# POWER TRANSISTORS

Power transistors are devices that have controlled turn-on and turn-off characteristics. These devices are used a switching devices and are operated in the saturation region resulting in low on-state voltage drop. They are turned on when a current signal is given to base or control terminal. The transistor remains on so long as the control signal is present. The switching speed of modern transistors is much higher than that of Thyristors and are used extensively in dc-dc and dc-ac converters. However their voltage and current ratings are lower than those of thyristors and are therefore used in low to medium power applications.

Power transistors are classified as follows

- Bipolar junction transistors(BJTs)
- Metal-oxide semiconductor filed-effect transistors(MOSFETs)
- Static Induction transistors(SITs)
- Insulated-gate bipolar transistors(IGBTs)

## 2.1 Bipolar Junction Transistors

The need for a large blocking voltage in the off state and a high current carrying capability in the on state means that a power BJT must have substantially different structure than its small signal equivalent. The modified structure leads to significant differences in the I-V characteristics and switching behavior between power transistors and its logic level counterpart.

### 2.1.1 Power Transistor Structure

If we recall the structure of conventional transistor we see a thin p-layer is sandwiched between two n-layers or vice versa to form a three terminal device with the terminals named as Emitter, Base and Collector. The structure of a power transistor is as shown below.

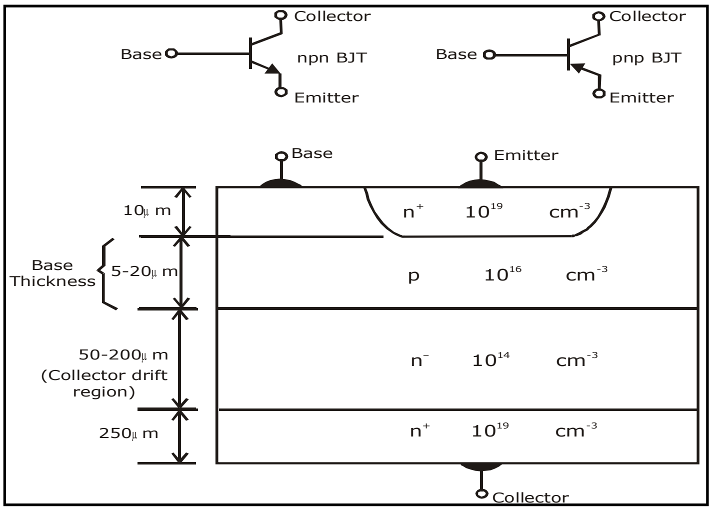


Fig.2.1: Structure of Power Transistor

The difference in the two structures is obvious.

A power transistor is a vertically oriented four layer structure of alternating p-type and n-type. The vertical structure is preferred because it maximizes the cross sectional area and through which the current in the device is flowing. This also minimizes on-state resistance and thus power dissipation in the transistor.

The doping of emitter layer and collector layer is quite large typically $10^{19}$ $cm^{-3}$. A special layer called the collector drift region ($n^-$) has a light doping level of $10^{14}$.

The thickness of the drift region determines the breakdown voltage of the transistor. 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.

### 2.1.2Steady State Characteristics

Figure 3(a) shows the circuit to obtain the steady state characteristics. Fig 3(b) shows the input characteristics of the transistor which is a plot of $I_B$ versus $V_{BE}$. Fig 3(c) shows the output characteristics of the transistor which is a plot $I_C$ versus $V_{CE}$. The characteristics shown are that for a signal level transistor.

The power transistor has steady state characteristics almost similar to signal level transistors except that the V-I characteristics has a region of quasi saturation as shown by figure 4.

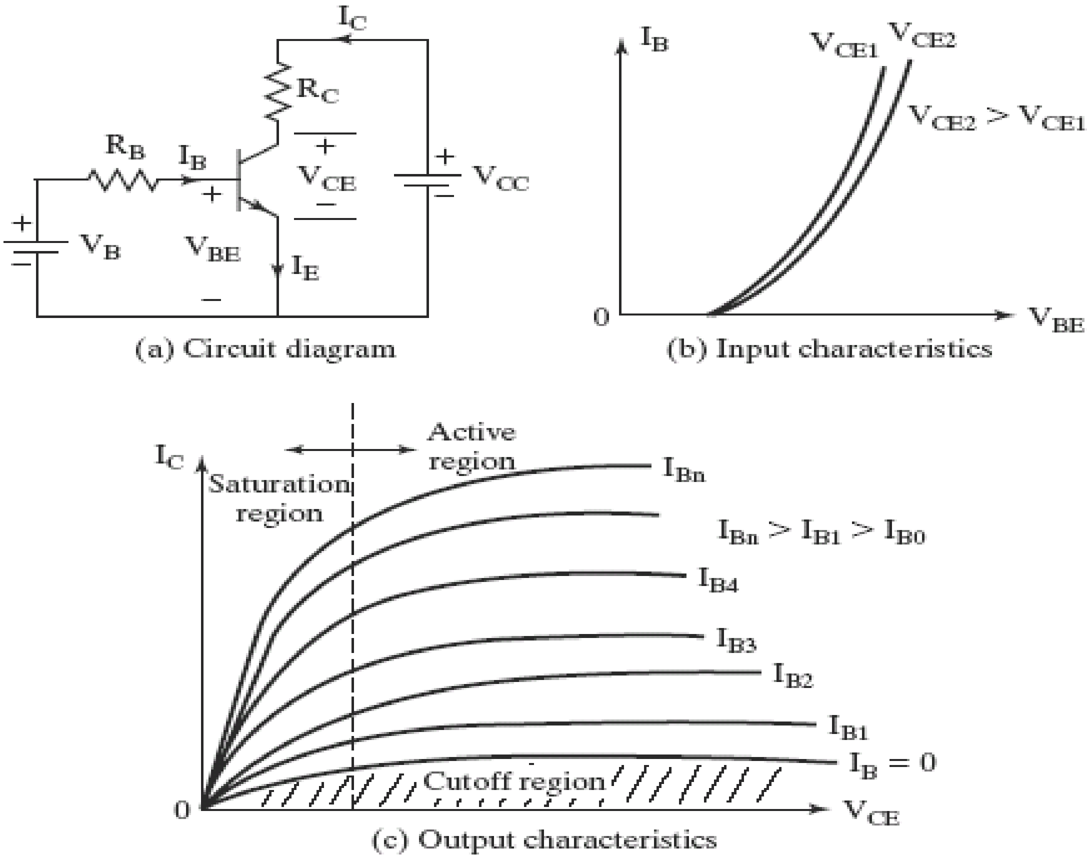


Fig 2.2. Steady State Characteristics of Power Transistor

There are four regions clearly shown: Cutoff region, Active region, quasi saturation and hard saturation. The cutoff region is the area where base current is almost zero. Hence no collector current flows and transistor is off. In the quasi saturation and hard saturation, the base drive is applied and transistor is said to be on. Hence collector current flows depending upon the load.

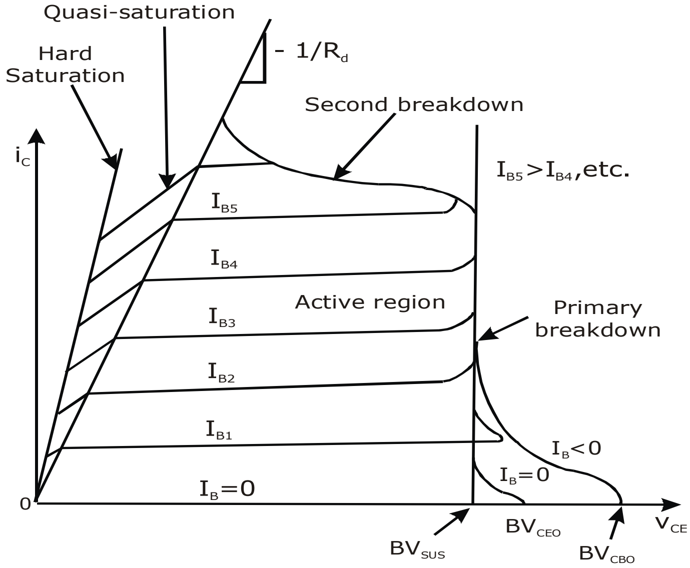


Fig. 2.3: Characteristics of NPN Power Transistors

The power BJT is never operated in the active region (i.e. as an amplifier) it is always operated between cutoff and saturation. The $BV_{SUS}$ is the maximum collector to emitter voltage that can be sustained when BJT is carrying substantial collector current. The $BV_{CEO}$ is the maximum collector to emitter breakdown voltage that can be sustained when base current is zero and $BV_{CBO}$ is the collector base breakdown voltage when the emitter is open circuited.

The primary breakdown shown takes place because of avalanche breakdown of collector base junction. Large power dissipation normally leads to primary breakdown.

The second breakdown shown is due to localized thermal runaway.

**Transfer Characteristics**

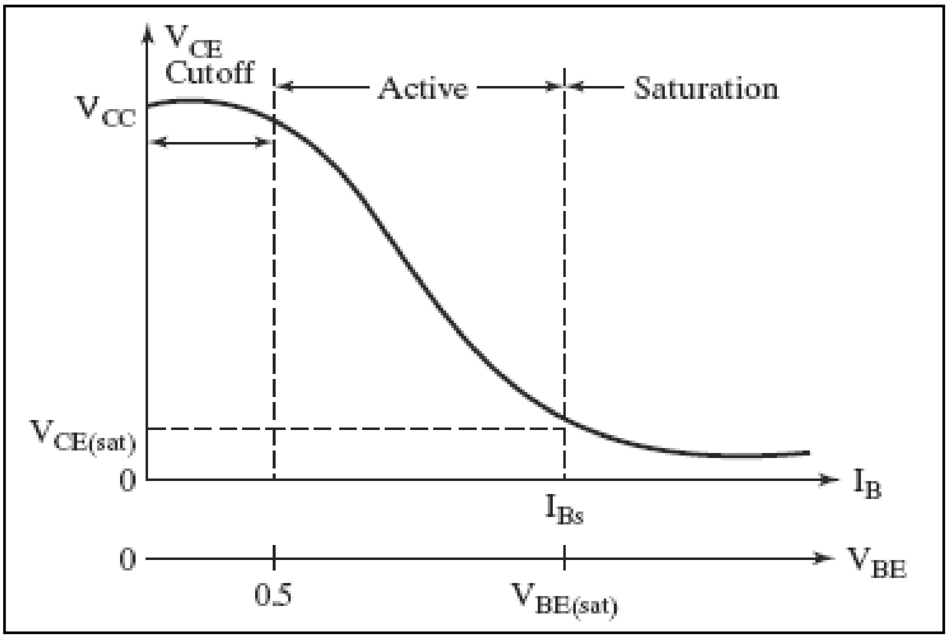


Fig. 2.4: Transfer Characteristics

$$I_E = I_C + I_B$$

$$\beta = h_{fE} = \frac{I_C}{I_B}$$

$$I_C = \beta I_B + I_{CEO}$$

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

$$\beta = \frac{\alpha}{1 - \alpha}$$

Source : http://elearningatria.files.wordpress.com/2013/10/ece-vii-power-electronics-10ec73-notes.pdf