DEPARTMENT OF ELECTRICAL ENGINEERING

GOVERNMENT COLLEGE OF ENGINEERING KALAHANDI

BHAWANIPATNA

Lecture Notes on Basic Electronics

By

Dr. Deepa Das

Assistant Professor

Department of Electrical Engineering

Disclaimer

This document does not claim any originality and cannot be used as a substitute for prescribed textbooks. The information presented here is merely a collection by the committee members for their respective teaching assignments. Various sources such as text book, reference books as well as freely available material from internet were consulted for preparing this document. The ownership of the information lies with the respective author or institutions. Further, this document is not intended to be used for commercial purpose.

Bipolar Junction Transistors

→ The transistor is a three – layer semiconductor device consisting of either two N- type and one - P type layers of material or two P- type and one N- type layers of material.

→ A ~~cor~~ transistor consists of a layer of P- type material sandwiched between two layers of N- type material called N-P-N transistor.

→ It may consist of a layer of N-type material sandwiched between two layers of P-type material called P-N-P transistor.

→ Out of three layers in the transistor, one side section supply free charges called the Emitter, other side section collects these charges called the collector and the middle section ~~i.e.d~~ i.e formed between the emitter and collector is called the base.

Emitter :- It supplies the majority charge carriers (holes in case of P-N-P transistors and electrons in case of N-P-N transistors) to the base.

- The emitter is forward biased w.r.t base. It is heavily doped so that it is able to inject a large number of charge carriers.

Collector :- Its main function is to collect majority charge carriers. Collector is always reverse biased so as to remove the charge carriers away from its junction. It is moderately doped.

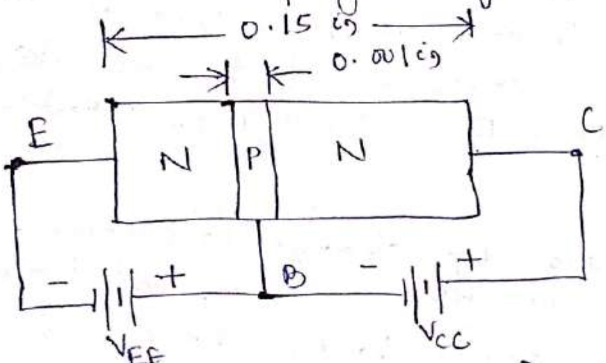
Base :- It is the middle section of the transistor and is very lightly doped. It is very thin in comparison to emitter and collector so that it may pass most of the injected charge carriers to the collector.

Dr. Deepa Das

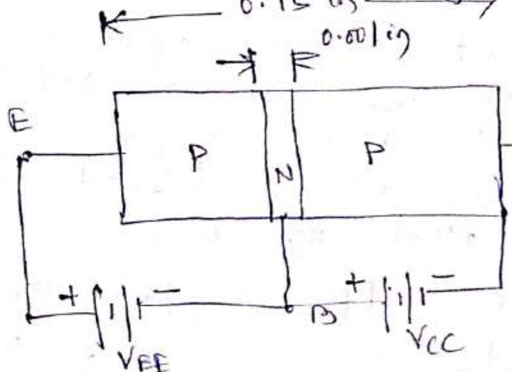
→ The forward biased Emitter-base junction offers low resistance to the Emitter current whereas the collector-base junction which is reverse-biased offers high resistance to the collector current.

→ As the resistance of emitter-base junction is very small as compared to the collector-base junction the forward bias applied to the Emitter-base junction is usually very small whereas the reverse bias on the collector-base junction is much large.

→ In most of the transistor, the collector region is made physically larger than emitter region.



(N-P-N transistor)



(P-N-P transistor).

E = Emitter C = Collector B = Base

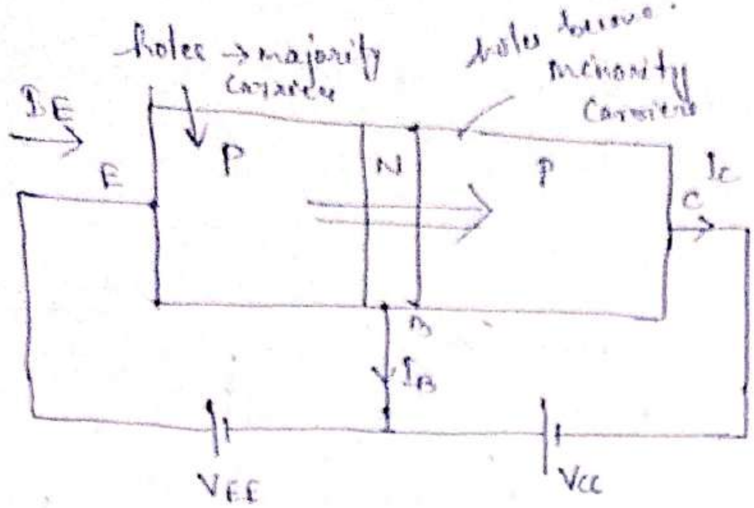
→ The bipolar junction transistor (BJT), here bipolar reflects the fact that holes and electrons participate in the injection process into the oppositely polarized material.

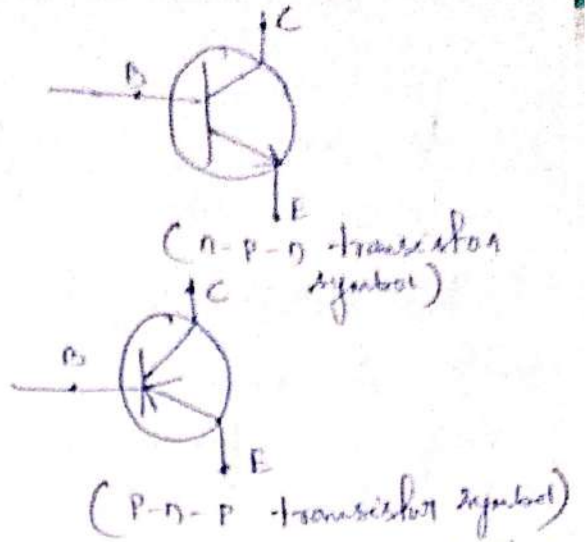
Transistor Operation :-

→ P-N-P and N-P-N transistors behave exactly in the same way except change in biasing and majority charge carriers.

→ In P-N-P transistor the conduction is by holes and in N-P-N transistor, the conduction is by electrons.

→ One P-N junction of a transistor is reverse biased whereas the other is forward biased.





→ A large number of majority carriers will diffuse across the forward biased P-N junction into N-type material.

→ Since the base 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 the base current I_B is typically on the order of <u>microampere</u>.

→ Hence, large number of majority carriers diffuse across the reverse-biased junction.

Applying Kirchoff's current law to the transistor

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

I_E = Emitter current
I_C = Collector current
I_B = Base current.

Further, the collector current comprises of two components.

→ Majority carriers (majority charge carrier current)
→ Minority carriers (leakage current)

Hence,

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

$I_{CO\,minority}$ = I_C current with emitter terminal open.

I_C and I_E are measured in milliamperes.
I_{CO} is measured in microampere.

Transistor Configuration :-

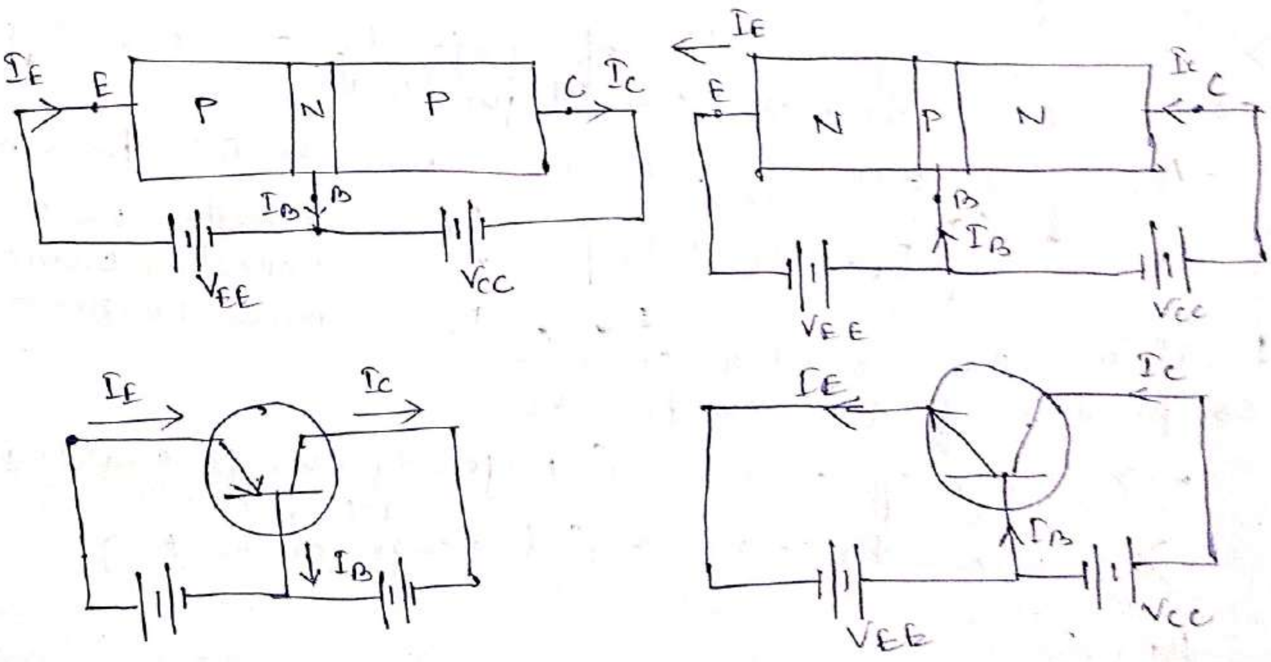
→ A transistor is a three terminal device but it requires four terminals - two for the input and two for the output for connecting it in a circuit. Hence, one of the terminals is made common to the input and output circuits.

Thus, there are three types of configurations of operation of transistor.

These are

1. Common Base (CB)
2. Common Emitter (CE)
3. Common Collector (CC)

Common Base Configuration



→ In CB configuration, input is connected between emitter and base and output is taken across collector and base.

→ The emitter current I_E flows in the input circuit and the collector current I_C in the output circuit.

— The ratio of collector current I_C to the emitter current I_E is called the current amplification factor α.

$$\alpha = \frac{I_C}{I_E}$$

For practical devices α typically extends from 0.90 to 0.998. The value of α can be increased by making base thin and lightly doped.

— The collector current consists of two parts

→ The current produced by normal transistor i.e current component depending upon emitter current (αI_E) which is produced by majority carriers.

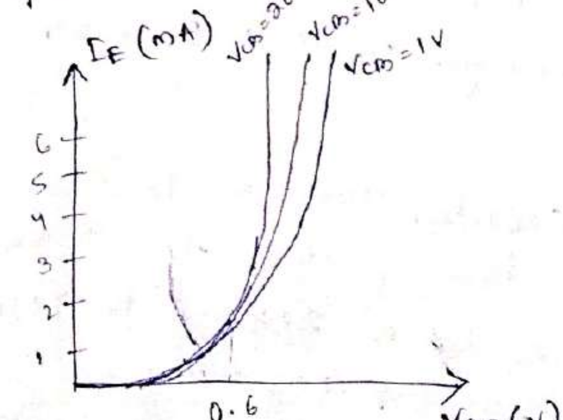
→ The leakage current due to movement of minority carriers across base-collector junction of it being reverse biased. It is denoted as I_{CBO} (Collector-base current with emitter open)

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

Characteristics of CB Configuration :-

— The performance of transistor may be determined from their characteristic curve.

Input characteristic :-

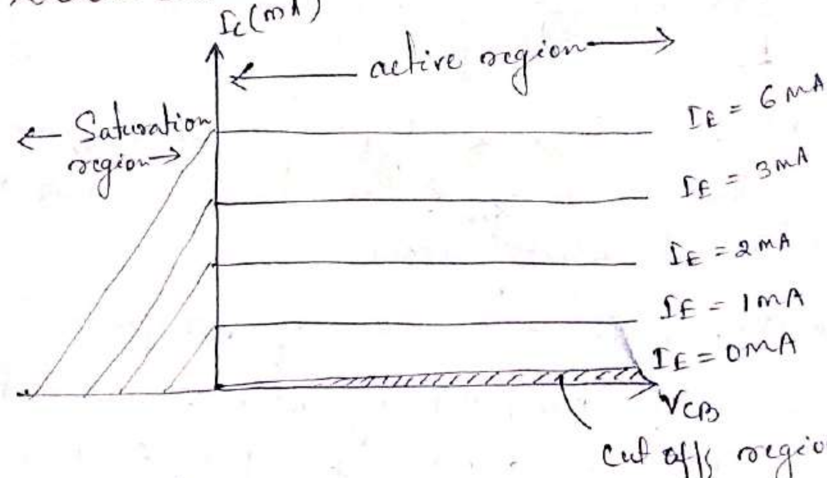


→ The curve between emitter current I_E and base-emitter voltage (V_{BE}) for a given value of collector-base voltage V_{CB} is known as input characteristic.

→ For a given value of V_{CB}, the curve is just like a forward-biased P-N junction diode.

→ It is observed that with increase in V_{CB}, it conducts better.

Output Characteristic :-



$I_C \simeq I_E$

→ The curve drawn between collector current I_C and collector base voltage V_{CB} for a given value of emitter current I_E is known as output characteristic.

– The output has three basic regions; the active, cutoff and saturation regions.

→ In active region collector current I_C is almost equal to I_E and appears to remain constant when V_{CB} is increased.

However, there is very small increase in I_C with increase in V_{CB}.

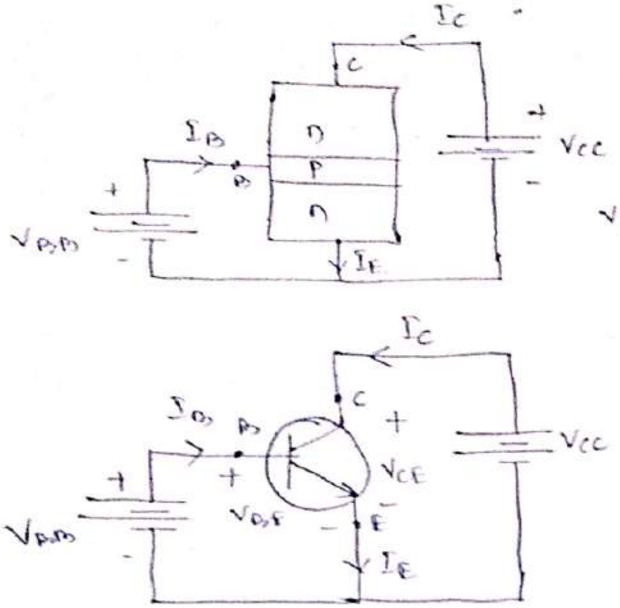
→ In cut-off region, small ~~current~~ collector current I_C flows even when emitter current $I_E = 0$.

This is the collector leakage current I_{CBO} or I_{CO}.

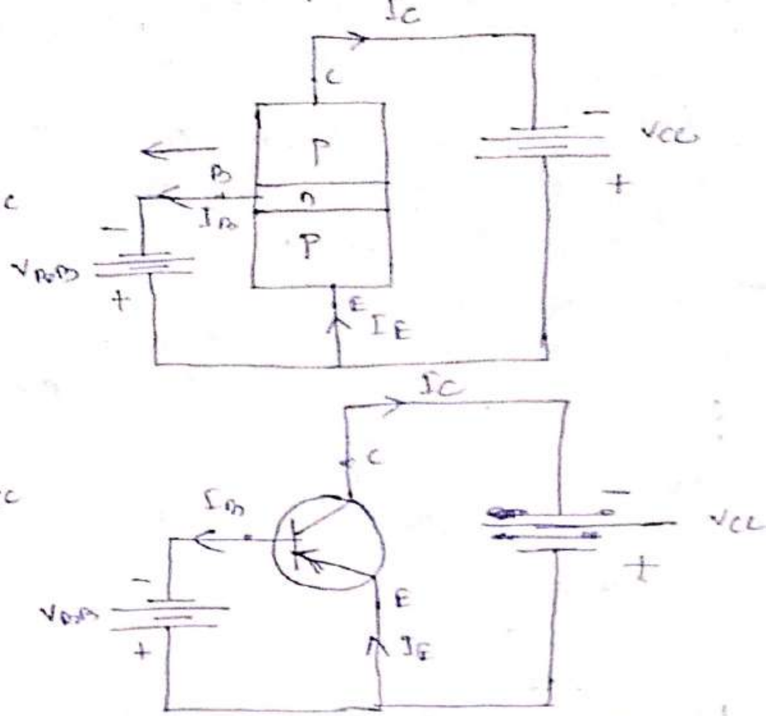
→ Even when $V_{CB} = 0V$, collector current I_C flows. To stop it, the collector - base junction has to be forward biased. Hence, I_C is reduced to zero ~~V_{CB}~~ when V_{CB} is increased negatively.

Common - Emitter Configuration -

In the Common - Emitter Configuration, the emitter is Common / reference to both the input and output terminals.



(n-p-n transistor)



(P-n-P transistor)

i/p current = I_B Output current = I_C

i/p voltage = V_{BE} output voltage = V_{CE}

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

$$\Rightarrow I_C = \alpha (I_C + I_B) + I_{CBO}$$

$$\Rightarrow I_C(1-\alpha) = \alpha I_B + I_{CBO}$$

$$\Rightarrow I_C = \frac{\alpha}{(1-\alpha)} . I_B + \frac{I_{CBO}}{(1-\alpha)}$$

Let $I_B = 0$ A and the typical value of α is 0.996.

$$I_C = \frac{\alpha}{(1-\alpha)} \times (0A) + \frac{I_{CBO}}{(1-\alpha)}$$

$$= \frac{0.996}{(1-0.996)} \times \frac{I_{CBO}}{(1-0.996)} = 250 I_{CBO}$$

If I_{CBO} is 1 μA, the collector current (I_C) with $I_B = 0$ A is 0.25 mA.

$$I_{CEO} = \frac{I_{CBO}}{(1-\alpha)}\bigg|_{I_B = 0\ \mu A}$$

→ Thus, the collector current (I_C) is larger than the input current (I_B). Hence, the current gain for this configuration is larger than unity.

– The active region of the CE configuration can be employed for voltage, current or power amplication.

Current amplification factor (β):-

– The ratio of the collector current (I_C) and base current (I_B) is called the base current amplification factor.

$$\beta_{dc} = \frac{I_C}{I_B}$$

– Almost in all transistor, the base current is less than 5% of the emitter current I_E, so β is usually higher than 20. Usually its typical value ranges from 50 to 400.

$$\beta = \frac{I_C}{I_B} = \frac{I_C}{I_E - I_C} = \frac{I_C/I_E}{\frac{I_E}{I_E} - \frac{I_C}{I_E}}$$

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

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

Substituting this values

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

$$I_C = \beta I_B + (\beta+1) I_{CBO}$$

Dr. Deepa Das

On specification sheet β_{dc} is usually included as h_{FE} with h derived from an ac hybrid equivalent circuit. The subscript FE is derived from forward-current amplification and common-emitter configuration, respectively.

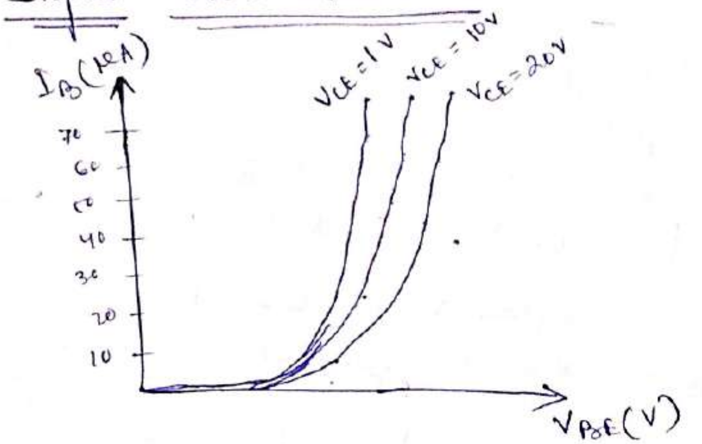
For ac situations,

$$\beta_{ac} = \left.\frac{\Delta I_C}{\Delta I_B}\right|_{V_{CE} = \text{constant}}$$

β_{ac} is common-emitter, forward current amplification factor.

Characteristics of Common-Emitter Configuration :-

Input characteristics



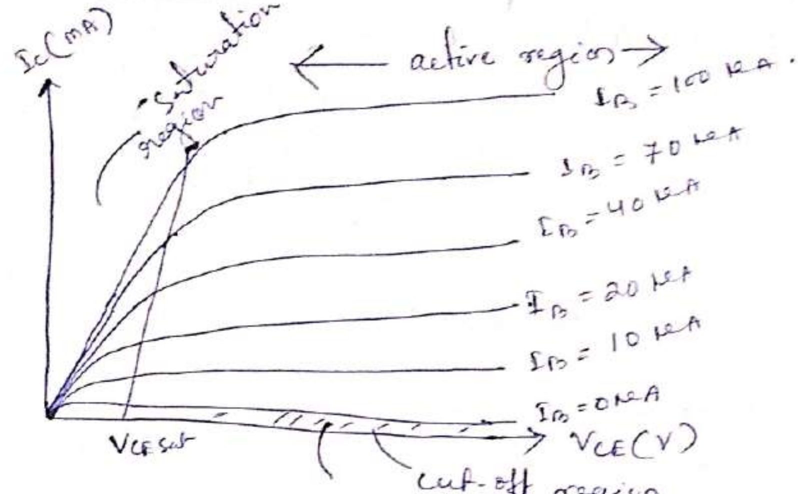
→ The curve between base current I_B and base-emitter voltage V_{BE} for a given value of collector-emitter voltage V_{CE} is known as the input characteristic.

→ In comparison to CB arrangement base current increases less rapidly with the increase in base-emitter voltage V_{BE}. This indicates that input resistance is larger in CE configuration than that in CB configuration.

→ An increment in value of V_{CE} causes the input current I_B to be lower for a given level of V_{BE}. This is because, the higher levels of V_{CE} provides greater collector-base junction reverse bias

Causing greater depletion region penetration into the base and thus reducing the distance between the collector - base and emitter - base regions. As a result more of the charge carriers from the emitter flows across the collector - base junction, and few flow out through the base lead.

Output characteristic



$I_{CEO} \cong \beta I_{CBO}$

→ Output characteristic is the curve between collector current I_C and collector - emitter voltage V_{CE}.

→ The collector current I_C varies with V_{CE} for V_{CE} between 0 and 1V and then becomes almost constant and independent of V_{CE}.

→ Output characteristic in CE configuration has some slope.

→ In active region, for small values of base current I_B, the effect of collector voltage V_{CE} over I_C is small but for large values of I_B this effect increases. The collector current I_C is larger than the input current (base current) I_B. Thus, the current gain for this configuration is larger than unity.

→ With low values of V_{CE}, the transistor is said to be operated in saturation region and in this region base current I_B does not cause corresponding change in collector current I_C.

→ In cut-off region, small amount of collector current I_C flows even when $I_B = 0$. This is called I_{CEO} (collector-Emitter current with base open).

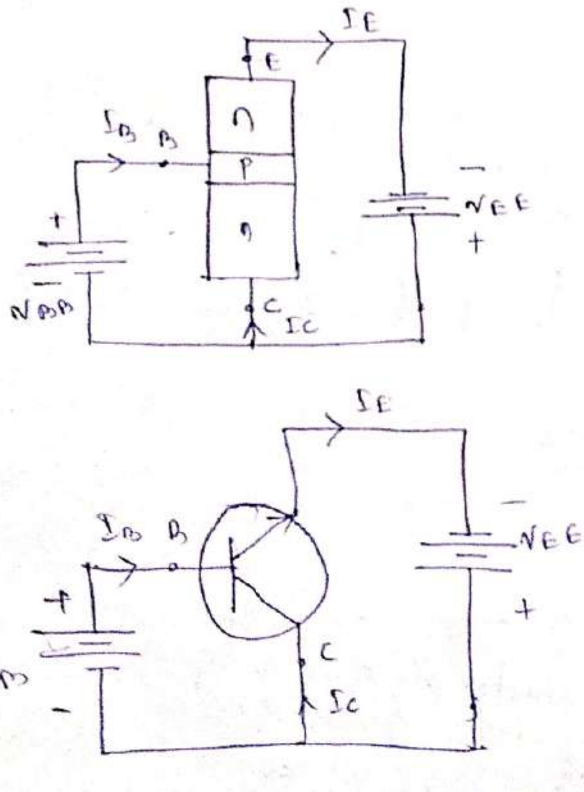
– The ratio of change in collector–Emitter voltage ΔV_{CE} to the change in collector current (ΔI_C) at constant base current is known as <u>dynamic output resistance</u>.

$$r_0 = \frac{\Delta V_{CE}}{\Delta I_C}\Bigg|_{I_B = \text{const.}}$$

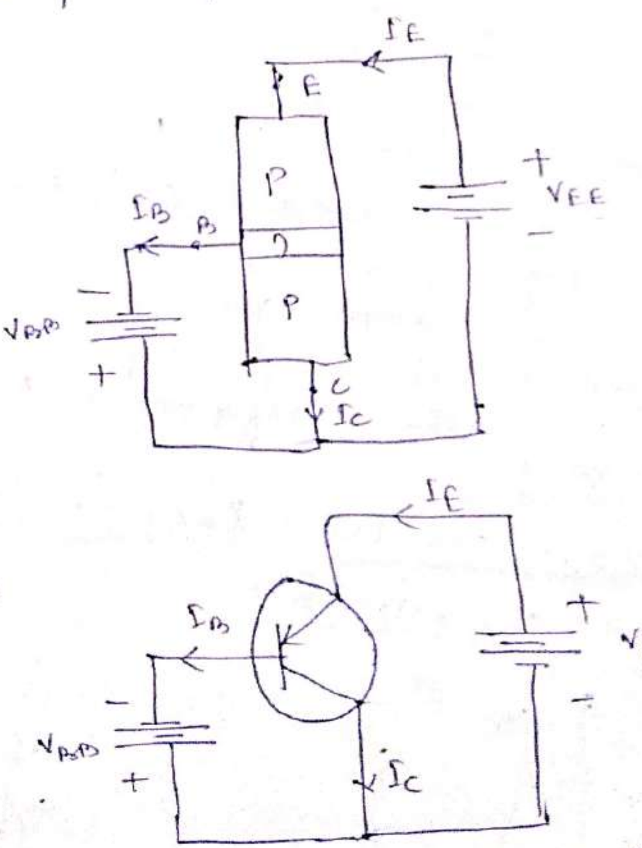
– The output resistance of CE configuration is less than that of CB configuration as the slope of the output characteristic is more. Its value is of the order of 50Ω.

Common Collector (CC) configuration

– The common-collector configuration is used for impedance matching purpose since it has high input impedance and low output impedance.



(n-p-n transistor)



(p-n-p transistor)

→ Here, base current I_B flows in the input circuit and emitter current I_E flows in the output circuit.

→ So, change in Emitter current ΔI_E to the change in base current ΔI_B gives the current amplification factor γ.

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

$$\Rightarrow I_E = I_B + I_C = I_B + \alpha I_E + I_{CBO}$$

$$\Rightarrow I_E(1-\alpha) = I_B + I_{CBO}$$

$$\Rightarrow I_E = \frac{I_B}{(1-\alpha)} + \frac{I_{CBO}}{(1-\alpha)} = (\beta+1) I_B + (\beta+1) I_{CBO}$$

$$\boxed{I_E = (\beta+1) I_B + (\beta+1) I_{CBO}}$$

Current gain $\gamma = \frac{\Delta I_E}{\Delta I_B} = \frac{\Delta I_E}{\Delta I_E - \Delta I_C} = \frac{\Delta I_E / \Delta I_C}{\frac{\Delta I_E}{\Delta I_C} - 1}$

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

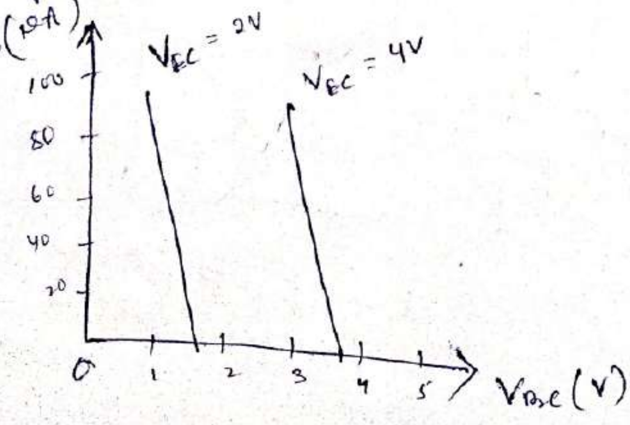
$$\boxed{\gamma = \frac{1}{1-\alpha} = \beta + 1}$$

The common-collector (CC) arrangement gives very high input impendance and very low output impendance. Therefore, voltage gain is less than unity.

→ Due to its high input impendance and low output impendance, the configuration is used for impendance matching.

Common-collector Characteristics

Input characteristics



→ The CC input characteristics are quite different from CB or CE input characteristics.

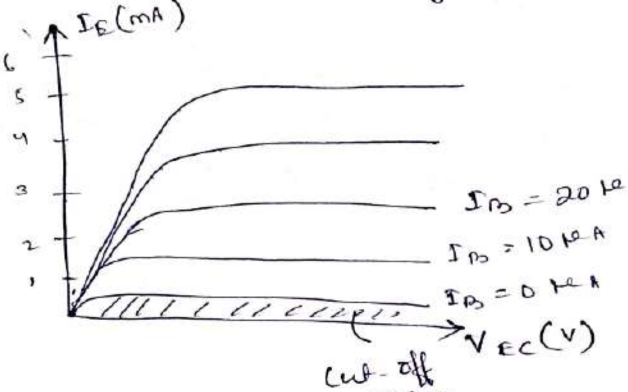
The difference is due to the fact that the output voltage V_{BC} is largely determined by the output voltage (V_{EC}).

$$V_{EC} = V_{EB} + V_{BC}$$

$$\Rightarrow V_{EB} = V_{EC} - V_{BC}$$

Increasing the level of V_{BC} with V_{EC} held constant reduces the base emitter voltage (V_{EB}) and thus reduces I_B.

Output and current gain characteries :-



→ The output characteristic is a plot of emitter current (I_E) versus emitter-collector voltage (V_{EC}) for several constant levels of base current (I_B).

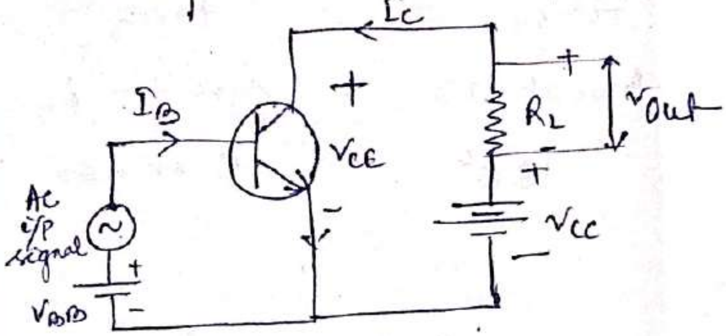
→ The CE output ~~ch~~ and current gain characteristic is practically identical to those CE circuit.

(A comparison of CB, CE and CC configuration)

Property	CB	CE	CC
Input resistance	Low (about 100 Ω)	Moderate (about 750 Ω)	High (750K
Output resistance	High (about 450 kΩ)	Moderate (about 45 kΩ)	Low (25 Ω)
Current gain	1	High	High
Voltage gain	about 150	About 500	Less than 1
Phase shift between i/p and output voltage	0° or 360°	180°	0° or 36

Transistor Load lines :-

It is defined as the locus of operating point on the output characteristic of the transistor.



V_{CC} = the supply voltage to collector.

R_L = collector resistance.

V_{CE} = collector-to-emitter voltage.

Applying KVL to the collector circuit

$$V_{CC} - I_C R_L - V_{CE} = 0$$

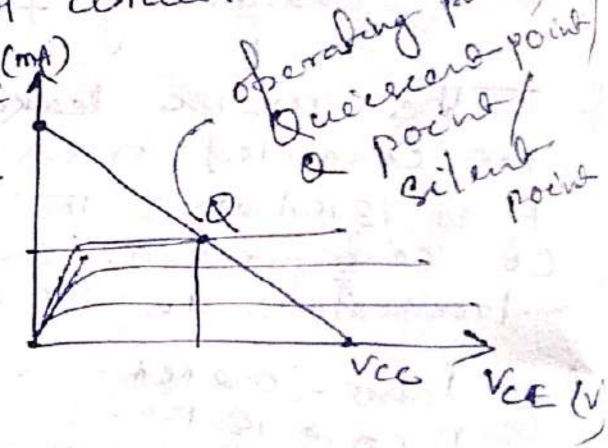
$$\Rightarrow V_{CC} = I_C R_L + V_{CE}$$

when $V_{CE} = 0$

$$V_{CC} = I_C R_L \Rightarrow \boxed{I_C = \frac{V_{CC}}{R_L}}$$

When $I_C = 0$

$$V_{CE} = V_{CC}$$



By joining these two ~~lines~~ points, dc load line is obtained. The dc load line gives the values of collector current I_C and collector-emitter voltage V_{CE} in the absence of ac signal.

→ It is also called operating point because the variations in V_{CE} and I_C take place about this point when signal is applied.

The best position for this point where $\boxed{V_{CE} = \frac{1}{2} V_{CC}}$

Transistor Biasing

The proper flow of zero signal collector current and the maintenance of proper collector emitter voltage during the passage of signal is called the transistor biasing.

→ A transistor is biased either with the help of battery or associating a circuit with the transistor. The circuit used for transistor biasing is called the biasing circuit.

Requirements of Biasing circuits:-

A biasing network associated with a transistor should fulfill the following requirements.

→ Establish the operating point in the middle of the active region of the characteristics, so that on applying the input signal the instantaneous operating point does not move either to the cut-off region or to the saturation region.

→ Stabilize the collector current I_C against temperature variations.

$$I_C = \beta I_B + (1+\beta) I_{CO}$$

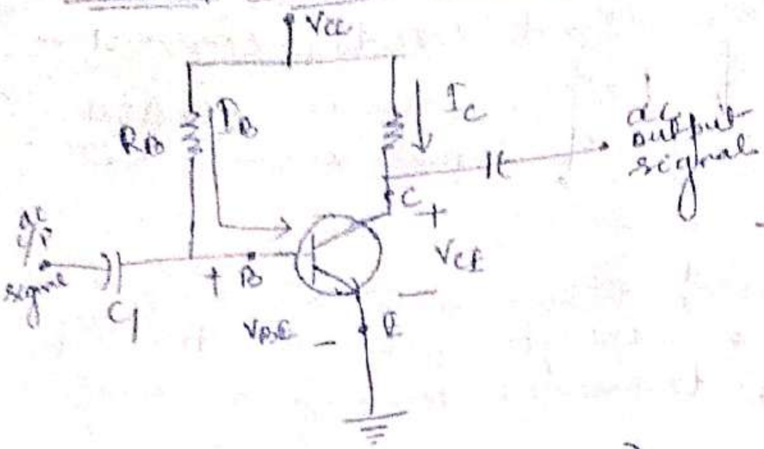
I_C increases with increase in temperature which leads to more power dissipation. This results burn-out of the transistor called thermal runaway.

Sol - If I_B is made to fall with increase in temp, then decrease in the term βI_B can be made to neutralize the increase in the term $(1+\beta) I_{CBO}$, thereby keeping I_C almost constant.

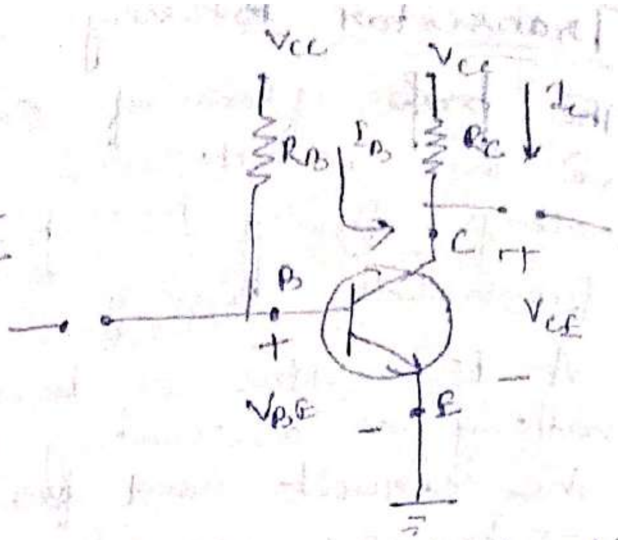
→ Make the operating point independent of transistor parameters so that replacement of the transistor by another of the same type in the circuit does not shift the operating point.

Dr. Deepa Das

Fixed Bias Configuration



(fixed-bias circuit)

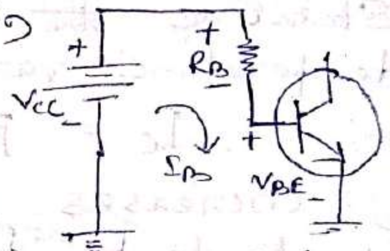


(DC equivalent ckt)

→ for dc analysis the network can be isolated from the indicated ac levels by replacing the capacitors with an open circuit equivalent because the reactance of a capacitor for dc is $X_C = \frac{1}{2\pi f C} = \frac{1}{2\pi(0)C} = \infty\ \Omega$. (open circuit)

Forward bias of Base-Emitter

Consider first the base-emitter circuit loop. Applying Kirchhoff's voltage equation in the clockwise direction for the loop, we obtain



$$V_{CC} - I_B R_B - V_{BE} = 0.$$

$$\Rightarrow \boxed{I_B = \frac{V_{CC} - V_{BE}}{R_B}}$$

Because the supply voltage V_{CC} and the base-emitter voltage V_{BE} are constants, the selection of a base resistor R_B sets the level of base current for the operating point.

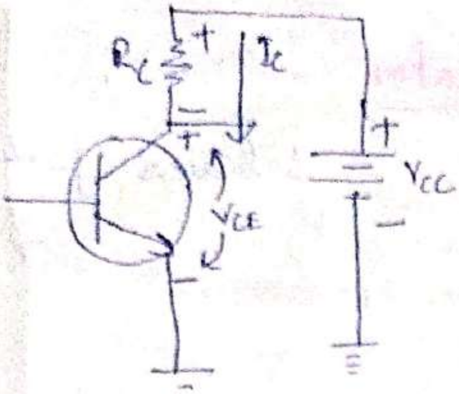
Collector - Emitter loop

The magnitude of the collector current is directly related to I_B

$$\boxed{I_C = \beta I_B}$$

Applying Kirchhoff's voltage law

Dr. Deepa Das



$$V_{CC} - V_{CE} - I_C R_C = 0$$

$$\Rightarrow \boxed{V_{CE} = V_{CC} - I_C R_C}$$

— This states that the voltage drop across the collector – emitter region of a transistor in the fixed – bias configuration is the supply voltage less the drop across R_C.

$$\boxed{V_{CE} = V_C - V_E}$$

where V_{CE} is the voltage from collector to emitter and V_C and V_E are the voltages from collector and emitter to ground, respectively.

Since $V_E = 0\ V$

$$\boxed{V_{CE} = V_C}$$

$$\boxed{V_{BE} = V_B - V_E}$$

As $V_E = 0$, $\boxed{V_{BE} = V_B}$

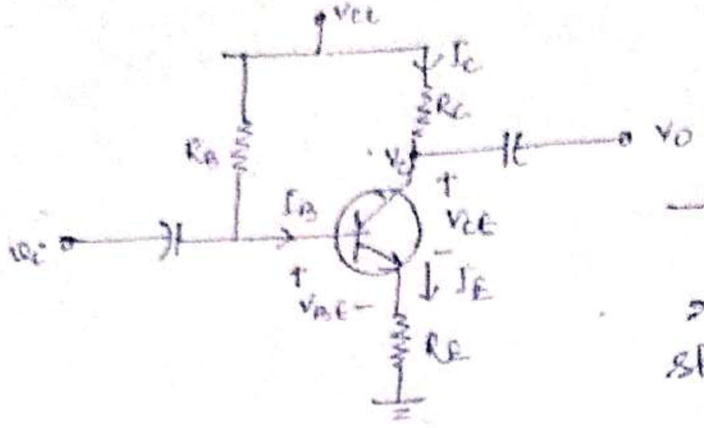
(E) Advantage

→ — The biasing circuit is very simple.

Disadvantages

→ — The circuit provides poor stability.

Emitter — Bias configuration :-



The dc bias network contains an emitter resistor to improve the stability level over that of fixed bias configuration

(BJT bias circuit with emitter resistor)

Base - Emitter loop

Applying KVL

$$V_{CC} - I_B R_B - V_{BE} - I_E R_E = 0$$

$$I_E = (\beta+1) I_B \quad \left(\because \begin{aligned} I_E &= I_C + I_B \\ &= \beta I_B + I_B \\ I_E &= (\beta+1) I_B \end{aligned} \right)$$

$$\Rightarrow V_{CC} - I_B R_B - V_{BE} - (\beta+1) I_B R_E = 0$$

$$\Rightarrow -I_B \left(R_B + (\beta+1) R_E \right) = -V_{CC} + V_{BE}$$

$$\Rightarrow I_B \left(R_B + (\beta+1) R_E \right) = V_{CC} - V_{BE}$$

$$\Rightarrow \boxed{I_B = \frac{V_{CC} - V_{BE}}{R_B + (\beta+1) R_E}}$$

Collector - Emitter loop

Applying KVL

$$V_{CC} - I_C R_C - V_{CE} - I_E R_E = 0$$

Substituting

$$I_C \cong I_E$$

$$V_{CE} = V_{CC} - I_C (R_C + R_E)$$

If V_E is the voltage from emitter to ground and is determined by

$$V_E = I_E R_E$$

$$V_{CE} = V_C - V_E$$

$$V_C = V_{CE} - V_E$$

$$V_C = V_{CC} - I_C R_C$$

Similarly

$$V_{BE} = V_B - V_E \Rightarrow V_B = V_{BE} + V_E$$

$$V_B = V_{CC} - I_B R_B$$

Advantage

- The addition of the emitter resistor to the dc bias of the BJT provides improved stability.

Voltage – Divider Bias Configuration

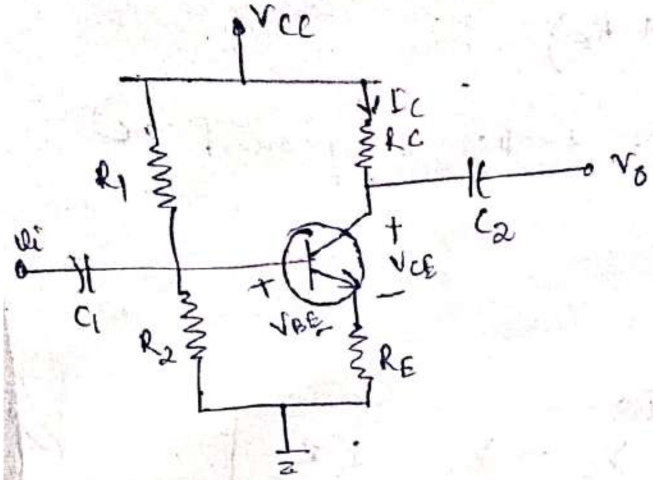
→ This is the most commonly used biasing arrangement.

→ The voltage – divider is formed by the resistors R_1 and R_2 across V_{CC}. The emitter resistance R_E provides stabilization. The.

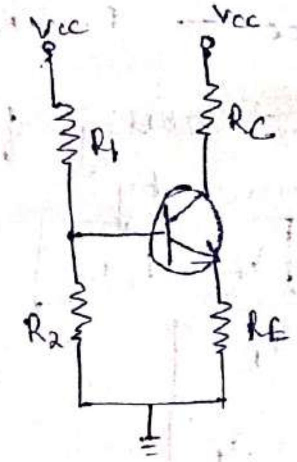
→ There are two methods that can be applied to analyze the voltage - divider configuration.

Exact method :- This can be applied to any voltage - divider configuration.

Approximate method :- This can be applied only if specific conditions are satisfied.



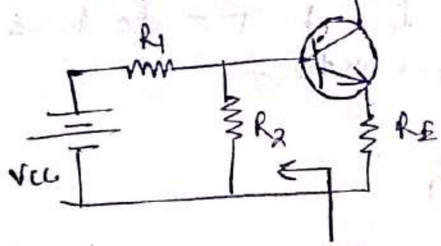
(Voltage – divider bias configuration)



(DC components of the voltage – divider configuration)

Exact Analysis

The Thevenin equivalent network for the network to the left of the base terminal can be found by the following manner.



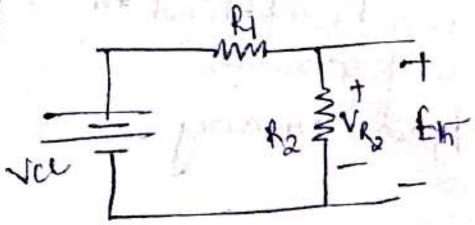
Thevenin

(Input side of the network)

Hence $R_{Th} = R_1 \| R_2 = \frac{R_1 R_2}{R_1 + R_2}$

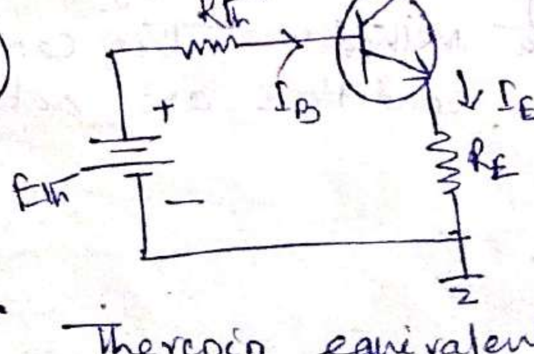
Applying the voltage – divider rule

$$E_{Th} = V_{R_2} = \frac{V_{CC} \cdot R_2}{R_1 + R_2}$$



(Determining E_{Th})

Then redrawing Thevenin network



(Thevenin equivalent circuit)

Applying KVL to the Thevenin equivalent circuit

$$E_{Th} - I_B R_{Th} - V_{BE} - I_E R_E = 0$$

$$I_E = (\beta+1) I_B$$

so $E_{Th} - I_B\left(R_{Th} + (\beta+1) R_E\right) - V_{BE} = 0$

so $$\boxed{I_B = \frac{E_{Th} - V_{BE}}{R_{Th} + (\beta+1) R_E}}$$

Analyzing the collector-emitter loop.

$$V_{CC} - I_C R_C - V_{CE} - I_E R_E = 0$$

$$I_E \cong I_C$$

$$V_{CE} = V_{CC} - I_C(R_C + R_E)$$

$$V_{CE} = V_C - V_E$$

so $$\boxed{V_C = V_{CC} - I_C R_C}$$

Approximate Analysis

The condition is

$$\boxed{\beta R_E \geq 10 R_2}$$

$$\boxed{V_B = \frac{V_{CC} R_2}{R_1 + R_2}}$$

$$V_{BE} = V_B - V_E$$

so $V_E = V_B - V_{BE}$

$$I_E = \frac{V_E}{R_E}$$

$$I_C \cong I_E$$

$$\boxed{V_{CE} = V_{CC} - I_C(R_C + R_E)}$$

Stability Factor

Stability factor is defined as the rate of change of collector current w.r.t I_{CO} keeping β and V_{BE} constant.

$$S = \frac{dI_C}{dI_{CO}} \text{ at constant } \beta \text{ and } V_{BE}$$

The smaller is the value of S, higher is the stability.

$$\text{Stability factor } S = \frac{1+\beta}{1-\beta\frac{dI_B}{dI_C}}$$

Fixed Bias circuit

$$I_B = \frac{V_{CC} - V_{BE}}{R_B}$$

I_B is independent of I_C. Hence $\frac{dI_B}{dI_C} = 0$.

So, $S = \beta + 1$

Emitter Bias circuit

$$V_{CC} - I_B R_B - V_{BE} - I_E R_E = 0$$

$$V_{CC} - I_B R_B - V_{BE} - (I_B + I_C) R_E = 0$$

$$V_{CC} - I_B R_B - V_{BE} - I_B R_E - I_C R_E$$

$$V_{CC} = I_B R_B + V_{BE} + I_B R_E + I_C R_E$$

differentiating both the w.r.t I_C,

$$\frac{dV_{CC}}{dI_C} = \frac{d(I_B R_B)}{dI_C} + \frac{d(V_{BE})}{dI_C} + \frac{d(I_B R_E)}{dI_C} + \frac{d(I_C R_E)}{dI_C}$$

$$\Rightarrow 0 = R_B \frac{dI_B}{dI_C} + R_E \frac{dI_B}{dI_C} + R_E$$

$$= R_E + (R_B + R_E)\frac{dI_B}{dI_C}$$

$$\Rightarrow \frac{dI_B}{dI_C} = \frac{-R_E}{(R_B + R_E)}$$

$$S = \frac{1+\beta}{1+\beta\left(\frac{R_E}{R_B+R_E}\right)} = \frac{(1+\beta)(R_B+R_E)}{R_B + R_E + \beta R_E}$$

Dr. Deepa Das

$$S = (1+\beta)\frac{\left(1+R_B/R_E\right)}{1+\frac{R_B}{R_E}+\beta}$$

Voltage divider Bias circuit

$$V_{th} = I_B R_{th} + V_{BE} + I_E R_E$$
$$= I_B R_{th} + V_{BE} + (I_B + I_C) R_E$$

Differentiating both side w.r.t I_C

$$\frac{dV_{th}}{dI_C} = \frac{d(I_B R_{th})}{dI_C} + \frac{dV_{BE}}{dI_C} + \frac{d(I_B R_E)}{dI_C} + \frac{d(I_C R_E)}{dI_C}$$

$$0 = R_{th}\left(\frac{dI_B}{dI_C}\right) + R_E\left(\frac{dI_B}{dI_C}\right) + R_E$$

$$\Rightarrow 0 = \frac{dI_B}{dI_C}\left(R_{th} + R_E\right) + R_E$$

$$\Rightarrow \frac{dI_B}{dI_C} = \frac{-R_E}{R_E + R_{th}}$$

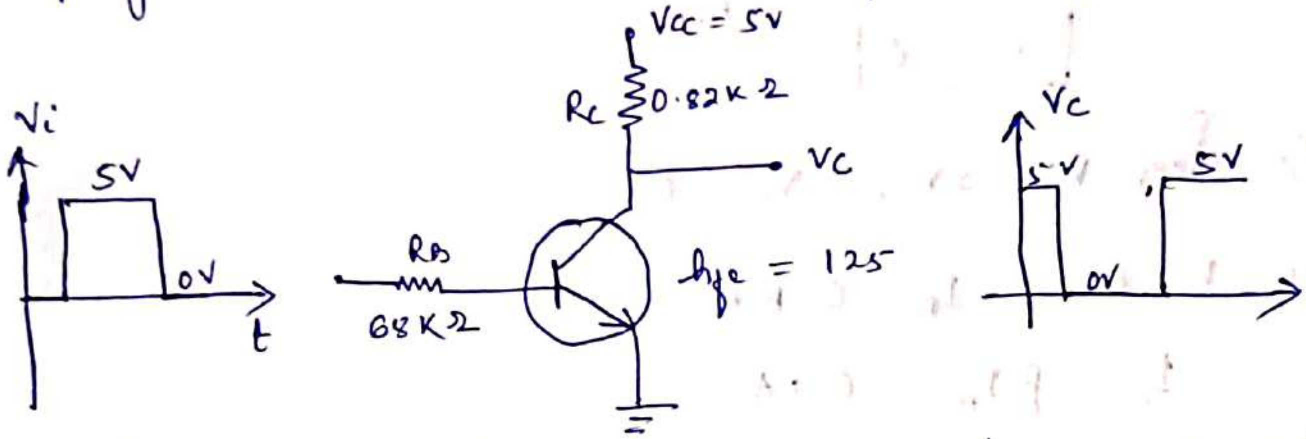
Stability factor $S = \dfrac{1+\beta}{1-\beta\frac{dI_B}{dI_C}}$

$$\Rightarrow S = \frac{1+\beta}{1+\beta\frac{R_E}{R_E+R_{th}}} = (1+\beta)\frac{R_E + R_{th}}{R_E + R_{th} + \beta R_E}$$

$$S = (1+\beta)\frac{1 + R_{th}/R_E}{1+\beta+R_{th}/R_E}$$

Transistor Switching Networks

- Through proper design, the transistor can be used as a switch for computer and control applications.
- The network of the following figure can be employed as an inverter in computer logic circuit.



→ Proper design for the inversion process requires that the operating point switch from cutoff to saturation along the load line.

→ When $V_i = 5V$, the transistor is "ON". The design must ensure that the network is heavily saturated by a level of I_B greater than that associated with the I_B curve appearing near the saturation level.

$$I_C = \beta I_B$$

Hence $I_{Bsat} \cong \frac{I_{Csat}}{\beta_{dc}}$

For the saturation level, the following condition must be satisfied i.e

$$I_{Bsat} > \frac{I_{Csat}}{\beta_{dc}}$$

From the above figure $I_B = \frac{V_i - 0.7}{R_B} = \frac{5V - 0.7V}{68K\Omega}$

$$I_B = 63\mu A$$

$$I_{Csat} = \frac{V_{CC}}{R_C} = \frac{5V}{0.82K\Omega} \cong 6.1\ mA$$

Dr. Deepa Das

$$I_B = 63\,\mu A > \frac{I_{Csat}}{\beta_{dc}} = \frac{6.1\,mA}{125} = 48.8\,\mu A.$$

Hence,

$$V_C = V_{CC} - I_C R_C$$

$$= V_{CC} - I_{sat} R_C$$

$$= V_{CC} - \frac{V_{CC}}{R_C} \cdot R_C$$

$$\boxed{V_C = 0}$$

So, for $V_i = 5V$, $V_C = 0V$.

For $V_i = 0V$, $I_B = 0\,\mu A$

$$I_C = \beta I_B = 0\,mA$$

$$V_C = V_{CC} - I_C R_C$$

$$\boxed{V_C = V_{CC}} \Rightarrow V_C = 5V$$