Add. P.1

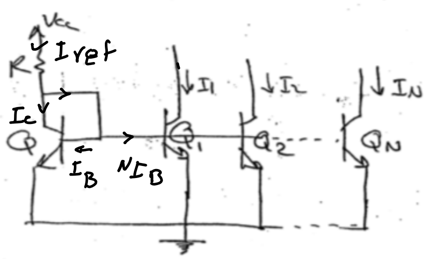
Wednesday, November 16, 2022 4:54 PM

For shown figure

a) prove that $I_1 = I_2 = \dots = I_N = \dfrac{I_{ref}}{1 + (N+1)/\beta}$

Assuming that all transistors are matched and have finite β

b) For $\beta = 100$, find the maximum number of Outputs for an Error not exceeding 10%.



$\because$ $Q_1, Q_2, \dots Q_N$ are matched

$$I_{B1} = I_{B2} = \dots I_{BN} = I_B$$

$$I_{ref} = I_C + I_B + N I_B$$

$$= \beta I_B + I_B + N I_B$$

$$I_{ref} = (\beta + 1 + N) I_B$$

$$I_1 = \beta I_B$$

$$I_{ref} = (\beta + 1 + N) \frac{I_1}{\beta}$$

$$I_1 = \frac{\cancel{\beta} I_{ref}}{\left(\cancel{\beta} + \frac{(1 + N)}{\beta}\right)}$$

$$I_o = I_1 = \frac{I_{ref}}{1 + \frac{(1+N)}{\beta}}$$

$\because$ $Q_1, Q_2, \cdots, Q_n$ are matched

$\therefore$ $I_1 = I_2 = \cdots = I_N$

$I_o \geq .90\ I_{ref}$

$$\frac{\cancel{I_{ref}}}{1 + \frac{(N+1)}{\underbrace{\beta}_{=100}}} \geq 0.9\ \cancel{I_{ref}}$$

$N \leq 10.11$

$$\boxed{N_{max} = 10}$$

Add. P.2

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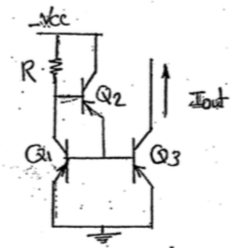
2-Determine the value of the output current if β of the PNP transistor is in the rang of 2-10. Compare this circuit with the simple (mirror) current source.



$$I_o = \frac{I_{ref}}{1 + \frac{2}{(1+\beta)\beta}}$$

if $\beta = 2$ if $\beta = 10$

$$I_o = \frac{I_{ref}}{1.33} \longrightarrow I_o = \frac{I_{ref}}{1.018}$$

$$I_o = \frac{I_{ref}}{1 + \frac{2}{\beta}}$$

if $\beta = 2$ if $\beta = 10$

$$I_o = \frac{I_{ref}}{2} \longrightarrow I_o = \frac{I_{ref}}{1.22}$$

Add. P.3

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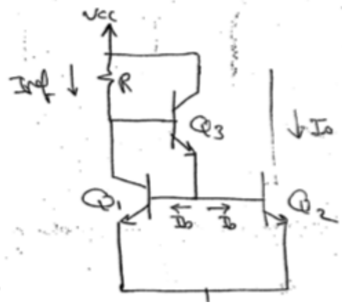
Example:

For The shown Circuit find The smallest value of β so That $I_o \geq 0.99\, I_{ref}$

Assume identical transistors.

This is improved Mirror Current source.



$$I_o = \frac{\cancel{I_{ref}}}{1 + \frac{2}{(1+\beta)\beta}} \geq 0.99\, \cancel{I_{ref}}$$

$$0.01\,\beta^2 + 0.01\,\beta - 2 \geq 0$$

$$\beta \rightarrow \begin{cases} 13.6 \\ -14.6 \quad \times \end{cases}$$

$$\beta \geq 13.6$$

$$\underline{\beta_{min} = 13.6}$$

Add. P.4

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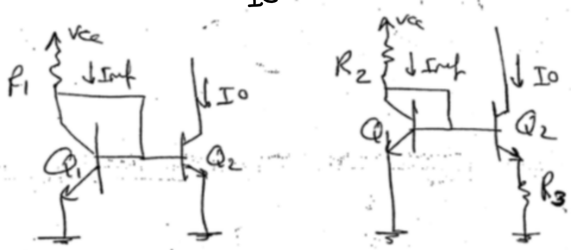
Example:

The two Circuits for generating a Constant Current $I_o = 10\mu A$. operate from a 10volt Supply. Determine the required resistors, Assuming $V_{BE} = 0.7$ v at a Current of 1mA.

I_C



(a) (b)

a)

$$I_{ref} = \frac{V_{CC} - V_{BE_1}}{R_1}$$

$$V_{BE} = V_T \ Ln\left(\frac{I_C}{I_S}\right)$$

$V_{BE_1} = 0.7$ at $I_{C_1} = 1mA$

$V_{BE_2} = ??$ at $I_{C_2} = 10\mu A$

$$V_{BE_1} - V_{BE_2} = \underset{0.025}{V_T} \ Ln\left(\frac{I_{C_1}}{I_{C_2}}\right)$$

$$0.7 - V_{BE_2} = 0.025 \ Ln\left(\frac{1mA}{10\mu A}\right)$$

$V_{BE2} = 0.584\ V$ at $I_C = 10\ \mu A$

assume β is ∞

$I_{ref} \simeq I_o = 10\ \mu A$

$$R_1 = \frac{V_{CC} - 0.584}{10\ \mu A} = 942\ K\Omega \simeq 1 M\Omega$$

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b)

$$I_o = \frac{V_T}{R_E} \ln\left(\frac{I_{ref}}{I_o}\right) \quad I_o \rightarrow 10\ \mu A$$

let $I_{ref} = 1 mA \longrightarrow V_{BE} = 0.7$

$$R_3 = \frac{V_T}{I_o} \ln\left(\frac{I_{ref}}{I_o}\right)$$

$R_3 = 11.5\ K\Omega$

$$R_2 = \frac{V_{CC} - V_{BE1}}{I_{ref}} = \frac{10 - 0.7}{1 mA} = 9.3 K\Omega$$

$$I_o = \frac{V_T}{\ } \ln\left(\frac{I_{ref}}{\ }\right) \rightarrow 1 mA$$

$$I_o = \frac{\quad}{R_E} \ln\left(\frac{\quad}{I_o}\right)$$

$R_E = \checkmark$ $\quad I_{ref} = \checkmark$

Trial and Error

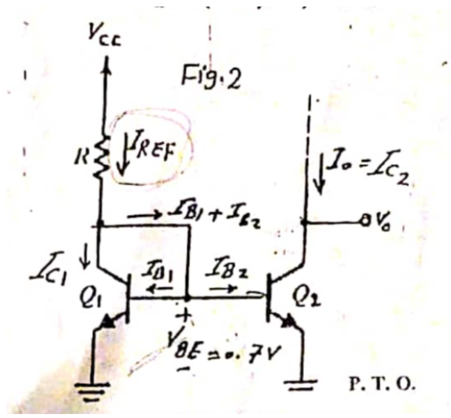
$$I_o = \checkmark$$

Add. P.5

Thursday, November 17, 2022 3:03 PM

Mid Term Exam 2nd year Comm. Electronic-3 — **First Term**

1- **The current source shown in Fig. 2 uses R = 20 kΩ, V_{CC}= 10V, V_{BE}=0.7V. Calculate (I_o) if the current ratio for Q1 and Q2 is $\frac{IS1}{IS2} = \frac{1}{2}$** , $\beta = 100$



$$\frac{I_{S1}}{I_{S2}} = \frac{1}{2}$$

$$V_{BE} = V_T \ln \frac{I_C}{I_S}$$

$$\cancel{V_{BE_1}} - \cancel{V_{BE_2}} = V_T \ln\left(\frac{I_{C1}}{I_{S1}} \cdot \frac{I_{S2}}{I_{C2}}\right)$$

$$\underbrace{V_T}_{0.025} \underbrace{\ln\left(\frac{I_{C1}}{I_{S1}} \cdot \frac{I_{S2}}{I_{C2}}\right)}_{} = 0$$

$$\ln\left(\frac{I_{C1}}{I_{S1}} \cdot \frac{I_{S2}}{I_{C2}}\right) = 0$$

$$\frac{I_{C1}}{I_{S1}} \cdot \frac{I_{S2}}{I_{C2}} = 1$$

$$\therefore \quad I_{S2} = \frac{1}{} = \frac{\beta I_{B1}}{}$$

$$\frac{I_{C1}}{I_{C2}} = \frac{\qquad}{I_{S2}} = 2 \qquad \beta I_{B2}$$

$$I_{B2} = 2 I_{B1} \longrightarrow 1$$

$$I_{ref} = I_{C1} + I_{B1} + I_{B2}$$

$$\beta I_{B2} = I_o \longrightarrow 2$$

$$I_{ref} = \beta I_{B1} + I_{B1} + I_{B2}$$

$$= (\beta+1) I_{B1} + I_{B2}$$

$$= (\beta+1) \frac{I_{B2}}{2} + I_{B2}$$

$$= \left(\frac{\beta+1}{2} + 1\right) I_{B2}$$

$$I_{ref} = \left(\frac{\beta+1}{2} + 1\right) \frac{I_o}{\beta}$$

$$I_o = \frac{\beta I_{ref}}{\frac{\beta+1}{2} + 1}$$

$$I_{ref} = \frac{10 - 0.7}{20} = 0.465 \text{ mA}$$

$$\boxed{I_o = 0.9 \text{ mA}}$$