COLLEGE OF ENGINEERING AND TECHNOLOGIES

ALMUSTAQBAL UNIVERSITY

Electronics

CTE 207

Lecture 18

- Voltage Divider Bias -

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Voltage-Divider Bias

- The voltage-divider bias configuration of Figure below 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 IC and VCE can be almost totally independent of beta.
- There are two methods that can be applied to analyze the voltage divider configuration.

Exact Analysis

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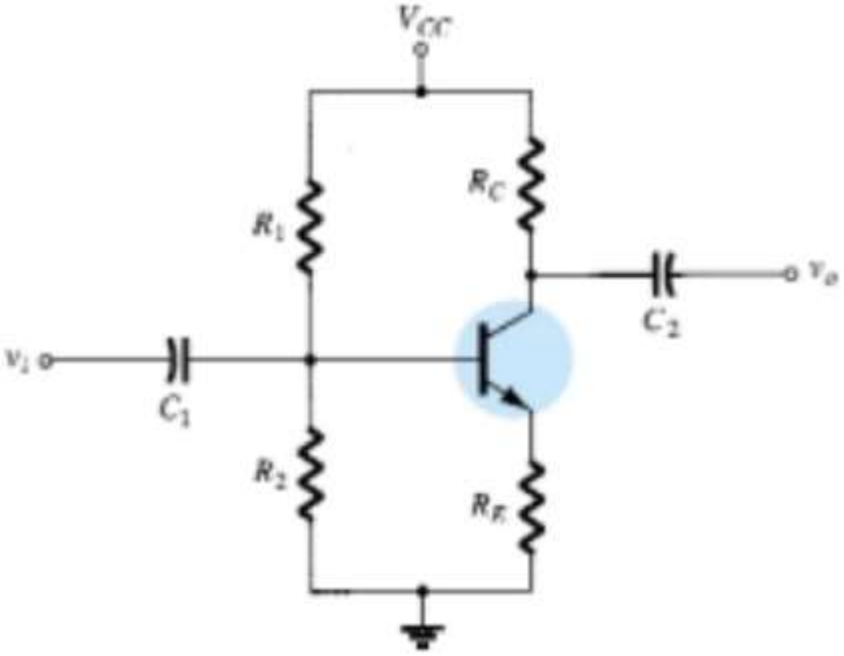
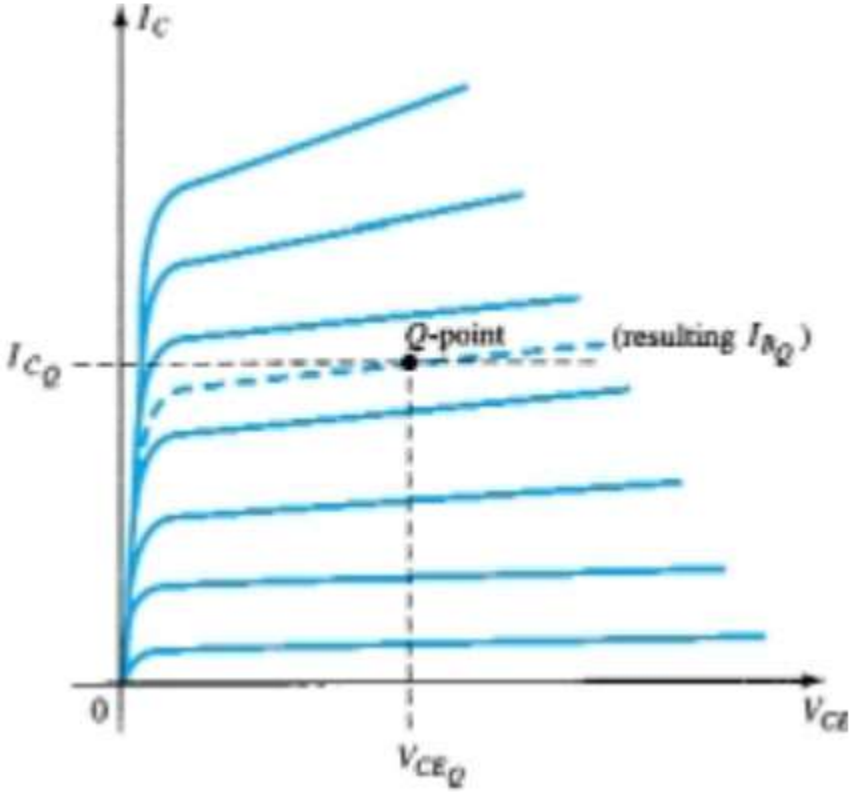




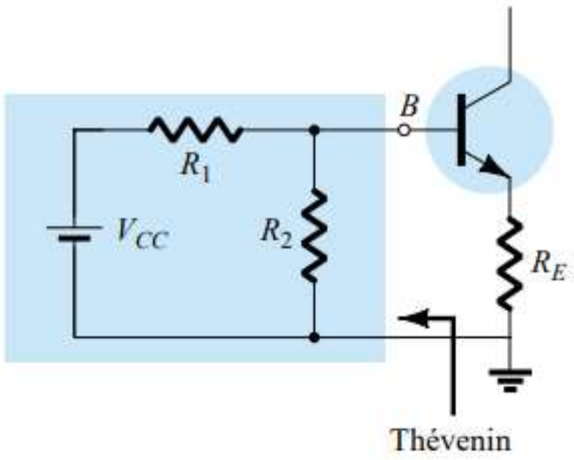
Voltage-divider bias configuration.

Defining the Q-point for the voltage divider bias configuration.

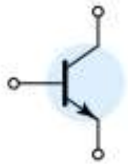
Exact Analysis

- The input side of the network of Figure above can be redrawn as shown in Figure below for the dc analysis.

- The thevenin equivalent network for the network to the left of the base terminal can then be found in the following manner:

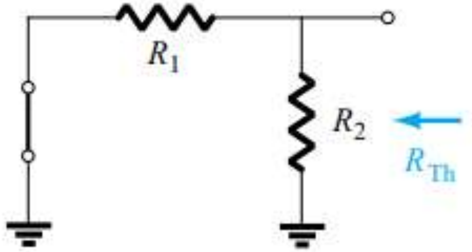


Exact Analysis



- R_{Th}: The voltage source is replaced by a short-circuit equivalent as shown in Figure below.

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

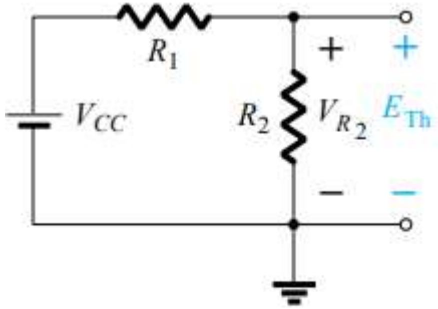


Determining R_{Th}

- E_{Th}: The voltage source VCC is returned to the network and the open-circuit Thevenin voltage of Figure below determined as follows:

Applying the voltage-divider rule:

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



Determining E_{Th}

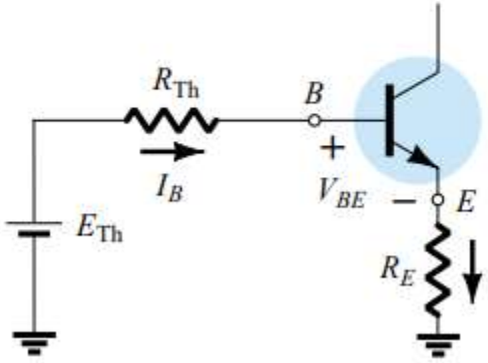
Exact Analysis

- The Thevenin network is then redrawn as shown in Figure below, and IBQ 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

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



Inserting the Thevenin equivalent circuit

Exact Analysis

- Once IB is known, the remaining quantities of the network can be found in the same manner as developed for the emitter-bias configuration.

That is,

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

- Which is exactly the same. The remaining equations for VE, VC, and VB are also the same as obtained for the emitter-bias configuration.

Example 1

Determine the DC bias voltage VCE and the current IC for the voltage-divider configuration of the Figure below.

Sol:

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

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

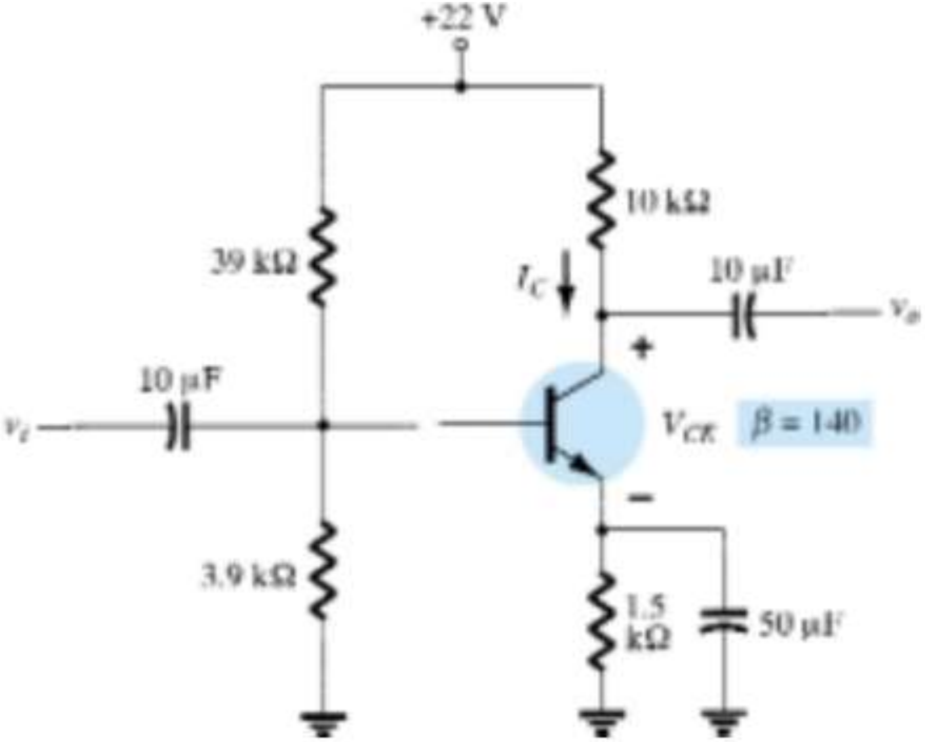
$$E_{Th} = \frac{R_2 V_{CC}}{R_1 + R_2}$$

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

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

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

$$= 6.05\ \mu A$$



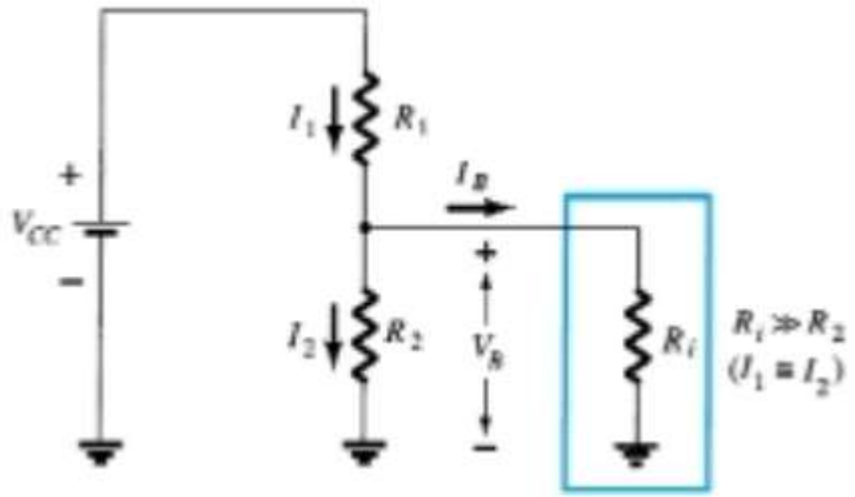
Solution

$$I_C = \beta I_B$$
$$= (140)(6.05\ \mu\text{A})$$
$$= \mathbf{0.85\ mA}$$
$$V_{CE} = V_{CC} - I_C(R_C + R_E)$$
$$= 22\text{ V} - (0.85\text{ mA})(10\text{ k}\Omega + 1.5\text{ k}\Omega)$$
$$= 22\text{ V} - 9.78\text{ V}$$
$$= \mathbf{12.22\ V}$$

Approximate Analysis

- The input section of the voltage-divider configuration can be represented by the network of the Figure below.

- The resistance Ri is the equivalent resistance between base and ground for the transistor with an emitter resistor RE.



Partial-bias circuit for calculating the approximate base voltage VB

Approximate Analysis

The voltage across R_2, which is actually the base voltage, can be determined using the voltage-divider rule (hence the name for the configuration). That is,

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

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:

$$\beta R_E \geq 10R_2$$

In other words, if β times the value of R_E is at least 10 times the value of R_2, the approximate approach can be applied with a high degree of accuracy.

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

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

Approximate Analysis

and the emitter current can be determined from

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

and

$$I_{C_Q} \cong I_E$$

The collector-to-emitter voltage is determined by

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

but since $I_E \cong I_C$,

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

Example 2

Repeat the analysis of Example 1 by using the approximate technique, and compare solutions for ICQ and VCEQ

Sol:

$$\beta R_E \geq 10R_2$$

$$(140)(1.5\text{ k}\Omega) \geq 10(3.9\text{ k}\Omega)$$

$$210\text{ k}\Omega \geq 39\text{ k}\Omega\ (\textit{satisfied})$$

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

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

$$= 2\text{ V}$$

Solution

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

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

compared to 0.85 mA with the exact analysis. Finally,

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

- ➢ The results for ICQ and VCEQ are certainly close, and considering the actual variation in parameter values one can certainly be considered as accurate as the other.
- ➢ The larger the level of Ri compared to R2, the closer the approximate to the exact solution.