Electronic Circuits
Elektronik Devreler

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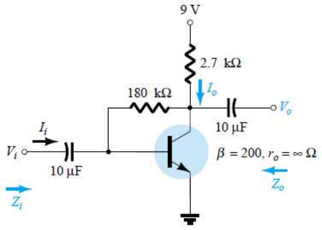
Example 14

- For the following network, determine:

(a) r_e
(b) Z_i
(c) Z_o
(d) A_v
(e) A_i



(f) Repeat parts (b) through (e) with r_o = 20 kΩ and compare results.

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Solution 14…

(a) $I_B = \dfrac{V_{CC} - V_{BE}}{R_F + \beta R_C} = \dfrac{9\text{ V} - 0.7\text{ V}}{180\text{ k}\Omega + (200)2.7\text{ k}\Omega}$

$= 11.53\ \mu\text{A}$

$I_E = (\beta + 1)I_B = (201)(11.53\ \mu\text{A}) = 2.32\text{ mA}$

$r_e = \dfrac{26\text{ mV}}{I_E} = \dfrac{26\text{ mV}}{2.32\text{ mA}} = \mathbf{11.21\ \Omega}$

(b) $Z_i = \dfrac{r_e}{\dfrac{1}{\beta} + \dfrac{R_C}{R_F}} = \dfrac{11.21\ \Omega}{\dfrac{1}{200} + \dfrac{2.7\text{ k}\Omega}{180\text{ k}\Omega}} = \dfrac{11.21\ \Omega}{0.005 + 0.015}$

$= \dfrac{11.21\ \Omega}{0.02} = 50(11.21\ \Omega) = \mathbf{560.5\ \Omega}$

(c) $Z_o = R_C \| R_F = 2.7\text{ k}\Omega \| 180\text{ k}\Omega = \mathbf{2.66\text{ k}\Omega}$

(d) $A_v = -\dfrac{R_C}{r_e} = -\dfrac{27\text{ k}\Omega}{11.21\ \Omega} = \mathbf{-240.86}$

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…Solution 14…

(e) $A_i = \dfrac{\beta R_F}{R_F + \beta R_C} = \dfrac{(200)(180\text{ k}\Omega)}{180\text{ k}\Omega + (200)(2.7\text{ k}\Omega)}$

$= \mathbf{50}$

(f) Z_i: The condition $r_o \geq 10R_C$ is *not* satisfied. Therefore,

$$Z_i = \frac{1 + \dfrac{R_C\|r_o}{R_F}}{\dfrac{1}{\beta r_e} + \dfrac{1}{R_F} + \dfrac{R_C\|r_o}{R_F r_e}} = \frac{1 + \dfrac{2.7\text{ k}\Omega\|20\text{ k}\Omega}{180\text{ k}\Omega}}{\dfrac{1}{(200)(11.21)} + \dfrac{1}{180\text{ k}\Omega} + \dfrac{2.7\text{ k}\Omega\|20\text{ k}\Omega}{(180\text{ k}\Omega)(11.21\ \Omega)}}$$

$$= \frac{1 + \dfrac{2.38\text{ k}\Omega}{180\text{ k}\Omega}}{0.45 \times 10^{-3} + 0.006 \times 10^{-3} + 1.18 \times 10^{-3}} = \frac{1 + 0.013}{1.64 \times 10^{-3}}$$

$= \mathbf{617.7\ \Omega}$ vs. 560.5 Ω above

Z_o:

$Z_o = r_o \| R_C \| R_F = 20\text{ k}\Omega \| 2.7\text{ k}\Omega \| 180\text{ k}\Omega$

$= \mathbf{2.35\text{ k}\Omega}$ vs. 2.66 kΩ above

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…Solution 14

A_v:

$$A_v = \frac{-\left[\dfrac{1}{R_F} + \dfrac{1}{r_e}\right](r_o\|R_C)}{1 + \dfrac{r_o\|R_C}{R_F}} = \frac{-\left[\dfrac{1}{180\text{ k}\Omega} + \dfrac{1}{11.21\Omega}\right](2.38\text{ k}\Omega)}{1 + \dfrac{2.38\text{ k}\Omega}{180\text{ k}\Omega}}$$

$$= \frac{-[5.56 \times 10^{-6} - 8.92 \times 10^{-2}](2.38\text{ k}\Omega)}{1 + 0.013}$$

$= \mathbf{-209.56}$ vs. −240.86 above

A_i:

$A_i = -A_v \dfrac{Z_i}{R_C}$

$= -(-209.56)\dfrac{617.7\ \Omega}{2.7\text{ k}\Omega}$

$= \mathbf{47.94}$ vs. 50 above

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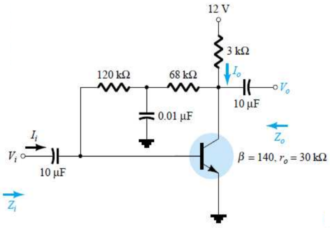
Example 15

- For the following network, determine:

(a) r_e
(b) Z_i
(c) Z_o
(d) A_v
(e) A_i



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Solution 15…

(a) DC: $I_B = \dfrac{V_{CC} - V_{BE}}{R_F + \beta R_C}$

$$= \frac{12\text{ V} - 0.7\text{ V}}{(120\text{ k}\Omega + 68\text{ k}\Omega) + (140)3\text{ k}\Omega}$$

$$= \frac{11.3\text{V}}{608\text{ k}\Omega} = 18.6\mu\text{A}$$

$$I_E = (\beta + 1)I_B = (141)(18.6\mu A)$$

$$= 2.62\text{ mA}$$

$$r_e = \frac{26\text{ mV}}{I_E} = \frac{26\text{ mV}}{2.62\text{ mA}} = \mathbf{9.92\ \Omega}$$

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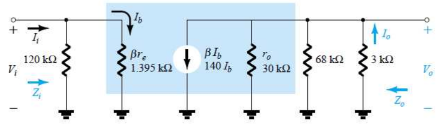
…Solution 15…

(b) $\beta r_e = (140)(9.92\ \Omega) = 1.39\text{ k}\Omega$

The ac equivalent network appears in Fig.

$$Z_i = R_{F_1} \| \beta r_e = 120\text{ k}\Omega \| 1.39\text{ k}\Omega$$

$$\cong \mathbf{1.37\text{ k}\Omega}$$



(c) Testing the condition $r_o \geq 10R_C$, we find

$$30\text{ k}\Omega \geq 10(3\text{ k}\Omega) = 30\text{ k}\Omega$$

which is satisfied through the equals sign in the condition. Therefore,

$$Z_o \cong R_C \| R_{F_2} = 3\text{ k}\Omega \| 68\text{ k}\Omega$$

$$= \mathbf{2.87\text{ k}\Omega}$$

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…Solution 15

(d) $r_o \geq 10R_C$, therefore,

$$A_v \cong -\frac{R_{F_2} \| R_C}{r_e} = -\frac{68\text{ k}\Omega \| 3\text{ k}\Omega}{9.92\ \Omega}$$

$$\cong -\frac{2.87\text{ k}\Omega}{9.92\ \Omega}$$

$$\cong \mathbf{-289.3}$$

(e) Since the condition $R_{F_1} \gg \beta r_e$ is satisfied,

$$A_i \cong \frac{\beta}{1 + \dfrac{R_C}{r_o \| R_{F_2}}} = \frac{140}{1 + \dfrac{3\text{ k}\Omega}{30\text{ k}\Omega \| 68\text{ k}\Omega}} = \frac{140}{1 + 0.14} = \frac{140}{1.14}$$

$$\cong \mathbf{122.8}$$

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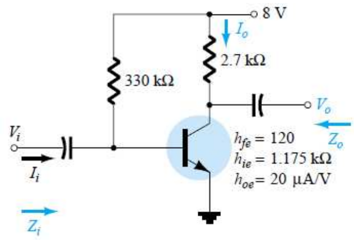
Example 16

- For the following network, determine:

(a) Z_i
(b) Z_o
(c) A_v
(d) A_i



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Solution 16

(a) $Z_i = R_B \| h_{ie} = 330\text{ k}\Omega \| 1.175\text{ k}\Omega$

$$\cong h_{ie} = \mathbf{1.171\text{ k}\Omega}$$

(b) $r_o = \dfrac{1}{h_{oe}} = \dfrac{1}{20\ \mu\text{A/V}} = 50\text{ k}\Omega$

$$Z_o = \frac{1}{h_{oe}} \| R_C = 50\text{ k}\Omega \| 2.7\text{ k}\Omega = \mathbf{2.56\text{ k}\Omega} \cong R_C$$

(c) $Av = -\dfrac{h_{fe}(R_C \| 1/h_{oe})}{h_{ie}} = -\dfrac{(120)(2.7\text{ k}\Omega \| 50\text{ k}\Omega)}{1.171\text{ k}\Omega} = \mathbf{-262.34}$

(d) $A_i \cong h_{fe} = 120$

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