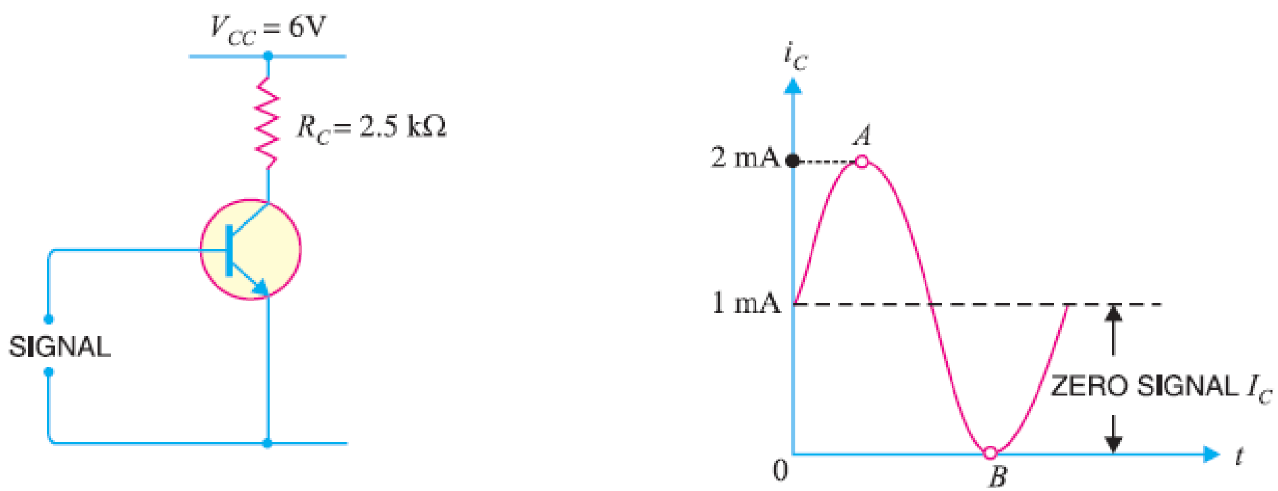
Solved Problems on Transistor Biasing

BASIC ELECTRONICS SOLVED PROBLEMS BY SASMITA JANUARY 9, 2020

Q1. An npn silicon transistor has VCC = 6 V and the collector load RC = 2.5 kΩ. Find : (i) The maximum collector current that can be allowed during the application of signal for faithful amplification. (ii) The minimum zero signal collector current required.

Solution :



(i) (ii)

Fig.1

silicon transistor.

∴ Max. voltage allowed across RC = 6 − 1 = 5 V

∴ Max. allowed collector current = 5 V/RC = 5 V/2.5 kΩ = 2 mA

Thus, the maximum collector current allowed during any part of the signal is 2 mA. If the collector current is allowed to rise above this value, VCE will fall below 1 V. Consequently, value of β will fall, resulting in unfaithful amplification.

(ii) During the negative peak of the signal, collector current can at the most be allowed to become zero. As the negative and positive half cycles of the signal are

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During the positive peak of the signal [point A in Fig. 1(ii)], iC = 1 + 1 = 2mA

And during the negative peak (point B), iC = 1 − 1 = 0 mA

Q2. A transistor employs a 4 kΩ load and VCC = 13V. What is the maximum input signal if β = 100 ? Given Vknee = 1V and a change of 1V in VBE causes a change of 5mA in collector current.

Solution :

- Conversion Rate Optimization (2)
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∴ Max. allowed voltage across RC = 13 − 1 = 12 V

∴ Max. allowed collector current, iC =12 V /RC = 12 V/ 4 KΩ = 3 mA

Maximum base current, iB = iC / β = 3 mA / 100 = 30 μA

Now Collector current / Base voltage (signal voltage) = 5 mA/V

∴ Base voltage (signal voltage) = Collector current / (5 mA/V)= 3 mA /(5 mA/V) = 600 mV

Q3. Fig. 2 (i) shows biasing with base resistor method. (i) Determine the collector current IC and collector-emitter voltage VCE . Neglect small base-emitter voltage. Given that β = 50. (ii) If RB in this circuit is changed to 50 kΩ, find the new operating point.

Solution :

- Oscilloscopes (2)
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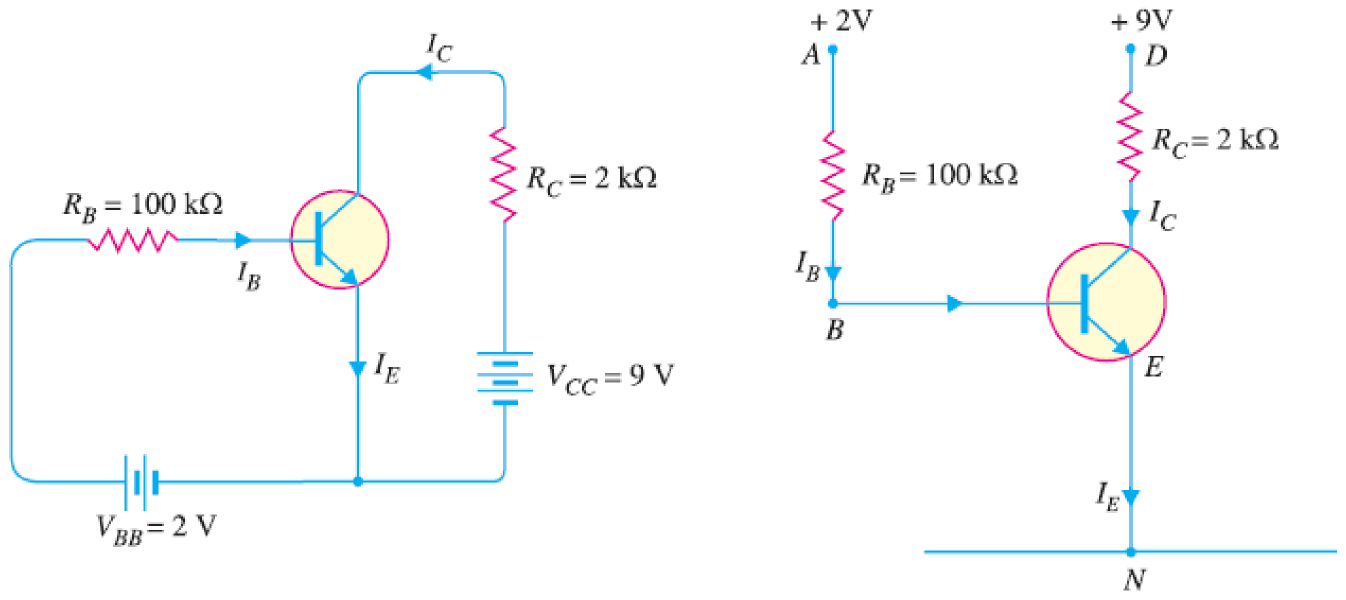


(i) (ii)

- Waveform coding techniques (2)
- Zener Diode (1)

In the circuit shown in Fig. 2 (i), biasing is provided by a battery VBB (= 2V) in the base circuit which is separate from the battery VCC (= 9V) used in the output circuit.

The same circuit is shown in a simplified way in Fig. 2 (ii). Here, we need show only the supply voltages, + 2V and +9V. It may be noted that negative terminals of the power supplies are grounded to get a complete path of current.

(i) Referring to Fig.2 (ii) and applying Kirchhoff 's voltage law to the circuit ABEN, we get,

$$I_B R_B + V_{BE} = 2\text{ V}$$

As V_{BE} is negligible,

$$\therefore \quad I_B = \frac{2\text{V}}{R_B} = \frac{2\text{V}}{100\text{ k}\Omega} = 20\ \mu\text{A}$$

$$\text{Collector current, } I_C = \beta I_B = 50 \times 20\ \mu\text{A} = 1000\ \mu\text{A} = \mathbf{1\ mA}$$

Applying Kirchhoff's voltage law to the circuit *DEN*, we get,

$$I_C R_C + V_{CE} = 9$$

or $$1\text{ mA} \times 2\text{ k}\Omega + V_{CE} = 9$$

or $$V_{CE} = 9 - 2 = \mathbf{7\ V}$$

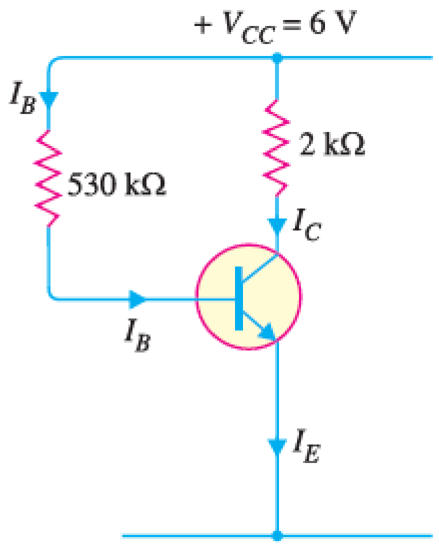
$\therefore$ Collector current, $I_C = \beta I_B = 50 \times 40 = 2000\ \mu A = 2\ mA$

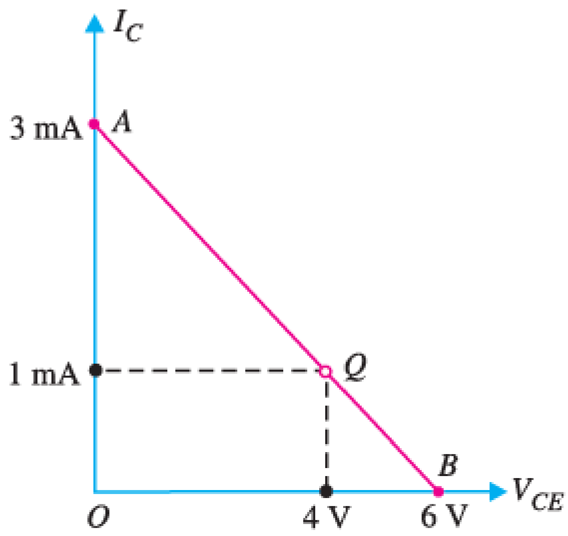
Collector-emitter voltage, $V_{CE} = V_{CC} - I_C R_C = 9 - 2\ mA \times 2\ k\Omega = 5\ V$

$\therefore$ New operating point is **5 V, 2 mA.**

Q4. Fig. 3 (i) shows that a silicon transistor with β = 100 is biased by base resistor method. Draw the d.c. load line and determine the operating point. What is the stability factor ?

Solution :





D.C. load line

Referring to Fig. 3 (i), VCE = VCC − ICRC

When IC = 0, VCE = VCC = 6 V. This locates the first point B (OB = 6V) of the load line on collector-emitter voltage axis as shown in Fig. 3 (ii).

When VCE = 0, IC = VCC/RC = 6V/2 kΩ = 3 mA.

This locates the second point A (OA = 3mA) of the load line on the collector current axis. By joining points A and B, d.c. load line AB is constructed as shown in Fig. 3(ii).

Operating point Q

As it is a silicon transistor, therefore, VBE = 0.7V. Referring to Fig. 3(i), it is clear that :

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

or

$$I_B = \frac{V_{CC} - V_{BE}}{R_B} = \frac{(6 - 0.7)\text{ V}}{530\text{ k}\Omega} = 10\ \mu\text{A}$$

Fig. 3 (ii) shows the operating point Q on the d.c. load line. Its co-ordinates are IC = 1mA and VCE = 4V.

$$\text{Stability factor} = \beta + 1 = 100 + 1 = 101$$

Q5. (i) A germanium transistor is to be operated at zero signal IC = 1mA. If the collector supply VCC = 12V, what is the value of RB in the base resistor method ? Take β = 100. (ii) If another transistor of the same batch with β = 50 is used, what will be the new value of zero signal IC for the same RB ?

Solution :

Given, $V_{CC} = 12$ V, $\beta = 100$

As it is a Ge transistor, therefore, $V_{BE} = 0.3$ V

(i) Zero signal $I_C = 1$ mA

$\therefore$ Zero signal $I_B = I_C/\beta = 1 \text{ mA}/100 = 0.01 \text{ mA}$

Using the relation, $V_{CC} = I_B R_B + V_{BE}$

$$\therefore \quad R_B = \frac{V_{CC} - V_{BE}}{I_B} = \frac{12 - 0.3}{0.01 \text{ mA}}$$

$$= 11.7 \text{ V}/0.01 \text{ mA} = \mathbf{1170\ k\Omega}$$

(ii) Now β = 50

Again using the relation, $V_{CC} = I_B R_B + V_{BE}$

$$\therefore \quad I_B = \frac{V_{CC} - V_{BE}}{R_B} = \frac{12 - 0.3}{1170 \text{ k}\Omega}$$

$$= 11.7 \text{ V}/1170 \text{ k}\Omega = 0.01 \text{ mA}$$

$\therefore$ Zero signal $I_C = \beta I_B = 50 \times 0.01 = \mathbf{0.5\ mA}$

Q6. Calculate the values of three currents in the circuit shown in Fig. 4.

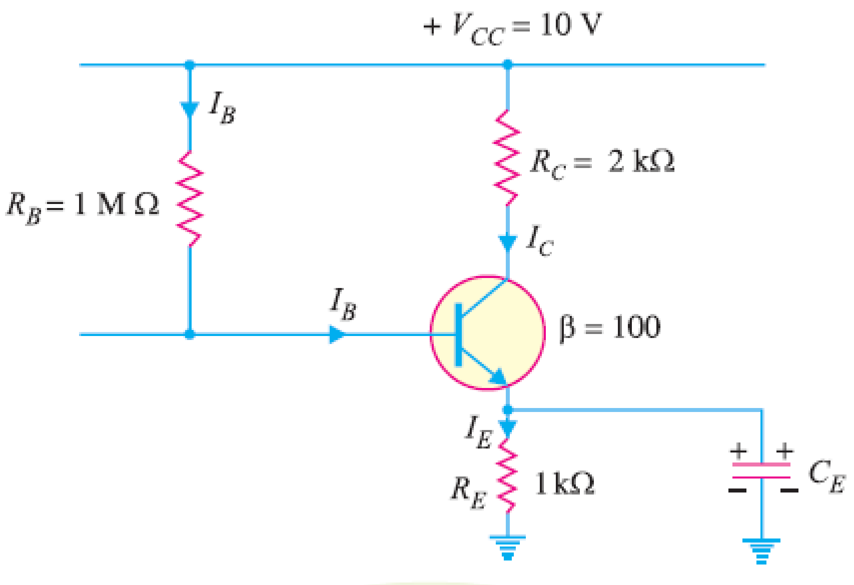


Fig. 4

Solution :

Applying Kirchhoff 's voltage law to the base side and taking resistances in kΩ and currents in mA, we have,

$$V_{CC} = I_B R_B + V_{BE} + I_E \times 1$$

or $$10 = 1000\, I_B + {}^*0 + (I_C + I_B)$$

or $$10 = 1000\, I_B + (\beta\, I_B + I_B)$$

or $$10 = 1000\, I_B + (100\, I_B + I_B)$$

or $$10 = 1101\, I_B$$

$$\therefore \quad I_B = 10/1101 = \mathbf{0.0091\ mA}$$

$$I_C = \beta\, I_B = 100 \times 0.0091 = \mathbf{0.91\ mA}$$

$$I_E = I_C + I_B = 0.91 + 0.0091 = \mathbf{0.919\ mA}$$

Q7. Design base resistor bias circuit for a CE amplifier such that operating point is VCE = 8V and IC = 2 mA. You are supplied with a fixed 15V d.c. supply and a silicon transistor with β = 100. Take base-emitter voltage VBE = 0.6V. Calculate also the value of load resistance that would be employed

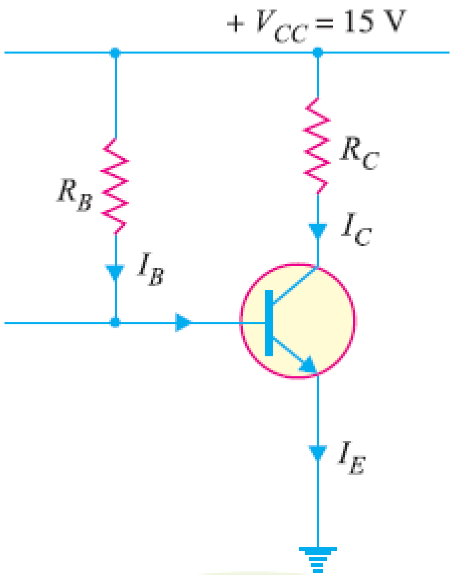


Fig. 5

$$V_{CC} = 15\text{ V} ;\ \beta = 100 ;\ V_{BE} = 0.6\text{V}$$

$$V_{CE} = 8\text{ V} ;\ I_C = 2\text{ mA};\ R_C = ?\ ;\ R_B = ?$$

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

or $$15\text{ V} = 8\text{ V} + 2\text{ mA} \times R_C$$

$\therefore$ $$R_C = \frac{(15 - 8)\text{ V}}{2\text{mA}} = \mathbf{3.5\ k\Omega}$$

$$I_B = I_C/\beta = 2/100 = 0.02\text{ mA}$$

Q8. A base bias circuit in Fig. 6 is subjected to an increase in temperature from 25°C to 75°C. If β = 100 at 25°C and 150 at 75°C, determine the percentage change in Q-point values (VCE and IC) over this temperature range. Neglect any change in VBE and the effects of any leakage current.

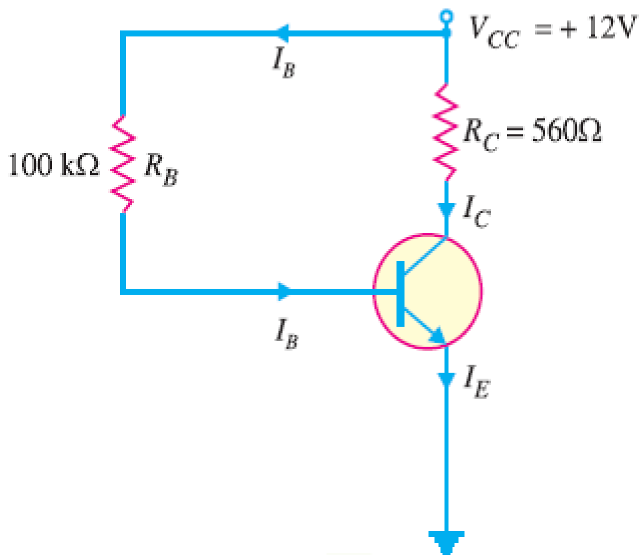


Fig 6

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

$$= \frac{12\ V - 0.7\ V}{100\ k\Omega} = 0.113 \text{ mA}$$

$$\therefore \quad I_C = \beta I_B = 100 \times 0.113 \text{ mA} = 11.3 \text{ mA}$$

and $\quad V_{CE} = V_{CC} - I_C R_C = 12\text{V} - (11.3 \text{ mA})(560\Omega) = 5.67\text{V}$

At 75 °C :

$$I_B = \frac{V_{CC} - V_{BE}}{R_B} = \frac{12\text{ V} - 0.7\text{ V}}{100\text{ k}\Omega} = 0.113 \text{ mA}$$

$$\therefore \quad I_C = \beta I_B = 150 \times 0.113 \text{ mA} = 17 \text{ mA}$$

and $\quad V_{CE} = V_{CC} - I_C R_C = 12\text{V} - (17 \text{ mA})(560\ \Omega) = 2.48\text{V}$

$$\text{\%age change in } I_C = \frac{I_{C\,(75°C)} - I_{C\,(25°C)}}{I_{C\,(25°C)}} \times 100$$

$$= \frac{17 \text{ mA} - 11.3 \text{ mA}}{11.3 \text{ mA}} \times 100 = 50\%\ (increase)$$

Note that I_C changes by the same percentage as β.

$$\text{\%age change in } V_{CE} = \frac{V_{CE\,(75°C)} - V_{CE\,(25°C)}}{V_{CE\,(25°C)}} \times 100$$

$$= \frac{2.48\text{V} - 5.67\text{V}}{5.67\text{V}} \times 100 = -56.3\%\ (decrease)$$

In addition to being affected by change in β, the Q-point is also affected by changes in VBE and ICBO in the base bias method.

(i) Effect of VBE :

The base-emitter-voltage VBE decreases with the increase in temperature (and vice-versa). The expression for IB in base bias method is given by ;

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

It is clear that decrease in VBE increases IB . This will shift the Q-point (IC = βIB and VCE = VCC – IC RC). The effect of change in VBE is negligible if VCC >> VBE (VCC atleast 10 times greater than VBE).

(ii) Effect of ICBO :

The reverse leakage current ICBO has the effect of decreasing the net base current and thus increasing the base voltage. It is because the flow of ICBO creates a voltage drop across RB that adds to the base voltage as shown in Fig. 7. Therefore, change in ICBO shifts the Q-point of the base bias circuit.

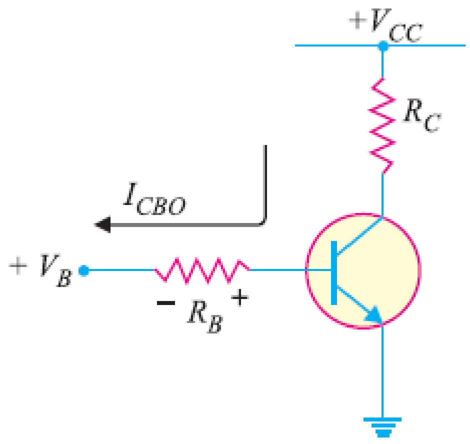


Fig. 7

However, in modern transistors, ICBO is usually less than 100 nA and its effect on the bias is negligible if VBB >> ICBO RB.

Q10. Fig. 8 (i) shows the base resistor transistor circuit. The device (i.e. transistor) has the characteristics shown in Fig. 8 (ii). Determine VCC, RC and RB .

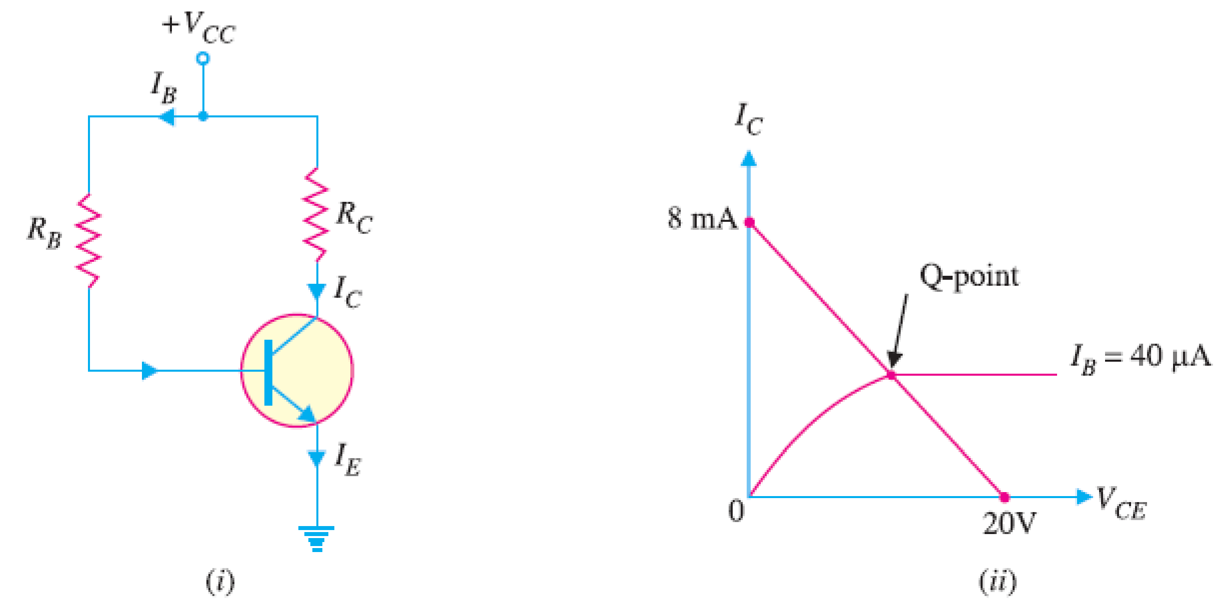


Fig. 8

Solution :

From the d.c load line, VCC = 20V.

$$\text{Max. } I_C = \frac{V_{CC}}{R_C} \text{ (when } V_{CE} = 0\text{V)}$$

$$\therefore \quad R_C = \frac{V_{CC}}{\text{Max. } I_C} = \frac{20\text{V}}{8\text{mA}} = 2.5 \text{ k}\Omega$$

Q11. What fault is indicated in (i) Fig. 9 (i) and (ii) Fig. 9 (ii) ?

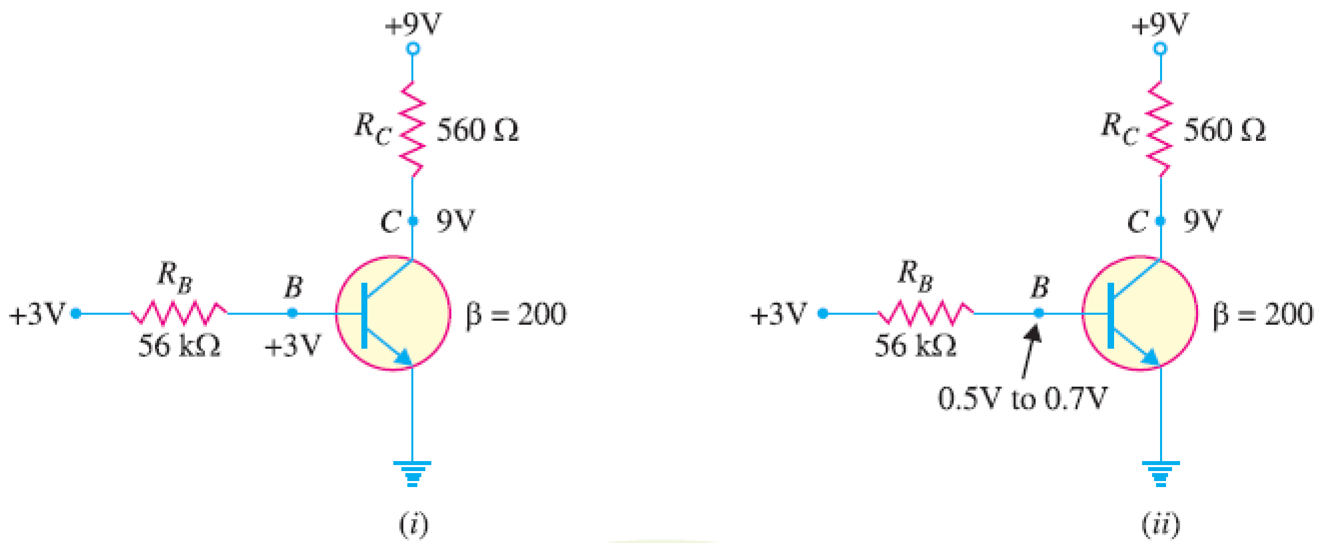


Fig. 9

Solution :

(i) The obvious fault in Fig. 9(i) is that the base is internally open. It is because 3V at the base and 9V at the collector mean that transistor is in cut-off state.

(ii) The obvious fault in Fig. 9 (ii) is that collector is internally open. The voltage at the base is correct. The voltage of 9V appears at the collector because the

Q12. For the emitter bias circuit shown in Fig. 10, find IE, IC, VC and VC and VCE for β= 85 and VBE = 0.7V.

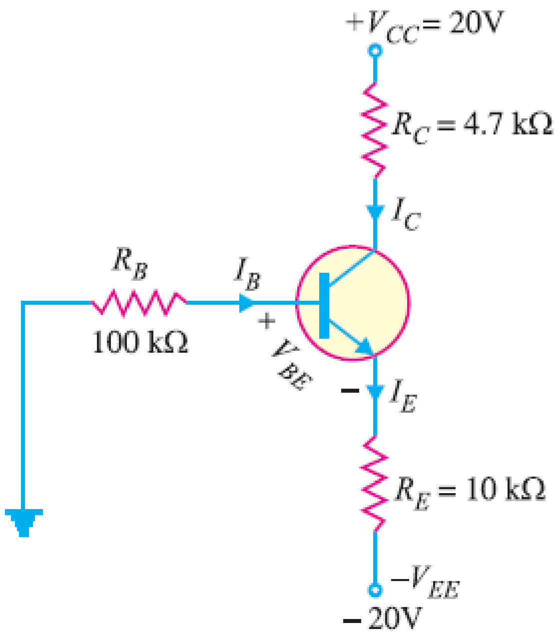


Fig. 10

Solution :

$$I_E \simeq I_C = \frac{V_{EE} - V_{BE}}{\dots} = \frac{20V - 0.7V}{\dots} = 1.73\ mA$$

Q13. Determine how much the Q-point in Fig. 11 will change over a temperature range where β increases from 85 to 100 and VBE ,decreases from 0.7V to 0.6V.

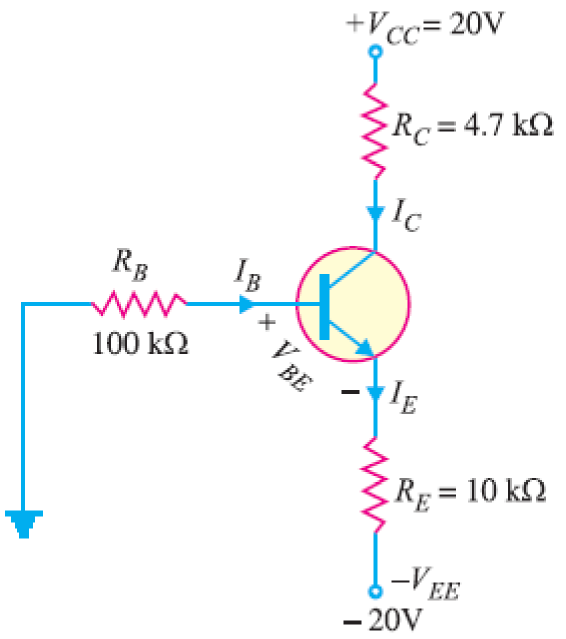


Fig. 11

Solution :

For β = 100 and VBE = 0.6V

$$I_C \simeq I_E = \frac{V_{EE} - V_{BE}}{R_E + R_B/\beta} = \frac{20V - 0.6V}{10\ k\Omega + 100\ k\Omega/100} = \frac{19.4V}{11\ k\Omega} = 1.76\ mA$$

$$V_C = V_{CC} - I_C R_C = 20V - (1.76\ mA)(4.7\ k\Omega) = 11.7V$$

$$V_E = -V_{EE} + I_E R_E = -20V + (1.76\ mA)(10\ k\Omega) = -2.4V$$

$$\therefore \quad V_{CE} = V_C - V_E = 11.7 - (-2.4) = 14.1V$$

$$\%\text{ age change in } I_C = \frac{1.76\ mA - 1.73\ mA}{1.73\ mA} \times 100 = 1.7\%\ (increase)$$

$$\%\text{ age change in } V_{CE} = \frac{14.1V - 14.6V}{14.1V} \times 100 = -3.5\%\ (decrease)$$

Q14. Fig. 12 shows a silicon transistor biased by collector feedback resistor method. Determine the operating point. Given that β = 100.

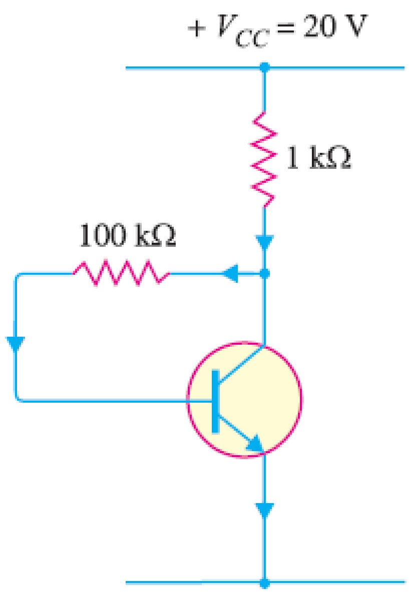


Fig. 12

Solution :

VCC = 20V, RB = 100 kΩ, RC = 1kΩ

Since it is a silicon transistor, VBE = 0.7 V.

Assuming IB to be in mA and using the relation,

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

or $$100 \times I_B = 20 - 0.7 - 100 \times I_B \times 1$$

or $$200\, I_B = 19.3$$

or $$I_B = \frac{19.3}{200} = 0.096 \text{ mA}$$

∴ Collector current, $I_C = \beta\, I_B = 100 \times 0.096 = 9.6$ mA

Collector-emitter voltage is

$$V_{CE} = V_{CC} - I_C R_C$$
$$= 20 - 9.6 \text{ mA} \times 1 \text{ k}\Omega$$
$$= 10.4 \text{ V}$$

∴ Operating point is **10.4 V, 9.6 mA.**

Q15. (i) It is required to set the operating point by biasing with collector feedback resistor at IC = 1mA, VCE = 8V. If β = 100, VCC = 12V, VBE = 0.3V, how will you do it ? (ii) What will be the new operating point if β = 50, all other circuit values remaining the same ?

Solution :

Now, collector load is

$$R_C = \frac{V_{CC} - V_{CE}}{I_C} = \frac{(12 - 8)\text{ V}}{1\text{ mA}} = 4\text{ k}\Omega$$

$$\text{Also} \quad I_B = \frac{I_C}{\beta} = \frac{1\text{ mA}}{100} = 0.01\text{ mA}$$

$$\text{Using the relation,} \quad R_B = \frac{V_{CC} - V_{BE} - \beta I_B R_C}{I_B}$$

$$= \frac{12 - 0.3 - 100 \times 0.01 \times 4}{0.01} = \mathbf{770\text{ k}\Omega}$$

(ii) Now β = 50, and other circuit values remain the same.

$$\therefore \quad V_{CC} = V_{BE} + I_B R_B + \beta I_B R_C$$

$$\text{or} \quad 12 = 0.3 + I_B (R_B + \beta R_C)$$

$$\text{or} \quad 11.7 = I_B (770 + 50 \times 4)$$

$$\text{or} \quad I_B = \frac{11.7\text{ V}}{970\text{ k}\Omega} = 0.012\text{ mA}$$

$$\therefore \quad \text{Collector current, } I_C = \beta I_B = 50 \times 0.012 = 0.6\text{ mA}$$

$$\therefore \quad \text{Collector-emitter voltage, } V_{CE} = V_{CC} - I_C R_C = 12 - 0.6\text{ mA} \times 4\text{ k}\Omega = 9.6\text{ V}$$

∴ New operating point is **9.6 V, 0.6 mA.**

collector feedback resistor RB. If β = 100, find the value of RB.

Solution :

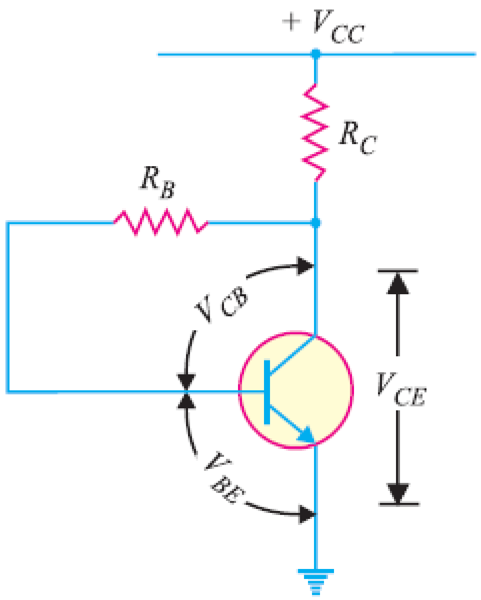


Fig. 13

For a silicon transistor,

$$V_{BE} = 0.7 \text{ V}$$

$$I_B = \frac{I_C}{\beta} = 1/100 = 0.01 \text{ mA}$$

Now $V_{CE} = V_{BE} + V_{CB}$

or $2 = 0.7 + V_{CB}$

$\therefore$ $V_{CB} = 2 - 0.7 = 1.3 \text{ V}$

$\therefore$ $R_B = \frac{V_{CB}}{I_B} = \frac{1.3\text{V}}{0.01 \text{ mA}} = 130 \text{ k}\Omega$

Q17. Find the Q-point values (IC and VCE) for the collector feedback bias circuit shown in Fig. 14.

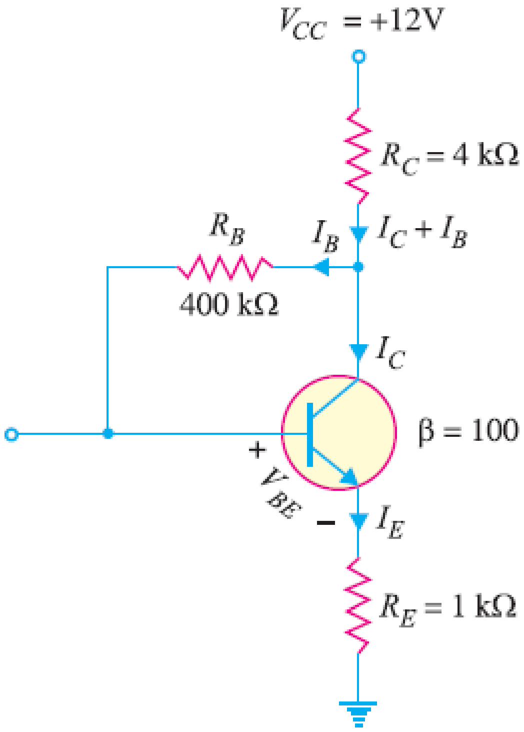


Fig. 14

Solution :

Fig. 14 shows the currents in the three resistors (RC, RB and RE) in the circuit. By following the path through VCC , RC, RB, VBE and RE and applying Kirchhoff's voltage law, we have, Now $I_B + I_C \simeq I_C$; $I_E \simeq I_C$ and $I_B = \frac{I_C}{\beta}$

$$\therefore \quad V_{CC} - I_C R_C - \frac{I_C}{\beta} R_B - V_{BE} - I_C R_E = 0$$

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

$$\therefore \quad I_C = \frac{V_{CC} - V_{BE}}{R_E + R_B/\beta + R_C}$$

Putting the given circuit values, we have,

$$I_C = \frac{12V - 0.7V}{1\ k\Omega + 400\ k\Omega/100 + 4\ k\Omega}$$

$$= \frac{11.3V}{9\ k\Omega} = 1.26\ mA$$

$$V_{CE} = V_{CC} - I_C (R_C + R_E)$$
$$= 12V - 1.26\ mA\ (4k\Omega + 1\ k\Omega)$$
$$= 12V - 6.3V = 5.7V$$

∴ The operating point is **5.7V, 1.26 mA.**

Q18. Find the d.c. bias values for the collector-feedback biasing circuit shown in Fig. 15. How does the circuit maintain a stable Q point against temperature variations ?

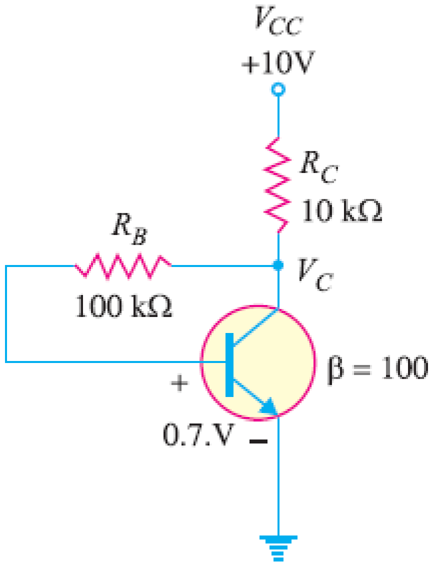


Fig.15

Solution :

The collector current is

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

$$= \frac{10\text{V} - 0.7\text{V}}{0 + 100\ \text{k}\Omega/100 + 10\ \text{k}\Omega}$$

$$= \frac{9.3\text{V}}{11\ \text{k}\Omega} = 0.845\ \text{mA}$$

Stability of Q-point :

We know that β varies directly with temperature and VBE varies inversely with temperature. As the temperature goes up, β goes up and VBE goes down. The increase in β increases IC (= βIB). The decrease in VBE increases IB which in turn increases IC . As IC tries to increase, the voltage drop across RC (= IC RC) also tries to increases. This tends to reduce collector voltage VC and, therefore, the voltage across RB. The reduced voltage across RB reduces IB and offsets the attempted increase in IC and attempted decrease in VC . The result is that the collector feedback circuit maintains a stable Q-point. The reverse action occurs when the temperature decreases.

Q19. Fig. 16 shows the voltage divider bias method. Draw the d.c. load line and determine the operating point. Assume the transistor to be of silicon.

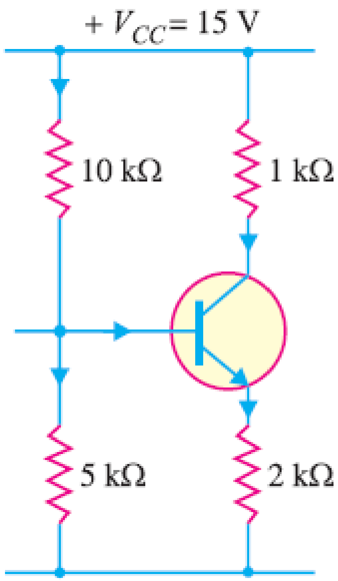


Fig. 16

Solution :

d.c. load line :

The collector-emitter voltage VCE is given by :

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

When $I_C = 0$, $V_{CE} = V_{CC} = 15V$. This locates the first point B ($OB = 15V$) of the load line on the

This locates the second point A (OA = 5 mA) of the load line on the collector current axis. By joining points A and B, the d.c. load line AB is constructed as shown in Fig. 17.

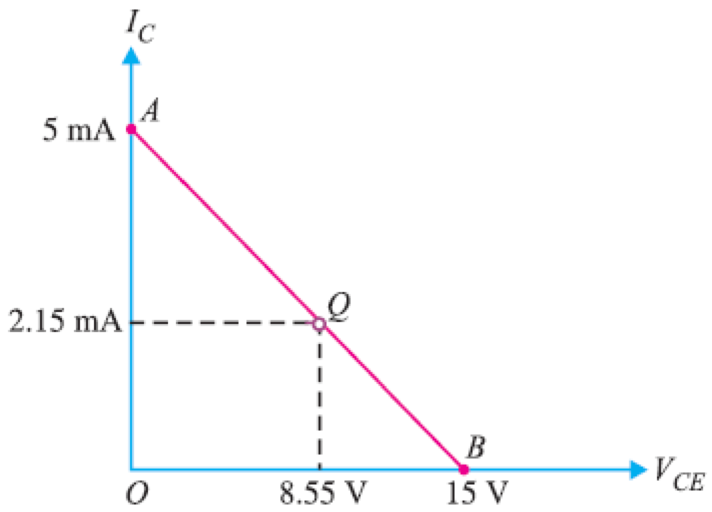


Fig. 17

Operating point :

For silicon transistor, VBE = 0.7 V

Voltage across 5 kΩ is

$$V_2 = \frac{V_{CC}}{10+5} \times 5 = \frac{15 \times 5}{10+5} = 5\text{ V}$$

$$\therefore \quad \text{Emitter current, } I_E = \frac{V_2 - V_{BE}}{R_E} = \frac{5-0.7}{2\text{ k}\Omega} = \frac{4.3\text{ V}}{2\text{ k}\Omega} = 2.15\text{ mA}$$

∴ Collector current is

$$I_C \simeq I_E = 2.15\text{ mA}$$

$$\text{Collector-emitter voltage, } V_{CE} = V_{CC} - I_C(R_C + R_E)$$

$$= 15 - 2.15\text{ mA} \times 3\text{ k}\Omega = 15 - 6.45 = 8.55\text{ V}$$

∴ Operating point is **8.55 V, 2.15 mA.**

Fig.17 shows the operating point Q on the load line. Its co-ordinates are IC = 2.15 mA, VCE = 8.55 V.

Q20. Calculate the emitter current in the voltage divider circuit shown in Fig. 18. Also find the value of VCE and collector potential VC.

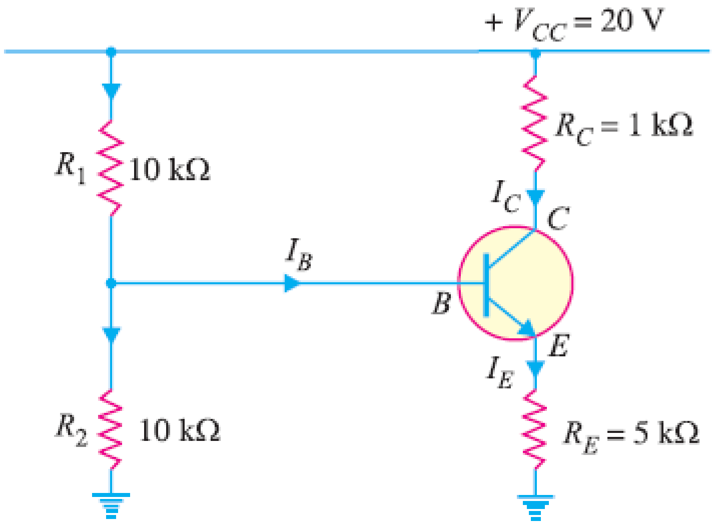


Fig. 18

Solution :

$$\text{Voltage across } R_2, V_2 = \left(\frac{V_{CC}}{R_1 + R_2}\right) R_2 = \left(\frac{20}{10+10}\right) 10 = 10 \text{ V}$$

Now $V_2 = V_{BE} + I_E R_E$

As V_{BE} is generally small, therefore, it can be neglected.

$$\therefore \quad I_E = \frac{V_2}{R_E} = \frac{10 \text{ V}}{5 \text{ k}\Omega} = 2 \text{ mA}$$

Now $I_C \simeq I_E = 2 \text{ mA}$

$$\therefore \quad V_{CE} = V_{CC} - I_C (R_C + R_E) = 20 - 2 \text{ mA } (6 \text{ k}\Omega)$$

Q21. For the circuit shown in Fig. 19, find the operating point. What is the stability factor of the circuit ? Given that β = 50 and VBE = 0.7V.

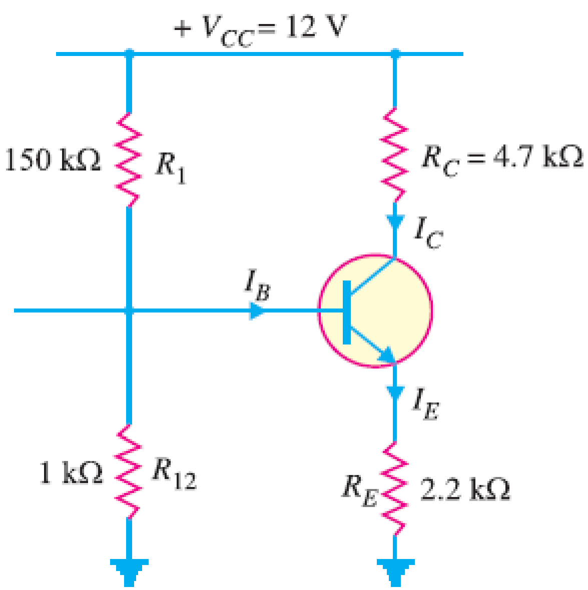


Fig. 19

Solution :

Fig. 19 shows the circuit of potential divider bias and Fig. 20 shows it with potential divider circuit replaced by Thevenin's equivalent circuit.

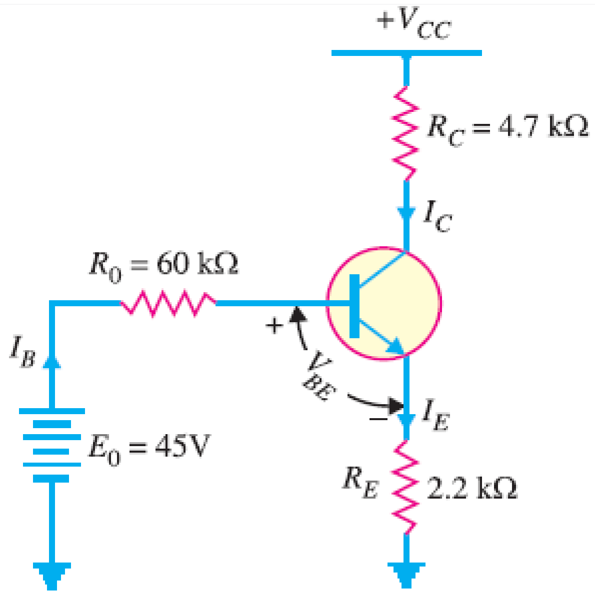


Fig. 20

$$E_0 = \frac{V_{CC}}{R_1 + R_2} \times R_2 = \frac{12\text{V}}{150\text{ k}\Omega + 100\text{ k}\Omega} \times 100\text{ k}\Omega = 4.8\text{V}$$

$$R_0 = \frac{R_1 R_2}{R_1 + R_2} = \frac{150\text{ k}\Omega \times 100\text{ k}\Omega}{150\text{ k}\Omega + 100\text{ k}\Omega} = 60\text{ k}\Omega$$

$$\therefore \quad I_B = \frac{E_0 - V_{BE}}{R_0 + \beta R_E} \quad \ldots$$

$$= \frac{4.8\text{V} - 0.7\text{V}}{60\text{ k}\Omega + 50 \times 2.2\text{ k}\Omega} = \frac{4.1\text{V}}{170\text{ k}\Omega} = 0.024\text{ mA}$$

Now $I_C = \beta I_B = 50 \times 0.024 = 1.2\text{ mA}$

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

$$= 12\text{V} - 1.2\text{mA}\,(4.7\text{ k}\Omega + 2.2\text{ k}\Omega) = 3.72\text{V}$$

∴ Operating point is **3.72V, 1.2 mA.**

Now $\frac{R_0}{R_E} = \frac{60\text{ k}\Omega}{2.2\text{ k}\Omega} = 27.3$

∴ Stability factor, $S = (\beta + 1) \times \frac{1 + R_0/R_E}{\beta + 1 + R_0/R_E}$

$$= (50 + 1) \times \frac{1 + 27.3}{50 + 1 + 27.3} = \mathbf{18.4}$$

Q22. The circuit shown in Fig. 21 uses silicon transistor having β = 100. Find the operating point and stability factor.

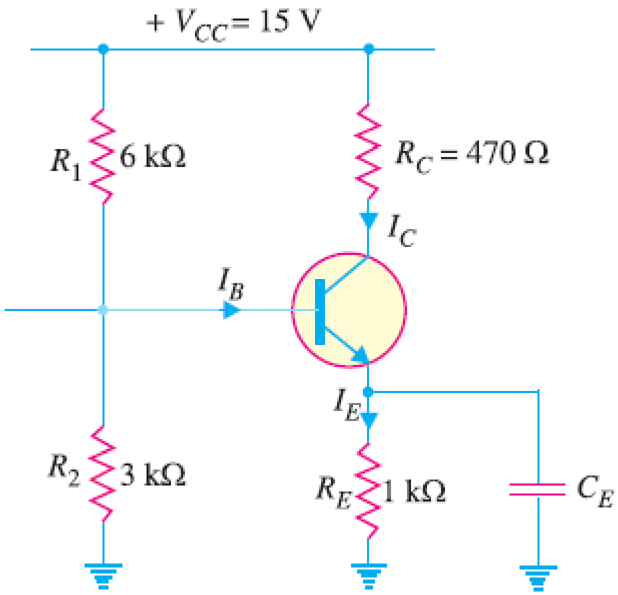


Fig. 21

Solution :

Fig. 21 shows the circuit of potential divider bias and Fig. 22 shows it with potential divider circuit replaced by Thevenin's equivalent circuit.

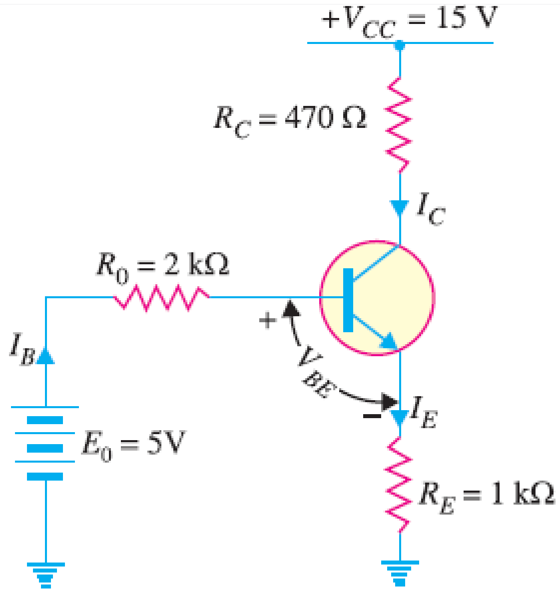


Fig. 22

$$E_0 = \frac{V_{CC}}{R_1 + R_2} \times R_2 = \frac{15\text{V}}{6\ \text{k}\Omega + 3\ \text{k}\Omega} \times 3\ \text{k}\Omega = \frac{15\text{V}}{9\ \text{k}\Omega} \times 3\ \text{k}\Omega = 5\text{V}$$

$$R_0 = \frac{R_1 R_2}{R_1 + R_2} = \frac{6\ \text{k}\Omega \times 3\ \text{k}\Omega}{6\ \text{k}\Omega + 3\ \text{k}\Omega} = 2\ \text{k}\Omega$$

Now $$I_B = \frac{E_0 - V_{BE}}{R_0 + \beta R_E}$$

$$= \frac{5\text{V} - 0.7\text{V}}{2\ \text{k}\Omega + 100 \times 1\text{k}\Omega} = \frac{4.3\text{V}}{102\ \text{k}\Omega} = 0.042\text{mA}$$

$\therefore$ $$I_C = \beta I_B = 100 \times 0.042 = 4.2\ \text{mA}$$

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

$$= 15\text{V} - 4.2\text{mA}\ (470\Omega + 1\ \text{k}\Omega) = 8.83\text{V}$$

$\therefore$ Operating point is **8.83V ; 4.2 mA.**

Now $$R_0/R_E = 2\ \text{k}\Omega / 1\ \text{k}\Omega = 2$$

$\therefore$ Stability factor, $$S = (\beta + 1) \times \frac{1 + R_0/R_E}{\beta + 1 + R_0/R_E}$$

$$= (100 + 1) \times \frac{1 + 2}{100 + 1 + 2} = \mathbf{2.94}$$

Q23. In the circuit shown in Fig. 23, the operating point is chosen such that IC = 2mA, VCE = 3V. If RC = 2.2 kΩ, VCC = 9V and β = 50, determine the values of R1, R2 and RE. Take

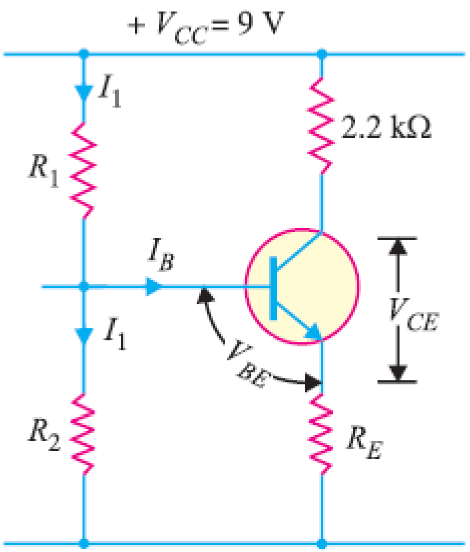


Fig. 23

Solution :

Given, RC = 2.2 kΩ, VCC = 9V and β = 50, VBE = 0.3V and I1 = 10IB .

As IB is very small as compared to I1, therefore, we can assume with reasonable accuracy that I1 flowing through R1 also flows through R2.

$$\text{Base current, } I_B = \frac{I_C}{\beta} = \frac{2\ mA}{50} = 0.04 \text{ mA}$$

Current through R_1 & R_2 is

$$I_1 = 10\, I_B = 10 \times 0.04 = 0.4 \text{ mA}$$

Now

$$I_1 = \frac{V_{CC}}{R_1 + R_2}$$

$$\therefore \quad R_1 + R_2 = \frac{V_{CC}}{I_1} = \frac{9 \text{ V}}{0.4 \text{ mA}} = 22.5 \text{ k}\Omega$$

Applying Kirchhoff 's voltage law to the collector side of the circuit, we get,

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

$$\text{or} \quad V_{CC} = I_C R_C + V_{CE} + I_C R_E \qquad (\because I_C \simeq I_E)$$

$$\text{or} \quad 9 = 2 \text{ mA} \times 2.2 \text{ k}\Omega + 3 + 2 \text{ mA} \times R_E$$

$$\therefore \quad R_E = \frac{9 - 4.4 - 3}{2} = 0.8 \text{ k}\Omega = \mathbf{800\ \Omega}$$

$$\text{Voltage across } R_2,\ V_2 = V_{BE} + V_E = 0.3 + 2 \text{ mA} \times 0.8 \text{ k}\Omega$$

$$= 0.3 + 1.6 = 1.9 \text{ V}$$

$$\therefore \quad \text{Resistance } R_2 = V_2/I_1 = 1.9 \text{ V}/0.4 \text{ mA} = \mathbf{4.75\ k\Omega}$$

$$\text{and} \quad R_1 = 22.5 - 4.75 = \mathbf{17.75\ k\Omega}$$

calculate R1 and RC to place Q point at IC = 2mA,VCE = 6 volts.

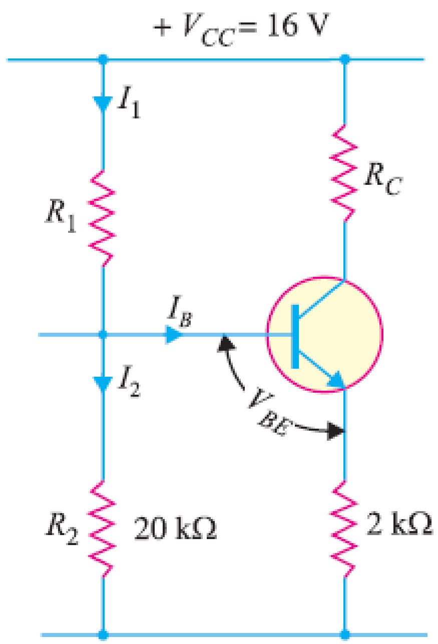


Fig. 24

Solution :

Given, α = 0.985 , VBE = 0.3V and VCC =16V

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

$$\text{Base current, } I_B = \frac{I_C}{\beta} = \frac{2\text{ mA}}{66} = 0.03\text{ mA}$$

$$\text{Voltage across } R_2, V_2 = V_{BE} + V_E = 0.3 + 2\text{ mA} \times 2\text{ k}\Omega$$
$$= 4.3\text{ V}$$

$$\therefore \quad \text{Voltage across } R_1 = V_{CC} - V_2 = 16 - 4.3 = 11.7\text{ V}$$

$\therefore$ Current through R_1 & R_2 is

$$I_1 = \frac{V_2}{R_2} = \frac{4.3\text{ V}}{20\text{ k}\Omega} = 0.215\text{ mA}$$

$$\therefore \quad \text{Resistance } R_1 = \frac{\text{Voltage across } R_1}{I_1} = \frac{11.7\text{ V}}{0.215\text{ mA}}$$
$$= \mathbf{54.4\text{ k}\Omega}$$

$$\text{Voltage across } R_C = V_{CC} - V_{CE} - V_E$$
$$= 16 - 6 - 2 \times 2 = 6\text{ V}$$

$$\therefore \quad \text{Collector resistance, } R_C = \frac{\text{Voltage across } R_C}{I_C} = \frac{6\text{ V}}{2\text{ mA}} = \mathbf{3\text{ k}\Omega}$$

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