Problems

1-The circuit in Fig. P1 provides a constant current I_o as long as the circuit to which the collector is which is maintained the BJT in active mode. Show that

$$I_o = \alpha \frac{V_{CC}[R_2/(R_1 + R_2)] - V_{BE}}{R_E + (R_1/R_2)/(\beta + 1)}$$

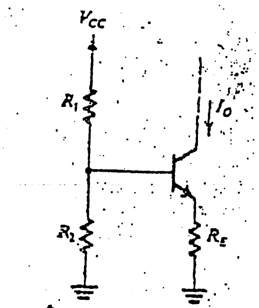
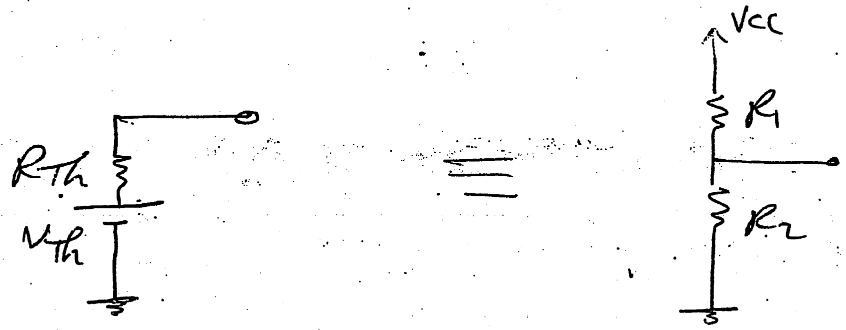


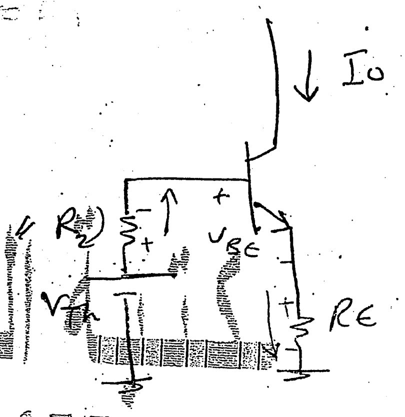
Fig. P6

using Thevinins Theorem



$R_{Th} = R_1 /\!/ R_2$

$V_{Th} = \dfrac{R_2 \, V_{CC}}{R_1 + R_2}$



$V_{Th} = (R_1 /\!/ R_2) I_b + V_{BE} + R_E I_E \rightarrow eq(1)$

∴ BJT in Active Mode

$$I_E = (\beta+1) I_b$$

$$I_C \cong I_o = \beta I_b$$

$$\boxed{\frac{\beta}{\beta+1} = \alpha}$$

$$\therefore \quad I_C = I_o = \alpha I_E$$

$$\therefore \quad \boxed{I_E = \frac{I_C}{\alpha} = \frac{I_o}{\alpha}}$$

from eq (1)

$$\frac{R_2}{R_1+R_2} V_{CC} = (R_1 \parallel R_2)\frac{I_E}{1+\beta} + V_{BE} + R_E \frac{I_o}{\alpha}$$

$$= (R_1 \parallel R_2)\frac{I_o}{(1+\beta)\alpha} + V_{BE} + R_E \frac{I_o}{\alpha}$$

$$\left(\frac{R_2}{R_1+R_2}\right) V_{CC} - V_{BE} = \frac{I_o}{\alpha}\left[\left(\frac{R_1 \parallel R_2}{1+\beta}\right) + R_E\right]$$

$$\therefore \quad \boxed{I_o = \frac{\alpha\left(\frac{R_2}{R_1+R_2} V_{CC} - V_{BE}\right)}{\left(\frac{R_1 \parallel R_2}{1+\beta}\right) + R_E}}$$

(3)

2-For the circuit in Fig. P2, assuming all transistors to be identical with β infinite, Drive an expression for the output current I_O, and show that by selecting

$R_1 = R_2$

And keeping the current in each junction the same, the current I_O will be

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$I_O = \alpha V_{CC}/2R_E$

Which is independent of V_{BE}. What the relationship of R_E to R_1 and R_2 be? For V_{cc} = 15 V, and assuming α » 1 and V_{BE} = 0.7 V, design the circuit to obtain an output current of 1 mA. What is lowest voltage that can be applied to the collector of Q_3 ? مطلوب

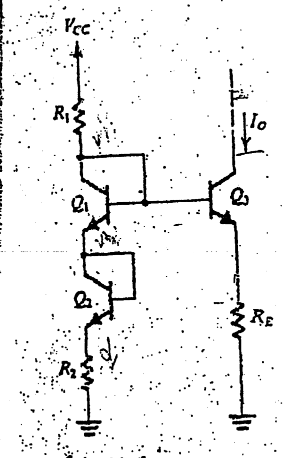
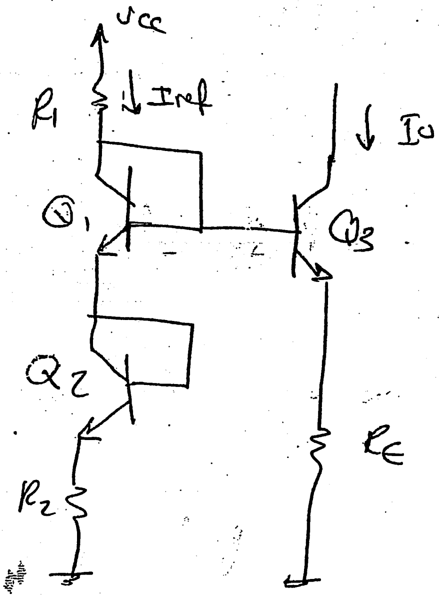


Fig. P6. 2

Assume all transistors identical



From KVL

$V_{BE_1} + V_{BE_2} + R_2 I_{E_2}$

$= V_{BE_3} + R_E I_{E_3}$

Neglecting the two Base Current (Q_1, Q_2)

$\therefore \quad I_{ref} \simeq I_{C_1} \simeq I_{C_2} \simeq I_{E_2}$

$\therefore \quad 0.7 + \cancel{0.7} + R_2 I_{ref} = \cancel{0.7} + R_E \dfrac{I_O}{\alpha}$

$$0.7 + R_2 I_{ref} = R_E \frac{I_o}{\alpha}$$

$$\therefore \quad I_o = \frac{\alpha(0.7 + R_2 I_{ref})}{R_E}$$

$\therefore$ we must find I_{ref} :

$$I_{ref} = \frac{V_{CC} - 1.4}{R_1 + R_2}$$

for $R_1 = R_2$

$$\therefore \quad \boxed{I_{ref} = \frac{V_{CC} - 1.4}{2R}} = \frac{V_{CC}}{2R} - \frac{0.7}{R}$$

$$\therefore \quad I_o = \frac{\alpha\left(0.7 + \frac{\cancel{R_2} V_{CC}}{2\cancel{R}} - \frac{0.7 \cancel{R_2}}{\cancel{R}}\right)}{R_E}$$

$$\therefore \quad \boxed{I_o = \frac{\alpha V_{CC}}{2R_E}}$$

To find The relation of R_E to R_1 and R_2

$\therefore$ Not Concern $R_1 = R_2 = R$

from KVL

$$V_{BE_1} + V_{BE_2} + R_2 I_{ref} = V_{BE_3} + R_E I_{E_3}$$

$$0.7 + \cancel{0.7} + R_2 I_{ref} = \cancel{0.7} + R_E \frac{I_o}{\alpha}$$

$$\therefore R_E = \frac{\alpha}{I_o} \left[R_2 I_{ref} + 0.7 \right]$$

but $I_{ref} = \dfrac{V_{cc} - 1.4}{R_1 + R_2}$

$$\therefore \boxed{R_E = \frac{\alpha}{I_o} \left[\frac{R_2 (V_{cc} - 1.4)}{R_1 + R_2} + 0.7 \right]}$$

Design the Circuit to obtain output Current of 1mA. (which mean find R_1, R_2, R_E)

$V_{cc} = 15$ Volt $\qquad \alpha \gg 1$

If $\alpha = 1$, $I_o = 1mA$, $V_{cc} = 15V$

$$\therefore R_E = \frac{\alpha}{I_o}\left(0.7 + \frac{(V_{cc}-1.4)R_2}{R_1+R_2}\right)$$

$$R_E = \frac{1}{10^{-3}}\left(0.7 + \frac{(15-1.4)R_2}{R_1+R_2}\right)$$

for selecting $R_1 = R_2$

$$\therefore R_E = \frac{1}{10^{-3}}\left(0.7 + \frac{(15-1.4)}{2}\right)$$

$$\boxed{R_E = 7.5\ k\Omega}$$

$\boxed{R_1 = R_2 = 1k\Omega}$ but any value for R_1, R_2 in suitable Range

The lowest voltage on Collector of Q_3

Q_3 must be in Active

So, V_{CE} at least $= 0.2\,V$

$V_{CE_{sat}} = 0.2\,V$

$\therefore V_{C_{3min}} = V_{CE_{sat}} + \frac{I_o}{\alpha} R_E$

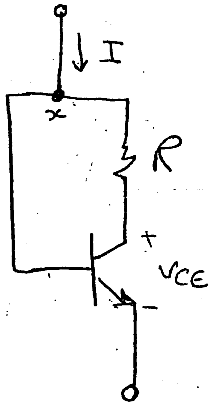
$= 0.2 + 1mA * 7.5k$

$= 0.2 + 7.5 = 7.7$ volt

$\therefore \boxed{V_{C_{3min}} = 7.7 \text{ volt}}$

ex:

* For the circuit shown in figure show that by selecting $R = \frac{1}{g_m}$ V_{CE} is kept constant for small change in current.



Sol:

at point x :

$$V_{BE} = R I_C + V_{CE}$$

$$\therefore V_{CE} = 0.7 - I_C R$$

if I_C change by ΔI_C

$$\therefore V_{CE} = 0.7 - (I_C + \Delta I_C) R$$

for select $\boxed{R = \frac{1}{g_m}}$

$$\therefore V_{CE} = 0.7 - (I_C + \Delta I_C) \cdot \frac{1}{g_m}$$

$$\boxed{g_m = \frac{I_C}{V_T}} \quad \left(V_T = \frac{kT}{q}\right)$$

$$\therefore \quad V_{CE} = 0.7 - (I_C + \Delta I_C)\frac{V_T}{I_C}$$

For Small chang in I_C $\quad \Delta I_C \simeq 0$

$$\therefore \quad V_{CE} = 0.7 - \frac{\cancel{I_C} \cdot V_T}{\cancel{I_C}}$$

$$\therefore \quad V_{CE} \simeq 0.7 - V_T$$

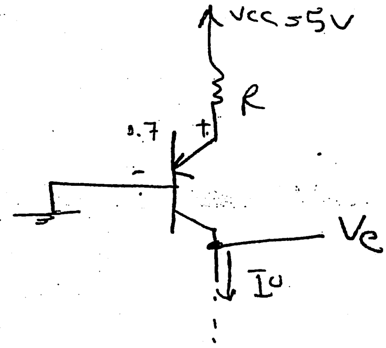
where $V_T = \frac{kT}{q} = 25mV$

$$\therefore \quad V_{CE} = 0.7 - 0.025 = 0.675\,V$$

$$\boxed{V_{CE} \simeq 0.675 \text{ volt}}$$

ex:

* For the circuit in figure
  - find the value of R that will result in $I_o = 1mA$.
  - what is the largest voltage that can be applied to the collector? Assume $|V_{BE}| = 0.7v$



Sol:

* $V_{BE} = -0.7v$

  $I_o = 1mA$

$$\therefore R = \frac{V_{cc} - 0.7}{1mA} = \frac{V_{cc} - V_{EB}}{I_o}$$

$$\boxed{R = 4.3\,k\Omega}$$

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* For the transistor to be on edge of Saturation $V_{EC} = 0.3V$

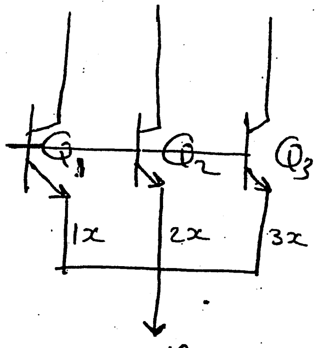
$$\therefore V_{Cmax} = 5 - I_o R - V_{EC}$$

$$= 5 - (1 \times 4.3) - 0.3 = 0.4V$$

$$\boxed{V_{Cmax} = 0.4V}$$

Ex:

- The transistors Q_1, Q_2 and Q_3 in Circuit of figure (1) have Emitter-base junction areas in the ratio of $1:2:3$ respectively.



a- If Q_1 is diode-Connected and fed with a 1-mA Current Source what ~~the collector voltage~~ Current result are Such That active mode operation is maintained

b- Repeat with Q_2 diode Connected and fed with a 1mA Current Source.

C- Repeat with Q_3 diode Connected and fed with a 1mA Current Source using a 1mA Current Source.

Sol:

(a) Q_1 is diode Connected

$$I_1 = 1mA$$

$$I_2 = 2 I_1 = 2mA$$

$$I_3 = 3 I_1 = 3mA$$

(b) Q_2 is diode Connected

$I_2 = 1\,mA$

$I_1 = \frac{1}{2} I_2 = 0.5\,mA$

$I_3 = 1.5\, I_2 = 1.5\,mA$

(c) Q_3 is diode Connected

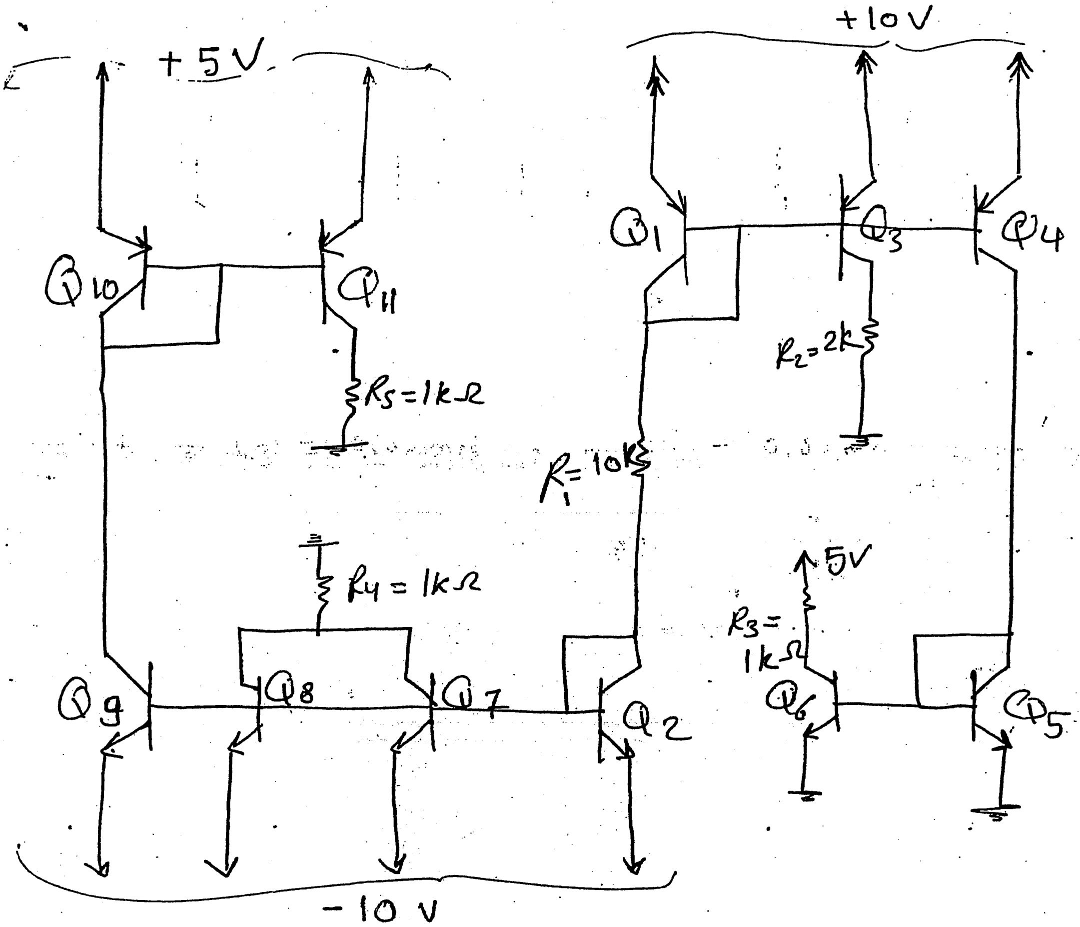
$I_3 = 1\,mA$

$I_1 = \frac{1}{3} I_3 = 0.33\,mA$

$I_2 = \frac{2}{3} I_3 = 0.67\,mA$

ex:

* Find the Voltages at all nodes and the Currents through all branches in the Circuit.
  Assume that $V_{BE} = 0.7$ and $\beta = \infty$



$I_{C1} = I_{C2} = I_{R_1}$

$V_{B_1} = 10 - 0.7 = 9.3V$

$V_{B2} = -10 + 0.7 = -9.3V$

$$I_{R_1} = \frac{9.3 + 9.3}{10} = 1.86\ mA$$

$$I_{R_1} = I_{C_1} = I_{C_2} = I_{C_3} = I_{C_4} = I_{C_5} = I_{C_6}$$

$$V_{C_3} = 1.86 \times 2 = 3.72\ V \quad , \quad V_{C_5} = 0.7\ V$$

$$V_{C_6} = 5 - 1.86 \times 1 = 3.14\ V$$

$$I_{C_9} = I_{C_8} = I_{C_7} = I_{C_2} = 1.86\ mA$$

$$I_{R_4} = 2 \times 1.86\ mA = 3.72\ mA$$

$$V_{C_7} = -3.72 \times 1 = -3.72\ V$$

$$I_{C_{10}} = I_{C_9} = 1.86\ mA$$

$$V_{C_9} = V_{C_{10}} = V_{B_{10}} = 5 - 0.7 = 4.3\ V$$

$$I_{C_{11}} = I_{C_{10}} = 1.86\ mA$$

$$V_{C_{11}} = 1.86 \times 1 = 1.86\ V$$