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

EEEB273 - Quiz 2 [Question Set 1]
SEMESTER 2, ACADEMIC YEAR 2011/2012
Date: 12 October 2011

**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) Find** $V_{BE2}$. [2 marks]

**(c)** The output resistance ($R_O$) of the Widlar current source in **Figure 1** can be calculated using the following formula.

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

If the Widlar current source circuit in **Figure 1** is used as an **active load** in a common-emitter BJT amplifier, what is the value of the **load resistance** provided by the Widlar current source? Use parameters and results from **part (a)** above. [4 marks]

**Answer:**

(a)

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

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

(b)

$$V_{BE2} = V_{BE1} - I_O R_E = 0.6 - (12\mu)(9.58\text{k}) = 0.485\text{V} \quad [2]$$

(c)

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

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

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

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

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

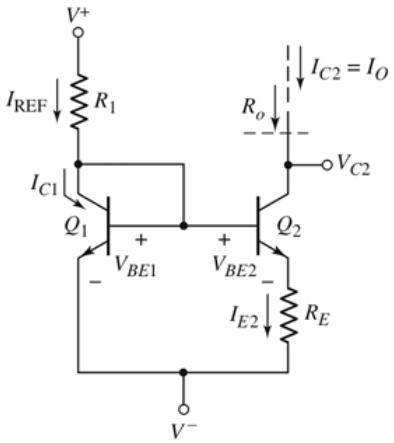


**Figure 1**

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| Name: | **Dr JBO** |
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| Section: | 01A / 01B |
| Lecturer: | Dr. Jamaludin Bin Omar |

EEEB273 - Quiz 2 [Question Set 2]
SEMESTER 2, ACADEMIC YEAR 2011/2012
Date: 12 October 2011

**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, $V_A = 80$ V, and $\beta = 120$ **(Therefore, we can assume that** $I_C \approx I_E$**)**.

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

**(b) Find** $V_{BE2}$. [2 marks]

**(c)** The output resistance ($R_O$) of the Widlar current source in **Figure 1** can be calculated using the following formula.

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

If the Widlar current source circuit in **Figure 1** is used as an **active load** in a common-emitter BJT amplifier, what is the value of the **load resistance** provided by the Widlar current source? Use parameters and results from **part (a)** above. [4 marks]

**Answer:**

(a)

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

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

(b)

$$V_{BE2} = V_{BE1} - I_O R_E = 0.6 - (12\mu)(9.98\text{k}) = 0.48\text{V} \quad [2]$$

(c)

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

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

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

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

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

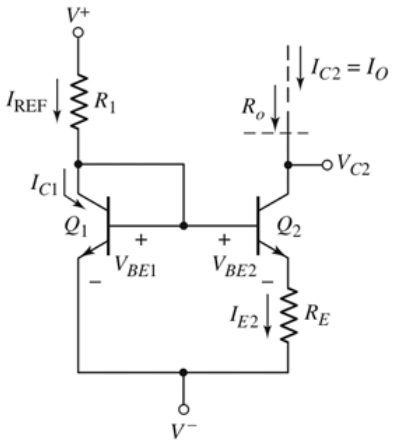


**Figure 1**

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EEEB273 - Quiz 2 [Question Set 3]
SEMESTER 2, ACADEMIC YEAR 2011/2012
Date: 12 October 2011

**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) Find** $V_{BE2}$. [2 marks]

**(c)** The output resistance ($R_O$) of the Widlar current source in **Figure 1** can be calculated using the following formula.

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

If the Widlar current source circuit in **Figure 1** is used as an **active load** in a common-emitter BJT amplifier, what is the value of the **load resistance** provided by the Widlar current source? Use parameters and results from **part (a)** above. [4 marks]

**Answer:**

(a)

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

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

(b)

$$V_{BE2} = V_{BE1} - I_O R_E = 0.6 - (10\mu)(11.97\text{k}) = 0.48\text{V} \quad [2]$$

(c)

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

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

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

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

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

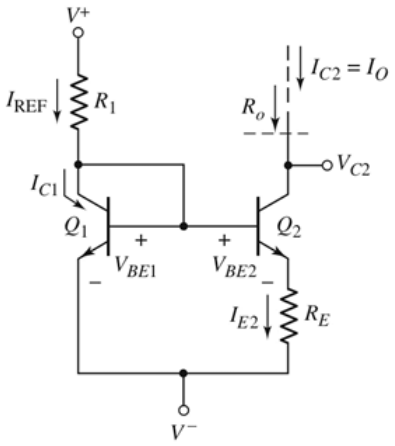


**Figure 1**

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| Name: | **Dr JBO** |
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| Lecturer: | Dr. Jamaludin Bin Omar |

EEEB273 - Quiz 2 [Question Set 4]
SEMESTER 2, ACADEMIC YEAR 2011/2012
Date: 12 October 2011

**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 $\beta$ **= 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) Find** $V_{BE2}$. [2 marks]

**(c)** The output resistance ($R_O$) of the Widlar current source in **Figure 1** can be calculated using the following formula.

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

If the Widlar current source circuit in **Figure 1** is used as an **active load** in a common-emitter BJT amplifier, what is the value of the **load resistance** provided by the Widlar current source? Use parameters and results from **part (a)** above. [4 marks]

**Answer:**

(a)

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

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

(b)

$$V_{BE2} = V_{BE1} - I_O R_E = 0.6 - (10\mu)(11.97\text{k}) = 0.48\text{V} \quad [2]$$

(c)

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

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

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

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

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

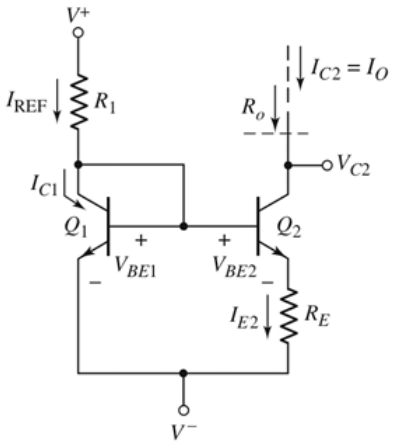


**Figure 1**