LECTURE 6/11/2020

METHODS OF TRANSISTOR BIASING

(1) BASE RESISTOR BIASING / FIXED BIAS / BASE BIAS

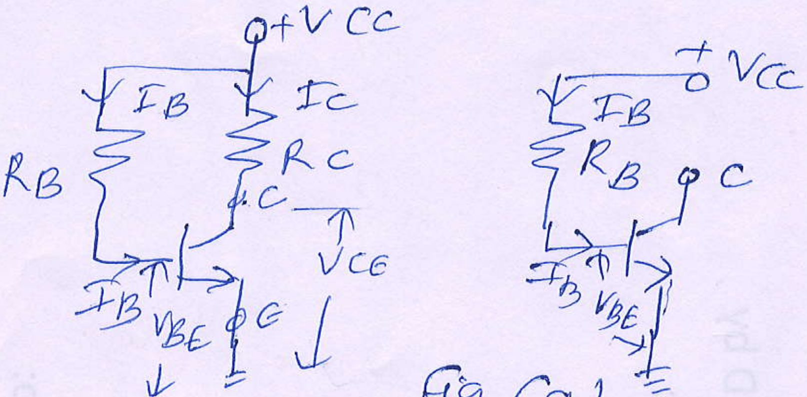


Fig (a)

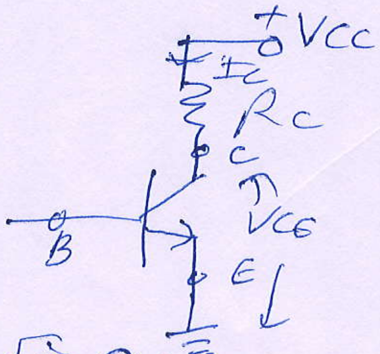


Fig (b)

Construction: A high resistance R_B is connected between +ve terminal of V_{CC} and B of transistor. The B-E junction is forward biased because B is +ve w.r.t. E.

circuit analysis

Refer fig(a) (a) Input section;

$V_{CC} = I_B R_B + V_{BE}$ (applying Kirchoff's Voltage law)

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

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

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

Since V_{CC} & V_{BE} have fixed values the selection of R_B fixes the value of I_B

$$I_C = B \frac{(V_{CC} - V_{BE})}{R_B}$$

$$\simeq B \frac{V_{CC}}{R_B} \quad (2) \qquad V_{BE} << V_{CC}$$

$\therefore V_{BE}$ can be

As $R_B = \frac{V_{CC}}{I_B}$ As I_B is fixed by (2) operating conditions therefore this method is also called fixed biasing method.

Refer fig(b) (b) Output Section.

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

$$\therefore V_{CE} = V_{CC} - I_C R_C \quad (3)$$

Q point (Operating point)

$$I_C = \frac{V_{CC}}{\beta / R_B}, \quad V_{CE} = V_{CC} - I_C R_C.$$

Stability factor

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

In this biasing method I_B is independent of I_C $\therefore \frac{dI_B}{dI_C} = 0$.

$$\therefore S = \beta + 1$$

As the value of S is high $\therefore$ poor thermal stability

NOTE: I_C & V_{CE} depend on β. But β is strongly dependent on temperature. It means I_C & V_{CE} will vary with β. Q point will shift. $\therefore$ Not used in amplifier circuits. This biasing is used in digital circuits where transistor is used as a switch between saturation and cut-off ~~points~~ regions

While designing following consideration should be taken into account. ③

According to equation ③ Vcc provides the voltage across Rc & also across C-E terminals ∴ $I_C R_C$ can never be more than Vcc

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

If $I_C = \frac{V_{CC}}{R_C}$ then Q point lies in the saturation region.

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

Advantages

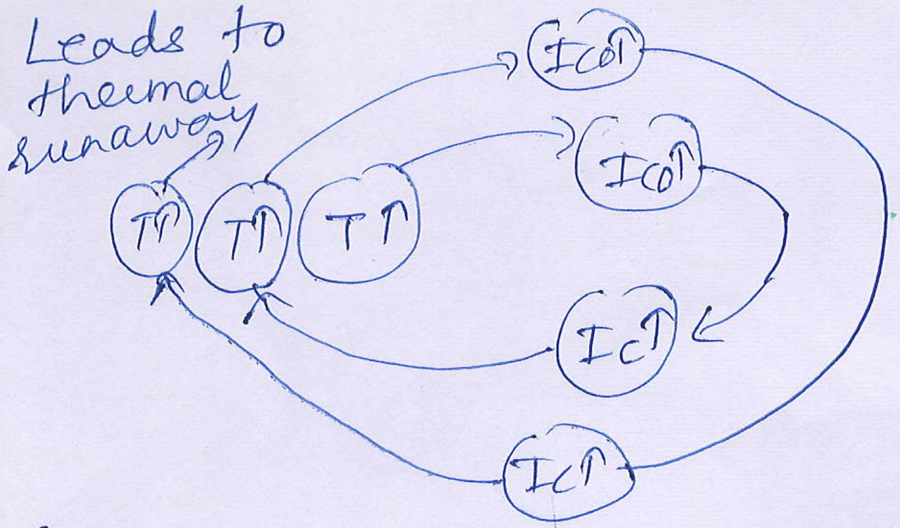
① Simple having very few components

② Very easy to fix Q point anywhere in the active region by changing value of RB providing maximum flexibility in design

Disadvantages:

(1) With rise in temperature a cumulative action takes place and I_C goes on increasing. The circuit provides no check on the increase in I_C.

Therefore Q point is not stable



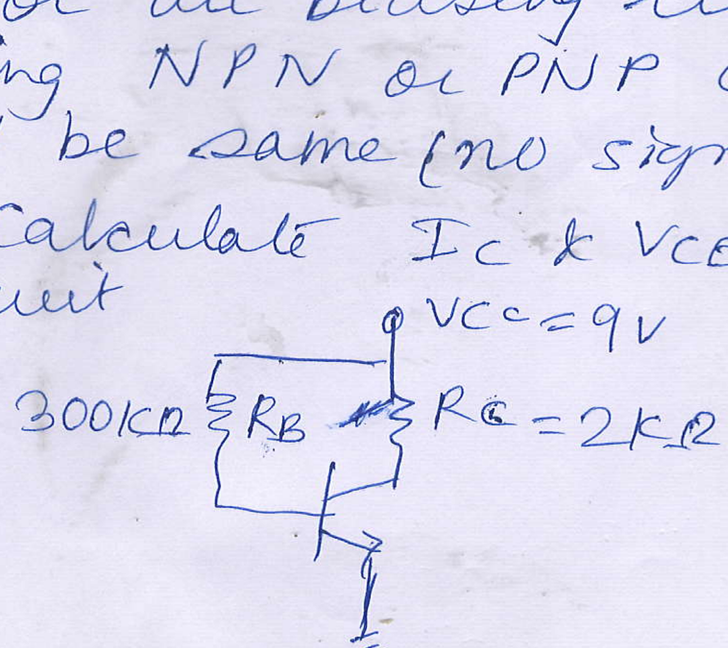
(2) Since $I_C = \beta I_B$, I_C is solely dependent on β. ∴ when a transistor is replaced by another with different values of β, Q point will shift. The stabilization of Q point is very poor.

I will solve some problems for you and will give problems for you to solve in your assignment copy. Answers for homework will be given in next lecture.

Point to remember

For all biasing circuits whether using NPN or PNP calculations will be same (no sign change)

(1) Calculate I_C & V_{CE} for the circuit



(5)

$$I_C = \frac{V_{CC}}{R_B} \times \beta = \frac{9}{\cancel{300}\,100 \times 10^3} \times 50$$

$$= 150 \times 10^{-5} A = 1.5 \times 10^{-3} A$$

$$= 1.5\, mA.$$

Check if I_C is less than $I_{C(sat)}$

$$I_{C(sat)} = \frac{V_{CC}}{R_C} = \frac{9}{2 \times 10^3} = 4.5\, mA.$$

$\therefore$ The transistor is not in saturation as $I_C < I_{C(sat)}$.

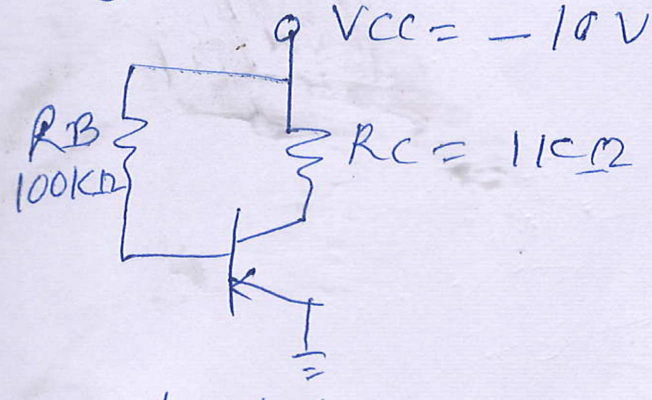
$$V_{CE} = V_{CC} - I_C R_C$$

$$= 9 - 1.5 \times 10^{-3} \times 2 \times 10^3$$

$$= 9 - 3 = 6V.$$

Ans $I_C = 1.5\, mA$, $V_{CE} = 6V$.

(2) Calculate the coordinates of the operating point as fixed in the circuit Given $R_C = 1K\Omega$, $R_B = 100 K\Omega$. If the transistor is replaced by another transistor, determine the Q point β changes from 60 to 150.



First calculate $I_{C(sat)}$

$$I_{C(sat)} = \frac{V_{CC}}{R_C} = \frac{10}{1 \times 10^3} = 10\, mA.$$

(i) $\beta = 60$

$$I_C = \beta \frac{V_{CC}}{R_B} = \frac{60 \times 10}{100 \times 10^3} = 6\ mA.$$

As $I_C < I_C(sat)$, the transistor is not in saturation.

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

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

$$= 10 - 6 = 4V.$$

Co-ordinates of Q point

$I_C = 6\ mA$, $V_{CE} = 4V$

(ii) $\beta = 150$

$$I_C = \beta \frac{V_{CC}}{R_B} = 150 \times \frac{10}{100 \times 10^3}$$

$I_C = 15\ mA$.

$I_C > I_C(sat)$

∴ The transistor is in saturation

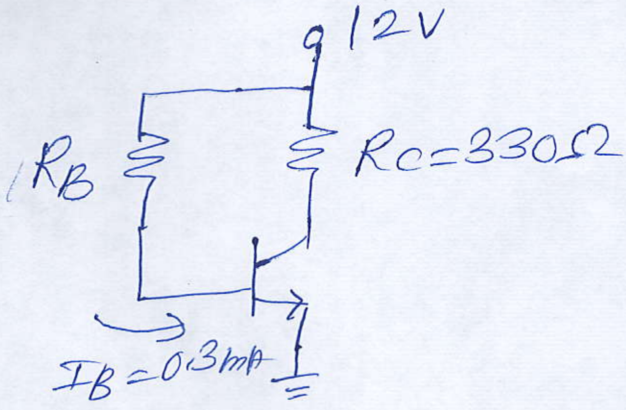
$I_C = I_C(sat) = 10\ mA.$

$V_{CE} = 0$

Co-ordinates of Q point are

$I_C = 10\ mA$ and $V_{CE} = 0$.

(3) Determine the value of R_B ~~and~~ V_{CE} & stability factor for a fixed bias circuit Given $V_{CC} = 12V$, $R_C = 330\Omega$, $I_B = 0.3\ mA$, $\beta = 100$



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

$$\therefore \quad R_B = \frac{V_{CC}}{I_B} = \frac{12}{0.3 \times 10^{-3}} = 40\ K\Omega$$

$$V_{CE} = V_{CC} - I_C R_C$$
$$= 12 - (100 \times 0.3 \times 10^{-3}) \times 330$$
$$= 12 - 9.9 = 2.1V$$

$$S = 1 + \beta = 1 + 100 = 101$$

Ans $R_B = 40K\Omega$, $V_{CE} = 2.1V$
& $S = 101$

Assignment problems

(1) Calculate the value of R_C & R_B if the operating point is to be fixed at $V_{CE} = 7V$, $I_C = 5mA$. Given $V_{CC} = 12V$, $\beta_{dc} = 100$

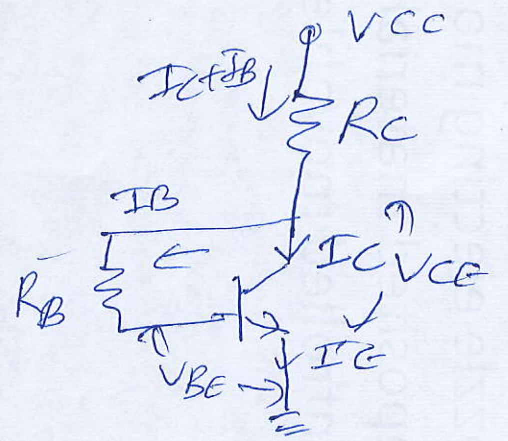
(2) A PNP transistor of $\beta = 200$ is used in the circuit. A d.c. supply of 9V and R_C of $1.5K\Omega$ are used. The operating point is to be fixed at $I_C = 2mA$. Calculate the value of RB and the voltage V_{CE}

Draw the circuit diagram

(3) A PNP transistor with $\beta = 100$, $V_{BE} = 200\ mV$, $V_{CC} = 15\ V$, $R_C = 5\ k\Omega$, $R_B = 790\ k\Omega$. Compute the Q point. Draw the relevant circuit diagram

LECTURE ~~6/11/2020~~ (1)

2) COLLECTOR FEEDBACK BIAS / COLLECTOR TO BASE BIAS / BASE BIAS WITH COLLECTOR FEEDBACK



Note: In this circuit RB is connected to C and not to Vcc. Therefore current through Rc is $I_C + I_B$.

P. Principle on which this circuit is designed

If the I_C tends to increase (either as a result of rise in temperature or as a result of transistor being replaced by another of larger β), the d.c. voltage drop across Rc increases and consequently V_{CE} decreases. As a result, I_B also reduces. This will tend to compensate for the original increase. This compensation is never exact.

Input section:

Applying KVL to input side.

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

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

Putting $I_C = \beta I_B$

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

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

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

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

$$I_C = \beta I_B$$

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

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

As $V_{BE} << V_{CC}$

$$\therefore I_C = \frac{V_{CC}}{R_C + \frac{R_B}{\beta}} \quad \ldots (2)$$

Output section:

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

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

As $I_B << I_C$

$$\therefore V_{CE} = V_{CC} - I_C R_C \quad - (3)$$

$\therefore$ Co-ordinates of Q point are

$$I_C = \frac{V_{CC}}{R_C + \frac{R_B}{\beta}}, \quad V_{CE} = V_{CC} - I_C R_C.$$

Rewriting the equations for input section. (3)

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

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

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

$$I_B = \frac{V_{CE} - V_{BE}}{R_C + R_B} \quad (4)$$

Let us test the stability of this circuit.

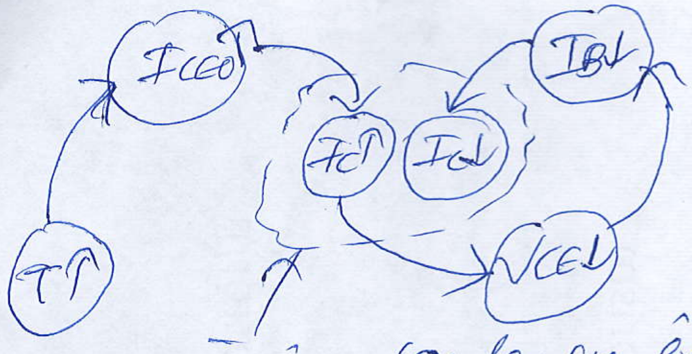
(i) EFFECT OF TEMPERATURE

If temperature increases, I_{CEO} and β increases ~~as~~ which in turn increases I_C because $I_C = \beta I_B + I_{CEO}$

Now from equation (4) as I_C increases V_{CE} decreases as $V_{CE} = V_{CC} - I_C R_C$

A reduced V_{CE} causes decrease in I_B which in turn reduces the original increase in I_C as $I_C = \beta I_B$.

Thus a mechanism exists in the circuit because of which the I_C is not allowed to increase rapidly. There is a tendency in the circuit to stabilize the operating point. (It does not provide exact compensation)



Voltage feedback: The resistor RB connects the collector (O/P) with the Base (input). This means that a feedback exists in the circuit. IB is dependent on V_{CE} & this dependence is such as to nullify the changes in I_B.

This circuit is also called as a voltage feedback circuit.

(2) EFFECT OF CHANGE IN B.

The shift in operating point will not be as much as it occurs for fixed bias ~~circuit~~ circuit when the transistor is replaced by another transistor having a different value of B. $\left[I_C = \frac{V_{CC}}{R_C + R_B/\beta} \right]$

WHY COLLECTOR FEEDBACK CIRCUIT IS NOT USED OFTEN

This circuit has a tendency to stabilize Q point against temperature and B variation but this circuit is

~~not~~ used much.

The resistor R_B not only provides a d.c. feedback for stabilization of Q point but also causes a.c. feedback which reduces the voltage gain of the amplifier. This is not desirable because the main aim of the circuit was to amplify a.c. signals properly

Stability factor (Derivation)

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

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

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

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

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

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

differentiating w.r.t. I_C

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

$$S = \frac{1+B}{1 - B\frac{dI_B}{dI_C}} = \frac{1+B}{1 - B \times -\frac{R_C}{R_C + R_B}}$$

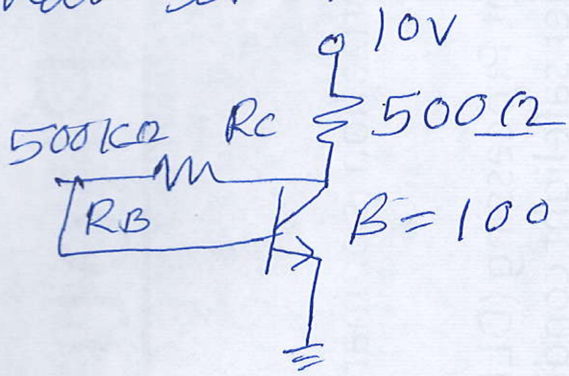
$$= \frac{1+B}{1 + B\frac{R_C}{R_C + R_B}}$$

S is less than $1+\beta$

Therefore this circuit is certainly an improvement over fixed bias circuit.

Solved problems.

(1) What is the value of I_C & V_{CE}.



$$I_C = \frac{V_{CC}}{R_C + \frac{R_B}{\beta}} = \frac{10}{500 + \frac{500\times10^3}{100}}$$

$$= 1.8 \text{ mA}.$$

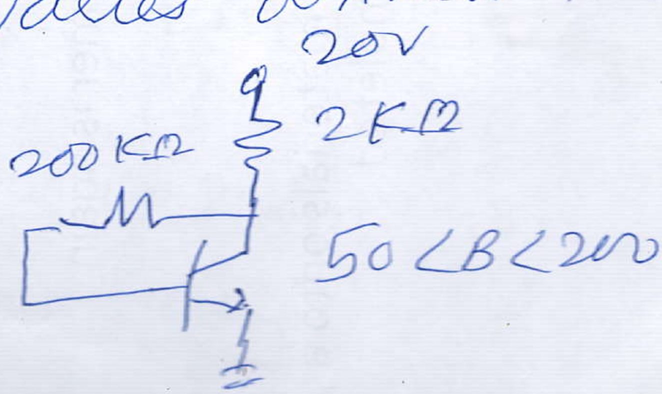
$$V_{CE} = V_{CC} - I_C R_C$$

$$= 10 - 1.8\times10^{-3}\times500$$

$$= 10 - 0.9 = 9.1 \text{ V}$$

Ans $I_C = 1.8$ mA, $V_{CE} = 9.V$

(2) Calculate the min. & max. I_C if β of the transistor varies within the limits indicated.



c(i) $\beta = 50$

$$I_C = \frac{V_{CC}}{R_C + \frac{R_B}{\beta}} = \frac{20}{2000 + \frac{200\times10^3}{50}}$$

$= 3.33\ mA.$

c(ii) $\beta = 200$

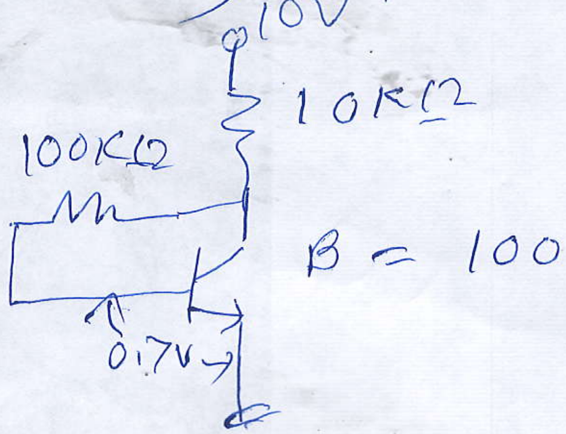
$$I_C = \frac{20}{2000 + \frac{200\times10^3}{200}}$$

$= 6.66\ mA.$

(Note: when β is increased 4 times, ~~IB is halved and~~ I_C ~~becom~~ becomes doubled, whereas in fixed bias circuit if β had increased 4 times, I_C would have increased 4 times)

(3) Calculate the Q point values. Draw a load line and plot Q point on it, Assume $V_{BE} = 0.7V$, $\beta = 100$

(Note: As V_{BE} is given it is taken into calculation)



$$I_C = \frac{V_{CC}-V_{BE}}{R_C+\frac{R_B}{\beta}} = \frac{10-0.7}{10\times10^3+\frac{100\times10^3}{100}}$$

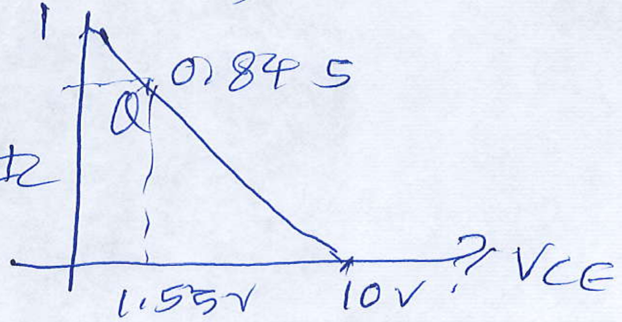
$$= 0.845\ mA$$

$$V_{CE} = V_{CC} - I_C R_C = 10 - 0.845\times10^{-3}\times10\times10^3$$

$$= 10 - 8.45 \doteq 1.55V$$

$$I_C(sat) = \cancel{V_{CC}=10V}\ \frac{V_{CC}}{R_C} = \frac{10}{10\times10^3} = 1mA$$

$$V_{CE}(cut\text{-}off) = V_{CC} = 10V$$



Assignment Problems (Collector feedback bias

(1) Determine the d.c. bias currents and voltage & stability factor. Assume $V_{BE} = 0.7V$. Given $V_{CC} = 3V$, $R_C = 1.8k\Omega$, $R_B = 33k\Omega$, $\beta = 90$

(2) Select the value of R_B. Set up the biasing condition such that $V_{CE} = 0.5V_{CC}$. Given $V_{CC} = 30V$, $R_C = 5k\Omega$, $\beta = 40$.

(3) Calculate the biasing point. Assume $V_{BE} = 0.7V$. Given $V_{CC} = 15V$, $R_B = 215k\Omega$, $R_C = 1k\Omega$ and $\beta = 100$. Calculate the new operating point if β is changed to 300.