Tikrit university

Collage of Engineering Shirqat

Department of Electrical Engineering

Second Class

Electronic I

Chapter 4

DC Biasing—BJTs

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6.4 Collector Feedback Configuration

An improved level of stability can also be obtained by introducing a feedback path from collector to base as shown in Fig. 38. Although the Q-point is not totally independent of beta (even under approximate conditions), the sensitivity to changes in beta or temperature variations are normally less than encountered for the fixed-bias or emitter-biased configurations. The analysis will again be performed by first analysing the base–emitter loop, with the results then applied to the collector–emitter loop.

base–emitter Loop Figure 39 shows the base–emitter loop for the voltage feedback configuration. Writing Kirchhoff's voltage law around the indicated loop in the clockwise direction will result in

VCC - ICRC - IBRF - VBE - IERE = 0

It is important to note that the current through RC is not IC, but IC (where IC^- = IC + IB). However, the level of IC and IC^- far exceeds the usual level of IB, and the approximation IC^-≈ IC is normally employed. Substituting IC^-≈ IC = βIB and IE ≈ IC results in

VCC - βIBRC - IBRF - VBE - βIBRE = 0

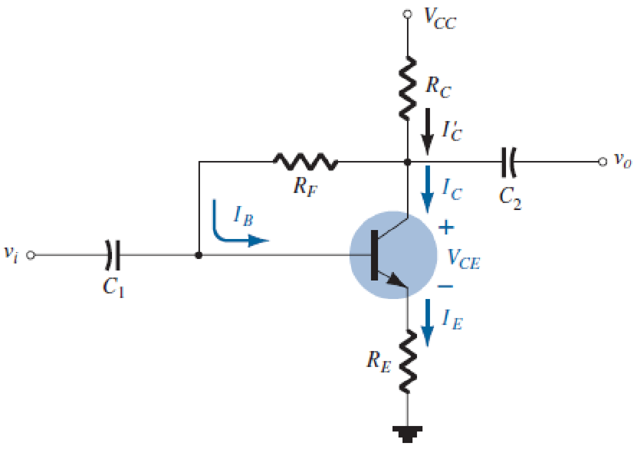

FIG. 38
DC bias circuit with voltage feedback.

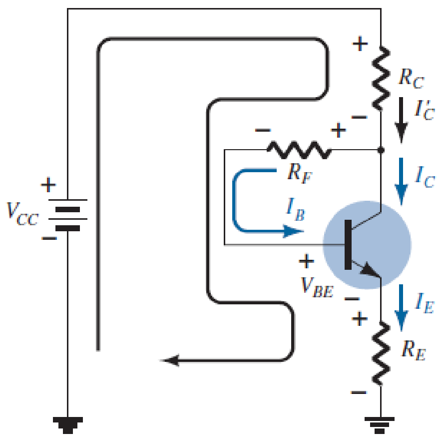

FIG. 39
Base–emitter loop for the network of Fig. 38.

Gathering terms, we have

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

and solving for I_B yields

$$\boxed{I_B = \frac{V_{CC} - V_{BE}}{R_F + \beta(R_C + R_E)}} \qquad (41)$$

Collector–emitter Loop

The collector–emitter loop for the network of Fig. 38 is provided in Fig. 40. Applying Kirchhoff's voltage law around the indicated loop in the clockwise direction results in

$IERE + VCE + IC^{-}RC - VCC = 0$

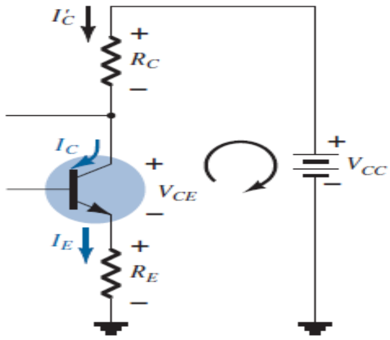

FIG. 40
Collector–emitter loop for the network of Fig. 38.

Because $I'_C \cong I_C$ and $I_E \cong I_C$, we have

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

and

$$\boxed{V_{CE} = V_{CC} - I_C(R_C + R_E)} \qquad (42)$$

which is exactly as obtained for the emitter-bias and voltage-divider bias configurations.

EXAMPLE 12 Determine the quiescent levels of I_{C_Q} and V_{CE_Q} for the network of Fig. 41.

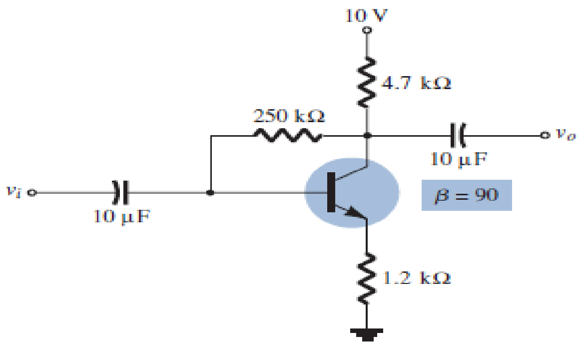

FIG. 41
Network for Example 12.

Solution: Eq. (41):

$$
\begin{aligned}
I_B &= \frac{V_{CC} - V_{BE}}{R_F + \beta(R_C + R_E)} \\
&= \frac{10\text{ V} - 0.7\text{ V}}{250\text{ k}\Omega + (90)(4.7\text{ k}\Omega + 1.2\text{ k}\Omega)} \\
&= \frac{9.3\text{ V}}{250\text{ k}\Omega + 531\text{ k}\Omega} = \frac{9.3\text{ V}}{781\text{ k}\Omega} \\
&= 11.91\ \mu\text{A} \\
I_{C_Q} &= \beta I_B = (90)(11.91\ \mu\text{A}) \\
&= \mathbf{1.07\ mA} \\
V_{CE_Q} &= V_{CC} - I_C(R_C + R_E) \\
&= 10\text{ V} - (1.07\text{ mA})(4.7\text{ k}\Omega + 1.2\text{ k}\Omega) \\
&= 10\text{ V} - 6.31\text{ V} \\
&= \mathbf{3.69\ V}
\end{aligned}
$$

EXAMPLE 14 Determine the dc level of I_B and V_C for the network of Fig. 42.

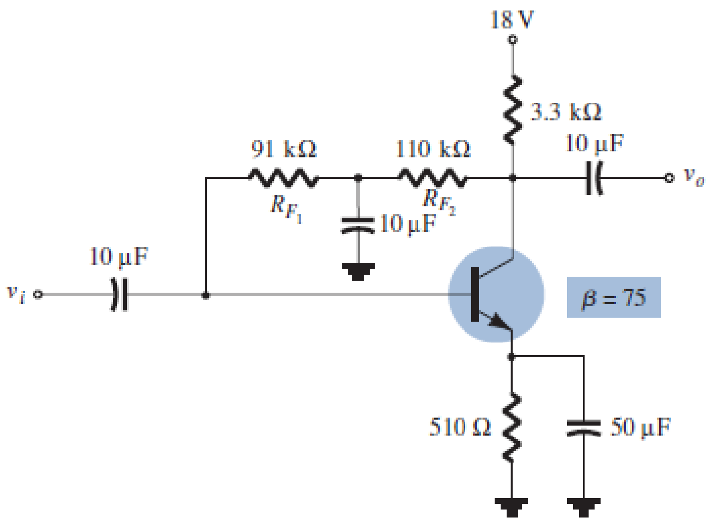

FIG. 42
Network for Example 14.

Solution: In this case, the base resistance for the dc analysis is composed of two resistors with a capacitor connected from their junction to ground. For the dc mode, the capacitor assumes the open-circuit equivalence, and $R_B = R_{F_1} + R_{F_2}$.

Solving for I_B gives

$$\begin{aligned}
I_B &= \frac{V_{CC} - V_{BE}}{R_B + \beta(R_C + R_E)} \\
&= \frac{18\text{ V} - 0.7\text{ V}}{(91\text{ k}\Omega + 110\text{ k}\Omega) + (75)(3.3\text{ k}\Omega + 0.51\text{ k}\Omega)} \\
&= \frac{17.3\text{ V}}{201\text{ k}\Omega + 285.75\text{ k}\Omega} = \frac{17.3\text{ V}}{486.75\text{ k}\Omega} \\
&= \mathbf{35.5\ \mu A}
\end{aligned}$$

$$\begin{aligned}
I_C &= \beta I_B \\
&= (75)(35.5\ \mu\text{A}) \\
&= 2.66\text{ mA} \\
V_C &= V_{CC} - I_C' R_C \cong V_{CC} - I_C R_C \\
&= 18\text{ V} - (2.66\text{ mA})(3.3\text{ k}\Omega) \\
&= 18\text{ V} - 8.78\text{ V} \\
&= \mathbf{9.22\ V}
\end{aligned}$$

Saturation Conditions

Using the approximation $IC^{-} = IC$, we find that the equation for the saturation current is the

same as obtained for the voltage-divider and emitter-bias configurations. That is,

$$\boxed{I_{C_{sat}} = I_{C_{max}} = \frac{V_{CC}}{R_C + R_E}} \qquad (43)$$

Load-Line analysis

Continuing with the approximation $IC^{-} = IC$ results in the same load line defined for the voltage-divider and emitter-biased configurations. The level of IBQ is defined by the chosen bias configuration.

EXAMPLE 15 Given the network of Fig. 43 and the BJT characteristics of Fig. 44.

a. Draw the load line for the network on the characteristics.
b. Determine the dc beta in the center region of the characteristics. Define the chosen point as the Q-point.
c. Using the dc beta calculated in part b, find the dc value of I_B.
d. Find I_{C_Q} and I_{CE_Q}.

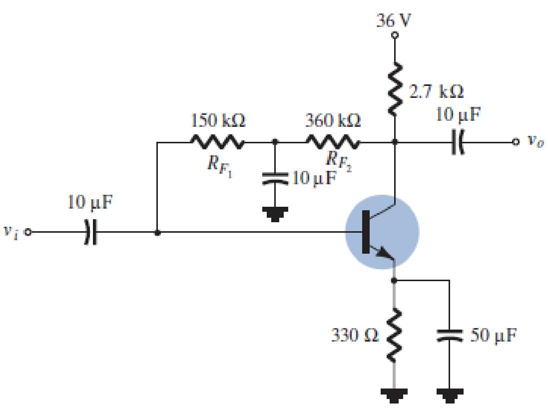

FIG. 43
Network for Example 15.

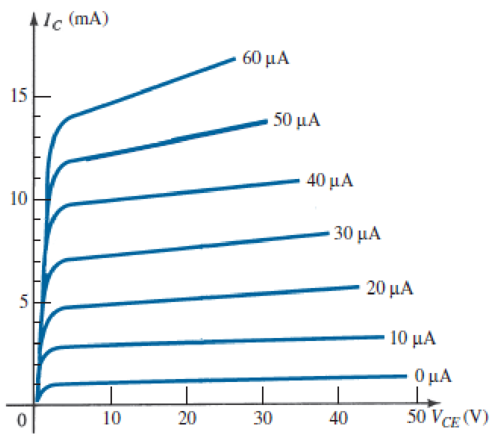

FIG. 44
BJT characteristics.

Solution:

a. The load line is drawn on Fig. 45 as determined by the following intersections:

$$V_{CE} = 0\text{ V}: I_C = \frac{V_{CC}}{R_C + R_E} = \frac{36\text{ V}}{2.7\text{ k}\Omega + 330\ \Omega} = \mathbf{11.88\ mA}$$

$$I_C = 0\text{ mA}: V_{CE} = V_{CC} = \mathbf{36\ V}$$

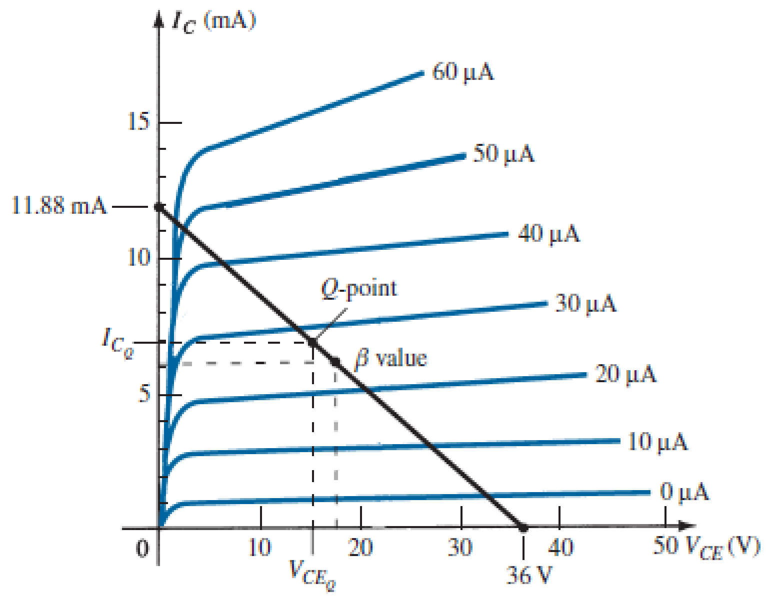

FIG. 45
Defining the Q-point for the voltage-divider bias configuration of Fig. 43.

b. The dc beta was determined using $I_B = 25\ \mu A$ and V_{CE} about 17 V.

$$\beta \cong \frac{I_{C_Q}}{I_{B_Q}} = \frac{6.2\text{ mA}}{25\ \mu\text{A}} = \mathbf{248}$$

c. Using Eq. 41:

$$I_B = \frac{V_{CC} - V_{BE}}{R_B + \beta(R_C + R_E)} = \frac{36\text{ V} - 0.7\text{ V}}{510\text{ k}\Omega + 248(2.7\text{ k}\Omega + 330\ \Omega)}$$

$$= \frac{35.3\text{ V}}{510\text{ k}\Omega + 751.44\text{ k}\Omega}$$

and $I_B = \dfrac{35.3\text{ V}}{1.261\text{ M}\Omega} = \mathbf{28\ \mu A}$

d. From Fig. 45 the quiescent values are

$I_{C_Q} \cong$ **6.9 mA** and $V_{CE_Q} \cong$ **15 V**

7.4 Emitter-Follower Configuration

The previous sections introduced configurations in which the output voltage is typically taken off the collector terminal of the BJT. This section will examine a configuration where the output is taken off the emitter terminal as shown in Fig. 46. The configuration of Fig. 46 is not the only one where the output can be taken off the emitter terminal. In fact, any of the configurations just described can be used so long as there is a resistor in the emitter leg.

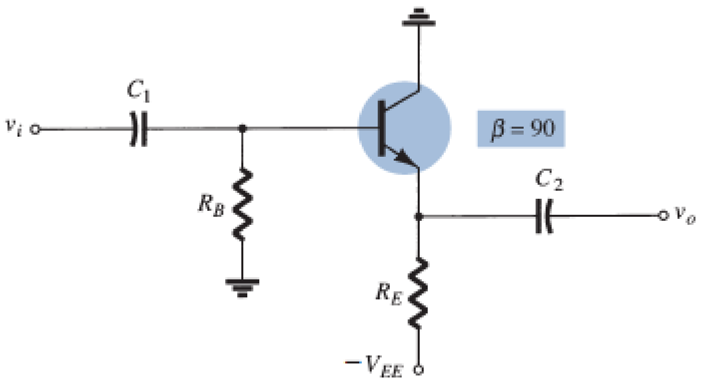

FIG. 46
Common-collecter (emitter-follower) configuration.

The dc equivalent of the network of Fig. 46 appears in Fig. 47

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

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

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

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

so that

$$\boxed{I_B = \frac{V_{EE} - V_{BE}}{R_B + (\beta + 1)R_E}} \qquad (44)$$

For the output network, an application of Kirchhoff's voltage law will result in

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

and

$$\boxed{V_{CE} = V_{EE} - I_E R_E} \qquad (45)$$

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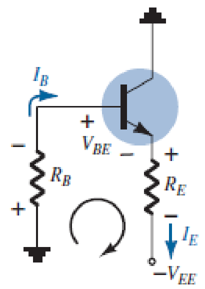

FIG. 47
dc equivalent of Fig. 46.

EXAMPLE 16 Determine V_{CE_Q} and I_{E_Q} for the network of Fig. 48.

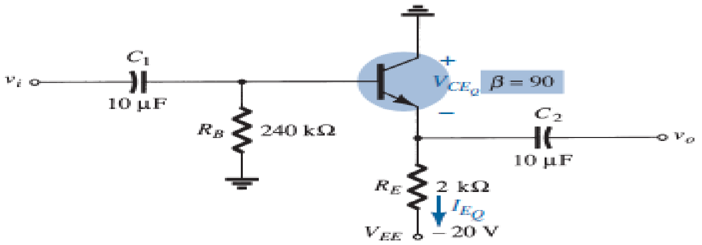

FIG. 48
Example 16.

Solution:

Eq. 44:
$$I_B = \frac{V_{EE} - V_{BE}}{R_B + (\beta + 1)R_E}$$
$$= \frac{20\text{ V} - 0.7\text{ V}}{240\text{ k}\Omega + (90 + 1)2\text{ k}\Omega} = \frac{19.3\text{ V}}{240\text{ k}\Omega + 182\text{ k}\Omega}$$
$$= \frac{19.3\text{ V}}{422\text{ k}\Omega} = 45.73\ \mu\text{A}$$

and Eq. 45:
$$\begin{aligned} V_{CE_Q} &= V_{EE} - I_E R_E \\ &= V_{EE} - (\beta + 1)I_B R_E \\ &= 20\text{ V} - (90 + 1)(45.73\ \mu\text{A})(2\text{ k}\Omega) \\ &= 20\text{ V} - 8.32\text{ V} \\ &= \mathbf{11.68\ V} \end{aligned}$$
$$\begin{aligned} I_{E_Q} &= (\beta + 1)I_B = (91)(45.73\ \mu\text{A}) \\ &= 4.16\text{ mA} \end{aligned}$$