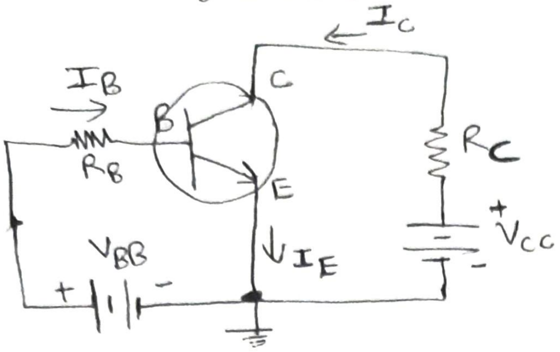
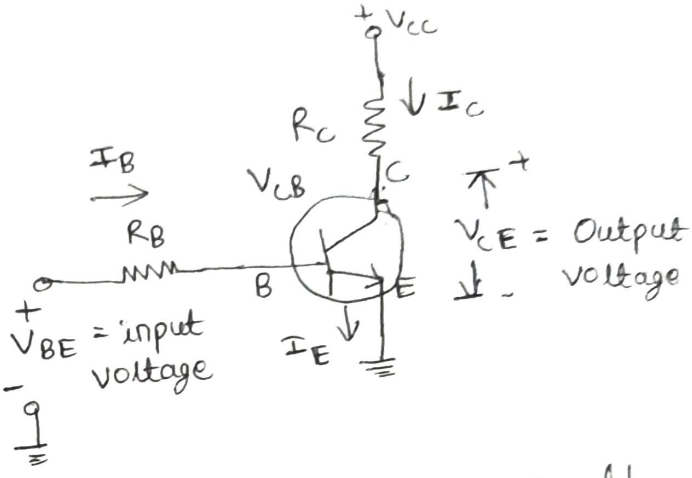
Common Emitter (CE configuration):-

Fig: CE configuration



Transistor currents and voltages in CE configuration



In CE configuration, I_B is the input current and I_C is the output current. Now we will see, how I_C is related to I_B.

optional

(We know that $I_C = \alpha_{dc} I_E + I_{CBO}$

$$I_C - I_{CBO} = \alpha_{dc} I_E$$

$$\frac{I_C}{\alpha_{dc}} - \frac{I_{CBO}}{\alpha_{dc}} = I_B + I_C \qquad (\because I_E = I_B + I_C)$$

$$\frac{I_C}{\alpha_{dc}} - I_C = I_B + \frac{I_{CBO}}{\alpha_{dc}}$$

$$I_C\left(\frac{1}{\alpha_{dc}} - 1\right) = I_B + \frac{I_{CBO}}{\alpha_{dc}}$$

$$I_C\left(\frac{1-\alpha_{dc}}{\alpha_{dc}}\right) = I_B + \frac{I_{CBO}}{\alpha_{dc}}$$

$$I_C = \left(\frac{\alpha_{dc}}{1-\alpha_{dc}}\right) I_B + \left(\frac{1}{1-\alpha_{dc}}\right) I_{CBO}$$

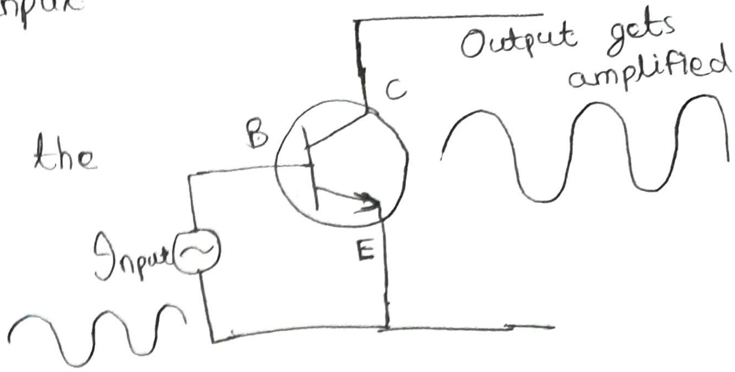
$$I_C = \beta_{dc} I_B + \underbrace{[1+\beta_{dc}]\, I_{CBO}}_{I_{CEO}} \qquad \left(\because \beta_{dc} = \frac{\alpha_{dc}}{1-\alpha_{dc}},\quad 1+\beta_{dc} = \frac{1}{1-\alpha_{dc}}\right)$$

Reverse leakage current in CE configuration, $I_{CEO} = (1+\beta_{dc}) I_{CBO}$)

optional

Base, Emitter junction of the input side is forward biased.

Collector, ~~Emitter~~ Base junction of the output side is Reverse biased

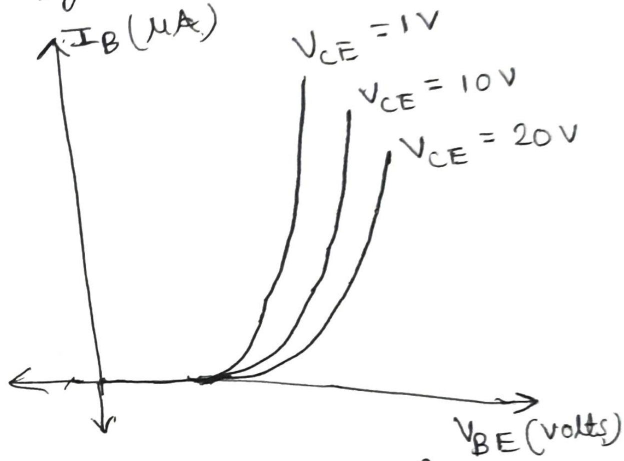


<u>Input characteristics</u> :- (V_{BE}, I_B) for constant V_{CE}

Input characteristics define the relationship between this base current I_b and the voltage V_{be}

These curves are similar to the forward characteristics of the PN junction diode.

<u>Fig: Input characteristics</u>



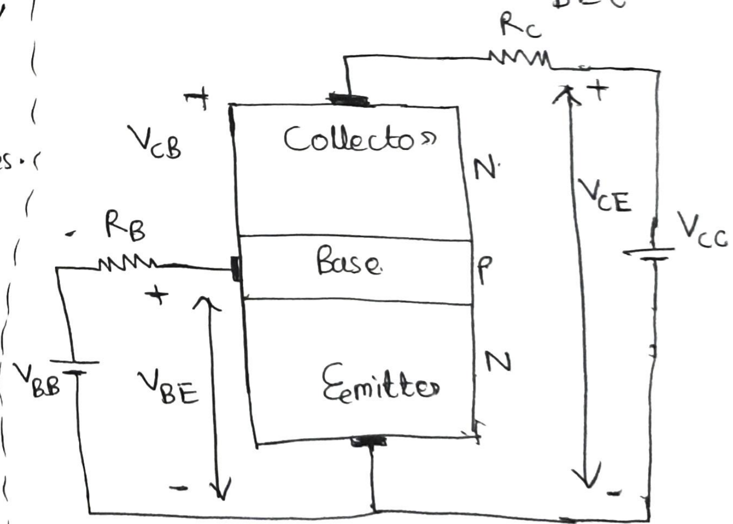
As V_{CE} increases, I_B reduces

$$\uparrow V_{CE} = V_{CB} + \underline{V_{BE}}$$

As V_{CB} (reverse bias) increases, the depletion region between collector to Base junction increases.

Due to this effective base width will reduce, then the probability of recombination in this base region will reduce.

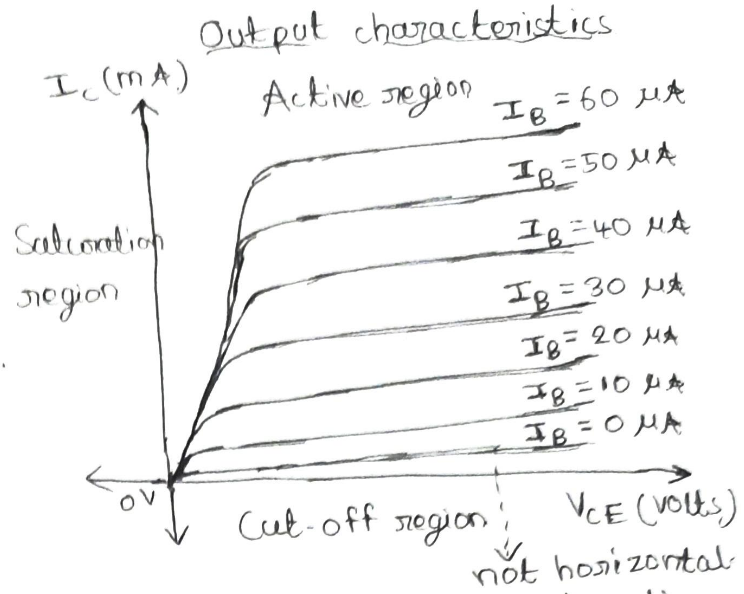
Due to this most of e^{-}'s will get collected at collector terminal. As $V_{CE}\uparrow$, $I_B\downarrow$.



<u>Output characteristics</u> :- (V_{CE}, I_C) for constant I_B

Output characteristics define the relationship between this collector current 'I_C' and the voltage V_{CE}

Here the different I_c vs V_{CE} curves are shown for different values of the I_B.



Active region

→ As $I_B\uparrow$ increases, $I_c\uparrow$

→ These curves are not horizontal.

As $V_{CE}\uparrow$, $I_c\uparrow$.

As $V_{CE}\uparrow = V_{CB}\uparrow + V_{BE}$

As $V_{CB}\uparrow$, effective base width $\downarrow$, Probability of recombination in Base region $\downarrow$. e^-'s reaching the collector $\uparrow$. i.e $I_c\uparrow$.

i.e in the active region, BJT is used as an amplifier.

i.e $I_c = \beta_{dc} I_B$ $\qquad$ β_{dc} → Current gain of CE configuration

Saturation region:-

As $V_{CB}\downarrow$, then collector to Base junction becomes forward biased

→ As collector to Base junction and the Base to Emitter junction are forward biased, then BJT operates in saturation region.

Cut-off region:-

Transistor operates in this region, when $I_B = 0$.

When $I_B = 0$, $I_c \neq 0$ (As shown in the graph)

In cut-off region, I_c is relatively large.

When $I_B = 0$, leakage current is more. ($I_{CEo}\uparrow$)

i.e $I_{CEo} = (1+\beta) I_{CBo}$

Features:- CE configuration has,

(i) Moderate Current Gain.

(ii) Moderate Voltage Gain

(iii) High Power Gain.

(iv) Moderate Input Impedance.

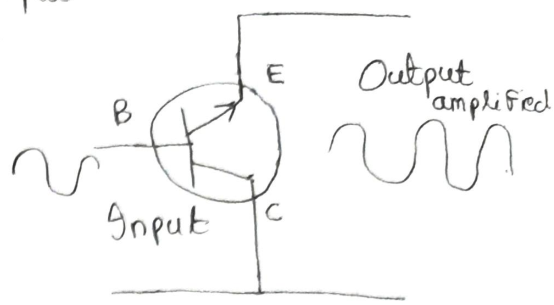
(v) Moderate Output Impedance.

Common Collector Configuration :- (CC)

Here 'C' is common in between ~~B~~ & ~~E~~ (input / output)

Input is applied between 'B' & 'C'

Output is collected between 'E' & 'C'.



To use BJT as an amplifier,

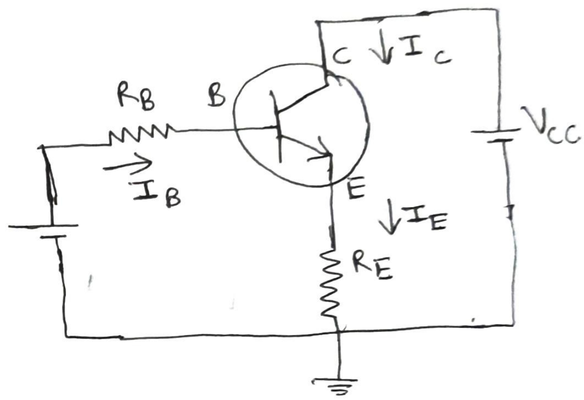
Base - Emitter Junction - Forward Bias.

Collector - Base Junction - Reverse Bias.

Input side : I_B, V_{CB}

Output side : I_E, V_{CE}

Fig: CC configuration



characteristics

Common collector configuration:-

This is also called grounded collector configuration. In this configuration, base is the input terminal, emitter is the output terminal and collector is the common terminal.

Input characteristics:-

To determine input characteristics, V_{EC} is kept at a suitable fixed value. The base-collector voltage V_{BC} is increased in equal steps and the corresponding increase in I_B is noted. this is repeated for different fixed values of V_{EC}. plots of V_{BC} versus I_B for different values of V_{EC}.

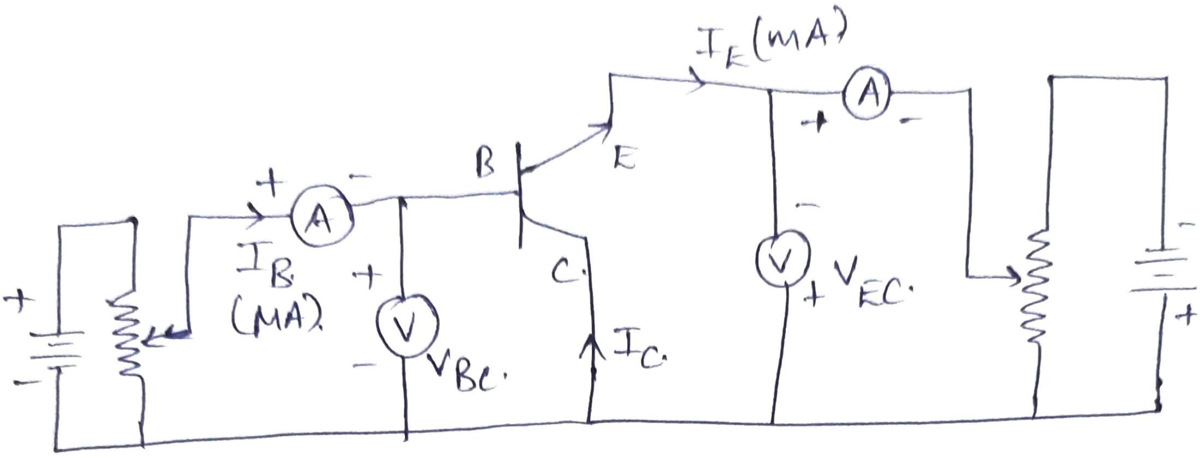
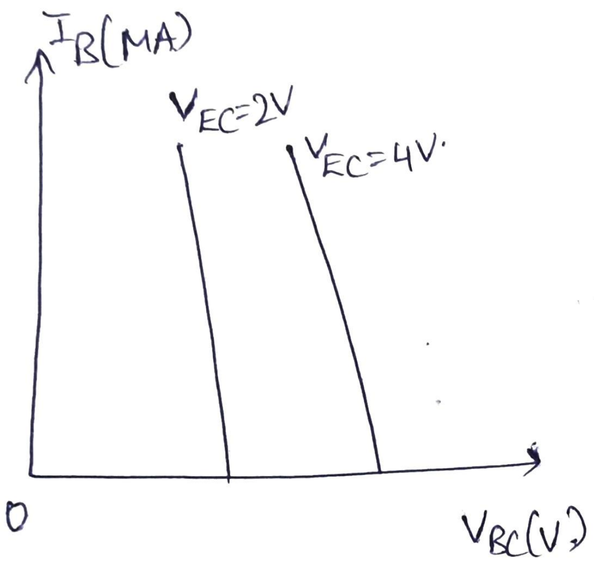
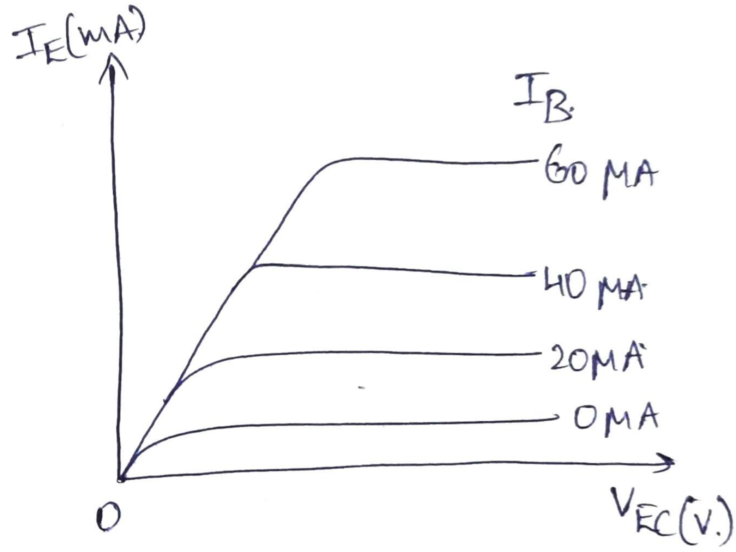


fig:- Circuit to determine CC static characteristics



(a) CC input characteristics



(b) CC output characteristics

Output characteristics:-

The output characteristics are same as those of CE configuration. Because the emitter current is approximately equal to collector current I_C.

i.e $\boxed{I_E \approx I_C}$; where I_B is very negligible.

Relation Between α, β and γ :-

In a transistor, the ratio of change in output current to the change in input current is known as the current amplification factor.

In the CB configuration the current amplification factor,

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

→ In the CE configuration the current amplification factor, $\beta = \frac{\Delta I_C}{\Delta I_B}$

→ In the CC configuration the current amplification factor, $\gamma = \frac{\Delta I_E}{\Delta I_B}$

we know that $\Delta I_E = \Delta I_C + \Delta I_B$

$$\Delta I_C = \alpha \Delta I_E$$

$$\Delta I_E = \alpha \Delta I_E + \Delta I_B$$

$$\Delta I_B = \Delta I_E (1-\alpha)$$

dividing both sides by ΔI_C, we get

$$\frac{\Delta I_B}{\Delta I_C} = \frac{\Delta I_E (1-\alpha)}{\Delta I_C}$$

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

$$\Rightarrow \boxed{\beta = \frac{\alpha}{1-\alpha}.}$$

Rearranging this, we get, $\boxed{\alpha = \frac{\beta}{1+\beta}}$

→ $$\gamma = \frac{\Delta I_E}{\Delta I_B}$$

$$\Delta I_B = \Delta I_E - \Delta I_C$$

$$\gamma = \frac{\Delta I_E}{\Delta I_E - \Delta I_C}$$

Dividing the numerator and denominator on RHS by ΔI_E,

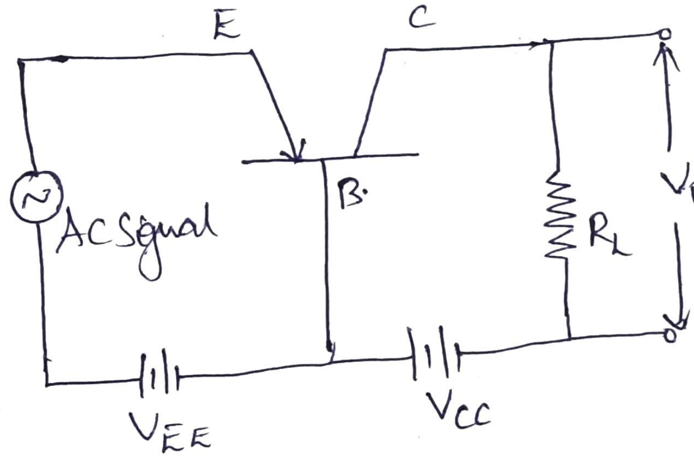
we get

$$\gamma = \frac{\frac{\Delta I_E}{\Delta I_E}}{\frac{\Delta I_E}{\Delta I_E} - \frac{\Delta I_C}{\Delta I_E}} = \frac{1}{1-\alpha}$$

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

Transistor as an Amplifier:-

The weak signal to be amplified is applied between emitter-base circuit and the output is taken across the load resistance. A voltage V_{EE} is also connected in the input circuit.



→ If V_{EE} is not connected in the circuit, then during negative peak, the emitter base junction will be in reverse bias, it will not amplify the signal. For sufficient operation EB junction should be forward biased.

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

The change in output voltage across the load is

$$\Delta V_0 = R_L \times \Delta I_C.$$
$$= R_L \times \alpha \times \Delta I_E$$

The voltage gain $A = \frac{\Delta V_0}{\Delta V_i}$

$$\Delta V_i = r_e \cdot \Delta I_E$$

$$A = \frac{R_L \times \alpha \times \Delta I_E}{r_e \cdot \Delta I_E} = \frac{\alpha R_L}{r_e}.$$

→ A is greater than unity, therefore transistor acts as an amplifier.

Comparision of CB, CE & CC. configurations:-

Property	CB.	CE	CC.
I/p resistance.	Low(≃100Ω)	Moderate	High.
O/p "	High	"	Low
Current gain	1	High	High.
Voltage gain	About 150	About 500	Less than 1

Transistor current components:-

In CB configuration, $\alpha = \frac{I_C}{I_E}$

→ Due to reverse bias of collector-base junction, small reverse saturation current of I_{CBO} flows in the collector region.

Then $\alpha = +\left(\frac{I_C - I_{CBO}}{I_E}\right)$

The negative signs comes because I_E and I_C are in opposite direction, α will be +ve.

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

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

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

But $I_E = I_C + I_B$

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

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

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

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

$$\Rightarrow \boxed{I_C = \beta I_B + (1+\beta) I_{CBO}} \quad \text{———} \quad (1)$$

→ for CE configuration, $\beta = \frac{I_C - I_{CEO}}{I_B}$

$$\Rightarrow I_C = \beta I_B + I_{CEO} \quad \text{———} \quad (2)$$

From eqn (1) & (2), we get $I_{CEO} = (1+\beta) I_{CBO}$

Emitter current $I_E = I_B + I_C$. ——— (3)

Subst eqn ① in ③, then.

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

(or)

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

Limits of operation / Breakdown in transist

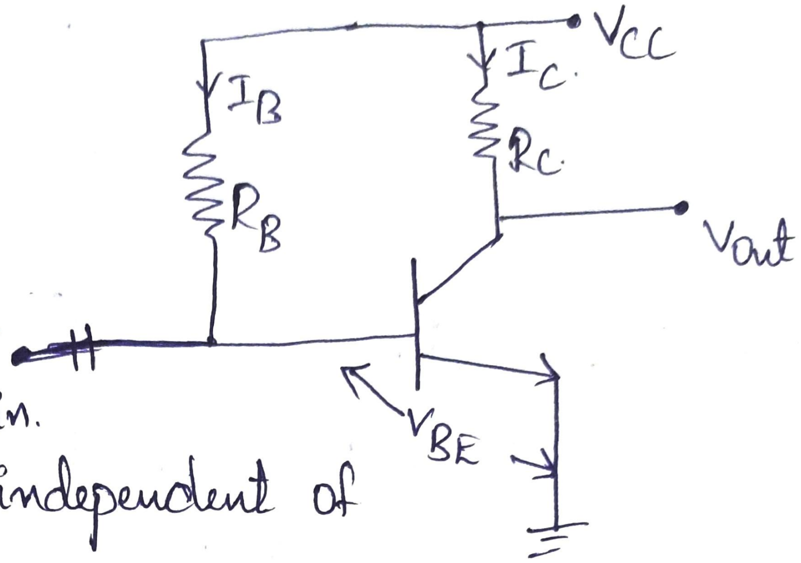
$\partial\beta \quad \Delta\beta$

Methods of Transistor Biasing:-

1) Fixed Bias (or) Base Resistor Method:-

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

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



Since this eqn is independent of current I_C, $dI_B/dI_C = 0$.

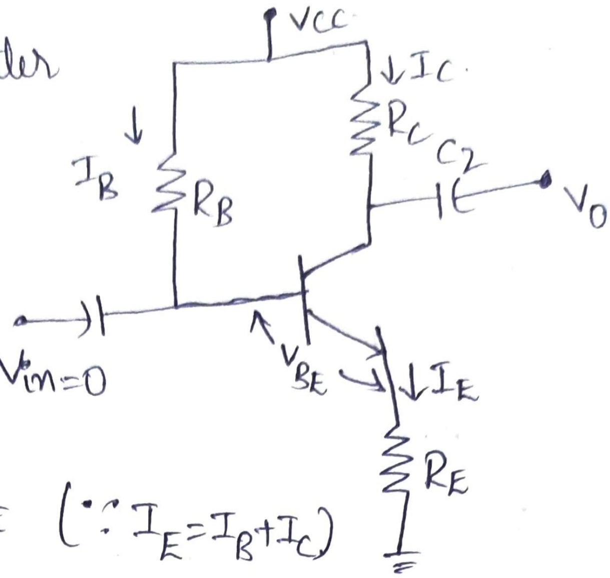
The stability factor $S = 1+\beta$.

Since β is a large quantity, this S becomes yields very poor stable circuit.

Emitter - Feedback Bias:-

This circuit contains an emitter resistance for improving the stability level over that of the fixed bias.

Applying KVL for base-emitter loop.



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

$$V_{CC} = I_B R_B + V_{BE} + (I_B + I_C) R_E \quad (\because I_E = I_B + I_C)$$

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

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

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

$$\frac{dI_B}{dI_C} = -\left(\frac{R_E}{R_B + R_E}\right) \quad [\because V_{BE} \text{ is independent of } I_C]$$

Then the stability factor

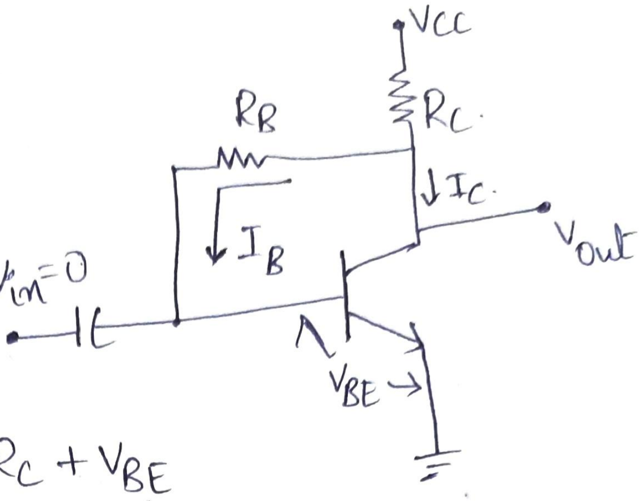
$$S = \frac{1+\beta}{1 + \beta \frac{R_E}{R_E + R_B}}$$

→ Since $1 + \beta \frac{R_E}{R_E + R_B} > 1$, $S < (1+\beta)$.

The stability factor is lower than the fixed bias circuit.

Collector to Base Bias or Collector-feedback Bias:-

Applying KVL to base-emitter loop then



$$V_{CC} = (I_B + I_C)R_C + I_B R_B + V_{BE}$$

$$V_{CC} = I_B(R_C + R_B) + I_C R_C + V_{BE}$$

$$\Rightarrow I_B(R_C + R_B) = V_{CC} - V_{BE} - I_C R_C$$

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

$$\frac{dI_B}{dI_C} = \frac{-R_C}{R_C + R_B}$$

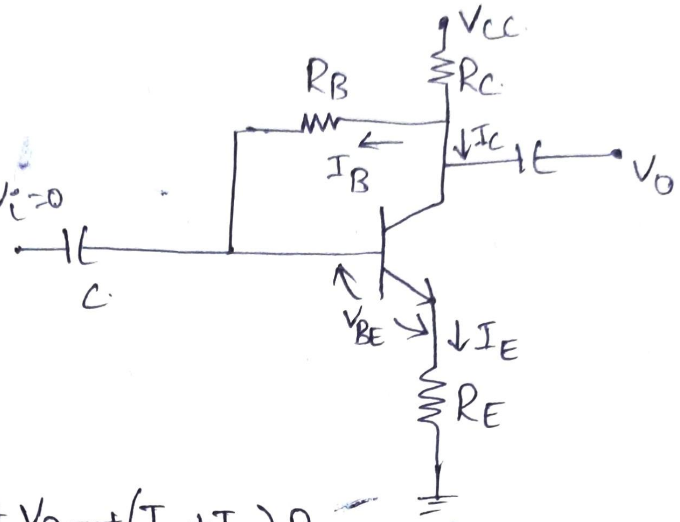
Then
$$S = \frac{1+\beta}{1 + \beta\left(\frac{R_C}{R_C + R_B}\right)}$$

→ Thus the stability can be improved by making R_B small & R_C large.

Collector - Emitter Feedback bias:-

Collector-emitter feedback bias circuit can be obtained by applying both the collector-feedback and emitter-feedback. Here collector-feedback is provided by connecting a resistance R_B from the collector to Base and emitter feedback is provided by connection of emitter resistance R_E from emitter to ground. Both the feedbacks are used to control the collector current I_C and base current I_B in the opposite direction to increase the stability.

Apply KVL, then



$$V_{CC} = (I_B + I_C)R_C + I_B R_B + V_{BE} + I_E R_E$$

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

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

$$\Rightarrow I_B = \frac{V_{CC} - V_{BE}}{R_C + R_B + R_E} + \frac{(R_E + R_C) I_C}{R_C + R_B + R_E}$$

Since V_{BE} is independent of I_C.

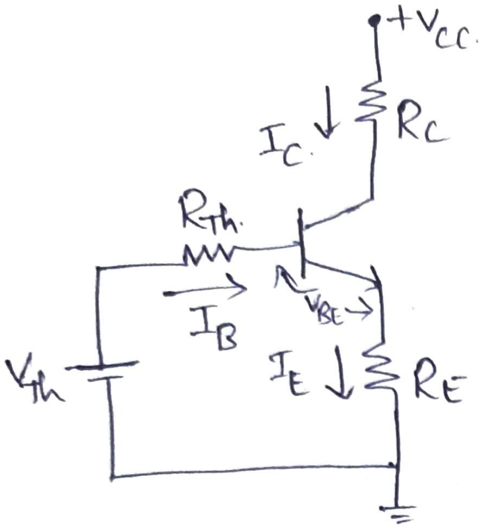
$$\frac{dI_B}{dI_C} = \frac{-(R_E + R_C)}{R_C + R_B + R_E}$$

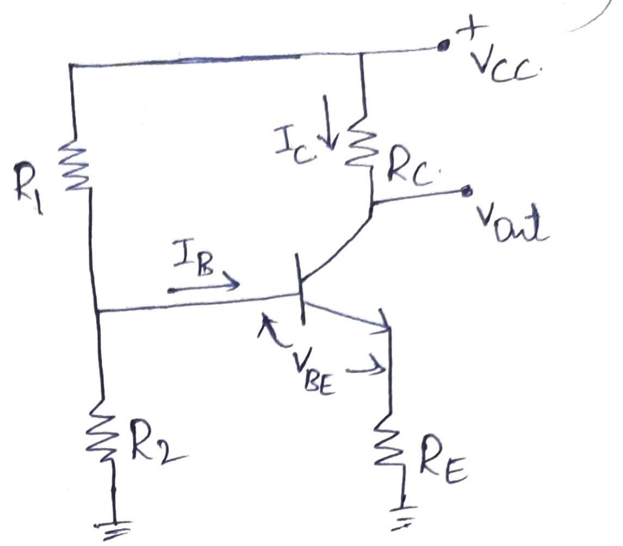
Then

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

→ Stability of this feedback is better than the those two feedback techniques.

Self bias or Voltage divider bias:-

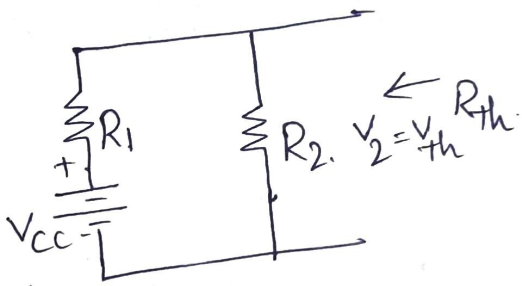




(b) Thevenin's Equivalent circuit (a) Self Bias

→ This biasing circuit is also called potential divider circuit.

$$V_{th} = \frac{V_{CC} \times R_2}{R_1 + R_2} \quad \text{and} \quad R_{th} = \frac{R_1 R_2}{R_1 + R_2}$$



Applying KVL to base-emitter loop

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

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

$$I_B = \frac{V_{th} - V_{BE}}{R_{th} + R_E} - \frac{I_C R_E}{R_{th} + R_E}$$

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

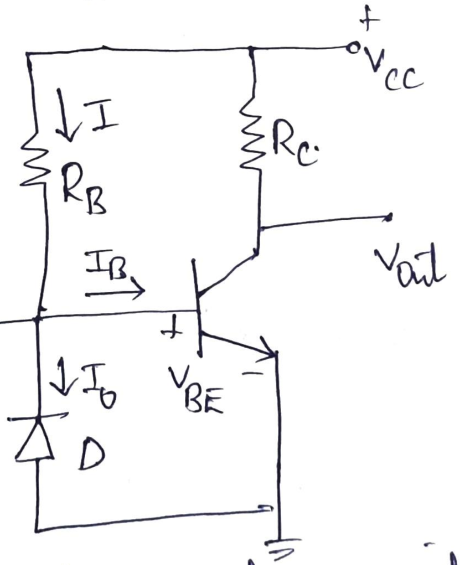
$$S = \frac{1+\beta}{1+\beta\left(\frac{R_E}{R_E+R_{th}}\right)}$$

$$= \frac{(1+\beta)(R_E+R_{th})}{R_E+R_{th}+\beta R_E} = \frac{(1+\beta)\left(1+\frac{R_{th}}{R_E}\right)}{1+\beta+\frac{R_{th}}{R_E}}$$

→ S is equal to one, if the ratio R_{th}/R_E is very small as compared to 1. To improve the stability, the equivalent resistance R_{th} must be decreased. Self bias is best one over other types of biasing.

Bias compensation using diode and Transistor:-

1) Diode Compensation:-



The diode D connected across the base-emitter junction for compensation of change in collector saturation current I_{CO}. The diode is of the same material as the transistor and it is reverse biased by the base-emitter voltage V_{BE}, allowing the diode reverse saturation current I_0 to flow through diode D. The base current

$$I_B = I - I_0.$$