# Electronic Circuits
# Elektronik Devreler


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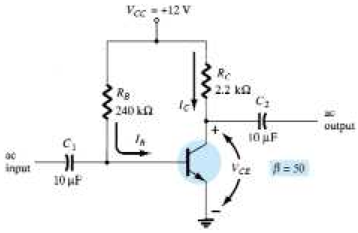
## Example 1

- Determine the following for the fixed-bias configuration shown in the figure.




(a) $I_{BQ}$ and $I_{CQ}$.
(b) $V_{CEQ}$.
(c) $V_B$ and $V_C$.
(d) $V_{BC}$.
(e) Determine the saturation current $I_{Csat}$



## Solution

(a) $$I_{B_Q} = \frac{V_{CC} - V_{BE}}{R_B} = \frac{12\text{ V} - 0.7\text{ V}}{240\text{ k}\Omega} = \mathbf{47.08\ \mu A}$$

$$I_{C_Q} = \beta I_{B_Q} = (50)(47.08\ \mu\text{A}) = \mathbf{2.35\ mA}$$

(b) $$V_{CE_Q} = V_{CC} - I_C R_C = 12\text{ V} - (2.35\text{ mA})(2.2\text{ k}\Omega) = \mathbf{6.83\ V}$$

(c) $V_B = V_{BE} = \mathbf{0.7\ V}$

$V_C = V_{CE} = \mathbf{6.83\ V}$

(d) Using double-subscript notation yields

$$V_{BC} = V_B - V_C = 0.7\text{ V} - 6.83\text{ V} = \mathbf{-6.13\ V}$$

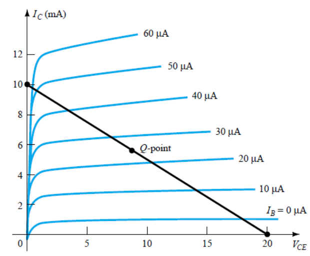
with the negative sign revealing that the junction is reversed-biased, as it should be for linear amplification.

(e) $$I_{C_{sat}} = \frac{V_{CC}}{R_C} = \frac{12\text{ V}}{2.2\text{ k}\Omega} = \mathbf{5.45\ mA}$$



## Example 2

- Given the following load line and the defined Q-point, determine the required values of $V_{CC}$, $R_C$, and $R_B$ for a fixed-bias configuration.






## Solution 2

- From the figure

$$V_{CE} = V_{CC} = \mathbf{20\ V} \text{ at } I_C = 0\text{ mA}$$

$$I_C = \frac{V_{CC}}{R_C} \text{ at } V_{CE} = 0\text{ V}$$

$$R_C = \frac{V_{CC}}{I_C} = \frac{20\text{ V}}{10\text{ mA}} = \mathbf{2\ k\Omega}$$

$$I_B = \frac{V_{CC} - V_{BE}}{R_B}$$

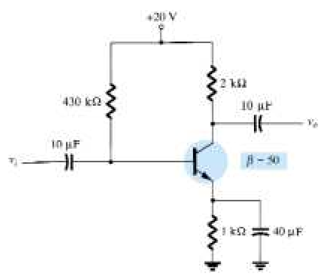
$$R_B = \frac{V_{CC} - V_{BE}}{I_B} = \frac{20\text{ V} - 0.7\text{ V}}{25\ \mu\text{A}} = \mathbf{772\ k\Omega}$$



## Example 3

- For the following emitter bias network, determine:

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



## Solution 3…

(a) $$I_B = \frac{V_{CC} - V_{BE}}{R_B + (\beta + 1)R_E} = \frac{20\text{ V} - 0.7\text{ V}}{430\text{ k}\Omega + (51)(1\text{ k}\Omega)}$$

$$= \frac{19.3\text{ V}}{481\text{ k}\Omega} = \mathbf{40.1\ \mu A}$$

(b) $I_C = \beta I_B$

$= (50)(40.1\ \mu\text{A})$

$\cong \mathbf{2.01\ mA}$

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

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

$= \mathbf{13.97\ V}$

(d) $V_C = V_{CC} - I_C R_C$

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

$= \mathbf{15.98\ V}$



## …Solution 3

(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) $V_{BC} = V_B - V_C$

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

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



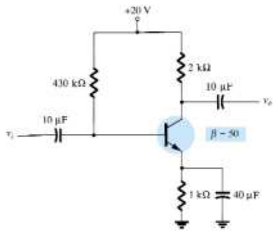
## Example 4

- Determine the saturation current for the network of Example 3.
- Solution:

$$I_{C_{\text{sat}}} = \frac{V_{CC}}{R_C + R_E}$$

$$= \frac{20\text{ V}}{2\text{ k}\Omega + 1\text{ k}\Omega} = \frac{20\text{ V}}{3\text{ k}\Omega}$$

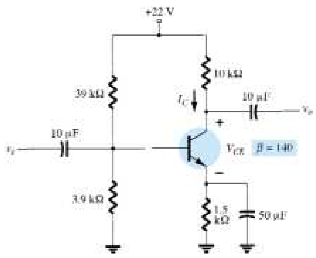
$$= \mathbf{6.67\ mA}$$






## Example 5

- Determine the dc bias voltage $V_{CE}$ and the current $I_C$ for the following voltage-divider network configuration.






## Solution 5

$R_{Th} = R_1 \| R_2$

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

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

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

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

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

$= 6.05\ \mu A$

$I_C = \beta I_B$

$= (140)(6.05\ \mu\text{A})$

$= \mathbf{0.85\ mA}$

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

$= 22\text{ V} - (0.85\text{ mA})(10\text{ k}\Omega + 1.5\text{ k}\Omega)$

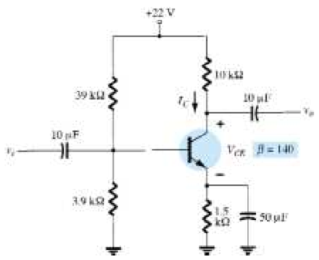
$= 22\text{ V} - 9.78\text{ V}$

$= \mathbf{12.22\ V}$



## Example 6

- Repeat the exact analysis of Example 5 if $\beta$ is reduced to 70, and compare solutions for $I_{CQ}$ and $V_{CEQ}$.



## Solution 6

$R_{Th} = 3.55\text{ k}\Omega, \quad E_{Th} = 2\text{ V}$

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

$$= \frac{2\text{ V} - 0.7\text{ V}}{3.55\text{ k}\Omega + (71)(1.5\text{ k}\Omega)} = \frac{1.3\text{ V}}{3.55\text{ k}\Omega + 106.5\text{ k}\Omega}$$

$$= 11.81\ \mu\text{A}$$

$$I_{C_Q} = \beta I_B$$

$$= (70)(11.81\ \mu\text{A})$$

$$= 0.83\text{ mA}$$

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

$$= 22\text{ V} - (0.83\text{ mA})(10\text{ k}\Omega + 1.5\text{ k}\Omega)$$

$$= \mathbf{12.46\ V}$$

- The results clearly show the relative insensitivity of the circuit to the change in $\beta$.
- Even though $\beta$ is drastically cut in half, from 140 to 70, the levels of $I_{CQ}$ and $V_{CEQ}$ are essentially the same

| $\beta$ | $I_{C_Q}$ (mA) | $V_{CE_Q}$ (V) |
|---|---|---|
| 140 | 0.85 | 12.22 |
| 70 | 0.83 | 12.46 |

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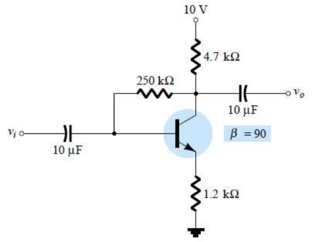
## Example 7

- Determine the quiescent levels of $I_{CQ}$ and $V_{CEQ}$ for the following network.

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## Solution 7

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

$$= \frac{10\text{ V} - 0.7\text{ V}}{250\text{ k}\Omega + (90)(4.7\text{ k}\Omega + 1.2\text{ k}\Omega)}$$

$$= \frac{9.3\text{ V}}{250\text{ k}\Omega + 531\text{ k}\Omega} = \frac{9.3\text{ V}}{781\text{ k}\Omega}$$

$$= 11.91\ \mu\text{A}$$

$$I_{C_Q} = \beta I_B = (90)(11.91\ \mu\text{A})$$

$$= \mathbf{1.07\ mA}$$

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

$$= 10\text{ V} - (1.07\text{ mA})(4.7\text{ k}\Omega + 1.2\text{ k}\Omega)$$

$$= 10\text{ V} - 6.31\text{ V}$$

$$= \mathbf{3.69\ V}$$

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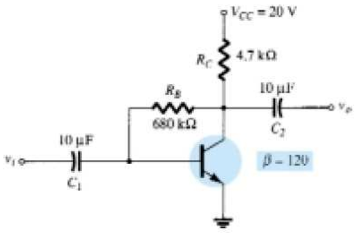
## Example 8

- For the following network:
  - (a) Determine $I_{CQ}$ and $V_{CEQ}$.
  - (b) Find $V_B$, $V_C$, $V_E$, and $V_{BC}$.

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## Solution 8

$$I_B = \frac{V_{CC} - V_{BE}}{R_B + \beta R_C}$$

$$= \frac{20\text{ V} - 0.7\text{ V}}{680\text{ k}\Omega + (120)(4.7\text{ k}\Omega)} = \frac{19.3\text{ V}}{1.244\text{ M}\Omega}$$

$$= 15.51\ \mu\text{A}$$

$$I_{C_Q} = \beta I_B = (120)(15.51\ \mu\text{A})$$

$$= \mathbf{1.86\ mA}$$

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

$$= 20\text{ V} - (1.86\text{ mA})(4.7\text{ k}\Omega)$$

$$= \mathbf{11.26\ V}$$

$$V_B = V_{BE} = \mathbf{0.7\ V}$$

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

$$V_E = \mathbf{0\ V}$$

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

$$= \mathbf{-10.56\ V}$$

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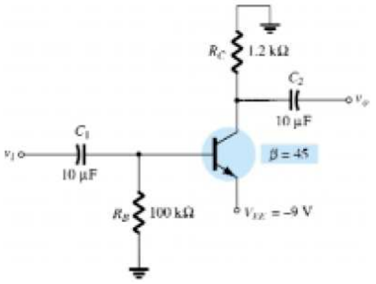
## Example 9

- Determine $V_C$ and $V_B$ for the following network.

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## Solution 9

$$-I_BR_B - V_{BE} + V_{EE} = 0$$

$$I_B = \frac{V_{EE} - V_{BE}}{R_B}$$

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

$$= \frac{8.3\text{ V}}{100\text{ k}\Omega}$$

$$= 83\ \mu\text{A}$$

$$I_C = \beta I_B$$
$$= (45)(83\ \mu\text{A})$$
$$= 3.735\text{ mA}$$

$$V_C = -I_CR_C$$
$$= -(3.735\text{ mA})(1.2\text{ k}\Omega)$$
$$= \mathbf{-4.48\ V}$$

$$V_B = -I_BR_B$$
$$= -(83\ \mu\text{A})(100\text{ k}\Omega)$$
$$= \mathbf{-8.3\ V}$$

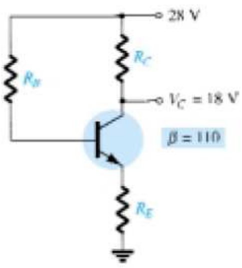


## Example 10

The following emitter-bias configuration has the following specifications:

$I_{CQ} = ½ I_{csat}$,
$I_{Csat} = 8$ mA,
$V_{CC} = 28$ V
$V_C = 18$ V, and
$\beta = 110$.

Determine $R_C$, $R_E$, and $R_B$.






## Solution 10

$$I_{C_Q} = \tfrac{1}{2}I_{C_{sat}} = 4\text{ mA}$$

$$R_C = \frac{V_{R_C}}{I_{C_Q}} = \frac{V_{CC} - V_C}{I_{C_Q}}$$

$$= \frac{28\text{ V} - 18\text{ V}}{4\text{ mA}} = \mathbf{2.5\ k\Omega}$$

$$I_{C_{sat}} = \frac{V_{CC}}{R_C + R_E}$$

$$R_C + R_E = \frac{V_{CC}}{I_{C_{sat}}} = \frac{28\text{ V}}{8\text{ mA}} = 3.5\text{ k}\Omega$$

$$R_E = 3.5\text{ k}\Omega - R_C$$
$$= 3.5\text{ k}\Omega - 2.5\text{ k}\Omega$$
$$= \mathbf{1\ k\Omega}$$

$$I_{B_Q} = \frac{I_{C_Q}}{\beta} = \frac{4\text{ mA}}{110} = 36.36\ \mu\text{A}$$

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

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

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

$$= \frac{28\text{ V} - 0.7\text{ V}}{36.36\ \mu\text{A}} - (111)(1\text{ k}\Omega)$$

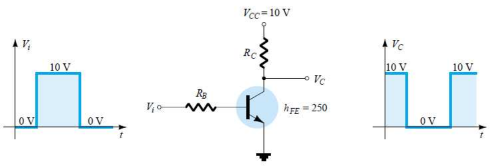
$$= \frac{27.3\text{ V}}{36.36\ \mu\text{A}} - 111\text{ k}\Omega$$

$$= \mathbf{639.8\ k\Omega}$$



## Example11

- Determine $R_B$ and $R_C$ for the following transistor inverter if $I_{Csat} = 10$ mA.






## Solution 11…

At saturation:

$$I_{C_{sat}} = \frac{V_{CC}}{R_C}$$

and $$10\text{ mA} = \frac{10\text{ V}}{R_C}$$

so that $$R_C = \frac{10\text{ V}}{10\text{ mA}} = 1\text{ k}\Omega$$

At saturation:

$$I_B \cong \frac{I_{C_{sat}}}{\beta_{dc}} = \frac{10\text{ mA}}{250} = 40\ \mu\text{A}$$

Choosing $I_B = 60\ \mu$A to ensure saturation and using

$$I_B = \frac{V_i - 0.7\text{ V}}{R_B}$$



## …Solution 11

we obtain $$R_B = \frac{V_i - 0.7\text{ V}}{I_B} = \frac{10\text{ V} - 0.7\text{ V}}{60\ \mu\text{A}} = 155\text{ k}\Omega$$

Choose $R_B = 150$ kΩ, which is a standard value. Then

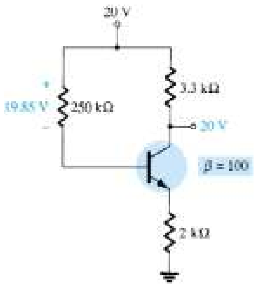
$$I_B = \frac{V_i - 0.7\text{ V}}{R_B} = \frac{10\text{ V} - 0.7\text{ V}}{150\text{ k}\Omega} = 62\ \mu\text{A}$$

and $$I_B = 62\ \mu\text{A} > \frac{I_{C_{sat}}}{\beta_{dc}} = 40\ \mu\text{A}$$

Therefore, use $R_B =$ **150 kΩ** and $R_C =$ **1 kΩ.**

## Example 12

- Based on the readings provided in the following network, determine whether the network is operating properly and, if not, the probable cause.






## Solution 12

The 20 V at the collector immediately reveals that $I_C = 0$ mA, due to an open circuit or a nonoperating transistor. The level of $V_{R_B} = 19.85$ V also reveals that the transistor is "off" since the difference of $V_{CC} - V_{R_B} = 0.15$ V is less than that required to turn "on" the transistor and provide some voltage for $V_E$. In fact, if we assume a short circuit condition from base to emitter, we obtain the following current through $R_B$:

$$I_{R_B} = \frac{V_{CC}}{R_B + R_E} = \frac{20\text{ V}}{252\text{ k}\Omega} = 79.4\ \mu\text{A}$$

which matches that obtained from

$$I_{R_B} = \frac{V_{R_B}}{R_B} = \frac{19.85\text{ V}}{250\text{ k}\Omega} = 79.4\ \mu\text{A}$$

If the network were operating properly, the base current should be

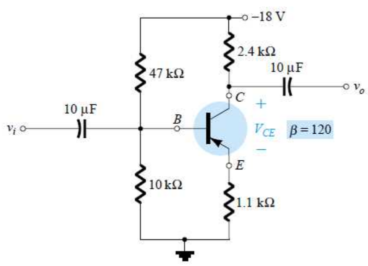
$$I_B = \frac{V_{CC} - V_{BE}}{R_B + (\beta + 1)R_E} = \frac{20\text{ V} - 0.7\text{ V}}{250\text{ k}\Omega + (101)(2\text{ k}\Omega)} = \frac{19.3\text{ V}}{452\text{ k}\Omega} = 42.7\ \mu\text{A}$$

The result, therefore, is that the transistor is in a damaged state, with a short-circuit condition between base and emitter.



## Example 13

- Determine $V_{CE}$ for the following voltage-divider bias configuration.






## Solution 13…

Testing the condition

$$\beta R_E \geq 10R_2$$

results in

$$(120)(1.1\text{ k}\Omega) \geq 10(10\text{ k}\Omega)$$

$$132\text{ k}\Omega \geq 100\text{ k}\Omega\ (\textit{satisfied})$$

Solving for $V_B$, we have

$$V_B = \frac{R_2 V_{CC}}{R_1 + R_2} = \frac{(10\text{ k}\Omega)(-18\text{ V})}{47\text{ k}\Omega + 10\text{ k}\Omega} = -3.16\text{ V}$$

Note the similarity in format of the equation with the resulting negative voltage for $V_B$.

Applying Kirchhoff's voltage law around the base–emitter loop yields

$$+V_B - V_{BE} - V_E = 0$$

and

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

Substituting values, we obtain

$$\begin{aligned} V_E &= -3.16\text{ V} - (-0.7\text{ V}) \\ &= -3.16\text{ V} + 0.7\text{ V} \\ &= -2.46\text{ V} \end{aligned}$$



## …Solution 13

Note in the equation above that the standard single- and double-subscript notation is employed. For an *npn* transistor the equation $V_E = V_B - V_{BE}$ would be exactly the same. The only difference surfaces when the values are substituted.

The current

$$I_E = \frac{V_E}{R_E} = \frac{2.46\text{ V}}{1.1\text{ k}\Omega} = 2.24\text{ mA}$$

For the collector–emitter loop:

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

Substituting $I_E \cong I_C$ and gathering terms, we have

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

Substituting values gives

$$\begin{aligned} V_{CE} &= -18\text{ V} + (2.24\text{ mA})(2.4\text{ k}\Omega + 1.1\text{ k}\Omega) \\ &= -18\text{ V} + 7.84\text{ V} \\ &= \mathbf{-10.16\text{ V}} \end{aligned}$$