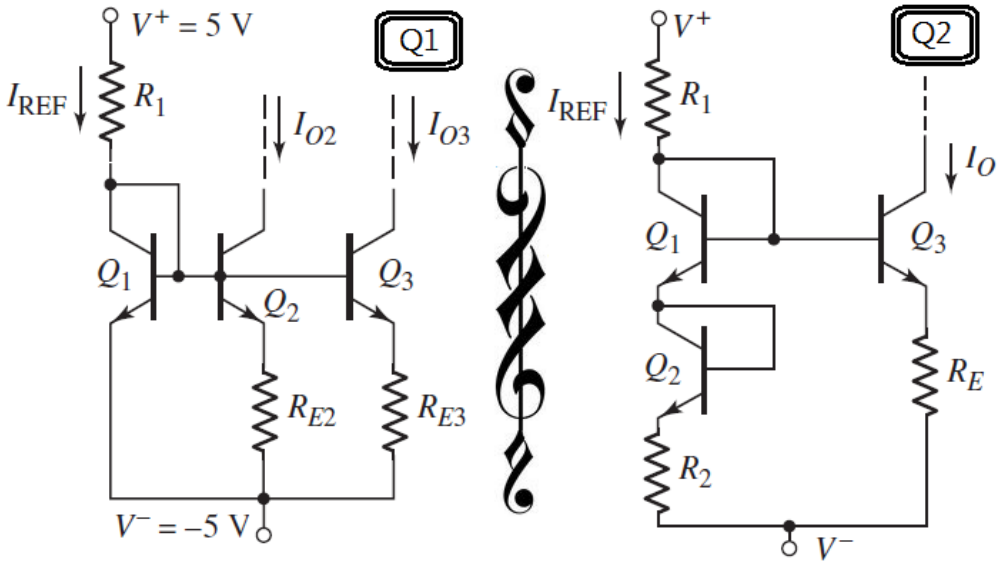
Subject: Electronic Circuits /(EEI 184)
Examiner : Dr. Mustafa M. Shiple

Term: Feb - May 2017/2018
Exam Time: 90 min

ANSWER THE FOLLOWING QUESTIONS:

1. Consider the Widlar current-source circuit with multiple output transistors shown in next Figure. Assume $V_{BE1} = 0.7V$. [5 marks] [A_q,C_a]
   (a) For circuit parameters $R_1 = 10k\Omega$, $R_{E2} = 1k\Omega$, and $R_{E2} = 2k\Omega$, find I_{REF}, I_{O2}, and I_{O3}.
   (b) Determine new values of R_{E2} and R_{E3} such that $I_{O2} = 20\mu A$ and $I_{O3} = 80\mu A$.



Solution:

(a)

$$I_{REF} = \frac{V^+ + V^- - V_{BE1}}{R_1} = 390\mu A$$

$$V_{BE1} = V_{BE2} + I_{E2}R_{E2}$$

$$I_{E2} = \frac{\beta I_{O2}}{(\beta + 1)}$$

$$\frac{\beta I_{O2}}{(\beta + 1)} R_{E2} = V_T ln\left(\frac{I_{REF}}{I_{O2}}\right)$$

$$38.5K I_{O2} = ln\left(\frac{0.39m}{I_{O2}}\right)$$

$$38.5K I_{O2} + ln I_{O2} = -7.8 \Rightarrow I_{O2} \cong 190\mu A$$

(b)

$$R_{E2} = V_T ln\left(\frac{I_{REF}}{I_{O2}}\right) \times \frac{(\beta + 1)}{\beta I_{O2}} = 9.95K\Omega$$

$$R_{E3} = V_T ln\left(\frac{I_{REF}}{I_{O3}}\right) \times \frac{(\beta + 1)}{\beta I_{O2}} = 2.03K\Omega$$

[Total Marks is 10]

Signature of:
Examiner:

Good Luck

2. Assume that all transistors in the circuit in previous Figure are matched and that $\beta = \infty$(neglect base currents). [5 marks] [A_p,B_i]

   (a) Derive an expression for I_O in terms of bias voltages and resistor values.

   (b) For $V^+ = +5V$ and $V^- = -5V$, design the circuit such that $I_O = 0.5$ mA.

   (c) Expand the current source circuit to supply $2I_O$.

Solution:

(a)

$$I_{REF} = \frac{V^+ + V^- - 2V_{BE1}}{R_1 + R_2} \tag{1}$$

$$V_B = V_{BE1} + V_{BE1} + I_{REF}R_2 = V_{BE3} + I_O R_E \qquad \text{tran. matched}$$

$$V_{BE} + I_{REF}R_2 = I_O R_E$$

$$V_T ln\left(\frac{I_{REF}}{I_S}\right) + I_{REF}R_2 = I_O R_E$$

$$I_O = \frac{V_T}{R_E} ln\left(\frac{I_{REF}}{I_S}\right) + \frac{R_2}{R_E} I_{REF}$$

(b) To simplify the solution since there are many variables, there are some assumptions will be made: assume $V_{BE} = 0.7V$, $R_1 = R_2$, $I_{REF} = I_O$

$$V_{BE} + I_{REF}R_2 = I_O R_E$$

$$V_{BE} + I_O R_2 = I_O R_E \Rightarrow R_E = R_2 + 1.4K$$

$$I_{REF} = \frac{V^+ + V^- - 2V_{BE1}}{R_1 + R_2} \Rightarrow R_2 = \frac{V^+ + V^- - 2V_{BE1}}{2I_O} = 8.6K\Omega \Rightarrow R_E = 10K\Omega$$