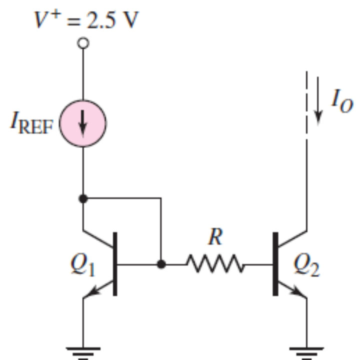
Subject: Advanced Electronic Circuits /(EEI 184)
Examiner : Dr. Mustafa M. Shiple

Term: Feb - May 2018

ANSWER THE FOLLOWING QUESTIONS:

1. Consider the circuit shown in next Figure. Assume $I_{REF} = 200\mu A$ and $R = 2k\Omega$. The transistor parameters are $\beta = 40$, $I_{S1} = I_{S2} = 5 \times 10^{-15}A$. Find V_{BE1},V_{BE2}, and I_O.



Solution:

(a) We know from two transistor current source that $I_{C1} = I_{C2}$ and both have a relation with I_{REF} as follows:

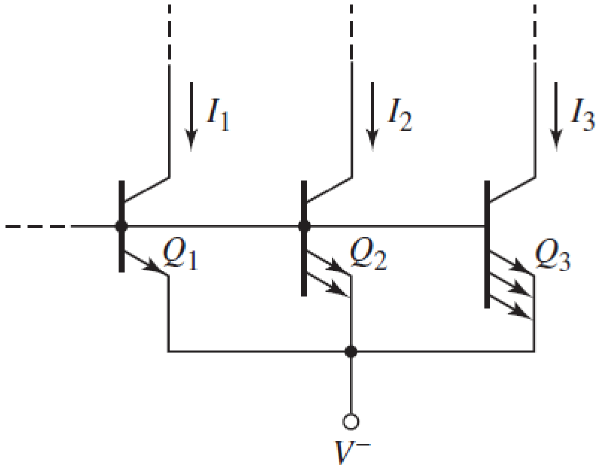
$$I_{C1} = \frac{I_{Ref}}{\left(1+\frac{2}{\beta}\right)}$$
$$= \frac{200\mu}{(1+\frac{2}{40})} = 190.48\mu A$$
$$\because I_C = \beta I_B \Rightarrow I_{B1} = 4.762\mu A$$
$$\therefore V_{BE1} = V_T \ln(\frac{I_{C1}}{I_{S1}}) = 0.63345V \qquad where \quad V_T = 0.026V$$
$$I_{Ref} = I_{B1} + I_{B2} + I_{C1} \Rightarrow I_{B2} = I_{Ref} - I_{C1} - I_{B1} = 4.758\mu A$$

(b)

$$V_{BE1} = I_{B2}R + V_{BE2} \Rightarrow V_{BE2} = 0.624V I_O = I_{S2}e^{\frac{V_{BE2}}{V_T}} = 132.4\mu A$$

2. The values of β for the transistors in next Figure are very large.
   (a) If Q_1 is diode-connected with $I_1 = 0.5mA$, determine the collector currents in the other two transistors.
   (b) Repeat part (a) if Q_2 is diode-connected with $I_2 = 0.5mA$.
   (c) Repeat part (a) if Q_3 is diode-connected with $I_3 = 0.5mA$.

[]



Solution:

(a)

$$I_2 = 2I_1 and I_3 = 3I_1$$
$$I_2 = 1.0mA, I_3 = 1.5mA$$

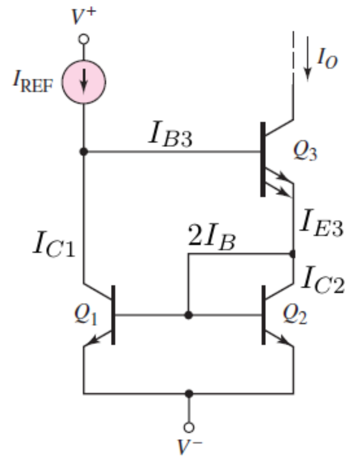
(b)

$$I_1 = 0.5I_2 and I_3 = 3(0.5I_2)$$
$$I_2 = 0.25mA, I_3 = 0.75mA$$

(c)

$$I_1 = \frac{I_3}{3} and I_2 = 2(\frac{I_3}{3})$$
$$I_2 = 0.167mA, I_2 = 0.333mA$$

3. Consider the Wilson current source in next Figure . The transistors have a finite β and an infinite Early voltage. Derive the expression for I_O in terms of I_REF and β.

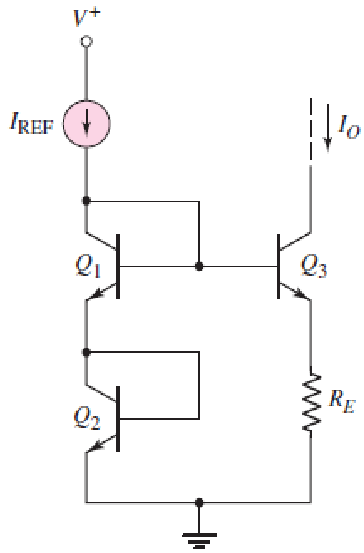


Solution:

$$I_{Ref} = I_{C1} + I_{B3}$$
$$I_{E3} = I_{C2} + 2I_B = I_{C2}\left(1 + \frac{2}{\beta}\right)$$
$$= I_{C2} + 2I_B = I_{C2}\left(1 + \frac{2}{\beta}\right)$$
$$I_{C2} = \frac{I_{E3}}{1 + \frac{2}{\beta}} = \frac{(1+\beta)}{(2+\beta)} I_{C3}$$
$$I_{Ref} = \frac{(1+\beta)}{(2+\beta)} I_{C3} + \frac{I_{C3}}{\beta}$$
$$I_o = I_{Ref}\left(\frac{1}{1 + \left(\frac{2}{\beta(2+\beta)}\right)}\right)$$

4. Consider the circuit in next Figure. Neglect base currents and assume $V_A = \infty$.
   (a) Derive the expression for IO in terms of I_{Ref} and R_E.
   (b) Determine the value of R_E such that $I_O = I_{Ref} = 100\mu A$. Assume $V_{BE} = 0.7V$ at a collector current of 1 mA.

Solution:



(a)

$$2V_{BE} = V_{BE} + I_o R_E$$
$$V_{BE} = I_o R_E$$
$$V_T \ln(\frac{I_{Ref}}{I_S}) = I_o R_E$$

(b)

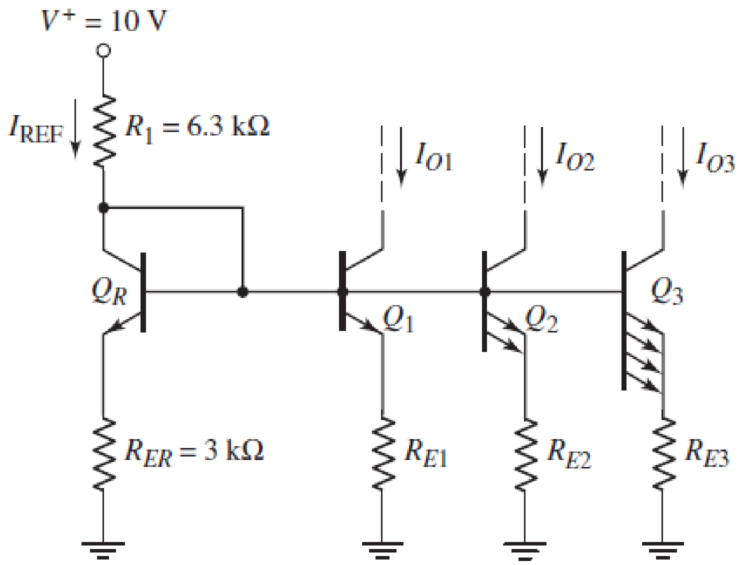
$$I_S = \frac{I_C}{e^{\frac{V_{BE1}}{V_T}}} = 2.03 \times 10^{-15} A$$
$$V_T \ln(\frac{I_{Ref}}{I_S}) = I_o R_E \Rightarrow R_E = 6.4K\Omega$$

5. Consider the circuit in next Figure. The transistor parameters are: $\beta = \infty$, $V_A = \infty$, and $V_{BE} = 0.7V$. Design the circuit such that the BE voltages of $Q_1, Q_2, and Q_3$ are identical to that of Q_R. What are the values of I_{O1}, I_{O2}, and I_{O3}?

Solution:

To keep BE voltages of $Q_1, Q_2, and Q_3$ are identical to that of Q_R, therefore voltages of $R_{ER}, R_{E1}, R_{E2} and R_{E3}$ must be identical too.

$$V_{R_{ER}} = I_{Ref} R_{ER} = \frac{V^+ - 0.7}{6.3K + 3K} \times 3K = 3V$$
$$V_{R_{E1}} = I_{o1} R_{E1} \Rightarrow R_{E1} = \frac{3}{1m} = 3K\Omega \qquad I_{o1} = I_{Ref}$$



$$V_{R_{E2}} = I_{o2}R_{E2} \Rightarrow R_{E2} = \frac{3}{2m} = 1.5K\Omega \qquad I_{o2} = 2I_{Ref}$$

$$V_{R_{E3}} = I_{o3}R_{E3} \Rightarrow R_{E3} = \frac{3}{4m} = 0.75K\Omega \qquad I_{o3} = 4I_{Ref}$$