كلية مدينة العلم الجامعة
قسم هندسة الحاسوب

محاضرات المرحلة الاولى لمادة الهندسة الالكترونية

اعداد
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DC Biasing

المحاضرة الخامسة

References

Text Books :

1-ELECTRONIC DEVICES AND CIRCUIT THEORY

Eleventh Edition By

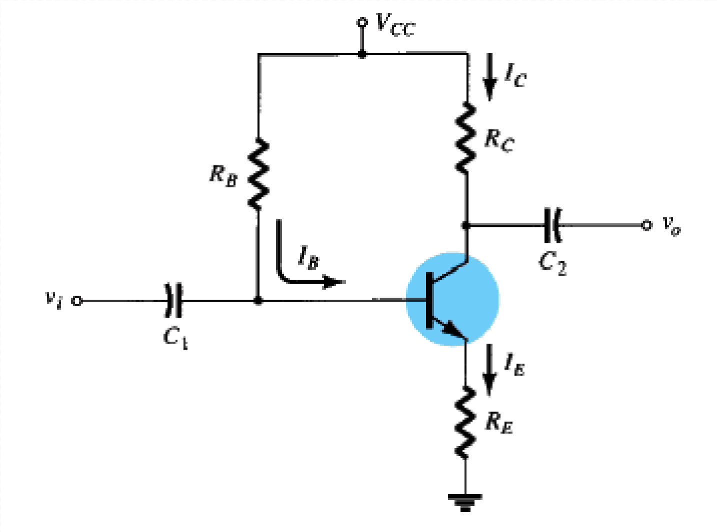
Robert L. Boylestad and Louis Nashelsky

2-ELECTRONIC DEVICES

Ninth Edition By

Thomas L. Floyd

DC Biasing



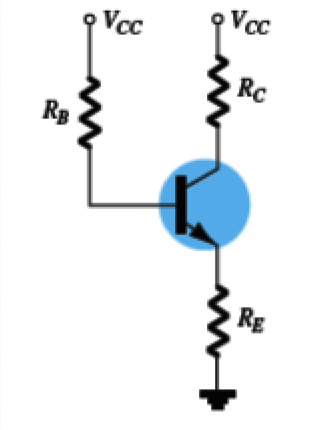
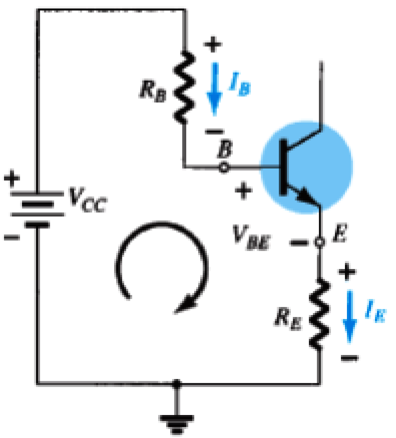


FIG. 4.18
DC equivalent of Fig. 4.17.



Base–emitter loop.

2-EMITTER-BIAS CONFIGURATION

The dc bias network of the above Fig. contains an emitter resistor to improve the stability level over that of the fixed-bias configuration. The more stable a configuration, the less its response will change due to undesirable changes in temperature and parameter variations. The improved stability will be demonstrated through a numerical example later in the section. The analysis will be performed by first examining the base–emitter loop and then using the results to investigate the collector–emitter loop. The dc equivalent of the circuit appears in Fig. on right with a separation of the source to create an input and output section

DC Biasing

Base–Emitter Loop

Writing Kirchhoff's voltage law around the loop in the Base–Emitter Loop results in the following equation:

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

Recall that

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

Substituting for I_E

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

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

with

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

and solving for I_B gives

$$I_B = V_{CC} - V_{BE} / R_B + (\beta + 1) R_E \quad *$$

Note that the only difference between this equation for I_B and that obtained for the fixed bias configuration is the term $(\beta + 1)\, R_E$.

DC Biasing

Collector–Emitter Loop

Writing Kirchhoff's voltage law for the indicated loop in the clockwise direction results in

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

Substituting $IE \cong IC$ and grouping terms gives

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

and

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

The single-subscript voltage V_E is the voltage from emitter to ground and is determined By :

$$V_E = I_E R_E$$

whereas the voltage from collector to ground can be determined from

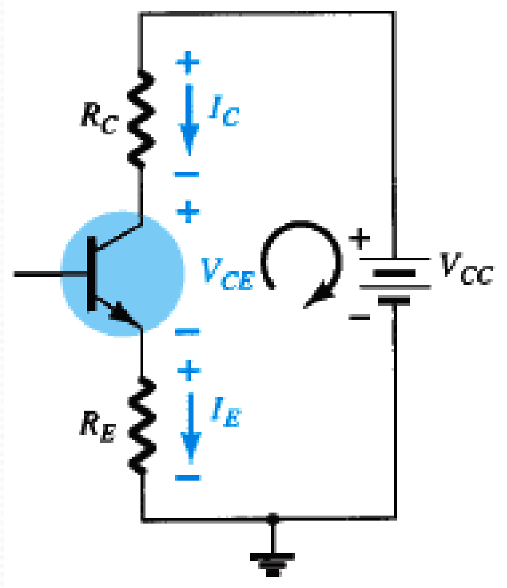
$$V_{CE} = V_C - V_E$$

and

$$V_C = V_{CE} + V_E$$

or

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



Collector–emitter loop.

The voltage at the base with respect to ground can be determined from

$$V_B = V_{CC} - I_B R_B$$

Or

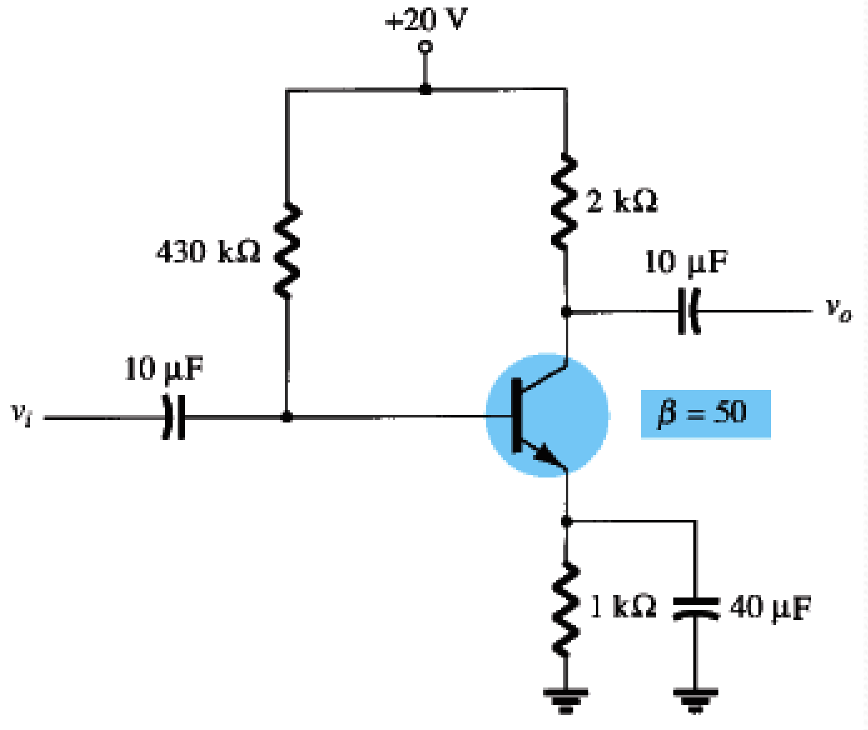
$$V_B = V_{BE} + V_E$$

DC Biasing

Example 7

For the emitter-bias network in the following Fig. determine:

a). I_B. b). I_C. c). V_{CE}. d). V_C. e). V_E. f). V_B. g). V_{BC}.



Emitter-stabilized bias circuit.

DC Biasing

Solution:

a. $I_B = V_{CC} - V_{BE} / R_B + (\beta + 1) R_E$

$= 20\text{ V} - 0.7\text{ V} / 430\text{ k}\Omega + (51)(1\text{ k}\Omega)$

$= 19.3\text{ V} / 481\text{ k}\Omega$

$= 40.1\text{ mA}$

b. $I_C = \beta I_B$

$= (50)(40.1\text{ mA}) \cong 2.01\text{ mA}$

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

$= 20\text{ V} - (2.01\text{ mA})(2\text{ k}\Omega + 1\text{ k}\Omega)$

$= 20\text{ V} - 6.03\text{ V}$

$= 13.97\text{ V}$

d. $V_C = V_{CC} - I_C R_C$

$= 20\text{ V} - (2.01\text{ mA})(2\text{ k}\Omega) = 20\text{ V} - 4.02\text{ V}$

$= 15.98\text{ V}$

e. $V_E = V_C - V_{CE}$

$= 15.98\text{ V} - 13.97\text{ V}$

$= 2.01\text{ V}$

Or $V_E = I_E R_E - I_C R_E$

= (2.01 mA)(1 k_)

$= 2.01\text{ V}$

DC Biasing

f. $V_B = V_{BE} + V_E$

= 0.7 V + 2.01 V

= 2.71 V

g. $V_{BC} = V_B - V_C$

= (+2.71 V) – (+ 15.98 V) **($V_B < V_C$)**

= -13.27 V (which means that Vc is +ve w.r.t V_B and reversed biased as required)

DC Biasing

3-Voltage-Divider Bias Configuration

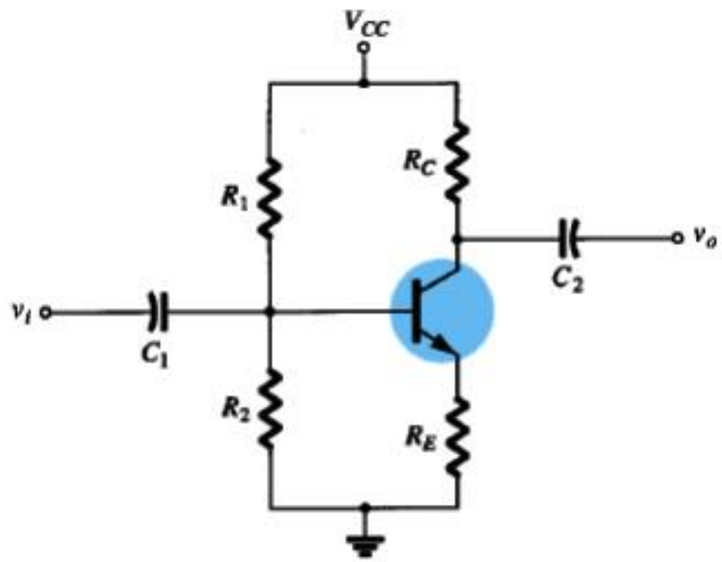
In the previous bias configurations the bias current I_{CQ} and voltage V_{CEQ} were a function of the current gain β of the transistor. However, because β is temperature sensitive, it would be desirable to develop a bias circuit that is independent of β. The voltage-divider bias configuration of Fig. 4.28 is such a network. If analyzed on an exact basis, the sensitivity to changes in beta is quite small. If the circuit parameters are properly chosen, the resulting levels of I_{CQ} and V_{CEQ} can be almost totally independent of beta. Recall from previous discussions

that a Q-point is defined by a fixed level of I_{CQ} and V_{CEQ} as shown in Fig. 4.29 .

The level of I_{BQ} will change with the change in beta, but the operating point on the characteristics defined by I_{CQ} and V_{CEQ} can remain fixed if the proper circuit parameters are employed.

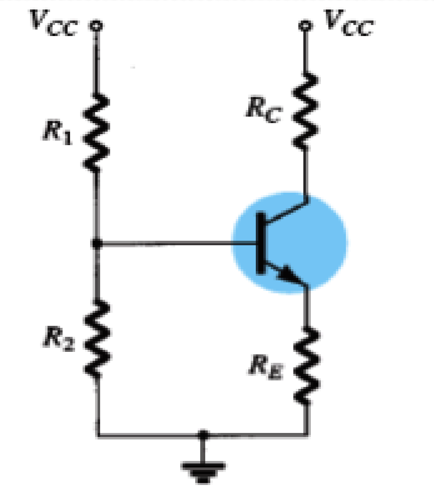
As noted earlier, there are two methods that can be applied to analyze the voltage-divider

DC Biasing

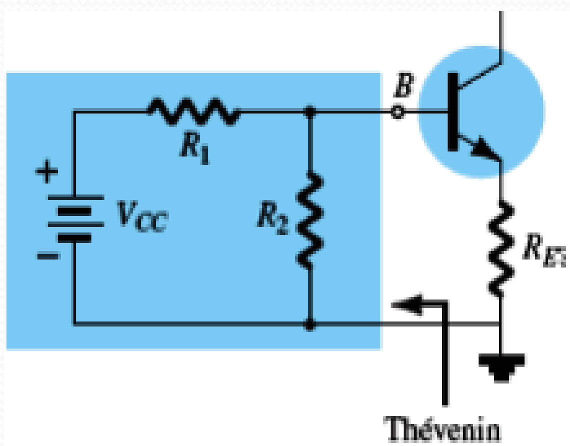


Voltage-divider bias configuration.

Fig.28

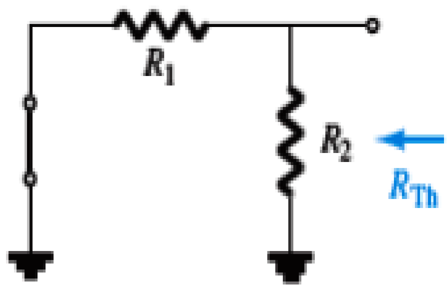


DC components of the voltage-divider configuration.



Redrawing the input side of the network of Fig. 4.28.

DC Biasing



Determining R_{Th}.

FIG. 4.32

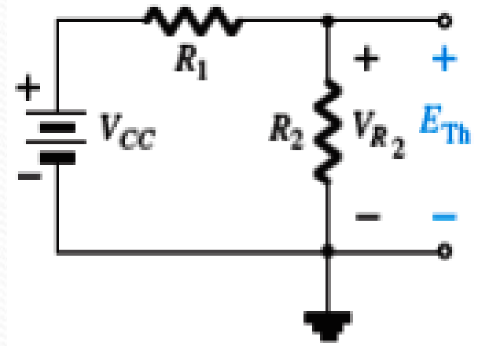


FIG. 4.33

Determining E_{Th}.

1- The voltage source is replaced by a short-circuit find R_{th}
2-Redrawing the input side of the network
For the dc analysis the network can be redrawn as shown above . The input side of the network can then be redrawn for the dc analysis.
The Thevenin's equivalent network for the network to the left of the base terminal can then be found in the following manner:
R_{Th} The voltage source is replaced by a short-circuit equivalent as shown in the following Fig.

$$R_{Th} = R1 || R2$$

DC Biasing

E_{Th} The voltage source V_{CC} is returned to the network and the open-circuit Thevenin's voltage of Fig. 4.33 determined as follows:

Applying the voltage-divider rule gives

$$E_{Th} = V_{R2} = R_2 V_{CC} / R1 + R2 \qquad (4.29)$$

The Thevenin's network is then redrawn as shown in Fig. 4.34 , and I_{BQ} can be determined by first applying Kirchhoff's voltage law in the clockwise direction for the loop indicated:

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

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

$$I_B = (E_{Th} - V_{BE}) / R_{Th} + (\beta + 1) R_E \qquad (4.30)$$

$$V_{CE} = V_{CC} - I_C (R_C + R_E) \qquad (4.31)$$

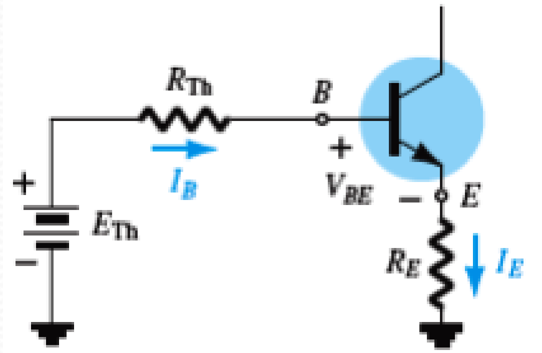


FIG. 4.34
Inserting the Thévenin equivalent circuit.

DC Biasing

EXAMPLE 7 : Determine the dc bias voltage V_{CE} and the current I_C for the voltage-divider configuration of Fig. 4.35

Solution: $R_{Th} = R1 || R2$

$= (39\ k\Omega)(3.9\ k\Omega) / 39\ k\Omega + 3.9\ k\Omega = 3.55\ k\Omega$

$E_{Th} = R_2 V_{CC} / R_1 + R_2 = (3.9\ k\Omega)(22V) / 39\ k\Omega + 3.9\ k\Omega = 2\ V$

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

$= 2\ V - 0.7\ V / 3.55\ k\Omega + (101)(1.5\ k\Omega)$

$= 1.3\ V / 3.55\ k\Omega + 151.5\ k\Omega$

$= 8.38\ \mu A$

$I_C = \beta I_B$

$= (100)(8.38\ mA)$

$= 0.84\ mA$

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

$= 22\ V - (0.84\ mA)(10\ k\Omega + 1.5\ k\Omega)$

$= 22\ V - 9.66\ V$

$= 12.34\ V$

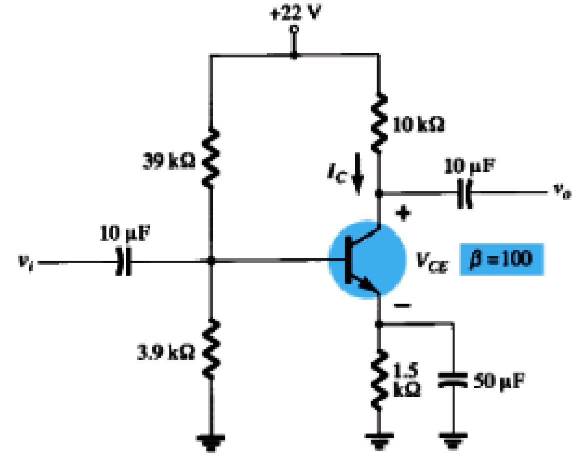


FIG. 4.35
Beta-stabilized circuit for Example 4.8.

DC Biasing

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. 4.38 . 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 then applied to the collector–emitter loop.

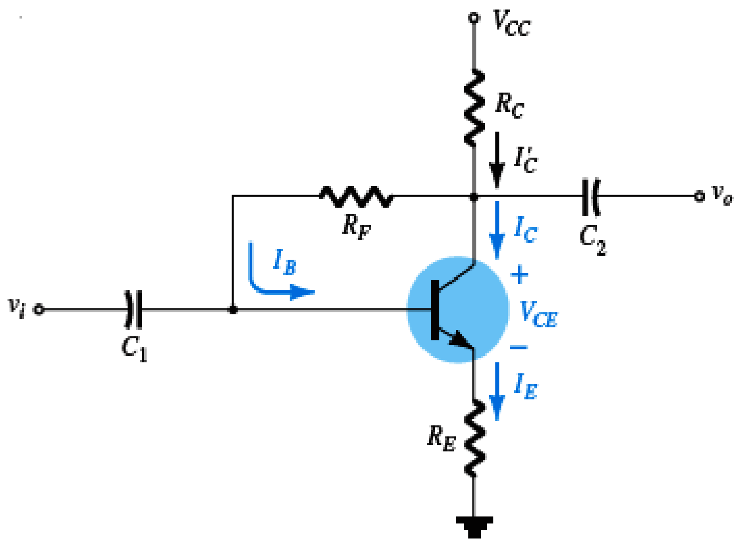


FIG. 4.38
DC bias circuit with voltage feedback.

DC Biasing

Base–Emitter Loop

Figure 4.39 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

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

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

$$I'_C \cong I_C = \beta I_B \text{ and } I_E \cong I_C \text{ results in}$$

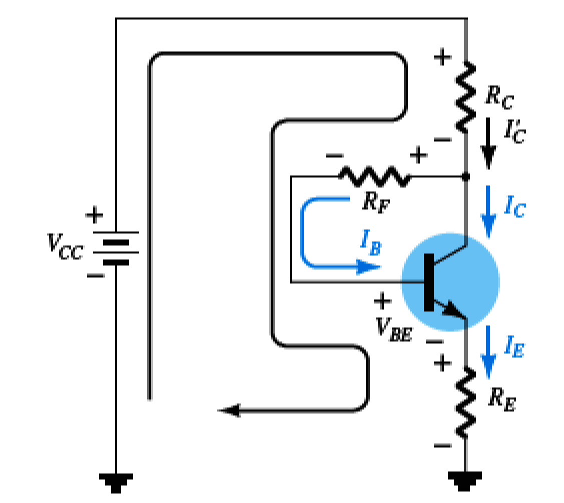


FIG. 4.39
Base–emitter loop for the network of Fig. 4.38.

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

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

$$I_B = \frac{V_{CC} - V_{BE}}{R_F + \beta (R_C + R_E)} \qquad \textbf{(4.41)}$$

DC Biasing

Collector–Emitter Loop

The collector–emitter loop for the network of Fig. 4.38 is provided in Fig. 4.40 . Applying Kirchhoff's voltage law around the indicated loop in the clockwise direction results in

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

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 $V_{CE} = V_{CC} - I_C(R_C + R_E)$ (4.42)

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

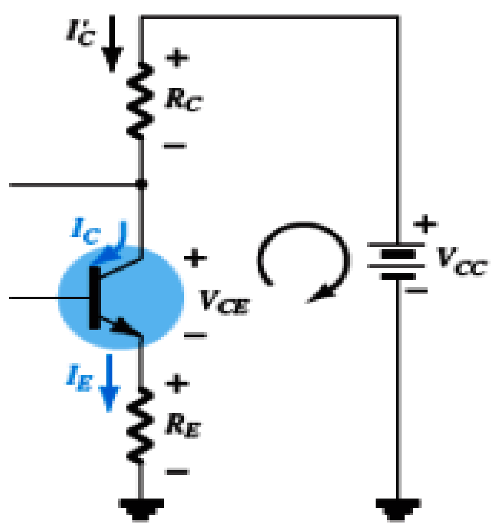


FIG. 4.40
Collector–emitter loop for the network of Fig. 4.38.

DC Biasing

EXAMPLE 4.12 Determine the quiescent levels of I_{CQ} and V_{CEQ} for the network of Fig.4.41 .

Solution:

$$I_B = V_{CC} - V_{BE} / (R_F + \beta (R_C + R_E))$$
$$= 10\text{ V} - 0.7\text{ V} / 250\text{ k}\Omega + (90)(4.7\text{ k}\Omega + 1.2\text{ k}\Omega)$$
$$= 9.3\text{ V} / 250\text{ k}\Omega + 531\text{ k}\Omega$$
$$= 9.3\text{ V}/ 781\text{ k}\Omega$$
$$= 11.91\text{ mA}$$

$$I_{CQ} = \beta I_B = (90)(11.91\text{ mA})$$
$$= 1.07\text{ mA}$$

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

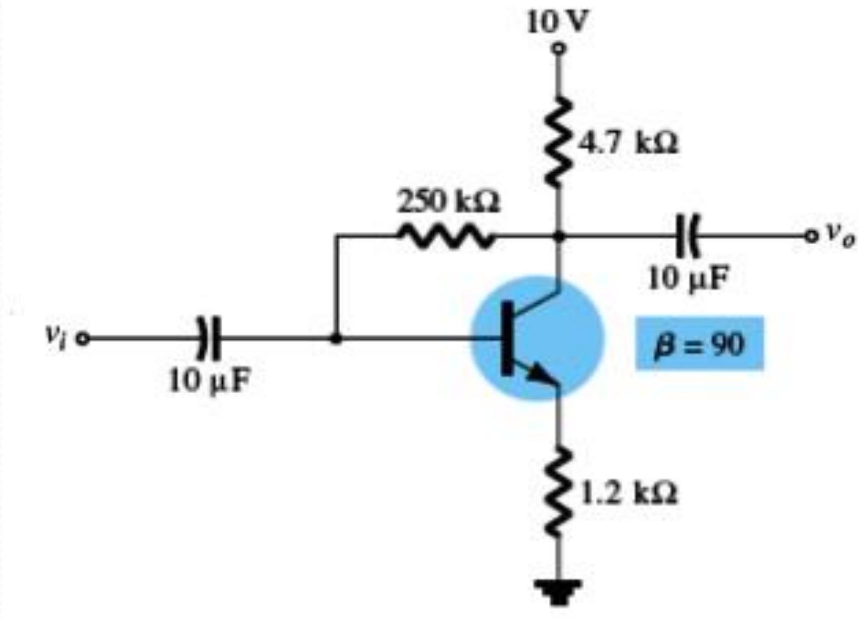


FIG. 4.41
Network for Example 4.12.

EXAMPLE 4.14 Determine the dc level of I_B and V_C for the network of Fig. 4.42

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 apacitor assumes the open-circuit equivalence, and $R_B = R_F1 + R_F2$. Solving for $I B$ gives :**

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

$$= 18\ V - 0.7\ V / (91\ k + 110\ k) + (75)(3.3\ k + 0.51\ k)$$

$$= 17.3\ V / 201\ k + 285.75\ k$$

$$= 17.3\ V / 486.75\ k$$

$$= 35.5\ \mu A$$

$$I_C = \beta\ I_B$$

$$= (75)\ (35.5\ mA)$$

$$= 2.66\ mA$$

$$V_C = V_{CC} - I_{\check{C}}\ R_C \cong V_{CC} - I_C R_C$$

$$= 18\ V - (2.66\ mA)(3.3\ k\_)$$

$$= 18\ V - 8.78\ V$$

$$= 9.22\ V$$

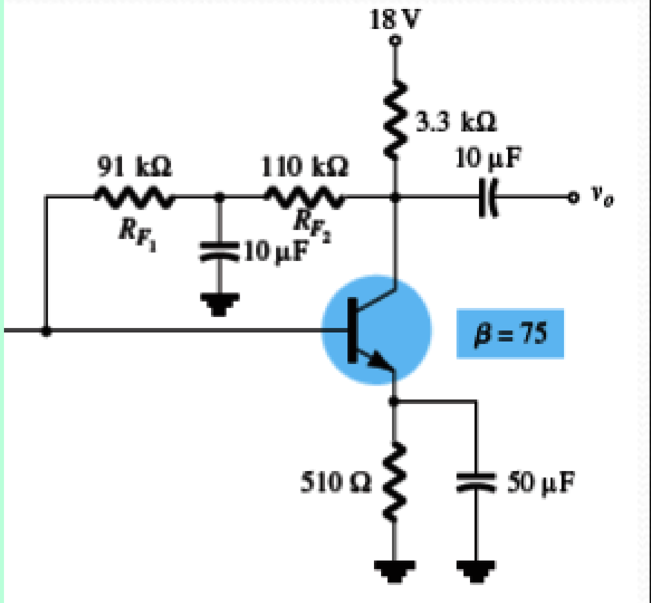


FIG. 4.42
Network for Example 4.14.

DC Biasing

5- 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. 4.46** . The configuration of **Fig. 4.46** 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.

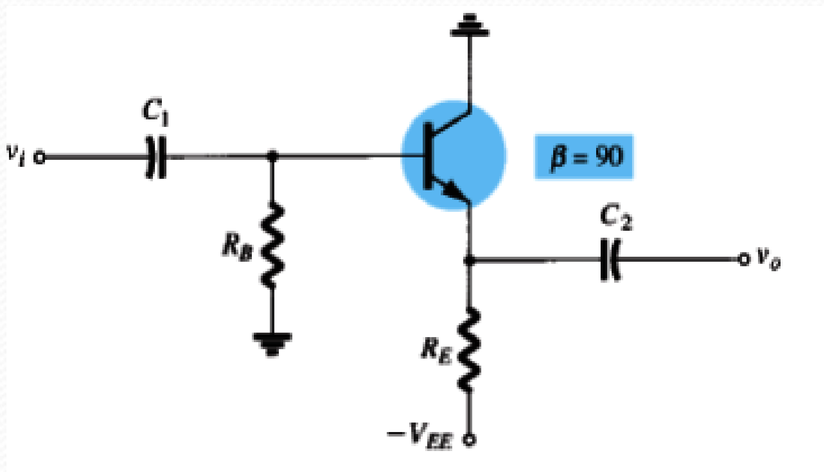


FIG. 4.46
Common-collecter (emitter-follower) configuration.

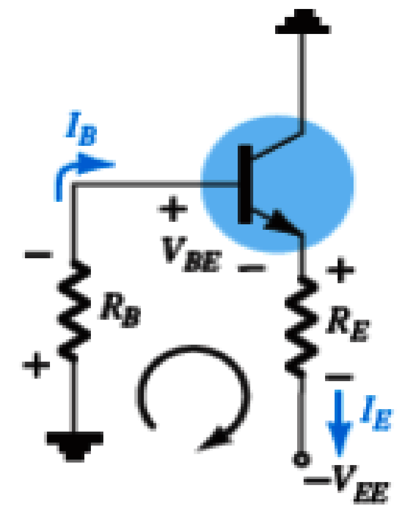


FIG. 4.47
dc equivalent of Fig. 4.46.

DC Biasing

The dc equivalent of the network of Fig. 4.46 appears in Fig. 4.47
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 $I_B = V_{EE} - V_{BE} / R_B + (\beta + 1) R_E$ (4.44)

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

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

And $V_{CE} = V_{EE} - I_E R_E$ (4.45)

DC Biasing

EXAMPLE 4.16 Determine V_{CEQ} and I_{EQ} for the network of Fig. 4.48 .

Solution:

Eq. 4.44: $I_B = V_{EE} - V_{BE} / R_B + (\beta + 1)\ R_E$

$= 20\text{ V} - 0.7\text{ V} / 240\text{ k} + (90 + 1)2\text{ k}$

$= 19.3\text{ V} / 240\text{ k} + 182\text{ k}$

$= 19.3\text{ V} / 422\text{ k}$

$= 45.73\text{ mA}$

and Eq. 4.45 $V_{CEQ} = V_{EE} - I_E R_E$

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

$= 20\text{ V} - (90 + 1)\ (45.73\text{ mA})\ (2\text{ k}$

$= 20\text{ V} - 8.32\text{ V}$

$= 11.68\text{ V}$

$I_{EQ} = (\beta + 1) I_B = (91)(45.73\text{ mA})$

$= 4.16\text{ mA}$

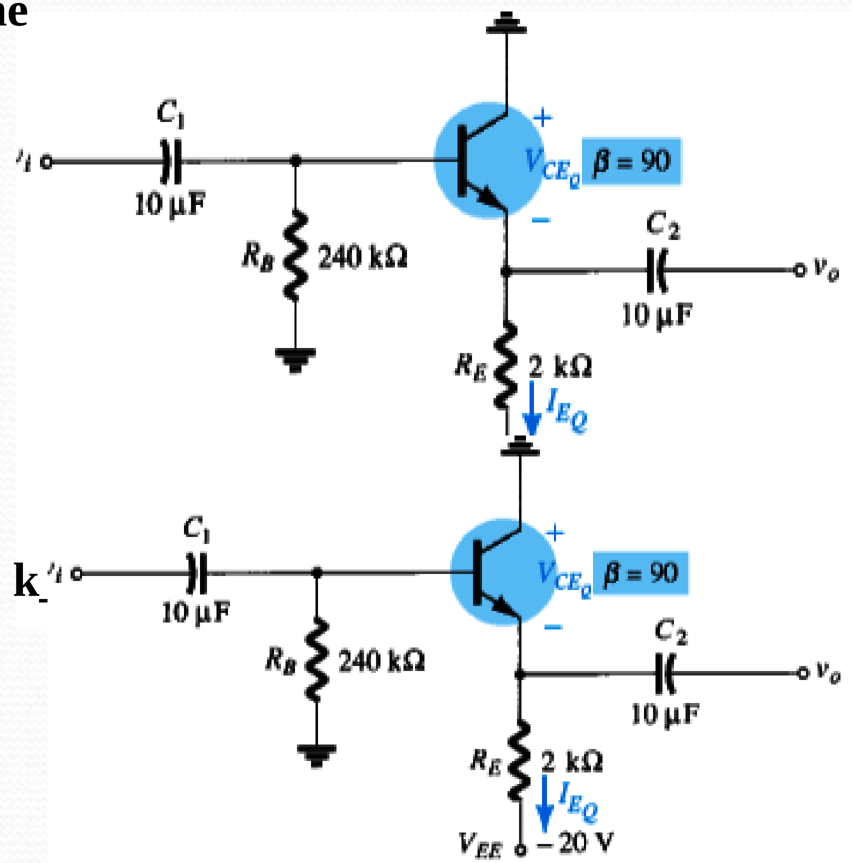


FIG. 4.48
Example 4.16.