

Methods of Transistor Biasing -

(from one source of supply V_{CC})

- (i) base resistor method or fixed bias method
- (ii) biasing with feedback resistor
- (iii) self bias or voltage divider bias
- (iv) bias circuit with emitter resistor

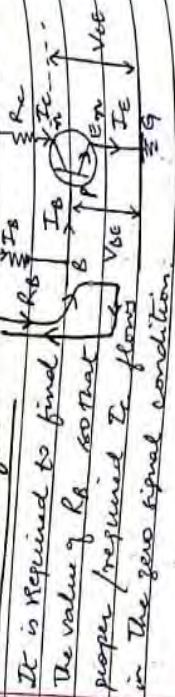
{ In all these methods base current I_B and hence I_C is obtained from V_{CC} in zero signal condition }

(i) BASE RESISTOR METHOD -

In this method, high resistance R_B ($\sim 100k\Omega$) is connected b/w base & +ve end of supply for n-p-n Transistor (or b/w base & -ve end of supply for p-n-p).

Here, zero signal base current = provided by V_{CC} & flows through R_B . As base is +ve w.r.t. emitter, i.e. B-E junction remain forward biased.

Circuit Analysis -



It is required to find the value of R_B so that proper/preferred I_C flows in the zero signal condition.

If $I_C =$ required zero signal collector current

$$I_C = \beta I_B$$

Consider circuit ABEGA, Apply Kirchhoff's law -

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

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

With V_{CC} and I_B known and V_{BE} as obtained from BJT manual, R_B can be evaluated.

If $V_{BE} \ll V_{CC} \Rightarrow R_B \approx \frac{V_{CC}}{I_B}$; R_B found directly.

As V_{CC} is fixed known quantity and I_B is chosen at some suitable value ; this method is also called fixed bias method.

ADVANTAGES -

No loading of the source by the biasing circuit since no resistor is employed across base-emitter junction.

DIS ADVANTAGES

- (i) Poor stability, gain
- (ii) High β (stability factor) \Rightarrow Strong chances of thermal runaway.

BIASING WITH FEEDBACK RESISTOR -

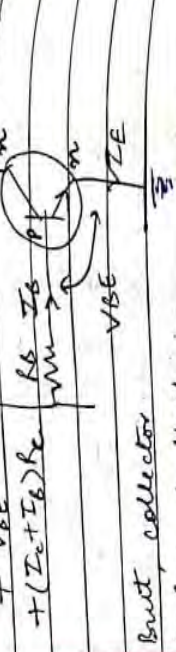
circuit is a way to provide some degree of stabilization to the amplifier operating point.

Circuit Analysis -

In this case,

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

$$+ V_{BE} + (I_C + I_B) R_C$$



built, collector

to base feedback

circuit seldom used even after it has tendency to stabilize the operating point (against temp & β). It is because resistor

R_B not only provides a DC feedback for stabilization of Q, but also causes AC feedback. This causes reduces voltage gain of amplifier. \therefore NOT DESIRED

(iii)

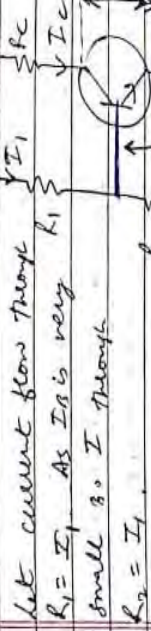
VOLTAGE DIVIDER BIAS METHOD -

Most widely used method for providing biasing & stabilization to a transistor. Here two resistances R_1 & R_2 are connected across the supply voltage V_{CC} to provide biasing.

R_E = provides stabilization.

Voltage drop across $R_2 \rightarrow$ forward biased β -E junction. This causes I_B and hence I_C flow in zero signal condition.

Circuit Analysis -



Let current flow through $R_1 = I_1$. As I_B is very small $\therefore I_1$ through $R_2 = I_2$

\therefore IC Assumed $I_2 \approx I_1$ where $I_2 = I_1 - I_B$ & $I_B =$ small }

Then for collector current $I_C =$

$$I_1 = \frac{V_{CC}}{R_1 + R_2} \text{ and } V_2 = \left(\frac{V_{CC}}{R_1 + R_2} \right) \times R_2 = I_1 R_2$$

Apply Kirchhoff's law to the base circuit -

$$V_2 = V_{BE} + V_E \Rightarrow V_2 = V_{BE} + I_E R_E$$

$$\therefore I_E = \frac{V_2 - V_{BE}}{R_E}$$

Since $I_E \approx I_C$ (I_B is small)

$$\therefore I_C = \frac{V_2 - V_{BE}}{R_E} \quad \text{--- (1)}$$

\therefore Here, I_C does not depend upon β . Though it depends on V_{BE} . But $V_{BE} \ll V_2$ so that I_C is practically independent of $V_{BE} \Rightarrow I_C$ is almost independent of transistor parameters \therefore hence good stabilization is ensured. **POTENTIAL DIVIDER BIAS** is a universal method for Biarray BJT.

Collector-emitter voltage -

V_{CE} can be obtained by applying K.V.L to the collector side -

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

$$= I_C R_C + V_{CE} + I_C R_E \quad (I_E = I_C)$$

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

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

TRV - DO as many numericals as possible for the finer methods of Transistor Biasing.

Thermal instability of β_{in} -

The collector current in a BJT changes rapidly when -

i. Temp changes

ii) Transistor replaced by another of the same type (due to small variations in transistor parameters such as β , V_{BE} etc.)
ie. inherent variation of Transistor parameters.

So when the Temp. changes or Transistor is replaced, the operating point (ie. zero signal I_C and V_{CE}) also changes. However, for faithful amplification it is essential that operating pt. remains fixed. This necessitates to make operating point independent of these variations - This is called Stabilization.

The process of making operating pt. independent of temp changes or variations in transistor parameters is called STABILIZATION.

STABILIZATION of operating pt. is necessary due to the following reasons -

- i) Temp dependence of I_C
- ii) Inherent/individual variation
- iii) Thermal runaway.

PRACTICE PROBLEMS

1. Fixed Bias or Base resistor method

Example 6.27 In the fixed bias compensation method (refer to Fig. 6.26), a silicon transistor with $\beta = 100$ is used. $V_{CC} = 6$ V, $R_C = 3$ k Ω , $R_B = 530$ k Ω . Draw the d.c. load line and determine the operating point. What is the stability factor?

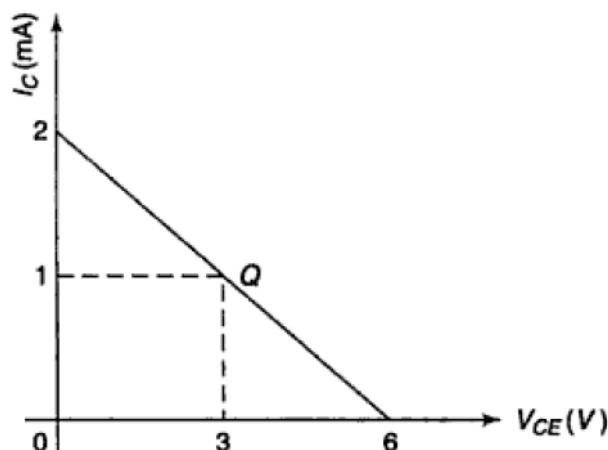


Fig. 6.27 DC load line

Solution:

(i) **DC load line:**

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

When $I_C = 0$, $V_{CE} = V_{CC} = 6$ V

When $V_{CE} = 0$, $I_C = \frac{V_{CC}}{R_C} = \frac{6}{3 \times 10^3} = 2$ mA

(ii) **Operating point Q:**

For silicon transistor, $V_{BE} = 0.7$ V
 $V_{CC} = I_B R_B + V_{BE}$

Therefore, $I_B = \frac{V_{CC} - V_{BE}}{R_B} = \frac{6 - 0.7}{530 \times 10^3} = 10$ μ A

Therefore, $I_C = \beta I_B = 100 \times 10 \times 10^{-6} = 1$ mA
 $V_{CE} = V_{CC} - I_C R_C = 6 - 1 \times 10^{-3} \times 3 \times 10^3 = 3$ V

Therefore operating point is $V_{CEQ} = 3$ V and $I_{CQ} = 1$ mA.

(iii) **Stability factor:** $S = 1 + \beta = 1 + 100 = 101$

2. Voltage divider Bias

Example 6.30 In a CE germanium transistor amplifier circuit, the bias is provided by self bias, i.e., emitter resistor and potential divider arrangement (refer to Fig. 6.27). The various parameters are: $V_{CC} = 16$ V, $R_C = 3$ k Ω , $R_E = 2$ k Ω , $R_1 = 56$ k Ω , $R_2 = 20$ k Ω and $\alpha = 0.985$. Determine (a) the coordinates of the operating point, and (b) the stability factor S .

Solution: For a germanium transistor, $V_{BE} = 0.3$ V. As $\alpha = 0.985$,

$$\beta = \frac{\alpha}{1 - \alpha} = \frac{0.985}{1 - 0.985} = 66$$

(a) *To find the coordinates of the operating point*

Referring to Fig. 6.29, we have

Thevenin's voltage,
$$V_T = \frac{R_2}{R_1 + R_2} V_{CC}$$

$$= \frac{20 \times 10^3}{76 \times 10^3} \times 16 = 4.21 \text{ V}$$

Thevenin's resistance,
$$R_B = \frac{R_1 R_2}{R_1 + R_2} = \frac{20 \times 10^3 \times 56 \times 10^3}{76 \times 10^3}$$

$$= 14.737 \text{ k}\Omega$$

The loop equation around the base circuit is

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

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

$$4.21 = \frac{I_C}{66} \times 14.737 \times 10^3 + 0.3 + I_C \left(\frac{1}{66} + 1 \right) \times 2 \times 10^3$$

$$3.91 = I_C [0.223 + 2.03] \times 10^3$$

Therefore,
$$I_C = \frac{3.91}{2.253 \times 10^3} = 1.73 \text{ mA}$$

Since I_B is very small, $I_C \approx I_E = 1.73$ mA

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

$$= V_{CC} - I_C [R_C + R_E] = 16 - 1.73 \times 10^{-3} \times 5 \times 10^3$$

$$= 7.35 \text{ V}$$

Therefore, the coordinates of the operating point are $I_C = 1.73$ mA and $V_{CE} = 7.35$ V.

(b) *To find the stability factor S*

$$\begin{aligned}
 S &= (1 + \beta) \frac{1 + \frac{R_B}{R_E}}{1 + \beta + \frac{R_B}{R_E}} \\
 &= (1 + 66) \frac{1 + \frac{14.737}{2}}{1 + 66 + \frac{14.737}{2}} \\
 &= 67 \times \frac{8.3685}{74.3685} = 7.537
 \end{aligned}$$

Example 6.31 A CE transistor amplifier with voltage divider bias circuit of Fig. 6.29 is designed to establish the quiescent point at $V_{CE} = 12$ V, $I_C = 2$ mA and stability factor ≤ 5.1 . If $V_{CC} = 24$ V, $V_{BE} = 0.7$ V, $\beta = 50$ and $R_C = 4.7$ k Ω determine the values of resistors R_E , R_1 and R_2 .

Solution:

(a) To determine R_E

$$\begin{aligned}
 V_{CE} &= V_{CC} - I_C R_C - I_E R_E \\
 &= V_{CC} - I_C [R_C + R_E], \text{ since } I_C \approx I_E \\
 12 &= 24 - 2 \times 10^{-3} [4.7 \times 10^3 + R_E]
 \end{aligned}$$

Therefore, $R_E = 1.3$ k Ω

(b) To determine R_1 and R_2

$$\text{Stability factor, } S = \frac{1 + \beta}{1 + \beta \left(\frac{R_E}{R_E + R_B} \right)}, \quad \text{where } R_B = \frac{R_1 R_2}{(R_1 + R_2)}$$

$$5.1 = \frac{51}{1 + 50 \left(\frac{1.3 \times 10^3}{1.3 \times 10^3 + R_B} \right)}$$

i.e. $1 + 50 \left(\frac{1.3 \times 10^3}{1.3 \times 10^3 + R_B} \right) = \frac{51}{5.1} = 10$

Therefore, $\left(\frac{50 \times 1.3 \times 10^3}{1.3 \times 10^3 + R_B} \right) = 9$

$$1.3 \times 10^3 + R_B = \frac{50 \times 1.3 \times 10^3}{9} = 7.2 \text{ k}\Omega$$

$$R_B = 5.9 \text{ k}\Omega$$

Also, we know that for a good voltage divider, the value of resistor $R_2 = 0.1\beta R_E$

Therefore, $R_2 = 0.1 \times 50 \times 1.3 \times 10^3 = 6.5 \text{ k}\Omega$

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

$$5.9 \times 10^3 = \frac{R_1 \times 6.5 \times 10^3}{R_1 + 6.5 \times 10^3}$$

Simplifying, we get $R_1 = 64 \text{ k}\Omega$

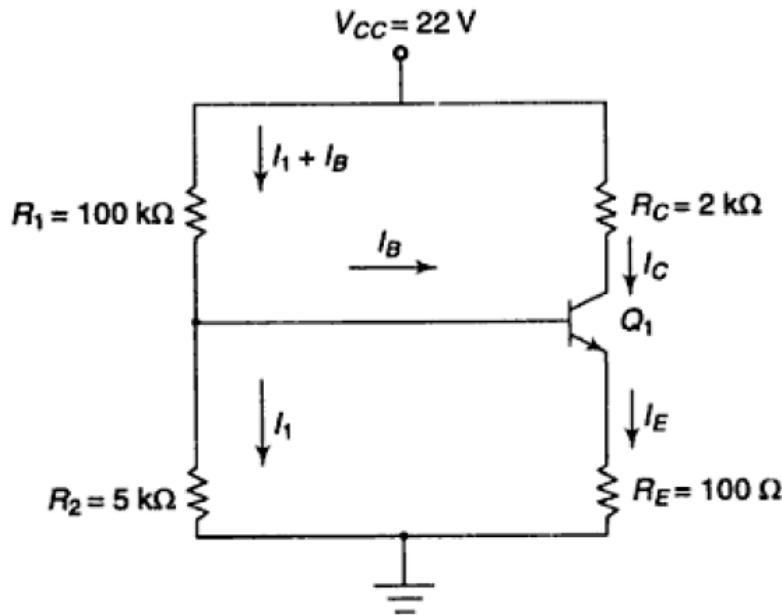


Fig. 6.31

$$I_E = I_C + I_B$$

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

Hence $V_{CC} = R_1 [I_1 + I_B] + V_{BE} + (1 + \beta) I_B R_E$

Substituting for I_1 from Eqn. (1), we get

$$V_{CC} = R_1 \left[\frac{V_{CC} - I_B R_1}{R_1 + R_2} + I_B \right] + V_{BE} + (1 + \beta) I_B R_E$$

$$V_{CC} = R_1 \left[\frac{V_{CC} + I_B R_2}{R_1 + R_2} \right] + V_{BE} + (1 + \beta) I_B R_E$$

Substituting for V_{CC} , R_1 , R_2 , V_{BE} , β and R_E

$$22 = 100 \times 10^3 \left[\frac{22 + I_B \times 5 \times 10^3}{(100 + 5) \times 10^3} \right] + 0.6 + (1 + 60) I_B \times 100$$

$$22 = 0.952 [22 + I_B \times 5 \times 10^3] + 0.6 + 6100 I_B$$

$$22 = 20.944 + 11,100 I_B + 0.6$$

$$I_B = 41.08 \mu\text{A}$$

$$I_C = \beta I_B = 60 \times 41.08 \times 10^{-6} = 2.46 \text{ mA}$$

Applying KVL to collector circuit, we get

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

Hence

$$\begin{aligned} V_{CE} &= V_{CC} - I_C R_C - (1 + \beta) I_B R_E \\ &= 22 - (2.46) \times 10^{-3} \times 2 \times 10^3 - (61) (41.08 \times 10^{-6}) (100) \\ &= 22 - 4.92 - 0.25 = 16.83 \text{ V} \end{aligned}$$