Analog Electronic Circuits

15EE34

Module-I

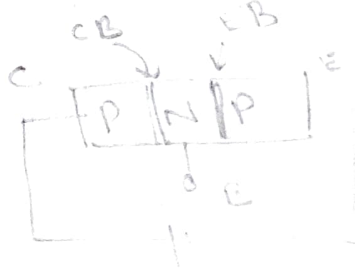
Transistor Biasing and stabilization.

Syllabus :

Operating point. Analysis and design of fixed bias circuits. Emitter stabilized bias ckt. Voltage deviderbias.ckt. stability factor of different biasing ckt problems.

Transistor switching circuits, Transistor switching circuits. PNP transistors & Thermal compensating techniques.

Transistor Biasing : Transistor can be operated in 3 regions cut-off, active & saturation by applying proper biasing conditions.



Region of operation	Emitter base jun	collector base jun
Cut off	Reversed bias	Reverse biased
Active	forword bias	Reverse biased
saturation	Forword bias	forword bias.

In order to operate transistor is the desired region We have to apply external dc voltages of currect polarity and magnitude to the ~~tool~~ two junctions of the transistors. this is nothing but biasing of the transistor. Since dc voltages are used to bias the transistor, biasing is known as DC biasing of the transistor.

In transistor amplifier circuit output power signal power is always greater than input power singnal. This large power is provided by the dc source used for biasing.

Biasing is favouring transistor to operate in a particular region and supplying power.

Operating point: When we bias a transistor we establish a certain current and voltage condition for the transistors These conditions are known as operating conditions are or dc operating point or quescent point (Q-point)

The operating point must be stable for proper operation of transistor. However the operating point shift with changes in transistor parameter such as β, I_{CO} & V_{BE}. As transistor parameters are temperature dependent. the operating point also changes with varies in temperature.

Analysis of fixed Bias Circuit

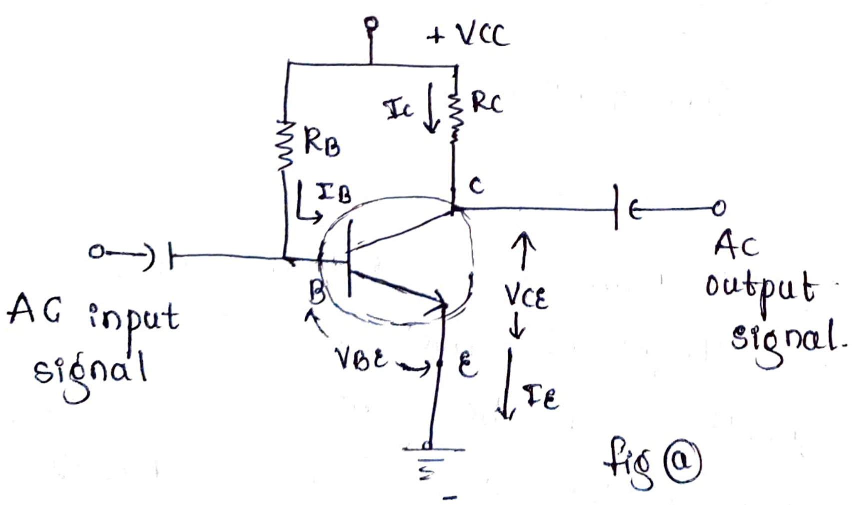
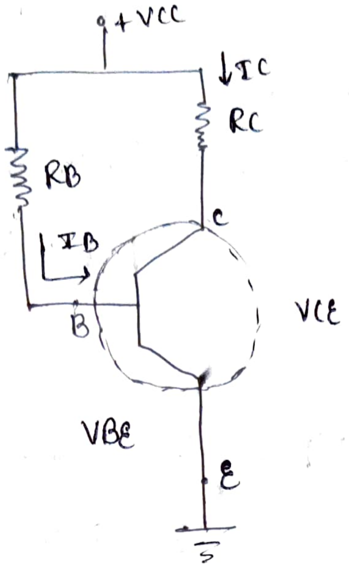


fig ⓐ

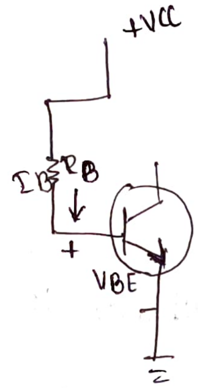
fixed bias ckt is shown in fig ⓐ it is the simplest DC bias Configeration. for the DC analysis we can replace the capacitor with an open ckt. The dc equivalent of fixed bias ckt is shown in fig (b)



(b) DC equivalent of fixed bias ckt

Circuit Analysis :

1) Base Circuit

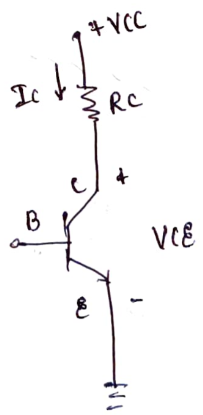


Writing voltage eqn

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

$$I_B = \frac{V_{CC} - V_{BE}}{R_B} \quad \text{--- (1)}$$

2) Collector circuit



voltage eqn

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

$$I_C = \frac{V_{CC} - V_{CE}}{R_C} \quad \text{--- (2)}$$

W.K. $I_C = \beta \cdot I_B$ — (3)

$$V_{CC} = \beta \cdot I_B R_C + V_{CE}$$

$$\boxed{V_{CE} = V_{CC} - I_C R_C} \quad \text{--- (4)}$$

It is imp to note that since the base current is controlled by R_B and collector current I_C is related to I_B by constant β. The magnitude of I_C is not a function of R_C. Changing R_C to any level will not affect I_C but V_{CE} will change.

Also note that, $V_{CE} = V_C - V_E$ where V_C = Collector voltage
V_E = Emitter voltage.

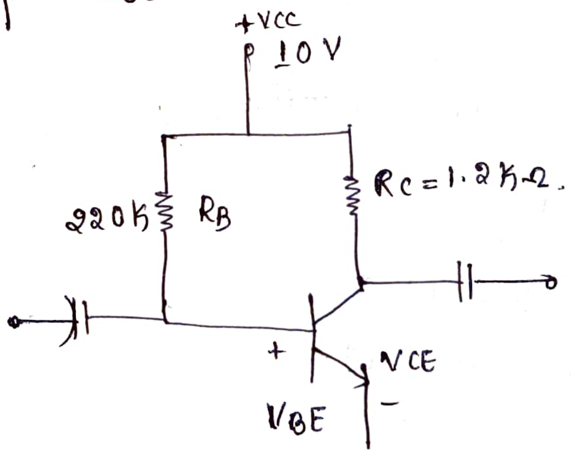
$V_{BE} = V_B - V_E$ where V_B = Base voltage.

But in the ckt $V_E = 0$,

$\therefore V_{CE} = V_C$

& $V_{BE} = V_B$.

Ex: 1 For the circuit shown in the figure calculate I_B, I_C, V_{CE}, I_B, V_C & V_{BE} assume $V_{BE} = 0.7V$ $\beta = 50$.



Soln:

$V_{BE} = 0.7\,V$

$\beta = 50$

$R_C = 1.2\,K\Omega$

$V_{CC} = 10\,V$

$I_C = \beta \cdot I_B$.

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

W.K.T. for the fixed bias ckt

$I_B = \frac{V_{CC} - V_{BE}}{R_B} = \frac{10 - 0.7}{220 \times 10^3}$

$= \frac{9.3 \times 10^{-3}}{220}$

$=$ ~~1.36~~ $42.27\,\mu A$.

$I_C = \beta \cdot I_B$

$= 50 \times 42.27 \times 10^{-6}$

$= 2.11 \times 10^{-3}$

$= 2.11\ mA$

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

$= 10 - 2.11 \times 10^{-3} \times 1.2 \times 10^{3}$

$= 10 - 2.532$

$= 7.468\ V$

$V_{BC} = V_B - V_C$ $\qquad V_{BE} = V_B$

$= 0.7 - 7.4$ $\qquad V_{CE} = V_C$

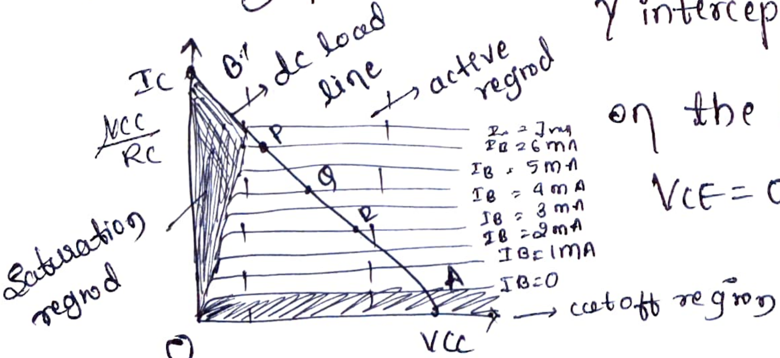
$= -6.7638\ V$

DC load line : For the fixed bias ckt

$$I_C = \frac{V_{CC} - V_{CE}}{R_C} = \frac{V_{CC}}{R_C} - \frac{V_{CE}}{R_C} = \frac{V_{CC}}{R_C} - \left(\frac{1}{R_C}\right) V_{CE}$$

$$I_C = -\frac{1}{R_C} V_{CE} + \frac{V_{CC}}{R_C} \qquad y = mx + c$$

By comparing this equation with the straight line i.e $y = mx + c$ Where m is the slope of the line and c is the intercept on y axis, then we can draw a straight line on the graph of I_C Vs V_{CE} Which is having slope $-1/R_C$ with y intercept $\frac{V_{CC}}{R_C}$. to determine two point on the line we assume $V_{CE} = V_{CC}$ & $V_{CE} = 0$.



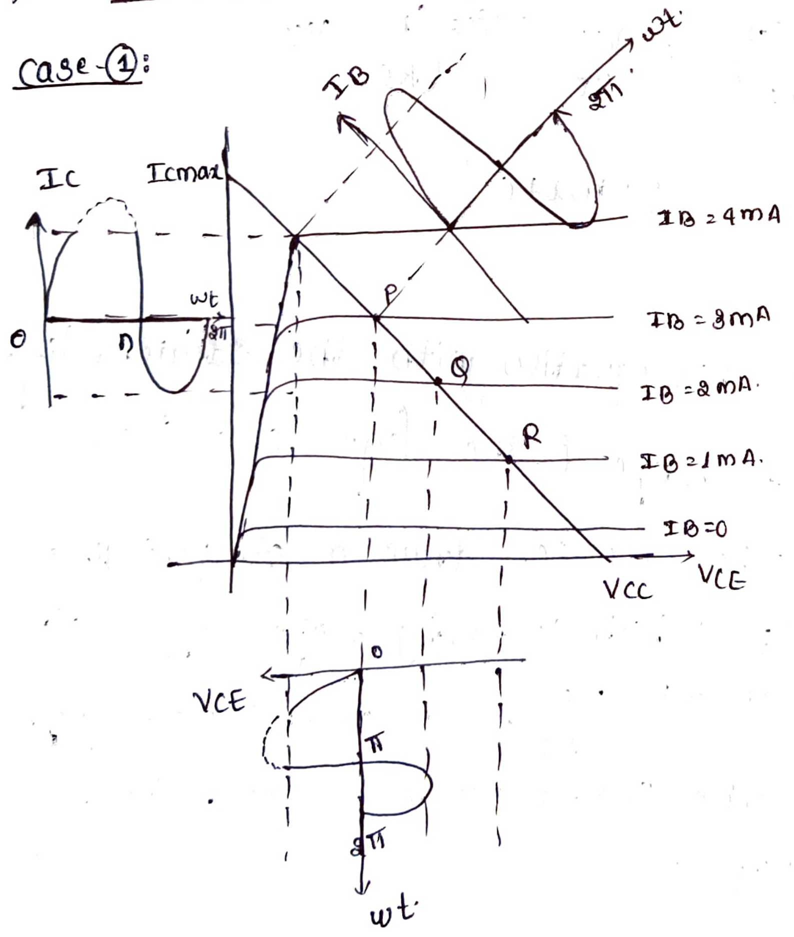
$V_{CE} = V_{CC}$ point A ; $I_C = 0$

$V_{CE} = 0$ Point B ; $I_C = V_{CC}/R_C$

Common Emitter output charecters with point A & B are shown in figure. the line drawn between A & B is called dc load line. the dc word indicate that only dc conditions are considered. The dc load line is a plot of I_C Vs V_{CE} for a given value of Rc and given value level of Vcc. (Thus it represents all collecter current and corresponding V_{CE}. (The intersection of curves of different values of I_B with dc load line gives different operating points. for different value of I_B we have different intersection points P. Q. R.

Imp
*** Selection of an operating point.

Case-①:

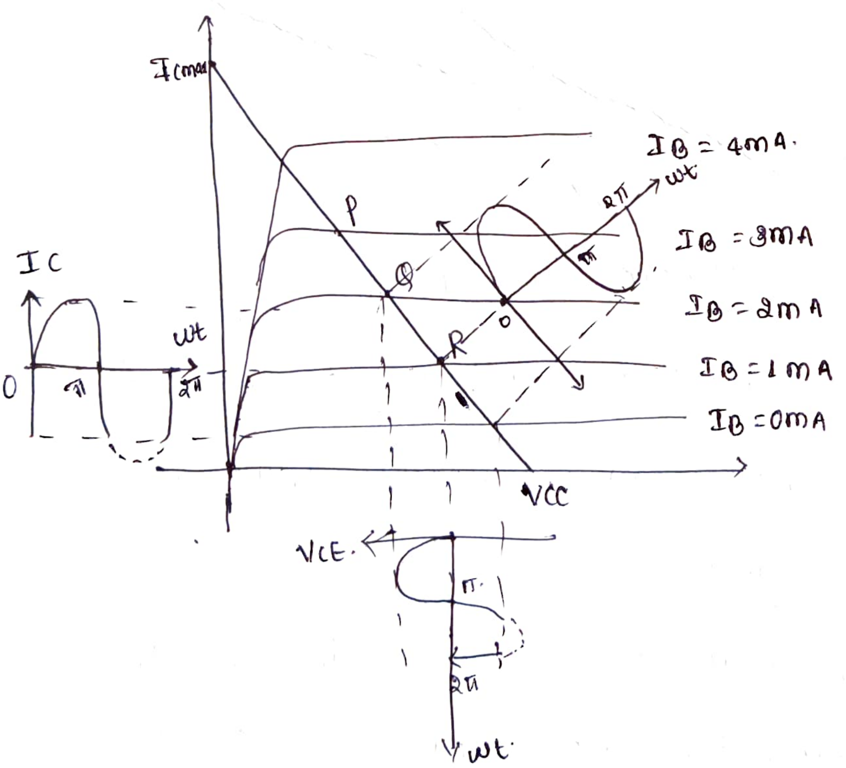


operating point of the transistor can be fixed at different points on the dc load line. Ex: P. Q. R.

The biasing ckt is designed so as to make transistor operate in saturation region, active region or/ cut off region. When transistor is to be operated as an amplifier the Q point should be fixed at active region. depending upon the location of this Q point the output of the transistor may be a desired signal of or/ may contain distortion. This can be understood by following 3 cases.

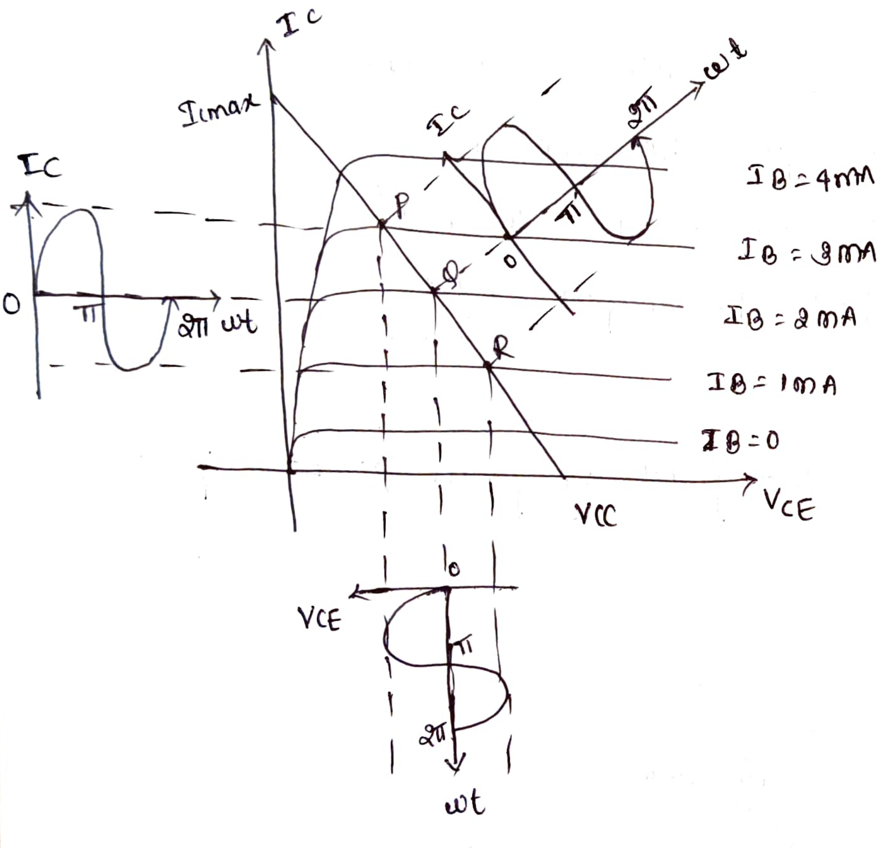
<u>case-1</u> : Here the biasing ckt is desired to fix the operating point at point P. point P is near the saturation region. due to which there is clipping off of positive half cycle of the collector current Ic. Thus the output signal is distorted sinusoidal signal.

<u>case-2</u> : Fixing the operating point at point R' in the dc load line.



Baising ckt is designed to fix a Q point at point 'R'. point R is very near to the cut off region as shown in figure B. the collector current is clipped at negative half cycle. So point R is not a suitable operating point.

Case-3 : fixing operating point at point - Q on dc load line.



Baising ckt is designed to fix the Q-point at point Q as shown in figure C. the output signal is sinusoidal wave form without any distortion thus point Q is the best operating point

from the above discussion we can conclude that for better operation of transistor the Q-point should be fixed at the center of the dc load line.

Imp ★★

Stability :-

From the study of biasing of the ckt it is clear that the biasing ckt should be designed to fix the operating point at the center of active region. But only fixing the operating point is not sufficient while designing the biasing ckt care should be taken so that operating point will not shift into an undesirable region. Designing the biasing ckt to stabilize Q point is known as bias stability.

Two imp factors are considered while designing the biasing ckt. Which are responsible for shifting the operating point

1) Temperature
2) Transistor current gain.
3) I_{CEO}

The flow of current in the ckt produces heat at the junctions. This heat increases temperature of the junction. We know that the minority carriers are temperature dependent they increase with the temperature. which in term increases the leakage current I_{CEO}. because

$$\because \; I_{CEO} = (1+\beta)\, I_{CBO}$$

Specifically I_{CBO} doubles for every $10°C$ rise in temperature. increase in I_{CEO} in term increases collector current I_C because

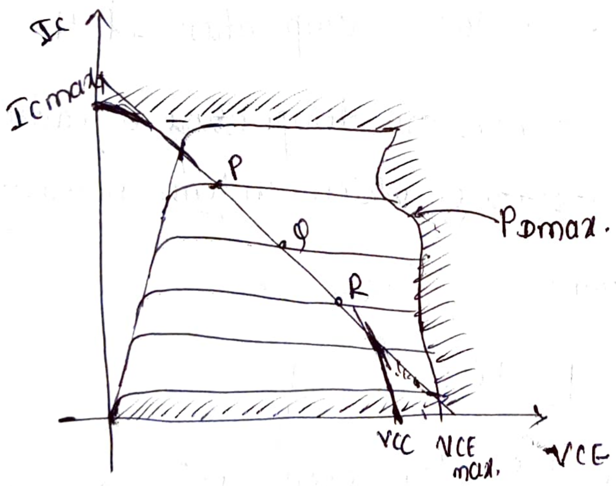
$$\because \; I_C = \beta I_B + I_{CEO}$$

The increase in I_C further raiseds the temperature at the collector junction and the same cycle repeats. this accessive increase in I_C shift the operating point into saturation region, changing the operating conditions set by biasing ckt. power dissipated in the transistor is given by.

$P_D = V_C I_C$.

*** the increase in collector current increases the power dessipation at the collector junction. this in turn increases collector current I_C. this process is cummulative. the excess heat produced at the collector base junction may even burn and destroy the transistor. this situation is called Thermal runaway of the transistor.

For any transistor maximum power dissipation is fixed value that is known as maximum power dissipation of transistor. if this limit is crossed the device will fail.

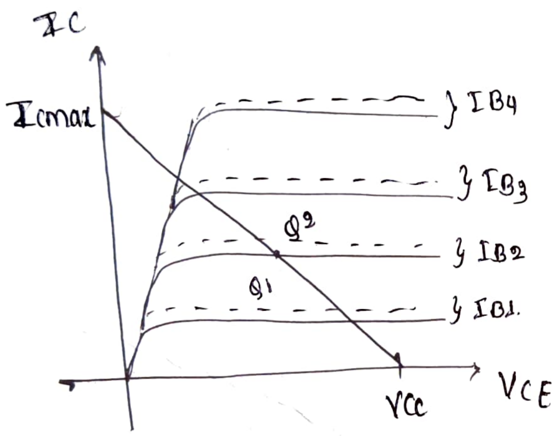


ii) VBE : Base to emitter voltage V_{BE} changes with temperature at the rate of 2.5mV/°C. Base current I_B depends upon V_{BE} ∴ I_C changes with temperature due to changes in V_{BE}. The change in I_C changes Q point.

iii) β_{dc} : β_{dc} of the transistor also temperature dependent. As β_{dc} varies I_C also varies as $I_C = \beta I_B$, the change in I_C changes the operating point therefore to avo

Therefor to avoid this situation the biasing ckt should be design to provide a degree of temp^r stability i.e even though the temperature changes the changes in the transistor parameter should be (V_{CEQ}, I_{CQ}, & P_{Dmax}) should be very less so that operating point should be minimum in the middle of active region.

2) Transistor current gain (β, h_{fe})



It is absorved that there are changes in the transistor parameter among different units of same type, same number. this means if we take two transistors units of same type and use them in ckt, there is change in β value in actual practice. the biasing ckt is designed according to the required β value. But due to changes in β from unit to unit the operation point may shift. The figure shows collector emitter output charecteristics of two transistor at same type. The dashed charecterstics for a transistor whose β value is much lorger then that of the transistor represented by a solid curve.

Hence for stabilizing the operating point, the above factor must be considered while desinging biasing ckt. We can summerise the requirment of a biasing ckt as follow.

***
Imp **Requirement for Biasing ckt**

1] The CE junction must be forword bias and CB jun must be reverse bias.

2] The operating point should be fixed at center of the active region.

3] The circuit design should provide the degree of tempr stability.

4] The operating point must be made the independent of transistor parameter such as β.

Advantages of fixed bias ckt

1] This is a sample circuit which uses very few components.

2] The operating point can be fixed any where in the active region of the charecteristics by simply changing the value of R_B, This provides maximum flexibility in Design.

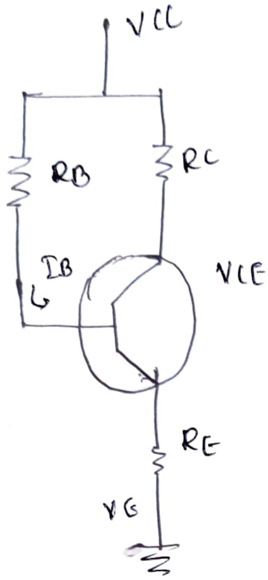
Disadvantage.

1] This circuit does not provide any check on the collectors current which increases with the rise in tempratue that is thermal stability is not provided by this circuit so the operating point is not maintained at a fix position.

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

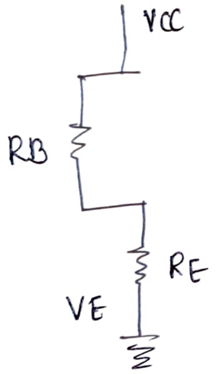
2) Since $I_C = \beta I_B$ & I_B is fixed I_C depends on 'β' which changes unit to unit and shifts the operating point. thus the stabilization of operating point is very poor in the fixed bias ckt

Analysis of Emitter stabilized bias ckt



To improve the stability of the biasing ckt over the fixed bias ckt the emitter resistance R_E is connected in bias ckt such biasing ckt is known as emitter bias ckt or self bias ckt.

Base circuit analysis



Voltage eqn

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

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

$V_{CE} = R_B I_B + V_{BE} + (I_B + \beta I_B) R_E$

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

$$\therefore I_B = \frac{V_{CE} - V_{BG}}{R_B + (1+\beta) R_E}$$

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

$\beta >> 1$

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

$V_B = V_{BE} + I_E R_E$

$V_B = V_{BE} + V_E$

Collector ckt analysis

writing vtg eqⁿ = 0 of collector ckt

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

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

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

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

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

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

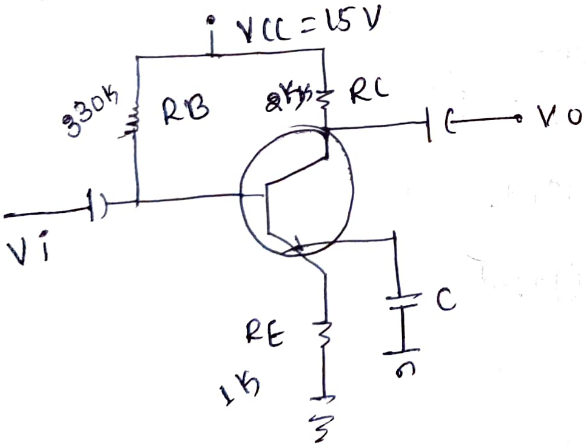
$V_{CE} = V_{CC} - I_C R_C - (1 + 1/\beta) I_C R_E$

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

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

example

For the ckt shown in fig. calculate I_B, I_C, V_{CE}, V_C, V_B & V_{BC}. $\beta = 100$. Draw the DC load line



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

$= \frac{15 - 0.7}{330 \times 10^3 \times 1 \times 10^3}$

$= \frac{14.3}{430 \times 10^3}$

$\boxed{I_B = 33.2 \mu A}$

$I_C = \beta \cdot I_B$

$= 100 \times 33.2 \times 10^{-6}$

$\boxed{I_C = 3.32 mA}$

$V_C = V_{CC} - I_C R_C$

$= 15 - (3.32 \times 10^{-3}) 2 \times 10^3$

$\boxed{V_C = 8.36 V}$

$V_B = V_{BE} + I_E R_E$

$V_B = 0.7 + 3.35 \times 10^{-3} \times 1 \times 10^3$

$\boxed{V_B = 4.05 V}$

$V_{BC} = V_B - V_C$

$= 4.05 - 8.36$

$\boxed{V_{BC} = 4.31 V}$

$I_E = I_C + I_B$

$= 3.32 \times 10^{-3} + 33.2 \times 10^{-6}$

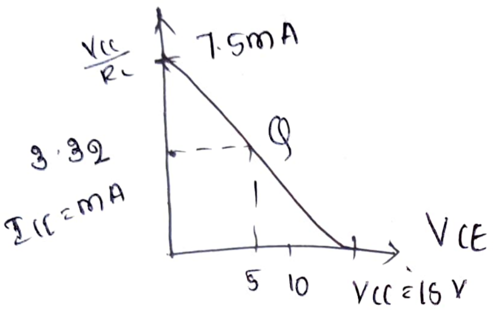
$I_E = 3.35 \times 10^{-3}$

$I_E = 3.35 mA$

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

$= 8.36 - 3.35 \times 10^{-3} \times 1 \times 10^{3}$

$V_{CE} = 5.01 V$



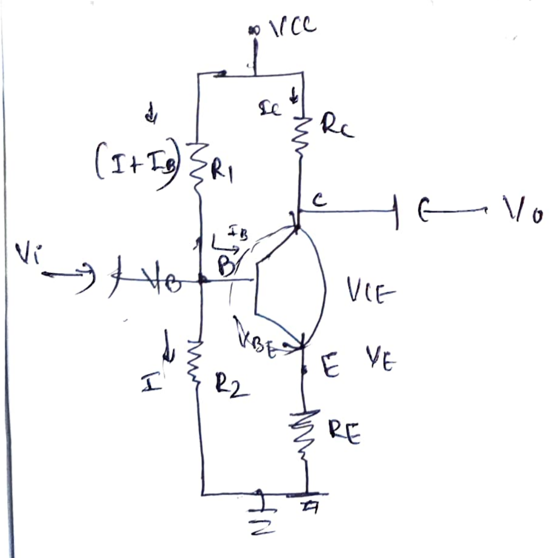
Advantage & Disadvantage of emitter stabilized bias ckt.

1) The addition of emitter resistance R_E in the emitter bias circuit include stability. i.e the dc bias current and voltage is remain closer to the point where they were set by the ckt against the changes in temperature and β.

Disadvantage: Increase in R_E increases negative feed back which reduces the gain of the ckt.

Analysis of voltage devider bias ckt.

$V_{BE} = 0.7V$.

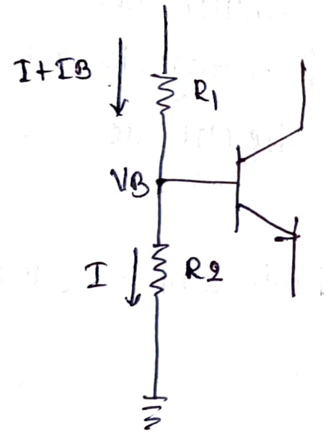


Voltage devider bias ckt is as shown in fig. In this biasing is provided by 3 resistances R_1 & R_2 & R_E. The Resistance R_1 & R_2 are acting potential devider giving the fixed voltage to point B which is base terminal. If collector current increases due to change in temperature and β. The emitter current I_E also increases. and voltage drop across R_E increases, Reducing the voltage difference between V_B & V_E. i.e $V_{BE} = V_B - V_E$.

Due to decrease in V_{BE} the base current I_B and hence collector current I_C also increases. this reduction in I_C components for the original increase in I_C

DC analysis

Base ckt

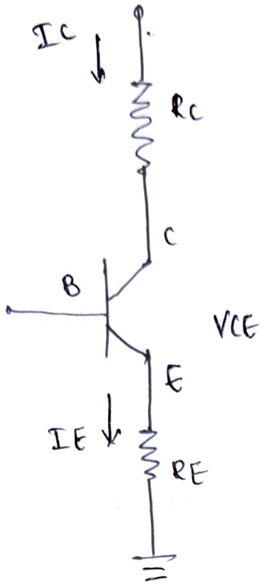


Let us consider the base ckt as shown in fig. The voltage across R_L is base voltage V_{BE} applying voltage devider rule. we get

$$V_B = \frac{R_2 I}{R_1(I + I_B) + R_2 I} \times V_{cc}$$

$$\therefore \boxed{V_B = \frac{R_2 V_{cc}}{R_1 + R_2}} \qquad \therefore I >> I_B.$$

Collector ckt



Let us consider collector ckt as shown in fig. Voltage across R_E can be obtained as,

$$V_E = I_E R_E$$

and also, $V_B - V_{BE} = V_E$

$$\boxed{I_E = \frac{V_B - V_{BE}}{R_E}}$$

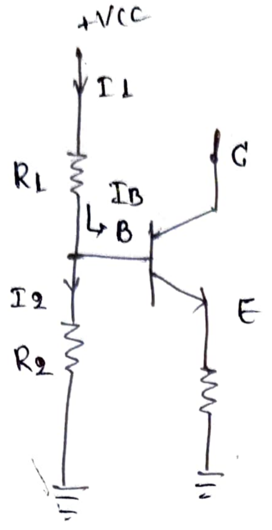
Writing voltage eqn for the collector ckt., we get

$$V_{CC} = I_C R_C + V_{CE} + V_E$$

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

The above analysis is called exact analysis or accurate analysis.

Approximate analysis



If we assume that current I_2 if far grater than I_B. we can neglect I_B and $I_1 = I_2$. ∴ $V_B = \frac{V_{CC} R_2}{R_1 + R_2}$

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

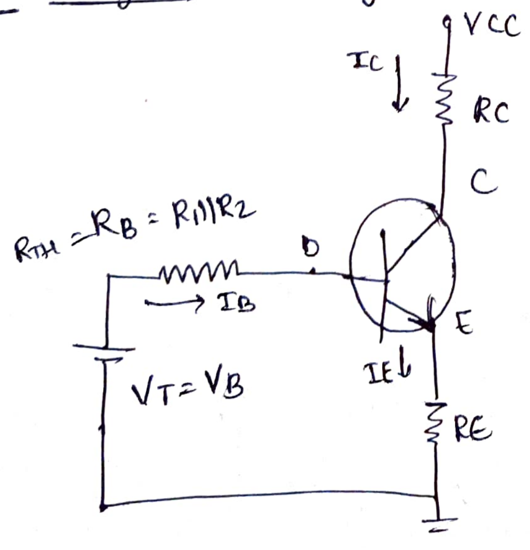
$$I_E = \frac{V_E}{R_E}$$

$$I_B = \frac{I_E}{1+\beta}.$$

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

We can use approximate analysis when $(1+\beta) R_E \gg 10 R_2$ condition is satisfied.

Exact analysis (or analysis of simplified voltage devider bias ckt)



Thevenin's equivalent ckt

$$R_{TH} = \frac{R_1 R_2}{R_1 + R_2}$$

$$V_{TH} = \frac{V_{CC}}{(R_1 + R_2)} \cdot R_2$$

When $(1+\beta) R_E$ is less $< 10R_2$ then we go for exact analysis fig shows the simplified ckt of voltage devider bias ckt where the R_B is $||^{el}$ combination of R_1 & R_2. V_B is Thevanin's voltage. R_B can be obtained as,

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

$$V_T = \frac{R_1 V_{CC} R_2}{(R_1 + R_2)}$$

Also from ckt

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

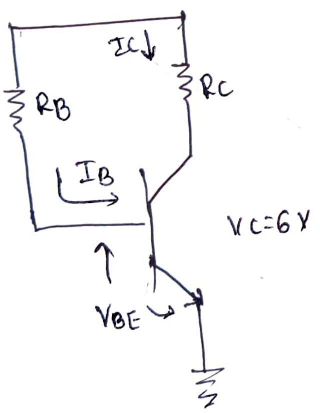
$$\therefore I_B = \frac{V_T - V_{BE}}{R_B + (1+\beta) R_E} \quad \&$$

& from collector ckt

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

Ex: 1) for the ckt shown in fig determine I_C, R_C, R_B & V_{CE} using the following specifications.

$V_{CC} = 12V$, $V_C = 6V$. $\beta = 80$. & $I_B = 40 \mu A$.



1) $I_C = \beta \times I_B$

$= 80 \times 40 \times 10^{-6}$

$= 3200 \times 10^{-6}$

$= \underline{3.2\ mA}$

2) $V_{CC} - I_C R_C - V_C = 0.$

$$R_C = \frac{V_{CC} - V_C}{I_C} = \frac{12-6}{3.2} = \frac{6}{3.2} = 1.875\Omega.$$

3) $$R_B = \frac{V_{CC} - V_{BE}}{I_B} = \frac{12 - 0.7}{40 \times 10^{-6}} = \frac{11.3 \times 10^6}{40}$$

$= 2.8 \times 10^6$

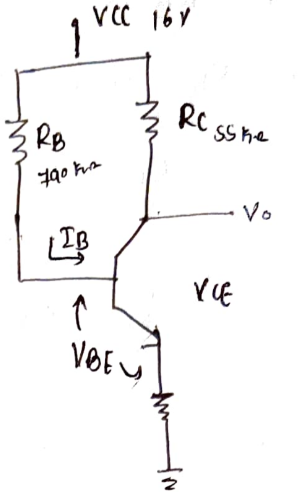
$= \underline{282.5\ k\Omega}$

4)

2) A Germanium transistor having $\beta = 100$ and $V_{BE} = 0.2V$ is used in a fixed bias amplifier ckt. where $V_{CC} = 16V$, $R_C = 5 k\Omega$ & $R_B = 790 k\Omega$ Determining the operating point.

Soln

Given that



$\beta = 100$

$V_{BE} = 0.2V$

$V_{CC} = 16V$

$R_C = 5 k\Omega$

$R_B = 790 k\Omega$

$I_C = \beta I_B$

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

$$= \frac{16 - 0.2}{790 \times 10^3}$$

$$= \frac{15.8}{790 \times 10^3} = 0.02 \times 10^{-3}$$

$= 20 \mu A$

$I_C = \beta \times I_B$

$= 100 \times 20 \times 10^{-6}$

$= 2000 \times 10^{-6}$

$= 2 mA$

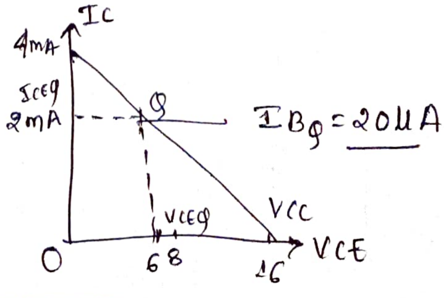
$V_{CEQ} = V_{CC} - I_C R_C$

$= 16 - 2 \times 10^{-3} \times 5 \times 10^{3}$

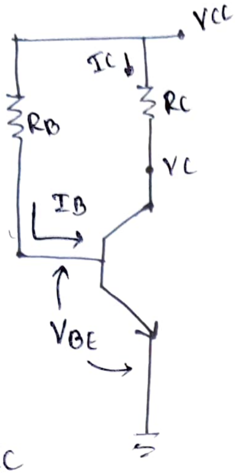
$= 16 - 10$

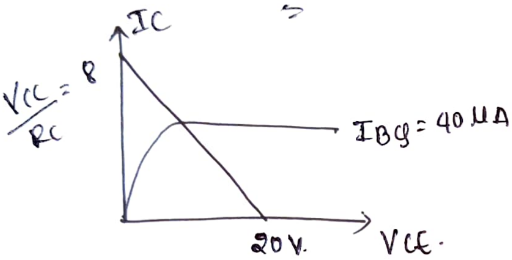
$= 6V$

Hence the operating point is at $I_{CQ} = 2mA$ & $V_{CEQ} = 6V$.



3) Given the device charecteristics, determine V_{CC}, R_B & R_C for the fixed bias configuration shown in figure





$V_{CC} = 20V$

$$R_B = \frac{V_{CC} - V_{CE}}{I_B} = \frac{20 - 0.7}{40 \times 10^{-6}} = 0.4825 \times 10^{6} = 482.5\,K\Omega.$$

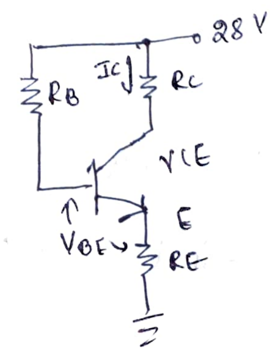
~~$R_C = \frac{V_{CC} - V_{CE}}{R_B} = \frac{20 - 0.7}{482.5 \times 10^{3}} = \frac{19.3}{482.5 \times 10^{3}} = 39.4\,\mu$~~

$$\frac{V_{CC}}{R_C} = 8mA = I_C$$

$$\frac{20}{8 \times 10^{-3}} = R_C$$

$$R_C = 2.5\,K\Omega.$$

4) The Emitter bias configuration of ckt given has the following specifications. $I_{CQ} = \frac{1}{2} I_{Csat}$, $I_{Csat} = 8\,mA$, $V_C = 18\,V$, $\beta = 110$. Determine R_C, R_E & R_B.



Sol)

$V_{CEsat} = 0.2$ to $0.3\,V$

$$I_{CQ} = \frac{1}{2} I_{Csat} = \frac{1}{2}(8mA) = 4mA$$

$$R_C = \frac{V_{CC} - V_C}{I_{CQ}}$$

$$= \frac{28-18}{4\times10^{-3}} = 2.5\,K\Omega$$

W.K.T. that

$$I_{Csat} = \frac{V_{CC}}{R_C+R_E} = \frac{28}{R_C+R_E} = 8$$

$$R_C+R_E = \frac{28}{I_{Csat}} = \frac{28}{8\times10^{-3}} = 3.5\,K\Omega$$

$$R_E = 3.5 - 2.5$$

$$\boxed{R_E = 1\,K\Omega}$$

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

$$\frac{V_{CC}-V_{BE}}{I_{BQ}} - (1+\beta)R_E = R_B.$$

$$R_B = \frac{28-0.7}{36.3\times10^{-6}} - (1+110)\times1$$

$$I_{BQ} = \frac{I_{CQ}}{\beta} = \frac{4\,mA}{110} = 36.3\,\mu A.$$

$$= 0.752\times10^{6} - 111\times1\times10^{3}$$

$$= 639.8\,K\Omega$$

***

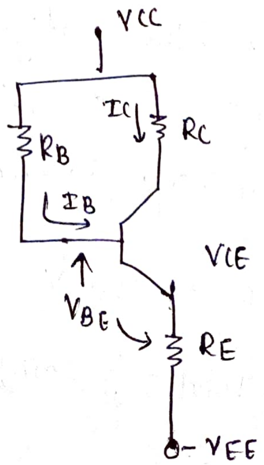
5) For the ckt shown.

$V_{CC} = 15V$, $V_{EE} = -10V$

$R_C = 2K\Omega$ $R_E = 5K\Omega$

$R_B = 400K\Omega$ $\beta = 60$

Find I_C & V_{CE}



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

$$= \frac{15 - 0.7 + 10}{400\times10^3 + (1+60)\, 5\times10^3}$$

$$= \frac{24.3}{10^3\left[400 + (61\times5)\right]}$$

$$= \frac{24.3\times10^{-3}}{705}$$

$$= 34.4\ \mu A.$$

$$I_C = \beta I_B$$

$$= 60\times34.4\times10^{-6}$$

$$= 2.07\ mA.$$

from the collector ckt,

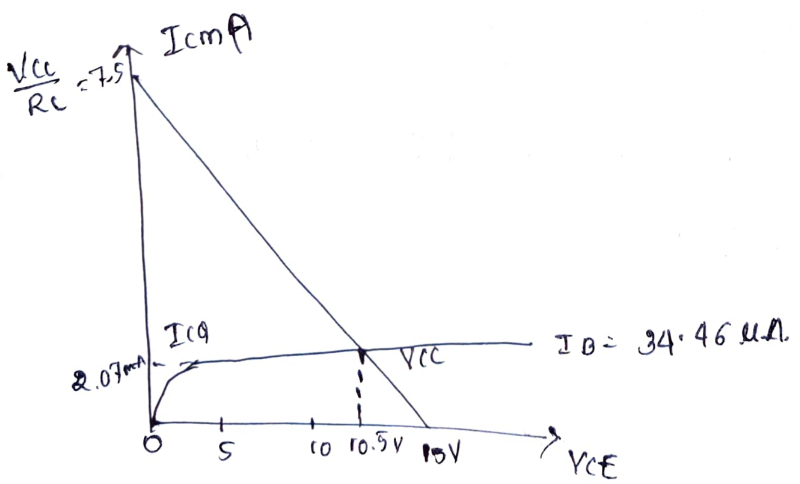
$$V_{CE} = V_{CC} - I_C R_C - (1+\beta) I_B R_E - V_{EE}.$$

$$= 15 - 2.07\times10^{3}\times2\times10^{3} - (1+60)\, 34.4\times10^{-6}\times5\times10^{3} + 10\times$$

$$= 15 - 4.14$$

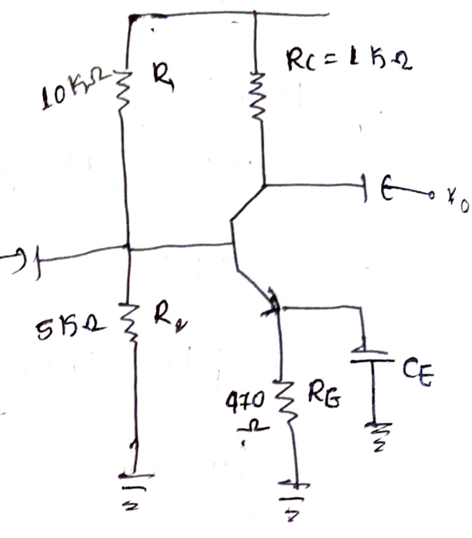
$$= 10.86\ V$$

$$= 10.51\ V.$$



6) For the ckt shown below, $\beta = 100$. Calculate V_{CE} & I_C

Soln



→ $(1+\beta) R_E \geq 10 R_2$

$(1+100) 470 \geq 10 (5k\Omega)$

$(1+100) 470 = 47.47 k\Omega < 50 k\Omega$.

Therefore we should use exact analysis.

$$V_T = \frac{V_{CC} R_2}{R_1 + R_2} = \frac{10 \times 5 \times 10^3}{(10+5) \times 10^3} = 3.33 \text{ V}$$

$$R_B = \frac{R_1 R_2}{R_1 + R_2} = \frac{10 \times 5}{10+5} k = 3.33 k\Omega.$$

$$I_B = \frac{V_T - V_{BE}}{R_B + (1+\beta) R_E} = \frac{3.33 - 0.7}{3.33 \times 10^3 + (1+100) 470 \times} = \frac{2.63}{52.173 \times 10^6} = \underline{51.77 \mu A}$$

$$I_C = \beta I_B = 100 \times 51.77 \times 10^{-6}$$
$$= \underline{5.23 mA}$$

$$I_E = I_B + I_C = (0.052 + 5.23) mA = \underline{5.28 mA}.$$

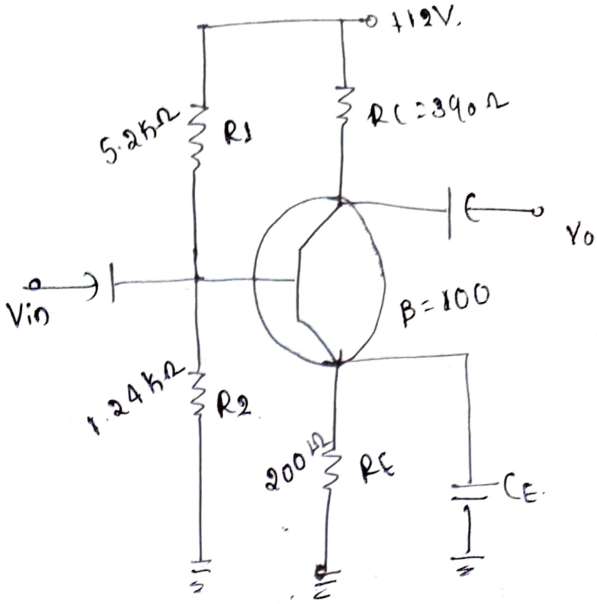
$$V_{CE} = V_{cc} - I_C R_C - I_E R_E$$
$$= 10 - 5.177 \times 1 - 5.28 \times 0.47$$

$$V_{CE} = 2.365 \text{ V}.$$

∴ $I_C = 5.23 mA$ & $V_{CE} = 2.365$

7) Draw the DC load line for the following transistor configuration obtain the Quescent point.

Soln



$(1+\beta)R_E \geq 10R_2$

$(1+100)\,200 \geq 10 \times 1.24 \times 10^3$

$(1+100)\,200 = 20.2k \geq 12.4k$

Therefore we should Approximate analysis.

$V_B = \dfrac{V_{CC}R_2}{R_1+R_2}$

$= \dfrac{12 \times 1.24 \times 10^3}{5.2 \times 10^3 + 1.24 \times 10^3} = \dfrac{14.88}{6.44} = 2.31\ V$

$V_E = V_B - V_{BE}$

$= 2.31 - 0.7 = 1.61V$

$I_E = \dfrac{V_E}{R_E} = \dfrac{1.61}{200} = 8.05mA$

$I_B = \dfrac{I_E}{1+\beta} = \dfrac{8.05 \times 10^{-3}}{1+100} = 7.97 \times 10^{-5}$

$= 79.7\,\mu A$

$V_{CE} = V_{CC} - I_CR_C - I_ER_E$

$= 12 - 7.97 \times 390 - 8.05 \times 200$

$= 12 - 3.108 - 1.61$

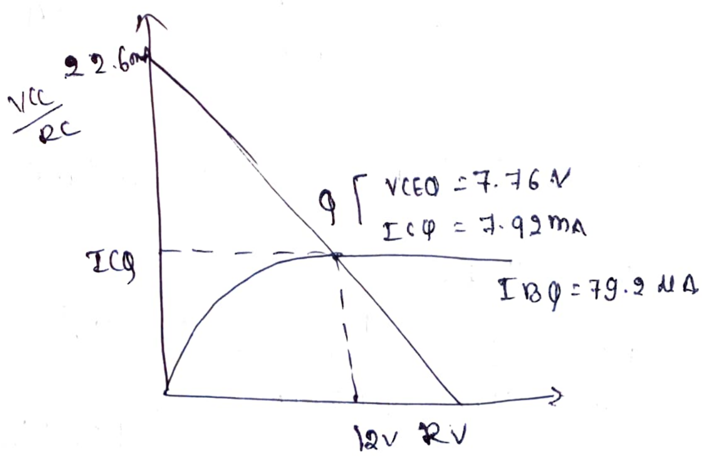
$= 12 - 4.718$

$= 7.282$

$I_C = \beta I_B$

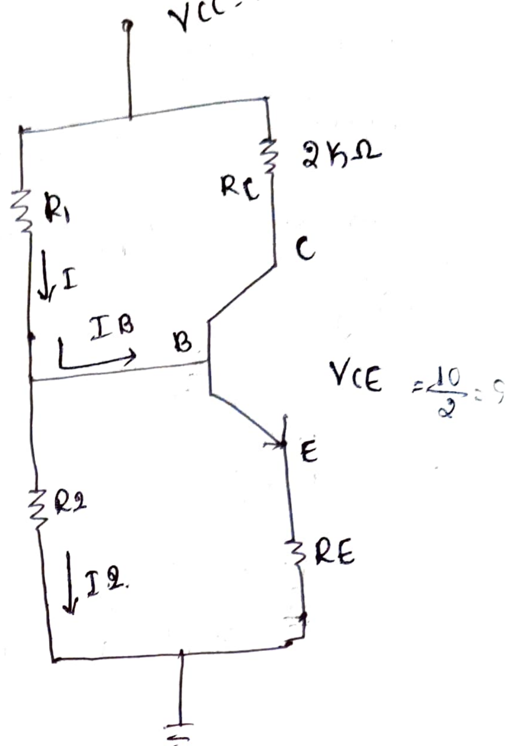
$= 100 \times 79.7 \times 10^{-6}$

$= 7.97mA$



*** Jan 2017 - 9m

8) Design a voltage devider ckt with supply of 10V & $V_{CE} = \frac{V_{CC}}{2}$. The load resistance is 2kΩ, β = 100



→ Rc is the load resistance.

For voltage devider ckt the voltage at E is VE can be obtained as

$$V_E = \left(\frac{1}{10}\right) V_{CC}$$

$$V_E = \frac{1}{10} \times 10 = 1V.$$

$V_{CC} = 10V, \quad V_{CE} = 5V, \quad V_E = 1V.$

~~$V_{CE} - I_C R_C - I_E R_E$~~

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

$$I_C = \frac{V_{CC} - V_{CE} - V_E}{R_C}$$

$$= \frac{10-5-1}{2\times10^3}$$

$$= \frac{10-6}{2} = \frac{4}{2} = 2\,mA$$

$$I_C = \beta I_B$$

$$I_B = \frac{I_C}{\beta} = \frac{2\times10^{-3}}{100} = 0.02\,mA.$$

$$I_E = I_C + I_B = 2 + 0.2 = 2.02\,mA.$$

$$V_E = I_E R_E$$

$$R_E = \frac{V_E}{I_E} = \frac{1}{2.02\times10^{-3}} = 0.495\times10^3 = 495\Omega.$$

$R_E = 495\Omega$

Sometimes **$I_E = I_C$**

To find R_1 & R_2

for the ckt to operate efficiently. it is assumed that the current through R_1 & R_2 should be approximately equal and much larger than base current (at least 10:1)

$I_1 = 10 I_B$.

$I_1 = 10 \times 0.02$

$= 0.2\,mA$.

Then $I_2 = I_1 - I_B$

$= 0.2 - 0.02$

$= 0.18\,mA$.

$V_{BE} = V_B - V_E$

$V_B = V_{BE} + V_E$

$= 0.7 + 1 = 1.7\,V$.

$\therefore R_2 = \frac{I_B}{I_2} = \frac{1.7}{0.18 \times 10^{-3}} = 9.44\,k\Omega$ (std value is $10\,k\Omega$)

$R_1 = \frac{V_B}{I_1} = \frac{1.7}{0.2 \times 10^{-3}} = 8.5\,k\Omega$

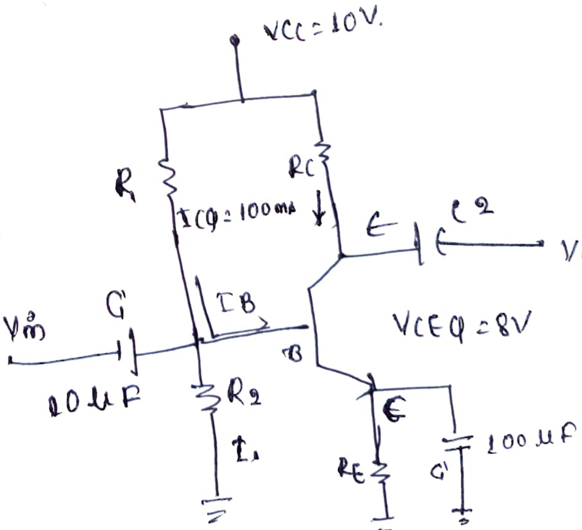
9] Determine the levels of R_C, R_E, R_1 & R_2 for the network shown below.

→ $V_{CC} = 10V$

$I_{CQ} = 100\,mA$

$V_{CEQ} = 8V$

$C_1 =$



9/8/17 10) Determine the levels of I_{CQ} & V_{CEQ} for the voltage devider configeration using exact and approximation techniques.

$V_{CC} = 18V$, $R_1 = 82k\Omega$, $R_C = 5.6k\Omega$, $R_E = 1.2k\Omega$, & $\beta = 50$, $R_2 = 22k\Omega$

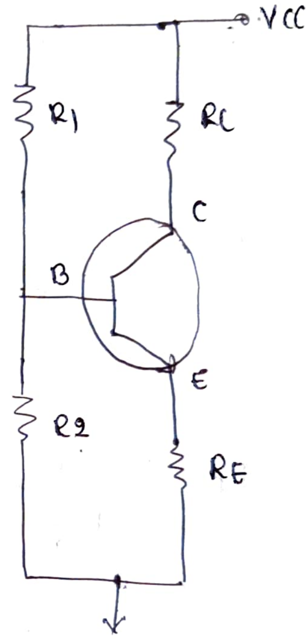
$\beta h_{fe\,min} = 50$ & $h_{fe\,max} = 100$.

→ $(1+\beta)R_E \geq 10 R_2$

$(1+50) \times 1.2\times10^3 \geq 10 \times 22 \times 10^3$

$61.2\times10^3 \ngeq 220\times10^3$

$61.2k\Omega < 220k\Omega$.



1) In Exact analysis.

$$R_B = \frac{R_1R_2}{R_1+R_2}$$

$$= \frac{82\times10^3 \times 22\times10^3}{82\times10^3 + 22\times10^3}$$

$$= \frac{1804}{104} = 17.346 k\Omega.$$

$$V_T = \frac{V_{CC}R_2}{(R_1+R_2)} = \frac{18\times22\times10^3}{(82+22)10^3} = \frac{396}{104} = 3.8V$$

$$I_B = \frac{V_T - V_{BE}}{R_B + (1+\beta)R_E} = \frac{3.8-0.7}{17.34\times10^3 + (1+50)1.2\times10^3} = \frac{3.1}{78.54\times10^3} = 39.47\mu A$$

$$I_{CQ} = \beta I_B = 50\times39.47\times10^{-6}$$
$$= 1.9735 mA.$$

$$I_E = I_C + I_B = 1.9735\times10^{-3} + 39.47\times10^{-6}$$
$$= 2.013 mA$$

$$V_{CEQ} = V_{CC} - I_CR_C - I_ER_E$$
$$= 18 - (1.9735\times10^{-3}\times5.6\times10^3) - (2.013\times10^{-3}\times1.2\times10^3)$$

$V_{CEQ} = 4.532\,V$

$I_{CQ} = 1.97\,mA$

ii) Approximate analysis.

$$V_B = \frac{V_{CC} R_2}{R_1 + R_2} = \frac{18 \times 22 \times 10^3}{(82+22)10^3} = 3.8\,V.$$

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

$$= 3.8 - 0.7 = 3.1\,V$$

$$I_E = \frac{V_E}{R_E} = \frac{3.1}{1.2 \times 10^3} = 2.58 \times 10^{-3}$$

$$= 2.58\,mA.$$

$$I_B = \frac{I_E}{1+\beta} = \frac{2.58 \times 10^{-3}}{1+50} = 50.6\,\mu A.$$

$$I_E = I_B + I_C$$

$$I_C = I_B - I_E$$

$$= 50.6 \times 10^{-6} - 2.58 \times 10^{-3}$$

$$= 2.52\,mA$$

$$V_{CEQ} = V_{CC} - I_C R_C - I_E R_E$$

$$= 18 - (2.52 \times 10^{-3} \times 5.6 \times 10^3) - (2.58 \times 10^{-3} \times 1.2 \times 10^3)$$

$V_{CEQ} = 0.792\,V.$

$I_{CQ} = 2.52\,mA$

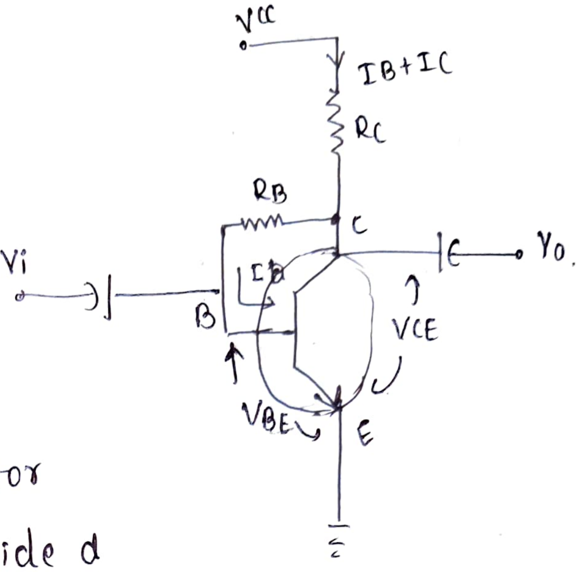
By observing the value of V_{CEQ} & I_{CQ} of both the techni[que] we can conclude that their is large difference between the operating

*** Imp *****

Analysis of collector base bias ckt

June / July 2017 6M

(Voltage feed back bias ckt)



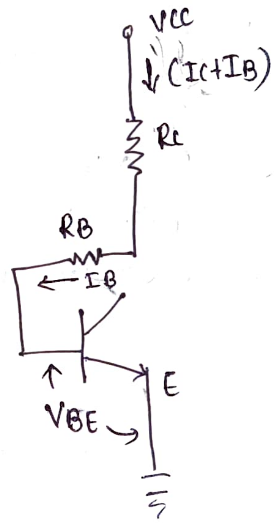
The fig shows the dc bias with voltage feed back it is called collecter to base bias ckt

it is an improvement over fixed bias ckt method. In this biasing resistor is connected between collector and base of the transistor to provide a feed back path.

I_B flows through R_B & $I_C + I_B$ flows through R_C.

DC analysis

Base ckt



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

$$I_B = \frac{V_{CC} - V_{BE}}{R_B + (1+\beta)R_C} \quad \text{— (1)}$$

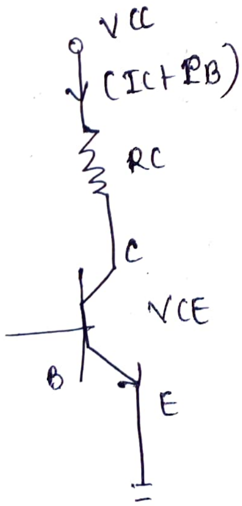
$(I_C + I_B)R_C + I_B R_B$

$(\beta I_B + I_B)R_C + I_B R_B$

$R_C I_B(\beta+1) + I_B R_B$

$I_B[(1+\beta)R_C + R_B]$

collector ckt



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

If there is change in β due to transistor of or temperature then collector current I_C tends to ~~decrea~~ increase

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

In this ckt resistance R_B provides a feed back path which keeps a check on I_C value. When β ~~changes~~ increases the base current I_B decreases. (reffered as eqⁿ ①) due to which collector current I_C also decreases. This decrease in I_C componsates both original increase in the I_C value. As the result the ckt tends to maintain stable value of I_C keeping the Q point fix

Here R_B is connected between to the output (collector) & input (base) and ↑ in I_C (increase) ↓ I_B (decrease). negative feed back exist in the ckt. hence the ckt is also called voltage feed back bias ckt

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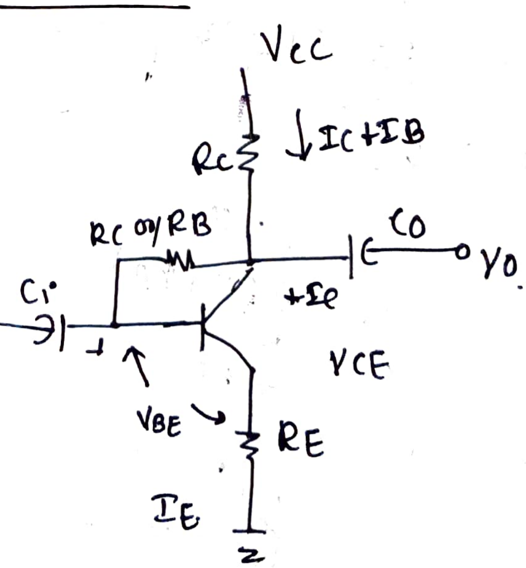
Modified DC bias with voltage feed back
[collector-base bias ckt]

To further improve the level of stability the emitter resistance R_E is connected as shown in figure.



DC analysis of the ckt

Base ckt

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

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

We know that, I_B for fixed bias ckt is given by

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

Comparing the two equation we can say that feed back path results in reflection of the resistance R_C back to the i/p ckt.

In general we can say that

$$I_B = \frac{V'}{R_B + \beta R'}$$

Where $V' = V_{CC} - V_{BE}$

$R' = 0$; for fixed bias ckt

$R' = R_E$: for emitter bias ckt

$R' = R_C$; for collector to base bias ckt

$R' = R_C + R_E$; for collector to base bias ckt with R_E

Collector ckt

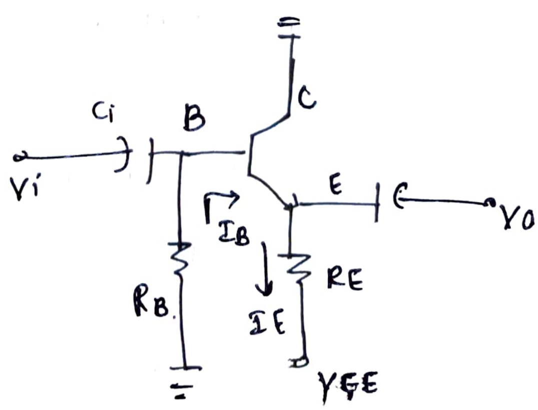
$$V_{CE} = V_{CC} - (I_C + I_B) R_C + I_E R_E$$

$$= V_{CC} - I_E R_C + I_E R_E$$

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

* Common collector [emitter follower] configeration.

Common collector configeration is as shown in fig as the o/p voltage at emitter follows the input voltage it called emitter follower ckt.



1) Determine the Quescent level of I_{CQ} and ~~V_{CEQ}~~ V_{CEQ}. for the ckt shown in fig below. Repeat this problem using β of 135. Comment on the changes in the Q point

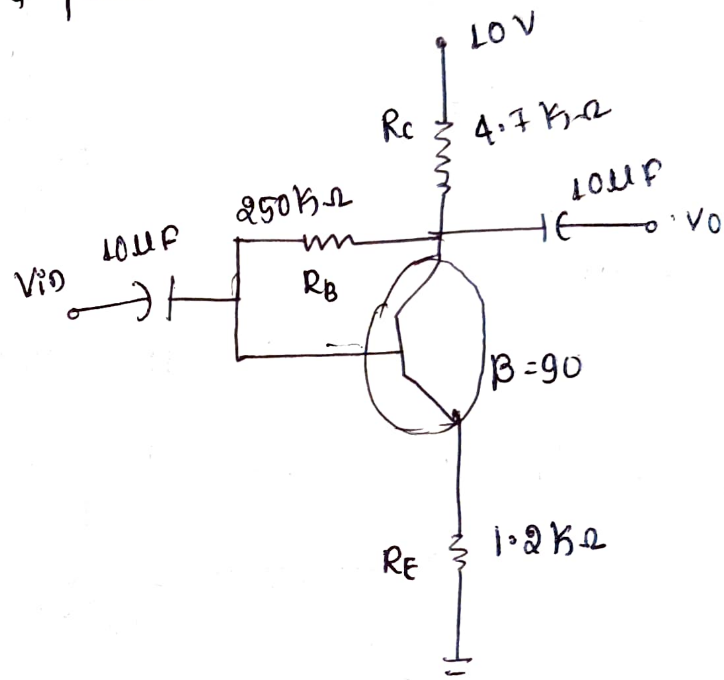
→ Given

$R_B = R_F = 250\,k\Omega$

$R_C = 4.7\,k\Omega$

$R_E = 1.2\,k\Omega$

$\beta = 90$



Collector to base bias.

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

$$= \frac{10 - 0.7}{250 + (4.7 + 1.2)90}$$

$$= \frac{9.3}{781} = 1.1908 \times 10^{-4}$$

$$= \frac{9.3}{250\times10^3 + (4.7\times10^3 + 1.2\times10^3)\,90}$$

$$\boxed{I_b = 11.91\,\mu A}$$

$I_{CQ} = \beta I_B$

$= 90 \times 11.91 \times 10^{-6}$

$I_{CQ} = 1.071\ mA$

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

$= 10 - 1.071 \times 10^{-3}(4.7 \times 10^{3} + 1.2 \times 10^{3})$

$= 10 - 6.31$

$V_{CEQ} = 3.69\ V$

Now β is changed to 135 (50% increase in β)

$$I_B = \frac{10 - 0.7}{250 \times 10^{3} + (4.7 \times 10^{3} + 1.2 \times 10^{3})\,135}$$

$$= \frac{9.3}{1046500} = 8.886 \times 10^{-6}\ A$$

$I_B = 8.89\ \mu A$

$I_C = \beta I_B$

$= 135 \times 8.89 \times 10^{-6}$

$I_{CE} = 1.199\ mA$

$I_{CQ} \approx 1.2\ mA$

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

$= 10 - 1.2 \times 10^{-3}(4.7 \times 10^{3} + 1.2 \times 10^{3})$

$V_{CEQ} = 2.92\ V$

We can observe that when β is increased by 50% the level of I_{CQ} only increased by 12.1%.

$$\frac{1.2 - 1.07}{1.07} \times 100 = 12.1\ \%$$

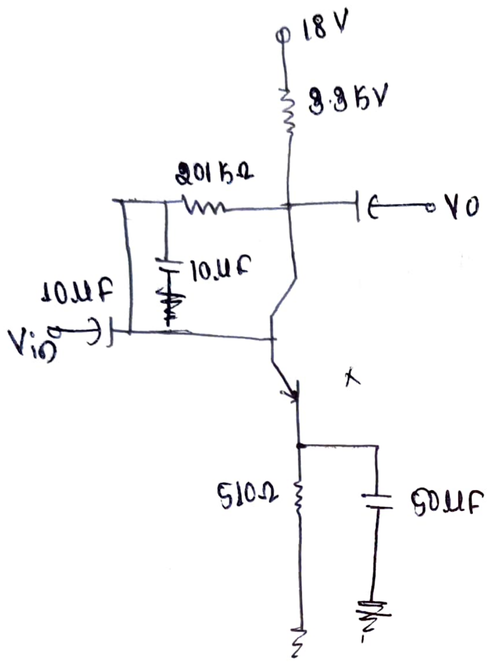
Where as levels of V_{CEQ} decreased about 20.9%

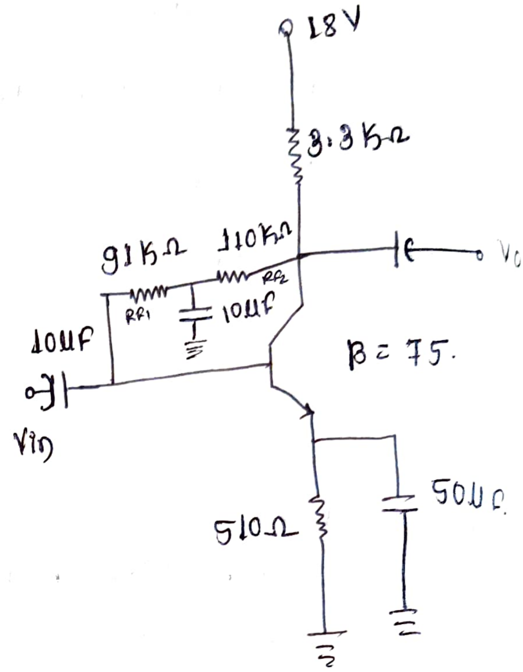
$$\%\ V_{CEQ} = \frac{3.69 - 2.92}{3.69} \times 100 = 20.9\ \%$$

if the network where fixed bias design a 50% increased in β would have resulted in 50% increase in I_{CQ} and there would have been dramatic change location of Q-point.

2) Determine the DC levels of I_B and V_C are

→ The equivalent ckt is,





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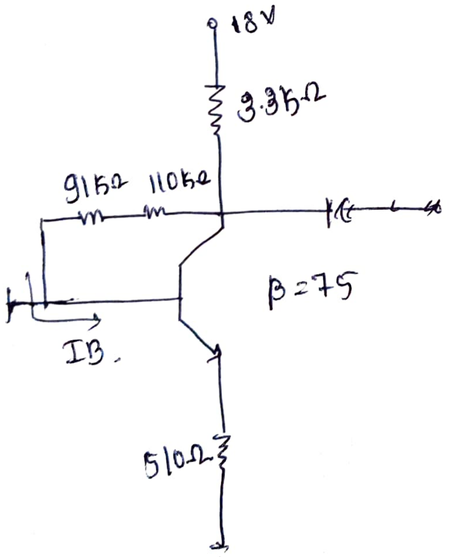
In DC ckt the capacitors are in open circuit.

we can remove the capacitor from the ckt.



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

$R_B = R_{F1} + R_{F2}$

$= 91 + 110$

$= 201\ k\Omega.$

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

$= \frac{18 - 0.7}{201 \times 10^3 + 75(3.3 \times 10^3 + 510)}$

$=$

$= \frac{17.3}{486750} = 3.55 \times 10^{-5}$

$= 35.5\ \mu A$

$\boxed{I_B = 35.5\ \mu A}$

$I_C = \beta I_B$

$= 75 \times 35.5$

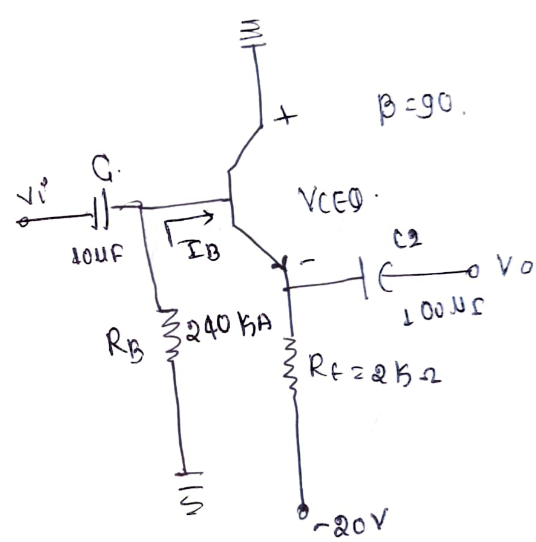
$= 2.6625 \times 10^{-3}\ A$

$V_C = V_{CC} - I_C R_C$

$= 18 - (2.66 \times 10^{-3} \times 3.3 \times 10^{3})$

$\boxed{V_C = 9.22\ V}$

3) Determine V_{CEQ} & I_{EQ} for the network shown.



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

$= \frac{+20 - 0.7}{240 \times 10^3 + (1+90)\, 2 \times 10^3}$

$= \frac{20 - 0.7}{422000}$

$= \frac{19.3}{422000} = 4.57 \times 10^{-5}$

$= 45.73\ \mu A$

$\boxed{I_B = 45.7\ \mu A}$

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

$= 91 \times 45.7 \times 10^{-6}$

$\boxed{I_{EQ} = 4.16\ mA}$

$I_E = I_B + I_C$

$= 45.7 \times 10^{-6} + 4.16 \times 10^{-3}$

$= 4.2\ mA$

$V_{CEQ} = V_{EE} - I_E R_E$

$= 20 - (4.2 \times 10^{-3} (2 \times 10^{3}))$

$= 20 - 8.4 = 11.6\ V$

*** Imp

Stability factor for Different Biasing ckts.

We have seen various biasing ckt to provide stability of I_C against the variations in I_{CO}, β & V_{BE} in order to compare the stability provided by these ckt one term is raised is called stability factor which indicates degree of change in operating point Due to variation in temperature. Since there are 3 variables which are temperature dependent. We can define 3 stability factor as below.

i) $S(I_{CO}) = \left.\frac{\partial I_C}{\partial I_{CO}}\right|_{\beta, V_{BE} \text{ constant}}$ or $S(I_{CO}) = \left.\frac{\Delta I_C}{\Delta I_{CO}}\right|_{\beta, V_{BE} \text{ constant}}$

ii) $S(V_{BE}) = \left.\frac{\partial I_C}{\partial V_{BE}}\right|_{\beta, I_{CO} \text{ constant}}$ or $S(V_{BE}) = \left.\frac{\Delta I_C}{\Delta V_{BE}}\right|_{\beta, I_{CO} \text{ constant}}$

iii) $S(\beta) = \left.\frac{\partial I_C}{\partial \beta}\right|_{I_{CO}, V_{BE} \text{ constant}}$ or $S(\beta) = \left.\frac{\Delta I_C}{\Delta \beta}\right|_{V_{BE}, I_{CO} \text{ constant}}$

Stability factor $S(I_{CO})$

For a Common Emitter Configeration collector current I_C is given as,

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

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

When I_{CBO} changes by ∂I_{CBO}, I_B changes by ∂I_B and I_C changes by ∂I_C. Hence the above eqn becomes

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

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

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

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

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

Stability factor for fixed bias ckt

For fixed bias ckt,

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

$$\frac{\partial I_B}{\partial I_C} = 0 \quad [\text{as } I_C \text{ is not present in the eq}^n \text{ of } I_B]$$

Substituting $\frac{\partial I_B}{\partial I_C} = 0$ in eq^n of $S(I_{CO})$ we get,

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

$$S(I_{CO}) = (1+\beta) \simeq \beta.$$

Stability factor $S(V_{BE})$

W.K.T $S(V_{BE}) = \frac{\partial I_C}{\partial V_{BE}}$

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

Now, representing I_B in terms of V_{BE} We get, $I_B = \frac{V_{CC} - V_{BE}}{R_B}$

$$\therefore I_C = \beta \left(\frac{V_{CC} - V_{BE}}{R_B} \right) + (1+\beta) I_{CBO}$$

$$I_C = \frac{\beta V_{CC}}{R_B} - \frac{\beta V_{BE}}{R_B} + (1+\beta) I_{CBO}.$$

$$\therefore \frac{\partial I_C}{\partial V_{BE}} = 0 - \frac{\beta}{R_B} + 0$$

$$\therefore S(V_{BE}) = \frac{-\beta}{R_B}$$

Relationship between $S(V_{BE})$ & $S(I_{CO})$

$S(V_{BE}) = \frac{-\beta}{R_B}$ & $S(I_{CO}) = 1+\beta$

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

$$= \frac{-\beta(S I_{CO})}{(1+\beta) R_B}$$

$$S(V_{BE}) = \frac{-S(I_{CO})}{R_B}$$

$\because \beta >> 1.$

Stability factor $S(\beta)$:

W.K.T $S(\beta) = \frac{\partial I_C}{\partial I_\beta}$

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

$$\frac{\partial I_C}{\partial \beta} = I_B + I_{CBO}$$

$$\frac{\partial I_C}{\partial \beta} = I_B \quad \because I_B >> I_{CBO}.$$

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

$$\boxed{S(\beta) = \frac{I_C}{\beta}}$$

Relationship between $S\beta$ & S_{ICO}

We have $S(\beta) = \frac{I_C}{\beta}$ & $S(I_{CO}) = 1+\beta = \beta$

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

$$\boxed{S(\beta) = \frac{I_C\, S(I_{CO})}{\beta(I+\beta)}}$$

$$S(\beta) = \frac{I_C}{\partial I_{CO}}.$$

stability factor for collector to base bias ckt or voltage feed back ckt.

stability factor $S(I_{CO})$:

for voltage feed back ckt.

We have,

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

When I_{CBO} changes by ∂I_{CBO},

I_B changes by ∂I_B,

I_C changes by ∂I_C.

there is no effect on V_{CC} & V_{BE} hence the eqn becomes

$$0 = \partial I_C R_C + \partial I_B(R_C + R_B) + 0$$

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

We know that

$$S_{ICO} = \frac{1+\beta}{1-\beta\left(\frac{\partial I_B}{\partial I_C}\right)}$$

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

As the value of this term is lesser than that of fixed bias ckt. hence this ckt provides better stability.

Stability factor $S(V_{BE})$

We know that

$$S(V_{BE}) = \frac{\partial I_C}{\partial V_{BE}}$$

from base ckt of the collector to base bias ckt,

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

$$\frac{I_C}{\beta} = \frac{\beta[V_{CC} - V_{BE}]}{R_B + (1+\beta)R_C}$$

$$I_C = \frac{\beta[V_{CC} - V_{BE}]}{R_B + (1+\beta)R_C}.$$

$$\frac{\partial I_C}{\partial V_{BE}} = \frac{-\beta}{R_B + (1+\beta)R_C}.$$

$$\boxed{S(V_{BE}) = \frac{-\beta}{R_B + (1+\beta)R_C}}$$

Relationship between S_{VBE} & $S(I_{CO})$

We have, $S(V_{BE}) = \dfrac{-\beta}{R_B + (1+\beta)R_C}$

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

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

$$S(I_{CO}) = -\frac{(R_C+R_B)(1+\beta)}{\beta}\left[\frac{-\beta}{R_B+(1+\beta)R_C}\right]$$

$$S(I_{CO}) = -(R_C+R_B)\,S_{VBE}$$

$$\boxed{S_{VBE} = -\frac{S(I_{CO})}{(R_C+R_B)}}$$

if $S(I_{CO})$ is small S_{VBE} is still smaller. If we provide stability against $I_{(CO)}$ variation, we get stability against V_{BE} Variation also.

stability factor $S(\beta)$

For voltage feed back ckt,

We have, $I_B = \dfrac{V_{CC}-V_{BE}}{R_B+(1+\beta)R_C}$

$$I_C = \frac{\beta[V_{CC}-V_{BE}]}{R_B+(1+\beta)R_C}$$

$$\therefore \frac{\partial I_C}{\partial \beta} = \frac{[V_{CC}-V_{BE}][R_B+(1+\beta)R_C] - \beta[V_{CC}-V_{BE}]R_C}{[R_B+(1+\beta)R_C]^2}$$

$$= R_B+(1+\beta)R_C-\beta R_C$$

$$= (R_B+R_C)$$

Here,
$R_B+(1+\beta)R_C-\beta R_C = R_B+R_C.$

$$\frac{\partial I_C}{\partial \beta} = \frac{(V_{CC}-V_{BE})(R_B+R_C)}{[R_B+(1+\beta)R_C)\,[R_B+(1+\beta)R_C)}$$

$$\frac{\partial I_C}{\partial \beta} = S(\beta) = I_B \times \frac{R_B + R_C}{R_B + (1+\beta)R_C}$$

or

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

Relationship between $S(\beta)$ & $S(I_{CO})$

$$S(\beta) = \frac{I_C \; R_B + R_C}{\beta [R_B + (1+\beta) R_C]} = \frac{I_C}{\beta} \frac{S(I_{CO})}{(1+\beta)}$$

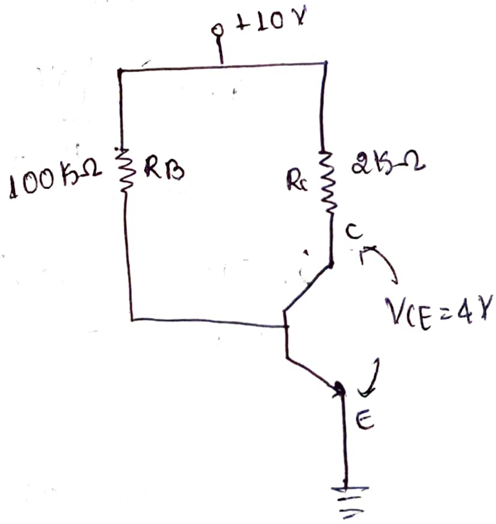
$$\boxed{S(\beta) = S(I_{CO}) \times \frac{I_C}{\beta (1+\beta)}}$$

$$\because S(I_{CO}) = \frac{(1+\beta)(R_C + R_B)}{R_B + (1+\beta) R_C}$$

Ex 1) In the ckt shown calculate stability factor for $S(I_{CO})$

→ The Given ckt is fixed bias configeration

We have $S(I_{CO}) = 1 + \beta$.



W.K.T

$$I_C = \beta I_B$$

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

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

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

$$I_B = \frac{V_{CC} - V_{BE}}{R_B} = \frac{10 - 0.7}{100 \times 10^3} = \frac{6}{100 \times 10^3} = 0.06 \times 10^{-3}$$

$$= 60 \mu A$$

$$= 6 \times 10^{-5}$$

$$\frac{9.3}{100 \times 10^3} = 9.3 \times 10^{-5}$$

$$= 93 \mu A$$

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

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

$I_C = \dfrac{V_{CC} - V_{CE}}{R_C} = \dfrac{10-4}{2\times10^3} = \dfrac{6}{2\times10^3} = 3\times10^{-3} = 3mA$

$\boxed{I_C = 3mA}$

$\beta = \dfrac{I_C}{I_B} = \dfrac{3\times10^{-3}}{6\times10^{-5}} = \dfrac{10^2}{2} = 0.5\times10^2 = 50$

$= \dfrac{3\times10^{-3}}{93\times10^{-6}} = 32.258$

$\boxed{\beta = 32.258}$

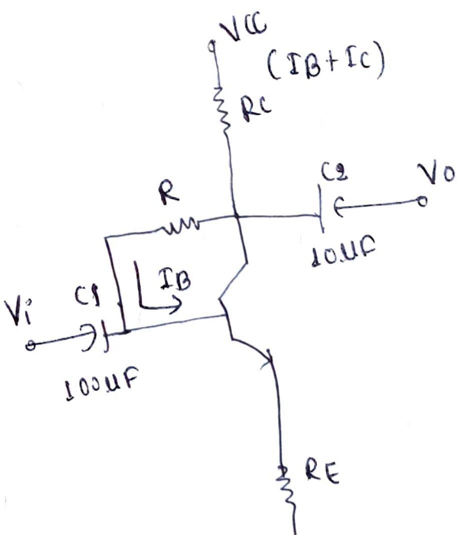
$S_{ICO} = 1 + \beta$

$= 1 + 32.258$

$\boxed{S_{ICO} = 33.258}$

2) In the ckt shown below $V_{CC} = 24V$, $R_C = 10k\Omega$. $R_E = 270\Omega$ If the silicon transistor is used with $\beta = 45$ and if under quiescent condition $V_{CE} = 5V$ determine R & the stability factor $S(I_{CO})$.

From collector ckt



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

$V_{CC} = (1+\beta)I_B R_C + I_C R_C \; V_{CE} + (1+\beta) R_E$

$I_B = \dfrac{V_{CC} - V_{CE}}{(1+\beta)(R_C + R_E)}$

$= \dfrac{24-5}{(1+45)(10k+270)} = \dfrac{19}{472420}$

$= 4.021\times10^{-5} = \underline{40.2 \mu A}$

From Base ckt,

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

$$V_{CC} = (1+\beta) I_B R_C + I_B R + V_{BE} + (1+\beta) I_B R_E$$

$$V_{CC} = (1+\beta)(R_C + R_E) I_B + V_{BE} + I_B R.$$

$$I_B R = V_{CC} - V_{BE} - (1+\beta)(R_C + R_E) I_B.$$

$$R = \frac{V_{CC} - V_{BE} - (1+\beta)(R_C+R_E) I_B}{I_B}$$

$$= \frac{24 - 0.7 - (1+45)(10\times10^3 + 270)\, 40.2\times10^{-6}}{40.2\times10^{-6}}$$

$$= \frac{24 - 0.7 - 18.991284}{40.2\times10^{-6}} = \frac{4.308716}{40.2\times10^{-6}} = 1.071\times10^{4}.$$

$$= 107.15\,\Omega$$

We know that basic Expression for $S_{(ICO)}$ is given by,

$$S_{(ICO)} = \frac{(1+\beta)}{1 - \beta\left(\frac{\partial I_B}{\partial I_C}\right)}$$

from the base ckt we have,

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

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

When I_B changes ∂I_B, I_C also changes by ∂I_C and V_{CC} & V_{BE} remain uneffected hence they are taken as zero

i.e $0 = (R_C + R + R_E)\partial I_B + (R_C + R_E)\partial I_C$

$$\frac{\partial I_B}{\partial I_C} = \frac{-(R_C+R_E)}{(R_C+R+R_E)}$$

$$= \frac{-(10\times10^3+270)}{(10\times10^3+107.1\times10^3+270)}$$

$$= \frac{-10270}{117370} = -0.0875$$

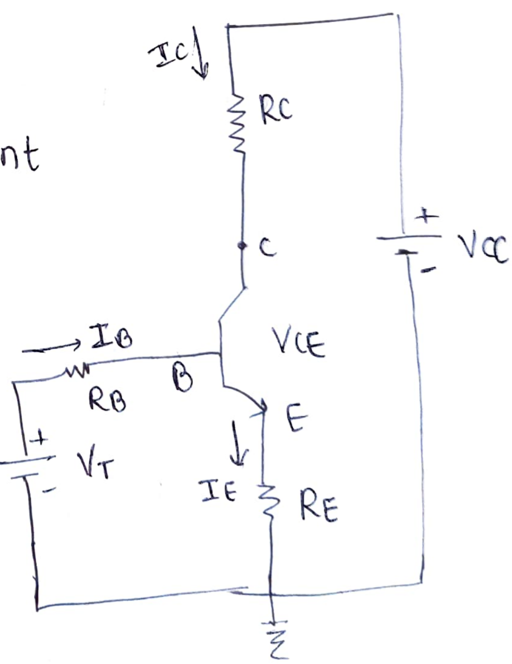
$$S_{(ICO)} = \frac{1+\beta}{1-\beta\left(\frac{\partial I_B}{\partial I_C}\right)} = \frac{1+45}{1-45(-0.087)} = \frac{46}{4.6} = 10.$$

$$\boxed{S_{(ICO)} = 10}$$

*** Imp

Stability factor for Voltage devider bias ckt.

To determine stability factor to $S_{(ICO)}$ for voltage devider bias ckt. We will consider Thevenins equivalent ckt of voltage devider bias.



Here Thevenins equivalent Voltage $V_T = \frac{V_{CC} R_2}{R_1+R_2}$

and R_1 and R_2 are replaced by R_B. which is equal to R_1 ||el to R_2.

from base ckt,

$$V_T = I_B R_B + V_{BE} + (I_B+I_C) R_E \quad \text{—(1)}$$

Differentiating eqn ① with respect to I_C.

$$0 = \frac{\partial I_B}{\partial I_C} \cdot R_B + 0 + \frac{\partial I_B}{\partial I_C} R_E + R_E$$

$$\frac{\partial I_B}{\partial I_C} = \frac{-R_E}{(R_B + R_E)} \quad \text{—②}$$

W.K.T the generalised expression for $S_{(I_{CO})}$ is given by

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

$$\boxed{S_{(I_{CO})} = \frac{1+\beta}{1-\beta\left[\frac{-R_E}{R_B+R_E}\right]}} \quad \text{—③}$$

$$S_{(I_{CO})} = \frac{(1+\beta)(R_B+R_E)}{(R_B+R_E)+\beta R_E}$$

÷ by R_E

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

$$= \frac{(1+\beta)\left(1+(R_B/R_E)\right)}{(1+\beta)+(R_B/R_E)} \quad \text{—④}$$

The ratio R_B/R_E controls the value of stability factor if $\frac{R_B}{R_E}$

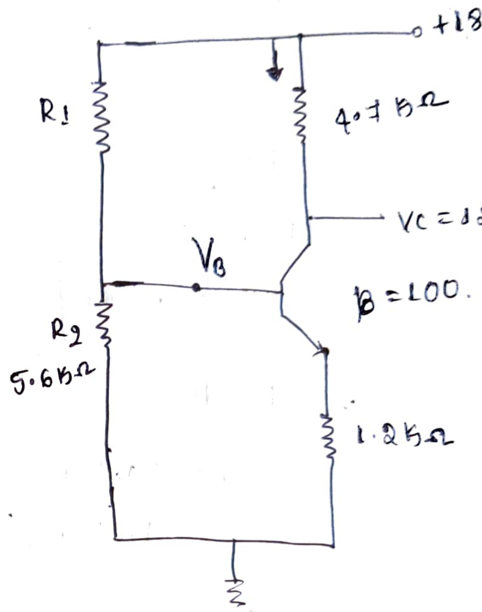
$R_B/R_E \ll 1$. then eqn ④ reduces to,

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

Practically R_B/R_E is cannot be zero hence we have to keep the ratio as small as possible

*** 8m June19.

Ex: I) For the ckt shown below find I_C, V_B, V_E, R_1 & $S_{I(CO)}$



→

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

$$= \frac{18-12}{4.7 \times 10^3} = 1.276\,mA$$

$$\boxed{I_C = 1.276\,mA}$$

ii) $V_B = V_{BE} + V_E$.

$= 0.7 + V_E$

$V_E = I_E R_E$

$= (1+\beta) I_B R_E$

$= (1+\beta)\frac{I_C}{\beta} \times R_E$.

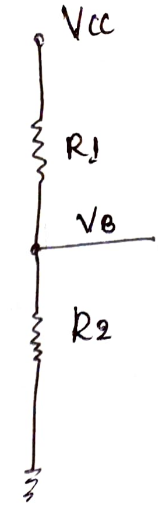
$$= \frac{(1+100) \times 1.276 \times 10^{-3} \times 1.2 \times 10^3}{100}$$

$$\boxed{V_E = 1.546\,V}$$

$\therefore V_B = 0.7 + 1.546$

$$\boxed{V_B = 2.246\,V}$$

iv) To find R_1



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

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

$$= \frac{18}{2.246} \times 5.6 \times 10^3$$

$$R_1 = 4489.78 - 5.6 \times 10^3$$

$$\boxed{R_1 = 39.27\ k\Omega}$$

v) $$S_{ICO} = \frac{1+\beta}{1-\beta\left[\frac{R_E}{R_B+R_E}\right]}$$

for voltage devider the base resistance

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

$$= \frac{39.27 \times 10^3 \cdot 5.6 \times 10^3}{(39.27 + 5.6)10^3}$$

$$= 4.9\ k\Omega$$

$$= \frac{1 + 100}{1 + \frac{100 \times (1.2 \times 10^{-3})}{(4.9 \times 10^3) + (1.2 \times 10^{-3})}}$$

$$= \frac{101}{1 + \frac{0.12}{4900.00}}$$

$$= \frac{101}{1 + 2.44 \times 10^{-5}}$$

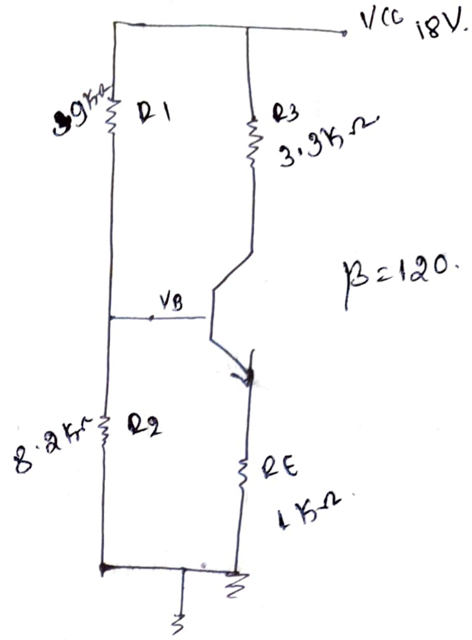
$$= \frac{101}{-0.999} = (101) \approx 4.885.$$

8m

** Dec. 2015.

2) A voltage devider bias ckt $R_1 = 39\ k\Omega$. $R_2 = 8.2\ k\Omega$. $R_3 = 3.3$ $R_E = 1\ k\Omega$. $V_{CC} = 18\ V$. The Si transistor used has $\beta = 120$. Find Q-point & stability factor.

→



Approximate $(1+\beta) R_E \geq 10 R_2$

$120\ k\Omega \geq 82\ k\Omega$.

So approximate analysis can be used

$$V_B = \frac{V_{CC} R_2}{R_1 + R_2} = 3.127\ V.$$

$$R_B = \frac{R_1 R_2}{R_1 + R_2} = 6.6775\ k\Omega.$$

$$V_E = V_B - V_{BE} = 2.4\ V$$

$$I_E = \frac{V_E}{R_E} = 2.4\ mA$$

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

$$\therefore I_B = \frac{I_E}{(1+\beta)} = 20\ \mu A.$$

$$I_{CQ} = \beta I_B. = 2.4\ mA$$

$$V_{CEQ} = V_{CC} - I_C R_C - V_E = 8.254\ V.$$

$\therefore$ Q point = $[I_{CQ} = 2.28\ mA \ \& \ V_{CEQ} = 8.290\ V]$

Stability factor $S_{ICO} = \dfrac{1+\beta}{1+\beta \frac{R_E}{R_B + R_E}}$

$$= 9.372.$$

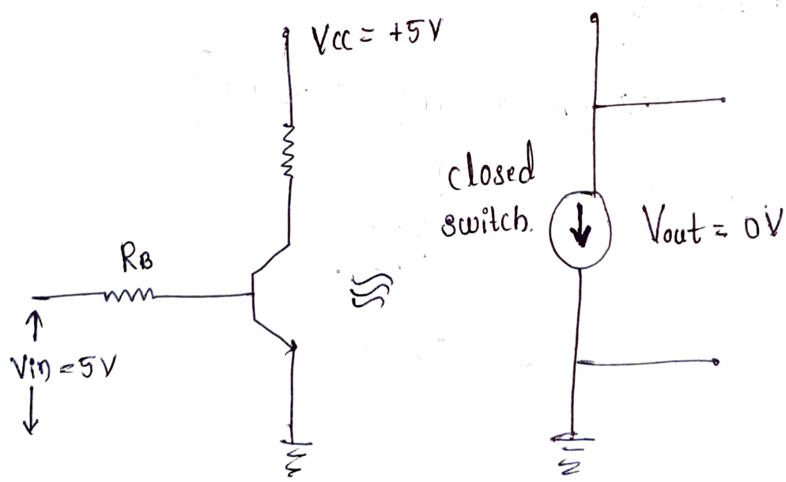
***

Transistor Biasing ckts

(M) Imp. for CUE

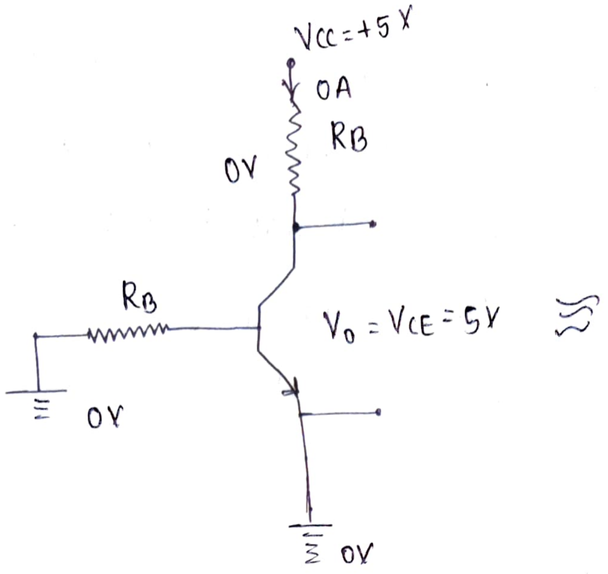
Transistor Switching ckts :—

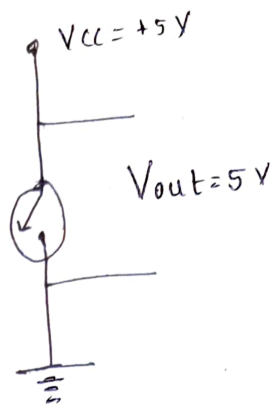
To operate transistor as a switch it is to be operated 2 region mainly. cut off and saturation. cutoff region both junction of transistor are reverse biased and only reverse current flow. This current is very small and practically neglected. No current flows through transistor in cut off region. Hence in this region transistor act as open switch. | In saturation region both the junctions are forword bias. the voltage dc drops to very small Value 0.2V to 0.3V. This is denoted as $V_{CE(sat)}$. In saturation Condn collector current is large and is only controlled by External resistance in collector circuit R_C practically $V_{CE(sat)}$ Can be neglected as it in very small hence V_{CE} (i.e output voltage) is '0' in saturation region. Thus the transistor act as closed Switch. Thus by driving transistor in saturation region & cutoff region it can be viewed as a switch. it is shown in fig. below.



Saturation region When $I_B \geq \frac{I_{C(sat)}}{\beta_{dc}}$

Transistor acting as a closed switch.



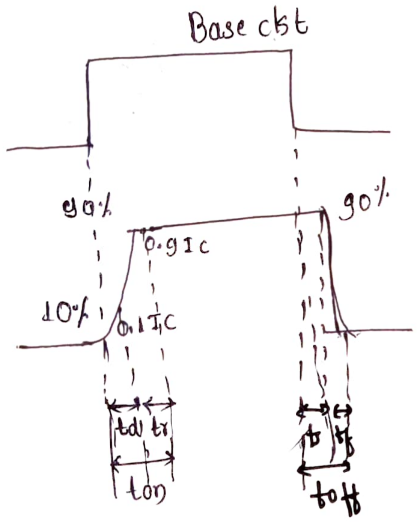


Cut off region

When $I_B = 0$

The transistor is acts as open switch.

Switching charecteristics



$t_{ON} = t_d + t_r$.

$t_{off} = t_s + t_f$

When the base current is applied transistor does not switch on immidiatly. This is because of the junction capacitance & transmision time of the $\bar{e}$ across junction. The time between application of the input pulse and the commensement of collector current flow in termal as delay time (t_d) and the time required for I_c to reach 90% of its maximum level is called rise level t_r. Thus the turn ON term is the sum of t_d & t_r i.e

$t_{ON} = t_d + t_r$.

Similarly when input current I_B is switched of I_c does not go to zero level immediately. it goes zero level after turn off the time which is the sum of storage time t_s & fall time t_f. The fall time is the time required for I_c to go from 90% to 10% of its maximum level.

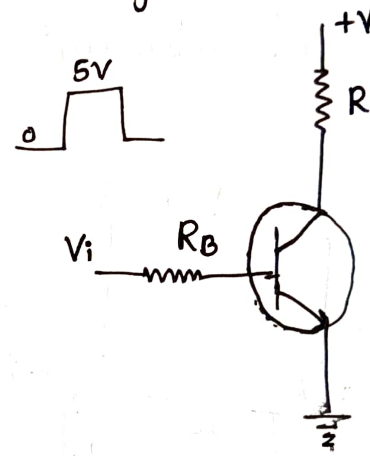
Problems

1] The ckt shown in fig. uses a silicon ~~wi~~ transistor having $\beta_{dc} = 100$, $R_c = 1\,k\Omega$, & $V_{cc} = 5V$ find the value of R_B which just barely saturates the transistor when the input voltage is +5 V.

→ $V_{cc} = 5V$

$\beta_{dc} = 100$

$R_c = 1\,k\Omega$



To drive the transistor to saturation region

$$I_B > \frac{I_{C(sat)}}{\beta_{dc}}$$

Voltage eqn at the collector side

$$V_{cc} = I_C R_C + V_{CE(sat)}$$

Assuming $V_{CE(sat)} = 0.2V$

$$I_C = \frac{V_{cc} - V_{CE(sat)}}{R_C}$$

$$= \frac{5 - 0.2}{1 \times 10^3} = 4.8 \times 10^{-3}$$

$$\boxed{I_{C(sat)} = 4.8\,mA.}$$

$\therefore I_B > \frac{4.8 \times 10^{-3}}{100}$

$I_B > 48 \mu A$

Now to find R_B we will write a voltage eqn to base ckt

$V_i = I_B R_B + V_{BE}$

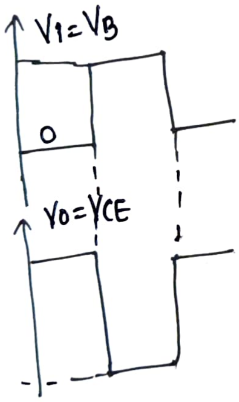
$R_B = \frac{V_i - V_{BE}}{I_B} = \frac{5 - 0.7}{48 \times 10^{-6}} = 89.5 \, k\Omega$

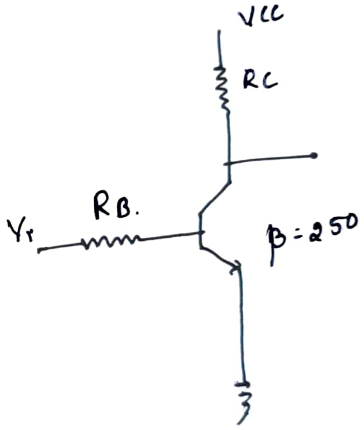
$\boxed{R_B = 89.5 \, k\Omega}$

Hence to drive transistor into sat region, R_B must be less than $89.5 \, k\Omega$.

2] Design a transistor inverter of $V_{cc} = 10V$, $I_{c(sat)} = 10mA$ & $\beta = 250$. Assume input to be pulse of 10V.

→





$V_{CC} = 10V$

$I_{c(sat)} = 10mA$

$\beta = 250.$

$R_C = \frac{V_{CC}}{I_{C(sat)}}$

$I_B = \frac{I_{C(sat)}}{\beta} = \frac{10 \times 10^{-3}}{250} = 40 \mu A.$

$R_B = \frac{V_i - V_{BE}}{I_{BE}} = 232.5 \, k\Omega.$

$R_B < 232.5 \, k\Omega$ & $I_B > 40 \mu A.$