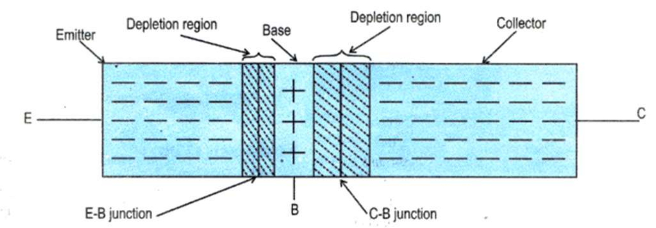
SEMICONDUCTORS PART 3

Bipolar Junction Transistor (BJT)



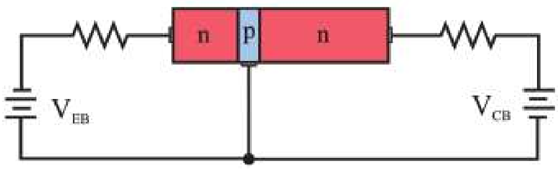
BJT is of two type n-p-n and p-n-p. Above is a schematic view of a n-p-n transistor. It consists of a heavily doped emitter, thin and very lightly doped base and a larger and moderately doped collector. There are two depletion regions formed between emitter base and base collector.

There are 3 regions of operation:

Active region: This is the most used mode of operation. Here the EB junction is forward biased and the CB junction is reverse biased

Cut-off region: In this mode current is almost zero, since both the junctions are reverse biased

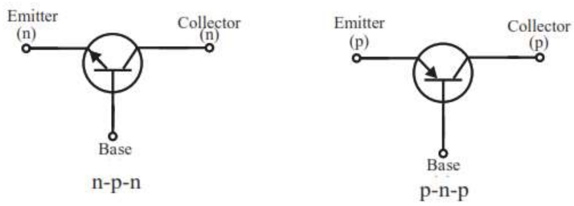
Saturation region: In this mode both the junctions are forward biased.



Above circuit has been bias for active mode operation. The emitter base junction being forward biased will cause the emitter to emit electrons. These electrons enter the base region (p-type). Since base region is thin and lightly doped, the base is able to collect very few electrons. Hence base current is negligibly small (in µA). Electron in the p base region act like minority carriers and since the collector is biased in such a way that the collector base junction is reversed biased, the electron goes through to the collector. Thus, a substantial collector current is produced (in mA). The collector current is almost equal to the emitter current.

NOTE: In case of the p-n-p transistor it's the holes instead of the electron which are responsible for most of the current.

Symbol:



Relationship between α and β

$I_E = I_C + I_B$

Dividing by I_C *we get,* $\frac{I_E}{I_C} = 1 + \frac{I_B}{I_C}$

$\frac{1}{\alpha} = 1 + \frac{1}{\beta}$, *where* $\alpha = \frac{I_C}{I_E}$ *and* $\beta = \frac{I_C}{I_B}$ *are the current gains*

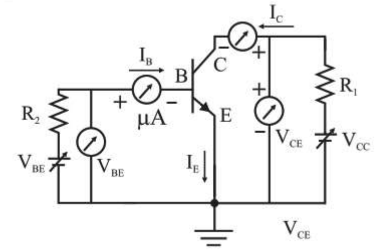
thus, $\alpha = \frac{\beta}{1+\beta}$, *close to 1 but less than 1*

and $\beta = \frac{\alpha}{1-\alpha}$, *Thus, β large from 20 − 200*

Transistor configurations

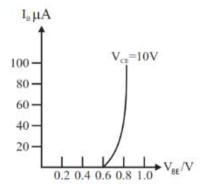
Configuration	Input	Output	Provides Amplification
Common Emitter	Base	Collector	Current and Voltage both
Common Collector	Base	Emitter	Current gain only
Common Base	Emitter	Collector	Voltage gain only

Common Emitter Characteristics:



A typical circuit for studying the input and output characteristics of a common emitter circuit is as shown. Ammeter and Voltmeters are attached in the circuit to measure the respective currents and voltages.

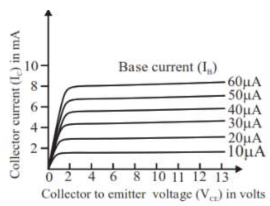
Input Characteristics



It is a plot of I_B vs V_{BE} for fixed value of V_{CE} . As can be seen there is almost no current till the value of V_{BE} crosses the barrier potential. Thereafter it behave similar to a forward biased diode.

$$Dynamic\ input\ resistance\ r_i = \frac{\Delta V_{BE}}{\Delta I_B}\ for\ constant\ V_{CE}$$

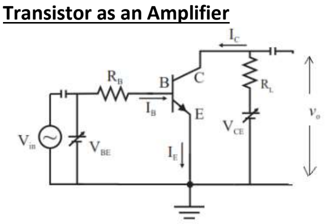
Output Characteristics



Each plot is a variation of I_C wrt to V_{CE} for fixed value of I_B. Each graph initially is linear/ohmic, where I_C varies linearly with V_{CE}. Then the plot becomes almost parallel to x-axis and hence independent of V_{CE}. Now the value of I_C is controlled by I_B and not by V_{CE}. Thus, BJT is also called current controlled device. Here it is where the transistor operates in Active mode as an amplifier.

$$Dynamic\ output\ resistance\ r_o = \frac{\Delta V_{CE}}{\Delta I_C}\ for\ constant\ I_B$$

Transistor as an Amplifier



AC input is applied at the base and output measured from the collector. Input and output capacitors have been added to block any DC from entering from input or coming in the output. The AC input causes I_B to vary over and above it DC value. Let ΔI_B be the variation in I_B caused by the AC input. Since $I_C=\beta I_B$, thus $\Delta I_C=\beta.\Delta I_B$ and β being 20-200 will cause high change in I_C for small changes in I_B

Change in output = ΔV_{CE}= - $\Delta I_C.R_L$ = - $\beta.\Delta I_B.R_L$

Since change is I_C was large (because β is large), for small change in I_B, thus, change if output voltage is also high. Negative sign indicates there is a phase reversal.

$$Voltage\ gain\ A_v = \frac{v_o}{v_i} = \frac{\Delta V_{CE}}{\Delta I_B.r_i} = \frac{-\beta \Delta I_B R_L}{\Delta I_B.r_i} = \frac{-\beta R_L}{r_i}$$

Negative sign shows the output voltage and input voltage are out of phase.

Since $|A_v|$>1, thus the transistor acts like an amplifier