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

EEEB273 - Quiz 2 [Question Set 1]
SEMESTER 2, ACADEMIC YEAR 2010/2011
Date: 28 December 2010

Question:

Figure 1 shows circuit diagram of a BJT current source.

(a) Name the circuit for the current source. [1 mark]

(b) Draw the AC equivalent circuit for the current source. [2 marks]

(c) Draw the small-signal equivalent circuit for the current source. Do not forget to connect external test signal, $\boldsymbol{V_x}$, to the circuit. [3 marks]

(d) Using the small-signal equivalent circuit derive the equation for output resistance, $\boldsymbol{R_O}$, of the current source. [4 marks]

Answer:

(a) BJT Cascode current source. [1]

(b) See next page. [2]

(c) See next page. [3]

(d) [4]

$$\boldsymbol{V_{be4} = - I_x (r_{o2} \parallel r_{\pi 4})}$$

Summing currents at output node yields

$$I_x = g_{m4} V_{be4} + \left(\frac{V_x - (-V_{be4})}{r_{o4}} \right)$$

$$I_x = -g_{m4} I_x (r_{o2} \parallel r_{\pi 4}) + \left(\frac{V_x - I_x (r_{o2} \parallel r_{\pi 4})}{r_{o4}} \right)$$

$$\frac{V_x}{r_{o4}} = I_x + g_{m4} I_x (r_{o2} \parallel r_{\pi 4}) + \frac{I_x (r_{o2} \parallel r_{\pi 4})}{r_{o4}}$$

$$V_x = I_x \left(r_{o4} + r_{o4} g_{m4} (r_{o2} \parallel r_{\pi 4}) + (r_{o2} \parallel r_{\pi 4}) \right)$$

$$V_x = I_x \left(r_{o4} + r_{o4} g_{m4} (r_{\pi 4}) + (r_{\pi 4}) \right)$$

Where $\boldsymbol{\beta = g_{m4} r_{\pi 4}}$ and assuming $\boldsymbol{r_{\pi 4} << r_{o2}}$

$$R_O = \frac{V_x}{I_x} = r_{o4}(1 + \beta) + r_{\pi 4} \ \approxeq \boldsymbol{\beta r_{o4}}$$

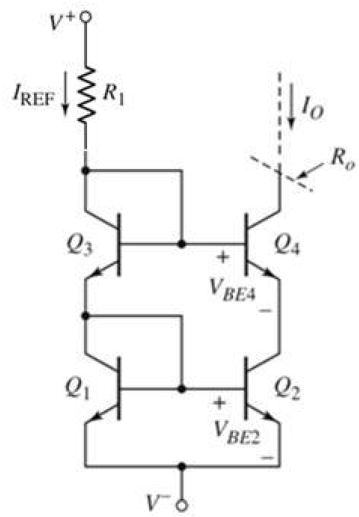
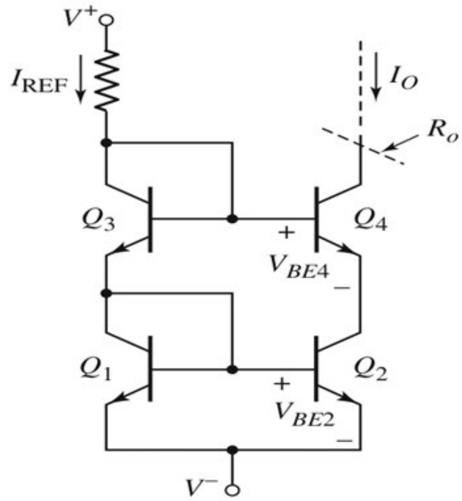
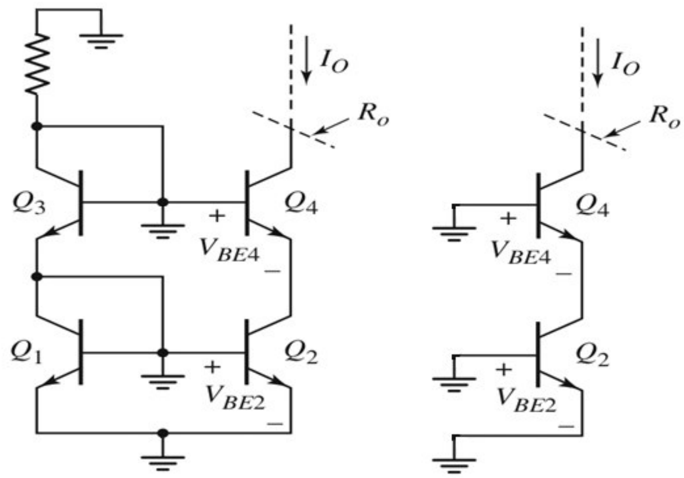


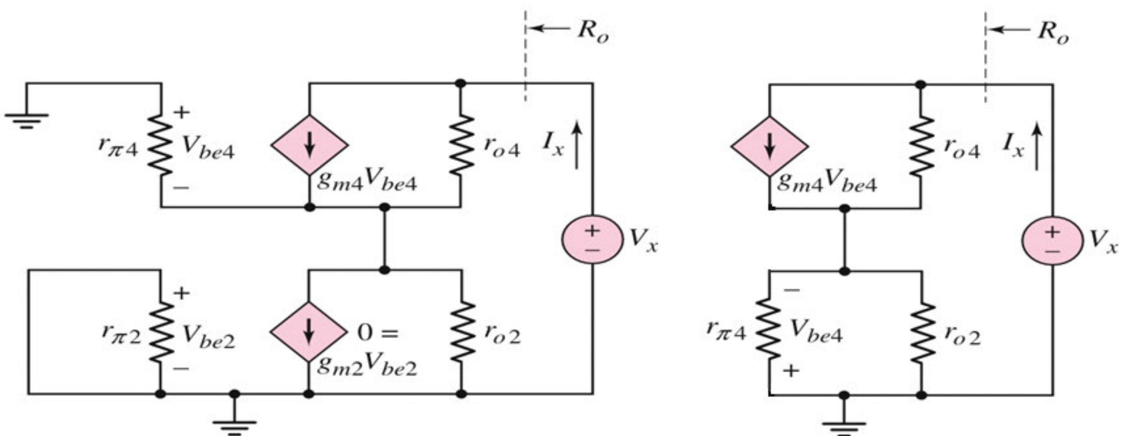
Figure 1



AC equivalent circuits



Small-signal equivalent circuits



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

EEEB273 - Quiz 2 [Question Set 2]
SEMESTER 2, ACADEMIC YEAR 2010/2011
Date: 28 December 2010

Question:

Figure 1 shows circuit diagram of a BJT current source.

(e) Name the circuit for the current source. [1 mark]

(f) Draw the AC equivalent circuit for the current source. [2 marks]

(g) Draw the small-signal equivalent circuit for the current source. Do not forget to connect external test signal, $\boldsymbol{V_x}$, to the circuit. [3 marks]

(h) Using the small-signal equivalent circuit derive the equation for output resistance, $\boldsymbol{R_O}$, of the current source. [4 marks]

Answer:

(e) BJT Widlar current source. [1]

(f) See next page. [2]

(g) See next page. [3]

(h) [4]

Define $R'_E = R_E \parallel r_{\pi 2}$

Then

$$V_{\pi 2} = -I_x R'_E$$

$$I_x = g_{m2} V_{\pi 2} + \frac{V_x - (-V_{\pi 2})}{r_{o2}}$$

$$I_x = g_{m2}(-I_x R'_E) + \frac{V_x}{r_{o2}} - \frac{I_x R'_E}{r_{o2}}$$

$$\frac{V_x}{r_{o2}} = I_x + g_{m2}(I_x R'_E) + \frac{I_x R'_E}{r_{o2}}$$

Normally $\mathbf{(1/r_{o2}) \ll g_{m2}}$, producing

$$\frac{V_x}{I_x} = R_O = r_{o2}\left[1 + R'_E\left(g_{m2} + \frac{1}{r_{o2}}\right)\right]$$

$$R_O \cong r_{o2}\left(1 + g_{m2} R'_E\right)$$

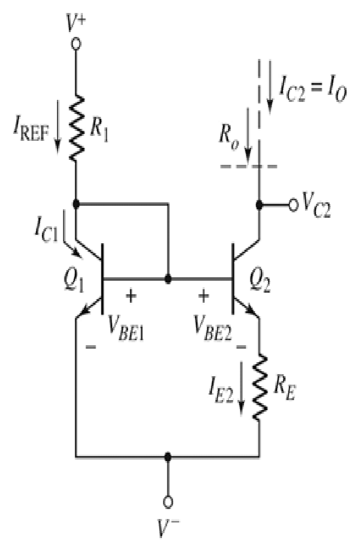
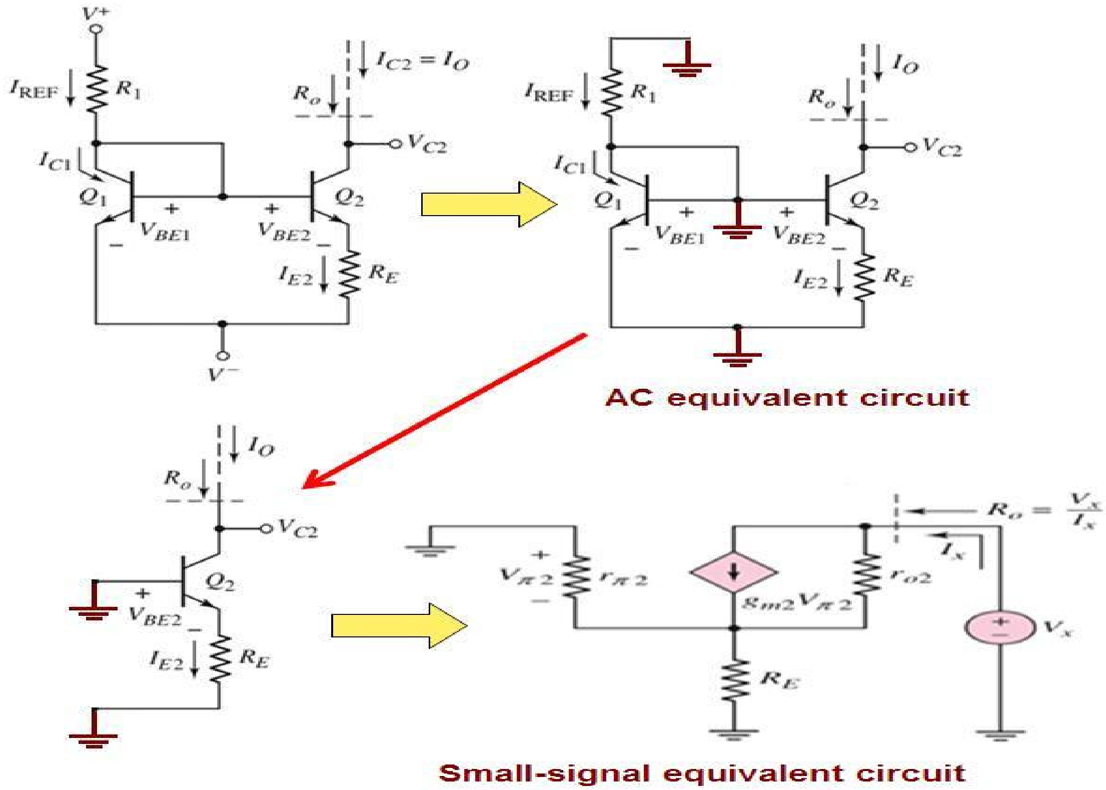


Figure 1



V+
I_REF
R1
I_C2 = I_O
R_o
V_C2
I_C1
Q1
Q2
V_BE1
V_BE2
I_E2
R_E
V−
I_O
AC equivalent circuit
V_π2
r_π2
g_m2 V_π2
r_o2
I_x
R_o = V_x / I_x
V_x
Small-signal equivalent circuit