

UNIT :-

* BIPOLAR JUNCTION TRANSISTOR *

INTRODUCTION:-

Transistor means transfer of resistance from input to output. There are two types of transistor

- * Bipolar Junction transistor (BJT)

- * Field effect transistor (FET)

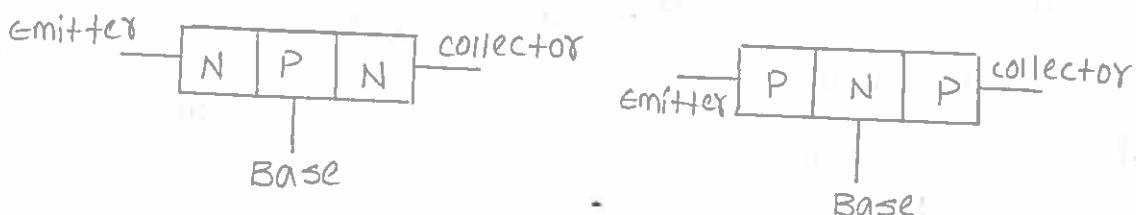
BIPOLAR JUNCTION TRANSISTOR:-

BJT are formed by combining of two PN diodes. Bipolar means in BJT the current is produced due to both majority and minority charge carriers.

There are two types of BJT's

- * NPN Transistor

- * PNP Transistor.



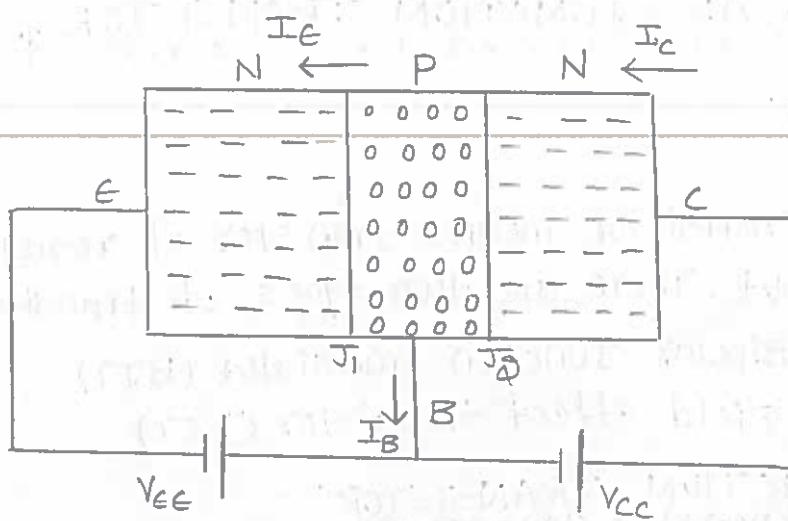
Transistor consist three terminals emitter, base, collector.

- * Emitter region having highly doped, moderate in size

- * Base is lightly doped and small in size

- * collector is moderately doped and large in size.

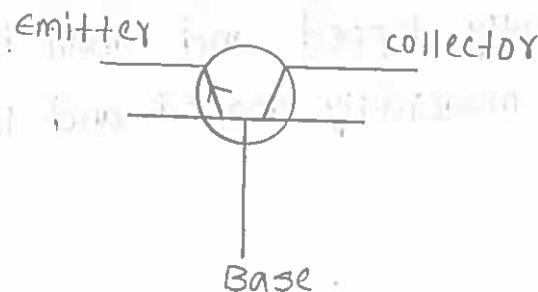
OPERATION OF NPN TRANSISTOR:-



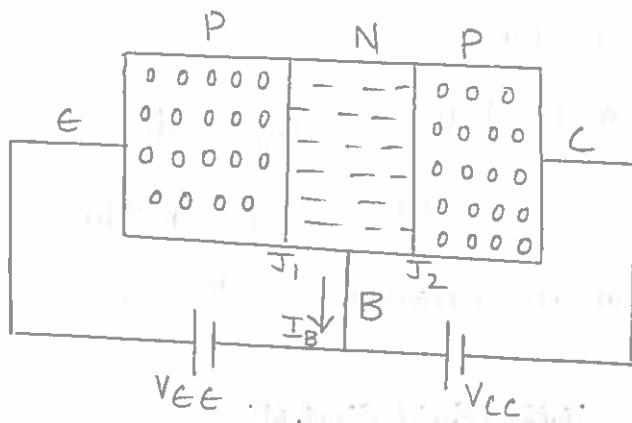
In NPN transistor emitter base junction is forward bias and collector base junction is reverse bias. The forward bias causes the electrons in the N type emitter to flow towards base. This constitutes emitter current I_E which flows from base to emitter. same electrons combine with holes in the base region remaining 95% of electrons flows towards collector terminal.

Total emitter current is equal to sum of base current and collector current.

$$I_E = I_B + I_C$$



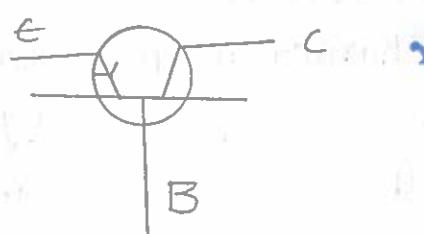
OPERATION OF PNP TRANSISTOR:-



In PNP transistor emitter base junction is forward bias and collector base junction is reverse bias. The forward bias causes the holes in the P type - emitter to flow towards base. This constitutes emitter current I_E which flows from base to emitter. Some holes combine with electrons in the base region remaining 95% of holes flows towards collector terminal.

Total emitter current is equal to sum of base current and collector current

$$I_E = I_B + I_C$$



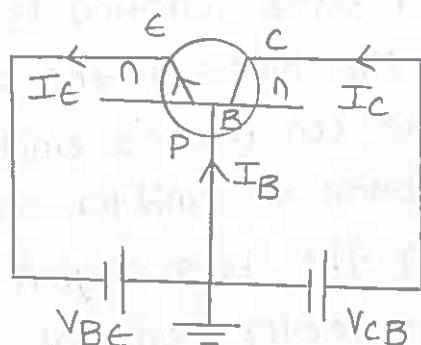
Transistor configuration:-

If transistor is used in any circuit, it requires four terminals but transistor having only three terminals. So when the transistor used in the circuit

one terminal is used as common terminal depending on which terminal is used as common terminal. There are three types of configurations.

- * common base configuration (CB)
- * common emitter configuration (CE)
- * common collector configuration (CC)

COMMON BASE CONFIGURATION:-

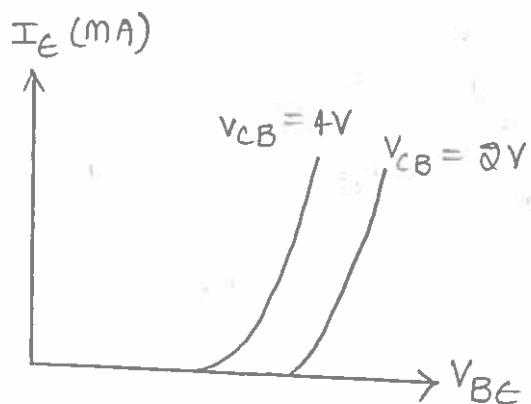


In common base configuration base terminal is common for both input and output. So in common base configuration emitter terminal is input terminal, collector terminal is output terminal.

INPUT CHARACTERISTICS:-

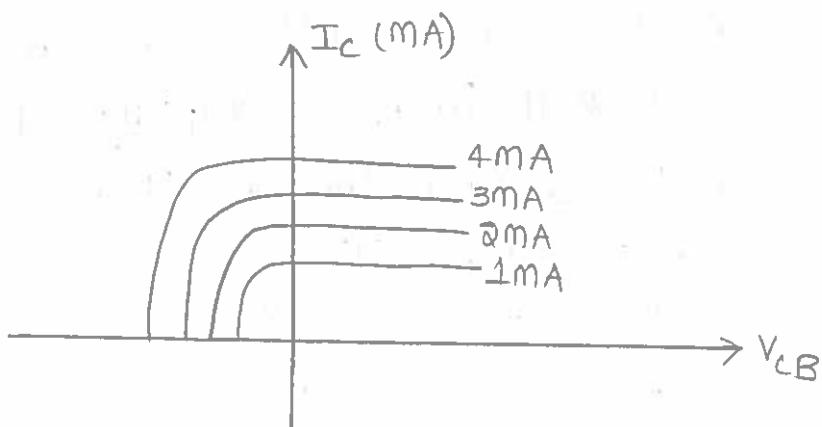
Input characteristics drawn between input current I_E and input voltage V_{BE} by keeping output voltage V_{CB} is constant. When $V_{CB} = 0V$ and "V_{BE}" voltage applied between emitter and base. The transistor acts as a forward bias PN junction diode i.e., upto 0.7V the current I_E is zero after 0.7V the current will increase rapidly. When V_{CB} voltage increased to 4V then the depletion region increased at base collector

junction and effective base will decrease. so the holes present in the base region push towards emitter region. Due to this emitter current will increase. so when output voltage V_{CB} increase the curve shift towards left side.

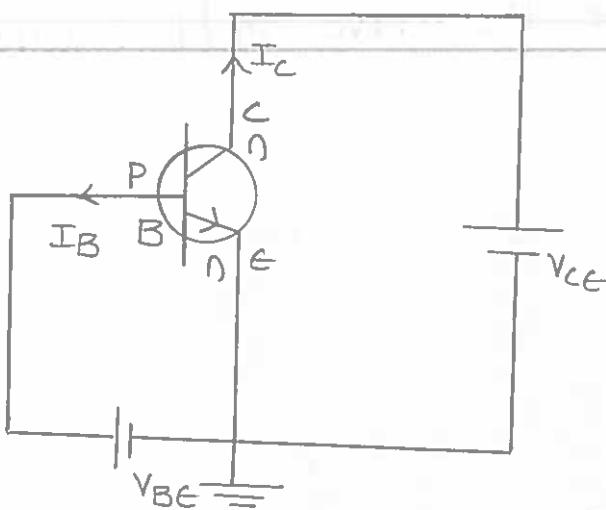


OUTPUT CHARACTERISTICS:-

In common base configuration output characteristics drawn between output current I_C and output voltage V_{CB} . By keeping input current I_E constant output current I_C does not depend on output voltage V_{CB} because it is always reverse bias. But I_C current it depend on input current I_E . considering base current is small I_E current nearly equal to I_C current. so output characteristics having constant curves.



COMMON EMITTER CONFIGURATION:-

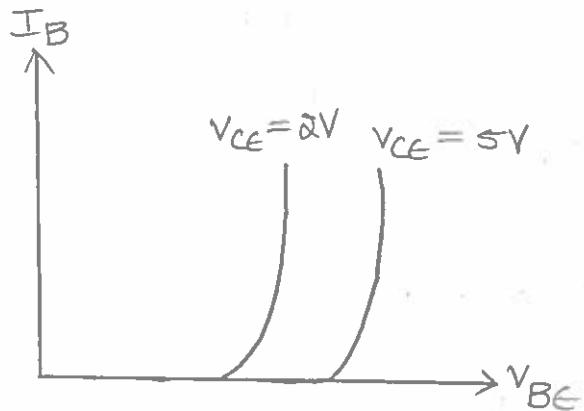


In common emitter configuration emitter terminal is common in between output and input. so the input terminal is base terminal and output terminal is collector terminal.

INPUT CHARACTERISTICS:-

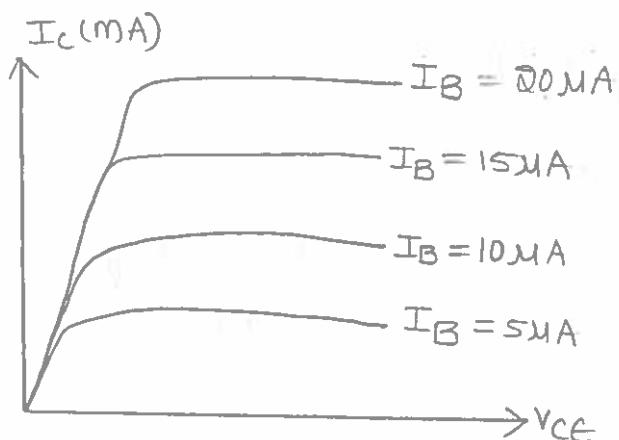
INPUT characteristics drawn between input current I_B and input voltage V_{BE} by keeping output voltage V_{CE} is constant. consider output voltage V_{CE} is 2V then the transistor act as a normal forward bias PN junction diode i.e., upto 0.7V current is zero after current will increase rapidly when output voltage increased to 5V then the depletion region between base and collector will increase. hence the holes present in base region push towards emitter region and base current will decreased.

When output reverse bias voltage increases, curve shift towards right side.

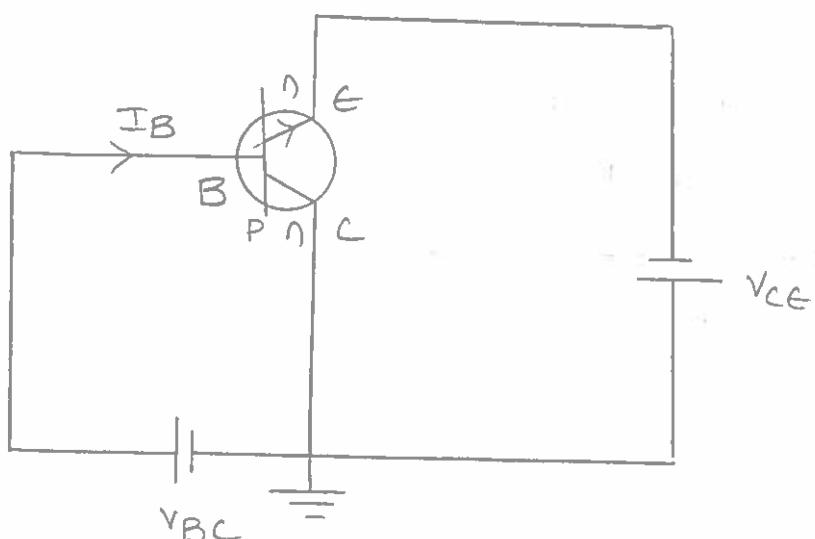


OUTPUT CHARACTERISTICS:-

Output characteristics drawn between output current I_C and output voltage V_{CE} . When by keeping input current I_B is constant. The output current I_C does not depends on output voltage V_{CE} . Because it is reverse bias voltage and it mainly depends on input current I_B .



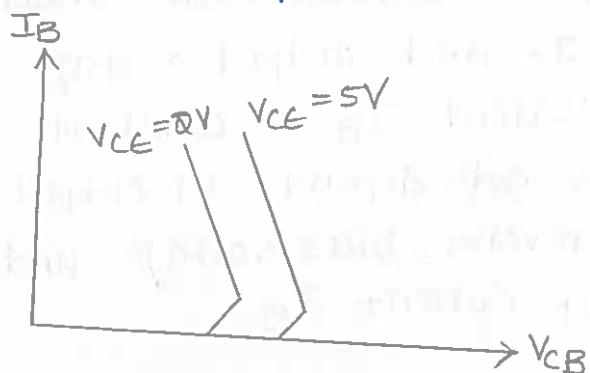
COMMON COLLECTOR CONFIGURATION:-



In common collector configuration collector terminal is common between input and output. so in common collector configuration base is input terminal, emitter is output terminal.

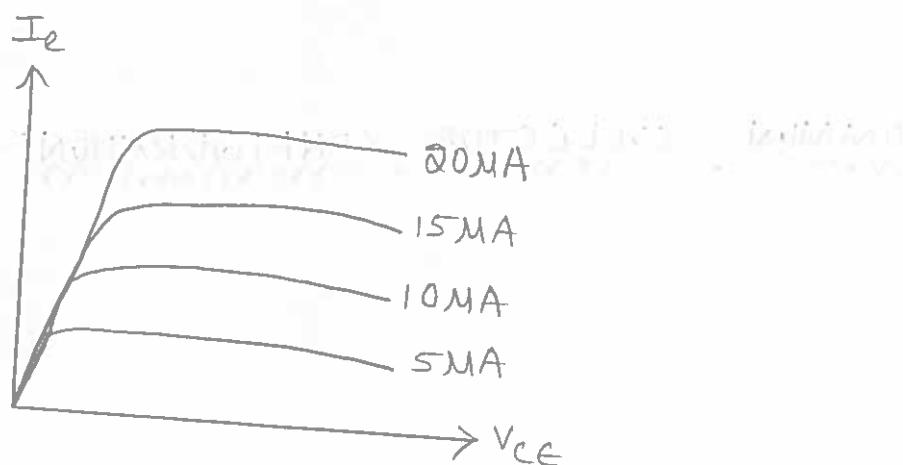
INPUT CHARACTERISTICS:-

Input characteristics drawn between input current I_B and input voltage V_{CB} by keeping output voltage V_{CE} is constant.



OUTPUT CHARACTERISTICS:-

Output characteristics drawn between output current I_E and output voltage V_{CE} by keeping input current "I" constant.



CURRENT GAIN OR CURRENT AMPLIFICATION FACTOR:-

current gain in common base:-

It is the ratio of output current I_C to the input current I_E

$$\text{current Gain } (\alpha) = \frac{I_C}{I_E}$$

Alpha value always less than 1 [0.9 to 0.99]

current gain in common emitter configuration:-

It is the ratio output current I_C to the input current I_B . 'B' value always [25 to 500]

$$\text{current Gain } (B) = \frac{I_C}{I_B}$$

common gain in common collector configuration:-

It is the ratio of output current I_C to the input current I_B . 'g' value always [50 - 500]

$$\text{current Gain } (g) = \frac{I_C}{I_B}$$

Relation between B & α :-

Divide both sides of I_C

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

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

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

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

Relation between β & γ :-

Divide both sides on I_B

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

$$\gamma = \beta + 1$$

Relation between γ & α :-

Divide both sides on I_E

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

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

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

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

collector current expression in common emitter configuration:-

consider

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

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

$$I_E = I_B + I_C$$

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

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

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

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

$$I_C = \frac{\alpha}{1-\alpha} I_B + \frac{1}{1-\alpha} I_{CBO} \rightarrow ①$$

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

$$\therefore I_{CEO} = \frac{1}{1-\alpha} I_{CBO}$$

From equation ①

$$I_C = \beta I_B + \gamma I_{CBO}$$

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

PROBLEMS:-

The reverse leakage current of a transistor in common base configuration is 0.3mA. While it is 16mA when the same transistor connected in CE configuration.

Determine α, β, γ

Given that:-

$$I_{CBO} = 0.3\text{mA}$$

$$I_{CEO} = 16\text{mA}$$

$$I_{CEO} = \frac{1}{1-\alpha} I_{CBO}$$

$$16\text{mA} = \frac{1}{1-\alpha} 0.3\text{mA}$$

$$\frac{16\text{mA}}{0.3\text{mA}} = \frac{1}{1-\alpha}$$

$$53.33 = \frac{1}{1-\alpha}$$

$$1-\alpha = \frac{1}{53.33}$$

$$1-\alpha = 0.018$$

$$1-0.018 = \alpha$$

$$\boxed{\alpha = 0.98}$$

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

$$0.98 = \frac{\beta}{\beta+1}$$

$$(0.98)\beta + 1 = \beta$$

$$0.98\beta + 0.98 = \beta$$

$$0.98 = \beta - 0.98\beta$$

$$0.98 = \beta(1-0.98)$$

$$0.98 = 0.02\beta$$

$$\beta = \frac{0.98}{0.02}$$

$$\beta = 49$$

$$\gamma = 1 + \beta$$

$$\gamma = 1 + 49$$

$$\gamma = 50$$

A transistor has $\beta = 100$. If the collector current is 40mA what is the value of emitter current.

Given that:-

$$\beta = 100$$

$$I_C = 40\text{mA}$$

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

$$100 = \frac{40}{I_B}$$

$$I_B = \frac{40}{100}$$

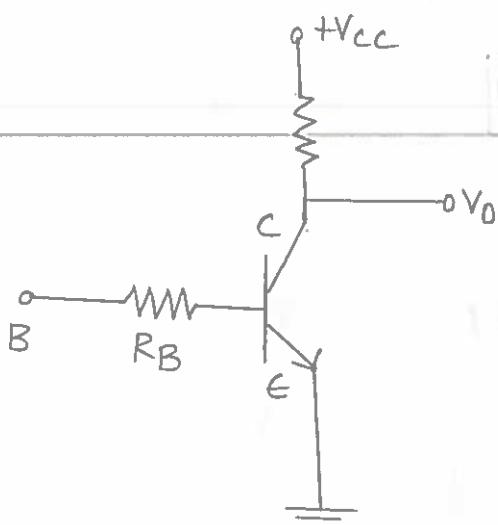
$$I_B = 0.4\text{mA}$$

$$I_E = I_B + I_C$$

$$I_E = 0.4 + 40$$

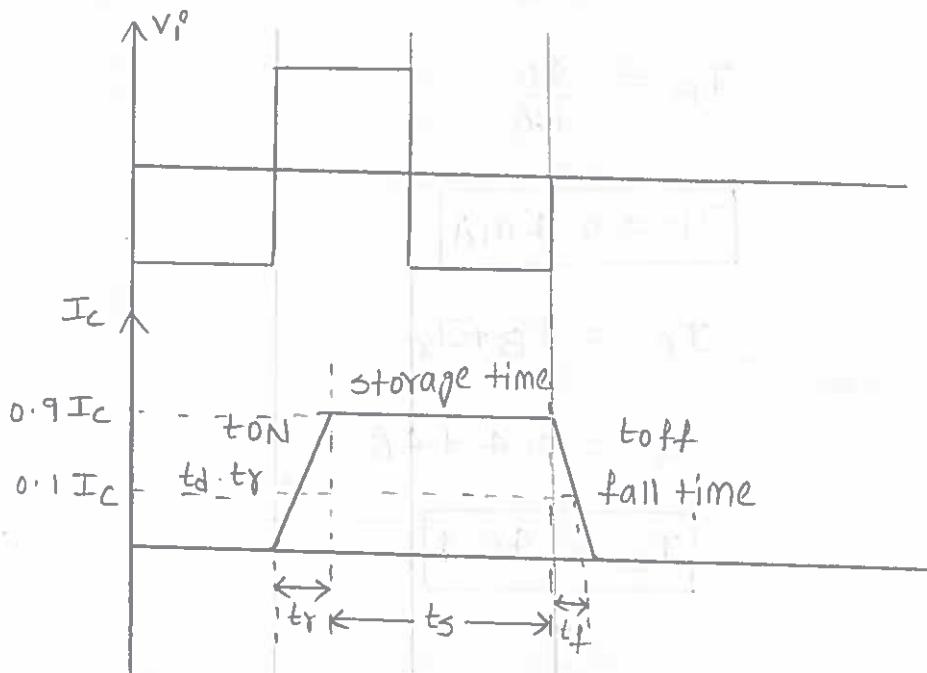
$$I_E = 40.4$$

TRANSISTOR SWITCHING TIMES! -



Transistor is used as switch when the transistor operates in cut-off and saturation regions. Consider a square waveform as a input signal during the negative half-cycle transistor operates in cut-off region and there is no current produced in the output. Hence the transistor act as OFF switch.

During the positive halfcycle the transistor operates in the saturation region and maximum output current produced hence the transistor act as ON switch.



(3)

The output current "I_c" does not immediately respond to the input voltage. There is a delay that delay is divided into different switching times.

DELAY TIME (t_d):-

Time required for the current to raise to 10% of its maximum current is called delay time.

RAISE TIME :-

Time required for the current to raise from 10 to 90% of maximum current is called raise current

sum of delay time and raise time is called turn ON time

$$t_{ON} = t_d + t_r$$

STORAGE TIME:-

Time required for the current fall to 90% from the maximum value of current is called storage time

FALL TIME:-

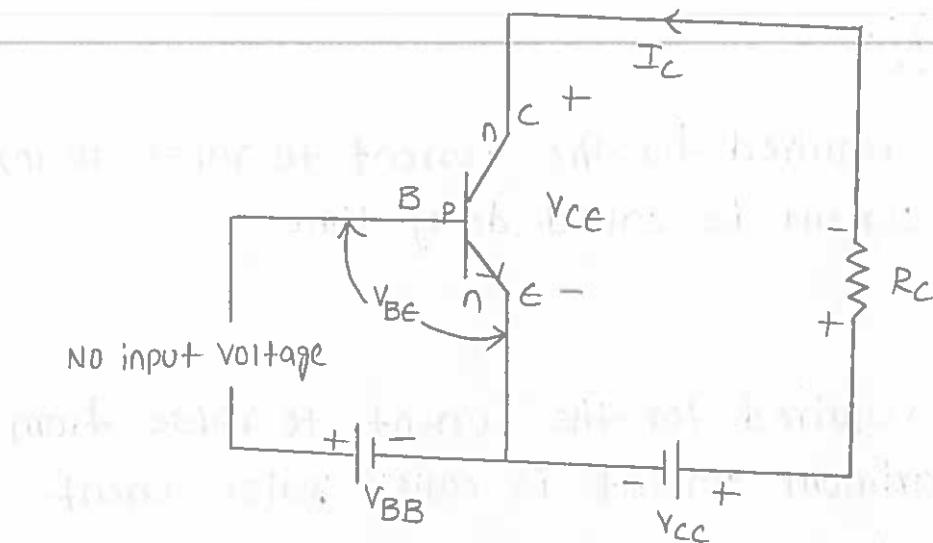
Time required for the current fall from 90% to 10% is called fall time

sum of storage time and fall time is called turn OFF time (t_{OFF})

$$t_{OFF} = t_s + t_f$$

TRANSISTOR BIASING:-

DC Load Line:-



Load line is a line drawn on the characteristic of the transistor which gives relation between voltage and current of a given transistor.

DC load line is a line drawn on the transistor characteristics with zero input voltage.

Consider a common emitter NPN transistor with emitter base junction is forward bias and collector base junction is reverse bias.

APPLY KVL to the output circuit

$$-V_{CC} + I_C R_C + V_{CE} = 0 \rightarrow ①$$

The above equation represents straight line with slope $-1/R_C$

The straight line touches x-axis at point B and touches y-axis at point A.

For point A:-

$$V_{CE} = 0$$

Substitute in equation $V_{CE} = 0$ in equation ①

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

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

$$I_C R_C = V_{CC}$$

$$I_C = \frac{V_{CC}}{R_C}$$

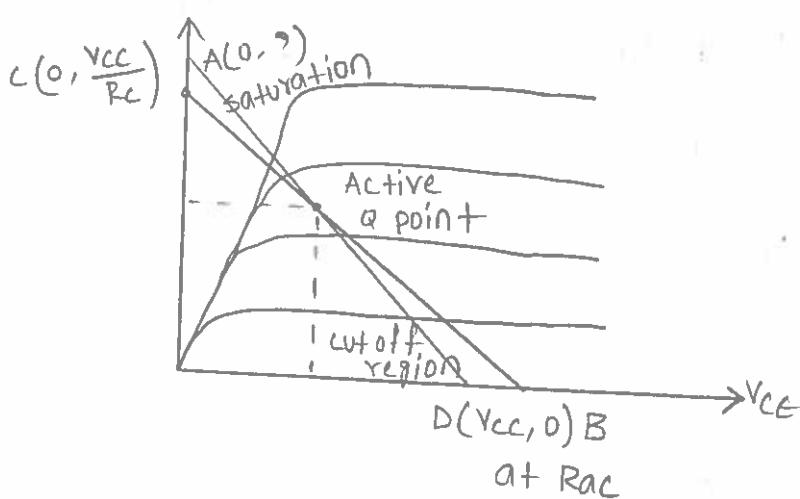
$$A \left(0, \frac{V_{CC}}{R_C} \right)$$

For point B:-

$$I_C = 0$$

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

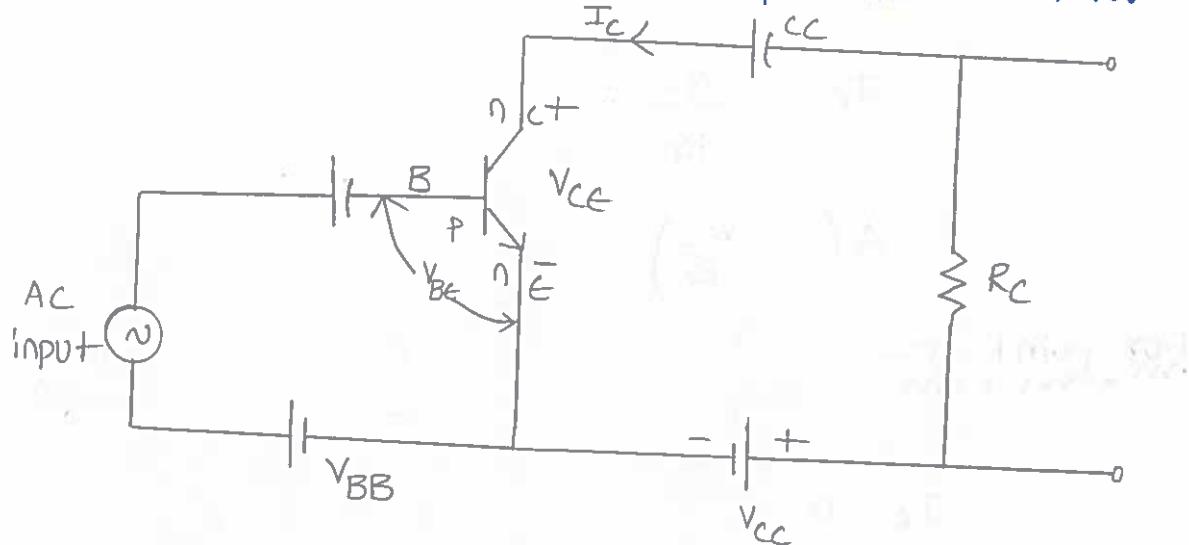
$$(V_{CC}, 0)$$



The zero signal value of I_C and V_{CE} are known as operating point or Q-point or co-efficient point for faithful amplification the Q-point must be in active region.

AC load line :-

Ac load line drawn on the transistor characteristic when ac signal is applied to the input of transistor.



APPLY KVL OUTPUT CIRCUIT

$$V_{CEQ} = V_{CC} - I_{CQ} R_{AC}$$

Here $R_{AC} = R_C$ parallel $R_L \Rightarrow R_C // R_L$

slope of AC load line is

$$-1/(R_C // R_L)$$

$$1/(R_C R_L / (R_C + R_L))$$

$$-\frac{R_C + R_L}{R_C R_L}$$

Need for stabilization!:-

For faithful amplification the operating point should be in the active region of a transistor characteristics. These operating point mainly depends on collector current I_c and collector to emitter voltage V_{CE} . The collector current expression in common emitter configuration is

$$I_c = \beta I_B + (1+\beta) I_{C0}$$

I_{C0} is a reverse saturation current which is produced due to minority charge carriers. It will be double for every 10° rise in temperature. When temperature increases I_{C0} will change. Hence I_c current will change due to this operating point will be shift near to saturation or cut off region.

V_{BE} is input voltage of a transistor. If will also change with temperature when V_{BE} changes I_B current will change. Hence I_c current also changes and operating point shift near to saturation or cut off region.

When transistor changes β value will change and I_c current also changes due to this operating point change. To produce faithful amplification I_{C0} , V_{BE} , β should be constant.

STABILITY FACTOR!:-

Stability factor (S)!:- It is defined as rate of change of I_c with respect to I_{C0} by keeping V_{BE} , β are constants

$$S = \frac{\partial I_c}{\partial I_{C0}} \quad |_{V_{BE}, \beta \text{ constants}}$$

stability factor s' :- It is defined as rate of change of I_C with respect to V_{BE} by keeping I_{CO} , β are constants.

$$s' = \frac{\partial I_C}{\partial V_{BE}} \quad |_{I_{CO}, \beta \text{ are constants}}$$

stability factor s'' :- It is defined as rate of change of I_C with respect to β by keeping I_{CO} , V_{BE} are constants

$$s'' = \frac{\partial I_C}{\partial \beta} \quad |_{I_{CO}, V_{BE} \text{ are constants}}$$

expression for stability factor:-

Collector current in common emitter configuration is $I_C = \beta I_B + (1+\beta) I_{CO}$

differentiate with respect to "I_C"

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

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

$$\frac{1 - \beta \frac{\partial I_B}{\partial I_C}}{1 + \beta} = \frac{\partial I_{CO}}{\partial I_C}$$

$$\frac{\partial I_C}{\partial I_{CO}} = \frac{1 + \beta}{1 - \beta \frac{\partial I_B}{\partial I_C}}$$

$$s = \frac{1 + \beta}{1 - \beta \frac{\partial I_B}{\partial I_C}}$$

NEED FOR BIASING:-

In order to produce faithful applying output the transistor must be operated in active region.

Biasing is used to operate transistor in active region by keeping emitter base junction is forward bias and base collector junction is reverse bias.

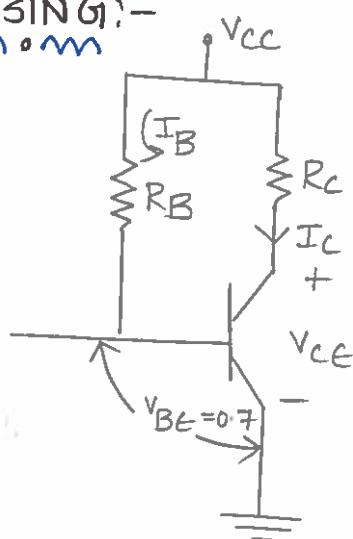
There are three types of biasing technique.

- * Fixed biasing

- * collector to base biasing

- * voltage divider biasing or self biasing.

FIXED BIASING:-



In fixed biasing circuit input circuit consist base resistance R_B which is connected between V_{CC} and Base terminal and it consist output resistance R_C which is connect in between V_{CC} and collector terminal

APPLY KVL to the input circuit

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

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

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

Apply KVL to the output circuit

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

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

STABILIZATION:-

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

$$\frac{\delta I_B}{\delta I_C} = 0$$

$$S = \frac{1+\beta}{1-\beta \frac{\delta I_B}{\delta I_C}}$$

$$S = \frac{1+\beta}{1-\beta(0)}$$

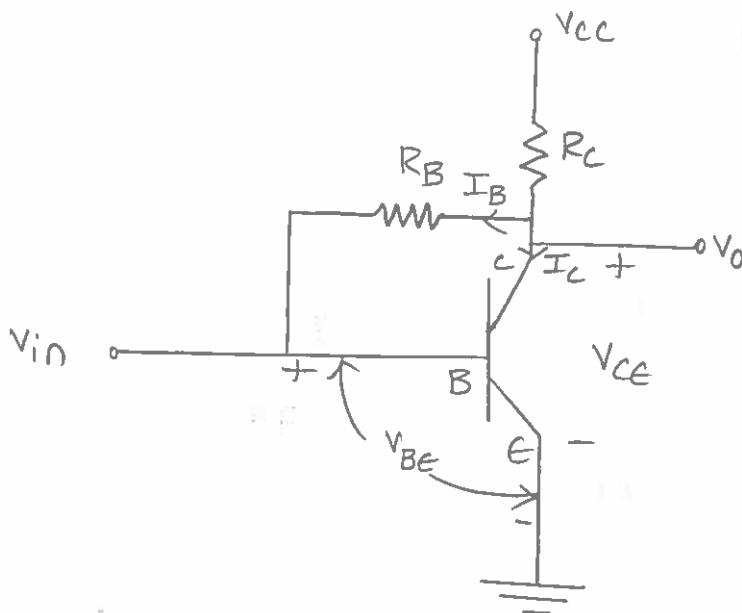
$$S = 1+\beta \quad [\because \beta = 50]$$

$$S = 1+50$$

$$S = 51$$

For fixed bias circuit stability factor value is high so stability is less.

COLLECTOR TO BASE FEEDBACK BIASING:-



In collector to base biasing base resistor R_B is connected in between collector and base terminals. Total current flows in the R_C resistor is $I_B + I_C$ and current flows in the base resistor is I_B , current flows in the collector terminal is I_C

Applied KVL to the input circuit

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

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

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

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

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

Applied KVL to the output circuit

$$-V_{CC} + R_C (I_B + I_C) + V_{CE} = 0$$

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

STABILITY FACTOR!

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

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

$$\frac{\delta I_B}{\delta I_C} = 0 - 0 - \frac{R_C}{R_C + R_B} \neq 1$$

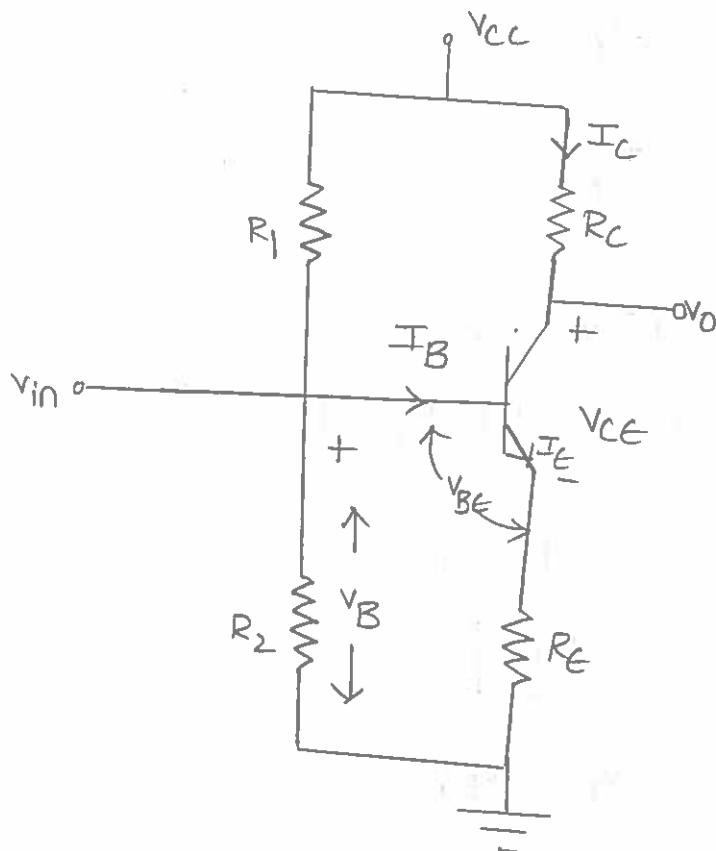
$$\frac{\delta I_B}{\delta I_C} = \frac{-R_C}{R_C + R_B}$$

$$S = \frac{1 + B}{1 - B \left(-\frac{R_C}{R_C + R_B} \right)}$$

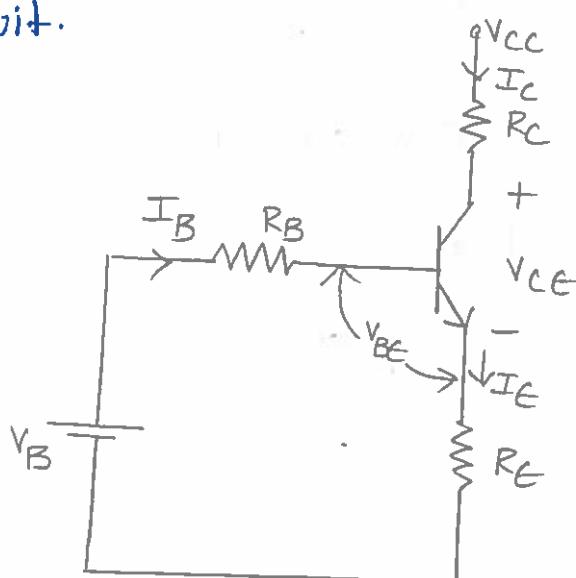
$$S = \frac{1 + B}{1 + B \frac{R_C}{R_C + R_B}}$$

For collector to base feedback biasing circuit stability factor is less so stability is high.

VOLTAGE DIVIDER AND BIASING OR SELF BIASING!



Voltage divider bias consist R_1 , R_2 Resistors. which are form a voltage divider circuit and it consist R_E Resistor which is connected in between emitter and ground terminals. Apply thevenin's theorem to the above circuit.



$$\text{where } V_B = \frac{V_{CC} R_Q}{R_1 + R_2}$$

$$\text{where } R_B = R_1 // R_2$$

$$R_B = \frac{R_1 R_2}{R_1 + R_2}$$

APPLY KVL to the input circuit

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

$$I_B R_B + I_E R_E = V_B - V_{BE}$$

$$I_E = I_B + I_C$$

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

$$I_B R_B + I_B R_E + I_C R_E = V_B - V_{BE}$$

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

$$I_B = \frac{V_B - V_{BE} - I_C R_E}{R_B + R_E}$$

APPLY KVL to the output circuit

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

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

stability factor:-

$$I_B = \frac{V_B - V_{BE} - I_C R_E}{R_B + R_E}$$

$$I_B = \frac{V_B}{R_B + R_E} - \frac{V_{BE..}}{R_B + R_E} - \frac{I_C R_E}{R_B + R_E}$$

$$\frac{\delta I_B}{\delta I_C} = 0 - 0 - \frac{R_E}{R_B + R_E} \cdot 1$$

$$\frac{\delta I_B}{\delta I_C} = - \frac{R_E}{R_B + R_E}$$

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

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

Voltage divider biasing having more stability compare to fixed biasing and collector to base biasing.

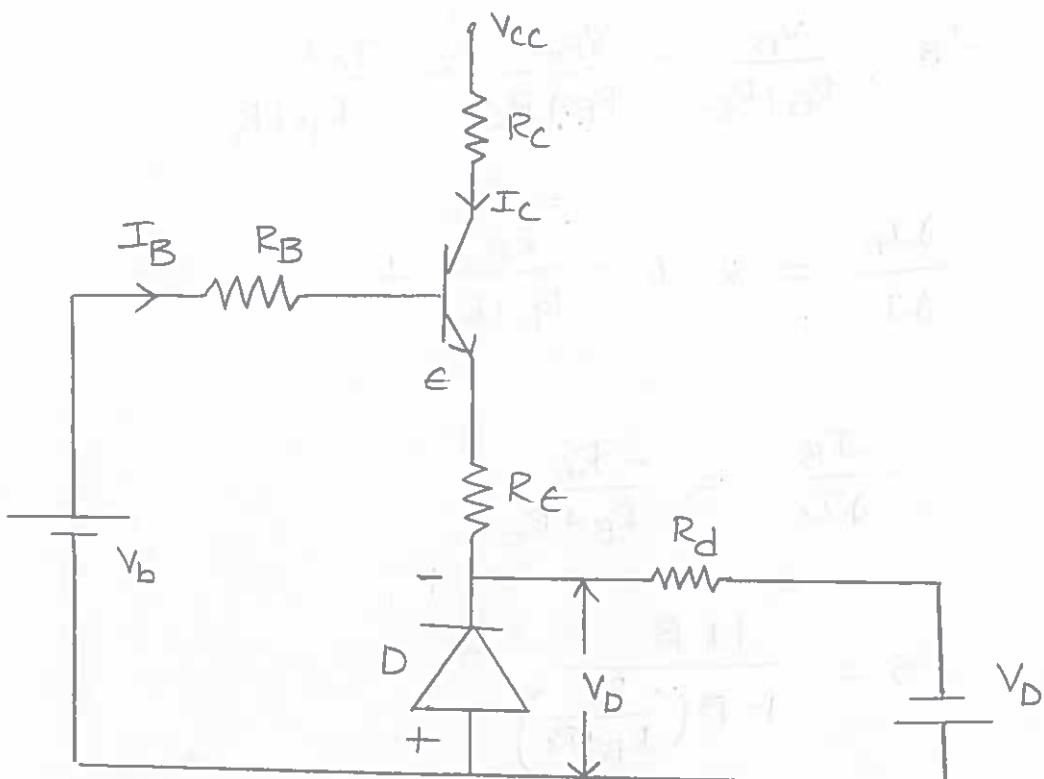
BIAS COMPENSATION:-

The output collector current varies due to I_{CO} , V_{BE} , β . Bias compensation techniques are used to stabilize variations of I_{CO} , V_{BE} . There are two types of compensation technique.

* Diode compensation for V_{BE}

* Diode compensation for I_{CO}

Diode compensation for V_{BE} :-



In this compensation technique we are using self bias technique. When temperature increases V_{BE} voltage decreased by 0.5 mV per degree. This change in V_{BE} compensated by diode in between emitter and ground terminal.

Apply KVL to the input circuit

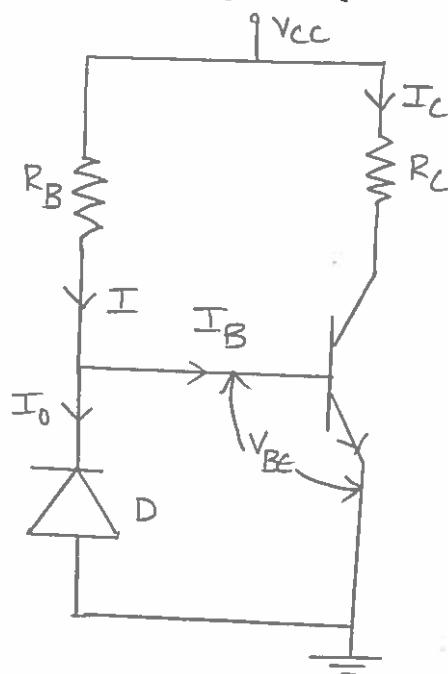
$$-V_b + I_B R_B + V_{BE} + I_E R_E - V_o = 0$$

$$I_B R_B = V_b + V_o - V_{BE} - I_E R_E$$

$$I_B = \frac{V_b + V_o - V_{BE} - I_E R_E}{R_B}$$

When temperature increases V_{BE} voltage decreases this will compensated by voltage across diode V_0 . Hence the Base current I_B is constant and output current I_C also constant.

Diode compensation for I_{CO} .



For every raising 10° temperature I_{CO} current will doubled this will compensated by diode which is connected in between base and emitter. If the diode and transistor having same material then the reverse saturation current I_0 of the diode will increase with temperature at the same rate as I_{CO}

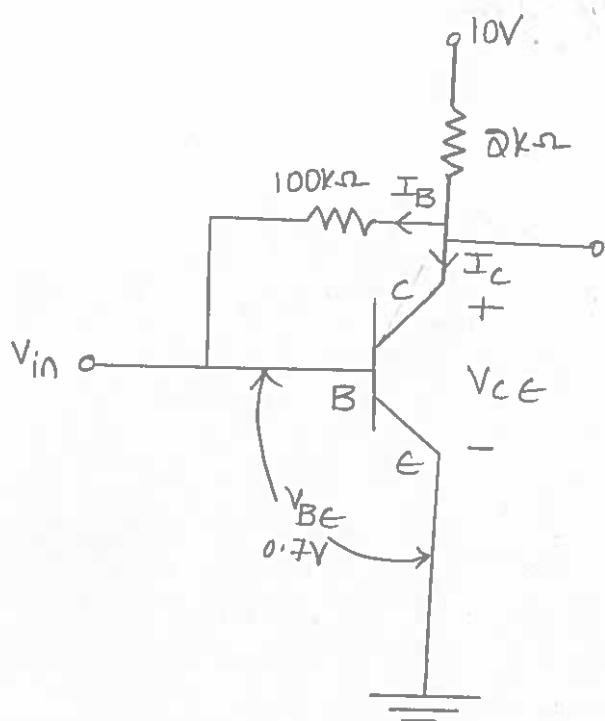
$$I_C = \beta I_B + (1+\beta) I_{CO}$$

$$I_C = \beta (I - I_0) + (1+\beta) I_{CO}$$

When temperature increases I_{CO} current will increase this will compensate by I_0 current. so the I_C current always constant.

PROBLEMS:-

- 1 An NPN transistor if $B=50$ used in CE circuit with $V_{CC} = 10V$, $R_C = 2k\Omega$ the bias is obtained by connecting $100k\Omega$ resistor from collector to base find co-efficient point.



Given that:-

$$B = 50$$

$$V_{CC} = 10V$$

$$R_C = 2k\Omega$$

Applied KVL to input circuit

$$-10 + (I_B + I_C) 2 \times 10^3 + 100 \times 10^3 \times I_B + 0.7 = 0$$

$$(I_B + I_C) 2 \times 10^3 + 100 \times 10^3 \times I_B = 9.3$$

$$(I_B + 50I_B) 2 \times 10^3 + 100 \times 10^3 \times I_B = 9.3$$

$$(51I_B) 2 \times 10^3 + 100 \times 10^3 \times I_B = 9.3$$

$$10^3 \times I_B [10\Omega + 100] = 9.3$$

$$10^3 \times I_B \times 80\Omega = 9.3$$

$$I_B = \frac{9.3}{10^3 \times 80\Omega}$$

$$I_B = 0.046 \times 10^{-3}$$

$$I_B = 0.046 \text{ mA}$$

$$I_B = 46 \mu\text{A}$$

$$I_C = 50 \times 46 \mu\text{A}$$

$$I_C = 2300 \mu\text{A}$$

$$I_C = 2.3 \text{ mA}$$

Applied KVL to output circuit

$$-V_{CC} + (I_C + I_B) R_C + V_{CE} = 0$$

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

$$V_{CE} = 10 - (2300 + 46) \times 10^{-6} \times 2 \times 10^3$$

$$V_{CE} = 10 - (2346 \times 2) \times 10^{-3}$$

$$V_{CE} = 10 - (4692) \times 10^{-3}$$

$$V_{CE} = 10 - 4.69 \times 10^{-3}$$

$$V_{CE} = 10 - 4.69$$

$$V_{CE} = 5.31 \text{ mA}$$

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Q. A transistor with $B = 100$ is used in common emitter configuration with collector to base bias the collector circuit resistance is $R_C = 1k\Omega$ and $V_{CC} = 10V$ assume $V_{BE} = 0$

1. choose R_B so that the co-efficient collector to emitter voltage is 4V.

2. Find the stability factor.

Given that:-

$$B = 100 ; V_{CC} = 10V ; I_C = B I_B$$

$$R_C = 1k\Omega ; V_{BE} = 0 ; V_{CE} = 4V$$

APPLY KVL to the input circuit

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

$$-10 + (I_B + B I_B) 10^3 + I_B R_B = 0$$

APPLY KVL to the output circuit

$$-V_{CC} + (I_B + I_C) R_C + V_{CE} = 0$$

$$-10 + (I_B + B I_B) 10^3 + 4 = 0$$

$$(I_B + 100 I_B) 10^3 = 10 - 4$$

$$(101 I_B) 10^3 = 6$$

$$I_B = \frac{6}{101 \times 10^3}$$

$$I_B = 5.94 \times 10^{-5}$$

$$I_B = 59 \mu A$$

$$-10 + (59 + 100(59))10^{-6} \times 10^3 + 59 \times 10^{-6} \times R_B = 0$$

$$(59 + 100(59))10^{-6} \times 10^3 + 59 \times 10^{-6} \times R_B = 10$$

$$5.959 + 59 \times 10^{-6} \times R_B = 10$$

$$59 \times 10^{-6} R_B$$

$$59 \times 10^{-6} R_B = 10 - 5.959$$

$$R_B \times 59 \times 10^{-6} = 4.041$$

$$R_B = \frac{4.041}{59 \times 10^{-6}}$$

$$R_B = 68.431 M$$

STABILITY FACTOR:-

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

$$S = \frac{1+100}{1+100 \left(\frac{10^3}{10^3 + (68.4 \times 10)} \right)}$$

$$S = 101$$

3 Determine co-efficient current (I_c) and collector to emitter voltage (V_{ce}) for germanium transistor with $\beta = 50$ in the self biasing arrangement the circuit component values are $V_{cc} = 20V$, $R_C = 2k\Omega$, $R_E = 0.1k\Omega$, $R_I = 100k\Omega$, $R_Q = 5k\Omega$ and find stability factor.

Given that:-

$$\beta = 50 ; R_I = 100k\Omega ; R_Q = 5k\Omega$$

$$V_{cc} = 20V ; R_C = 2k\Omega ; R_E = 0.1k\Omega$$

$$V_B = \frac{V_{cc} \cdot R_Q}{R_I + R_Q}$$

$$V_B = \frac{20 \times 5}{100 + 5}$$

$$V_B = \frac{100 \times 10^3}{105 \times 10^3}$$

$$V_B = 0.95V$$

$$R_B = R_I // R_2$$

$$R_B = \frac{R_I R_2}{R_I + R_2}$$

$$R_B = \frac{100 \times 5}{100 + 5}$$

$$R_B = \frac{500}{105}$$

$$R_B = 4.76k\Omega$$

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

$$-0.95 + I_B R_B + V_{BE} + I_E R_E = 0$$

$$-0.95 + I_B (4.76) \times 10^3 + 0.3 + (I_B + I_C) R_E = 0$$

$$-0.95 + I_B (4.76) \times 10^3 + 0.3 + (I_B + \beta I_B) 0.1 \times 10^3 = 0$$

$$I_B (4.76) \times 10^3 + (51 I_B) 0.1 \times 10^3 = 0.65$$

$$I_B [(4.76 \times 10^3) + 51 \times 0.1 \times 10^3] = 0.65$$

$$I_B [(4.76 + 5.1) \times 10^3] = 0.65$$

$$I_B = \frac{0.65}{9.86 \times 10^3}$$

$$I_B = 6.59 \text{ mA}$$

$$I_C = \beta \cdot I_B$$

$$I_C = 50 (6.59) \times 10^{-6}$$

$$I_C = 32.95 \text{ mA}$$

STABILITY FACTOR:-

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

$$= \frac{51}{51 \left(\frac{0.1 \times 10^3}{(4.76 \text{ N} \times 10^3) + 0.1 \times 10^3} \right)}$$

$$\zeta = 48.6$$

- 4 In a voltage divider circuit $V_{CC} = 20V$, $R_C = 1.5k\Omega$ the Q-point is $V_{CE} = 8V$ & $I_C = 4mA$, $S = 1\Omega$, $B = 50$ find R_1 & R_D , R_E .

Given that:-

$$V_{CE} = 8V ; I_C = 4mA ; S = 1\Omega$$

$$B = 50 ; R_1 = ? ; R_D = ? ; R_E = ?$$

APPLY KVL to the input circuit

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

$$-20 + 4 \times 10^{-3} \times 7.5 \times 10^3 + 8 + (I_B + I_C) R_E = 0$$

$$-20 + 6 + 8 + \left(\frac{I_C}{B} + I_C \right) R_E = 0$$

$$\left(\frac{I_C}{B} + I_C \right) R_E = 6$$

$$I_C \left(\frac{1+B}{B} \right) R_E = 6$$

$$I_C (1.0\Omega) R_E = 6$$

$$R_E = \frac{6}{4 \times 10^{-3} \times 1.0\Omega} = 1.47 \times 10^3$$

$R_E = 1.47 k\Omega$

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

$$1\Omega = \frac{1+50}{1+B \left(\frac{R_E}{R_B + R_E} \right)}$$

$$I_Q = \frac{5I}{1+\beta \left(\frac{R_E}{R_B + R_E} \right)}$$

$$1+\beta \left(\frac{R_E}{R_B + R_E} \right) = \frac{5I}{I_Q}$$

$$1+\beta \frac{R_E}{R_B + R_E} = 4.25$$

$$\frac{R_E}{R_B + R_E} = \frac{4.25}{50}$$

$$R_E = 0.065R_B + 0.065R_E$$

$$R_E - 0.065R_E = 0.065R_B$$

$$0.93R_E = 0.065R_B$$

$$0.93 \times 1.47 \times 10^3 = 0.065R_B$$

$$\frac{0.93 \times 1.47 \times 10^3}{0.065} = R_B$$

$$R_B = 21.14 \text{ k}\Omega$$

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

$$-V_B + \left(\frac{I_C}{\beta} \right) R_B + V_{BE} + I_E R_E = 0$$

$$\frac{4 \times 10^{-3}}{50} \times 21.14 \times 10^3 + 0.7 + \left(\frac{I_C}{\beta} + I_C \right) \times 1.5 \times 10^3 = V_b$$

$$2.41 + I_C \left(\frac{1+\beta}{\beta} \right) \times 1.5 \times 10^3 = V_b$$

$$2.41 + I_C \times 1.0 \Omega \times 1.5 \times 10^3 = V_b$$

$$2.41 + 4 \times 10^{-3} \times 1.0 \Omega \times 1.5 \times 10^3 = V_b$$

$$V_b = 8.53$$

$$V_b = \frac{V_{CC} R_Q}{R_1 + R_2}$$

$$8.53 = \frac{20 \cdot R_Q}{R_1 + R_2}$$

$$\frac{R_Q}{R_1 + R_2} = \frac{8.53}{20}$$

$$\frac{R_Q}{R_1 + R_2} = 0.4265$$

$$R_B = \frac{R_1 R_2}{R_1 + R_2}$$

$$21.14 \times 10^3 = \frac{R_1 R_2}{R_1 + R_2}$$

$$21.14 \times 10^3 = R_1 \times 0.4265$$

$$R_1 = \frac{21.14 \times 10^3}{0.4265}$$

$$R_1 = 49.5 k\Omega$$

$$\frac{R_Q}{R_1 + R_2} = 0.4265$$

$$R_Q = 0.4265 (R_1 + R_2)$$

$$R_Q = 0.4265 (49.5 \times 10^3 + R_D)$$

$$R_Q = 21.11k + 0.4265 R_D$$

$$R_Q - 0.4265 R_Q = 21.11k$$

$$R_Q (1 - 0.4265) = 21.11k$$

$$R_Q (0.5735) = 21.11k$$

$$R_Q = \frac{21.11k}{0.5735}$$

$$R_Q = 36.8k\Omega$$

$$(1 - \sqrt{1 + k^2}) \cos \theta = u^2$$

$$= 2064.0 + 211.7$$

$$2064.0 + 211.7 = 2275.7$$

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$$2064.0 + 211.7 = 2275.7$$

$$\frac{2064.0}{2275.7} = 0.9$$

$$\boxed{0.9}$$