Electronic Devices

Mid Term
Lecture - 10

Faculty Name: Mr. A N M Shahebul Hasan
Email : shahebul@aiub.edu

Reference book:
Electronic Devices and Circuit Theory (Chapter-4)
Robert L. Boylestad and L. Nashelsky , (11^{th} Edition)

Objectives

- Be able to determine the dc levels for the variety of important BJT configurations.
- Understand how to measure the important voltage levels of a BJT transistor configuration and use them to determine whether the network is operating properly.
- Become aware of the saturation and cutoff conditions of a BJT network and the expected voltage and current levels established by each condition.
- Be able to perform a load-line analysis of the most common BJT configurations.
- Become acquainted with the design process for BJT amplifiers.
- Understand the basic operation of transistor switching networks.
- Begin to understand the troubleshooting process as applied to BJT configurations.
- Develop a sense for the stability factors of a BJT configuration and how they affect its operation due to changes in specific characteristics and environmental changes.

EMITTER-BIAS CONFIGURATION

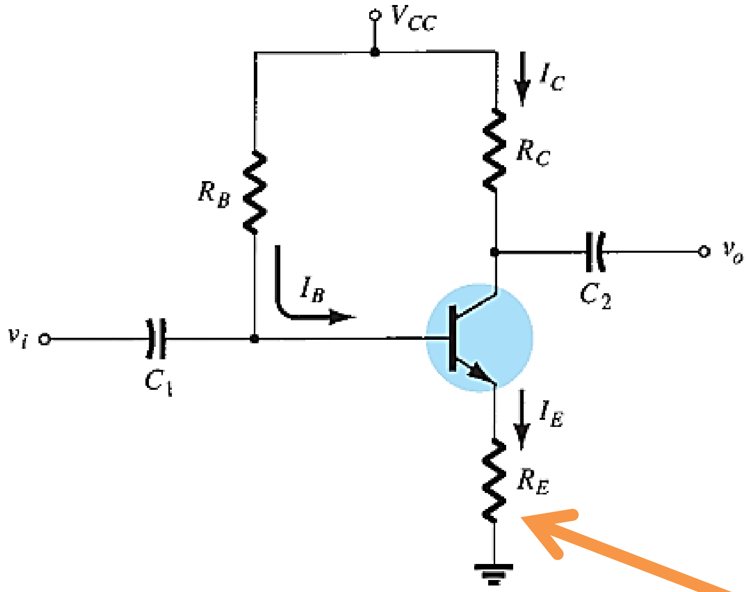

FIG. 4.17
BJT bias circuit with emitter resistor.

Adding a resistor in the Emitter circuit stabilizes the bias circuit.

BIAS STABILITY

- If V_{BE} is held constant and the temperature rises, the current through the base-emitter diode I_B will increase, and thus the collector I_C will also increase. The power dissipated in the transistor may also increase, which will further increase its temperature and exacerbate the problem. This deleterious positive feedback results in thermal runaway.

- Adding R_E to the Emitter improves the stability of a transistor.

- Stability refers to a bias circuit in which the currents and voltages will remain fairly constant for a while range of temperatures and transistor Beta's (β).

- $V_{RB} = V_{CC} - I_E R_E - V_{BE}$

BIAS STABILITY

- If temperature increases, emitter current increases.
- However, a larger I_E increases the emitter voltage $V_E = I_E R_E$, which in turn reduces the voltage V_{RB} across the base resistor.
- A lower base-resistor voltage drop reduces the base current, which results in less collector current because $I_C = \beta I_B$.

BASE–EMITTER LOOP

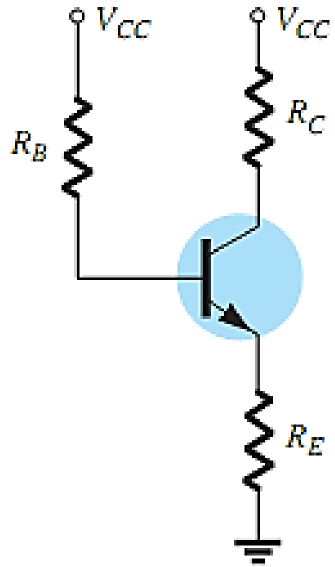

FIG. 4.18
DC equivalent of Fig. 4.17.

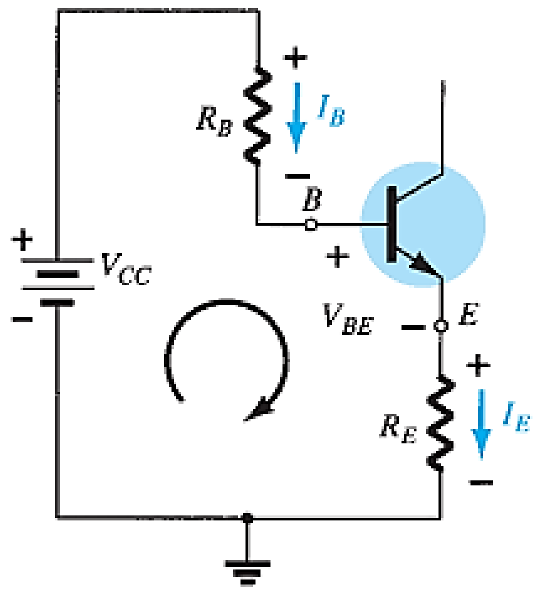

FIG. 4.19
Base–emitter loop.

BASE–EMITTER LOOP

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

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

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

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

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

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

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

$$\boxed{R_i = (\beta + 1)R_E}$$

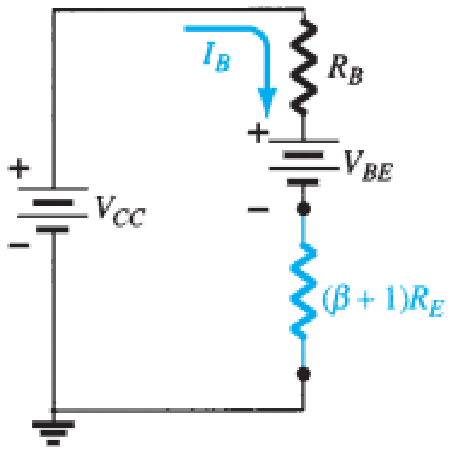

FIG. 4.20
Network derived from Eq. (4.17).

COLLECTOR–EMITTER LOOP

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

Substituting $I_E \cong I_C$ and grouping terms gives

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

and

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

$$\boxed{V_E = I_E R_E} \qquad V_{CE} = V_C - V_E \qquad \boxed{V_C = V_{CC} - I_C R_C}$$

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

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

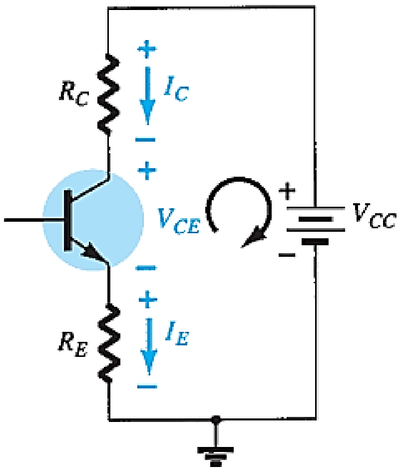

FIG. 4.22
Collector–emitter loop.

EXAMPLE

EXAMPLE 4.4 For the emitter-bias network of Fig. 4.23, determine:

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

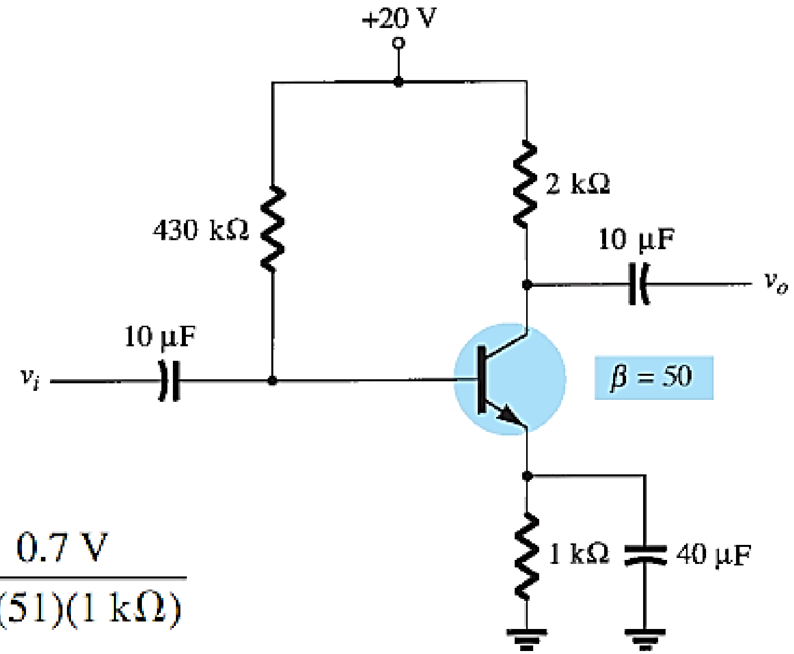

FIG. 4.23
·stabilized bias circuit for Example 4.4.

a. Eq. (4.17): $$I_B = \frac{V_{CC} - V_{BE}}{R_B + (\beta + 1)R_E} = \frac{20\text{ V} - 0.7\text{ V}}{430\text{ k}\Omega + (51)(1\text{ k}\Omega)}$$
$$= \frac{19.3\text{ V}}{481\text{ k}\Omega} = \mathbf{40.1\ \mu A}$$

b. $$I_C = \beta I_B$$
$$= (50)(40.1\ \mu\text{A})$$
$$\cong \mathbf{2.01\ mA}$$

EXAMPLE

c. Eq. (4.19): $V_{CE} = V_{CC} - I_C(R_C + R_E)$

$$= 20\text{ V} - (2.01\text{ mA})(2\text{ k}\Omega + 1\text{ k}\Omega) = 20\text{ V} - 6.03\text{ V}$$

$$= \mathbf{13.97\ V}$$

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

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

$$= \mathbf{15.98\ V}$$

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

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

$$= \mathbf{2.01\ V}$$

or $V_E = I_E R_E \cong I_C R_E$

$$= (2.01\text{ mA})(1\text{ k}\Omega)$$

$$= \mathbf{2.01\ V}$$

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

$$= 0.7\text{ V} + 2.01\text{ V}$$

$$= \mathbf{2.71\ V}$$

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

$$= 2.71\text{ V} - 15.98\text{ V}$$

$$= \mathbf{-13.27\ V} \text{ (reverse-biased as required)}$$

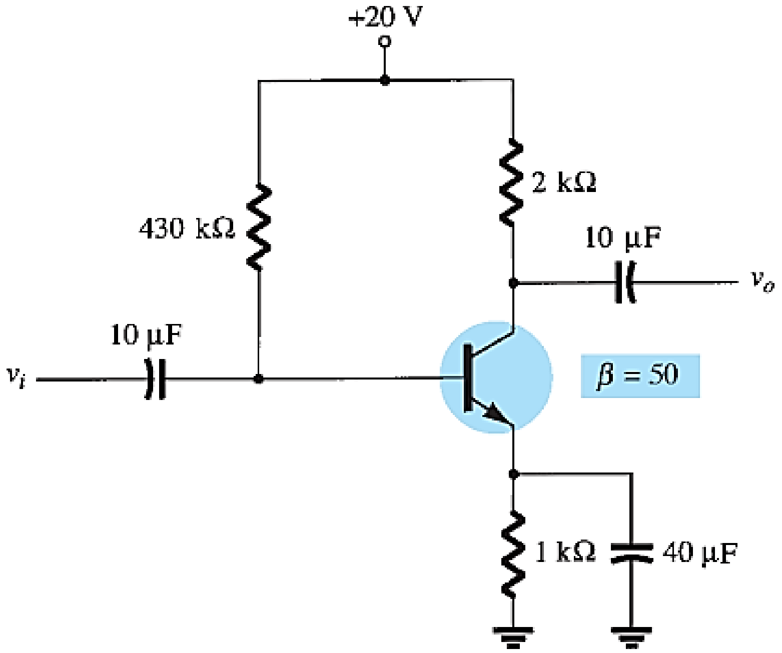

FIG. 4.23
Emitter-stabilized bias circuit for Example 4.4.

VOLTAGE-DIVIDER BIAS CONFIGURATION

- The bias current I_{C_Q} and voltage V_{CE_Q} is a function of the current gain **β** of the transistor
- Since **β** is temperature sensitive, especially for silicon transistors, it would be desirable to develop a bias circuit that is independent of, the transistor **β**.

The voltage-divider bias configuration is such a network.

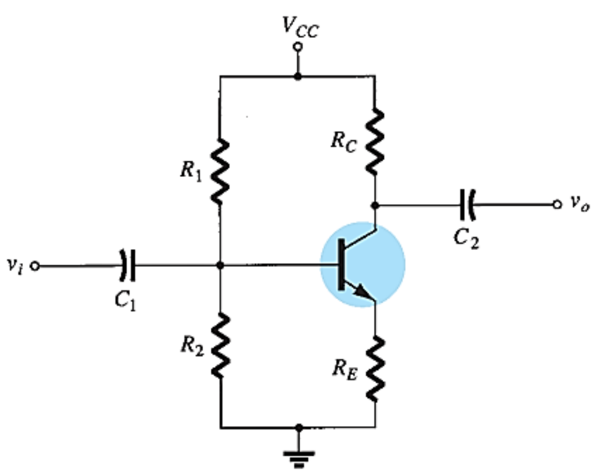

FIG. 4.28
Voltage-divider bias configuration.

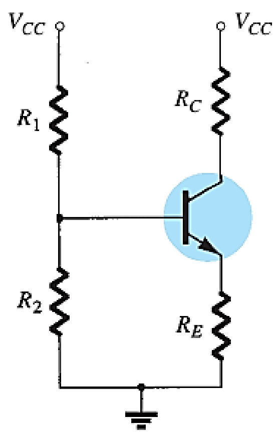

FIG. 4.30
DC components of the voltage-divider configuration.

EXACT ANALYSIS

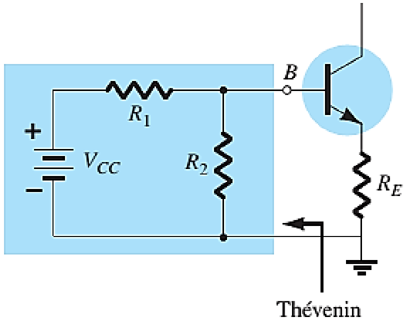

FIG. 4.31
Redrawing the input side of the network of Fig. 4.28.

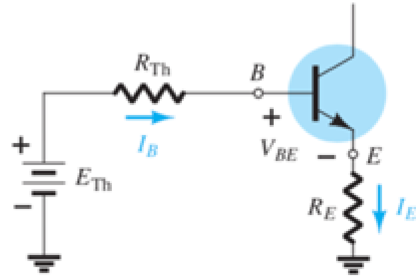

FIG. 4.34
Inserting the Thévenin equivalent circuit.

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

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

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

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

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

EXAMPLE

EXAMPLE 4.8 Determine the dc bias voltage V_{CE} and the current I_C for the voltage-divider configuration of Fig. 4.35.

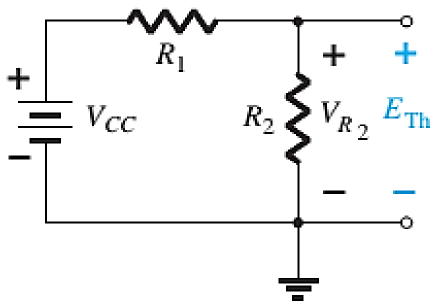

FIG. 4.33
Determining E_{Th}.

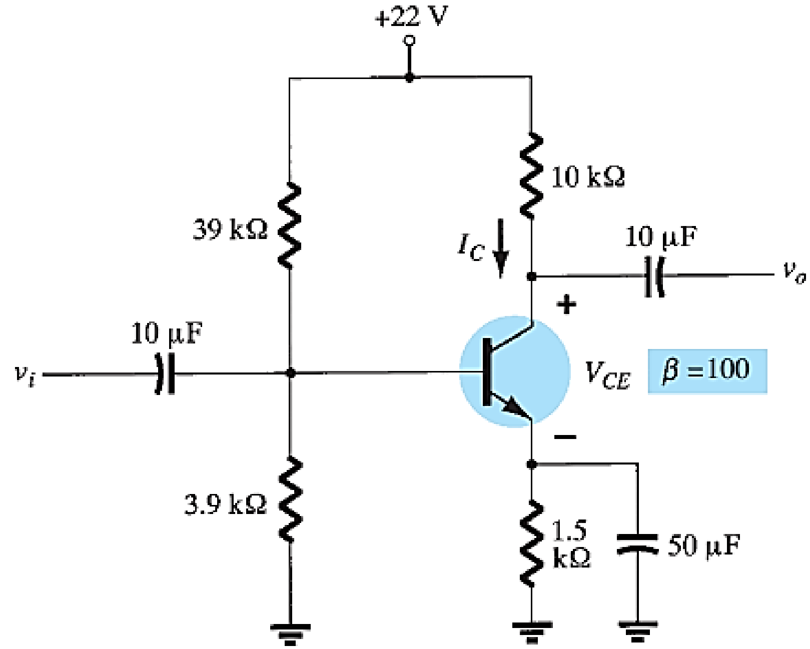

FIG. 4.35
Beta-stabilized circuit for Example 4.8.

$$R_{Th} = R_1 \| R_2$$
$$= \frac{(39\ \mathrm{k\Omega})(3.9\ \mathrm{k\Omega})}{39\ \mathrm{k\Omega} + 3.9\ \mathrm{k\Omega}} = 3.55\ \mathrm{k\Omega}$$

EXAMPLE CONTD.

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

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

$$= \frac{2\ \text{V} - 0.7\ \text{V}}{3.55\ \text{k}\Omega + (101)(1.5\ \text{k}\Omega)} = \frac{1.3\ \text{V}}{3.55\ \text{k}\Omega + 151.5\ \text{k}\Omega}$$

$$= 8.38\ \mu\text{A}$$

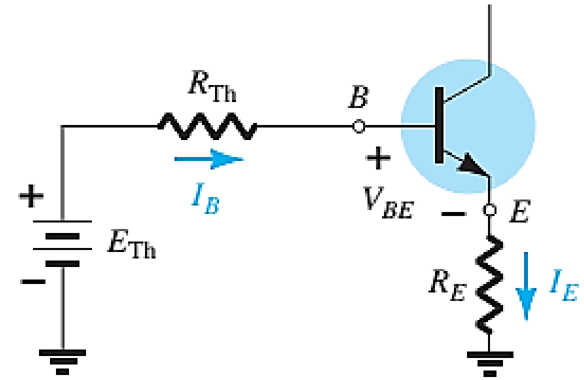

FIG. 4.34
Inserting the Thévenin equivalent circuit.

$$I_C = \beta I_B = (100)(8.38\ \mu\text{A}) = \mathbf{0.84\ mA}$$

$$V_{CE} = V_{CC} - I_C(R_C + R_E)$$
$$= 22\ \text{V} - (0.84\ \text{mA})(10\ \text{k}\Omega + 1.5\ \text{k}\Omega)$$
$$= 22\ \text{V} - 9.66\ \text{V}$$
$$= \mathbf{12.34\ V}$$

Approximate Analysis

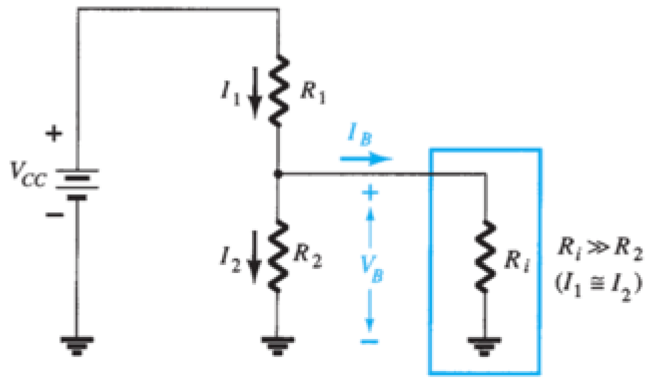

FIG. 4.36
Partial-bias circuit for calculating the approximate base voltage V_B.

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

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

$$R_i = (\beta + 1) R_E \cong \beta R_E$$

Once V_B is determined, the level of V_E can be calculated from

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

and the emitter current can be determined from

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

and

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

The collector-to-emitter voltage is determined by

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

but because $I_E \cong I_C$,

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

EXAMPLE

EXAMPLE 4.9 Repeat the analysis of Fig. 4.35 using the approximate technique, and compare solutions for I_{C_Q} and V_{CE_Q}.

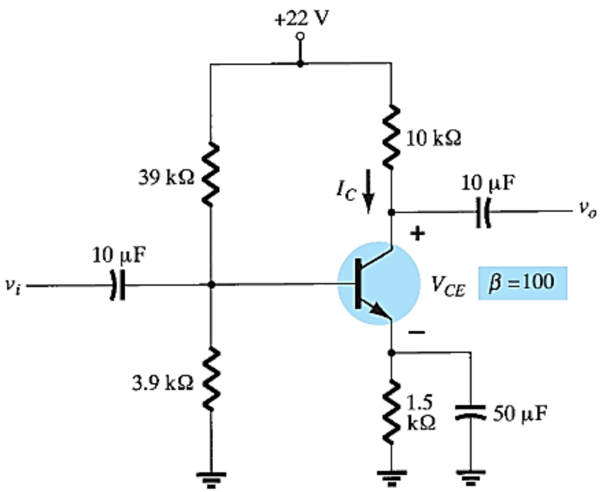

FIG. 4.35
Beta-stabilized circuit for Example 4.8.

Testing:

$$\beta R_E \geq 10R_2$$
$$(100)(1.5\text{ k}\Omega) \geq 10(3.9\text{ k}\Omega)$$
$$150\text{ k}\Omega \geq 39\text{ k}\Omega\ (\textit{satisfied})$$

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

Eq. (4.34):
$$V_E = V_B - V_{BE} = 2\text{ V} - 0.7\text{ V} = 1.3\text{ V}$$

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

compared to 0.84 mA with the exact analysis. Finally,

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

versus 12.34 V obtained in Example 4.8.

COLLECTOR FEEDBACK CONFIGURATION

- An improved level of stability can also be obtained by introducing a feedback path from collector to base
- 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

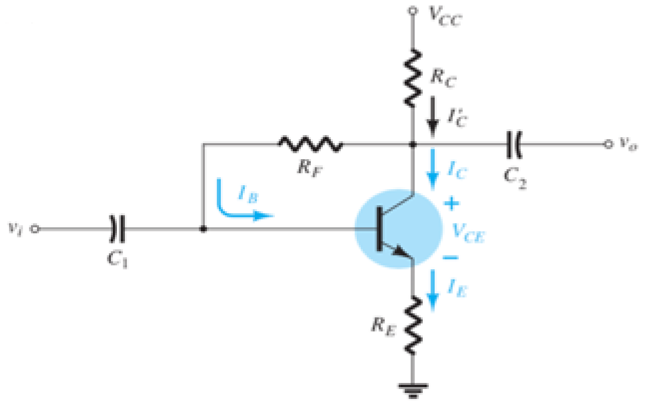

FIG. 4.38
DC bias circuit with voltage feedback.

BASE–EMITTER LOOP

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

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

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

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

$$I_B = \frac{V'}{R_F + \beta R'}$$

$$I_{C_Q} = \frac{\beta V'}{R_F + \beta R'} = \frac{V'}{\frac{R_F}{\beta} + R'}$$

$$I_{C_Q} \cong \frac{V'}{R'}$$

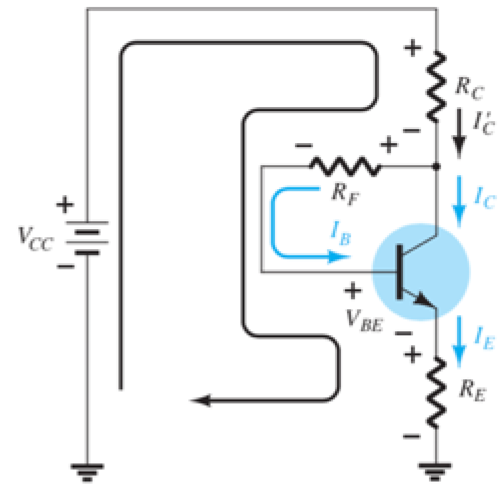

FIG. 4.39
Base–emitter loop for the network of Fig. 4.38.

COLLECTOR–EMITTER LOOP

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

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

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

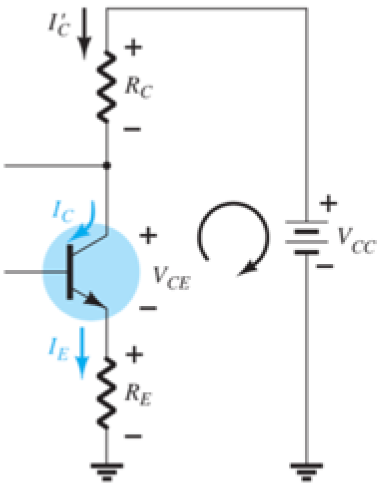

FIG. 4.40
Collector–emitter loop for the network of Fig. 4.38.

EXAMPLE 4.12

Thank You