Transistor As an Amplifier :

→ The main utility of a transistor lies in its ability of amplifying weak signals. The weak signal is applied at the input terminals and the amplified output is obtained across the output terminals.

→ A transistor alone cannot perform the function of amplification and some passive components such as resistors, capacitors and biasing voltage is to be connected.

→ Common emitter (CE) configuration, because of its high current, voltage & power gains, is much suited for most of the amplifier circuits.

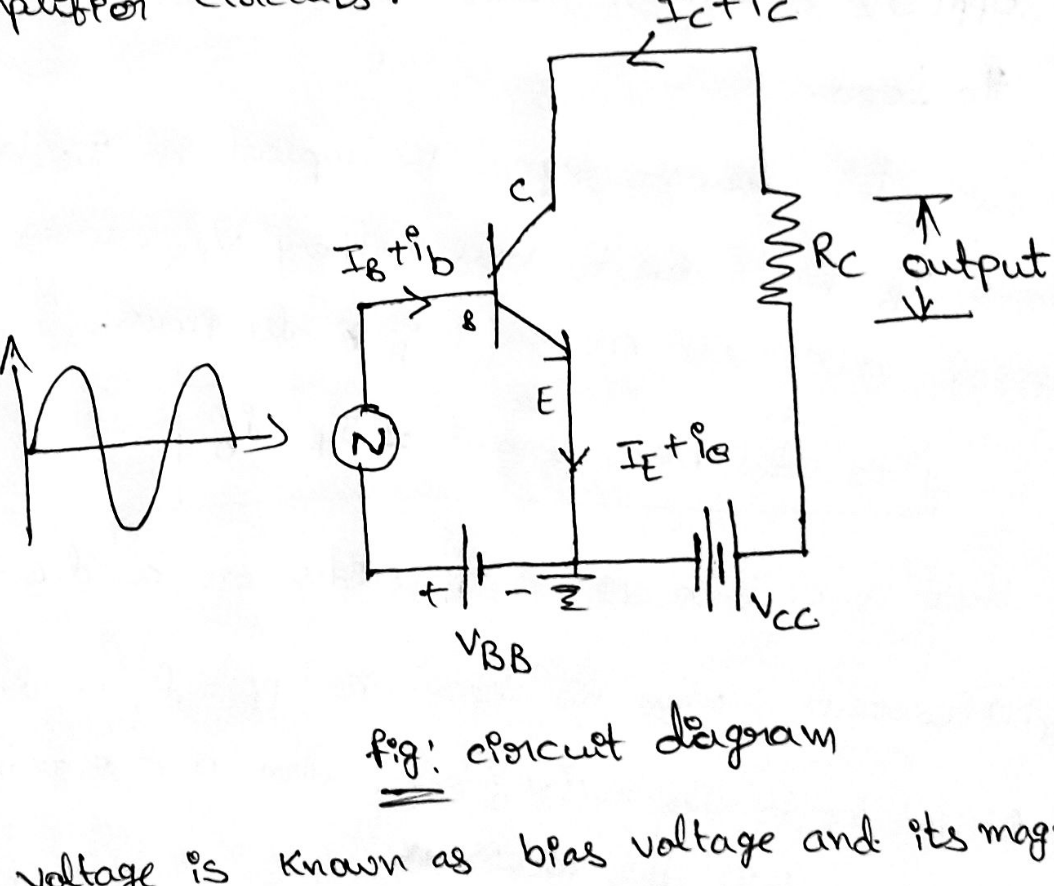


fig: circuit diagram

→ Applied D.C voltage is known as bias voltage and its magnitude is such that it always keeps the emitter-base junction forward biased regardless of the polarity of the signal source.

Various currents: In a transistor amplifier, there is a D.C bias as well as A.C signal. Therefore, a transistor amplifier carries direct current as well as alternating current.

Operation:

① During positive half cycle of the input signal, the forward bias across the emitter-base junction is increased. Therefore, more electrons flow from the n-type emitter to the collector via the base. This causes an increase in collector current. The increased collector current causes a greater voltage drop across the collector load resistance R_C.

② During negative half-cycle of the signal, the forward bias across emitter-base junction is decreased. Therefore, collector current decreases. This results in the decreased output voltage (in the opposite direction). Hence amplified output is obtained across the load.

Base current: when no signal is applied in the base, a D.C base current I_B flows due to bias battery V_{BB}. when a.c signal is applied, a.c base current i_b is also flows.

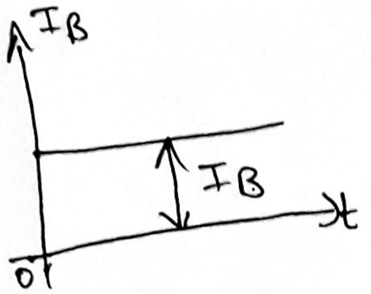
$$\boxed{\text{the total base current} = I_B + i_b}$$

Note that a.c base current i_b rides on a d.c base current I_B.

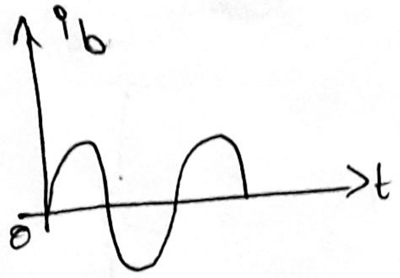
Collector current: when no signal is applied, a d.c collector current I_C flows due to bias battery V_{BB}. when a.c signal is applied, a.c collector current i_c also flows.

$$\boxed{\text{the total collector current} = I_C + i_c}$$

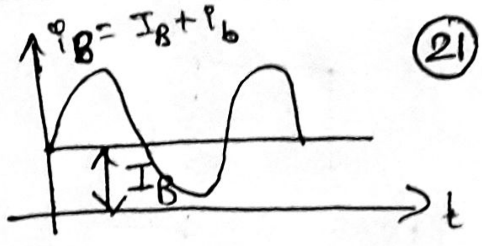
Voltage gain: $A_V = \dfrac{\text{output voltage}}{\text{input voltage}} = \dfrac{\Delta V_{CE}}{\Delta V_{BE}}$



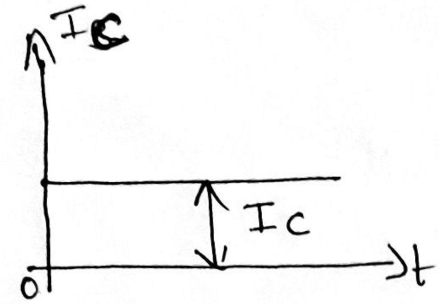
(i) DC base current



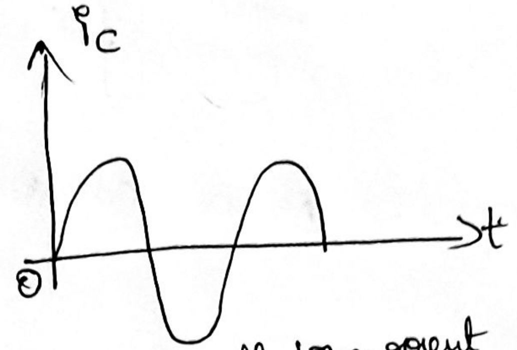
(ii) A.C Base current



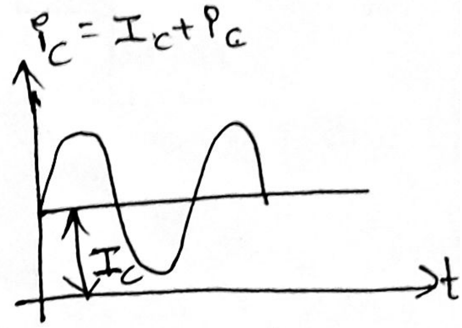
(iii) total Base current i_B.



(i) DC collector current



(ii) A.C collector current



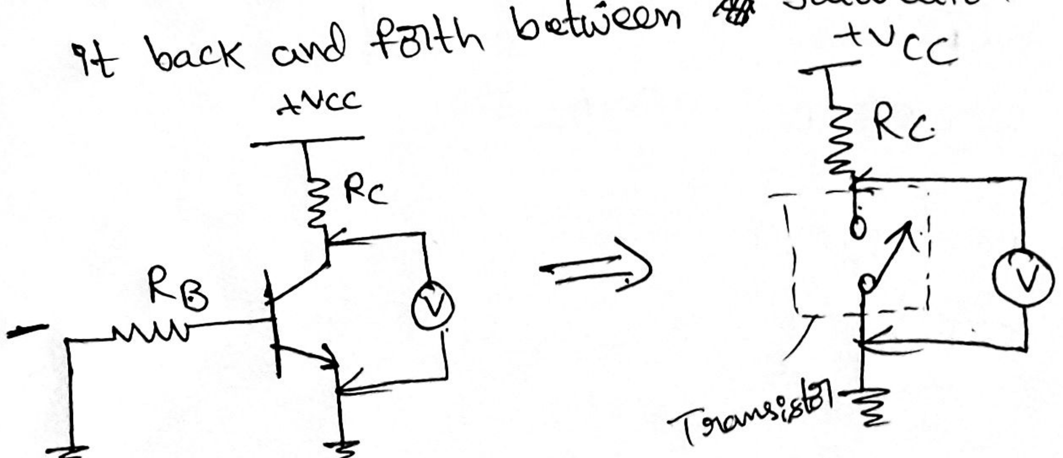
(iii) total collector current i_C.

Transistor As a switch :

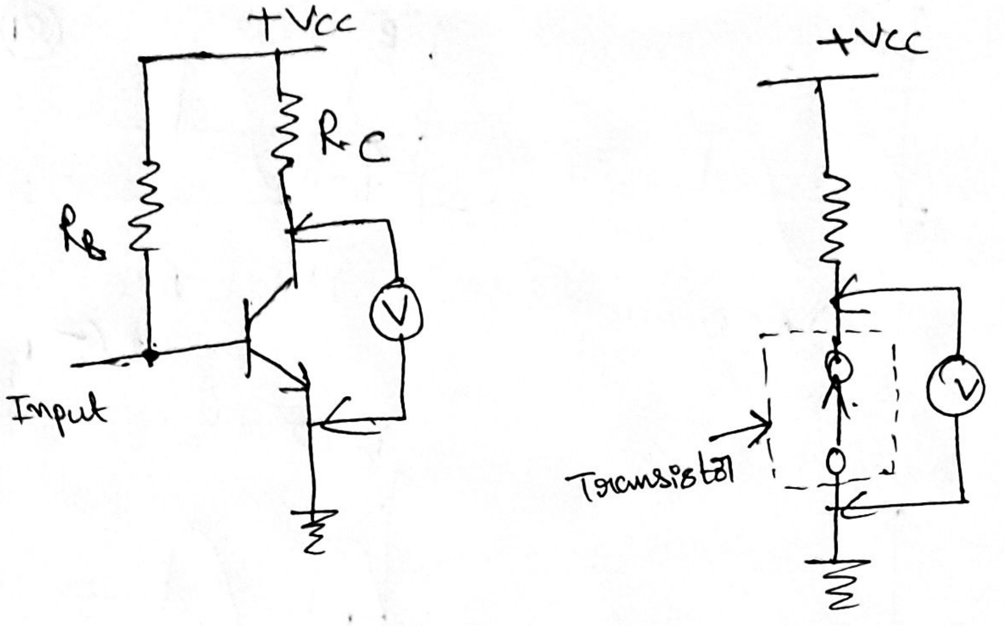
→ As we know that diode behaves like a switch. when diode is forward biased, it conducts current easily and behaves like a closed switch.

→ when diode is reverse biased, it practically conducts no current and behaves like an open switch.

→ A transistor can also be used as a switch by driving it back and forth between saturation and cut off.



(i) Transistor as open switch



Transistor AS a closed switch

Note:

→ Transistor works as an amplifier in Active region.

→ Transistor works as a closed switch in saturation region.

→ Transistor works as a open switch in cutoff region.

① In a common base connection, current amplification factor is 0.9. If the emitter current is 1mA, determine the base current.

Sol:

$$\alpha = \frac{\Delta I_C}{\Delta I_E} = 0.9 \qquad \because I_E = I_B + I_C$$

$$I_B = I_E - I_C$$

$$0.9 = \frac{I_C}{1mA}$$

$$I_C = 0.9 \times 1mA = 0.9mA$$

$$I_B = 1mA - 0.9\,mA$$

$$\boxed{I_B = 0.1mA}$$

(2) for a certain transistor, $I_B = 20\mu A$, $I_C = 2mA$ & $\beta = 80$ calculate I_{CBO}?

sol: $I_C = \alpha . I_E + I_{CBO}$ $\quad$ $I_C = \beta I_B + I_{CEO}$

$$\alpha = \frac{\beta}{\beta+1} = \frac{80}{80+1} = 0.988$$

$$2mA = 80 \times 20\mu A + I_{CEO}$$

$$I_{CEO} = 2\times10^{-3} - 80\times20\times10^{-6}$$

$$I_{CEO} = 4\times10^{-4} = 0.4mA$$

$$I_{CEO} = \frac{I_{CBO}}{1-\alpha}$$

$$0.4mA = \frac{I_{CBO}}{1-0.988}$$

$$I_{CBO} = \frac{0.4\times10^{-3}}{0.0123} = 4.8\times10^{-3} = 0.0048mA$$

(3) A transistor has $\beta = 100$. If the collector current is $40mA$. find the value of emitter current?

sol: $\beta = 100$ & $I_C = 40mA$

$$\beta = \frac{I_C}{I_B} = \frac{40}{I_B}$$

$$100 = \frac{40}{I_B}$$

$$I_B = \frac{4\cancel{0}}{10\cancel{0}} = 0.4mA$$

$$I_E = I_B + I_C = 40.4mA$$

(4) If a transistor has a α of 0.97, find the value of β. If $\beta = 200$, find the value of α.

sol: $\alpha = 0.97$, $\beta = \frac{\alpha}{1-\alpha} = \frac{0.97}{1-0.97} = 32.33$

$\beta = 200$

$$\alpha = \frac{\beta}{\beta+1} = \frac{200}{200+1} = 0.995.$$

(5) A N-P-N transistor with $\alpha = 0.98$ is operated in the CB configuration. If the emitter current is 3mA and reverse saturation current is 10μA. what are the base current and collector current?

Sol: Given data:

$\alpha = 0.98$ $\quad$ $I_B = ?$

$I_E = 3mA$ $\quad$ $I_C = ?$

$I_{CBO} = 10\mu A$

$$I_C = \alpha I_E + I_{CBO} = 0.98 \times 3 \times 10^{-3} + 10 \times 10^{-6}$$
$$= 2.95mA$$

$$I_B = I_E - I_C = 3 - 2.95 = 0.05mA$$

(6) Amplifier with internal emitter resistance of 20ohms and external collector resistance of 1200 ohms. Find the voltage gain?

Sol: Given data: $R_E = 20\Omega$

$R_C = 1200\Omega$

$$\text{Voltage gain } A_V = \alpha \cdot \frac{R_C}{R_E} = 0.99 \times \frac{\cancel{1200}^{60}}{\cancel{20}}$$
$$= 59.4$$

$$\boxed{A_V = 60}$$

(7) In an NPN transistor, $\alpha = 0.995$, $I_E = 10mA$ and $I_{CO} = 0.5\mu A$. Determine the values of I_C, I_B, β and I_{CEO}.

Sol: Given data

$$\alpha = 0.995$$
$$I_E = 10mA$$
$$I_{CBO} = 0.5\mu A$$

$$I_C = \alpha I_E + I_{CBO}$$
$$= 0.995 \times 10 \times 10^{-3} + 0.5 \times 10^{-6}$$
$$I_C = 9.9505 \text{ mA}$$

Base current $I_B = I_E - I_C = 10 - 9.9505$
$= 0.0495 mA$
$= 49.5 \mu A$.

current gain factor, $\beta = \frac{\alpha}{1-\alpha} = \frac{0.995}{1-0.995}$

$$\beta = 199$$

leakage current $I_{CEO} = \frac{I_{CBO}}{1-\alpha} = \frac{0.5 \times 10^{-6}}{1-0.995}$
$= \frac{0.5 \times 10^{-6}}{5 \times 10^{-3}} = 0.1 \times 10^{-3}$
$= 1 \times 10^{-4}$

$$\boxed{I_{CEO} = 100\mu A}$$

Early effect and Base width modulation:

→ In active region, Emitter Base junction is forward biased & collector Base junction is reverse biased, so the barrier width at Emitter base junction is negligible in comparision with the barrier width at CB junction.

→ As the voltage applied across the junction increases, the transition region penetrates deeper into the collector & base.

→ Since the doping in the base is substantially smaller than that of collector, the penetration of the depletion layer into the base is much larger than that into collector region. Hence the collector depletion region is neglected and all the immobile charge is indicated in the base region.

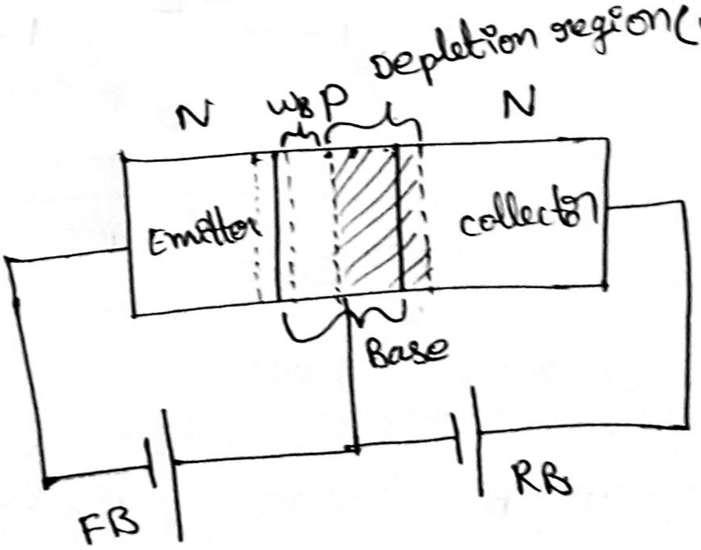
→ This modulation of the effective base width by the collector voltage V_{CB} is known as the Early effect. $V_{CB} = \dfrac{e N_D W^2}{2\epsilon}$

Three consequences:

① There is less chance for recombination with in the base region. Hence α & β increase in CB junction voltage.

② The concentration gradient of ~~majority~~ minority carriers is increased with in the base, and consequently, emitter current increases.

③ For extremely large voltages, W_B may be reduced to zero causing voltage breakdown. This phenomenon is known as punch through.



Operational Amplifier :

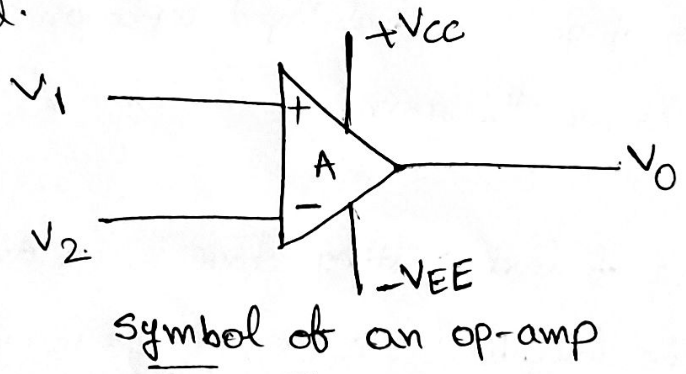
→ An operational Amplifier, abbreviated as op-amp, is basically a multistage, very high gain, direct coupled, negative feedback amplifier that provides a stabilized voltage gain.

→ op-amp amplifies signals having frequency ranging from 0Hz to 1MHz. and op-amp amplifies analog signal as well as digital signal.

→ op-amp used in different circuits such as phase shifting, voltage regulation, oscillator circuits, comparators, Analog to digital coverters, and digital to analog coverters.

→ The op-amp is a complete amplifier having the advantages of an I.C such as low cost, small size, high reliability and high voltage gain, current gain.

→ An op-amp refered to as the IC 741 has become an Industry standard.



Symbol of an op-amp

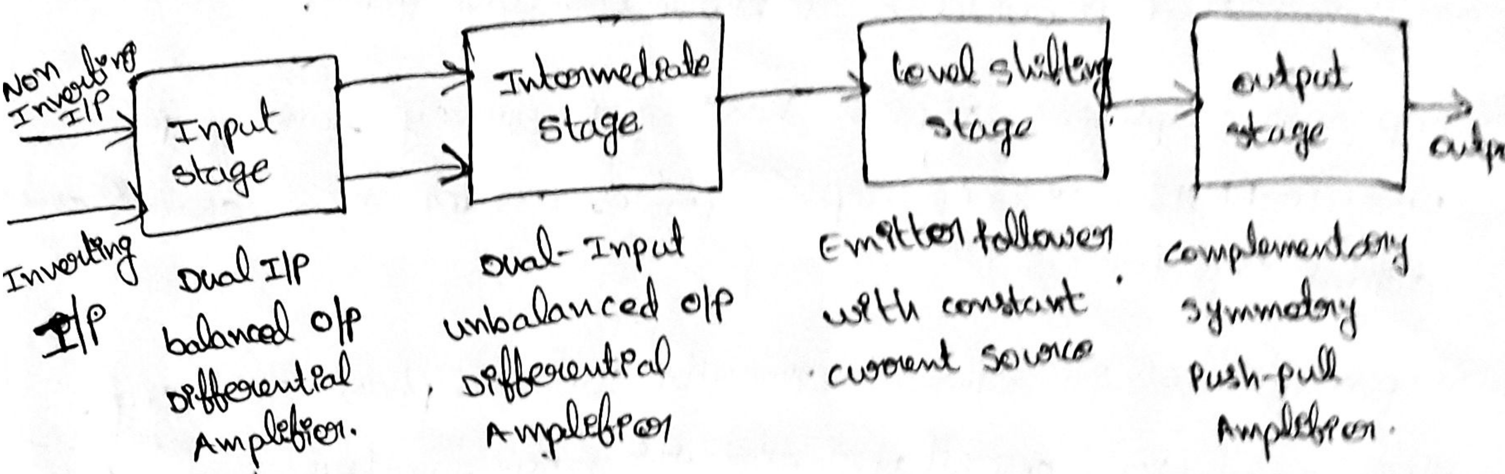
→ op-amp has two inputs and single output. non-inverting input and inverting input represented with + and − signs respectively.

→ A is the voltage gain.

$$\boxed{\text{output voltage } V_0 = A(V_1 - V_2)}$$

Block Diagram of a Typical operational Amplifier:

→ An operational amplifier being a multistage amplifier, consists of some basic building blocks as shown in block diagram.



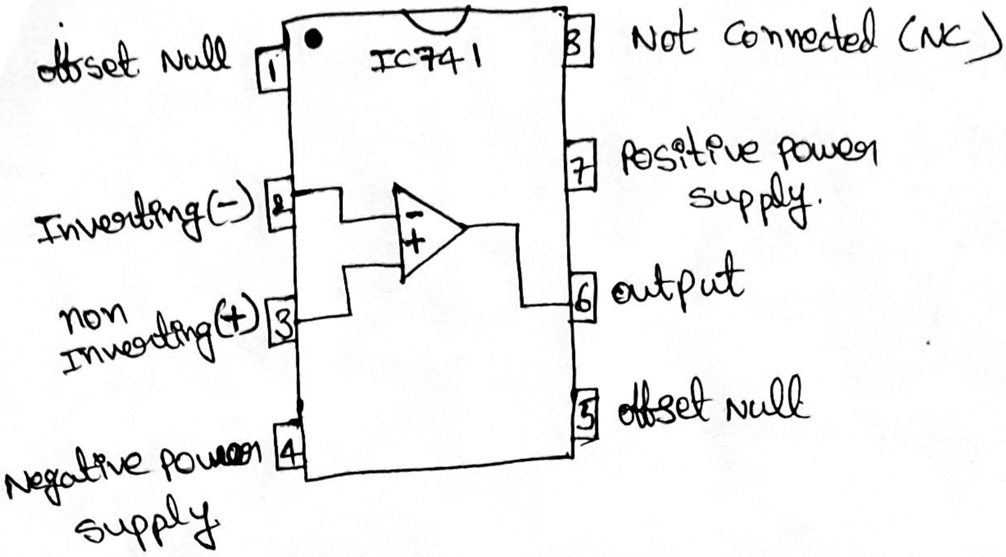
Input stage: The input stage is a dual input, balanced output differential amplifier. The two i/p's are inverting and non-inverting input terminals. This stage provides most of the voltage gain of the op Amp and decides the value of Input resistance R_i

Intermediate stage: This is usually another differential amplifier. The i/p stage drives the stage. The is stage is a dual input un-balanced output differential amplifier to increase the gain.

level shifting stage: the input of level shifting stage is an amplified signal with some non-zero dc level. level shifting stage is used to bring dc level to zero volts with respect to ground.

output stage: The final stage is usually a push-pull complementary amplifier. It increases the magnitude of voltage and raises the current supplying capability of OP-AMP. It also ensures that the output resistance of OPAmp is low.

Pin diagram of IC 741 operational Amplifier:



Ideal operational Amplifier:

→ The characteristics of an ideal op-amp are as follows;

1. Infinite input resistance, R_i = infinity
2. zero output resistance, $R_o = 0$
3. Infinite voltage gain, A_V = infinity.
4. Infinite Bandwidth, BW = infinity
5. Infinite common-mode rejection ratio (CMRR)
6. Infinite slew-rate
7. zero offset, i.e., when $V_1 = V_2$, $V_0 = 0$
8. characteristics do not drift with temperature.

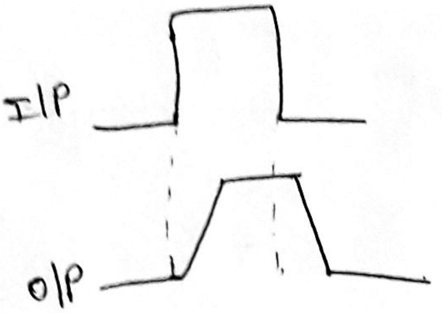
→ CMRR is defined as the ratio of differential voltage gain to common mode voltage gain.

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

→ ~~CMM~~

→ CMRR in dB $= 20 \log_{10} \frac{A_d}{A_{cm}}$

Slew rate: The slew rate of an op-amp is the rate of change in the output voltage caused by a step change on the input.



effect of op-amp slewrate.

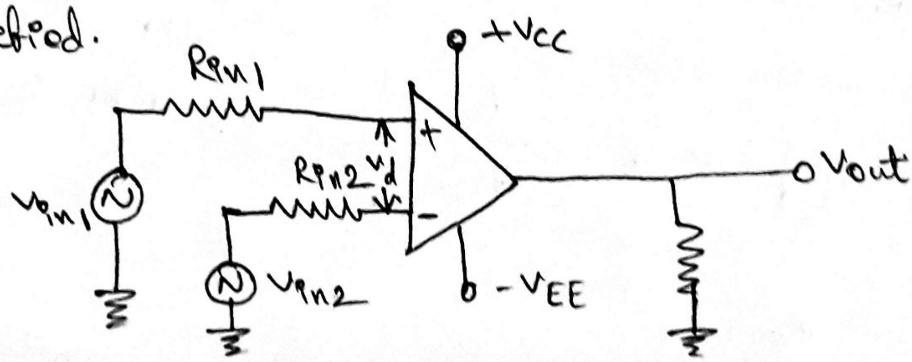
Open-loop op-Amp Configurations:

→ open-loop means that there is no connection between input and output terminals either direct (or) via another network. It means that output signal is not fed back in any form as part of the input signal.

→ An op-amp in open-loop configuration acts as a high gain amplifier. The three open loop op-amp configurations are:

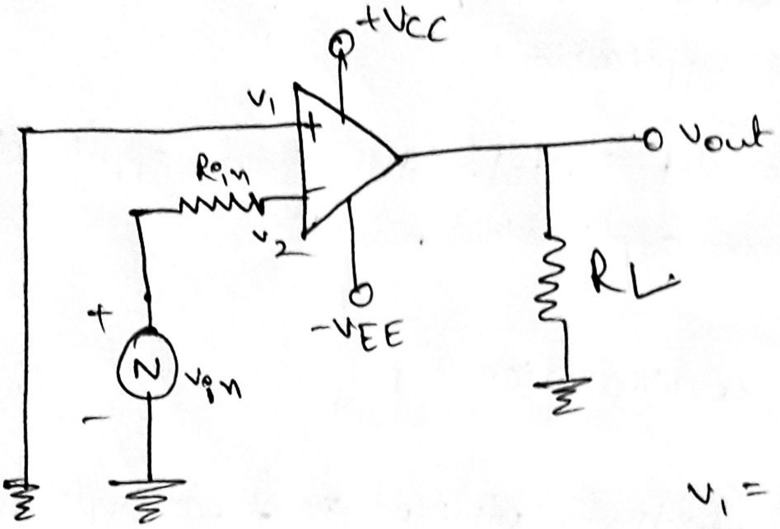
1. Differential amplifier.
2. Inverting amplifier.
3. Non-Inverting amplifier.

Differential Amplifier: In this circuit, inputs are applied to both the inverting and noninverting terminals. The difference between two input signals is amplified.



$$\boxed{V_{out} = A(V_{in1} - V_{in2})}$$

Inverting Amplifier: The input signal is applied to the inverting (−) input terminal & non-inverting (+) input terminal is grounded.



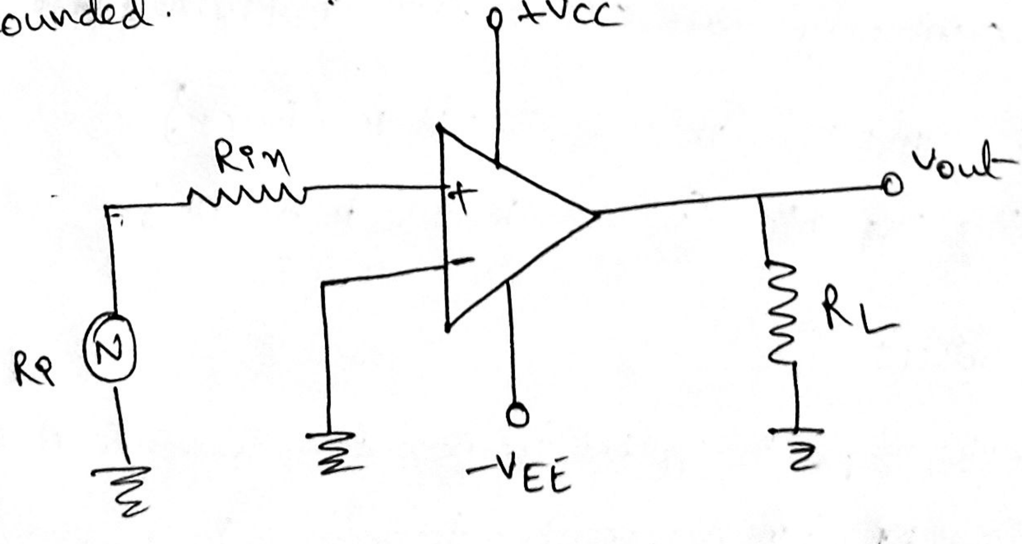
$V_1 = 0$

$V_2 = V_{in}$

$$V_{out} = A(V_1 - V_2)$$

$$\boxed{V_{out} = -A V_{in}}$$

Non-inverting Amplifier: The input signal is applied to the non-inverting (+) input terminal & inverting (−) input terminal is grounded.



$$\boxed{V_{out} = A V_{in}}$$

Limitations of open-loop opamp

→ The open loop gain of opamp is not a constant and varies with changing temperature & power supply.

→ Band width of openloop opamp is very small, this makes it is unsuitable for AC applications.

→ openloop op-amp is not suitable for linear applications and suitable for non linear applications.

closed loop opamp configuration

→ The opamp can be effectively utilized in linear applications by providing feedback from the output to the input either directly (or) via another network.

→ If the signal feedback is out of phase by 180° with respect to the input, then the feedback is referred as negative feedback.

→ If the signal feedback is in phase with input, then the f/b is referred as positive feedback.

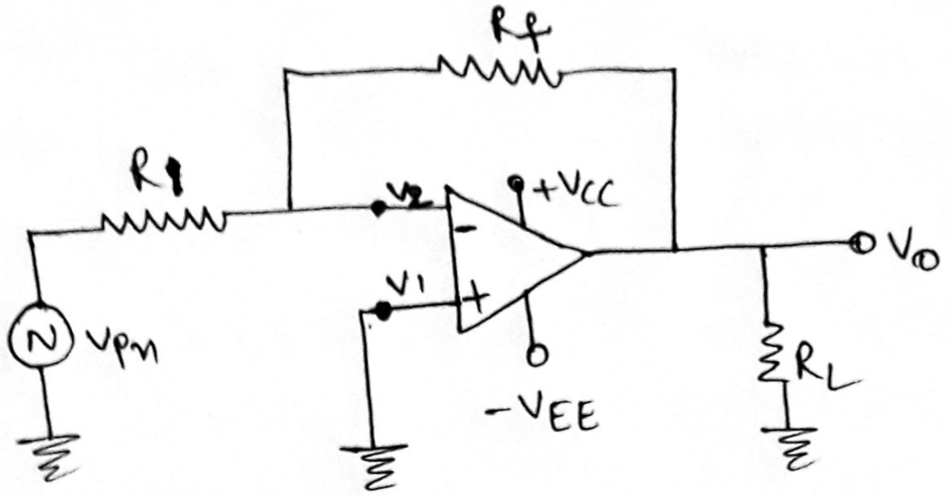
→ The most commonly used closed loop configurations are

(i) inverting amplifier (voltage shunt feedback)

(ii) non inverting amplifier (voltage series feedback)

Inverting Amplifier:

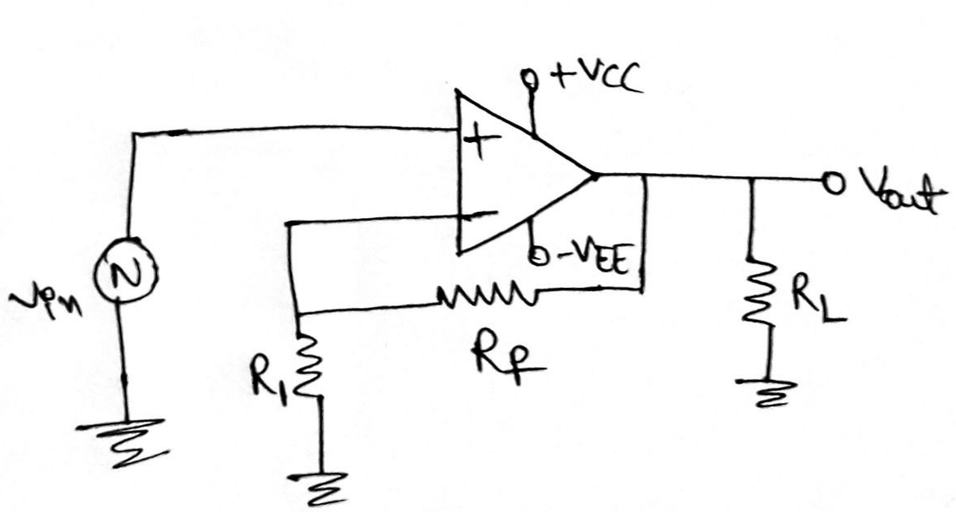
→ In this circuit, Input is applied to inverting terminal of op-amp via the resistor R_1 & non inverting terminal is grounded. feed back resistor R_f is connected in between output terminal and inverting terminal.



$$\boxed{\text{voltage gain } A_f = -\frac{R_f}{R_1}}$$

~~Not~~ **Non-inverting Amplifier :**

-> In this circuit, input is applied to non inverting terminal of op-amp & inverting terminal is grounded via resistor R_1 feed back resistor is connected in between output terminal and inverting terminal.



$$\boxed{\text{Voltage gain } A_f = 1 + \frac{R_f}{R_1}}$$