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

EEEB273 - Quiz 2 .
SEMESTER 2, ACADEMIC YEAR 2017/2018
Date: 1 Nov 2017 Time: 15 minutes

Question:

A **Widlar current source** circuit to be designed has the configuration shown in **Figure 1**. The circuit parameters are: $V^+ = +5.5$ **V** and $V^- = -5.5$ **V**. The transistor parameters are: $V_{BE1} = 0.6$ **V**, $V_A = 80$ **V**, and $\beta = 120$ **(Therefore, we can assume that $I_C \approx I_E$).**

(a) Design the Widlar current source circuit such that $I_{REF} = 1$ **mA** and $I_O = 12$ **µA**. [4 marks]

(b) Calculate the output resistance (R_O) of the Widlar current source in **Figure 1** using the following formula. Use parameters and results from **part (a)** above. [6 marks]

$$R_O = r_{o2}\left[1 + g_{m2}R_E^{'}\right] \text{where } R_E^{'} = R_E \| r_{\pi 2}$$

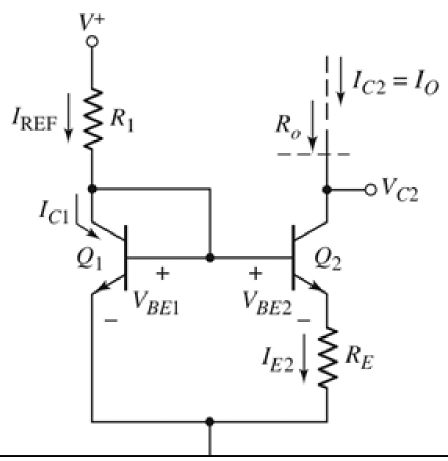
$$i_C = I_S e^{v_{BE}/V_T}\text{; npn}$$

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

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

$$i_E = i_B + i_C$$

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



; Small signal

$$\beta = g_m r_\pi$$

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

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

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

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

(a)

$$R_1 = \frac{V^+ - V_{BE1} - V^-}{I_{REF}} = \frac{5.5 - 0.6 - (-5.5)}{1\text{m}} = 10.4\text{k}\Omega \quad [2]$$

$$R_E = \frac{V_T}{I_O}\ln\left(\frac{I_{REF}}{I_O}\right) = \frac{0.026}{12\varepsilon}\ln\left(\frac{1\text{m}}{12\varepsilon}\right) = 9.58\text{k}\Omega \quad [2]$$

(b)

$$g_{m2} = \frac{I_O}{V_T} = \frac{12\mu}{0.026} = 0.462\text{mA/V} \quad [1]$$

$$r_{\pi 2} = \frac{\beta V_T}{I_O} = \frac{(120)(0.026)}{12\mu} = 260\text{k}\Omega \quad [1]$$

$$r_{o2} = \frac{V_A}{I_O} = \frac{80}{12\mu} = 6.67\text{M}\Omega \quad [1]$$

$$R_O = r_{o2}\left[1 + g_{m2}\left(R_E \| r_{\pi 2}\right)\right]$$

$$R_O = (6.67\text{M})\left[1 + (0.462\text{m})\left(9.58\text{k}\|260\text{k}\right)\right] = 35.1\text{M}\Omega \quad [3]$$

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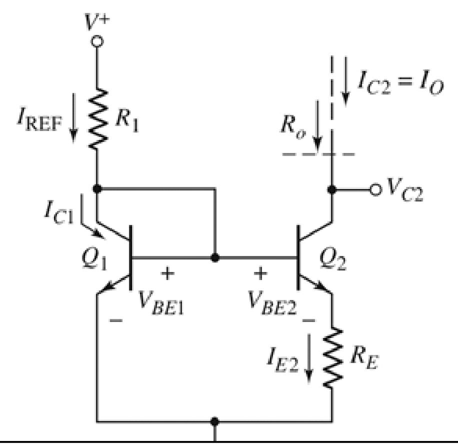
<u>Question:</u>

A **Widlar current source** circuit to be designed has the configuration shown in **Figure 1**. The circuit parameters are: $\boldsymbol{V^+ = +5.0}$ **V** and $\boldsymbol{V^- = -5.0}$ **V**. The transistor parameters are: $\boldsymbol{V_{BE1} = 0.6}$ **V**, $\boldsymbol{V_A = 80}$ **V**, and $\boldsymbol{\beta = 120}$ **(Therefore, we can assume that** $\boldsymbol{I_C \approx I_E}$**).**

(a) Design the Widlar current source circuit such that $\boldsymbol{I_{REF} = 1.2}$ **mA** and $\boldsymbol{I_O = 12}$ **µA**. [4 marks]

(b) Calculate the output resistance ($\boldsymbol{R_O}$) of the Widlar current source in **Figure 1** using the following formula. Use parameters and results from **part (a)** above. [6 marks]

$$R_O = r_{o2}\left[1 + g_{m2}R_E^{'}\right] \text{where } R_E^{'} = R_E \| r_{\pi 2}$$



(a)

$$R_1 = \frac{V^+ - V_{BE1} - V^-}{I_{REF}} = \frac{5 - 0.6 - (-5)}{1.2\text{m}} = 7.83\text{k}\Omega \quad [2]$$

$$R_E = \frac{V_T}{I_O}\ln\left(\frac{I_{REF}}{I_O}\right) = \frac{0.026}{12\varepsilon}\ln\left(\frac{1.2\text{m}}{12\varepsilon}\right) = 9.98\text{k}\Omega \quad [2]$$

(b)

$$g_{m2} = \frac{I_O}{V_T} = \frac{12\mu}{0.026} = 0.462\text{mA/V} \quad [1]$$

$$r_{\pi 2} = \frac{\beta V_T}{I_O} = \frac{(120)(0.026)}{12\mu} = 260\text{k}\Omega \quad [1]$$

$$r_{o2} = \frac{V_A}{I_O} = \frac{80}{12\mu} = 6.67\text{M}\Omega \quad [1]$$

$$R_O = r_{o2}\left[1 + g_{m2}\left(R_E \| r_{\pi 2}\right)\right]$$

$$R_O = (6.67\text{M})\left[1 + (0.462\text{m})\left(9.98\text{k} \| 260\text{k}\right)\right] = 36.2\text{M}\Omega \quad [3]$$

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

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

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

$$i_E = i_B + i_C$$

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

; 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:

A **Widlar current source** circuit to be designed has the configuration shown in **Figure 1**. The circuit parameters are: $V^+ = +5.0$ **V** and $V^- = -5.0$ **V**. The transistor parameters are: $V_{BE1} = 0.6$ **V**, $V_A = 100$ V, and $\beta = 120$ **(Therefore, we can assume that** $I_C \approx I_E$**)**.

(a) **Design** the Widlar current source circuit such that $I_{REF} = 1$ **mA** and $I_O = 10$ **µA**. [4 marks]

(b) Calculate the output resistance (R_O) of the Widlar current source in **Figure 1** using the following formula. Use parameters and results from **part (a)** above. [6 marks]

$$R_O = r_{o2}\left[1 + g_{m2}R_E'\right] \text{where } R_E' = R_E \| r_{\pi 2}$$

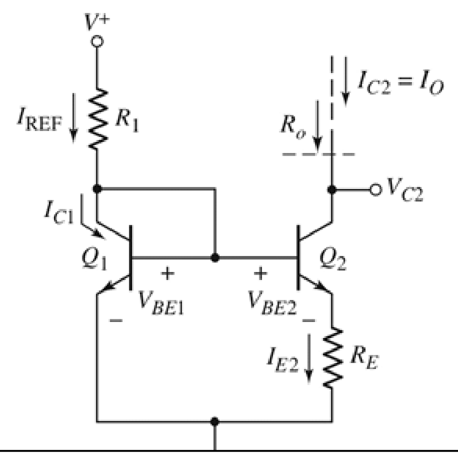
$$i_C = I_S e^{v_{BE}/V_T}\text{; npn}$$

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

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

$$i_E = i_B + i_C$$

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



; Small signal

$$\beta = g_m r_\pi$$

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

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

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

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

(a)

$$R_1 = \frac{V^+ - V_{BE1} - V^-}{I_{REF}} = \frac{5 - 0.6 - (-5)}{1\text{m}} = 9.40\text{k}\Omega \quad [2]$$

$$R_E = \frac{V_T}{I_O}\ln\left(\frac{I_{REF}}{I_O}\right) = \frac{0.026}{10\varepsilon}\ln\left(\frac{1\text{m}}{10\varepsilon}\right) = 11.97\text{k}\Omega \quad [2]$$

(b)

$$g_{m2} = \frac{I_O}{V_T} = \frac{10\mu}{0.026} = 0.385\text{mA/V} \quad [1]$$

$$r_{\pi 2} = \frac{\beta V_T}{I_O} = \frac{(120)(0.026)}{10\mu} = 312\text{k}\Omega \quad [1]$$

$$r_{o2} = \frac{V_A}{I_O} = \frac{100}{10\mu} = 10.0\text{M}\Omega \quad [1]$$

$$R_O = r_{o2}\left[1 + g_{m2}\left(R_E \| r_{\pi 2}\right)\right]$$

$$R_O = (10.0\text{M})\left[1 + (0.385\text{m})(11.97\text{k} \| 312\text{k})\right] = 54.3\text{M}\Omega \quad [3]$$

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Date: 1 Nov 2017 Time: 15 minutes

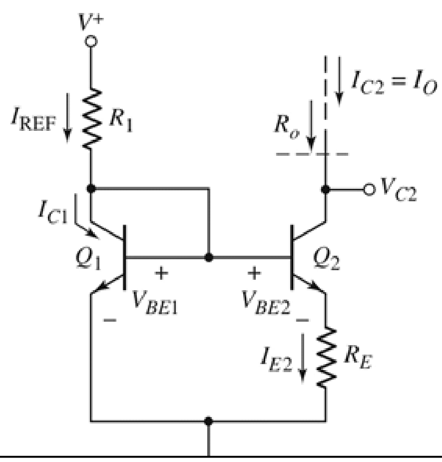
Question:

A **Widlar current source** circuit to be designed has the configuration shown in **Figure 1**. The circuit parameters are: V^+ = **+5.5 V** and V^- = **-5.5 V**. The transistor parameters are: V_{BE1} **= 0.6 V**, V_A = **100 V**, and β **= 120 (Therefore, we can assume that $I_C \approx I_E$).**

(a) Design the Widlar current source circuit such that I_{REF} **= 1.2 mA** and I_O **= 10 µA**. [4 marks]

(b) Calculate the output resistance (R_O) of the Widlar current source in **Figure 1** using the following formula. Use parameters and results from **part (a)** above. [6 marks]

$$R_O = r_{o2}\left[1 + g_{m2}R_E^{'}\right] \text{where } R_E^{'} = R_E \| r_{\pi 2}$$



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

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

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

$$i_E = i_B + i_C$$

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

; Small signal

$$\beta = g_m r_\pi$$

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

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

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

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

(a)

$$R_1 = \frac{V^+ - V_{BE1} - V^-}{I_{REF}} = \frac{5.5 - 0.6 - (-5.5)}{1.2\text{m}} = 8.67\text{k}\Omega \quad [2]$$

$$R_E = \frac{V_T}{I_O}\ln\left(\frac{I_{REF}}{I_O}\right) = \frac{0.026}{10\varepsilon}\ln\left(\frac{1.2\text{m}}{10\varepsilon}\right) = 12.44\text{k}\Omega \quad [2]$$

(b)

$$g_{m2} = \frac{I_O}{V_T} = \frac{10\mu}{0.026} = 0.385\text{mA/V} \quad [1]$$

$$r_{\pi 2} = \frac{\beta V_T}{I_O} = \frac{(120)(0.026)}{10\mu} = 312\text{k}\Omega \quad [1]$$

$$r_{o2} = \frac{V_A}{I_O} = \frac{100}{10\mu} = 10.0\text{M}\Omega \quad [1]$$

$$R_O = r_{o2}\left[1 + g_{m2}\left(R_E \| r_{\pi 2}\right)\right]$$

$$R_O = (10.0\text{M})\left[1 + (0.385\text{m})\left(12.44\text{k}\|312\text{k}\right)\right] = 56.05\text{M}\Omega \quad [3]$$