Name:	**Dr JBO**
Student ID Number:	**Model Answer**
Section:	01 A/B
Lecturer:	Dr. Jamaludin Bin Omar

EEEB273 - Quiz 3
SEMESTER 1, ACADEMIC YEAR 2016/2017
Date: 21 July 2016 Time: 15 minutes

Question:

Consider the BJT differential amplifier in **Figure 1**. Transistors are matched. The circuit and transistor parameters are $I_Q = 1$ **mA**, $\beta = 100$, and $V_A = \infty$. Neglect base currents.

(a) Design the circuit such that one-sided differential-mode output voltage v_O taken at $v_{C2} = 8$ **V** when a differential-mode input voltage of $v_d = 0.05$ **V** is applied. Assume $v_{cm} = 0$ **V.** [7 marks]

(b) Determine the differential-mode input resistance, R_{id}. [3 marks]

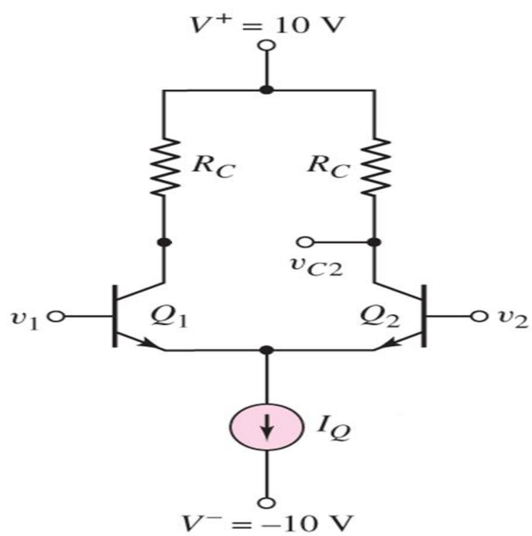

Figure 1

$$i_C = I_S e^{v_{BE}/V_T}\ ;\text{npn}$$
$$i_C = I_S e^{v_{EB}/V_T}\ ;\text{pnp}$$
$$i_C = \alpha i_E = \beta i_B$$
$$i_E = i_B + i_C$$
$$\alpha = \frac{\beta}{\beta + 1}$$

;Small signal

$$\beta = g_m r_\pi$$
$$g_m = \frac{I_{CQ}}{V_T}$$
$$r_\pi = \frac{\beta V_T}{I_{CQ}}$$
$$r_o = \frac{V_A}{I_{CQ}}$$
$$V_T = 26\ \text{mV}$$

Answer:

(a) The differential-mode voltage gain is given by

$$A_d = \frac{v_o}{v_d} = \frac{g_{m2} R_C}{2} \quad [2]$$

$$g_{m2} = \frac{I_{CQ2}}{V_T} = \frac{0.5mA}{26mV} = 19.231 mA/V \quad [2]$$

$$A_d = \frac{v_o}{v_d} = \frac{8}{0.05} = \frac{g_{m2} R_C}{2} = \frac{(19.231m) R_C}{2} \quad [2]$$

$$\Rightarrow R_C = \frac{320}{19.231m} = 16.64k\Omega \quad [1]$$

(b) $R_{id} = 2r_\pi = \dfrac{2\beta V_T}{I_{CQ2}} = \dfrac{2 \times 100 \times 0.026}{0.5mA} = 10.4k\Omega$ [1,1,1]

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Question:

Consider the BJT differential amplifier in **Figure 1**. Transistors are matched. The circuit and transistor parameters are $\boldsymbol{I_Q}$ **= 1.2 mA**, $\boldsymbol{\beta}$ **= 110**, and $V_A = \infty$. Neglect base currents.

(c) Design the circuit such that one-sided differential-mode output voltage $\boldsymbol{v_O}$ taken at $\boldsymbol{v_{C2}}$ **= 8 V** when a differential-mode input voltage of $\boldsymbol{v_d}$ **= 0.05 V** is applied. Assume $\boldsymbol{v_{cm}}$ **= 0 V.** [7 marks]

(d) Determine the differential-mode input resistance, $\boldsymbol{R_{id}}$. [3 marks]

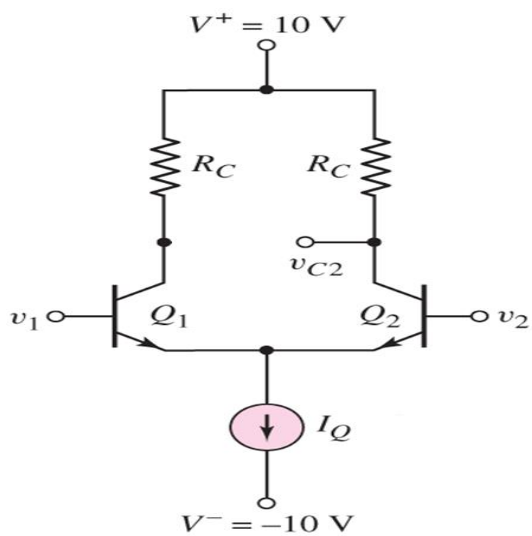

Figure 1

$$i_C = I_S e^{v_{BE}/V_T};\text{npn}$$

$$i_C = I_S e^{v_{EB}/V_T};\text{pnp}$$

$$i_C = \alpha i_E = \beta i_B$$

$$i_E = i_B + i_C$$

$$\alpha = \frac{\beta}{\beta+1}$$

$$;\text{Small signal}$$

$$\beta = g_m r_\pi$$

$$g_m = \frac{I_{CQ}}{V_T}$$

$$r_\pi = \frac{\beta V_T}{I_{CQ}}$$

$$r_o = \frac{V_A}{I_{CQ}}$$

$$V_T = 26\text{ mV}$$

Answer:

(c) The differential-mode voltage gain is given by

$$A_d = \frac{v_o}{v_d} = \frac{g_{m2}R_C}{2} \quad [2]$$

$$g_{m2} = \frac{I_{CQ2}}{V_T} = \frac{0.6mA}{26mV} = 23.076mA/V \quad [2]$$

$$A_d = \frac{v_o}{v_d} = \frac{8}{0.05} = \frac{g_{m2}R_C}{2} = \frac{(23.076m)R_C}{2} \quad [2]$$

$$\Rightarrow R_C = \frac{320}{23.076m} = 13.867k\Omega \quad [1]$$

(d) $$R_{id} = 2r_\pi = \frac{2\beta V_T}{I_{CQ2}} = \frac{2\times110\times0.026}{0.6mA} = 9.53k\Omega \quad [1,1,1]$$

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Question:

Consider the BJT differential amplifier in **Figure 1**. Transistors are matched. The circuit and transistor parameters are I_Q **= 1.2 mA**, β **= 110**, and $V_A = \infty$. Neglect base currents.

(e) Design the circuit such that one-sided differential-mode output voltage v_O taken at v_{C2} **= 7 V** when a differential-mode input voltage of v_d **= 0.05 V** is applied. Assume v_{cm} **= 0 V.** [7 marks]

(f) Determine the differential-mode input resistance, R_{id}. [3 marks]

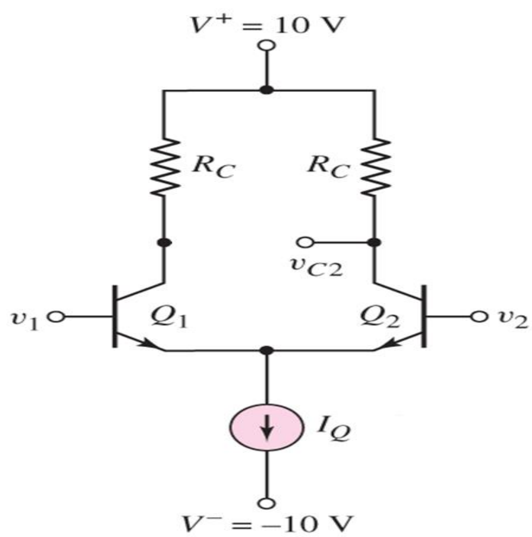

Figure 1

$$i_C = I_S e^{v_{BE}/V_T}\text{; npn}$$
$$i_C = I_S e^{v_{EB}/V_T}\text{; pnp}$$
$$i_C = \alpha i_E = \beta i_B$$
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; Small signal

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$$g_m = \frac{I_{CQ}}{V_T}$$
$$r_\pi = \frac{\beta V_T}{I_{CQ}}$$
$$r_o = \frac{V_A}{I_{CQ}}$$
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Answer:

(e) The differential-mode voltage gain is given by

$$A_d = \frac{v_o}{v_d} = \frac{g_{m2} R_C}{2} \quad [2]$$

$$g_{m2} = \frac{I_{CQ2}}{V_T} = \frac{0.6mA}{26mV} = 23.076mA/V \quad [2]$$

$$A_d = \frac{v_o}{v_d} = \frac{7}{0.05} = \frac{g_{m2} R_C}{2} = \frac{(23.076m) R_C}{2} \quad [2]$$

$$\Rightarrow R_C = \frac{280}{23.076m} = 12.134k\Omega \quad [1]$$

(f) $$R_{id} = 2r_\pi = \frac{2\beta V_T}{I_{CQ2}} = \frac{2 \times 110 \times 0.026}{0.6mA} = 9.53k\Omega \quad [1,1,1]$$

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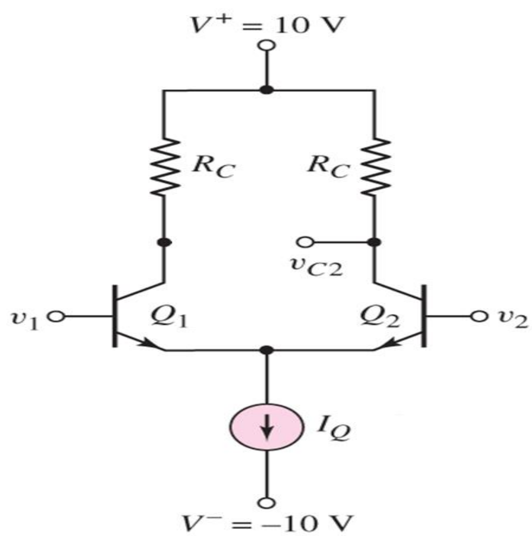
(g) Design the circuit such that one-sided differential-mode output voltage v_O taken at $v_{C2} = 7$ **V** when a differential-mode input voltage of $v_d = 0.05$ **V** is applied. Assume $v_{cm} = 0$ **V.** [7 marks]

(h) Determine the differential-mode input resistance, R_{id}. [3 marks]



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$$r_\pi = \frac{\beta V_T}{I_{CQ}}$$

$$r_o = \frac{V_A}{I_{CQ}}$$

$$V_T = 26\ \text{mV}$$

Answer:

(g) The differential-mode voltage gain is given by

$$A_d = \frac{v_o}{v_d} = \frac{g_{m2} R_C}{2} \quad [2]$$

$$g_{m2} = \frac{I_{CQ2}}{V_T} = \frac{0.5mA}{26mV} = 19.231 mA/V \quad [2]$$

$$A_d = \frac{v_o}{v_d} = \frac{7}{0.05} = \frac{g_{m2} R_C}{2} = \frac{(19.231m) R_C}{2} \quad [2]$$

$$\Rightarrow R_C = \frac{280}{19.231m} = 14.56 k\Omega \quad [1]$$

(h) $$R_{id} = 2 r_\pi = \frac{2\beta V_T}{I_{CQ2}} = \frac{2 \times 100 \times 0.026}{0.5mA} = 10.4 k\Omega \quad [1,1,1]$$