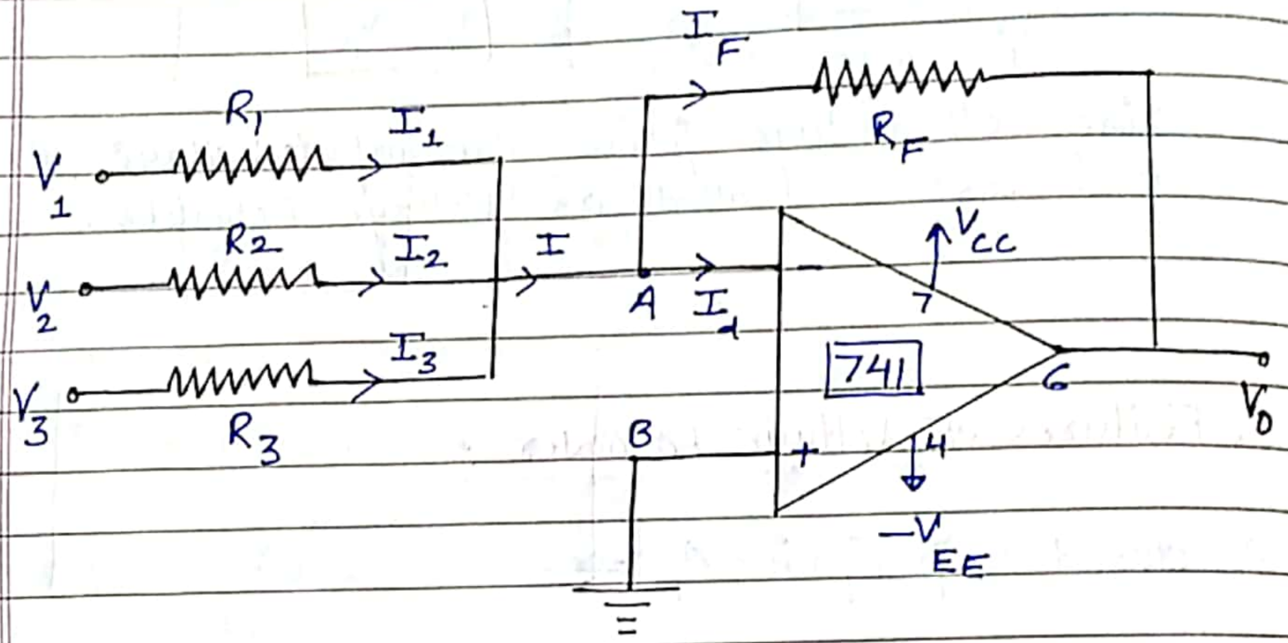
3) Very low o/p Resistance.

4) Large bandwidth.

Note :- Voltage Followers are placed between two networks to reduce the loading on First network due to its high input impedance.

Applications of op-amp :-

(1) op-amp As Adder | Summer | Summing Amp^r :-



→ Ideally, open Loop Gain $A = \infty$

$$A = \frac{V_0}{|V_d|} = \frac{V_0}{|V_A - V_B|}$$

For $A = \infty$, $|V_A - V_B| = 0$

$\therefore \boxed{V_A = V_B}$

Since $\boxed{V_B = 0}$ $\therefore$ $\boxed{V_A = 0}$ From Virtual Ground Concept.

Apply KCL at node A :-

$$I = I_d + I_F$$

but For ideal op-amp $\boxed{R_i = \infty}$ $\therefore \boxed{I_d = 0}$

$$\therefore \quad I = I_F$$

$$\downarrow$$

$$\rightarrow \quad I_1 + I_2 + I_3 = I_F$$

$$\frac{V_1 - V_A}{R_1} + \frac{V_2 - V_A}{R_2} + \frac{V_3 - V_A}{R_3} = \frac{V_A - V_0}{R_F}$$

$\rightarrow$ $\boxed{V_A = 0}$ From Virtual Ground Concept

$$\therefore \quad \frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3} = -\frac{V_0}{R_F}$$

$$\boxed{V_0 = -R_F\left[\frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3}\right]} \longrightarrow (1)$$

IF $R_1 = R_2 = R_3 = R_F$ then

$$\boxed{V_0 = -(V_1 + V_2 + V_3)}$$

* (-ve) sign indicates that there is 180° phase shift between input and output.

Average Ampr :- From eqn ①

$$V_0 = -R_F\left[\frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{V_3}{R_3}\right]$$

IF $\boxed{R_1 = R_2 = R_3 = R}$

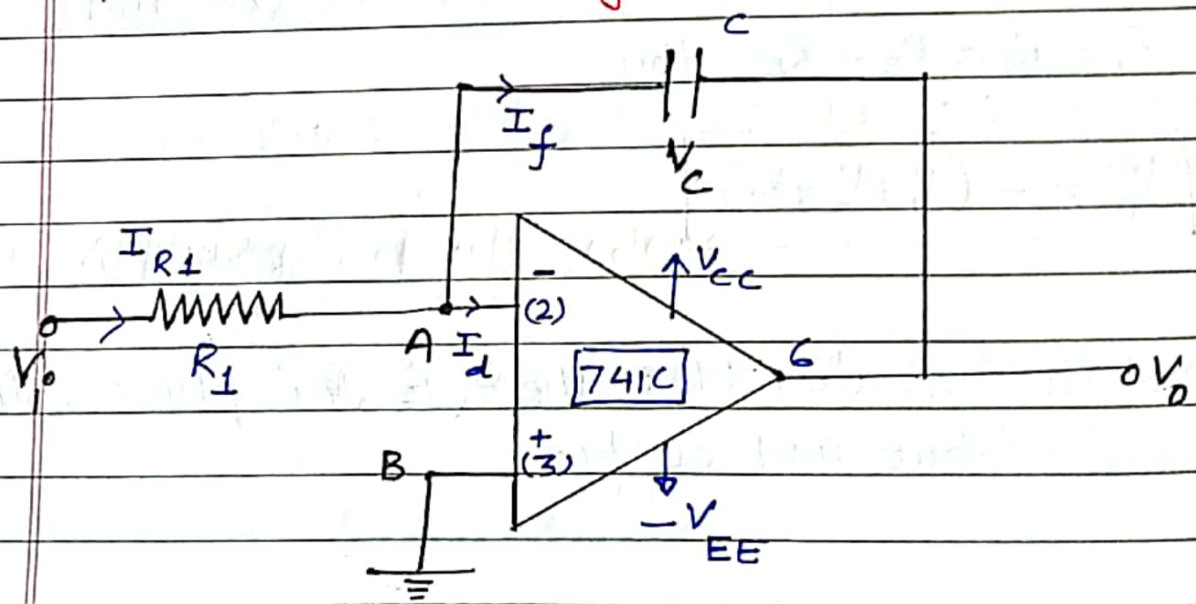
And

$\boxed{R_F = \frac{R}{3}}$ then

$$\boxed{V_0 = -\frac{(V_1 + V_2 + V_3)}{3}}$$

* Hence Adder behaves like an Average Ampr.

② op-amp As an Integrator :-



Ideally, open Loop Gain $A = \infty$

$$\therefore \quad A = \frac{V_o}{|V_d|} = \frac{V_o}{|V_A - V_B|}$$

For $A = \infty$, $|V_A - V_B| = 0$ $\quad \therefore \boxed{V_A = V_B}$

But $\boxed{V_B = 0}$ $\therefore \boxed{V_A = 0}$ From Virtual Ground Concept.

Now Applying KCL at node A :-

$$I_{R1} + I_d = I_f$$

but $I_d = 0$, b'coz for an ideal op-amp $\boxed{r_i = \infty}$

$$\therefore \quad I_{R1} = I_f$$

$$\frac{V_i - V_A}{R_1} = C\frac{dV_c}{dt}$$

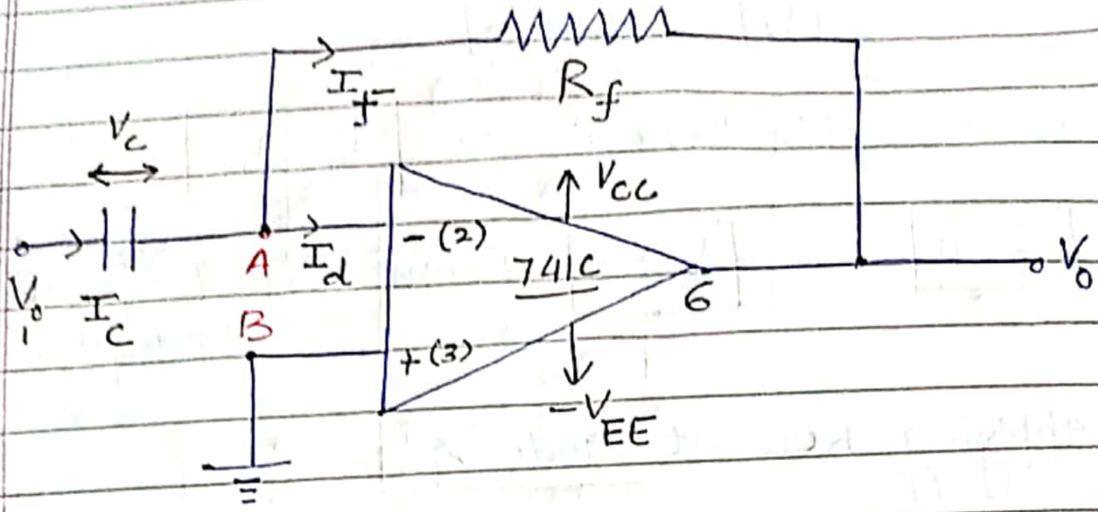
but $\boxed{V_A = 0}$, $\therefore \quad \frac{V_i}{R_1} = C\frac{dV_c}{dt}$

$$\therefore \frac{V_i}{R_1} = C\frac{d(V_A - V_o)}{dt} \quad \Rightarrow \frac{V_i}{R_1} = C\frac{d}{dt}(-V_o)$$

$$\frac{dV_o}{dt} = -\frac{1}{R_1C}V_i \quad \Rightarrow \boxed{V_o = -\frac{1}{R_1C}\int V_i \, dt}$$

* R_1C is called as time Constant of the Integrator.

③ op-amp As Differentiator :-



Ideally, open Loop Gain $A = \infty$

$$A = \frac{V_o}{|V_d|} = \frac{V_o}{|V_A - V_B|}$$

For $A = \infty$, $|V_A - V_B| = 0$

$$\therefore V_A = V_B$$

but $\boxed{V_B = 0}$ $\therefore$ $\boxed{V_A = V_B = 0}$, As node B is grounded.

↳ From Virtual Ground concept.

→ Applying KCL at node A :-

$$I_c = I_d + I_f$$

but $I_d = 0$, (For an ideal op-amp $R_i = \infty$)

$$\therefore \quad I_c = I_f$$

$$C \frac{dV_c}{dt} = \frac{V_A - V_0}{R_F}$$

$$C \frac{d}{dt}(V_i - V_A) = \frac{V_A - V_0}{R_f}$$

But $V_A = 0$

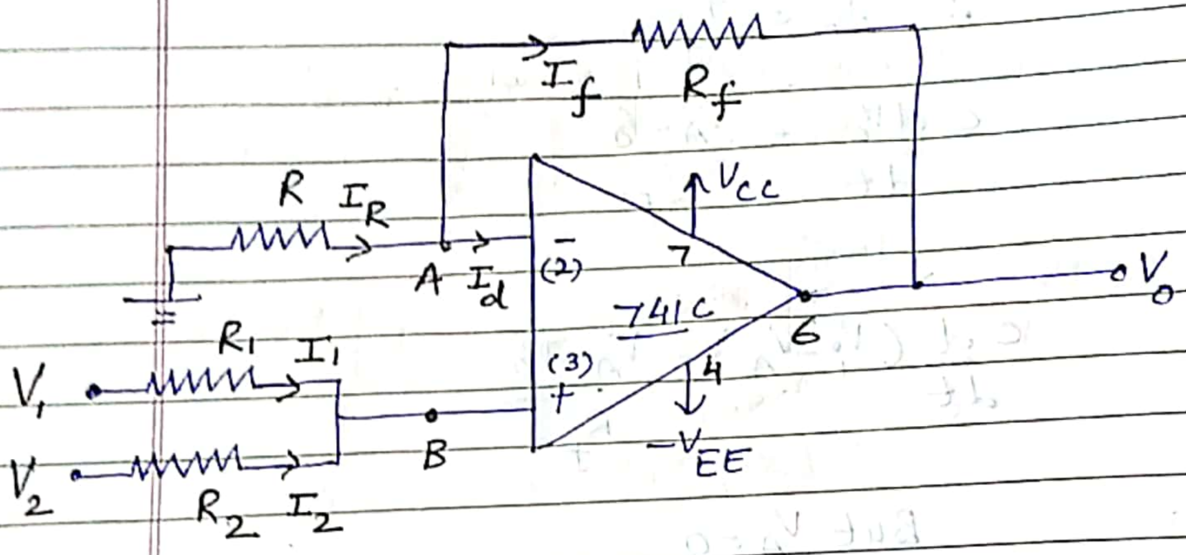
$$\therefore \quad C \frac{d}{dt} V_i = \frac{-V_0}{R_f}$$

Hence $\boxed{V_0 = -R_f C \frac{d}{dt} V_i}$

Hence it produces the diffrentiation of the input voltage at its output is called as diffrentiator.

* $-R_f C$ is called as time Constant of the differentiator.

Non-Inverting Summing Amplifier / Adder :-



→ Ideally, open Loop Gain $A = \infty$

$$A = \frac{V_o}{|V_d|} = \frac{V_o}{|V_A - V_B|}$$

For $A = \infty$, $|V_A - V_B| = 0$ $\therefore$ $\boxed{V_A = V_B}$

* As Input Current of op-amp is zero b'coz $R_i = \infty$

$$\therefore I_1 + I_2 = 0$$

$$\frac{V_1 - V_B}{R_1} + \frac{V_2 - V_B}{R_2} = 0$$

$$\frac{V_1}{R_1} + \frac{V_2}{R_2} = V_B\left[\frac{1}{R_1} + \frac{1}{R_2}\right]$$

$$\boxed{V_B = \frac{V_1R_2 + V_2R_1}{R_1+R_2}}$$

But $V_A = V_B$, From Virtual Ground Concept

$$\therefore \boxed{V_A = V_B = \frac{V_1R_2 + V_2R_1}{R_1+R_2}}$$

* Applying KCL at node A :-

$$I_R = I_d + I_f$$

but $I_d = 0$ (For ideal op-amp, $r_i = \infty$ $\therefore I_d = 0$)

$$\therefore I_R = I_f$$

$$\frac{0 - V_A}{R} = \frac{V_A - V_0}{R_f}$$

$$-\frac{V_A}{R} = \frac{V_A}{R_f} - \frac{V_0}{R_f}$$

$$V_0 = R_f\left[\frac{V_A}{R_f} + \frac{V_A}{R}\right]$$

$$V_0 = V_A\left[1 + \frac{R_f}{R}\right] \longrightarrow 1$$

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put the Value OF V_A in eq^n 1 :-

$$V_0 = \left[1+\frac{R_F}{R}\right]\left(\frac{V_1R_2 + V_2R_1}{R_1+R_2}\right)$$

⇒ If $\boxed{R_1 = R_2 = R_f = R}$:- we get

$$V_0 = 2 \times \frac{V_1+V_2}{2}$$

$$\boxed{V_0 = V_1+V_2}$$

As there is no phase difference between Input and output, it is called as Non-Inverting summer Amplifier.

M. Imp

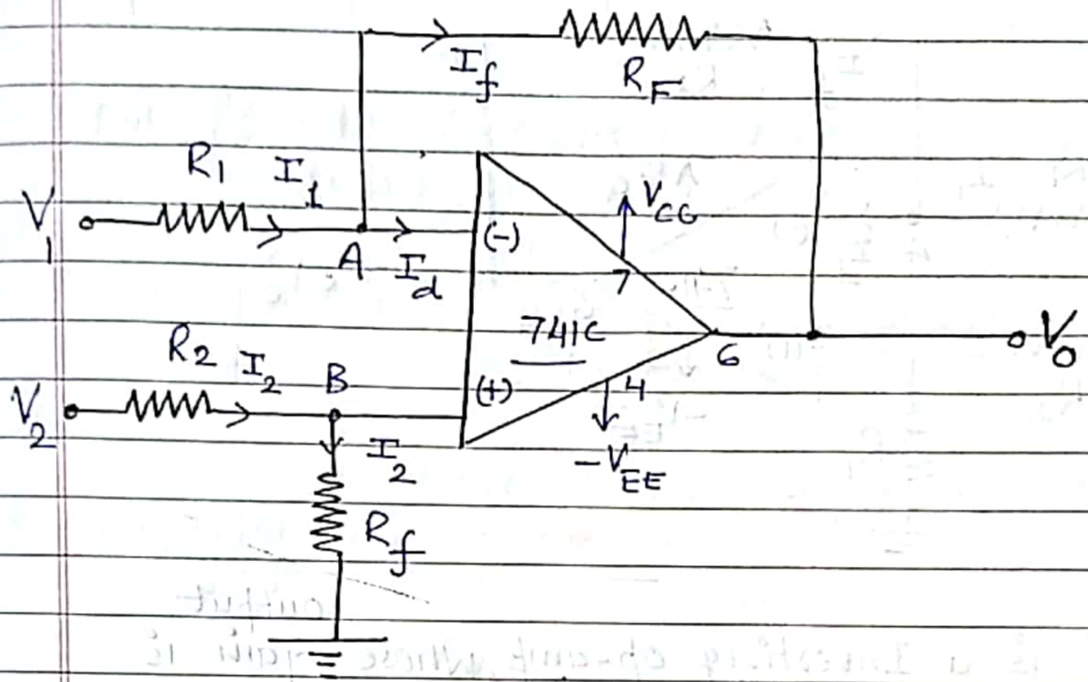
Q NO1) Draw a neat ckt diagram OF 3 input Non-Inverting summing Amplifier and obtain the expression for its output voltage.

Hint :- Same As Above, but in 3rd last step, Assume

$$\boxed{R_1=R_2=R_3=R \text{ and } R_F=2R}$$

Ans :- $\boxed{V_0=V_1+V_2+V_3}$

op-amp As subtractor :- or Diffrence Amplifier :-



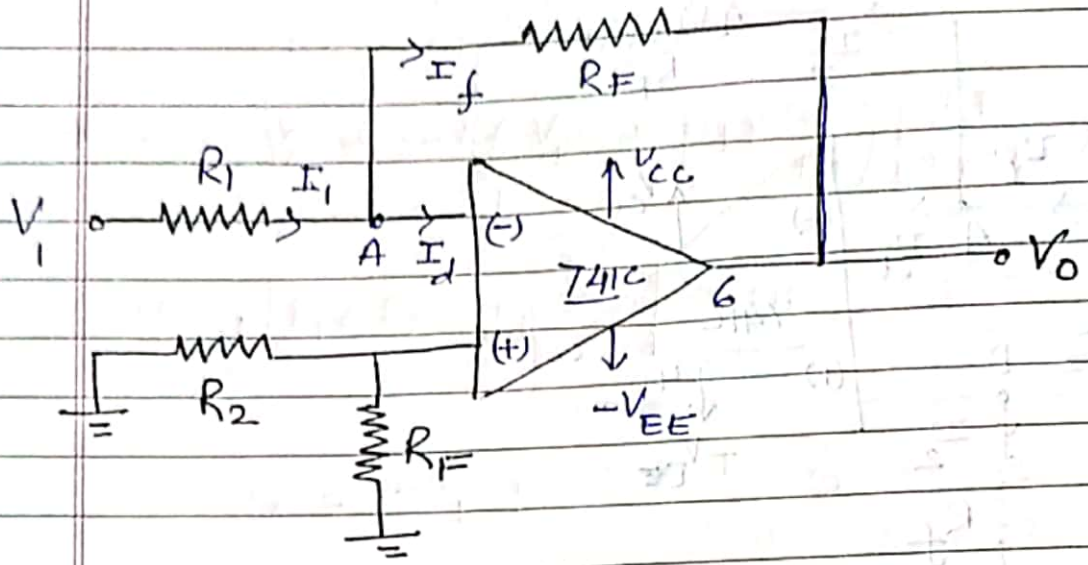
→ To Find relation between Input and output, we Apply superposition theorm.

→ Let V_{01} be the output, when Input V_1 is acting. Assuming V_2 to be zero.

→ Let V_{02} be the output, when Input V_2 is acting Assuming V_1 to be zero.

P.T.O

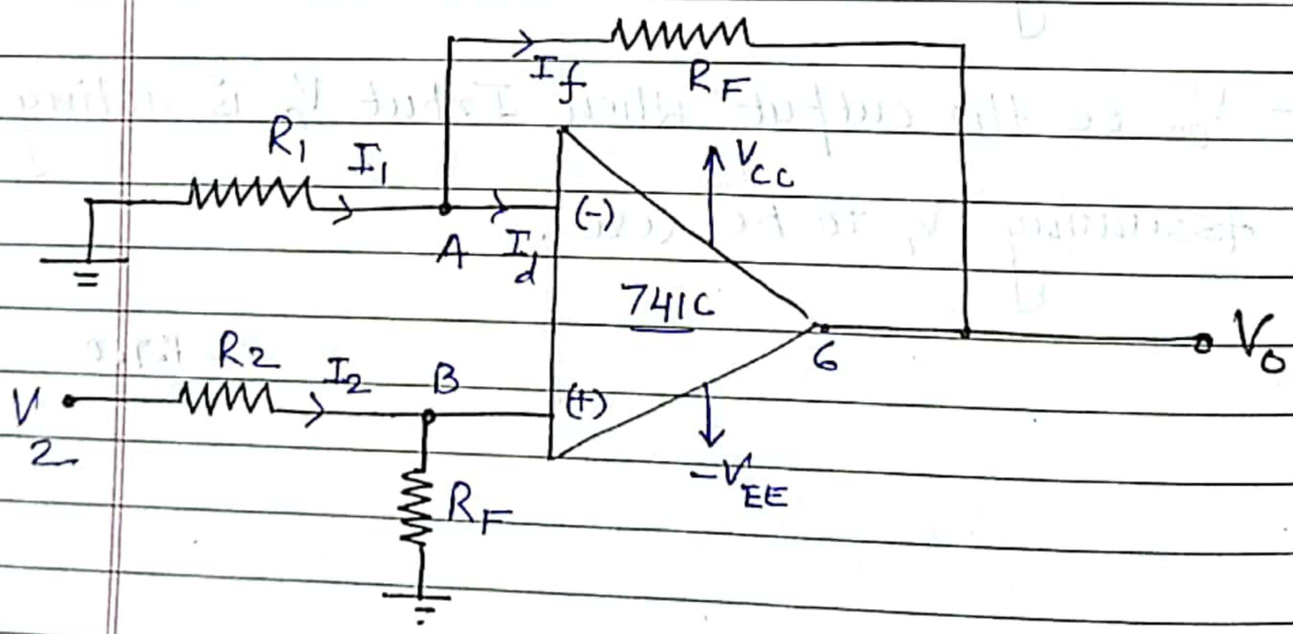
Considering Input V_1 and V_2 zero :-



→ This is a Inverting op-amp, whose output is given by -

$$\boxed{V_{01} = -\frac{R_F}{R_1} V_1}$$

Considering Input V_2 and V_1 zero :-



* Now we need to find V_B. Apply Voltage Divider Rule:-

$$\boxed{V_B = \frac{R_F}{R_2+R_F} V_2}$$

→ Now Apply KCL at node 1 :-

$$I_1 = I_d + I_f$$

But $I_d = 0$, b'coz For an ideal op-amp $r_i = \infty$
$\therefore I_d = 0$

$$I_1 = I_f$$

$$\frac{0 - V_A}{R_1} = \frac{V_A - V_{02}}{R_f}$$

$$\frac{-V_A}{R_1} = \frac{V_A}{R_f} - \frac{V_{02}}{R_f} \Rightarrow V_{02} = \left[1 + \frac{R_f}{R_1}\right] V_A$$

but $\boxed{V_A = V_B}$, From Virtual Ground Concept

$$\therefore \boxed{V_{02} = \left[1 + \frac{R_F}{R_1}\right] V_B}$$, put the Value of V_B.

$$\Rightarrow \boxed{V_{02} = \left(1 + \frac{R_F}{R_1}\right)\left(\frac{R_F}{R_2+R_F}\right) V_2}$$

Hence using superposition theorm :-

$$V_0 = V_{01} + V_{02}$$

$$V_0 = -\frac{R_f}{R_1} V_1 + \left(1 + \frac{R_F}{R_1}\right)\left(\frac{R_F}{R_F + R_2}\right) V_2$$

if $\boxed{R_1 = R_2 = R_F = R}$ then

$$V_0 = -V_1 + 2 \times \frac{1}{2} V_2$$

$$\boxed{V_0 = V_2 - V_1}$$

Thus o/p voltage is equal to the diffrence of two input voltages, thus it acts as subtractor.