BIPOLAR JUNCTION TRANSISTOR (BJT).

* A semi-conductor device that can amplify electronic signals as radio and television signals

→ Advantages of transistor :

i) Low operating voltage
ii) Higher efficiency.
iii) Small size & ruggedness.
iv) Does not require any filament power.

Olden days
Vaccum tubes.

→ Transistor is a 3 terminal device :

i) Base
ii) Emitter
iii) Collector.

→ It can be operated in 3 config.

* Common emitter
* Common base
* Common collector.

* According to config. , it can be used for voltage or current amplification.

* The input signal of small amplitude is applied at the base to get the magnified output signal at collector.

* The amplification in the transistor is achieved by passing input current signal from a regio of low resistance to high resistance

→ Two types of transistor :

* Unipolar juncⁿ transistor [UJT]
  ↳ Current conduction is only due to one type of carriers

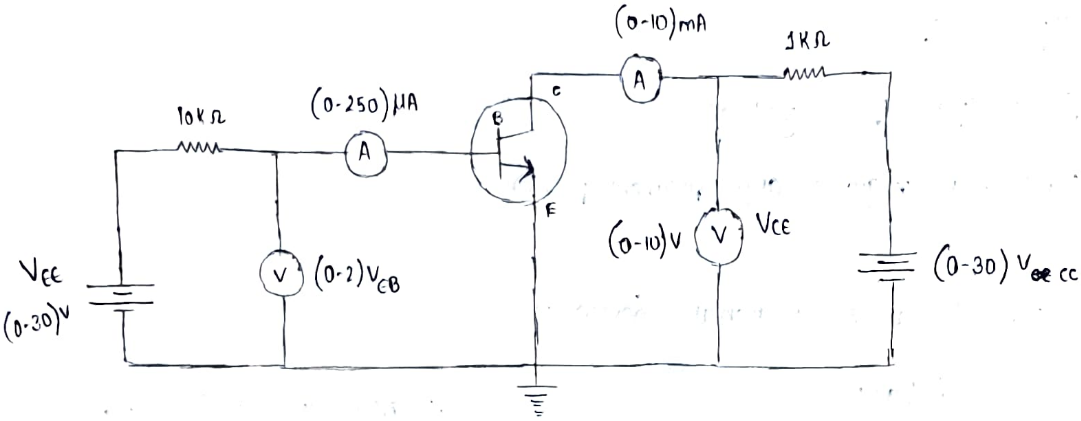
* Bipolar juncⁿ transistor [B.J.T]
  ↳ Conduction due to both holes & e^-.

→ Two types of BJT → NPN Type
→ PNP Type

→ BIASED TRANSISTOR :

The transistor works in one of the three regions :

Region	E-B Junc^n	C-B Junc^n
Active	Forward	Reverse
Cut-off	Reverse	Reverse
Saturation	Forward	Forward

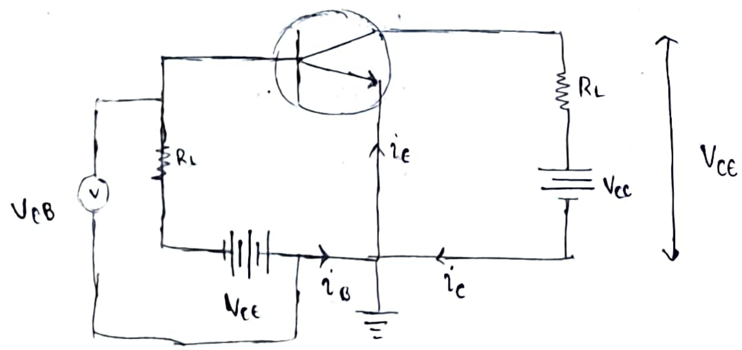


V_{EE} → const. , V_{CC} → const

V_{EB} → varied & corresponding readings of base current are noted [I_B].

I_B → const

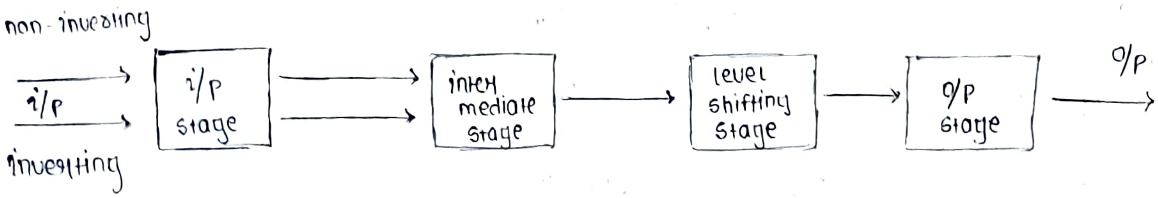
V_{CE} → varied & corresponding readings of collector current are noted (I_C).

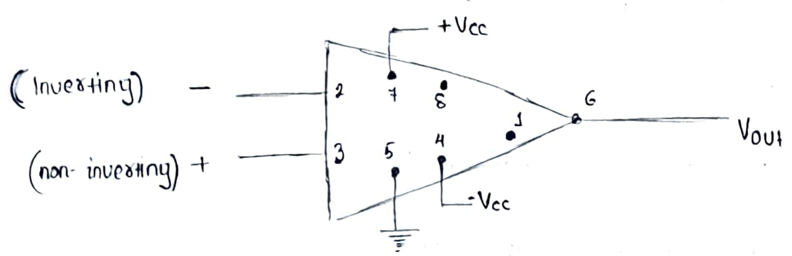


OPERATIONAL AMPLIFIER [OP AMP]

* An operational amplifier is a direct coupled, high gain, amplifier with feedback. It is commonly known as 'opamp'. This is called so because of its ability to perform mathematical operations such as addition, int, diff, etc.

→ Block diag. of opamp :





opamp in diagram

* Input stage :

It is a dual i/p, double ended o/p differential amplifier.

It has highest gain

* Intermediate stage :

It is a dual i/p, single ended o/p differential amplifier.

It also provides some amplification

* Level shifting stage :

It is an emitter follower circuit. It shifts the o/p of intermediate stage to zero dc voltage wrt ground.

* Output stage :

It is a push pull complementary amplifier to raise the current supplying capacity, to increase O/P voltage ~~shunt~~ shunt and to provide low O/P resistance

→ Properties of an ideal opamp :

* open loop voltage gain is infinity ($A_v = \infty$)
* A large voltage gain when operating without feedback
* Input impedence is infinity ($Z_{in} = \infty$)
* O/P impedence is zero ($Z_{out} = 0$)
* Bandwidth is infinity ($BW = \infty$)
* Common mode rejection ratio is infinity ($CMRR = \infty$)
* Slew rate is ∞
* Perfect balance is $V_0 = 0$, when $V_1 = V_2$
* Characteristic do not vary with temperature.
* Voltage gain remains constant over a wide freq. range.

→ Slew rate of opamp :

It is defined as the max^m rate of change of O/P voltage/~~unit~~ per unit of time. It is expressed in volts / microsecond.

$$SR = \left(\frac{dV_0}{dt}\right)_{max} \; V/\mu sec.$$

→ Open loop gain of opamp :

open loop gain (A_v) of an opamp is the ratio of O/P voltage (V_0) to the differential I/P voltage (V_{id}) without feed back.

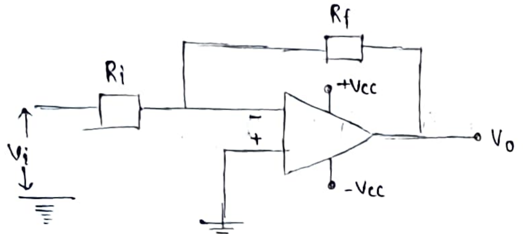
$$A_v = \frac{V_0}{V_{id}}$$

→ CMRR of an opamp :

It is a measure of ability of opamp to suppress the common mode signals. It is defined as ratio of differential mode gain to the common mode gain

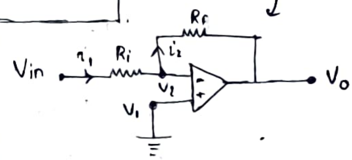
$$CMRR = \frac{\text{Diff. mode gain}}{\text{Common mode gain}} = \frac{A_d}{A_{cm}}$$

→ Circuit diagram of an inverting amplifier and its o/p expression.



$$V_o = \frac{-R_f}{R_i} \cdot V_i$$

no i pass through opamp due to high resisiance value.



∴ KCL : $i_1 = i_2$

$$\frac{V_{in} - V_2}{R_i} = \frac{V_2 - V_o}{R_f}$$

$V_1 = V_2 = 0$ (Due to ground V_1 is zero, due to opamp V_2 is zero)

$$\frac{V_i}{R_i} = -\frac{V_o}{R_f}$$

$$\frac{V_o}{V_i} = -\frac{R_f}{R_1}$$

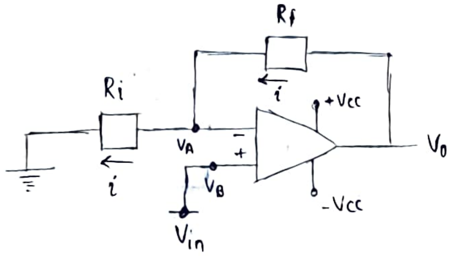
Gain of inverting amplifier :

$$\text{Gain } A_{vf} = \frac{V_o}{V_i} = -\frac{R_f}{R_i}$$

where R_f = feed back resistance

R_i = i/p resistance

→ Circuit diag. of a non-inverting amplifier :



$$V_o = \left(1 + \frac{R_f}{R_i}\right) \cdot V_i$$

Gain expression : $A_{vf} = \frac{V_o}{V_i} = 1 + \frac{R_f}{R_i}$

$V_{in} = V_A = V_B$, $i = \frac{V_o - V_A}{R_F} = \frac{V_o - V_{in}}{R_F}$

$i = \frac{V_A - 0}{R_i}$

$\therefore i = i$

$$\frac{V_o}{R_f} - \frac{V_{in}}{R_f} = \frac{V_{in}}{R_i} \Rightarrow \frac{V_o}{R_f} = V_{in}\left[\frac{1}{R_f} + \frac{1}{R_i}\right] \Rightarrow V_o = \left[1 + \frac{R_f}{R_1}\right] V_{in}$$

Inverting	Non - inverting
* input voltage is applied to inverting terminal of opamp through R_i	* Input voltage is directly applied to non- inverting terminal of opamp.
* Voltage shunt feedback in used	* Voltage series feedback is used
* The o/p is phase reversed.	* The o/p is inphase with the i/p
* Gain : $A_{vf} = -\frac{R_f}{R_i}$	* Gain : $A_{vf} = \left(1+\frac{R_f}{R_i}\right)$

⇒ Draw the ckt diagram of non- inverting amplifier with a feedback gain of 30

Soln

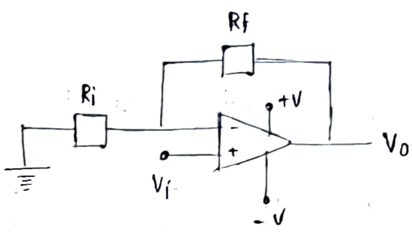
$A_{vf} = 30$

$1+\frac{R_f}{R_i} = 30$

$R_f = 29 R_i$

Assume, $R_1 = 10\ K\Omega$

$R_f = 290\ K\Omega$.



⇒ Design a ckt using opamp to get an o/p of 6V from an i/p of 2V

Soln

$V_o = 6V, \quad V_i = 2V$.

$R_f = ?$

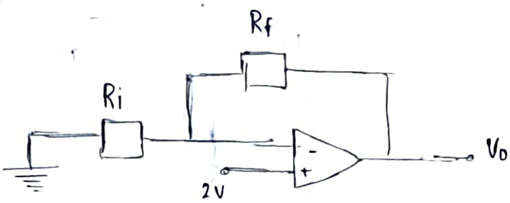
for non - inverting amplifier.

$V_o = \left(1+\frac{R_f}{R_i}\right)\cdot V_i$

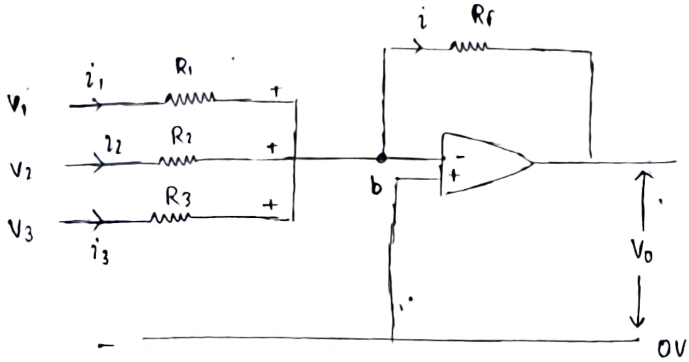
$R_f = 2R_i$

Assume, $R_i = 10\ K\Omega$

$R_f = 20\ K\Omega$



→ ADDER / SUMMER CKt using opamp :



* Calculations :

$$i_1 = \frac{V_1}{R_1}, \quad i_2 = \frac{V_2}{R_2}, \quad i_3 = \frac{V_3}{R_3} \quad \& \quad i = -\frac{V_0}{R_f}$$

At KCL at point 'b',

$$i_1 + i_2 + i_3 = i$$

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

if $R_1 = R_2 = R_3 = R$.

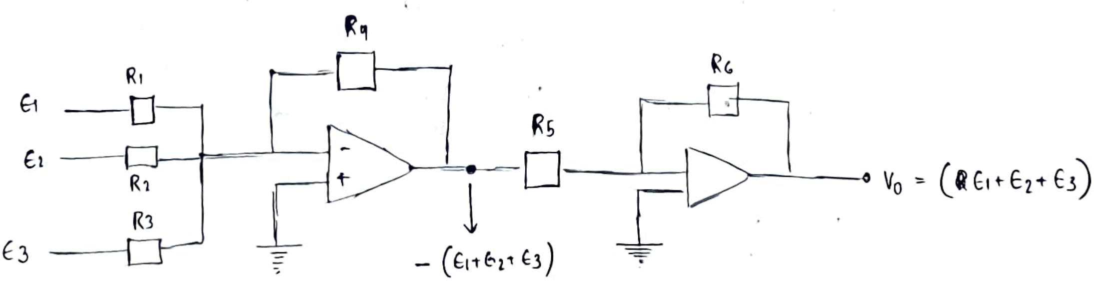
$$\Rightarrow V_0 = -\frac{R_f}{R}\left[V_1 + V_2 + V_3\right]$$

$$\Rightarrow V_0 = -K\left[V_1 + V_2 + V_3\right]$$

↳ Thus the voltages are added and amplified.

⇛ Draw ckt diag. using opamp to get o/p vol of $E_1 + E_2 + E_3$.

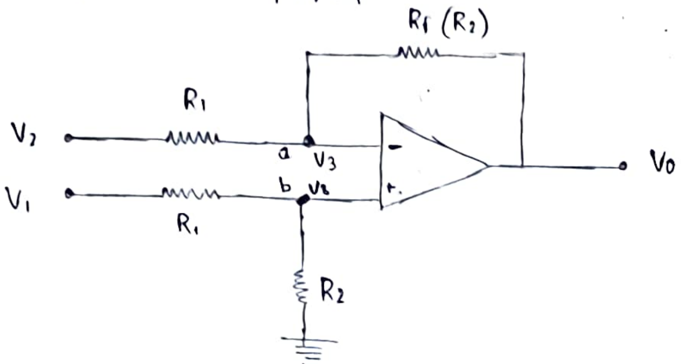
Solⁿ



Condⁿ : $R_1 = R_2 = R_3 = R_4 = R_5 = R_6 = R$

→ DIFFERENTIAL AMPLIFIER : [Deriving V_o eqⁿ interms of I/P's]

A ckt that amplifies the diff b/w two signal is called difference or differential amplifier.



The eqⁿ at 'a' is : $\frac{V_3 - V_2}{R_1} + \frac{V_3 - V_0}{R_2} = 0 \longrightarrow ①$

The eqⁿ at 'b' : $\frac{V_3 - V_1}{R_1} + \frac{V_3}{R_2} = 0 \longrightarrow ②$

② − ① ⇒ $V_o = \frac{R_2}{R_1}[V_1 - V_2]$ } Imp derivation. ↓ down

where $R_2 = R_f$ → feedback resistor.

* Such a ckt is very useful in detecting very small difference in signals, since the gain R_2/R_1 can be chosen to be very large

for ex : If $R_2 = 100 R_1$, then a small diff. $(V_1 - V_2)$ is amplified 100 times.

① → $\frac{V_3}{R_1} + \frac{V_3}{R_2} - \frac{V_2}{R_1} - \frac{V_o}{R_2} = 0$,

⇒ $V_3\left[\frac{1}{R_1} + \frac{1}{R_2}\right] - \frac{V_2}{R_1} = \frac{V_o}{R_2}$

If R_1 is not same in V_2 & V_1 then use derivation to solve

② → $\frac{V_3}{R_1} - \frac{V_1}{R_1} + \frac{V_3}{R_2} = 0$

⇒ $V_3\left[\frac{1}{R_1} + \frac{1}{R_2}\right] = \frac{V_1}{R_1}$

∴ ① - ② = $-\frac{V_2}{R_1} = \frac{V_o}{R_2} - \frac{V_1}{R_1}$

$= \frac{1}{R_1}[V_1 - V_2] = \frac{V_o}{R_2}$ ⇒ $V_o = \frac{R_2}{R_1}[V_1 - V_2]$