Name:	**Dr JBO**
Student ID Number:	**Model answer**
Section:	02/02A/02B
Lecturer:	Dr. Jamaludin Bin Omar

EEEB2014/EEEB273 - Quiz 1
SEMESTER 1, ACADEMIC YEAR 2019/2020
Date: 12 June 2019 Time: 15 minutes

Question:

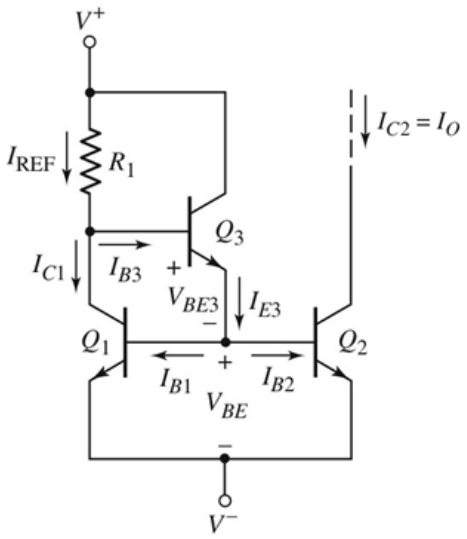
Refer to a three-transistor current source in **Figure 1**. All transistors are matched.
The circuit parameters are: $V^+ = 8$ V and $V^- = -8$ V.
The transistor parameters are: $\beta = 50$, $V_{BE}(\text{on}) = 0.6$ V, and $V_A = 120$ V.

(a) **Design** a three-transistor current source using all parameters given above so that $I_{B2} = 5.6$ µA. [8 marks]

(b) **Calculate** the **output resistance (R_O)** of the three-transistor current source. [2 marks]

Show clearly all calculations as marks are given according to this.

Answer:



(a) Design

I_O	$= I_{C2}$	$= \beta I_{B2}$	[1]
		$= (50)(5.6\ \mu A)$	[0.5]
		$= 0.28$ mA	[0.5]
I_{REF}		$= I_O [1 + 2/\beta(1 + \beta)]$	[2]
		$= (0.28\text{m})[1 + 2/(50\text{x}51)]$	[0.5]
		$= 0.2802$ mA	[0.5]
R_1		$= (V^+ - 2V_{BE} - V^-) / I_{REF}$	[2]
		$= (8 - 2\text{x}0.6 - (-8)) / (0.2802\text{ m})$	[0.5]
		$= 52.8194$ kΩ	[0.5]

(b) Calculate R_O

R_O	$= r_{O2}$	$= V_A / I_O$	[1]
		$= (120\text{ V}) / (0.28\text{ mA})$	[0.5]
		$= 428.57$ kΩ	[0.5]

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

; Small signal

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

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

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Question:

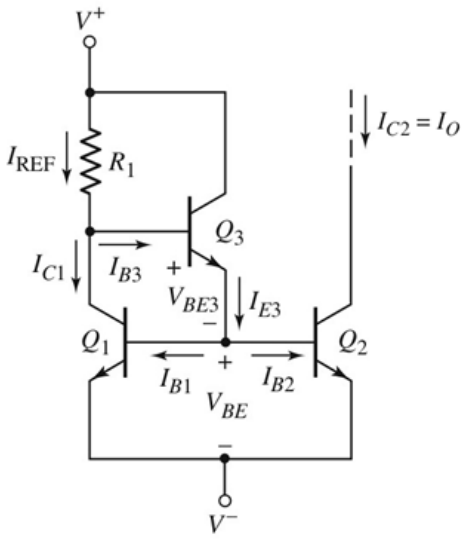
Refer to a three-transistor current source in **Figure 1**. All transistors are matched.
The circuit parameters are: $V^+ = 8$ V and $V^- = -8$ V.
The transistor parameters are: $\beta = 40$, $V_{BE}(\text{on}) = 0.6$ V, and $V_A = 130$ V.

(c) **Design** a three-transistor current source using all parameters given above so that $I_{B2} = 5.4\ \mu$A. [8 marks]

(d) **Calculate** the **output resistance (R_O)** of the three-transistor current source. [2 marks]

Show clearly all calculations as marks are given according to this.

Answer:



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

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

$i_C = \alpha i_E = \beta i_B$

$i_E = i_B + i_C$

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

; Small signal

$\beta = g_m r_\pi$

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

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

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

$V_T = 26$ mV

(a) Design

I_O	$= I_{C2}$	$= \beta I_{B2}$	[1]
		$= (40)\ (5.4\ \mu\text{A})$	[0.5]
		$= 0.216$ mA	[0.5]
I_{REF}		$= I_O\ [1 + 2/\beta(1 + \beta)]$	[2]
		$= (0.216\text{m})[1 + 2/(40\text{x}41)]$	[0.5]
		$= 0.2162$ mA	[0.5]
R_1		$= (V^+ - 2V_{BE} - V^-) / I_{REF}$	[2]
		$= (8 - 2\text{x}0.6 - (-8)) / (0.2162\text{ m})$	[0.5]
		$= 68.4551$ kΩ	[0.5]

(b) Calculate R_O

R_O	$= r_{O2}$	$= V_A / I_O$	[1]
		$= (130\text{ V}) / (0.2162\text{ mA})$	[0.5]
		$= 601.29$ kΩ	[0.5]

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Question:

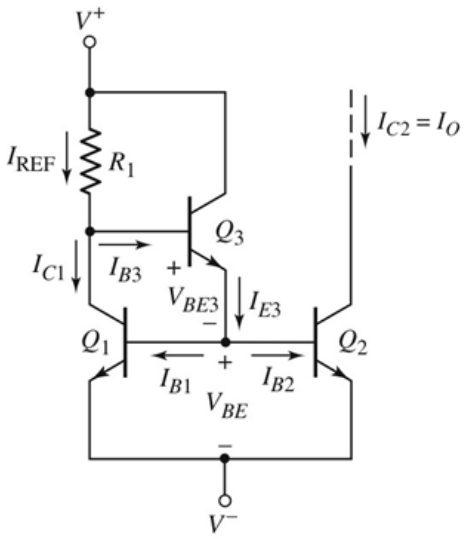
Refer to a three-transistor current source in **Figure 1**. All transistors are matched.
The circuit parameters are: $V^+ = 8.5$ V and $V^- = -8.5$ V.
The transistor parameters are: $\beta = 50$, $V_{BE}(\text{on}) = 0.6$ V, and $V_A = 130$ V.

(e) **Design** a three-transistor current source using all parameters given above so that $I_{B2} = 5.8$ µA. [8 marks]

(f) **Calculate** the **output resistance (R_O)** of the three-transistor current source. [2 marks]

Show clearly all calculations as marks are given according to this.

Answer:



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

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

$i_C = \alpha i_E = \beta i_B$

$i_E = i_B + i_C$

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

; Small signal

$\beta = g_m r_\pi$

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

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

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

$V_T = 26$ mV

(a) Design

I_O	$= I_{C2}$	$= \beta I_{B2}$	[1]
		$= (50)\ (5.8\ \mu A)$	[0.5]
		$= 0.29$ mA	[0.5]
I_{REF}		$= I_O\ [1 + 2/\beta(1 + \beta)]$	[2]
		$= (0.29\text{m})[1 + 2/(50\text{x}51)]$	[0.5]
		$= 0.2902$ mA	[0.5]
R_1		$= (V^+ - 2V_{BE} - V^-) / I_{REF}$	[2]
		$= (8.5 - 2\text{x}0.6 - (-8.5)) / (0.2902\text{ m})$	[0.5]
		$= 54.4452$ kΩ	[0.5]

(b) Calculate R_O

R_O	$= r_{O2}$	$= V_A / I_O$	[1]
		$= (130\text{ V}) / (0.29\text{ mA})$	[0.5]
		$= 448.27$ kΩ	[0.5]

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Question:

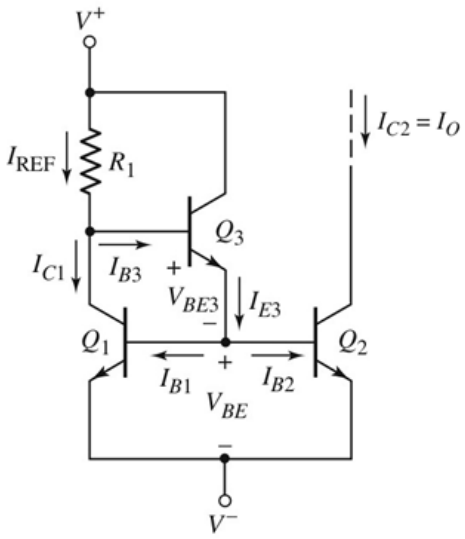
Refer to a three-transistor current source in **Figure 1**. All transistors are matched.
The circuit parameters are: $V^+ = 8.5$ V and $V^- = -8.5$ V.
The transistor parameters are: $\beta = 40$, $V_{BE}(\text{on}) = 0.6$ V, and $V_A = 120$ V.

(g) **Design** a three-transistor current source using all parameters given above so that $I_{B2} = 5.2$ µA. [8 marks]

(h) **Calculate** the **output resistance (R_O)** of the three-transistor current source. [2 marks]

Show clearly all calculations as marks are given according to this.

Answer:



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

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

$i_C = \alpha i_E = \beta i_B$

$i_E = i_B + i_C$

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

; Small signal

$\beta = g_m r_\pi$

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

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

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

$V_T = 26$ mV

(a) Design

I_O	$= I_{C2}$	$= \beta I_{B2}$	[1]
		$= (40)\ (5.2\ \mu A)$	[0.5]
		$= 0.208$ mA	[0.5]
I_{REF}		$= I_O\ [1 + 2/\beta(1 + \beta)]$	[2]
		$= (0.208\text{m})[1 + 2/(40\text{x}41)]$	[0.5]
		$= 0.2082$ mA	[0.5]
R_1		$= (V^+ - 2V_{BE} - V^-) / I_{REF}$	[2]
		$= (8.5 - 2\text{x}0.6 - (-8.5)) / (0.2082\text{ m})$	[0.5]
		$= 75.888$ kΩ	[0.5]

(b) Calculate R_O

R_O	$= r_{O2}$	$= V_A / I_O$	[1]
		$= (120\text{ V}) / (0.2082\text{ mA})$	[0.5]
		$= 576.368$ kΩ	[0.5]