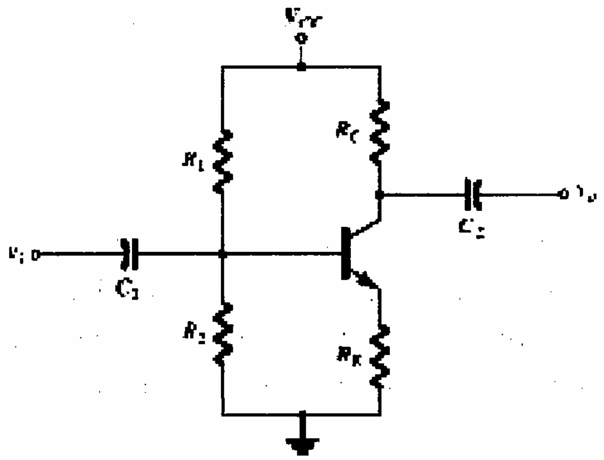


Fig (1-20) Voltage-divider bias configuration

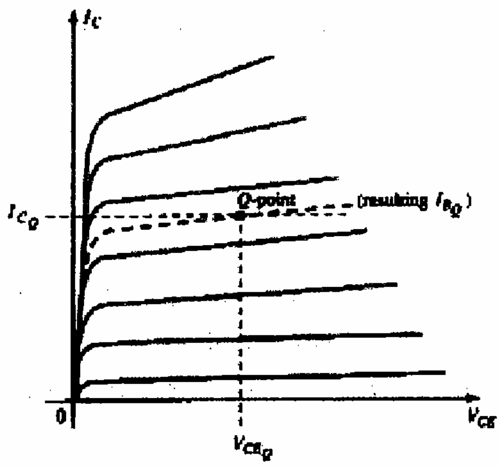


Figure (1-21)Defining the Q-point for the voltage-divider bias configuration

*Exact Analysis

The input side of the network of Fig. 1-20 can be redrawn as shown in Fig. 1-22 for the dc analysis. The Thévenin equivalent network for the network to the left of the base terminal can then be found in the following manner:

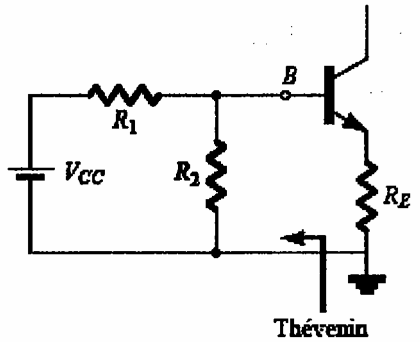


Figure (1-22) Redrawing the input side of the network of Fig. 1-20

R_{TH}: The voltage source is replaced by a short-circuit equivalent as shown in Fig. 1-23.

$$\boxed{R_{Th} = R_1 \| R_2}$$

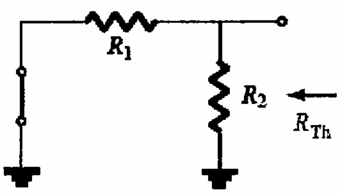
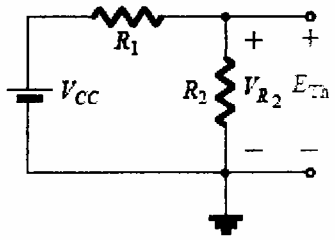


Figure (1-23) Determining R_{TH}

E_{TH}: The voltage source V_{cc} is returned to the network and the open-circuit Théevenin voltage of Fig. 1-23a determined as follows:
Applying the voltage-divider rule:

$$\boxed{E_{Th} = V_{R_2} = \frac{R_2 V_{CC}}{R_1 + R_2}}$$



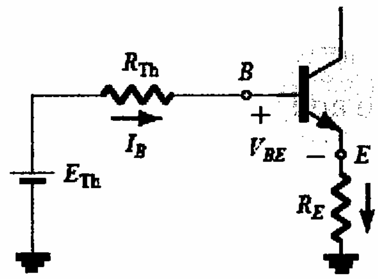
Figure(1-23a) Determining.E_{TH}

$$E_{Th} - I_B R_{Th} - V_{BE} - I_E R_E = 0$$

Substituting $I_E = (\beta + 1)I_B$ and solving for I_B yields

$$\boxed{I_B = \frac{E_{Th} - V_{BE}}{R_{Th} + (\beta + 1)R_E}}$$

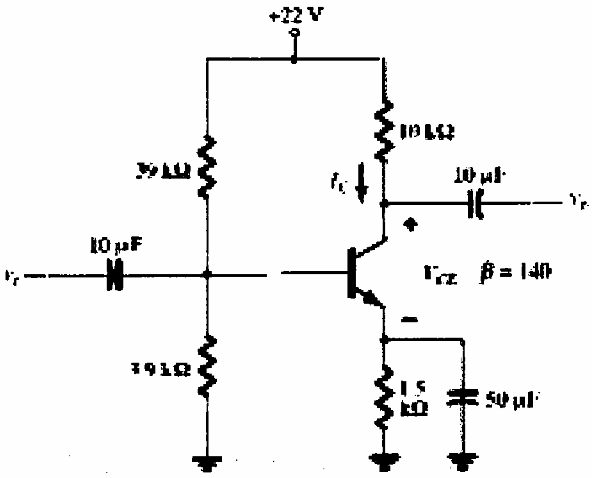
$$\boxed{V_{CE} = V_{CC} - I_C(R_C + R_E)}$$



Figure(123b)Inserting theThévenin equivalent circuit.

Example: 5

Determine the dc bias voltage$V_{CE}$and the current $I_c$for the voltage-divider configuration of Fig. 1-24



Fig(1-24)

$$R_{Th} = R_1 \| R_2$$

$$= \frac{(39\ \text{k}\Omega)(3.9\ \text{k}\Omega)}{39\ \text{k}\Omega + 3.9\ \text{k}\Omega} = 3.55\ \text{k}\Omega$$

$$E_{Th} = \frac{R_2 V_{CC}}{R_1 + R_2}$$

$$= \frac{(3.9\ \text{k}\Omega)(22\ \text{V})}{39\ \text{k}\Omega + 3.9\ \text{k}\Omega} = 2\ V$$

$$I_B = \frac{E_{Th} - V_{BE}}{R_{Th} + (\beta + 1)R_E}$$

$$= \frac{2\ \text{V} - 0.7\ \text{V}}{3.55\ \text{k}\Omega + (141)(1.5\ \text{k}\Omega)} = \frac{1.3\ \text{V}}{3.55\ \text{k}\Omega + 211.5\ \text{k}\Omega}$$

$$= 6.05\ \mu A$$

$$I_C = \beta I_B$$

$$= (140)(6.05\ \mu\text{A})$$

$$= \mathbf{0.85\ mA}$$

$$V_{CE} = V_{CC} - I_C(R_C + R_E)$$
$$= 22\text{ V} - (0.85\text{ mA})(10\text{ k}\Omega + 1.5\text{ k}\Omega)$$
$$= 22\text{ V} - 9.78\text{ V}$$
$$= \mathbf{12.22\text{ V}}$$

**Approximate Analysis*

The input section of the voltage-divider configuration can be represented by the network of Fig. 1-25. The resistance R_i is the equivalent resistance between base and ground for the transistor with an emitter resistor R_E.

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

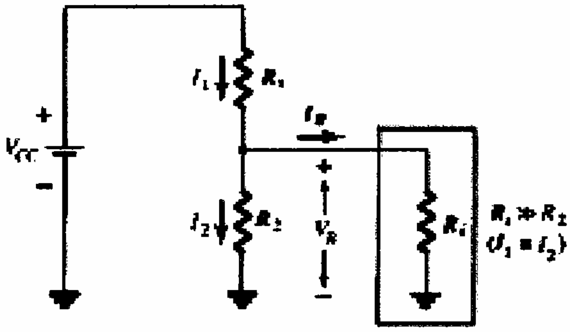


Figure 1-25 Partial-bias circuit for calculating the approximate base voltage VB.

Since $R_i = (\beta + 1)R_E \cong \beta R_E$ the condition that will define whether the approximate approach can be applied will be the following:

$$\boxed{\beta R_E \geq 10R_2}$$

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

and the emitter current can be determined from

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

$$\boxed{I_{C_Q} \cong I_E}$$

The collector-to-emitter voltage is determined by

$$V_{CE} = V_{CC} - I_C R_C - I_E R_E$$, but since $I_E \cong I_C$,

$$\boxed{V_{CE_Q} = V_{CC} - I_C(R_C + R_E)}$$

Example: 6
Repeat the analysis of Fig.5 using the approximate technique, and compare solutions for$I_{CQ} and\ V_{CQ}$.

$$\beta R_E \geq 10R_2$$
$$(140)(1.5\ \text{k}\Omega) \geq 10(3.9\ \text{k}\Omega)$$
$$210\ \text{k}\Omega \geq 39\ \text{k}\Omega\ (\textit{satisfied})$$

$$\text{Eq. (4.32):}\quad V_B = \frac{R_2 V_{CC}}{R_1 + R_2} = \frac{(3.9\ \text{k}\Omega)(22\ \text{V})}{39\ \text{k}\Omega + 3.9\ \text{k}\Omega} = 2\ \text{V}$$

Note that the level ofV_B is the same asE_{TH} determined in Example 5. Essentially, therefore, the primary difference between the exact and approximate techniques is the effect of R_{TH} in the exact analysis that separatesE_{TH} and V_B.

$$V_E = V_B - V_{BE} = 2\ \text{V} - 0.7\ \text{V} = 1.3\ \text{V}$$

$$I_{CQ} \cong I_E = \frac{V_E}{R_E} = \frac{1.3\ \text{V}}{1.5\ \text{k}\Omega} = \mathbf{0.867\ mA}$$

Compared to 0.85 mA with the exact analysis. Finally,

$$V_{CE_Q} = V_{CC} - I_C(R_C + R_E) = 22\ \text{V} - (0.867\ \text{mA})(10\ \text{kV} + 1.5\ \text{k}\Omega) = 22\ \text{V} - 9.97\ \text{V} = \mathbf{12.03\ V}$$

Example: 7
Repeat the exact analysis of Example 5 if β is reduced to 70, and compare solutions forI_{CQ} and V_{CEQ}.
Solution
This example is not a comparison of exact versus approximate methods but a testing of how much the *Q*-point will move if the level of β is cut in half.R_{TH} and E_{TH} are the same:

$$R_{Th} = 3.55\ k\Omega, \qquad E_{Th} = 2\ V$$

$$I_B = \frac{E_{Th} - V_{BE}}{R_{Th} + (\beta + 1)R_E}$$

$$= \frac{2\ V - 0.7\ V}{3.55\ k\Omega + (71)(1.5\ k\Omega)} = \frac{1.3\ V}{3.55\ k\Omega + 106.5\ k\Omega}$$

$$= 11.81\ \mu A$$

$$I_{C_Q} = \beta I_B$$

$$= (70)(11.81\ \mu A)$$

$$= 0.83\ mA$$

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

$$= 22\ V - (0.83\ mA)(10\ k\Omega + 1.5\ k\Omega)$$

$$= \mathbf{12.46\ V}$$

Tabulating the results, we have:

β	I_{C_Q} (mA)	V_{CE_Q} (V)
140	0.85	12.22
70	0.83	12.46

The results clearly show the relative insensitivity of the circuit to the change in β. Even though β is drastically cut in half, from 140 to 70, the levels of I_{C_Q} and V_{CE_Q} are essentially the same.

Example: 8

Determine the levels of I_{CQ} and V_{CEQ} for the voltage-divider configuration of Fig. 1-26 using the exact and approximate techniques and compare solutions.

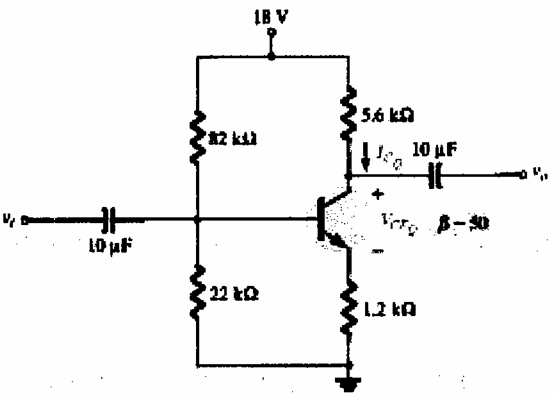


Fig (1-26)

Solution

Exact Analysis

$$\beta R_E \geq 10R_2$$

$$(50)(1.2\ \text{k}\Omega) \geq 10(22\ \text{k}\Omega)$$

$$60\ \text{k}\Omega \not\geq 220\ \text{k}\Omega\ (\textit{not satisfied})$$

$$R_{\text{Th}} = R_1 \| R_2 = 82\ \text{k}\Omega \| 22\ \text{k}\Omega = 17.35\ \text{k}\Omega$$

$$E_{\text{Th}} = \frac{R_2 V_{CC}}{R_1 + R_2} = \frac{22\ \text{k}\Omega(18\ \text{V})}{82\ \text{k}\Omega + 22\ \text{k}\Omega} = 3.81\ \text{V}$$

$$I_B = \frac{E_{\text{Th}} - V_{BE}}{R_{\text{Th}} + (\beta + 1)R_E} = \frac{3.81\ \text{V} - 0.7\ \text{V}}{17.35\ \text{k}\Omega + (51)(1.2\ \text{k}\Omega)} = \frac{3.11\ \text{V}}{78.55\ \text{k}\Omega}$$

$$= 39.6\ \mu\text{A}$$

$$I_{C_Q} = \beta I_B = (50)(39.6\ \mu\text{A}) = \mathbf{1.98\ mA}$$

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

$$= 18\ \text{V} - (1.98\ \text{mA})(5.6\ \text{k}\Omega + 1.2\ \text{k}\Omega)$$

$$= \mathbf{4.54\ V}$$

Approximate Analysis

$$V_B = E_{\text{Th}} = 3.81\ \text{V}$$

$$V_E = V_B - V_{BE} = 3.81\ \text{V} - 0.7\ \text{V} = 3.11\ \text{V}$$

$$I_{C_Q} \cong I_E = \frac{V_E}{R_E} = \frac{3.11\ \text{V}}{1.2\ \text{k}\Omega} = \mathbf{2.59\ mA}$$

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

$$= 18\ \text{V} - (2.59\ \text{mA})(5.6\ \text{k}\Omega + 1.2\ \text{k}\Omega)$$

$$= \mathbf{3.88\ V}$$

Tabulating the results, we have:

	I_{C_Q} *(mA)*	V_{CE_Q} *(V)*
Exact	1.98	4.54
Approximate	2.59	3.88

The results reveal the difference between exact and approximate solutions. I_{CQ} is about 30% greater with the approximate solution, while V_{CEQ} is about 10% less. The results are notably different in magnitude, but even though βR_E is only about three times larger than R_2, the results are still relatively close to each other.

For the future,
however, our analysis will be dictated by Eq.

$$\boldsymbol{\beta R_E \geq 10R_2}$$

to ensure a close similarity between exact and approximate solutions.

Transistor Saturation

The output collector–emitter circuit for the voltage-divider configuration has the same appearance as the emitter-biased circuit.
The resulting equation for the saturation current (when V_{CE} is set to zero volts on the schematic) is therefore the same as obtained for the emitter-biased configuration. That is,

$$\boxed{I_{C_{sat}} = I_{C_{max}} = \frac{V_{CC}}{R_C + R_E}}$$

Load-Line Analysis

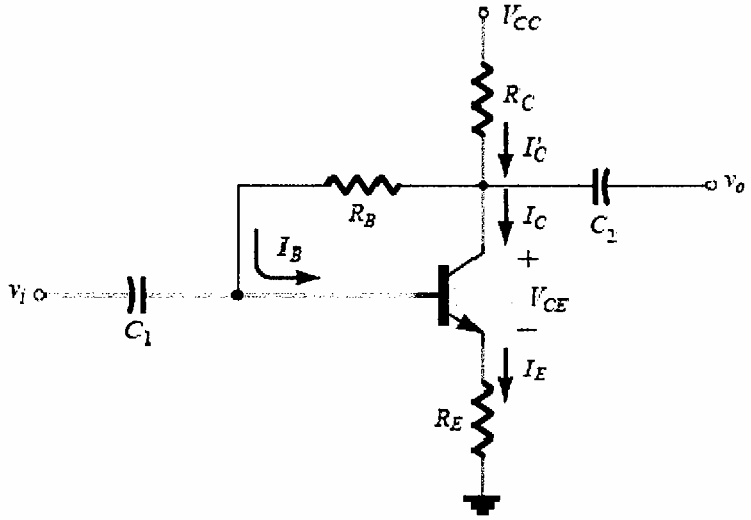
The similarities with the output circuit of the emitter-biased configuration result in the same intersections for the load line of the voltage-divider configuration. The load line will therefore have the same appearance as that of Fig. 1-19, with

$$\boxed{I_C = \frac{V_{CC}}{R_C + R_E}\bigg|_{V_{CE}=0\text{ V}}}$$

$$\boxed{V_{CE} = V_{CC}\big|_{I_C=0\text{ mA}}}$$

DC BIAS WITH VOLTAGE FEEDBACK

An improved level of stability can also be obtained by introducing a feedback path from collector to base as shown in Fig. 1-27. Although the *Q*-point is not totally independent of beta (even under approximate conditions), the sensitivity to changes in beta or temperature variations is normally less than encountered for the fixed-bias or emitter-biased configurations. The analysis will again be performed by first analyzing the base–emitter loop with the results applied to the collector–emitter loop.



Fig(1-27) dc bias circuit with voltage feedback.

*Base–Emitter Loop

Writing Kirchhoff's voltage law around the indicated loop in the clockwise direction Fig (1-28) will result in

$$V_{CC} - I'_C R_C - I_B R_B - V_{BE} - I_E R_E = 0$$

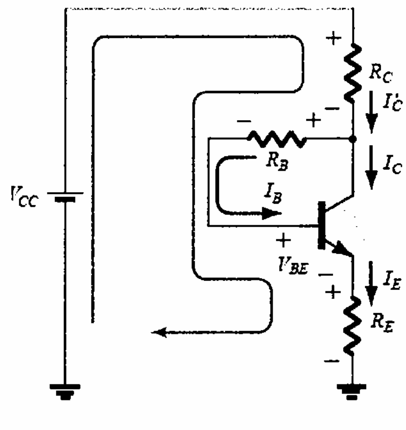


Fig (1-28)

It is important to note that the current through R_C is not I_C but I'_C (where $I'_C = I_C + I_B$). However, the level of I_C and I'_C far exceeds the usual level of I_B and the approximation $I'_C \cong I_C$ is normally employed. Substituting $I'_C \cong I_C = \beta I_B$ and $I_E \cong I_C$ will result in

$$V_{CC} - \beta I_B R_C - I_B R_B - V_{BE} - \beta I_B R_E = 0$$

$$V_{CC} - V_{BE} - \beta I_B(R_C + R_E) - I_B R_B = 0$$

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

*Collector–Emitter Loop

Applying Kirchhoff's voltage law around the indicated loop in the clockwise direction in fig (1-29) will result in

$$I_E R_E + V_{CE} + I_C' R_C - V_{CC} = 0$$

Since $I_C' \cong I_C$ and $I_E \cong I_C$, we have

$$I_C(R_C + R_E) + V_{CE} - V_{CC} = 0$$

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

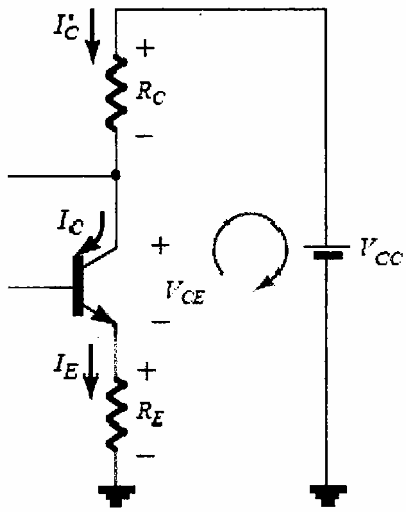


Fig (1-29)

Example: 9

Determine the quiescent levels of I_{CQ} and V_{CEQ} for the network of Fig 1-30

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

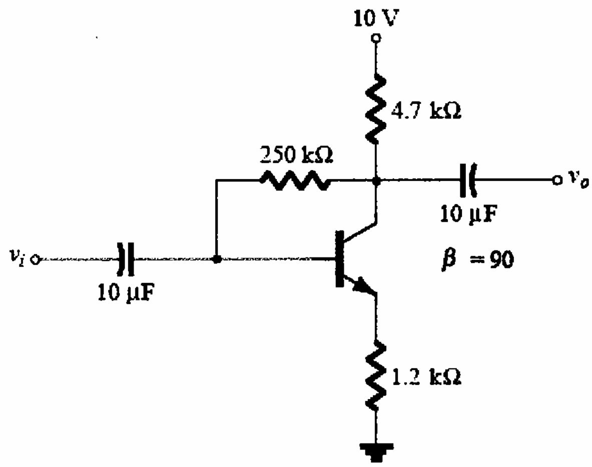
$$= \frac{10\text{ V} - 0.7\text{ V}}{250\text{ k}\Omega + (90)(4.7\text{ k}\Omega + 1.2\text{ k}\Omega)}$$

$$= \frac{9.3\text{ V}}{250\text{ k}\Omega + 531\text{ k}\Omega} = \frac{9.3\text{ V}}{781\text{ k}\Omega}$$

$$= 11.91\ \mu\text{A}$$

$$I_{C_Q} = \beta I_B = (90)(11.91\ \mu\text{A})$$

$$= \mathbf{1.07\ mA}$$



Fig(1-30)

$$V_{CE_Q} = V_{CC} - I_C(R_C + R_E)$$
$$= 10\text{ V} - (1.07\text{ mA})(4.7\text{ k}\Omega + 1.2\text{ k}\Omega)$$
$$= 10\text{ V} - 6.31\text{ V}$$
$$= \mathbf{3.69\text{ V}}$$

Example:10

Determine the dc level of I_B and V_C for the network of Fig.(1-31).

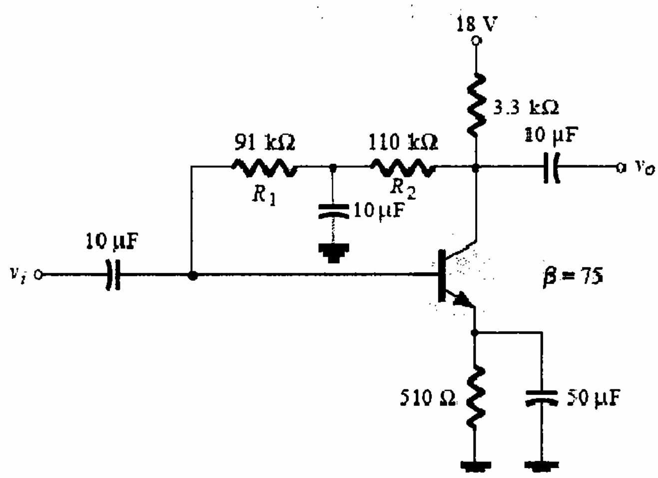


Fig (1-31)

Solution

$$I_B = \frac{V_{CC} - V_{BE}}{R_B + \beta(R_C + R_E)}$$
$$= \frac{18\text{ V} - 0.7\text{ V}}{(91\text{ k}\Omega + 110\text{ k}\Omega) + (75)(3.3\text{ k}\Omega + 0.51\text{ k}\Omega)}$$

$$= \frac{17.3\text{ V}}{201\text{ k}\Omega + 285.75\text{ k}\Omega} = \frac{17.3\text{ V}}{486.75\text{ k}\Omega}$$
$$= \mathbf{35.5\ \mu A}$$

$$I_C = \beta I_B$$
$$= (75)(35.5\ \mu\text{A})$$
$$= 2.66\text{ mA}$$

$$V_C = V_{CC} - I'_C R_C \cong V_{CC} - I_C R_C$$
$$= 18\text{ V} - (2.66\text{ mA})(3.3\text{ k}\Omega)$$
$$= 18\text{ V} - 8.78\text{ V}$$
$$= \mathbf{9.22\text{ V}}$$

Saturation Conditions

Using the approximation $I'_C = I_C$, the equation for the saturation current is the same as obtained for the voltage-divider and emitter-bias configurations. That is,

$$I_{C_{sat}} = I_{C_{max}} = \frac{V_{CC}}{R_C + R_E}$$

Load-Line Analysis

Continuing with the approximation $I'_C = I_C$ will result in the same load line defined for the voltage-divider and emitter-biased configurations. The level of I_{B_Q} will be defined by the chosen bias configuration.

Example:11

For the network of Fig. 1-32:

(a) Determine I_{CQ} and V_{CEQ}.

(b) Find V_B, V_C and V_{BC}.

(a)

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

$$= \frac{20\text{ V} - 0.7\text{ V}}{680\text{ k}\Omega + (120)(4.7\text{ k}\Omega)} = \frac{19.3\text{ V}}{1.244\text{ M}\Omega}$$

$$= 15.51\ \mu\text{A}$$

$$I_{C_Q} = \beta I_B = (120)(15.51\ \mu\text{A})$$

$$= \mathbf{1.86\ mA}$$

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

$$= 20\text{ V} - (1.86\text{ mA})(4.7\text{ k}\Omega)$$

$$= \mathbf{11.26\ V}$$

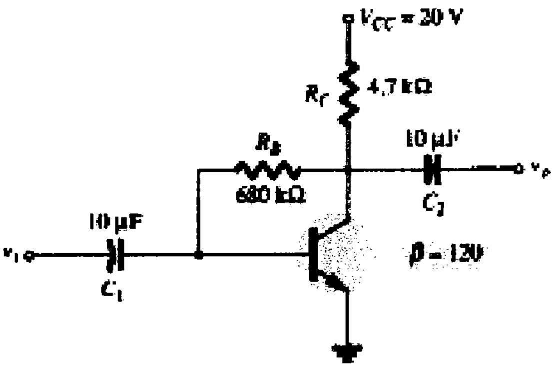


Fig (1-32)

(b)

$$V_B = V_{BE} = \mathbf{0.7\ V}$$

$$V_C = V_{CE} = \mathbf{11.26\ V}$$

$$V_E = \mathbf{0\ V}$$

$$V_{BC} = V_B - V_C = 0.7\text{ V} - 11.26\text{ V}$$

$$= \mathbf{-10.56\ V}$$

Example:12

Determine *VC* and *VB* for the network of Fig. 1-33

Solution

Applying Kirchhoff's voltage law in the clockwise direction for the base–emitter loop will result in

$$-I_B R_B - V_{BE} + V_{EE} = 0$$

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

$$I_B = \frac{9\text{ V} - 0.7\text{ V}}{100\text{ k}\Omega}$$

$$= \frac{8.3\text{ V}}{100\text{ k}\Omega}$$

$$= 83\ \mu\text{A}$$

$$I_C = \beta I_B$$

$$= (45)(83\ \mu\text{A})$$

$$= 3.735\text{ mA}$$

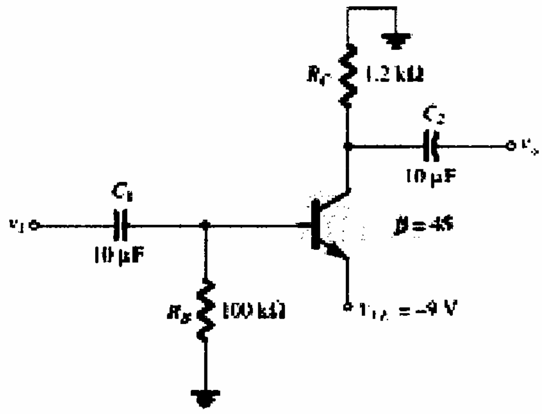


Fig (1-33)

$$V_C = -I_C R_C$$

$$= -(3.735\text{ mA})(1.2\text{ k}\Omega)$$

$$= \mathbf{-4.48\text{ V}}$$

$$V_B = -I_B R_B$$

$$= -(83\ \mu\text{A})(100\text{ k}\Omega)$$

$$= \mathbf{-8.3\text{ V}}$$

Example: 13

Determine V_{CEQ} *and* I_E for the Common-collector (**emitter-follower**) configuration.

Shown in Fig. 1-34

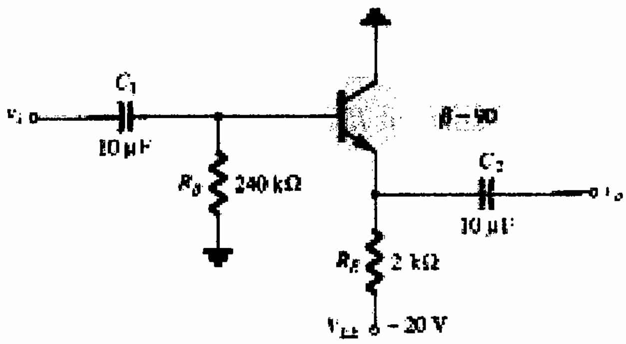


Figure (1-34) emitter-follower configuration.

Applying Kirchhoff's voltage law to the input circuit will result in

$$-I_B R_B - V_{BE} - I_E R_E + V_{EE} = 0$$

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

$$V_{EE} - V_{BE} - (\beta + 1)I_B R_E - I_B R_B = 0$$

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

$$I_B = \frac{20\text{ V} - 0.7\text{ V}}{240\text{ k}\Omega + (91)(2\text{ k}\Omega)}$$

$$= \frac{19.3\text{ V}}{240\text{ k}\Omega + 182\text{ k}\Omega} = \frac{19.3\text{ V}}{422\text{ k}\Omega}$$

$$= 45.73\ \mu\text{A}$$

$$I_C = \beta I_B$$

$$= (90)(45.73\ \mu\text{A})$$

$$= 4.12\text{ mA}$$

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

$$-V_{EE} + I_E R_E + V_{CE} = 0$$

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

$$V_{CE_Q} = V_{EE} - (\beta + 1)I_B R_E$$

$$= 20\text{ V} - (91)(45.73\ \mu\text{A})(2\text{ k}\Omega)$$

$$= \mathbf{11.68\ V}$$

$$I_E = \mathbf{4.16\ mA}$$

Example: 14

Determine the voltage V_{CB} and the current *IB* for the common-base configuration of Fig. (1.35)

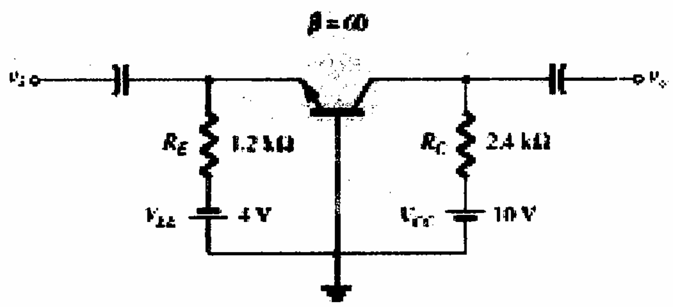


Figure (1-35) Common-base configuration

Solution

Applying Kirchhoff's voltage law to the input circuit yields

$$-V_{EE} + I_E R_E + V_{BE} = 0$$

$$I_E = \frac{V_{EE} - V_{BE}}{R_E}$$

$$I_E = \frac{4\text{ V} - 0.7\text{ V}}{1.2\text{ k}\Omega} = 2.75\text{ mA}$$

Applying Kirchhoff's voltage law to the output circuit gives

$$-V_{CB} + I_C R_C - V_{CC} = 0$$

$$V_{CB} = V_{CC} - I_C R_C \text{ with } I_C \cong I_E$$

$$= 10\text{ V} - (2.75\text{ mA})(2.4\text{ k}\Omega)$$

$$= \mathbf{3.4\text{ V}}$$

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

$$= \frac{2.75\text{ mA}}{60}$$

$$= \mathbf{45.8\ \mu A}$$

Example: 15

Determine *VC* and *VB* for the network of Fig. 1-36.

Solution

The Thévenin resistance and voltage are determined for the network to the left of the base terminal as shown in Figs. (1-36a) and(1-36b).

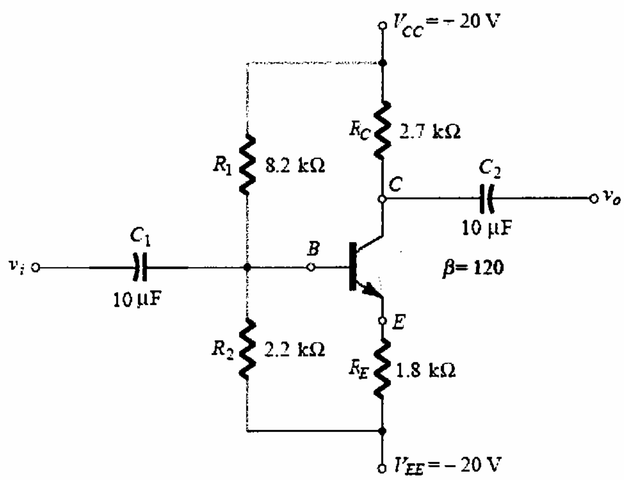


Fig (1-36)

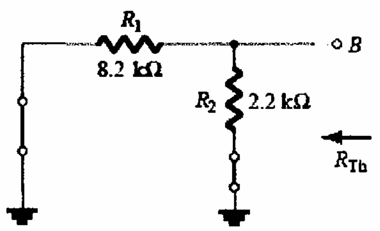


Figure 1-36a Determining RTh.

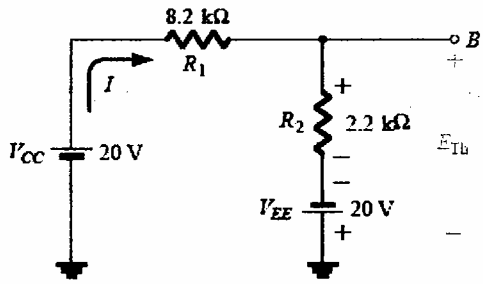


Figure 1-36b Determining Eth

$$R_{Th} = 8.2\ k\Omega \| 2.2\ k\Omega = 1.73\ k\Omega$$

$$I = \frac{V_{CC} + V_{EE}}{R_1 + R_2} = \frac{20\ V + 20\ V}{8.2\ k\Omega + 2.2\ k\Omega} = \frac{40\ V}{10.4\ k\Omega}$$

$$= 3.85\ mA$$

$$E_{Th} = IR_2 - V_{EE}$$

$$= (3.85\ mA)(2.2\ k\Omega) - 20\ V$$

$$= -11.53\ V$$

The network can then be redrawn as shown in Fig. 1-36c, where the application of Kirchhoff's voltage law will result in

$$-E_{Th} - I_B R_{Th} - V_{BE} - I_E R_E + V_{EE} = 0$$

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

$$V_{EE} - E_{Th} - V_{BE} - (\beta + 1)I_B R_E - I_B R_{Th} = 0$$

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

$$= \frac{20\ V - 11.53\ V - 0.7\ V}{1.73\ k\Omega + (121)(1.8\ k\Omega)}$$

$$= \frac{7.77\ V}{219.53\ k\Omega}$$

$$= 35.39\ \mu A$$

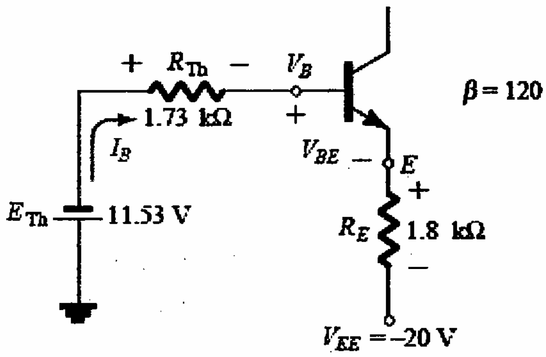


Figure 1-36c Substituting the Thévenin equivalent circuit.

$$I_C = \beta I_B$$
$$= (120)(35.39\ \mu A)$$
$$= 4.25\ mA$$
$$V_C = V_{CC} - I_C R_C$$
$$= 20\ V - (4.25\ mA)(2.7\ k\Omega)$$
$$= \mathbf{8.53\ V}$$

$$V_B = -E_{Th} - I_B R_{Th}$$
$$= -(11.53\ V) - (35.39\ \mu A)(1.73\ k\Omega)$$
$$= \mathbf{-11.59\ V}$$

DESIGN OPERATIONS

EXAMPLE: 16

Given the device characteristics of Fig. 1-37a, determine V_{CC}, R_B *and* R_c for the fixed bias configuration of Fig. 1-37b.

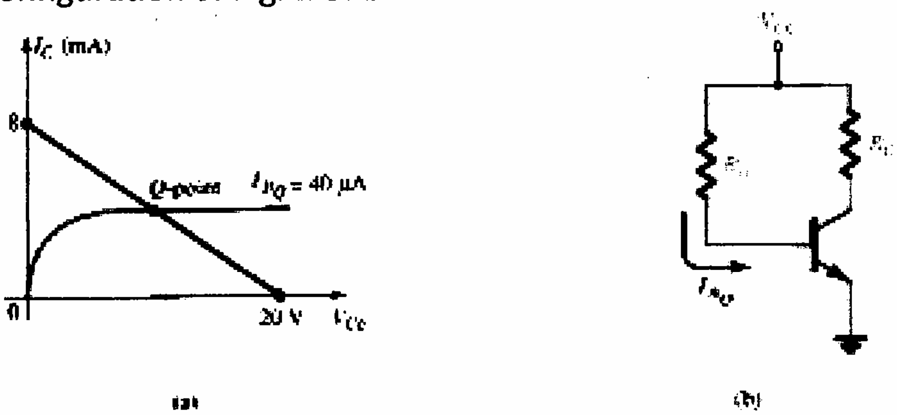


Fig (1-37) a. Characteristics device b. Fixed bias circuit

Solution

From the load line

$$V_{CC} = 20\ V$$

$$I_C = \left.\frac{V_{CC}}{R_C}\right|_{V_{CE} = 0\,V}$$

$$R_C = \frac{V_{CC}}{I_C} = \frac{20\ V}{8\ mA} = 2.5\ k\Omega$$

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

$$R_B = \frac{V_{CC} - V_{BE}}{I_B}$$
$$= \frac{20\text{ V} - 0.7\text{ V}}{40\ \mu\text{A}} = \frac{19.3\text{ V}}{40\ \mu\text{A}}$$
$$= \mathbf{482.5\ k\Omega}$$

Standard resistor values:

$$R_C = 2.4\ \text{k}\Omega$$
$$R_B = 470\ \text{k}\Omega$$

Using standard resistor values gives

$$I_B = 41.1\ \mu\text{A}$$

This is well within 5% of the value specified

Example: 17

Design a voltage divider bias cct. That given $I_{CQ} = 2mA$, and $V_{CEQ} = 10V$ for the cct. Shown in fig (1-38)

$$V_E = I_E R_E \cong I_C R_E$$
$$= (2\text{ mA})(1.2\text{ k}\Omega) = 2.4\text{ V}$$
$$V_B = V_{BE} + V_E = 0.7\text{ V} + 2.4\text{ V} = 3.1\text{ V}$$

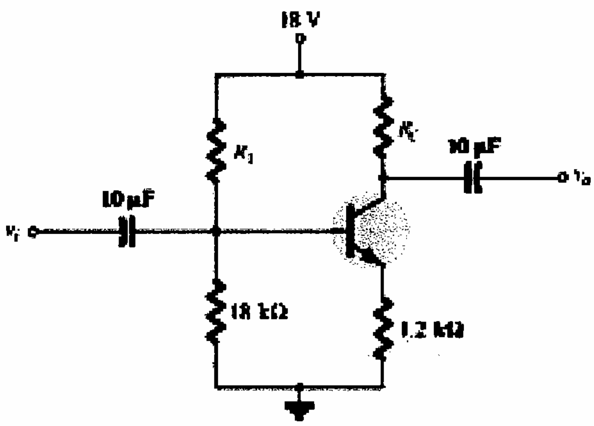


Fig (1-38) voltage divider bias

$$V_B = \frac{R_2 V_{CC}}{R_1 + R_2} = 3.1\text{ V}$$
$$\frac{(18\text{ k}\Omega)(18\text{ V})}{R_1 + 18\text{ k}\Omega} = 3.1\text{ V}$$

$$324\text{ k}\Omega = 3.1R_1 + 55.8\text{ k}\Omega$$
$$3.1R_1 = 268.2\text{ k}\Omega$$
$$R_1 = \frac{268.2\text{ k}\Omega}{3.1} = \mathbf{86.52\ k\Omega}$$

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

$$V_C = V_{CE} + V_E = 10\text{ V} + 2.4\text{ V} = 12.4\text{ V}$$

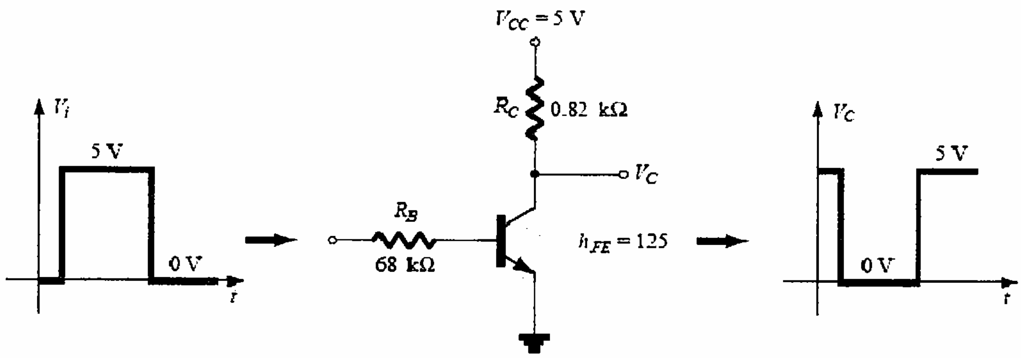
$$R_C = \frac{18\text{ V} - 12.4\text{V}}{2\text{mA}}$$

$$= \mathbf{2.8\ k\Omega}$$

TRANSISTOR SWITCHING NETWORKS

The application of transistors is not limited solely to the amplification of signals. Through proper design it can be used as a switch for computer and control applications.

The network of Fig (1-39) can be employed as an *inverter* in computer logic circuitry. Note that the output voltage V_C is opposite to that applied to the base or input terminal



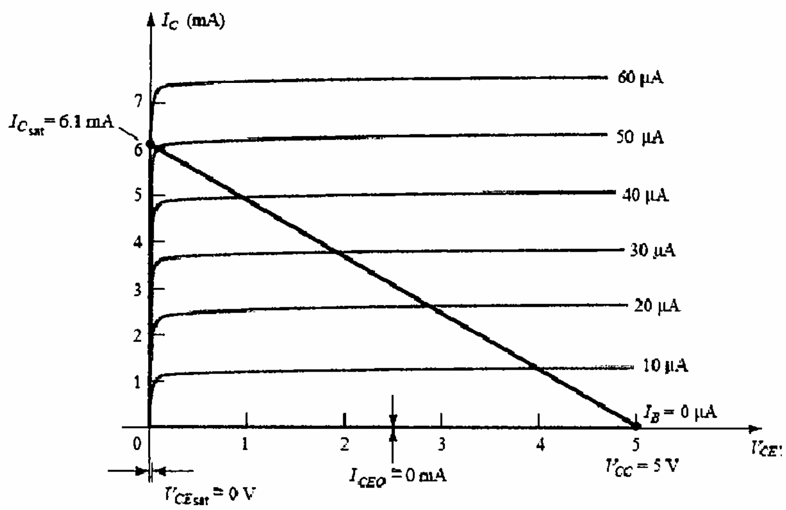


Figure (1-39) Transistor inverter.

$$\boxed{I_{C_{sat}} = \frac{V_{CC}}{R_C}}$$

The level of I_B in the active region just before saturation results can be approximated by the following equation:

$$I_{B_{max}} \cong \frac{I_{C_{sat}}}{\beta_{dc}}$$

For the saturation level we must therefore ensure that the following condition is satisfied:

$$\boxed{I_B > \frac{I_{C_{sat}}}{\beta_{dc}}}$$

For the network of Fig.1-39b, when *Vi* = 5 V, the resulting level of I_B is the following:

$$I_B = \frac{V_i - 0.7\ \text{V}}{R_B} = \frac{5\ \text{V} - 0.7\ \text{V}}{68\ \text{k}\Omega} = 63\ \mu\text{A}$$

$$I_{C_{sat}} = \frac{V_{CC}}{R_C} = \frac{5\ \text{V}}{0.82\ \text{k}\Omega} \cong 6.1\ \text{mA}$$

Testing Eq. (I_B) gives

$$I_B = 63\ \mu\text{A} > \frac{I_{C_{sat}}}{\beta_{dc}} = \frac{6.1\ \text{mA}}{125} = 48.8\ \mu\text{A}$$

which is satisfied. Certainly, any level of I_B greater than 60 μA will pass through a *Q*-point on the load line that is very close to the vertical axis.

For *Vi*= 0 V, I_B = 0 µA, and since we are assuming that $I_c = I_{CEO}$ = 0mA, the voltage drop acrossR_C as determined by$V_c = I_C R_C = 0V$, resulting in V_c=5 V for the response indicated in Fig. 1-39a.