كلية مدينة العلم الجامعة
قسم هندسة الحاسوب

محاضرات المرحلة الاولى لمادة الهندسة الالكترونية

اعداد
د.سعيد سلمان كمون

DC Biasing

المحاضرة السادسة

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

6- COMMON-BASE CONFIGURATION

The common-base configuration is unique in that the applied signal is connected to the emitter terminal and the base is at, or just above, ground potential. It is a fairly popular configuration because in the ac domain it has a very low input impedance, high output impedance, and good gain.

A typical common-base configuration appears in Fig. 4.49 . Note that two supplies are used in this configuration and the base is the common terminal between the input emitter terminal and output collector terminal.

The dc equivalent of the input side of Fig. 4.49 appears in Fig. 4.50 .

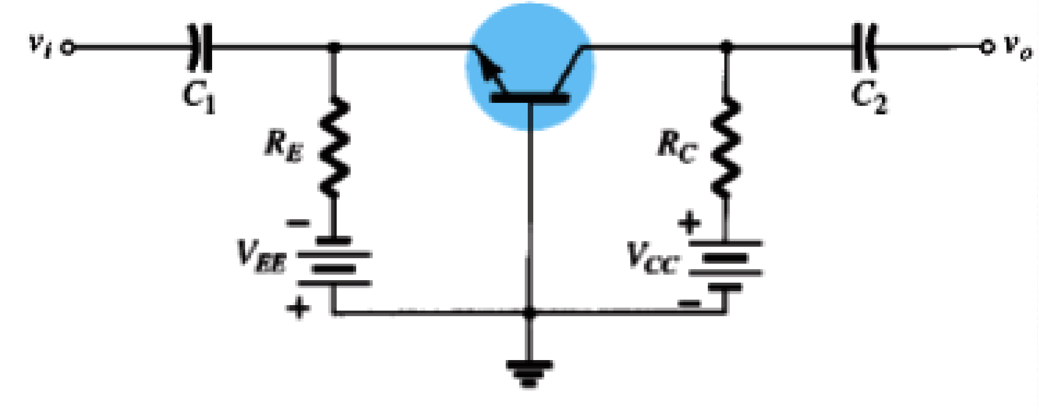


FIG. 4.49
Common-base configuration.

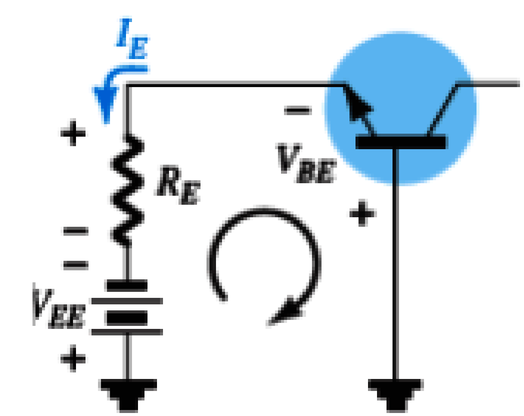


FIG. 4.50
Input dc equivalent of Fig. 4.49.

DC Biasing

Applying Kirchhoff's voltage law will result in

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

$$I_E = V_{EE} - V_{BE} / R_E \qquad (4.46)$$

Applying Kirchhoff's voltage law to the entire outside perimeter of the network of Fig.4.51 will result in

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

and solving for V_{CE}**:**

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

Because $I_E \cong I_C$

$$V_{CE} = V_{EE} + V_{CC} - I_E (R_C + R_E) \qquad (4.47)$$

The voltage V_{CB} **of Fig. 4.51 can be found by applying Kirchhoff's voltage law to the output loop of Fig 4.51 to obtain:**

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

or $V_{CB} = V_{CC} - I_C R_C$

Using $IC \cong IE$

we have $V_{CB} = V_{CC} - I_C R_C \qquad$ **(4.48)**

DC Biasing

EXAMPLE 4.17 Determine the currents I_E and I_B and the voltages V_{CE} and V_{CB} for the common-base configuration of Fig. 4.52 .

Solution:

$I_E = V_{EE} - V_{BE} / R_E$

= 4 V - 0.7 V / 1.2 kΩ

= 2.75 mA

$I_B = I_E / (\beta + 1)$ **= 2.75 mA / 60 + 1 = 2.75 mA / 61**

= 45.08 µA

Eq. 4.47: $V_{CE} = V_{EE} + V_{CC} - I_E (R_C + R_E)$

= 4 V + 10 V - (2.75 mA)(2.4 kΩ + 1.2 kΩ)

= 14 V - (2.75 mA) (3.6 kΩ)

= 14 V - 9.9 V

= 4.1 V

Eq. 4.48: $V_{CB} = V_{CC} - I_C R_C = V_{CC} - \beta I_B R_C$

= 10 V - (60)(45.08 mA)(24 kΩ)

= 10 V - 6.49 V

= 3.51 V

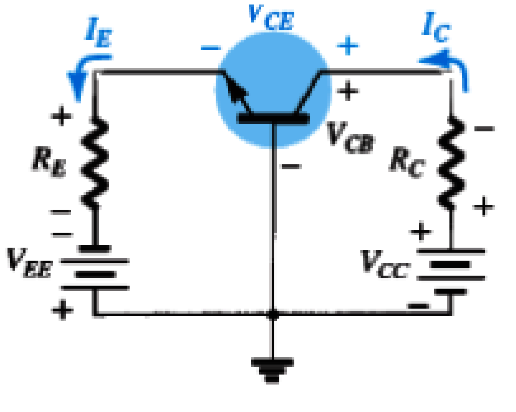


FIG. 4.51
Determining V_{CE} and V_{CB}.

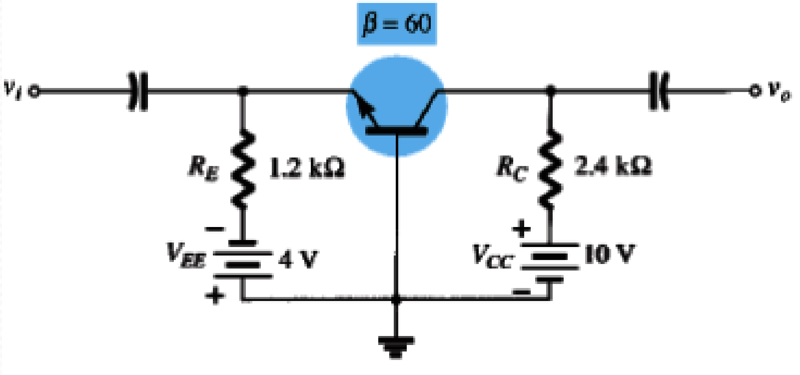


FIG. 4.52
Example 4.17.

DC Biasing

EXAMPLE 4.18 For the network of Fig. 4.53 :

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

b. Find V_B, V_C, V_E and V_{BC}.

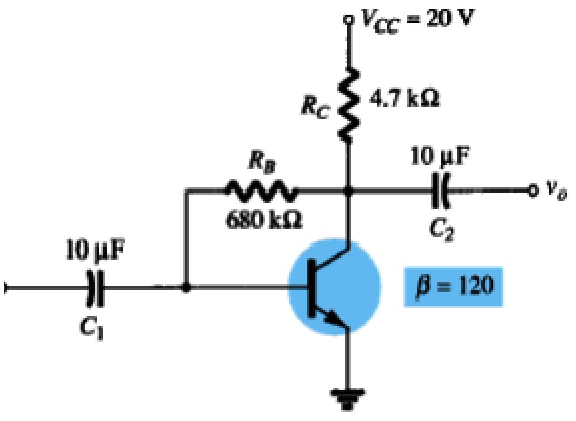


FIG. 4.53
Collector feedback with $R_E = 0\ \Omega$.

Solution:

a.The absence of R_E reduces the reflection of resistive levels to simply that of R_C, and the equation for I_B reduces to

$$I_B = V_{CC} - V_{BE} / R_B + \beta R_C$$
$$= 20\text{ V} - 0.7\text{ V} / 680\text{ k} + (120)(4.7\text{ k})$$
$$= 19.3\text{ V} / 1.244\text{ M}\Omega \quad = 15.51\ \mu\text{A}$$

$$I_{CQ} = \beta I_B = (120)(15.51\text{ mA})$$
$$= 1.86\text{ mA}$$

$$V_{CEQ} = V_{CC} - I_C R_C$$
$$= 20\text{ V} - (1.86\text{ mA})(4.7\text{ k}) = 11.26\text{ V}$$

b. $V_B = V_{BE} = 0.7\text{ V}$

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

$V_E = 0\text{ V}$

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

$= -10.56\text{ V}$

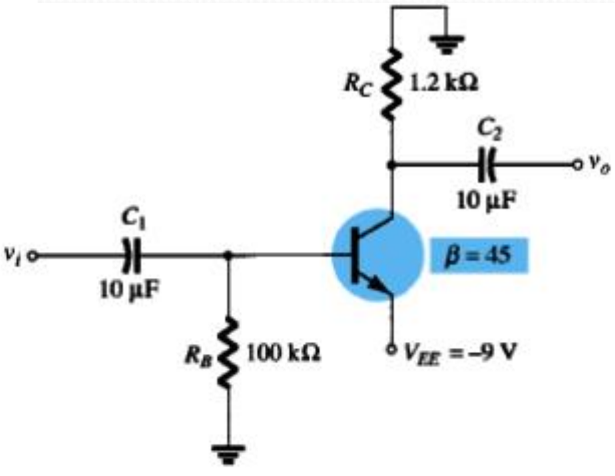


FIG. 4.54
Example 4.19.

DC Biasing

EXAMPLE 4.19 Determine V_C and V_B for the network of Fig. 4.54 .

Solution: **Applying Kirchhoff's voltage law in the clockwise direction for the base–emitter loop results in**

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

and $I_B = V_{EE} - V_{BE} / R_B$

Substitution yields

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

$= 8.3\text{ V} / 100\text{ k} = 83\ \mu\text{A}$

$I_C = \beta I_B$

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

$= 3.735\text{ mA}$

$V_C = -I_C R_C$

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

$= -4.48\text{ V}$

$V_B = -I_B R_B$

$= -(83\text{ mA})(100\text{ k})$

$= -8.3\text{ V}$

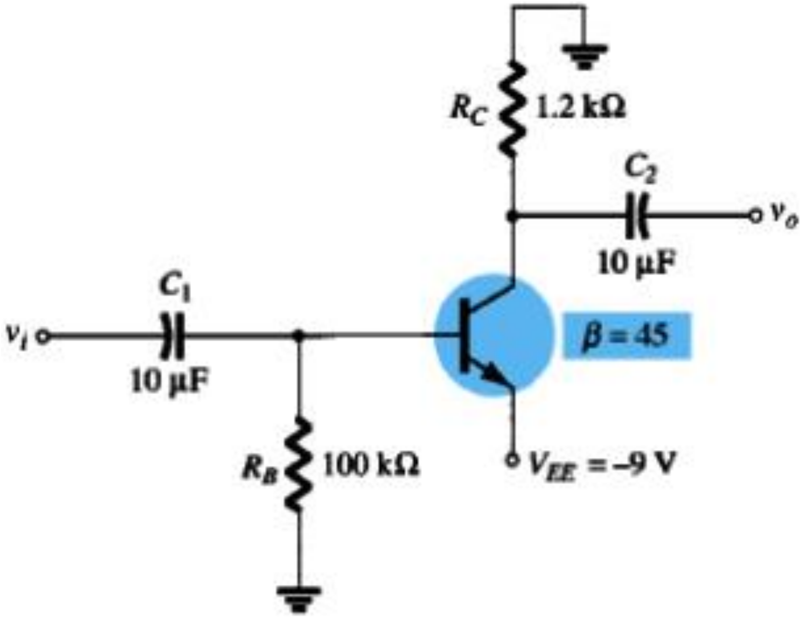


FIG. 4.54
Example 4.19.

DC Biasing

EXAMPLE 4.20 Determine V_C and V_B for the network of Fig. 4.55 .
Solution: **The Thévenin resistance and voltage are determined for the network to the left**
of the base terminal as shown in Figs. 4.56 and 4.57 .R_{Th}

$$R_{Th} = 8.2\text{ k} \parallel 2.2\text{ k} = 1.73\text{ k}$$

To find E_{Th}

$I = (V_{CC} + V_{EE}) / (R1 + R2)$
$= (20\text{ V} + 20\text{ V}) / (8.2\text{ k} + 2.2\text{ k})$
$= 40\text{ V} / 10.4\text{ k}$_
$= 3.85\text{ mA}$

$E_{Th} = I \times R_2 - V_{EE}$
$= (3.85\text{ mA})(2.2\text{ k}) - 20\text{ V}$
$= -11.53\text{ V}$

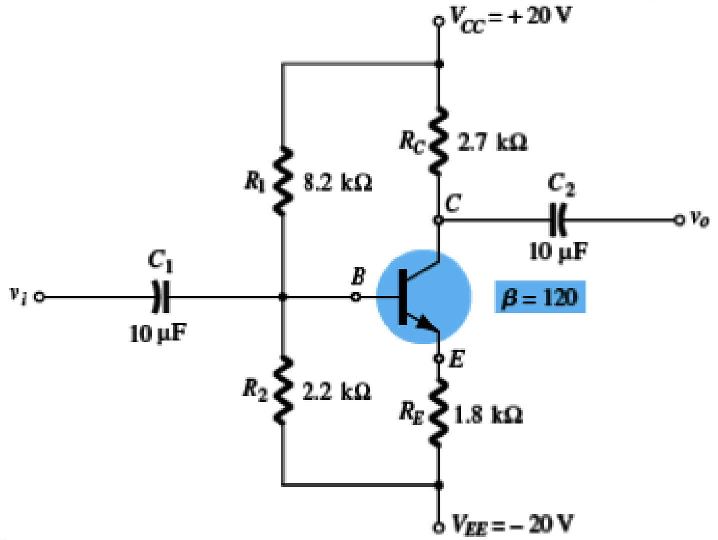


FIG. 4.55
Example 4.20.

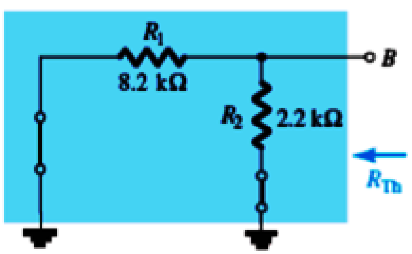


FIG. 4.56
Determining R_{Th}.

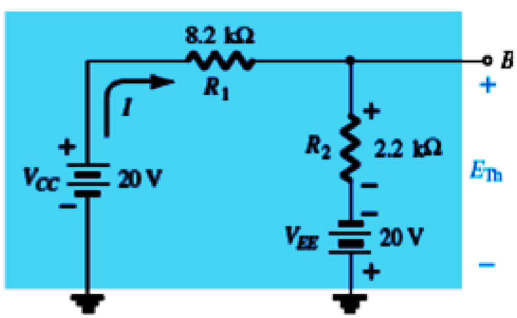


FIG. 4.57
Determining E_{Th}.

DC Biasing

The network can then be redrawn as shown in Fig. 4.58 , where the application of Kirchhoff's voltage law results in

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

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

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

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

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

$= 7.77\text{ V} / 219.53\text{ k}$

$= 35.39\text{ mA}$

$I_C = \beta I_B$

$= (120)(35.39\text{ mA})$

$= 4.25\text{ mA}$

$V_C = V_{CC} - I_C R_C$

$= 20\text{ V} - (4.25\text{ mA})(2.7\text{ k})$

$= \mathbf{8.53\text{ V}}$

$V_B = -E_{Th} - I_B R_{Th}$

$= -(11.53\text{ V}) - (35.39\text{ mA})(1.73\text{ k})$

$= \mathbf{-11.59\text{ V}}$

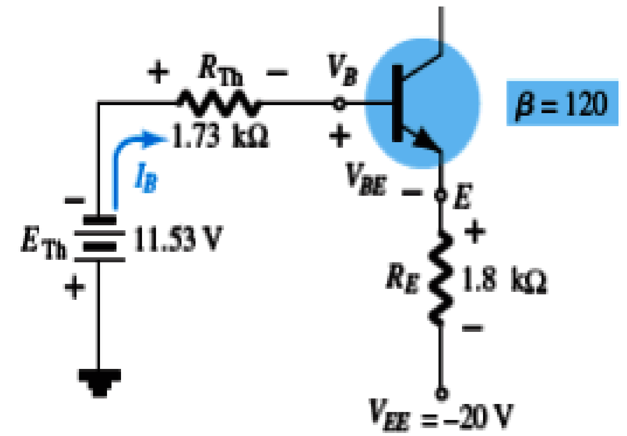


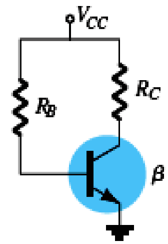
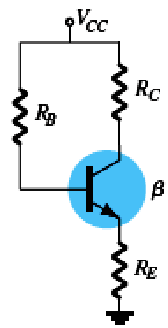
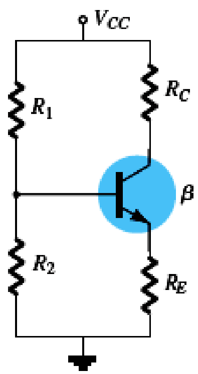
FIG. 4.58
Substituting the Thévenin equivalent circuit.

4.10 SUMMARY TABLE

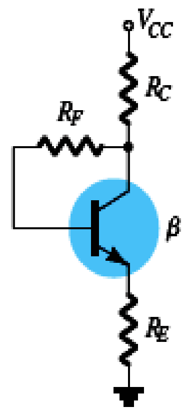
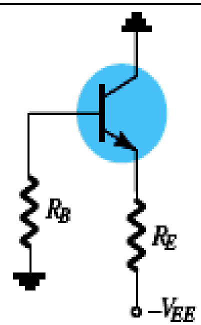
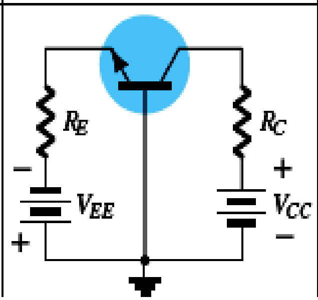
Table 4.1 is a review of the most common single-stage BJT configurations with their respective equations. Note the similarities that exist between the equations for the various configurations.

TABLE 4.1

BJT Bias Configurations

Type	Configuration	Pertinent Equations
Fixed-bias		$I_B = \dfrac{V_{CC} - V_{BE}}{R_B}$ $I_C = \beta I_B, I_E = (\beta + 1)I_B$ $V_{CE} = V_{CC} - I_C R_C$
Emitter-bias		$I_B = \dfrac{V_{CC} - V_{BE}}{R_B + (\beta + 1)R_E}$ $I_C = \beta I_B, I_E = (\beta + 1)I_B$ $R_i = (\beta + 1)R_E$ $V_{CE} = V_{CC} - I_C(R_C + R_E)$
Voltage-divider bias		EXACT: $R_{Th} = R_1 \| R_2, E_{Th} = \dfrac{R_2 V_{CC}}{R_1 + R_2}$ $I_B = \dfrac{E_{Th} - V_{BE}}{R_{Th} + (\beta + 1)R_E}$ $I_C = \beta I_B, I_E = (\beta + 1)I_B$ $V_{CE} = V_{CC} - I_C(R_C + R_E)$ APPROXIMATE: $\beta R_E \geq 10R_2$ $V_B = \dfrac{R_2 V_{CC}}{R_1 + R_2}, V_E = V_B - V_{BE}$ $I_E = \dfrac{V_E}{R_E}, I_B = \dfrac{I_E}{\beta + 1}$ $V_{CE} = V_{CC} - I_C(R_C + R_E)$

DC Biasing

Collector-feedback		$I_B = \dfrac{V_{CC} - V_{BE}}{R_F + \beta(R_C + R_E)}$ $I_C = \beta I_B, I_E = (\beta + 1)I_B$ $V_{CE} = V_{CC} - I_C(R_C + R_E)$
Emitter-follower		$I_B = \dfrac{V_{EE} - V_{BE}}{R_B + (\beta + 1)R_E}$ $I_C = \beta I_B, I_E = (\beta + 1)I_B$ $V_{CE} = V_{EE} - I_E R_E$
Common-base		$I_E = \dfrac{V_{EE} - V_{BE}}{R_E}$ $I_B = \dfrac{I_E}{\beta + 1}, I_C = \beta I_B$ $V_{CE} = V_{EE} + V_{CC} - I_E(R_C + R_E)$ $V_{CB} = V_{CC} - I_C R_C$

DC Biasing

7- DESIGN OPERATIONS

The design process is one where a current and/or voltage may be specified and the elements required to establish the designated levels must be determined.

One of the most powerful equations is simply Ohm's law in the following form:

$$R_{\text{unknown}} = V_R / I_R \qquad (4.49)$$

In a particular design the voltage across a resistor can often be determined from specified levels. If additional specifications define the current level, Eq. (4.49) can then be used to calculate the required resistance level. The first few examples will demonstrate how particular

elements can be determined from the design specifications. A complete design procedure will then be introduced for two popular configurations.

DC Biasing

EXAMPLE 4.21 Given the device characteristics of Fig. 4.59a , determine V_{CC}, R_B, and R_C for the fixed-bias configuration of Fig. 4.59b .

Solution: **From the load line**

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

$IC = V_{CC} / R_C$

$V_{CE} = 0\ \text{V}$

and $R_C = V_{CC} / I_C$

$= 20\ \text{V} / 8\ \text{mA} = 2.5\ \text{k}$

$I_B = (V_{CC} - V_{BE}) / R_B$

$R_B = V_{CC} - V_{BE} / I_B$

$= 20\ \text{V} - 0.7\ \text{V} / 40\ \text{mA}$

$= 19.3\ \text{V} / 40\ \text{mA}$

$= 482.5\ \text{k}\Omega$

Standard resistor values are

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

Using standard resistor values gives

$I_B = 41.1\ \text{mA}$

which is well within 5% of the value specified.

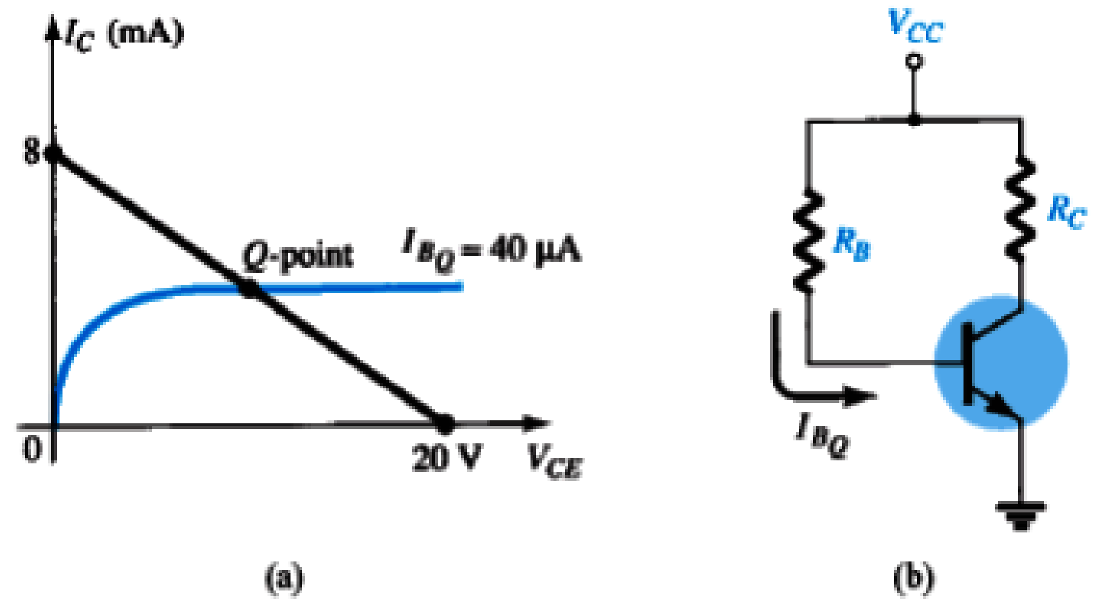


FIG. 4.59
Example 4.21.

DC Biasing

EXAMPLE 4.22 Given that I_{CQ} = 2 mA and V_{CEQ} = 10 V, determine $R1$ and R_C for the network of Fig. 4.60 .

Solution:

$V_E = I_E R_E \cong I_C R_E$

= (2 mA) (1.2 k) = 2.4 V

$V_B = V_{BE} + V_E$ = 0.7 V + 2.4 V = 3.1 V

$V_B = R_2 V_{CC} / (R1 + R2)$

= 3.1 V

and

(18 k) (18 V)/ $R1$ + 18 k = 3.1 V

324 k = 3.1$R1$ + 55.8 k

3.1$R1$ = 268.2 k

$R1$ = 268.2 k / 3.1 = **86.52 k**

Eq. (4.49): $R_C = V_{RC} / I_C$

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

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

and R_C = 18 V - 12.4 V / 2 mA

= **2.8 k**

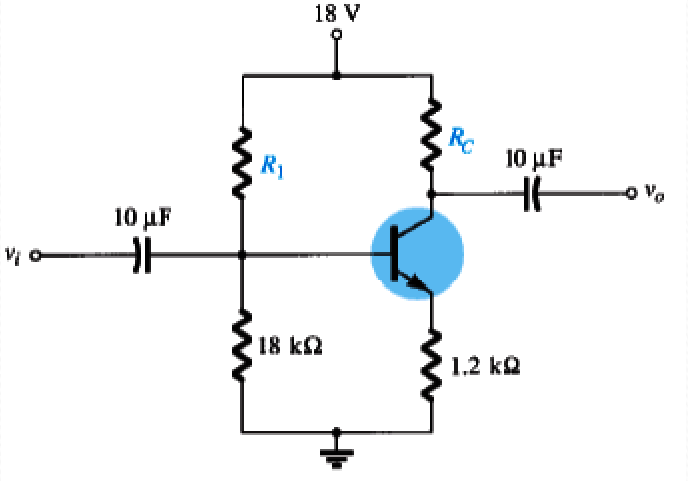


FIG. 4.60
Example 4.22.

DC Biasing

EXAMPLE 4.23 The emitter-bias configuration of Fig. 4.61 has the following specifications:

I_{CQ} =(½)Isat, ICsat = 8 mA, V_C = 18 V, and β = 110. Determine R_C, R_E, and R_B.

Solution:

I_{CQ} = (1/2) ICsat = 4 mA

$R_C = V_{RC} / I_{CQ}$

$= V_{CC} – V_C / I_{CQ}$

= 28 V - 18 V / 4 mA = 2.5 k

$I_{Csat} = V_{CC} / (R_C + R_E)$

and $R_C + R_E = V_{CC} / I_{Csat}$

= 28 V / 8 mA = 3.5 k

R_E = 3.5 k - R_C

= 3.5 k - 2.5 k = 1 k

$I_{BQ} = I_{CQ} / \beta$ = 4 mA / 110 = 36.36 mA

$I_{BQ} = V_{CC} – V_{BE} / (R_B + (\beta + 1) R_E)$

and $R_B + (\beta + 1) R_E = V_{CC} – V_{BE} / I_{BQ}$

with $R_B =(V_{CC} – V_{BE} / I_{BQ}) - (\beta + 1) R_E$

= (28 V - 0.7 V /36.36 mA) - (111)(1 k)

= (27.3 V / 36.36 mA)- 111 k

= 639.8 k

For standard values, *RC* = 2.4 k *RE* = 1 k *RB* = 620 k