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Solved Problems on Transistor

BASIC ELECTRONICS SOLVED PROBLEMS BY SASMITA JANUARY 9, 2020

Q1. A common base transistor amplifier has an input resistance of $20\ \Omega$ and output resistance of $100\ \text{k}\Omega$. The collector load is $1\ \text{k}\Omega$. If a signal of $500\ \text{mV}$ is applied between emitter and base, find the voltage amplification. Assume α_{ac} to be nearly one.

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Fig.1 shows the conditions of the problem. Here the output resistance is very high as compared to input resistance, since the input junction (base to emitter) of the transistor is forward biased while the output junction (base to collector) is reverse biased.



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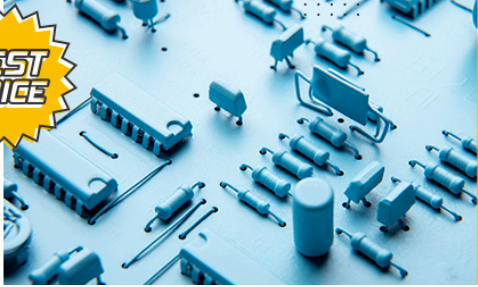
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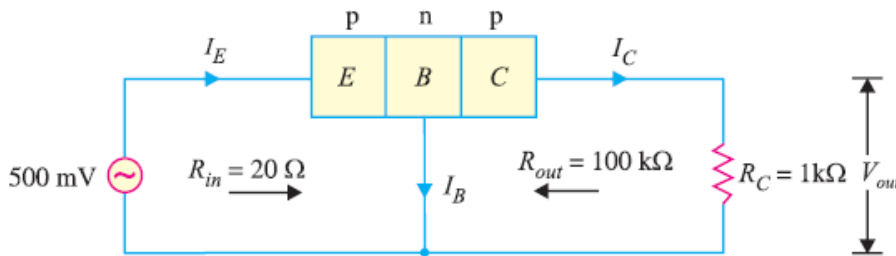


Fig. 1



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Input current, $I_E = \frac{\text{Signal}}{R_{in}} = \frac{500 \text{ mV}}{20 \Omega} = 25 \text{ mA}$. Since α_{ac} is nearly 1, output current, $I_C = I_E = 25 \text{ mA}$.

Output voltage, $V_{out} = I_C R_C = 25 \text{ mA} \times 1 \text{ k}\Omega = 25 \text{ V}$

$\therefore$ Voltage amplification, $A_v = \frac{V_{out}}{\text{signal}} = \frac{25 \text{ V}}{500 \text{ mV}} = 50$

Q2. In a common base connection, $I_E = 1 \text{ mA}$, $I_C = 0.95 \text{ mA}$. Calculate the value of I_B .

Solution :

Using the relation, $I_E = I_B + I_C$

Q3. In a common base connection, current amplification factor is 0.9. If the emitter current is 1mA, determine the value of base current.

Solution :

$$\text{Here, } \alpha = 0.9, I_E = 1 \text{ mA}$$

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

$$\text{or } I_C = \alpha I_E = 0.9 \times 1 = 0.9 \text{ mA}$$

$$\text{Also } I_E = I_B + I_C$$

$$\therefore \text{Base current, } I_B = I_E - I_C = 1 - 0.9 = 0.1 \text{ mA}$$

Q4. In a common base connection, $I_C = 0.95 \text{ mA}$ and $I_B = 0.05 \text{ mA}$. Find the value of α .

Solution :

$$\text{We know } I_E = I_B + I_C = 0.05 + 0.95 = 1 \text{ mA}$$

$$\therefore \text{Current amplification factor, } \alpha = \frac{I_C}{I_E} = \frac{0.95}{1} = 0.95$$

Q5. In a common base connection, the emitter current is 1mA. If the emitter circuit is open, the collector current is $50 \mu\text{A}$. Find the total collector current. Given that $\alpha = 0.92$.

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Q6. In a common base connection, $\alpha = 0.95$. The voltage drop across $2\text{ k}\Omega$ resistance which is connected in the collector is 2V . Find the base current.

Solution :

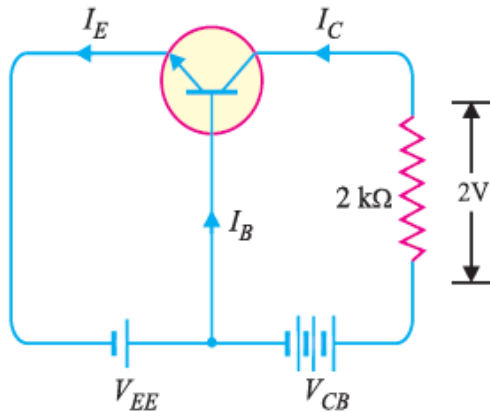


Fig. 2

Fig. 2 shows the required common base connection.

The voltage drop across RC ($= 2\text{ k}\Omega$) is 2V .

$$\therefore \quad I_C = 2\text{ V} / 2\text{ k}\Omega = 1\text{ mA}$$

Now $\alpha = I_C / I_E$

$$\therefore \quad I_E = \frac{I_C}{\alpha} = \frac{1}{0.95} = 1.05\text{ mA}$$

Using the relation, $I_E = I_B + I_C$

$$\therefore \quad I_B = I_E - I_C = 1.05 - 1 = 0.05\text{ mA}$$

Q7. For the common base circuit shown in Fig. 3, determine I_C and V_{CB} . Assume the transistor to be of silicon.



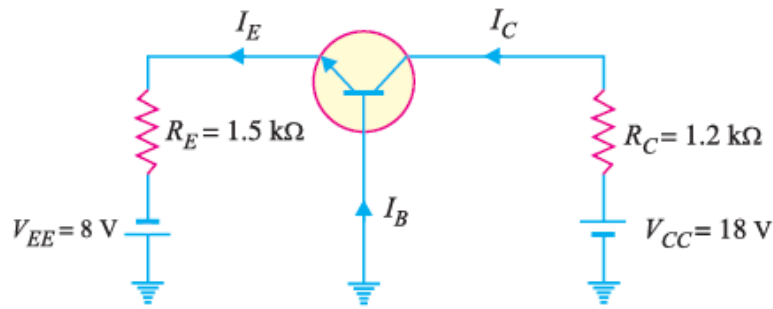


Fig. 3

Solution :

Since the transistor is of silicon, $V_{BE} = 0.7V$.

Applying Kirchhoff's voltage law to the emitter-side loop, we get,

$$\begin{aligned}
 V_{EE} &= I_E R_E + V_{BE} \\
 \text{or } I_E &= \frac{V_{EE} - V_{BE}}{R_E} \\
 &= \frac{8V - 0.7V}{1.5 \text{ k}\Omega} = 4.87 \text{ mA} \\
 \therefore I_C \simeq I_E &= \mathbf{4.87 \text{ mA}}
 \end{aligned}$$

Applying Kirchhoff's voltage law to the collector-side loop, we have,

$$\begin{aligned}
 V_{CC} &= I_C R_C + V_{CB} \\
 \therefore V_{CB} &= V_{CC} - I_C R_C \\
 &= 18 \text{ V} - 4.87 \text{ mA} \times 1.2 \text{ k}\Omega = \mathbf{12.16 \text{ V}}
 \end{aligned}$$

**Q8. Find the value of β if (i) $\alpha = 0.9$
(ii) $\alpha = 0.98$ (iii) $\alpha = 0.99$.**

Solution :

(i) $\alpha = 0.9$

$$\beta = \frac{\alpha}{1 - \alpha} = \frac{0.9}{1 - 0.9} = \mathbf{9}$$

(ii) $\alpha = 0.98$

$$\beta = \frac{\alpha}{1 - \alpha} = \frac{0.98}{1 - 0.98} = \mathbf{49}$$

$$\beta = \frac{\alpha}{1-\alpha} = \frac{0.99}{1-0.99} = 99$$

Q9. Calculate I_E in a transistor for which $\beta = 50$ and $I_B = 20 \mu\text{A}$.

Solution :

$$\text{Here } \beta = 50, \quad I_B = 20 \mu\text{A} = 0.02 \text{ mA}$$

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

$$\therefore I_C = \beta I_B = 50 \times 0.02 = 1 \text{ mA}$$

$$\text{Using the relation, } I_E = I_B + I_C = 0.02 + 1 = 1.02 \text{ mA}$$

Q10. Find the α rating of the transistor shown in Fig. 4. Hence determine the value of I_C using both α and β rating of the transistor.

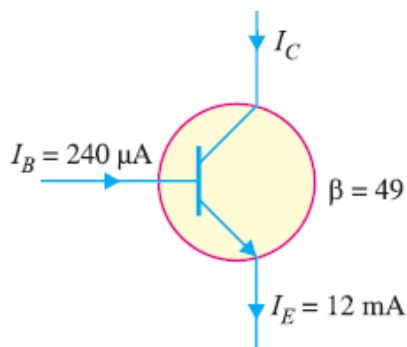


Fig. 4

Solution :

Fig. 8.20 shows the conditions of the problem.



$$\alpha = \frac{\beta}{1 + \beta} = \frac{49}{1 + 49} = \mathbf{0.98}$$

The value of I_C can be found by using either α or β rating as under :

$$I_C = \alpha I_E = 0.98 (12 \text{ mA}) = \mathbf{11.76 \text{ mA}}$$

$$\text{Also } I_C = \beta I_B = 49 (240 \mu\text{A}) = \mathbf{11.76 \text{ mA}}$$

Q11. For a transistor, $\beta = 45$ and voltage drop across $1\text{k}\Omega$ which is connected in the collector circuit is 1 volt. Find the base current for common emitter connection.

Solution :

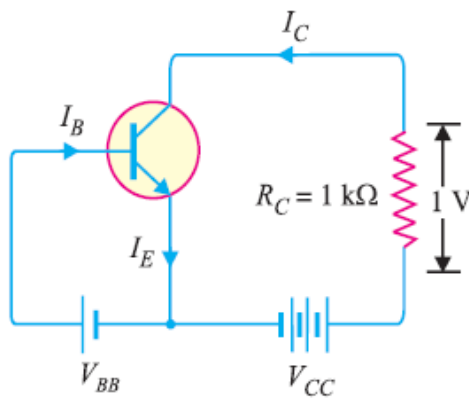


Fig. 5

Fig. 5 shows the required common emitter connection. The voltage drop across $R_C (= 1 \text{ k}\Omega)$ is 1 volt.

$$\therefore I_C = \frac{1 \text{ V}}{1 \text{ k}\Omega} = 1 \text{ mA}$$

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

$$\therefore I_B = \frac{I_C}{\beta} = \frac{1}{45} = \mathbf{0.022 \text{ mA}}$$

Q12. A transistor is connected in common emitter (CE) configuration in which collector supply is 8 V and

= 0.96, determine : (i) collector-emitter voltage (ii) base current.

Solution :

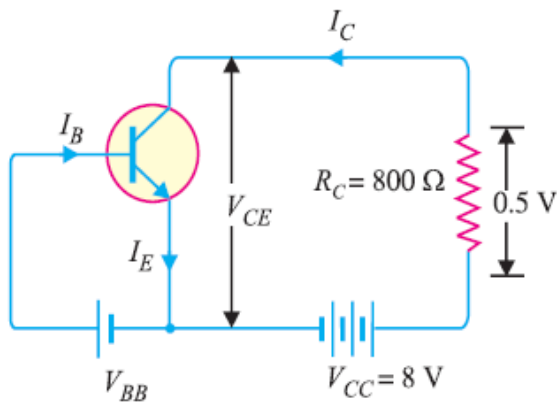


Fig.6

Fig. 6 shows the required common emitter connection with various values.

Collector-emitter voltage, (i)

$$V_{CE} = V_{CC} - 0.5 = 8 - 0.5 = 7.5 \text{ V}$$

(ii)

The voltage drop across $R_C (= 800 \Omega)$ is 0.5 V.

$$I_C = \frac{0.5 \text{ V}}{800 \Omega} = \frac{5}{8} \text{ mA} = 0.625 \text{ mA}$$

$$\text{Now } \beta = \frac{\alpha}{1 - \alpha} = \frac{0.96}{1 - 0.96} = 24$$

$$\therefore \text{ Base current, } I_B = \frac{I_C}{\beta} = \frac{0.625}{24} = 0.026 \text{ mA}$$

Q13. An n-p-n transistor at room temperature has its emitter disconnected. A voltage of 5 V is applied between collector and base

disconnected and the same voltage is applied between collector and emitter, the current is found to be $20\ \mu\text{A}$. Find α , I_E and I_B when collector current is $1\ \text{mA}$.

Solution :

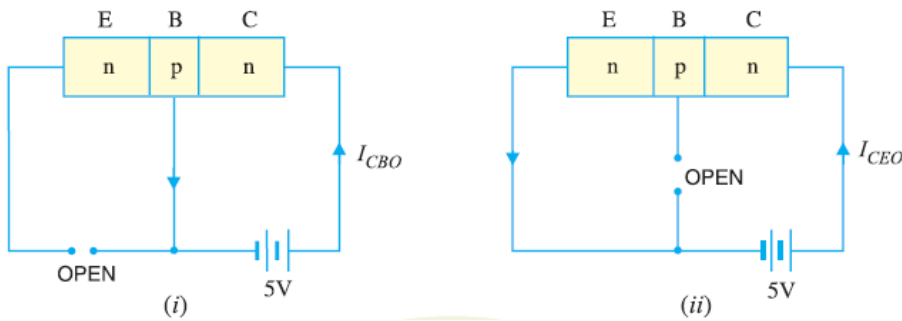


Fig. 7

When the emitter circuit is open as shown in Fig.7 (i) , the collector-base junction is reverse biased. A small leakage current I_{CBO} flows due to minority carriers.

$\therefore$	$I_{CBO} = 0.2\ \mu\text{A}$	...given
When base is open [See Fig. 8.23 (ii)], a small leakage current I_{CEO} flows due to minority carriers.		
$\therefore$	$I_{CEO} = 20\ \mu\text{A}$	... given
We know	$I_{CEO} = \frac{I_{CBO}}{1 - \alpha}$	
or	$20 = \frac{0.2}{1 - \alpha}$	
$\therefore$	$\alpha = 0.99$	
Now	$I_C = \alpha I_E + I_{CBO}$	
Here	$I_C = 1\text{mA} = 1000\ \mu\text{A}$; $\alpha = 0.99$; $I_{CBO} = 0.2\ \mu\text{A}$	
$\therefore$	$1000 = 0.99 \times I_E + 0.2$	
or	$I_E = \frac{1000 - 0.2}{0.99} = 1010\ \mu\text{A}$	
and	$I_B = I_E - I_C = 1010 - 1000 = 10\ \mu\text{A}$	

Q14. The collector leakage current in a transistor is $300\ \mu\text{A}$ in CE arrangement. If now the transistor is connected in CB arrangement what will be the

$$I_{CEO} = 300 \mu\text{A}$$

$$\beta = 120 ; \alpha = \frac{\beta}{\beta + 1} = \frac{120}{120 + 1} = 0.992$$

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

$$\therefore I_{CBO} = (1 - \alpha) I_{CEO} = (1 - 0.992) \times 300 = 2.4 \mu\text{A}$$

Note that leakage current in CE arrangement (i.e. I_{CEO}) is much more than in CB arrangement (i.e. I_{CBO}).

Q15. For a certain transistor, $I_B = 20 \mu\text{A}$; $I_C = 2 \text{ mA}$ and $\beta = 80$. Calculate I_{CBO} .

Solution :

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

or $2 = 80 \times 0.02 + I_{CEO}$

$$\therefore I_{CEO} = 2 - 80 \times 0.02 = 0.4 \text{ mA}$$

Now $\alpha = \frac{\beta}{\beta + 1} = \frac{80}{80 + 1} = 0.988$

$$\therefore I_{CBO} = (1 - \alpha) I_{CEO} = (1 - 0.988) \times 0.4 = 0.0048 \text{ mA}$$

Q16. Using diagrams, explain the correctness of the relation $I_{CEO} = (\beta + 1)I_{CBO}$.

Solution :

The leakage current I_{CBO} is the current that flows through the base-collector junction when emitter is open as shown in Fig. 8.

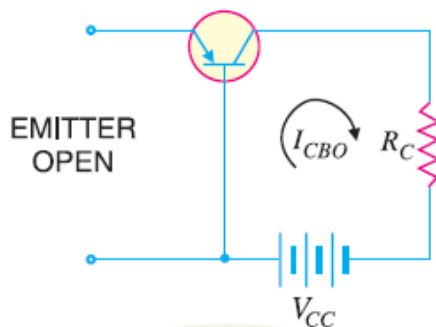


Fig. 8

When the transistor is in CE arrangement, the base current (i.e. I_{CBO}) is multiplied by β in the collector as shown in Fig. 9.

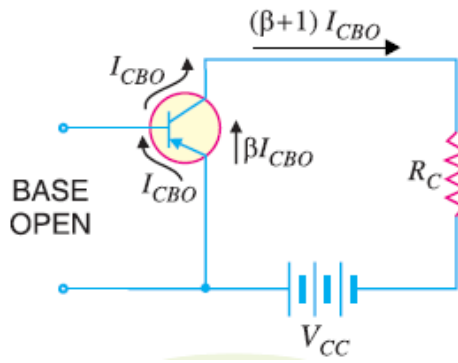


Fig.9

$$\therefore I_{CEO} = I_{CBO} + \beta I_{CBO} = (\beta + 1) I_{CBO}$$

Q17. Determine VCB in the transistor circuit shown in Fig. 10 (i). The transistor is of silicon and has $\beta = 150$.

Solution :

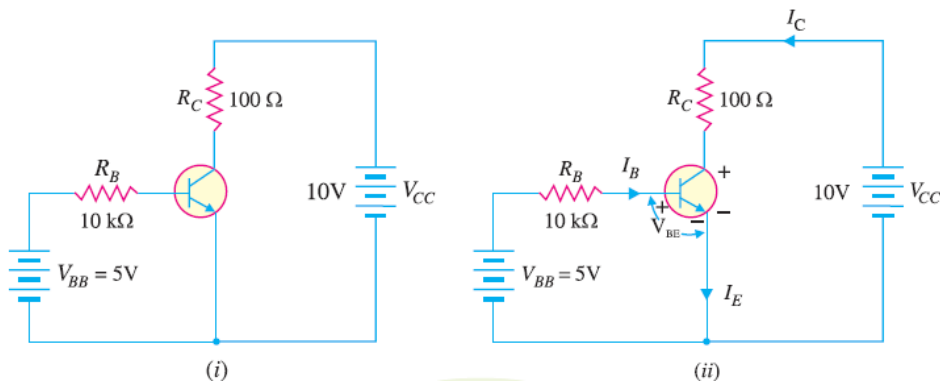


Fig.10

Fig. 10 (i) shows the transistor circuit while Fig. 10 (ii) shows the various currents and voltages along with polarities.

Applying Kirchhoff's voltage law to base-emitter loop, we have,

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

$$\text{or } I_B = \frac{V_{BB} - V_{BE}}{R_B} = \frac{5V - 0.7V}{10 \text{ k}\Omega} = 430 \mu\text{A}$$

$$\therefore I_C = \beta I_B = (150)(430 \mu\text{A}) = 64.5 \text{ mA}$$

$$\checkmark \text{ Now } V_{CE} = V_{CC} - I_C R_C = 10V - (64.5 \text{ mA})(100\Omega) = 10V - 6.45V = 3.55V$$

Q18. In a transistor, $I_B = 68 \mu\text{A}$, $I_E = 30 \text{ mA}$ and $\beta = 440$. Determine the α rating of the transistor. Then determine the value of I_C using both the α rating and β rating of the transistor.

Solution :

$$\alpha = \frac{\beta}{\beta + 1} = \frac{440}{440 + 1} = 0.9977$$

$$I_C = \alpha I_E = (0.9977) (30 \text{ mA}) = 29.93 \text{ mA}$$

Also

$$I_C = \beta I_B = (440) (68 \mu\text{A}) = 29.93 \text{ mA}$$

Q19. A transistor has the following ratings : $I_C (\text{max}) = 500 \text{ mA}$ and $\beta_{\text{max}} = 300$. Determine the maximum allowable value of I_B for the device.

Solution :

$$I_{B(\text{max})} = \frac{I_{C(\text{max})}}{\beta_{\text{max}}} = \frac{500 \text{ mA}}{300} = 1.67 \text{ mA}$$

For this transistor, if the base current is allowed to exceed 1.67 mA, the collector current will exceed its maximum rating of 500 mA and the transistor will probably be destroyed.

Q20. Fig. 11 shows the open circuit failures in a transistor. What will be the circuit behaviour in each case ?

Solution :



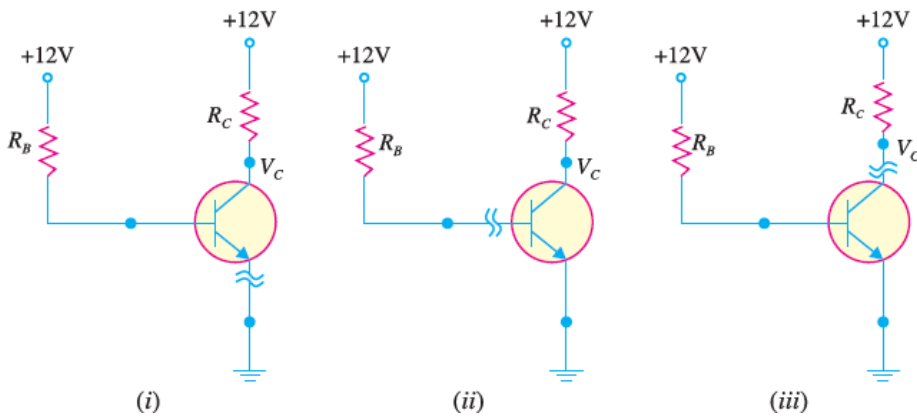


Fig. 11

Fig 11 shows the open circuit failures in a transistor. We shall discuss the circuit behaviour in each case.

(i) Open emitter :

Fig. 11 (i) shows an open emitter failure in a transistor. Since the collector diode is not forward biased, it is OFF and there can be neither collector current nor base current.

Therefore, there will be no voltage drops across either resistor and the voltage at the base and at the collector leads of the transistor will be 12V.

(ii) Open-base :

Fig. 11 (ii) shows an open base failure in a transistor. Since the base is open, there can be no base current so that the transistor is in cut-off. Therefore, all the transistor currents are 0A. In this case, the base and collector voltages will both be at 12V.

(iii) Open collector :

Fig. 11 (iii) shows an open collector failure in a transistor. In this case, the emitter diode is still ON, so we expect to see 0.7V at the base. However, we will see 12V at the collector because there is no collector current.

Q21. For the circuit shown in Fig. 12 ,

Fig.12

Solution :

The collector-emitter voltage V_{CE} is given by ;

This locates the point A of the load line on the collector current axis. By joining these two points, we get the d.c. load line AB as shown in Fig. 13.

Fig.13

Q22. In the circuit diagram shown in Fig. 14, if $V_{CC} = 12V$ and $R_C = 6\text{ k}\Omega$, draw the d.c. load line. What will be the Q point if zero signal base

Fig.14

Solution :

The collector-emitter voltage V_{CE} is given by :

When $I_C = 0$, $V_{CE} = V_{CC} = 12 \text{ V}$. This locates the point B of the load line.

When $V_{CE} = 0$, $I_C = V_{CC} / R_C = 12 \text{ V} / 6 \text{ k}\Omega = 2 \text{ mA}$.

This locates the point A of the load line. By joining these two points, load line AB is constructed as shown in 15.

Fig. 15



Fig. 15 shows the Q point. Its co-ordinates are $I_C = 1 \text{ mA}$ and $V_{CE} = 6 \text{ V}$.

Q23. In a transistor circuit, collector load is $4 \text{ k}\Omega$ whereas quiescent current (zero signal collector current) is 1 mA . (i) What is the operating point if $V_{CC} = 10 \text{ V}$? (ii) What will be the operating point if $R_C = 5 \text{ k}\Omega$?

Solution :

(i) When collector load $R_C = 4 \text{ k}\Omega$, then,

(ii) When collector load $R_C = 5 \text{ k}\Omega$, then,

Q24. Determine the Q point of the transistor circuit shown in Fig. 16. Also draw the d.c. load line. Given $\beta = 200$ and $V_{BE} = 0.7 \text{ V}$.

✓

Fig. 16

Solution :

The presence of resistor R_B in the base circuit should not disturb you because we can apply Kirchhoff's voltage law to find the value of I_B and hence $I_C (= \beta I_B)$. Referring to Fig. 16 and applying Kirchhoff's voltage law to base-emitter loop, we have,

D.C. load line:

In order to draw the d.c. load line, we need two end points.

When $I_C = 0$, $V_{CE} = V_{CC} = 20V$. This locates the point B of the load line on the collector-emitter voltage axis as shown in Fig. 17.

When $V_{CE} = 0$, $I_C = V_{CC} / R_C = 20V / 330\Omega = 60.6 \text{ mA}$. This locates the point A of the load line on the collector current axis.



By joining these two points, d.c. load line AB is constructed as shown in Fig. 17.

Fig. 17

Q25. Determine the Q point of the transistor circuit shown in Fig. 18. Also draw the d.c. load line. Given $\beta = 100$ and $V_{BE} = 0.7V$.



Fig.18

Solution :

The transistor circuit shown in Fig. 18 may look complex but we can easily apply Kirchhoff's voltage law to find the various voltages and currents in the circuit.

D.C. load line :

The d.c. load line can be constructed as under :

This locates the second point A ($O_A = 3.51 \text{ mA}$) 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. 19.



Q26. In the above example, find (i) emitter voltage w.r.t. ground (ii) base voltage w.r.t. ground (iii) collector voltage w.r.t. ground.

Solution :

Fig.20

Referring to Fig. 20:

(i) The emitter voltage w.r.t. ground is

(ii) The base voltage w.r.t. ground is

(iii) The collector voltage w.r.t. ground is

Q27. If the collector current changes from 2 mA to 3mA in a transistor when collector-emitter voltage is increased from 2V to 10V, what is the output resistance

Change in collector-emitter voltage is :

Q28. A change of 200 mV in base-emitter voltage causes a change of 100 μ A in the base current. Find the input resistance of the transistor.

Solution :

Change in base-emitter voltage is :

Q29. For a single stage transistor amplifier, the collector load is $R_C = 2\text{k}\Omega$ and the input resistance $R_i = 1\text{k}\Omega$. If the current gain is 50, calculate the voltage gain of the amplifier.

Solution :



Q30. Find $I_{C(sat)}$ and $V_{CE(cutoff)}$ for the circuit shown in Fig. 21.

Fig.21

Solution :

As we decrease R_B , base current and hence collector current increases. The increased collector current causes a greater voltage drop across R_C ; this decreases the collector-emitter voltage.

Eventually at some value of R_B , V_{CE} decreases to V_{knee} . At this point, collector-base junction is no longer reverse biased and transistor action is lost.

Consequently, further increase in collector current is not possible. The transistor conducts maximum collector current

As we increase R_B , base current and hence collector current decreases. This decreases the voltage drop across R_C . This increases the collector-emitter voltage. Eventually, when $I_B = 0$, the emitter-base junction is no longer forward biased and transistor action is lost.

Consequently, further increase in V_{CE} is not possible. In fact, V_{CE} now equals to V_{CC} .

Fig. 22 shows the saturation and cut off points. Incidentally, they are end points of the d.c. load line.

Fig. 22

Q31. Determine the values of $V_{CE}(\text{off})$ and $I_C(\text{sat})$ for the circuit shown in Fig. 23.



Fig. 23

Solution :

Applying Kirchhoff's voltage law to the collector side of the circuit in Fig. 23, we have ,

Q32. Determine whether or not the transistor in Fig. 24 is in stauration. Assume $V_{knee} = 0.2V$.



Fig.24

Solution :

Now we shall see if I_B is large enough to produce $I_C(\text{sat})$.

This shows that with specified β , this base current ($= 0.23 \text{ mA}$) is capable of producing I_C greater than $I_C(\text{sat})$. Therefore, the transistor is **saturated**. In fact, the collector current value of 11.5 mA is never reached. If the base current value corresponding to $I_C(\text{sat})$ is increased, the collector current remains at the saturated value ($= 9.8 \text{ mA}$).

Q33. Is the transistor in Fig. 25 operating in saturated state ?

Fig.25

Solution :



Let us relate the values found to the transistor shown in Fig. 26.

Fig.26

As we can see, the value of V_{BE} is 0.95V and the value of $V_{CE} = 0.3V$.

This leaves V_{CB} of 0.65V (Note that $V_{CE} = V_{CB} + V_{BE}$).

In this case, collector–base junction (i.e., collector diode) is forward biased as is the emitter-base junction (i.e., emitter diode). Therefore, the transistor is operating in the **saturation region**.

Q34. For the circuit in Fig. 27, find the base supply voltage (V_{BB}) that just puts the transistor into saturation. Assume $\beta = 200$.



When transistor first goes into saturation, we can assume that the collector shorts to the emitter (i.e. $V_{CE} = 0$) but the collector current is still β times the base current.

Applying Kirchhoff's voltage law to the base circuit, we have,

Q35. Determine the state of the transistor in Fig. 28 for the following values of collector resistor : (i) $R_C = 2\text{ k}\Omega$ (ii) $R_C = 4\text{ k}\Omega$ (iii) $R_C = 8\text{ k}\Omega$.

Fig. 28

Solution •

(i) When $RC = 2\text{ k}\Omega$

Suppose the transistor is active.

Since $V_C (= 6\text{V})$ is greater than $V_E (= 2\text{V})$, the transistor is active. Therefore, our assumption that transistor is active is correct.

(ii) When $RC = 4\text{ k}\Omega$

Suppose the transistor is active.

Since $V_C = V_E$, the transistor is just at the edge of saturation. We know that at the edge of saturation, the relation between the transistor currents is the same as in the active state. Both answers are correct.

(iii) When $RC = 8\text{ k}\Omega$

Suppose the transistor is active.

Since $V_C < V_E$, the transistor is saturated and our assumption is not correct

values:

(i) $V_{BB} = 0.5V$ (ii) $V_{BB} = 1.5V$ (iii) $V_{BB} = 3V$. Determine the state of the transistor for each value of the base supply voltage V_{BB} .

Fig.29

Solution :

The state of the transistor also depends on the base supply voltage V_{BB}

(i) For $V_{BB} = 0.5V$

Because the base voltage $V_B (= V_{BB} = 0.5V)$ is less than $0.7V$, the transistor is **cut-off**.

(ii) For $V_{BB} = 1.5V$

The base voltage V_B controls the emitter voltage V_E which controls the emitter current I_E .



Since $V_C > V_E$, the transistor is **active** and our assumption is correct.

(iii) For $V_{BB} = 3V$

Assuming the transistor is active, we have,

Since $V_C < V_E$, the transistor is saturated and our assumption is not correct.

Q37. The maximum power dissipation of a transistor is 100mW. If $V_{CE} = 20V$, what is the maximum collector current that can be allowed without destruction of the transistor?

Solution :

Q38. For the circuit shown in Fig. 30, find the transistor power dissipation. Assume that $\beta = 200$.



Fig.30

Solution :

Q39. For the circuit shown in Fig. 31, find the power dissipated in the transistor. Assume $\beta = 100$.

Fig. 31



The transistor is usually used with a resistor R_C connected between the collector and its power supply V_{CC} as shown is Fig.31.

The collector resistor R_C serves two purposes. Firstly, it allows us to control the voltage V_C at the collector.

Secondly, it protects the transistor from excessive collector current I_C and, therefore, from excessive power dissipation.

Referring to Fig. 31 and applying Kirchhoff's voltage law to the base side, we have,

**Q40. The transistor in Fig.32 has the following maximum ratings :
 $P_D(\text{max}) = 800 \text{ mW}$; $V_{CE}(\text{max}) = 15\text{V}$; $I_C(\text{max}) = 100 \text{ mA}$. Determine the maximum value to which V_{CC} can be adjusted without exceeding any rating. Which rating would be exceeded first ?**



Fig.32

Note that I_C is much less than $I_{C(max)}$ and will not change with V_{CC} . It is determined only by I_B and β . Therefore, current rating is not exceeded.

If base current is removed causing the transistor to turn off, $V_{CE(max)}$ will be exceeded because the entire supply voltage V_{CC} will be dropped across the transistor.



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Hi! I am Sasmita . At ElectronicsPost.com I pursue my love for teaching. I am an M.Tech in Electronics & Telecommunication Engineering. And, if you really want to know more about me, please visit my "About" Page. [Read More](#)



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