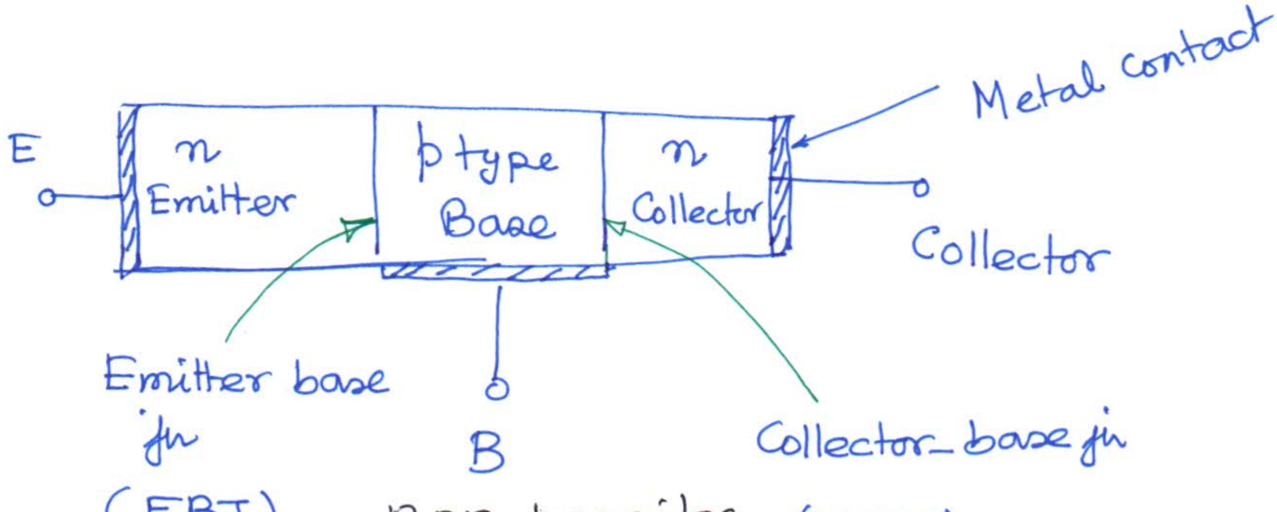
BIPOLAR JUNCTION TRANSISTOR

BJT



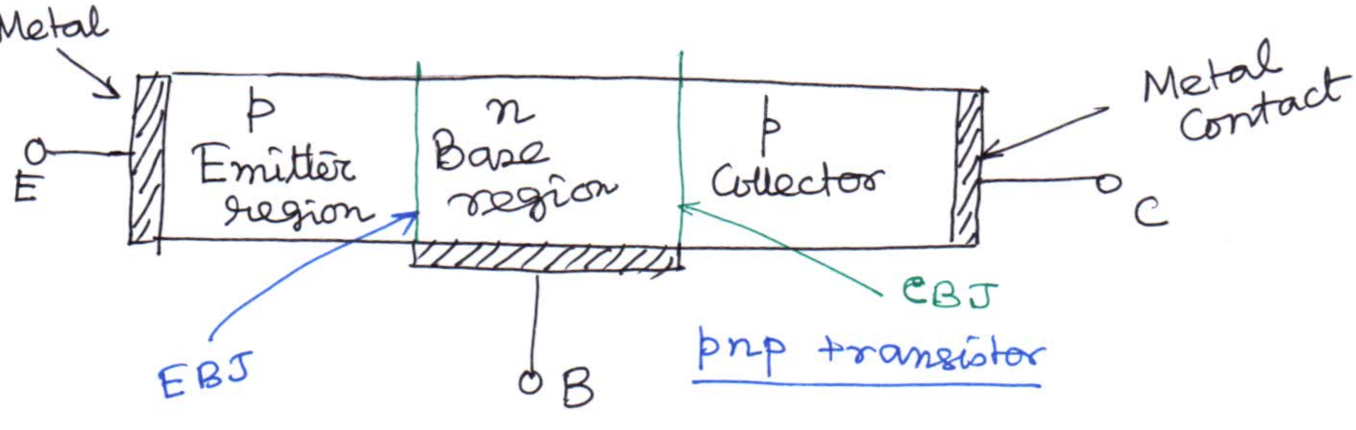
npn transistor

BJT has three semiconductor regions:

Emitter region (n type)
Base region (p type)
Collector region (n type)

npn transistor

Another transistor pnp, has p type Emitter, n type Base, p type Collector as shown below



pnp transistor

The transistor consists of two pn junctions
(i) EBJ (ii) CBJ

Depending on the bias condition (forward/reverse) of each of these junctions, different modes of operation of BJT are obtained

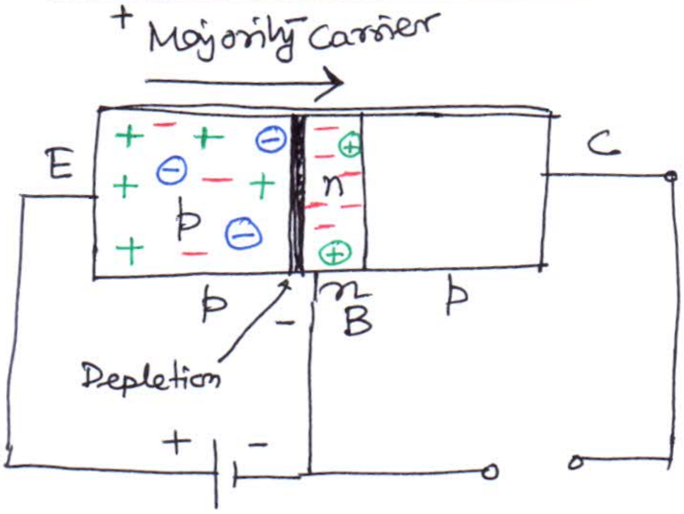
Mode	EBJ	CBJ
Cutoff	Reverse	Reverse
Active	Forward	Reverse
Saturation	Forward	Forward

Active Mode : Transistor operates as an amplifier

Switching application (logic circuits) :
cut off and saturation mode.

Cut off mode : No current flows as both junctions are reverse biased.

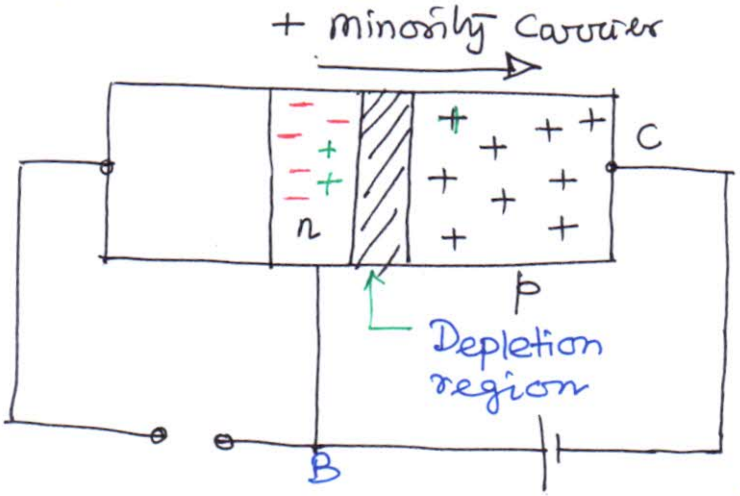
Transistor Operation



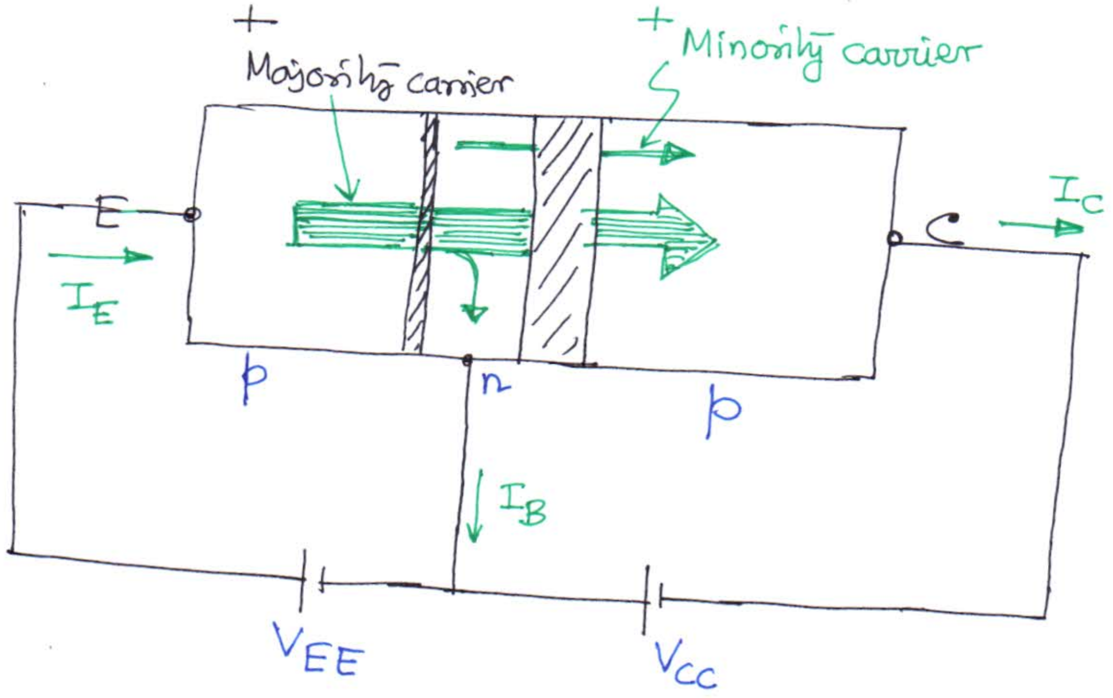
pnp transistor

No Base to Collector Bias

Emitter to Base jn is forward bias
Depletion region is reduced due to forward bias. ⇒ Heavy flow of majority carriers from p to n type material.



Now remove forward Bias (Base-Emitter) and reverse bias Collector Base jn.
Majority carrier flow is zero, only minority carrier flows. Depletion region is widened.



Both biasing potentials have been applied to a pnp transistor, majority and minority carrier flow indicated.

1. A large no. of majority carrier will diffuse across the forward biased p-n jn into n material.

2. Whether these carriers will contribute directly to base ct I_B or pass directly to p type material.

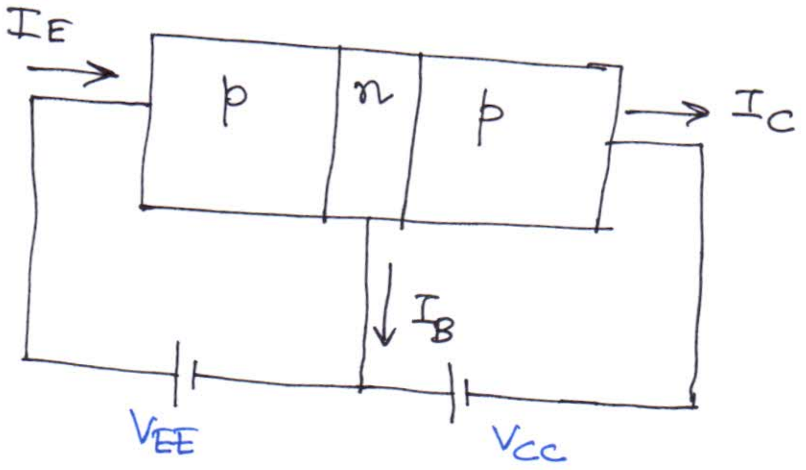
3. Since the sandwiched n type material is very thin, and has a low conductivity, a very small number of these carriers will take this path of high resistance to the base terminal.

The magnitude of base current (I_B) is typically on the order of microamperes as compared to milliamp of emitter and collector ct.

5. The larger number of these majority carriers will diffuse across the reverse-biased junction into p type material connected to the collector terminal

6. Note that injected majority carrier from p side (Emitter) becomes minority carriers in the n type material (Base). Thus there has been an injection of minority carriers into the n type base region.

Combining this with the fact that all the minority carriers in the depletion region will cross the reverse-biased junction of the diode accounts for the flow.



Apply Kirchhoff's current law to the transistor

$$\boxed{I_E = I_B + I_C}$$

The collector current is composed of two components

(i) majority carriers (ii) minority carriers

The Minority carrier component is called the leakage current and it is given by I_{CO}

I_{CO} (I_C current with emitter terminal open)

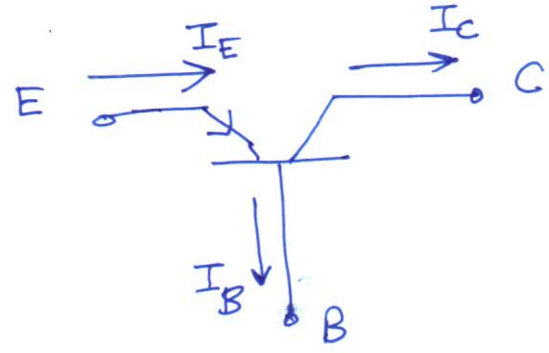
$$\boxed{I_C = I_{C\,majority} + I_{CO\,minority}}$$

I_C is measured in mA, I_{CO} in μA or nA.

Like I_S, I_{CO} is temparature sensitive.

It can severely affect the stability at high temp if not considered properly.

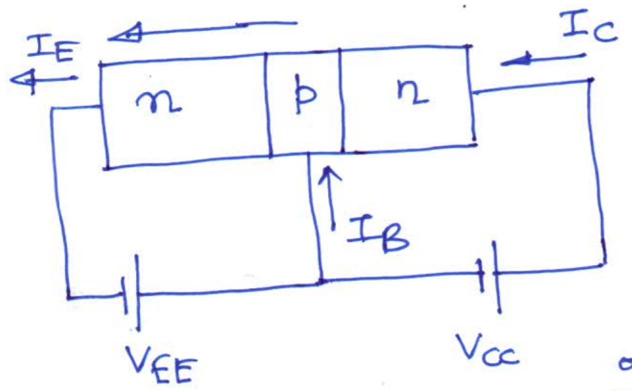
COMMON BASE CONFIGURATION



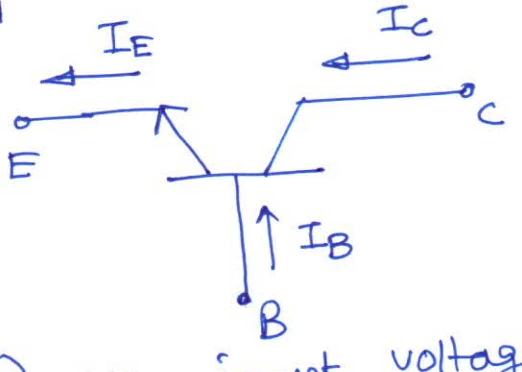
Base is common to both i/p and o/p

The arrow in the graphic symbol defines the direction of emitter current (Conventional flow) through the device.

$\underline{I_E = I_C + I_B.}$ Applied bias should be such as to establish current in the direction indicated for each branch.

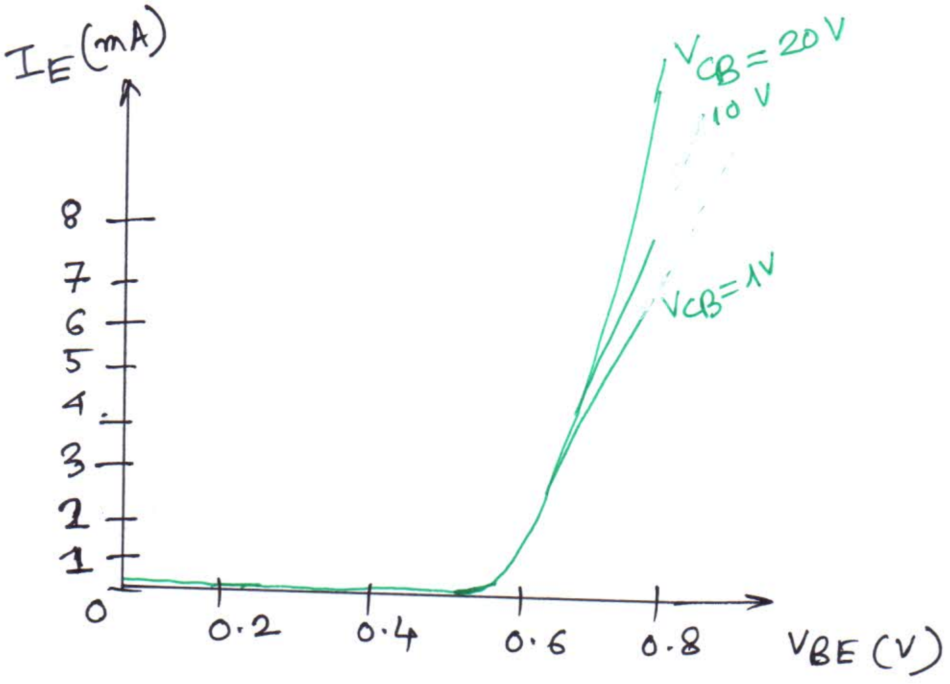


current flow direction in an npn transistor

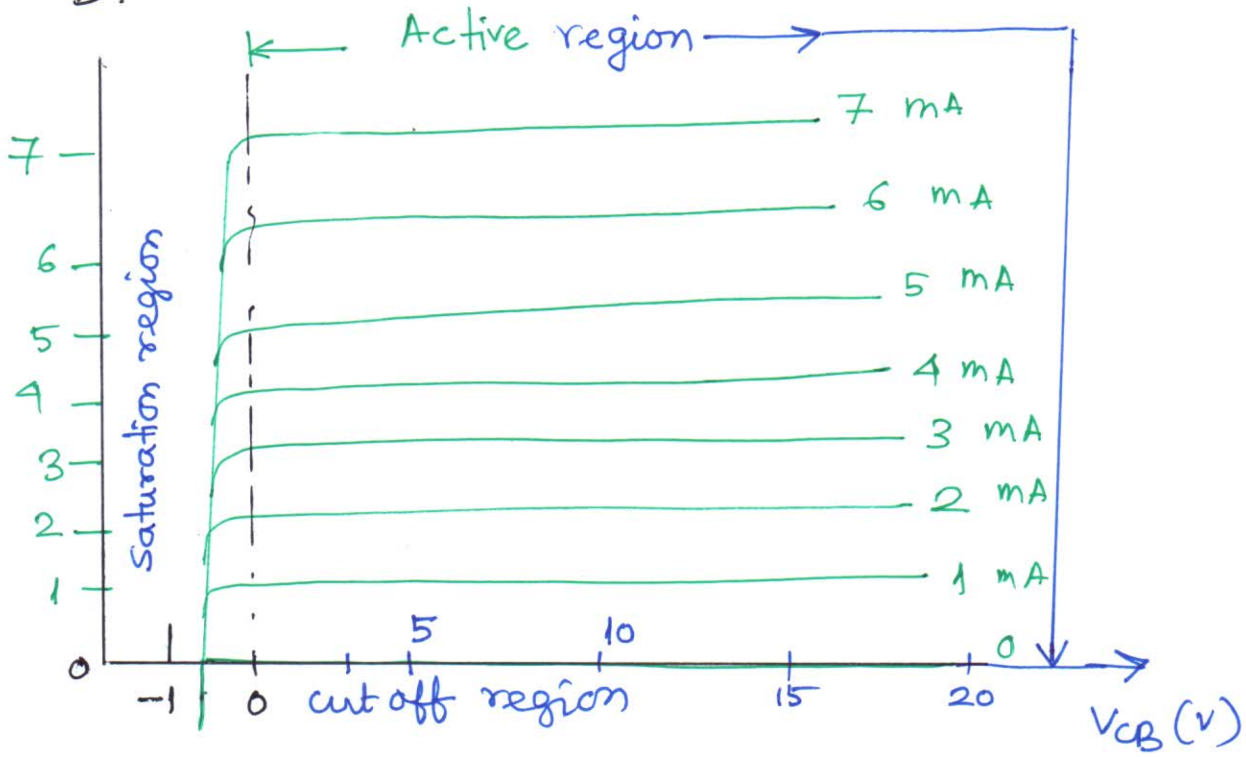


input characteristic

I_E (input current) vs input voltage (V_{BE}) for various levels of o/p voltage V_{CB}



i/p characteristics of CB, mode, shows variation of I_E vs V_{BE} for various levels of V_{CB}.



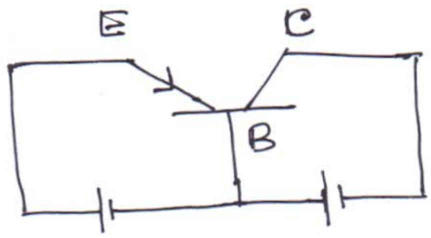
o/p characteristic of CB

O/P characteristics relate output ct (I_C) to an output voltage (V_{CB}). for various levels of input current (I_E).

Three regions of interest: active, saturation and cutoff.

Active region : CB jn is reverse biased
EB jn forward biased

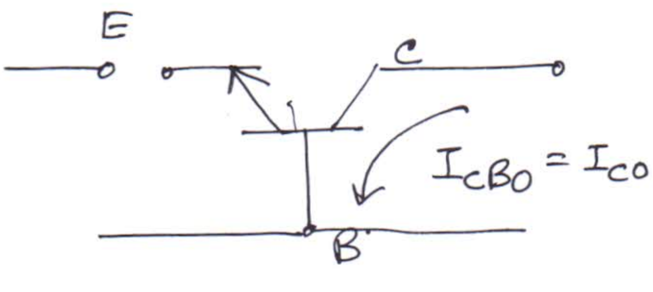
used for linear amplification.



B.E jn is fwd biased
CB jn is rev biased.

At lower end of active region $I_E = 0$

$I_C = I_{CO}$ I_{CO} is very small, of the order of μA.



ckt Condition when $I_E = 0$.

I_{CO} is $\underline{I_{CBO}}$. I_{CBO} is temp dependent

At higher temperature, I_{CBO} effect may become imp.

- As I_E increases above zero, collector ct I_C increases to a magnitude essentially equal to I_E.

Effect of V_{CB} is negligible on collector ct I_C for the active region.

Thus in the active region $\boxed{I_C \cong I_E}$

Cutoff region : The region where $I_C = 0$

In cutoff region, the collector-base jn and base-emitter jn both are reverse biased.

Saturation region

The region of characteristic left of $V_{CB} = 0V$

Note the exponential increase in collector ct I_C as voltage V_{CB} increases toward 0V.

In saturation region the Collector-base and base emitter junctions are forward biased.

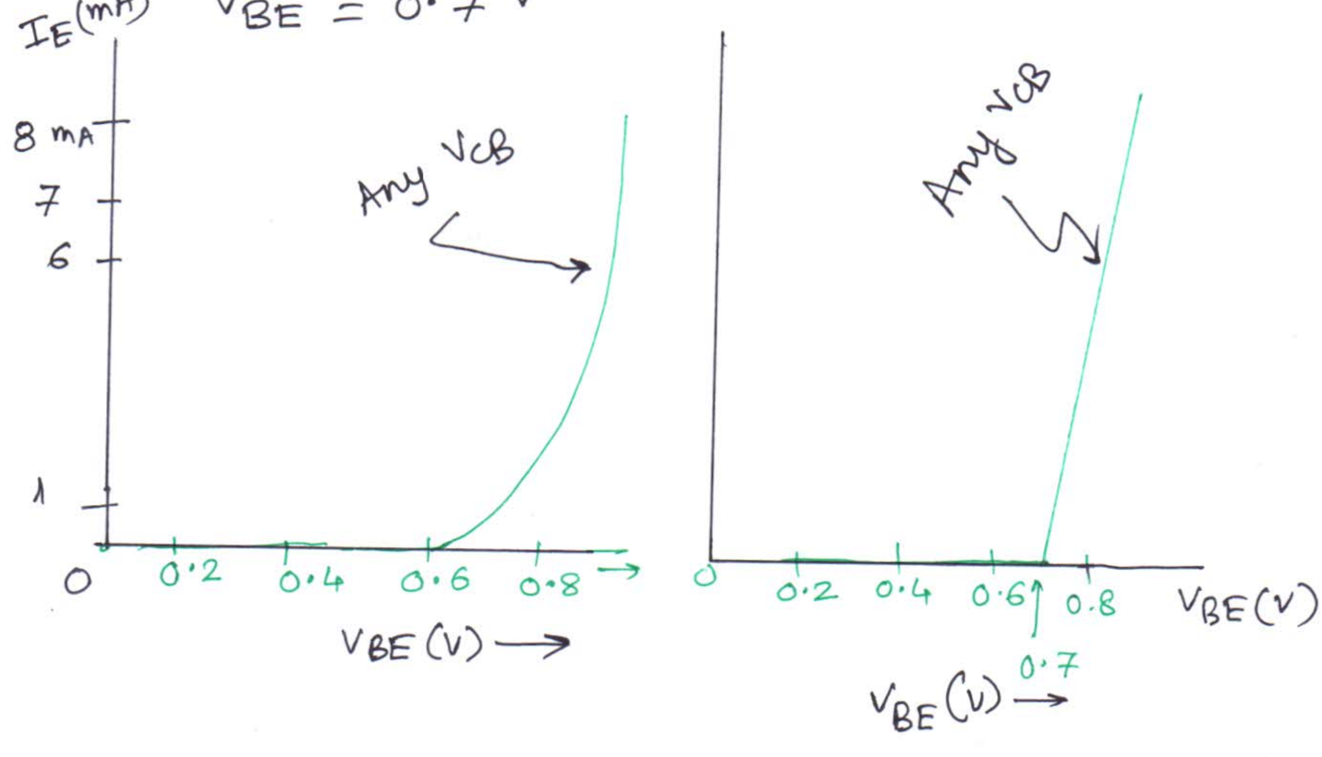
Input characteristics of CB

For fixed values of Collector voltage (V_{CB}), as base to emitter voltage increases, the emitter current increases in a manner that closely resembles diode characteristic.

Increasing levels of V_{CB} have such a small effect on characteristics that as a first approximation, the change due to changes in V_{CB} can be ignored.

Once a transistor is in 'ON' state, the base to emitter voltage will be assumed to be

$V_{BE} = 0.7\ V$



Alpha (α)

In the dc mode, the levels of I_C and I_E are due to majority carrier and they are related by a quantity called 'α', defined as

$$\boxed{\alpha_{dc} = \frac{I_C}{I_E}}$$

I_C & I_E are levels of current at the point of operation.

Although the characteristics suggest $\alpha = 1$, for practical devices, the level of α typically lies between 0·9 to 0·99

$$I_C = I_{C\,majority} + I_{CO\,minority}$$

$$= \alpha I_E + I_{CBO}$$

when $I_E = 0$, mA $\underline{I_C = I_{CBO}}$

But I_{CBO} is very small,

so when $I_E = 0$ mA, I_C appears to be 0 mA in the figure.

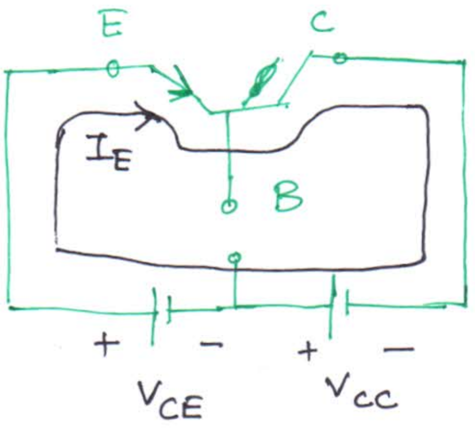
For ac situations, where the point of operation moves on the characteristic curve,

then an ac alpha is defined by

$$\alpha_{ac} = \left.\frac{\Delta I_C}{\Delta I_E}\right|_{V_{CB}\ \text{const}}$$

common base short ckt amplification factor

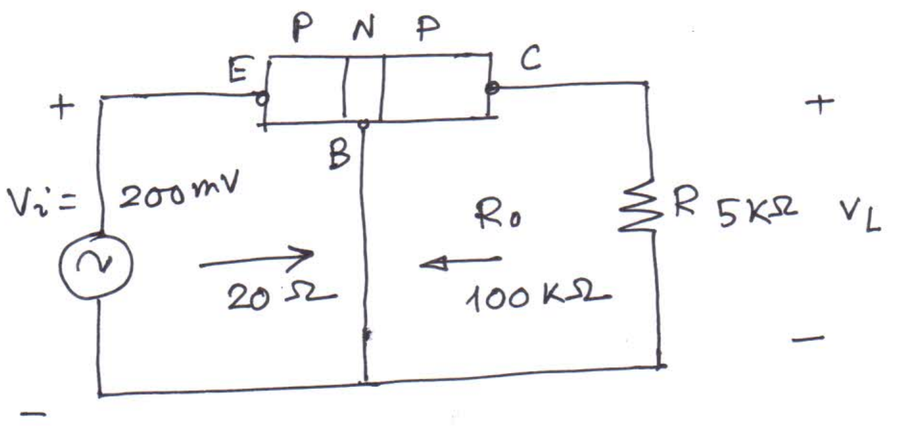
<u>Biasing</u> Proper biasing of common-base configuration in the active region can be determined quickly using $I_C \cong I_E$ and assuming for the moment that $I_B \cong 0\ \mu A$



The arrow of the symbol defines the direction of conventional flow for $I_E \cong I_C$

<u>PNP transistor</u>

Transistor Amplifying Action



We do not show biasing as we are interested in ac operation.

i/p resistance is determined by i/p characteristic I_E vs V_{BE} (that of a typically fwd biased diode).

o/p resistance determined by o/p characteristic (More horizontal the curves, higher the resistance) typically 50 kΩ to 1 MΩ.

$$I_i = \frac{V_i}{R_i} = \frac{200\text{ mV}}{20\,\Omega} = 10\text{ mA}$$

$$\alpha_{AC} = 1, \quad I_e = I_i = 10\text{ mA}.$$

$$I_L = I_c \simeq I_e = 10\text{ mA}.$$

$$V_L = I_L . R = (10\text{ mA}) . 5\text{ k}\Omega = 50\text{ V}$$

Amplification Factor

$$A_V = \frac{V_L}{V_i} = \frac{50V}{200mV} = 250$$

Typical values for voltage amplification for common base configuration vary from 50 to 300.

The current amplification is always less than 1 for CB configuration.

Thus the basic amplifying action is produced by transferring a current I from a low to high resistance ckt.

transfer + resistor $\Rightarrow$ transistor