1.5 BIPOLAR JUNCTION TRANSISTOR

BJT is a 3-layer, 2-junction, 3-terminal npn or pnp semiconductor device. Bipolar= 2 polarities of charge carriers constitute the current flow in the device. There are 2 types, NPN and PNP. NPN type is widely used as they are easy to manufacture and cheaper.

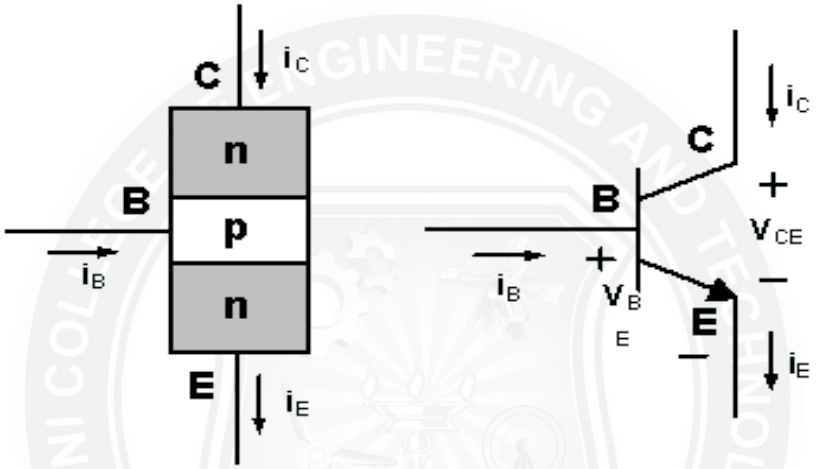

Figure 1.5.1 Symbol

[Source: "Power Electronics" *by* P.S.Bimbra, Khanna Publishers *Page: 11]*

CONSTRUCTION

A power transistor is a vertically oriented four-layer structure of alternating p-type and n-type. It helps in maximizing the cross-section area and results in higher current rating of BJT, minimize the on-state resistance, and thus reduce the power losses.

- It has an extra lightly doped (n-) region called as collector drift region in addition toNPN layers
- The n-layer increases the voltage blocking capacity of transistor which is needed isfast switching application in efficient power control
- The characteristics of the device is determined by the doping level in each of the layers and the thickness of the layers.

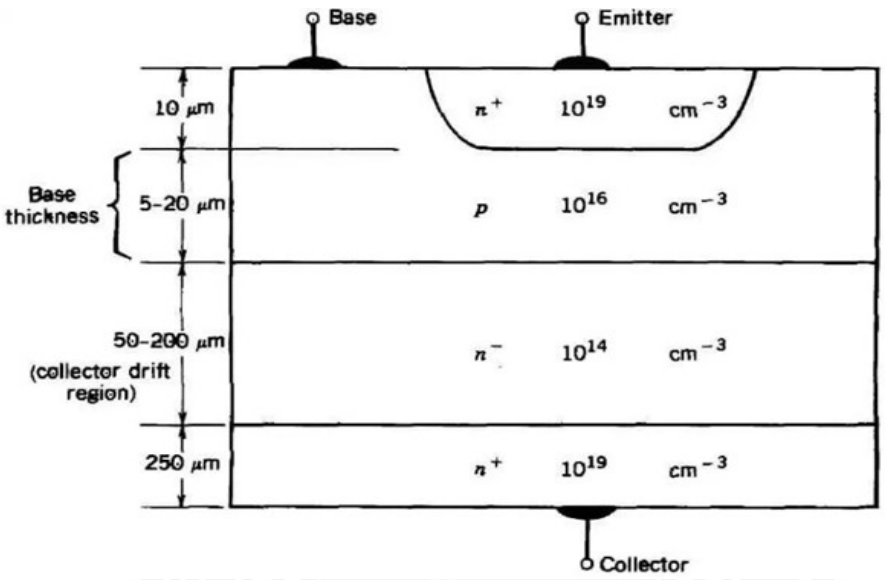

Figure 1.5.2 Structure of BJT

[Source: "Power Electronics" *by* P.S.Bimbra*,* Khanna Publishers *Page: 11]*

The thickness of the drift region determines the breakdown voltage of the Powertransistor. The base thickness is made as small as possible in order to have good amplification capabilities, however if the base thickness is small the breakdown voltage capability of the transistor is compromised.

POWER BJT – VI CHARACTERISTICS

The VI characteristics of the Power BJT is different from signal level transistor. The major differences are Quasi saturation region & secondary breakdown region. The Quasi saturation region is available only in Power transistor characteristic not in signal transistors. It is because of the lightly doped collector drift region present in Power BJT. The primary breakdown is similar to the signal transistor's avalanche breakdown. Operation of device at primary and secondary breakdown regions should be avoided as it will lead to the catastrophic failure of the device.

Input characteristics

A graph between base current IB and base emitter voltage VBE is called as input characteristics. The base emitter region is a diode and hence the input characteristics resembles the V-I characteristics of a PN junction diode. Base current decreases as collector emitter voltage increases for the same base emitter voltage.

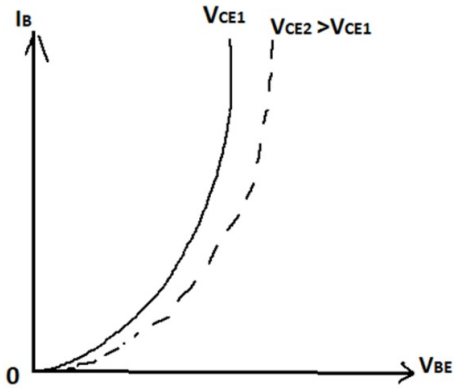

Figure 1.5.3 Input characteristics of BJT

[Source: "Power Electronics" *by* P.S.Bimbra, Khanna Publishers *Page: 11]*

Output characteristics

A graph between collector current IC and collector emitter voltage VCE is called as output characteristics, Power BJT operates in four regions

- *Cutoff region-Both BE and CE junction must be reversed biased.*
- Active region-BE junction must be forward biased and CB reverse biased
- *Quasi-saturation region-Both forward biased.*
- Hard-saturation region-Both forward biased.

Quasi-saturation region

- Quasi saturation region is a new region in Power BJT due to lightly doped (n-) drift region. If the BJT is to be operated in high switching frequency, they operate in this region. It provides low resistance to voltage in on state than active region. Since it does not get into deep saturation we can turn on and off power BJT very quickly.

- In power handling and control purposes power BJT are generally used in cutoff for off state and quasi-saturation for on state to act as a switch.

Cut-off Region

- When the base current (IB) is zero, the collector current (IC) is insignificant and the transistor is driven into the cutoff region. The transistor is now in the OFF state.

- The collector–base and base–emitter junctions are reverse biased in the cutoff regionor OFF state, the transistor behaves as an open switch.

- In this region:IC= 0 and the collector–emitter voltage VCE is equal to the supply voltage VCC

Saturation Region

When the base current is sufficient to drive the transistor into saturation.During saturation, both junctions are forward-biased and the transistor acts like a closed switch.In the quasi saturation and hard saturation, the base drive is applied and transistor issaid to be on.

In this region: I(C)=VCC/RC and VCE=0.

Active Region

In the active region, the collector–base junction is reversed-biased and the base–emitter junction is forward-biased.

The active region of the transistor is mainly used for amplifier applications and shouldbe avoided for switching operation.

The power BJT is never operated in the active region (i.e. as an amplifier) it is alwaysoperated between cut-off and saturation.

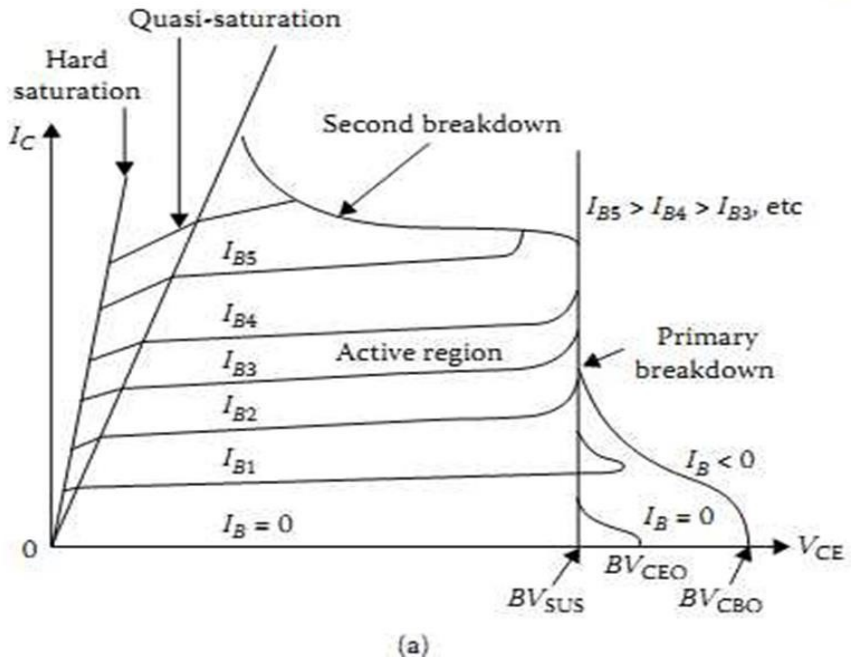

Fig 1.5.4 output characteristics of BJT

[Source: "Power Electronics" *by* P.S.Bimbra, Khanna Publishers *Page: 11]*

SWITCHING CHARACTERISTICS OF POWER BJT

Switching characteristics of power BJT is shown in Fig. As the positive base voltage is applied, base current starts to flow but there is no collector current for some time. This time is known as the delay time (td) required to charge the junction capacitance of the base to emitter to 0.7 V approx. (known as forward-bias voltage). For t > td, collector current starts rising and VCE starts to drop with the magnitude of90% of its peak value. This time is called rise time, required to turn on the transistor. The transistor remains on so long as the collector current is at least of this value.

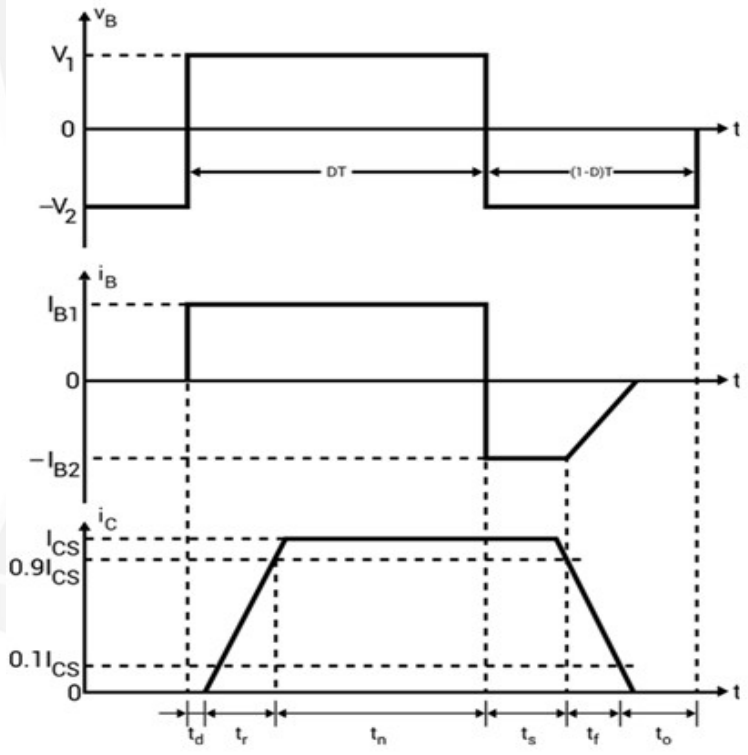

Fig 1.5.5 Switching characteristics of BJT

[Source: "Power Electronics" *by* P.S.Bimbra, Khanna Publishers *Page: 15]*

For turning off the BJT, polarity of the base voltage is reversed and thus the base current polarity will also be changed as shown in Fig. The base current required during the steady-state operation is more than that required to saturate the transistor. Thus, excess minority carrier charges are stored in the base region which needs to be removed during the turn-off process. The time required to nullify this charge is the storage time ts. Collector current remains at the same value for this time. After this, collector current starts decreasing and base-to-emitter junction charges to the negative polarity, base current also get reduced.

APPLICATIONS OF POWER BJT

- SMPS (Switch mode power supply) used in computers.
- Final audio amplifier in stereo systems.
- Power amplifiers.
- DC to AC inverters.
- Relay and display drivers.
- AC motor speed controllers.
- control circuits.