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

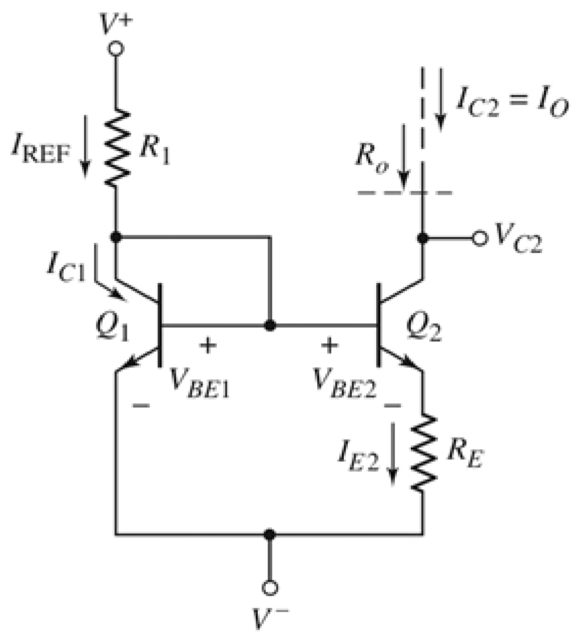
EEEB273 - Quiz 2
SEMESTER 2, ACADEMIC YEAR 2014/2015
Date: 20 November 2014 Time: 15 minutes

Question:

For a **Widlar** current source circuit shown in **Figure 1, design** the circuit such that $\boldsymbol{I_{REF}}$ **= 2 mA** and $\boldsymbol{I_O}$ **= 50 μA.** Let V^+ **= 15 V** and V^- **= 0 V**. The transistor are matched, and $\boldsymbol{V_{BE}}$ **= 0.7 V** at **1 mA.** Show clearly all calculations as marks are given according to this.

[10 marks]

Answer:



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

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

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

$$i_E = i_B + i_C$$

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

;Small signal

$$\beta = g_m r_\pi$$

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

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

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

V_{BE}	$= V_T \ln(I_C / I_S)$	
I_S	$= I_C / \{\exp(V_{BE} / V_T)\}$	[1]
	$= (1\text{m}) / \{\exp(0.7 / 0.026)\}$	[1]
	$= 2.03 \times 10^{-15}$ A	[0.5]

At I_{REF} **= 2 mA,**

V_{BE1}	$= V_T \ln(I_{REF} / I_S)$	[1]
	$= (0.026) \ln(2\text{m} / 2.03 \times 10^{-15})$	[1]
	$= 0.718$ V	[0.5]

I_{REF}	$= (V^+ - V_{BE1} - 0) / R_1$	
R_1	$= (V^+ - V_{BE1} - 0) / I_{REF}$	[1]
	$= (15 – 0.718) / (2\text{m})$	[1]
	$= 7.14$ kΩ	[0.5]

$I_O R_E$	$= V_T \ln(I_{REF} / I_O)$	
R_E	$= (V_T / I_O) \ln(I_{REF} / I_O)$	[1]
	$= (26\text{m} / 50\mu) \ln(2\text{m} / 50\mu)$	[1]
	$= 1.92$ kΩ	[0.5]

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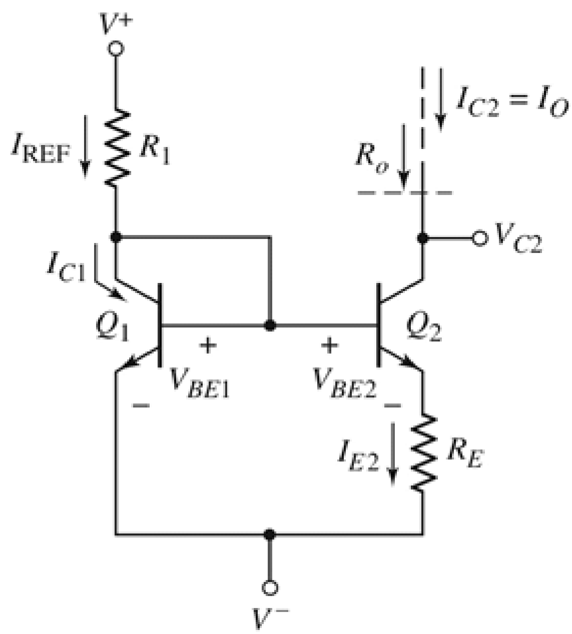
Question:

For a **Widlar** current source circuit shown in **Figure 1, design** the circuit such that $\boldsymbol{I_{REF} = 2.2}$ **mA** and $\boldsymbol{I_O = 60}$ **µA.** Let $\mathbf{V^+ = 15}$ **V** and $\mathbf{V^- = 0}$ **V**. The transistor are matched, and $\boldsymbol{V_{BE} = 0.7}$ **V** at **1 mA.** Show clearly all calculations as marks are given according to this.

[10 marks]

Answer:



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

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

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$$\beta = g_m r_\pi$$

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

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

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

V_{BE}	$= V_T \ln(I_C / I_S)$	
I_S	$= I_C / \{\exp(V_{BE} / V_T)\}$	[1]
	$= (1\text{m}) / \{\exp(0.7 / 0.026)\}$	[1]
	$= 2.03 \times 10^{-15}$ A	[0.5]

At $I_{REF} = 2.2$ mA,

V_{BE1}	$= V_T \ln(I_{REF} / I_S)$	[1]
	$= (0.026) \ln(2.2\text{m} / 2.03 \times 10^{-15})$	[1]
	$= 0.720$ V	[0.5]

I_{REF}	$= (V^+ - V_{BE1} - 0) / R_1$	
R_1	$= (V^+ - V_{BE1} - 0) / I_{REF}$	[1]
	$= (15 – 0.720) / (2.2\text{m})$	[1]
	$= 6.49$ kΩ	[0.5]

$I_O R_E$	$= V_T \ln(I_{REF} / I_O)$	
R_E	$= (V_T / I_O) \ln(I_{REF} / I_O)$	[1]
	$= (26\text{m} / 60\mu) \ln(2.2\text{m} / 60\mu)$	[1]
	$= 1.56$ kΩ	[0.5]

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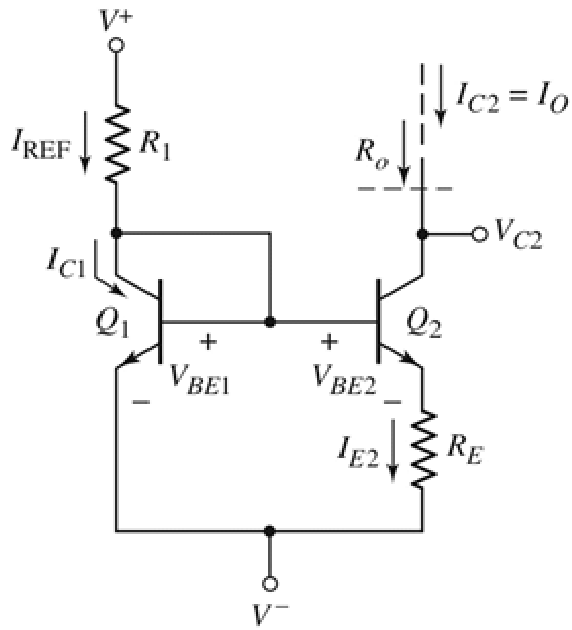
Question:

For a **Widlar** current source circuit shown in **Figure 1, design** the circuit such that $\boldsymbol{I_{REF} = 2.2}$ **mA** and $\boldsymbol{I_O = 50}$ **µA.** Let V^+ **= 12 V** and V^- **= 0 V**. The transistor are matched, and $\boldsymbol{V_{BE} = 0.7}$ **V** at **1 mA.** Show clearly all calculations as marks are given according to this.

[10 marks]

Answer:



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$$i_C = \alpha i_E = \beta i_B$$
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;Small signal

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

V_{BE}	$= V_T \ln(I_C / I_S)$	
I_S	$= I_C / \{\exp(V_{BE} / V_T)\}$	[1]
	$= (1m) / \{\exp(0.7 / 0.026)\}$	[1]
	$= 2.03 \times 10^{-15}$ A	[0.5]

At I_{REF} = 2 mA,

V_{BE1}	$= V_T \ln(I_{REF} / I_S)$	[1]
	$= (0.026) \ln(2.2m / 2.03 \times 10^{-15})$	[1]
	$= 0.720$ V	[0.5]

I_{REF}	$= (V^+ - V_{BE1} - 0) / R_1$	
R_1	$= (V^+ - V_{BE1} - 0) / I_{REF}$	[1]
	$= (12 - 0.720) / (2.2m)$	[1]
	$= 5.13$ kΩ	[0.5]

$I_O R_E$	$= V_T \ln(I_{REF} / I_O)$	
R_E	$= (V_T / I_O) \ln(I_{REF} / I_O)$	[1]
	$= (26m / 50\mu) \ln(2.2m / 50\mu)$	[1]
	$= 1.97$ kΩ	[0.5]

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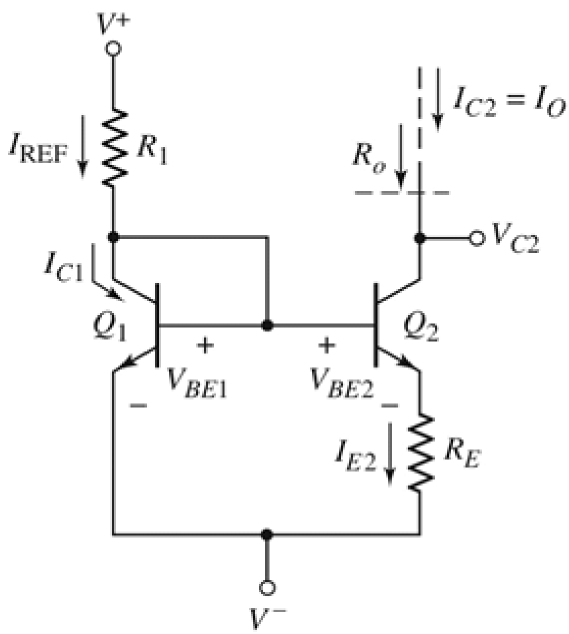
Question:

For a **Widlar** current source circuit shown in **Figure 1, design** the circuit such that $\boldsymbol{I_{REF}}$ **= 2 mA** and $\boldsymbol{I_O}$ **= 60 µA.** Let **V$^+$ = 12 V** and **V$^-$ = 0 V**. The transistor are matched, and $\boldsymbol{V_{BE}}$ **= 0.7 V** at **1 mA.** Show clearly all calculations as marks are given according to this.

[10 marks]

Answer:



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

;Small signal

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

$V_{BE} = V_T \ln(I_C / I_S)$
$I_S = I_C / \{\exp(V_{BE} / V_T)\}$ [1]
$= (1m) / \{\exp(0.7 / 0.026)\}$ [1]
$= 2.03 \times 10^{-15}$ A [0.5]

At I_{REF} = 2 mA,
$V_{BE1} = V_T \ln(I_{REF} / I_S)$ [1]
$= (0.026) \ln(2m / 2.03 \times 10^{-15})$ [1]
$= 0.718$ V [0.5]

$I_{REF} = (V^+ - V_{BE1} - 0) / R_1$
$R_1 = (V^+ - V_{BE1} - 0) / I_{REF}$ [1]
$= (12 – 0.718) / (2m)$ [1]
$= 5.64$ kΩ [0.5]

$I_O R_E = V_T \ln(I_{REF} / I_O)$
$R_E = (V_T / I_O) \ln(I_{REF} / I_O)$ [1]
$= (26m / 60µ) \ln(2m / 60µ)$ [1]
$= 1.52$ kΩ [0.5]