Current gains α and β do not completely describe the behaviour of transistor. Characteristic curves which relate the transistor currents and voltages, can be very useful in studying the behaviour of transistor.

There are 2 sets of characteristic curves.

(1) Input characteristics - They give the relationship between the input current and input voltage for a given output voltage.

(2) Output characteristics: They give the relationship between the output current and output voltage for a given input current.

These curves completely describe the static operation of transistor.

We will be studying the characteristic curves for CB and CE configuration

(1) COMMON BASE CONFIGURATION

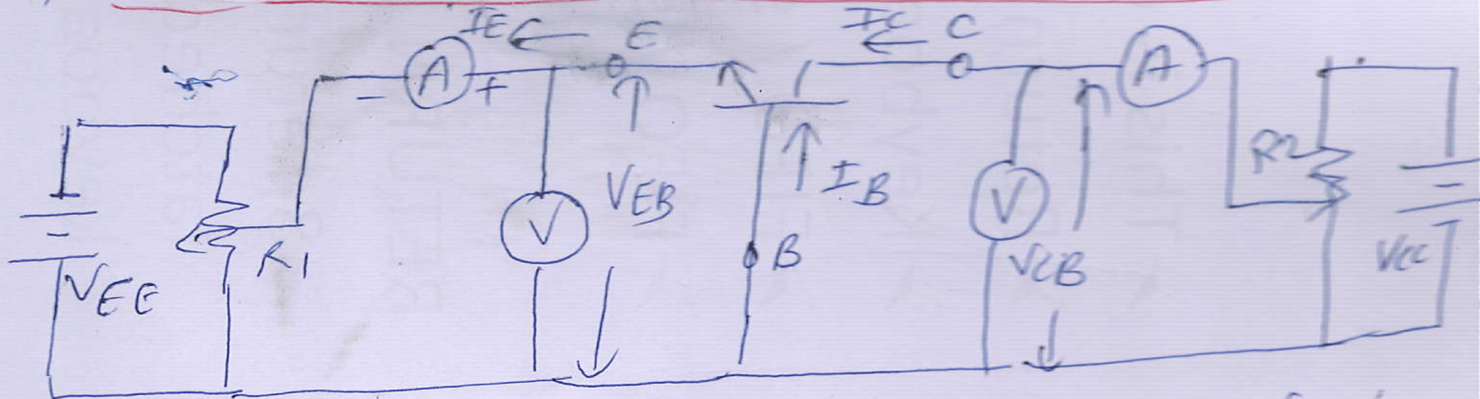


Fig: Circuit arrangement for determining CB transistor characteristics

(I) Input characteristics in CB configuration

I_E = Input current
V_{EB} = Input voltage
V_{CB} = Output voltage

It is the curve between input current I_E and input voltage V_{EB} at constant output voltage V_{CB}.

Procedure: Adjust V_{CB} to 1 V. Then increase V_{EB} in small ~~stue~~ steps (e.g. 0.1V) and record the corresponding values of I_E at each step. Then graph is plotted. By changing V_{CB} to different voltages (5V & 10V) ~~by changing R2~~ different curves can be obtained

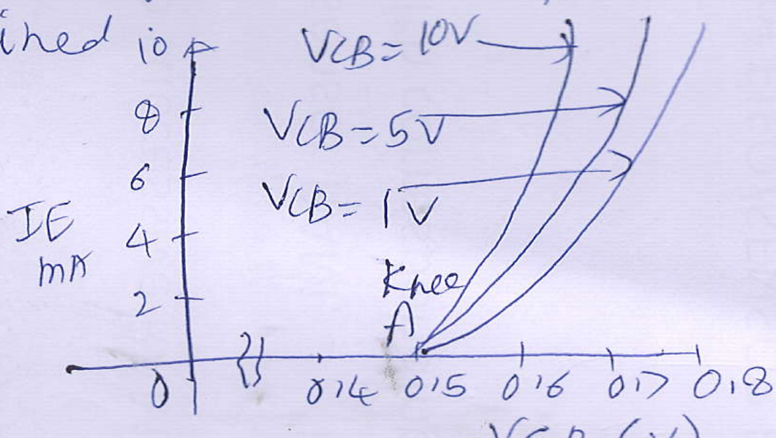


Fig: Input characteristics of CB transistor

Information given by input characteristics

(i) There exists a threshold voltage (offset / cut-in / knee voltage) indicated by OA below which I_E is negligibly small

V_K = knee or threshold voltage

For Si, $V_K = 0.5V$ and Ge $V_K = 0.1V$

(2) Beyond point A, for a fixed V_{CB}, I_E increases rapidly with a small increase in V_{EB}. It means that the input resistance (R_i) of a transistor in CB configuration is very small.

(3) As V_{CB} is increased above 1 volt, the curves shift upwards. It occurs due to phenomenon called base width modulation or early effect.

(4) The input characteristic may be used to determine the value of a.c. input resistance. Its value at any point on the curve is given by the ratio of a change in V_{EB} (ΔV_{BEB}) to the resulting change in I_E (ΔI_E) for a constant V_{CB}.

$$\therefore R_i = \frac{\Delta V_{EB}}{\Delta I_E} \Big/ \text{constant } V_{CB}.$$

R_i depends upon the location of the operating point selected along the curve. Value of $R_i = 50\ \Omega$ in linear region.

Base width modulation or Early effect.

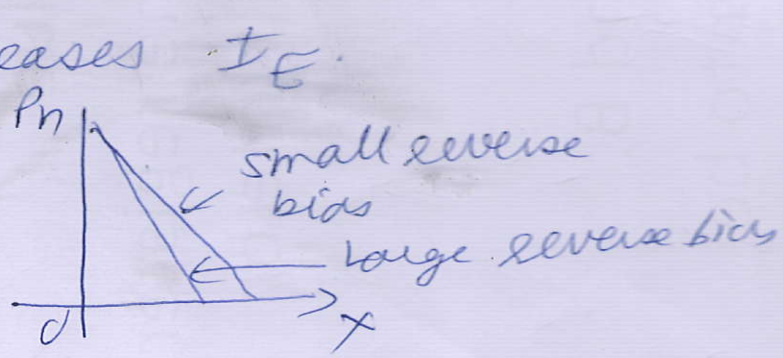
In a P-N junction, the width of a depletion region increases as the reverse bias voltage increase. In a transistor since the E-B junction is forward biased it has no effect on width of depletion region. But C-B junction is reverse biased, therefore as the reverse bias voltage across the C-B junction increases, the width of depletion region also increases. Since the B is lightly doped as compared to C, depletion region penetrate deeper into the base region; This reduces the effective width of the B region.

This variation or modulation of the effective base width by collector voltage is known as base width modulation or early effect.

The decrease in base width by the collector voltage has the following three effects or consequences.

(1) It reduces the chances of recombination of electrons with the holes in the base region. Hence α increases with increase in V_{CB}

(2) The concentration gradient of minority carriers within the base increases. This in turn increases I_E.



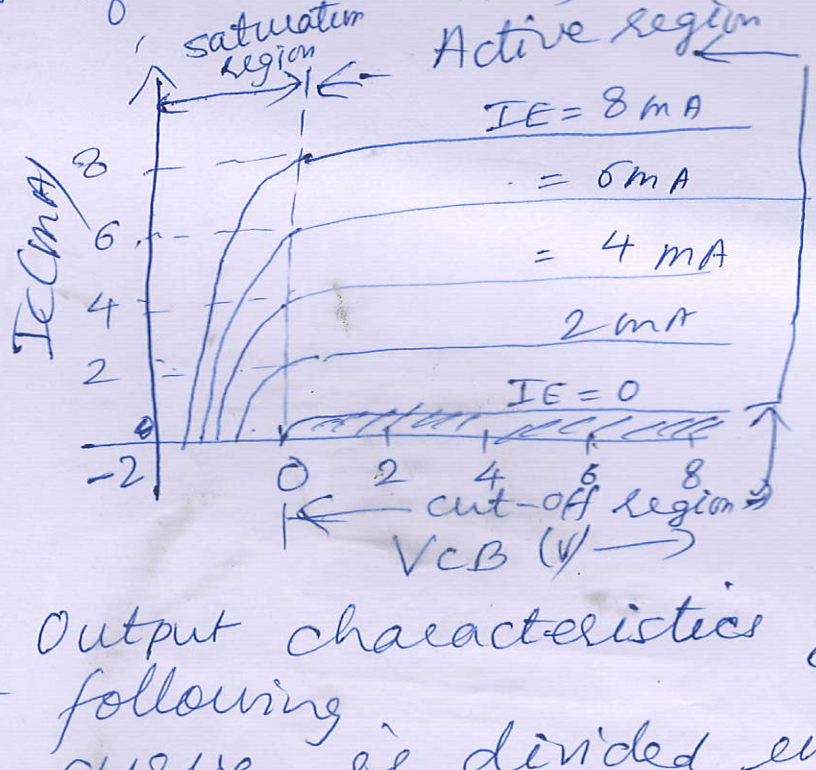
(3) For extremely large V_{CB} the effective base width may be reduced to zero ~~ca~~ causing voltage breakdown of a transistor. This phenomenon is known as punch through.

Output Characteristics of transistor in CB configuration

These characteristics are obtained using same circuit used for input characteristics. V_{EB} is adjusted to get suitable value of I_E. Keeping I_E constant, V_{CB} is increased in suitable steps and corresponding values of I_C are recorded at each step. Graph is plotted

I_C = output current
V_{CB} = output voltage
I_E = Input current

A similar procedure may be used to obtain the characteristics for different values of I_E = 4, 6, 8 mA ...



The Output characteristics give information about following

(i) The curve is divided into 3 regions

(a) Saturation region – Here V_{CB} is negative. It means that the C-B junction is forward biased. A small change in V_{CB} results in a large value of current

(b) Active region - Here I_C ~~$= I_E$~~ is constant and nearly equal to I_E

(c) Cut-off - It is along horizontal axis and corresponds to the curve marked $I_E = 0$. Here both junctions are reverse biased.

(2) I_C flows even when $V_{CB} = 0$. This is because the electrons are injected into the base under the action of forward biased E-B junction. These electrons are collected by the collector due to internal junction voltage (i.e. the barrier potential) at the C-B junction.

(3) A small I_C flows even when $I_E = 0$. This current is current is called leakage current and is designated as I_{CBO}.

(4) I_C is practically independent of V_{CB} in the active region. However if V_{CB} is increased beyond a certain large value I_C increases rapidly due to avalanche breakdown and transistor action is lost.

(5) It is used to determine CB a.c. ~~input~~ output resistance. Its value at any point is given by the ratio of change in V_{CB} (ΔV_{CB}) to change in I_C (ΔI_C) for a constant I_E.

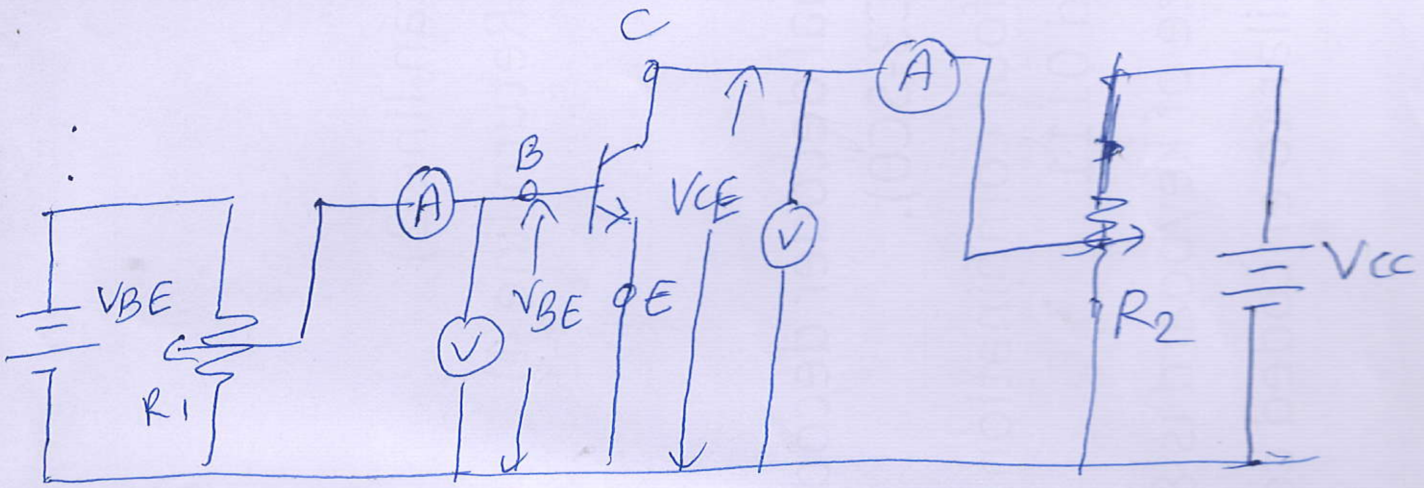
$$R_O = \frac{\Delta V_{CB}}{\Delta I_C} \Big/ \text{constant } I_E$$

~~(5)~~ As characteristic curves of CB are almost horizontal, the value of output resistance R_0 is very high. Its typical value is $500 K\Omega$.

(6) It is used to determine a.c. alpha (α_0) of transistor

$$\alpha_0 = \frac{\Delta I_C}{\Delta I_E}$$

Characteristics of CE configuration



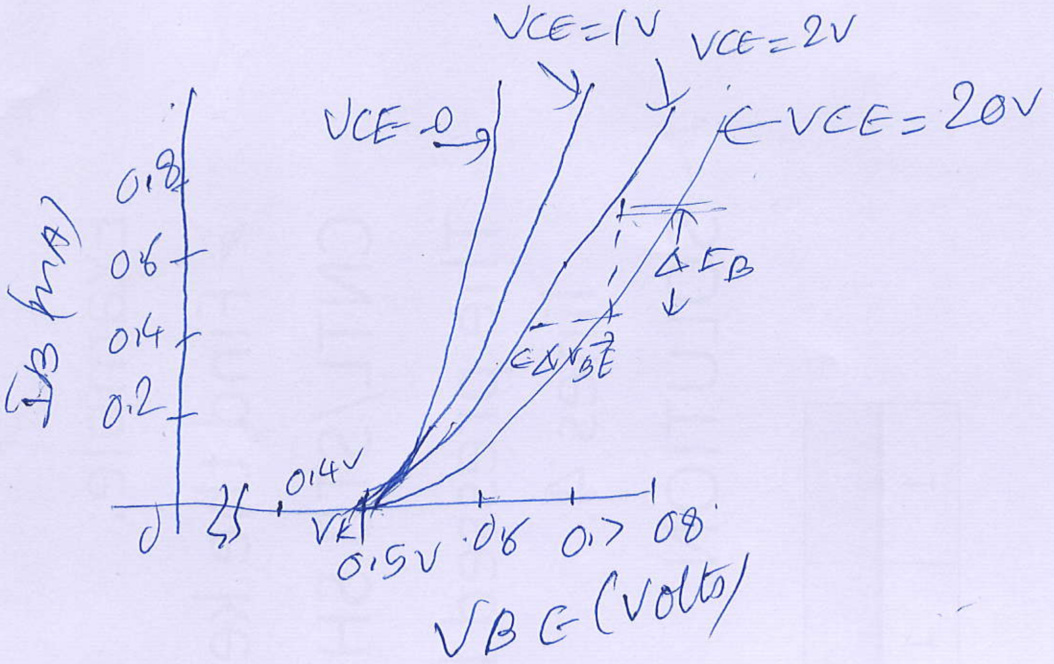
circuit arrangement for determining CE characteristics

(I) Input Characteristics:

First V_{CE} is adjusted to 1 volt. Then V_{BE} is increased in small steps and the corresponding values of I_B ~~are~~ is noted at each step. Graph is plotted. Same procedure is adopted for V_{CE} = 2, 10 and 20 V.

I_B = input current $\quad V_{CE}$ = Output voltage

V_{BE} = Input voltage



Input characteristic gives information about following.

(1) There exists a threshold or knee voltage (V_K) below which I_B is very small. The value of knee voltage is 0.5V for Si and 0.1 V for Ge transistor.

(2) Beyond the knee, I_B increases with increase in V_{BE} for a constant V_{CE}. The value of I_B does not increase as rapidly as the input characteristic of CB transistor which means that input resistance of transistor in CE configuration is higher than that in CB configuration,

(3) As V_{CE} is increased above 1 volt, the curves shift downwards because as V_{CE} is increased, the depletion width in the B region increases. This

in turn reduces the I_B (9)

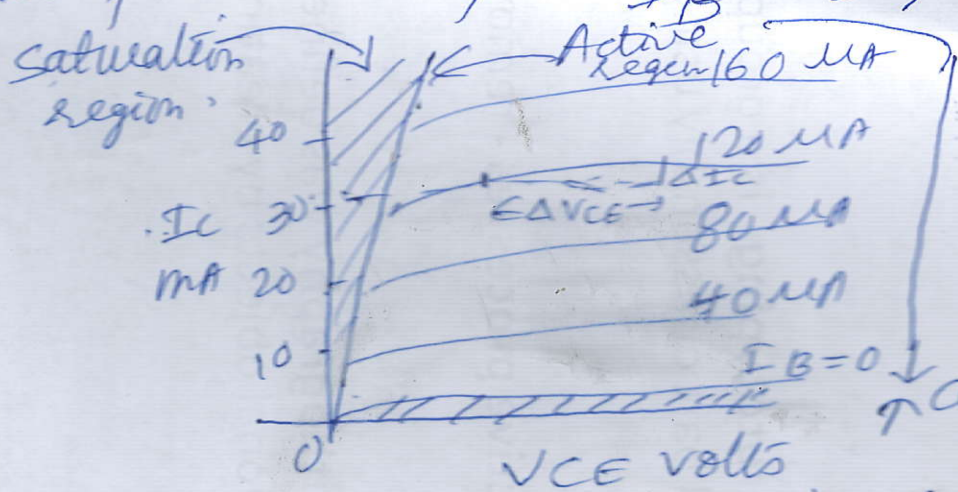
(4) The characteristic can be used to determine the value of CE a.c. input resistance R_i. It is given by the ratio of change in V_{BE} (ΔV_{BE}) to change in I_B (ΔI_B) at a constant V_{CE}.

$$\therefore R_i = \frac{\Delta V_{BE}}{\Delta I_B} \Big/ \text{constant } V_{CE}.$$

R_i varies from 600 to 4000 Ω.

Output Characteristics of CE transistor

The characteristics are obtained using same circuit as in input characteristics. Here I_B is made constant to 40 μA value and V_{CE} is increased in steps and corresponding values of I_C are noted. Graph is plotted. Similar procedure is followed for I_B = 80, 120, 160 μA.



I_C = output current
V_{CE} = output voltage
I_B = Input current

Following information is obtained

(1) Output characteristics may be divided into three regions.

(i) Saturation (ii) cut-off (iii) Active region