Ex. (On Operational Amplifiers)

The circuit shown represents a simple operational amplifier. Terminals 1, 2 connected to the ground are the op amp's input terminals and terminal 3 is the output terminal. Q_6 has 4 times the area of each Q_4, Q_3.

(a) Perform an approximate dc analysis ($\beta \gg 1$) to calculate the dc currents & voltages at all branches and nodes

Hint: Q_6 carry 4 time the collector current of either Q_4 or Q_3!

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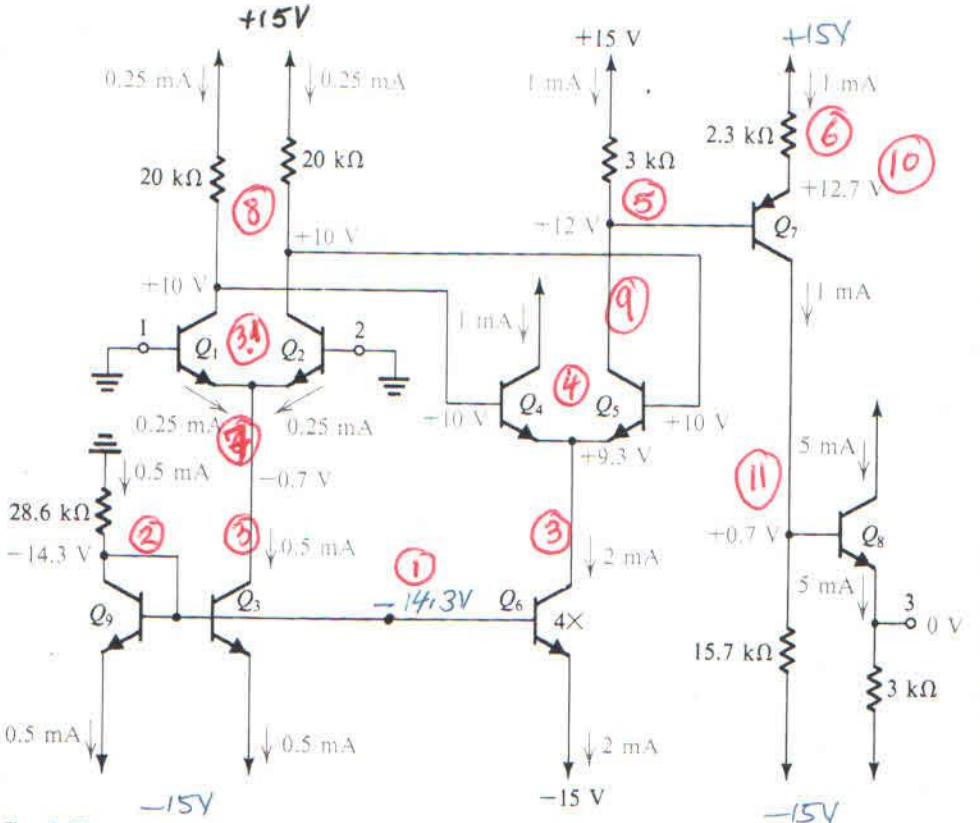

Fig. 9.23 Circuits for Example 9.2.

Solution

(1.) Voltage at Base of Q_6 is $-15 + 0.7 = -14.3\,V$ same as collector voltage of Q_9

(2.) $\therefore I_{CQ_9} = \dfrac{0-(-14.3)}{28.6} = 0.5\,mA$

(3.) $\therefore$ 3. Q_3 conducts 0.5 mA & accordingly Q_6 conducts $(4(0.5)) = 2\,mA$

(3.1) $\therefore Q_1, Q_2$ conducts $\frac{0.5}{2} = 0.25\,mA$

$\therefore V_{CQ_1} = V_{CQ_2} = 15 - 20(0.25) = 10^V$

$\therefore V_{BQ_4} = V_{BQ_5} = 10^V \therefore V_{EQ_4} = 9.3V$

(4.) Q_4, Q_5 conducts 1 mA each

(5.) $\therefore V_{CQ_5} = 15 - 1(3) = 12V = V_{BQ_7} \quad \therefore V_{EQ_7} = 12 + 0.7 = 12.7V$

(6) $\therefore I_{EQ_7} = \frac{15 - 12.7}{2.3} = 1\,mA$

$I_{CQ_5} = I_{CQ_4} = \frac{15-12}{3} = 1\,mA$

Also from symmetry, since $I_{CQ_3} = 0.5\,mA$, then $I_{EQ_2} = I_{EQ_1} = \frac{0.5}{2}$

$= 0.25\,mA$

(7) $V_{EQ_2} = V_{EQ_1} = 0 - 0.7 = -0.7V$

(8) Since $I_{CQ_2} = I_{EQ_2} = I_{CQ_1} = I_{EQ_1} = 0.25\,mA$

$\therefore V_{CQ_1} = V_{CQ_2} = 15 - 0.25(20) = 10V$

$\therefore V_{EQ_4} = V_{EQ_5} = 10 - 0.7 = 9.3\,V$

(9) since $V_{CQ_5} = 12\,V = V_{BQ_7}$

$\therefore V_{EQ_7} = 12.7\,V$

(10) $\therefore I_{EQ_7} = \frac{15 - 12.7}{2.3} = 1\,mA$

$\therefore V_{BQ_8} = -15 + 15.7(1) = 0.7V$

(11) $\therefore V_{EQ_8} = 0.7 - 0.7 = 0\,V$

$\therefore I_{EQ_7} = \frac{15}{3} = 5\,mA$