Chapter 17

Exercise Solutions

E17.1

a. $i_E = \dfrac{-0.7-(-5)}{R_E} = 1 \text{ mA} \Rightarrow \underline{R_E = 4.3 \text{ k}\Omega}$

$i_{C1} = i_{C2} = 0.5 \text{ mA} = \dfrac{5-3.5}{R_{C1}}$

$\Rightarrow \underline{R_{C1} = R_{C2} = 3 \text{ k}\Omega}$

b. i. $v_1 = 1$ V

$i_E = \dfrac{(1-0.7)-(-5)}{4.3} \Rightarrow \underline{i_E = 1.23 \text{ mA}}$

$i_{C1} = i_E = v_{01} = 5-(1.23)(3)$

$\Rightarrow \underline{v_{01} = 1.31 \text{ V}}$

$\underline{v_{02} = 5 \text{ V}}$

ii. $v_I = -1$ V

$i_E = 1 \text{ mA} \Rightarrow v_{02} = 5-(1)(3)$

$\Rightarrow \underline{v_{02} = 2 \text{ V}}$

$\underline{v_{01} = 5 \text{ V}}$

E17.2

a. Q_R on

$i_E = \dfrac{1.5-0.7-(-3.5)}{R_E} = 2 \text{ mA}$

$\Rightarrow \underline{R_E = 2.15 \text{ k}\Omega}$

$i_{CR} \approx i_E = 2 \text{ mA} = \dfrac{3.5-2}{R_{C2}}$

$\Rightarrow \underline{R_{C2} = 0.75 \text{ k}\Omega}$

b. $v_X = v_Y = 2 \text{ V} \Rightarrow Q_1$ and Q_2 on

$i_E = \dfrac{2-0.7-(-3.5)}{R_E} = \dfrac{4.8}{2.15} \Rightarrow \underline{i_E = 2.23 \text{ mA}}$

$R_{C1} = \dfrac{3.5-2}{i_{CXY}} = \dfrac{1.5}{2.23} \Rightarrow \underline{R_{C1} = 0.673 \text{ k}\Omega}$

E17.3

logic $1 = -0.7$ V

Q_1 and Q_2 on when $v_X = v_Y = -0.7$ V

$i_E = \dfrac{-0.7-0.7-(-5.2)}{R_E} = 2.5$

$\Rightarrow \underline{R_E = 1.52 \text{ k}\Omega}$

$v_{NOR} = -1.5 \Rightarrow R_{C1} = \dfrac{0-(-1.5+0.7)}{2.5}$

$\Rightarrow \underline{R_{C1} = 320 \ \Omega}$

$V_R = \dfrac{-1.5-0.7}{2} \Rightarrow \underline{V_R = -1.1 \text{ V}}$

$Q_R \text{ on} \Rightarrow i_E = \dfrac{-1.1-0.7-(-5.2)}{1.52} = 2.24 \text{ mA}$

$R_{C2} = \dfrac{0-(-1.5+0.7)}{2.24} \Rightarrow \underline{R_{C2} = 357 \ \Omega}$

$R_3 = R_4 = \dfrac{-0.7-(-5.2)}{2.5} \Rightarrow \underline{R_3 = R_4 = 1.8 \text{ k}\Omega}$

E17.4

$P(i_{CXY} + i_{CR} + i_3 + i_4)(5.2)$

a. $v_X = v_Y = $ logic 1

$\Rightarrow i_{CXY} = 3.22$ mA

$i_{CR} = 0$

$i_3 = \dfrac{-0.7+5.2}{1.5} = 3 \text{ mA}$

$i_4 = \dfrac{-1.4+5.2}{1.5} = 2.53 \text{ mA}$

$P = (3.22+0+3+2.53)(5.2)$

$\Rightarrow \underline{P = 45.5 \text{ mW}}$

b. $v_X = v_Y = $ logic 0

$\Rightarrow i_{CXY} = 0$

$i_{CR} = 2.92$ mA

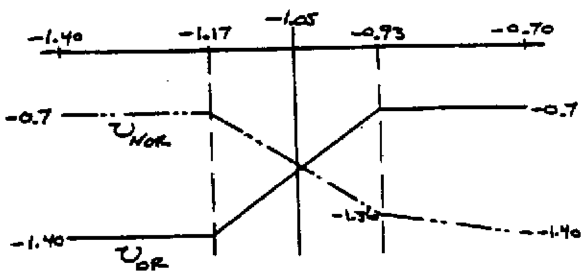
$i_3 = 2.53$ mA

$i_4 = 3$ mA

$P = (0+2.92+2.53+3)(5.2)$

$\Rightarrow \underline{P = 43.9 \text{ mW}}$

E17.5



$NM_H = -0.70-(-0.93) \Rightarrow \underline{NM_H = 0.23 \text{ V}}$

$NM_L = -1.17-(-1.40) \Rightarrow \underline{NM_L = 0.23 \text{ V}}$

E17.6

$P = I_Q \cdot V_{CC} \Rightarrow 0.2 = I_Q(1.7)$

$\Rightarrow \underline{I_Q = 118\ \mu A}$

Q_R on $\Rightarrow v_0 = 1.7 - I_Q R_C = 1.7 - 0.4$

$\Rightarrow R_C = \dfrac{0.4}{0.118} \Rightarrow \underline{R_C = 3.39\ k\Omega}$

$V_R = \dfrac{1.7 + 1.3}{2} \Rightarrow \underline{V_R = 1.5\ V}$

E17.7

State	A	B	C	Q_{01}	Q_{02}	Q_{03}	Q_1	Q_2	Q_R	v_0
1	0	0	0	off	off	off	off	on	on	0
2	1	0	0	"on"	off	off	off	on	on	0
3	0	1	0	off	on	off	off	on	"off"	1
4	0	0	1	off	off	on	on	off	on	0
5	1	1	0	on	on	off	off	on	off	1
6	1	0	1	on	off	on	on	off	"off"	1
7	0	1	1	off	on	on	on	off	on	0
8	1	1	1	on	on	on	on	off	off	1

$$\underbrace{\underbrace{(A \text{ AND } C)}_{\substack{\text{true for}\\ \text{states 6 and 8}}} \text{ OR } \underbrace{(B \text{ AND } \overline{C})}_{\substack{\text{true for}\\ \text{states 3 and 5}}}}_{\text{Output goes high for these 4 states}}$$

E17.8

A	B	C	v_0
0	0	0	0
1	0	0	1
0	1	0	1
0	0	1	1
1	1	0	0
1	0	1	0
0	1	1	0
1	1	1	1

$\Rightarrow (A \oplus B) \oplus C$

E17.9

$i_C = \dfrac{5 - 0.1}{1} = 4.9$ mA

$i_B = \dfrac{4.9}{30} = 0.163 \text{ mA} = \dfrac{v_I - 0.7}{R_B} = \dfrac{4.3}{R_B}$

$\Rightarrow \underline{R_B = 26.4\ k\Omega}$

E17.10

(a) $v_X = v_Y = 5V$

$v_1 = V_{BE}(sat) + 2V_\gamma = 0.8 + 2(0.7) = 2.2\ V$

$i_1 = \dfrac{5 - 2.2}{4} = 0.70\ mA$

$i_{RC} = \dfrac{V_{CC} - V_{CE}(sat)}{R_C} = \dfrac{5 - 0.1}{4} = 1.23\ mA$

$P = (i_1 + i_{RC})V_{CC} = (0.70 + 1.23)(5)$

or $\underline{P = 9.65\ mW}$

(b) $v_X = v_Y = 0 \Rightarrow v_1 = 0.70V$

$i_1 = \dfrac{V_{CC} - v_1}{R_1} = \dfrac{5 - 0.70}{4} = 1.08\ mA$

$P = i_1 \cdot V_{CC} = (1.08)(5) \Rightarrow \underline{P = 5.4\ mW}$

E17.11

a. Inputs high $v_1 = 0.8 + 0.7 + 0.8 = 2.3$ V

$i_1 = i_{B1} = \dfrac{5 - 2.3}{4} = 0.675$ mA

$v_{C1} = 0.8 + 0.7 + 0.7 = 1.6$ V

$i_2 = \dfrac{5 - 1.6}{2} = 1.7$ mA

$i_3 = 1.7 + 0.675 = 2.38$ mA

$i_4 = \dfrac{0.8}{10} = 0.08$ mA

$i_{B0} = 2.38 - 0.08 = 2.3$ mA

$i_{RC} = \dfrac{5 - 0.1}{4} = 1.23$ mA

$i'_L = \dfrac{5 - 0.8}{4} = 1.05$ mA

$\beta i_{B0} = N i'_L + i_{RC}$

$(30)(2.3) = N(1.05) + 1.23 \Rightarrow \underline{N = 64}$

b. $I_{C,\text{rated}} = 20$ mA

$20 = N i'_L + i_{RC} = N(1.05) + 1.23$

$\Rightarrow \underline{N = 17}$

E17.12

a. $v_X = v_Y = 0.1 \Rightarrow v_1 = 0.8$

$i_1 = \frac{5-0.8}{6} \Rightarrow \underline{i_1 = 0.7\text{ mA}}$

$\underline{i_2 = i_R = i_B = i_{RC} = 0}$

$\underline{v_0 = 5\text{ V}}$

b. Same as part (a).

c. $v_X = v_Y = 5\text{ V} \Rightarrow v_1 = 0.8 + 0.7 + 0.7 = 2.2\text{ V}$

$i_1 = i_2 = \frac{5-2.2}{6} \Rightarrow \underline{i_1 = i_2 = 0.467\text{ mA}}$

$i_R = \frac{0.8}{15} \Rightarrow \underline{i_R = 0.053\text{ mA}}$

$i_B = i_2 - i_R \Rightarrow \underline{i_B = 0.414\text{ mA}}$

$i_{RC} = \frac{5-0.1}{5} \Rightarrow \underline{i_{RC} = 0.98\text{ mA}}$

$\underline{v_0 = 0.1\text{ V}}$

E17.13

a. $v_X = v_Y = 0.1\text{ V}$

$i_1 = \frac{5-0.8}{8} = 0.525\text{ mA}$

$P = i_1(5-0.1) = (0.525)(4.9)$

$\Rightarrow \underline{P = 2.57\text{ mW}}$

b. $v_X = v_Y = 5\text{ V},\ v_1 = 2.3\text{ V}$

$i_1 = \frac{5-2.3}{8} = 0.338\text{ mA}$

$v_{C1} = 1.6\text{ V} \Rightarrow i_2 = \frac{5-1.6}{3.6} = 0.944\text{ mA}$

$i_{RC} = \frac{5-0.1}{6} = 0.817\text{ mA}$

$P = (i_1 + i_2 + i_{RC})(V_{CC})$

$= (0.338 + 0.944 + 0.817)(5)$

$\underline{P = 10.3\text{ mW}}$

E17.14

a. $v_X = v_Y = 0.1\text{ V}$

$v_{B1} = 0.1 + 0.8 = 0.9\text{ V}$

$i_{B1} = i_1 = \frac{5-0.9}{6} \Rightarrow \underline{i_1 = i_{B1} = 0.683\text{ mA}}$

$i_{C1} \approx 0$

$i_{B2} = i_{C2} = 0$

$i_{B0} = i_{C0} = 0$

b. $v_X = v_Y = 3.6\text{ V}$

$v_{B1} = 0.8 + 0.8 + 0.7 = 2.3\text{ V}$

$i_1 = i_{B1} = \frac{5-2.3}{6} \Rightarrow \underline{i_1 = i_{B1} = 0.45\text{ mA}}$

$i_{BX} = i_{BY} = i_1 \cdot \beta_R = (0.45)(0.1) = 0.045\text{ mA}$

$i_{B2} = |i_{C1}| = i_1 + i_{BX} + i_{BY} = 0.45 + 2(0.045)$

$\underline{i_{B2} = |i_{C1}| = 0.54\text{ mA}}$

$v_{C2} = 0.8 + 0.1 = 0.9$

$i_2 = i_{C2} = \frac{5-0.9}{1.5} \Rightarrow \underline{i_2 = i_{C2} = 2.73\text{ mA}}$

$i_{E2} = 2.73 + 0.54 = 3.27\text{ mA}$

$i_4 = \frac{0.8}{1.5} = 0.533\text{ mA}$

$i_{B0} = 3.27 - 0.533 \Rightarrow \underline{i_{B0} = 2.74\text{ mA}}$

$i_3 = i_{C0} = \frac{5-0.1}{2.2} \Rightarrow \underline{i_3 = i_{C0} = 2.23\text{ mA}}$

For Q_2:

$\frac{i_{C2}}{i_{B2}} = \frac{2.73}{0.54} = 5.06 < \beta_F \Rightarrow Q_2$ in saturation

For Q_0:

$\frac{i_{C0}}{i_{B0}} = \frac{2.23}{2.74} = 0.81 < \beta_F \Rightarrow Q_0$ in saturation

E17.15

a. Output low:

$i'_L = \frac{5-(0.1+0.8)}{6} = 0.683$

$i_{C0}(\max) = \beta_F \cdot i_{B0} = N i'_L + i_3$

$(20)(2.74) = N(0.683) + 2.23$

$\Rightarrow \underline{N = 76}$

b. Output high:

Q'_1 inverse active

$i'_1 = \frac{5-2.3}{6} = 0.45\text{ mA}$

$i'_L = \beta_R \cdot i'_1 = (0.1)(0.45) = 0.045\text{ mA}$

$v_0(\min) = 2.4\text{ V} \Rightarrow i_L(\max) = \frac{5-2.4}{2.2} - N \cdot i'_L$

$1.18 = N(0.045)$

$\Rightarrow \underline{N = 26}$

E17.16

a. $v_X = v_Y = 0.1\text{ V} \Rightarrow v_0(\max) = 3.6\text{ V}$

Q'_1 inverse active

$i'_1 = \frac{5-2.3}{6} = 0.45\text{ mA}$

$i'_L = \beta_R \cdot i'_1 = (0.1)(0.45) = 0.045$

$i_{B3} = \frac{0.1}{2} = 0.05\text{ mA}$

$i_L = (1+\beta_F)i_{B3} = (21)(0.05) = 1.05\text{ mA}$

$i_L = N i'_L \Rightarrow 1.05 = N(0.045) \Rightarrow \underline{N = 23}$

b. $v_X = v_Y = 3.6$ V, Output low:

$i_1 = \frac{5-2.3}{6} = 0.45$ mA

$i_{B2} = (1+2\beta_R)i_1$

$i_{B2} = 0.54$ mA

$v_{B3} = 0.8 + 0.1 = 0.9$

$i_2 = \frac{5-0.9}{2} = 2.05$ mA

$i_{B0} = 2.05 + 0.54 - \frac{0.8}{1.5} \Rightarrow i_{B0} = 2.06$ mA

$i'_L = \frac{5-0.9}{6} = 0.683$ mA

$\beta_F \cdot i_{B0} = N \cdot i'_L \Rightarrow (20)(2.06) = N(0.683)$

$\Rightarrow \underline{N = 60}$

E17.17

a. $v_X = v_Y = 3.6$ V

$i_{B1} = \frac{5-2.3}{4} = \underline{0.675 \text{ mA} = i_{B1} = |i_{C1}| = i_{B2}}$

$v_{B4} = 0.8 + 0.1 = 0.9$ V

$i_2 = \frac{5-0.9}{1.6} = 2.56$ mA

$i_{B4} = \frac{0.2}{(1+\beta_F)(4)} = \frac{0.2}{(31)(4)} \Rightarrow \underline{i_{B4} = 1.61\ \mu\text{A}}$

$\underline{i_{C4} = 48.3\ \mu\text{A}}$

$\underline{i_{B3} = i_{C3} = 0}$

$\Rightarrow \underline{i_{C2} \approx i_2 = 2.56 \text{ mA}}$

$i_{B0} = 2.45 + 0.675 - \frac{0.8}{1} \Rightarrow \underline{i_{B0} = 2.44 \text{ mA}}$

One load:

$i'_L = i_{C0} = \frac{5-0.9}{4} \Rightarrow \underline{i_{C0}(\max) = 1.03 \text{ mA}}$

b. $v_X = v_Y = 0.1$ V

$i_{B1} = \frac{5-0.9}{4} \Rightarrow \underline{i_{B1} = 1.03 \text{ mA}}$

$\underline{|i_{C1}| = i_{B2} = i_{C2} = 0}$

$\underline{i_{B0} = i_{C0} = 0}$

Output high, $\beta_R = 0 \Rightarrow \underline{i_{B3} = i_{C3} = 0}$

$5 = i_{B4}(1.6) + 0.7 + (31)i_{B4}(4)$

$\Rightarrow \underline{i_{B4} = 0.0342 \text{ mA}}$

$\underline{i_{C4} = 1.03 \text{ mA}}$

E17.18

Q_1 in saturation

$i_{B1} = \frac{5-0.9}{6} \Rightarrow \underline{i_{B1} = 0.683 \text{ mA}}$

$\underline{|i_{C1}| = i_{B2} = i_{C2} = 0}$

$\underline{i_{B0} = i_{C0} = 0}$

$v_{B4} = 0.1 + 0.7 = 0.8$ V

$i_{B4} = \frac{0.1}{(21)(4)} \Rightarrow \underline{i_{B4} = 1.19\ \mu\text{A}}$

$\underline{i_{C4} = 23.8\ \mu\text{A}}$

$\underline{i_{B3} = i_{C3} = 0}$

E17.19

a. $i_{RC} = \frac{5-0.4}{2.25} = 2.04$ mA

$i'_C = \frac{2+2.04}{1+\frac{1}{10}} \Rightarrow \underline{i'_C = 3.67 \text{ mA}}$

$\underline{i'_B = \frac{3.67}{10} = 0.367 \text{ mA}}$

$i_D = 2 - 0.367 \Rightarrow \underline{i_D = 1.63 \text{ mA}}$

b. $i_D = 0 \Rightarrow i'_B = i_B = 2$ mA

$i'_C = \beta i'_B = (10)(2) = 20 \text{ mA} = i_{RC} + i_L$

$i_L = 20 - 2.04 \Rightarrow \underline{i_L(\max) \approx 18 \text{ mA}}$

Chapter 17

Problem Solutions

17.1

a. $v_I = -1.5$ V; Q_1 off, Q_2 on

$i_E = \frac{-0.7-(-3.5)}{5} \Rightarrow \underline{i_E = 0.56 \text{ mA}}$

$i_{C1} = 0 \Rightarrow \underline{v_{01} = 3.5 \text{ V}}$

$i_{C2} = i_E \Rightarrow v_{02} = 3.5 - i_E R_{C2} = 3.5 - (0.56)(2)$

or

$\underline{v_{02} = 2.38 \text{ V}}$

b. $v_I = 1.0$ V; Q_1 on, Q_2 off

$i_E = \frac{(1-0.7)-(-3.5)}{5} \Rightarrow \underline{i_E = 0.76 \text{ mA}}$

$i_{C2} = 0 \Rightarrow \underline{v_{02} = 3.5 \text{ V}}$

c. logic 0 at v_{02} (low level) $= 2.38$ V

Then

$v_{01} = 2.38 = 3.5 - (0.76)R_{C1}$

or

$\underline{R_{C1} = 1.47 \text{ k}\Omega}$

17.2

(a) Q_2 on, $v_E = -1.2 - 0.7 = -1.9\,V$

$i_E = i_{C2} = \frac{-1.9-(-5.2)}{2.5} = 1.32\,mA$

$v_2 = -1\,V = -i_{C2}R_{C2} = -(1.32)(R_{C2})$

$\underline{R_{C2} = 0.758\,k\Omega}$

(b) Q_1 on, $v_E = -0.7 - 0.7 = -1.40\,V$

$i_E = i_{C1} = \frac{-1.4-(-5.2)}{2.5} = 1.52\,mA$

$v_1 = -1\,V = -i_{C1}R_{C1} = -(1.52)(R_{C1})$

$\underline{R_{C1} = 0.658\,k\Omega}$

(c) For $v_{in} = -0.7\,V$, Q_1 on, Q_2 off

$\underline{\Rightarrow v_{O1} = -0.70\,V}$

$v_{O2} = -1 - 0.7 \Rightarrow \underline{v_{O2} = -1.7\,V}$

For $v_{in} = -1.7\,V$, Q_1 off, Q_2 on

$\Rightarrow v_{O2} = -0.7\,V$

$v_{O1} = -1 - 0.7 \Rightarrow \underline{v_{O1} = -1.7\,V}$

(d) (i) For $v_{in} = -0.7\,V$, $i_E = 1.52\,mA$

$i_{C4} = \frac{-1.7-(-5.2)}{3} = 1.17\,mA$

$i_{C3} = \frac{-0.7-(-5.2)}{3} = 1.5\,mA$

$P = (i_E + i_{C4} + i_{C3})(5.2) = (1.52 + 1.17 + 1.5)(5.2)$

or $\underline{P = 21.8\,mW}$

(ii) For $v_{in} = -1.7\,V$, $i_E = 1.32\,mA$

$i_{C4} = \frac{-0.7-(-5.2)}{3} = 1.5\,mA$

$i_{C3} = \frac{-1.7-(-5.2)}{3} = 1.17\,mA$

$P = (1.32 + 1.5 + 1.17)(5.2)$

or $\underline{P = 20.7\,mW}$

17.3

a. $I_3 = \frac{3.7-0.7}{0.67+1.33} = 1.5$ mA

$V_R = I_3 R_4 + V_\gamma = (1.5)(1.33) + 0.7$

or

$\underline{V_R = 2.70 \text{ V}}$

b. logic 1 level $= 3.7 - 0.7 \Rightarrow \underline{3.0 \text{ V}}$

For $v_X = v_Y =$ logic 1,

$i_E = \frac{3-0.7}{0.8} = 2.875 \text{ mA} = i_{RC1}$

$v_{B3} = 3.7 - (2.875)(0.21) = 3.10$ V

$\Rightarrow \underline{v_{01}(\text{logic } 0) = 2.4 \text{ V}}$

For $v_X = v_Y =$ logic 0, Q_R on

$i_E = \frac{2.7-0.7}{0.8} = 2.5 \text{ mA} = i_{RC2}$

$v_{B4} = 3.7 - (2.5)(0.24) = 3.1$ V

$\Rightarrow \underline{v_{02}(\text{logic } 0) = 2.4 \text{ V}}$

17.4

$V_R = \frac{\text{logic 1} + \text{logic 0}}{2} = \frac{1+0}{2} = 0.5$ V

For $i_2 = 1$ mA

$R_5 = \frac{0.5-(-2.3)}{1} \Rightarrow \underline{R_5 = 2.8 \text{ k}\Omega}$

For Q_R on,

$i_E = \frac{V_R - V_{BE} - (-2.3)}{R_E}$

or

$R_E = \frac{0.5 - 0.7 + 2.3}{1} \Rightarrow \underline{R_E = 2.1 \text{ k}\Omega}$

$V_{B2} = V_R + V_{BE} = 0.5 + 0.7 = 1.2$ V

$$i_1 = \frac{1.2 - 1.4 - (-2.3)}{R_2}$$

or

$$R_2 = \frac{1.2 - 1.4 + 2.3}{1} \Rightarrow \underline{R_2 = 2.1\ \text{k}\Omega}$$

$$R_1 = \frac{1.7 - 1.2}{1} \Rightarrow \underline{R_1 = 0.5\ \text{k}\Omega}$$

$$i_3 = \frac{1 - (-2.3)}{R_3} = 3 \Rightarrow \underline{R_3 = 1.1\ \text{k}\Omega}$$

$$i_4 = \frac{0 - (-2.3)}{R_4} = 3 \Rightarrow \underline{R_4 = 0.767\ \text{k}\Omega}$$

For Q_R on,

$v_{0R} = \text{logic } 0 = 0 \text{ V} \Rightarrow v_{B3} = 0.7$ V

$i_E = i_{CR} = 1$ mA

So

$$R_{C2} = \frac{1.7 - 0.7}{1} \Rightarrow \underline{R_{C2} = 1\ \text{k}\Omega}$$

For $v_I = \text{logic } 1 = 1$ V,

$$i_E = \frac{1 - 0.7 - (-2.3)}{2.1} = 1.238 \text{ mA}$$

For $v_{NOR} = \text{logic } 0 = 0$ V,

$$v_{B4} = 0.7 \text{ V}$$

Then

$$R_{C1} = \frac{1.7 - 0.7}{1.238} \Rightarrow \underline{R_{C1} = 0.808\ \text{k}\Omega}$$

17.5

Maximum i_E for $v_I = \text{logic } 1 = 3.3$ V

Then $i_E = 5 \text{ mA} = \dfrac{3.3 - 0.7}{R_E} \Rightarrow \underline{R_E = 0.52\ \text{k}\Omega}$

For $v_{02} = \text{logic } 1 = 3.3$ V

$$i_{E3} = \frac{3.3 - 0}{R_3} = 5 \text{ mA}$$

or

$$\underline{R_3 = 0.66\ \text{k}\Omega}$$

By symmetry,

$$\underline{R_2 = 0.66\ \text{k}\Omega}$$

For Q_1 on,

$$i_E = i_{RC1} = 5 \text{ mA} = \frac{4 - (2.7 + 0.7)}{R_{C1}}$$

So

$$\underline{R_{C1} = 0.12\ \text{k}\Omega}$$

For Q_R on,

$$i_E = \frac{3 - 0.7}{0.52} = 4.423 \text{ mA} = i_{RC2}$$

and $i_{RC2} = 4.423 = \dfrac{4 - (2.7 + 0.7)}{R_{C2}}$

$$\Rightarrow \underline{R_{C2} = 0.136\ \text{k}\Omega}$$

17.6

Neglecting base currents:

(a) $\underline{I_{E1} = 0,\ I_{E3} = 0}$

$I_{E5} = \dfrac{5 - 0.7}{2.5} \Rightarrow \underline{I_{E5} = 1.72\ mA}$

$\underline{Y = 0.7\,V}$

(b) $I_{E1} = \dfrac{5 - 0.7}{18} \Rightarrow \underline{I_{E1} = 0.239\ mA}$

$\underline{I_{E3} = 0}$

$I_{E5} = \dfrac{5 - 0.7}{2.5} \Rightarrow \underline{I_{E5} = 1.72\ mA}$

$\underline{Y = 0.7\,V}$

(c) $I_{E1} = I_{E3} = \dfrac{5 - 0.7}{18} \Rightarrow \underline{I_{E1} = I_{E3} = 0.239\ mA}$

$\underline{I_{E5} = 0,\ Y = 5\,V}$

(d) Same as (c).

17.7

(a) $V_R = -(1)(1) - 0.7 \Rightarrow V_R = -1.7\,V$

(b) Q_R off, then $v_{O1} = Logic\,1 = -0.7\,V$

Q_R on, then $v_{O1} = -(1)(2) - 0.7 \Rightarrow$

$\underline{v_{O1} = Logic\,0 = -2.7\,V}$

$Q_A\,/\,Q_B$ off, then $\underline{v_{O2} = Logic\,1 = -0.7\,V}$

$Q_A\,/\,Q_B$ on, then $v_{O2} = -(1)(2) - 0.7 \Rightarrow$

$\underline{v_{O2} = Logic\,0 = -2.7\,V}$

(c) $A = B = Logic\,0 = -2.7\,V$, Q_R on,

$V_E = -1.7 - 0.7 \Rightarrow \underline{V_E = -2.4\,V}$

$A = B = Logic\,1 = -0.7\,V$, $Q_A\,/\,Q_B$ on,

$V_E = -0.7 - 0.7 \Rightarrow \underline{V_E = -1.4\,V}$

(d) $A = B = Logic\,1 = -0.7\,V$, $Q_A\,/\,Q_B$ on,

$$i_{C3} = \frac{-2.7 - (-5.2)}{1.5} = 1.67\ mA$$

$$i_{C2} = \frac{-0.7 - (-5.2)}{1.5} = 3\ mA$$

$P = (1.67 + 1 + 1 + 1 + 3)(5.2) \Rightarrow \underline{P = 39.9\ mW}$

$A = B = Logic\,0 = -2.7\,V$

$i_{C3} = 3\ mA,\ i_{C2} = 1.67\ mA$

$\underline{P = 39.9\ mW}$

17.8

a. AND logic function

b. $\underline{\text{logic } 0 = 0 \text{ V}}$

Q_3 on, $i = \dfrac{5 - (1.6 + 0.7)}{1.2} = 2.25$ mA

$V_2 = (2.25)(0.8) \Rightarrow \underline{\text{logic } 1 = 1.8 \text{ V}}$

c. $i_{E1} = \frac{5-0.7}{2.6} \Rightarrow \underline{i_{E1} = 1.65 \text{ mA}}$

$i_{E2} = \frac{5-(0.7+0.7)}{1.2} \Rightarrow \underline{i_{E2} = 3 \text{ mA}}$

$\underline{i_{C3} = 0}, \ \underline{i_{C2} = i_{E2} = 3 \text{ mA}}$

$\underline{V_2 = 0}$

d. $i_{E1} = \frac{5-(1.8+0.7)}{2.6} \Rightarrow \underline{i_{E1} = 0.962 \text{ mA}}$

$i_{E2} = \frac{5-(1.6+0.7)}{1.2} \Rightarrow \underline{i_{E2} = 2.25 \text{ mA}}$

$\underline{i_{C2} = 0}, \ \underline{i_{C3} = i_{E2} = 2.25 \text{ mA}}$

$\underline{V_2 = 1.8 \text{ V}}$

17.9

a. $V_R = \frac{3.5+3.1}{2} - 0.7 \Rightarrow \underline{V_R = 2.6 \text{ V}}$

b. For Q_1 on, $v_X = v_Y = \text{logic } 1 = 3.5 \text{ V}$

$i_E = \frac{3.5-(0.7+0.7)}{12} = 0.175 \text{ mA}$

Want $i_{RC1} = \frac{0.175}{2} = \frac{0.4}{R_{C1}} \Rightarrow \underline{R_{C1} = 4.57 \text{ k}\Omega}$

c. For Q_2 on, $i_E = \frac{2.6-0.7}{12} = 0.158 \text{ mA}$

Want $i_{RC2} = \frac{0.158}{2} = \frac{0.4}{R_{C2}} \Rightarrow \underline{R_{C2} = 5.06 \text{ k}\Omega}$

d. For $v_Y = \text{logic } 1 = 3.5 \text{ V}$

$i_{R1} = \frac{3.5-0.7}{8} = 0.35 \text{ mA}, \ i_E = 0.175 \text{ mA}$

$P = (i_{R1} + i_E)(V_{CC}) = (0.35+0.175)(3.5)$

$\Rightarrow \underline{P = 1.84 \text{ mW}}$

17.10

a. $\text{logic } 1 = 0.2 \text{ V}$

$\text{logic } 0 = -0.2 \text{ V}$

b. $i_E = \frac{(0-0.7)-(-3.1)}{R_E} = 0.8$

So

$\underline{R_E = 3 \text{ k}\Omega}$

c. Want $i_{R1} = \frac{0.8}{2} = \frac{0.4}{R_1} \Rightarrow \underline{R_1 = 1 \text{ k}\Omega}$

d. For $v_X = v_Y = \text{logic } 1 = 0.2 \text{ V}$

$i_E = \frac{(0.2-0.7)-(-3.1)}{3} = 0.867 \text{ mA}$

$i_{R2} = \frac{0.4}{1} \Rightarrow \underline{i_{R2} = 0.4 \text{ mA}}$

$\underline{i_{D2} = 0.467 \text{ mA}}$

e. $i_E = 0.867 \text{ mA}$

$i_3 = \frac{0.2-(-3.1)}{3.3} = 1 \text{ mA}$

$i_4 = \frac{-0.2-(-3.1)}{3.3} = 0.879 \text{ mA}$

$P = (0.867 + 1 + 0.879)(0.9 - (-3.1))$

or

$\underline{P = 11.0 \text{ mW}}$

17.11

a. $i_1 = \frac{(-0.9-0.7)-(-3)}{1} \Rightarrow \underline{i_1 = 1.4 \text{ mA}}$

$i_3 = \frac{(-0.2-0.7)-(-3)}{15} \Rightarrow \underline{i_3 = 0.14 \text{ mA}}$

$i_4 = \frac{(-0.2-0.7)-(-3)}{15} \Rightarrow \underline{i_4 = 0.14 \text{ mA}}$

$i_2 + i_D = i_1 + i_3 = 1.4 + 0.14 = 1.54 \text{ mA}$

$i_2 = \frac{0.4}{0.5} \Rightarrow \underline{i_2 = 0.8 \text{ mA}}$

$\underline{i_D = 0.74 \text{ mA}}$

$\underline{v_0 = -0.4 \text{ V}}$

b. $\underline{i_1 = 1.4 \text{ mA}}$

$i_3 = \frac{(0-0.7)-(-3)}{15} \Rightarrow \underline{i_3 = 0.153 \text{ mA}}$

$i_4 = i_3 \Rightarrow \underline{i_4 = 0.153 \text{ mA}}$

$i_2 + i_D = i_4 \Rightarrow \underline{i_2 = 0.153 \text{ mA}}$

$\underline{i_D = 0}$

$v_0 = -(0.153)(0.5) \Rightarrow \underline{v_0 = -0.0765 \text{ V}}$

c. $i_1 = \frac{(0-0.7-0.7)-(-3)}{1} \Rightarrow \underline{i_1 = 1.6 \text{ mA}}$

$i_3 = \frac{(-0.2-0.7)-(-3)}{15} \Rightarrow \underline{i_3 = 0.14 \text{ mA}}$

$i_4 = i_3 \Rightarrow \underline{i_4 = 0.14 \text{ mA}}$

$i_2 + i_D = i_3 \Rightarrow \underline{i_2 = 0.14 \text{ mA}}$

$\underline{i_D = 0.0}$

$v_0 = -(0.14)(0.5) \Rightarrow \underline{v_0 = -0.07 \text{ V}}$

d. $i_1 = \frac{(0-0.7-0.7)-(-3)}{1} \Rightarrow \underline{i_1 = 1.6 \text{ mA}}$

$i_3 = \frac{(0-0.7)-(-3)}{15} \Rightarrow \underline{i_3 = 0.153 \text{ mA}}$

$i_4 = i_3 \Rightarrow \underline{i_4 = 0.153 \text{ mA}}$

$i_2 + i_D = i_1 + i_4 = 1.6 + 0.153 = 1.753 \text{ mA}$

$i_2 = \frac{0.4}{0.5} \Rightarrow \underline{i_2 = 0.8 \text{ mA}}$

$\underline{i_D = 0.953 \text{ mA}}$

$\underline{v_0 = -0.40 \text{ V}}$

17.12

a. i. $A = B = C = D = 0 \Rightarrow Q_1 - Q_4$ cutoff

So

$$V_{DD} = 2I_E R_1 + V_{EB} + I_B R_2$$

and

$$I_B = \frac{I_E}{1+\beta_P} = \frac{I_E}{51}$$

Then

$$2.5 = 2I_E(2) + 0.7 + \frac{I_E}{51}\cdot(15)$$
$$2.5 - 0.7 = I_E \cdot \left(4 + \frac{15}{51}\right)$$

So

$$I_E = 0.419 \text{ mA}$$

and

$Y = 2.5 - 2(0.419)(2) \Rightarrow \underline{Y = 0.824 \text{ V}}$

ii. $A = C = 0,\ B = D = 2.5$ V

Now

$$v_{B5} = v_{B6} = 2.5 - 0.7 = 1.8 \text{ V}$$

and

$$Y = v_{B5} + 0.7 \Rightarrow \underline{Y = 2.5 \text{ V}}$$

b. $Y = (A \text{ OR } B) \text{ AND } (C \text{ OR } D)$

17.13

a. logic 1 = 0 V

logic 0 = −0.4 V

b. $v_{01} = \overline{A \text{ OR } B}$

$v_{02} = \overline{C \text{ OR } D}$

$v_{03} = \overline{v_{01} \text{ OR } v_{02}}$

or

$v_{03} = (A \text{ OR } B) \text{ AND } (C \text{ OR } D)$

17.14

a. For CLOCK = high, I_{DC} flows through the left side of the circuit.. If D is high, I_{DC} flows through the left R resistor pulling $\overline{Q}$ low. If D is low, I_{DC} flows through the right R resistor pulling Q low.

For CLOCK = low, I_{DC} flows through the right side of the circuit maintaining Q and $\overline{Q}$ in their previous state.

b. $P = (I_{DC} + 0.5I_{DC} + 0.1I_{DC} + 0.1I_{DC})(3)$

$P = 1.7I_{DC}(3) = (1.7)(50)(3) \Rightarrow \underline{P = 255\ \mu\text{W}}$

17.15

i. For $v_X = v_Y = 0.1$ V $\Rightarrow \underline{v' = 0.8 \text{ V}}$

$i_1 = \dfrac{5-2.2}{8} \Rightarrow \underline{i_1 = 0.525 \text{ mA}}$

$\underline{i_3 = i_4 = 0}$

ii. For $v_X = v_Y = 5$ V,

$v' = 0.8 + 0.7 + 0.7 \Rightarrow\Rightarrow \underline{v' = 2.2 \text{ V}}$

$i_1 = \dfrac{5-2.2}{8} \Rightarrow \underline{i_1 = 0.35 \text{ mA}}$

$i_4 = i_1 - \dfrac{0.8}{15} \Rightarrow \underline{i_4 = 0.297 \text{ mA}}$

$i_3 = \dfrac{5-0.1}{2.4} \Rightarrow \underline{i_3 = 2.04 \text{ mA}}$

17.16

a. For $v_X = v_Y = 5$ V, both Q_1 and Q_2 driven into saturation.

$v_1 = 0.8 + 0.7 + 0.8 \Rightarrow \underline{v_1 = 2.3 \text{ V}}$

$i_1 = \dfrac{5-2.3}{4} \Rightarrow \underline{i_1 = i_{B1} = 0.675 \text{ mA}}$

$i_2 = \dfrac{5-(0.8+0.7+0.1)}{2} \Rightarrow \underline{i_2 = 1.7 \text{ mA}}$

$i_4 = i_{B1} + i_2 \Rightarrow \underline{i_4 = 2.375 \text{ mA}}$

$i_5 = \dfrac{0.8}{10} \Rightarrow \underline{i_5 = 0.08 \text{ mA}}$

$i_{B2} = i_4 - i_5 \Rightarrow \underline{i_{B2} = 2.295 \text{ mA}}$

$i_3 = \dfrac{5-0.1}{4} \Rightarrow \underline{i_3 = 1.225 \text{ mA}}$

$\underline{v_0 = 0.1 \text{ V}}$

b. $i'_L = \dfrac{5-(0.1+0.7)}{4} = 1.05$ mA

$$i_C(\max) = \beta i_{B2} = Ni'_L + i_3$$

$(20)(2.295) = N(1.05) + 1.225$

So

$\underline{N = 42}$

17.17

D_X and D_Y off, Q_1 forward active mode

$v_1 = 0.8 + 0.7 + 0.7 = 2.2\, V$

$5 = i_1R_1 + i_2R_2 + v_1$ and $i_1 = (1+\beta)i_2$

So $5 - 2.2 = i_2[(1+\beta)R_1 + R_2]$

Assume $\beta = 25$

$i_2 = \dfrac{5-2.2}{(26)(1.75)+2} \Rightarrow \underline{i_2 = 0.0589\, mA}$

$i_1 = (1+\beta)i_2 = (26)(0.0589) \Rightarrow \underline{i_1 = 1.53\, mA}$

$i_3 = \beta i_2 \Rightarrow \underline{i_3 = 1.47\, mA}$

$i_{Bo} = i_2 + i_3 - \dfrac{0.8}{5} = 0.0589 + 1.47 - 0.16 \Rightarrow$

$\underline{i_{Bo} = 1.37\, mA}$

$\underline{Q_o \text{ in saturation}}$

$i_{Co} = \dfrac{5-0.1}{6} \Rightarrow \underline{i_{Co} = 0.817\, mA}$

17.18

a. i. $v_X = v_Y = 0.1$ V, so Q_1 in saturation.

$$i_1 = \frac{5-(0.1+0.8)}{6} \Rightarrow \underline{i_1 = 0.683 \text{ mA}}$$
$$\Rightarrow \underline{i_{B2} = i_2 = i_4 = i_{B3} = i_3 = 0}$$

ii. $v_X = v_Y = 5$ V, so Q_1 in inverse active mode. Assume Q_2 and Q_3 in saturation.

$$i_1 = \frac{5-(0.8+0.8+0.7)}{6} \Rightarrow \underline{i_1 = i_{B2} = 0.45 \text{ mA}}$$
$$i_2 = \frac{5-(0.8+0.1)}{2} \Rightarrow \underline{i_2 = 2.05 \text{ mA}}$$
$$i_4 = \frac{0.8}{1.5} \Rightarrow \underline{i_4 = 0.533 \text{ mA}}$$

$$i_{B3} = (i_{B2}+i_2) - i_4 = 0.45 + 2.05 - 0.533$$

or

$$\underline{i_{B3} = 1.97 \text{ mA}}$$
$$i_3 = \frac{5-0.1}{2.2} \Rightarrow \underline{i_3 = 2.23 \text{ mA}}$$

b. For Q_3:

$$\frac{i_3}{i_{B3}} = \frac{2.23}{1.97} = 1.13 < \beta$$

For Q_2:

$$\frac{i_2}{i_{B2}} = \frac{2.05}{0.45} = 4.56 < \beta$$

Since $(I_C/I_B) < \beta$, then each transistor is in saturation.

17.19

(a) $v_X = v_Y = Logic\ 1$

$v' = 0.8 + 2(0.7) = 2.2\ V$

$i_1 = \dfrac{5-2.2}{8} = 0.35\ mA$

$i_4 = i_1 - \dfrac{0.8}{15} = 0.35 - 0.0533 = 0.2967\ mA$

$i_3 = \dfrac{5-0.1}{2.4} = 2.04\ mA$

$i_L' = \dfrac{5-(0.1+0.7)}{8} = 0.525\ mA$

Assume $\beta = 25$

Then $(25)(0.2967) = 2.04 + N(0.525)$

So $N = 10.2 \Rightarrow \underline{N = 10}$

(b) Now

$5 = 2.04 + N(0.525)$

So $N = 5.64 \Rightarrow \underline{N = 5}$

17.20

a. For $v_X = v_Y = 5$ V, Q_1 in inverse active mode.

$$i_{B1} = \frac{5-(0.8+0.8+0.7)}{6} = 0.45 \text{ mA}$$
$$i_{B2} = i_{B1} + 2\beta_R i_{B1} = 0.45(1+2[0.1]) = 0.54 \text{ mA}$$

$$i_{C2} = \frac{5-(0.8+0.1)}{2} = 2.05 \text{ mA}$$

$$i_{B3} = (i_{B2}+i_{C2}) - \frac{0.8}{1.5} = 0.54 + 2.05 - 0.533$$

or

$$\underline{i_{B3} = 2.06 \text{ mA}}$$

Now

$$i_L' = \frac{5-(0.1+0.8)}{6} = 0.683 \text{ mA}$$

Then

$$i_{C3}(\max) = \beta_F i_{B3} = N i_L'$$

or $(20)(2.06) = N(0.683)$

$$\Rightarrow \underline{N = 60}$$

b. From above, for v_0 high, $I_L' = (0.1)(0.45) = 0.045$ mA. Now

$$I_L'(\max) = (1+\beta_F)\left(\frac{5-4.9}{R_2}\right) = \frac{(21)(0.1)}{2} = 1.05 \text{ mA}$$

So

$$I_L(\max) = N I_L'$$

or $1.05 = N(0.045)$

$$\Rightarrow \underline{N = 23}$$

17.21

(a) $V_{in} = 0.1V$: Q_I, Sat: Q_S, Q_O, Cutoff

$i_1 = \dfrac{5-(0.1+0.8)}{4} = 1.025\ mA$

$P = i_1(5-0.1) = (1.025)(4.9) \Rightarrow$

$\underline{P = 5.02\ mW}$

(b) $V_{in} = 5V$, Q_I, Inverse Active; Q_S, Q_O, Saturation

$v_{BI} = 0.7 + 0.8 + 0.7 = 2.2\ V$

$i_1 = \dfrac{5-2.2}{4} = 0.7\ mA$

$i_{BI} = \beta_R \cdot i_1 = (0.1)(0.7) = 0.07\ mA$

$V_{out} = 0.7 + 0.1 = 0.8\ V$

$i_2 = \dfrac{5-0.8}{1} = 4.2\ mA$

$P = (i_1 + i_{BI} + i_2)(5) = (0.7 + 0.07 + 4.2)(5) \Rightarrow$

$\underline{P = 24.9\ mW}$

17.22

a. $v_X = v_Y = v_Z = 0.1$ V

$$i_{B1} = \frac{5-(0.1+0.8)}{3.9} \Rightarrow \underline{i_{B1} = 1.05 \text{ mA}}$$

Then

$$\underline{i_{C1} = i_{B2} = i_{C2} = i_{B3} = i_{C3} = 0}$$

b. $v_X = v_Y = v_Z = 5$ V

$$i_{B1} = \frac{5-(0.8+0.8+0.7)}{3.9} \Rightarrow \underline{i_{B1} = 0.692 \text{ mA}}$$

Then

$$i_{C1} = i_{B2} = i_{B1}(1+3\beta_R) = (0.692)(1+3[0.5])$$

$$\Rightarrow \underline{i_{C1} = i_{B2} = 1.73 \text{ mA}}$$

$$i_{C2} = \frac{5-(0.1+0.8)}{2} \Rightarrow \underline{i_{C2} = 2.05 \text{ mA}}$$

$$i_{B3} = i_{B2} + i_{C2} - \frac{0.8}{0.8} = 1.73 + 2.05 - 1.0$$

$$\Rightarrow \underline{i_{B3} = 2.78 \text{ mA}}$$

$$i_{R3} = \frac{5-0.1}{2.4} = 2.04 \text{ mA}$$

$$i_L' = \frac{5-(0.1+0.8)}{3.9} = 1.05 \text{ mA}$$

$$i_{C3} = i_{R3} + 5i_L' = 2.04 + (5)(1.05)$$

$$\Rightarrow \underline{i_{C3} = 7.29 \text{ mA}}$$

17.23

a. $v_X = v_Y = v_Z = 2.8$ V, Q_1 biased in the inverse active mode.

$$i_{B1} = \frac{2.8-(0.8+0.8+0.7)}{2} \Rightarrow \underline{i_{B1} = 0.25 \text{ mA}}$$

$$i_{B2} = i_{B1}(1+3\beta_R) = 0.25(1+3[0.3])$$

$$\Rightarrow \underline{i_{B2} = 0.475 \text{ mA}}$$

$$v_{C2} = 0.8 + 0.1 = 0.9 \text{ V}$$

$$i_{B4} = \frac{0.9-(0.7+0.1)}{(1+\beta_F)(0.5)} = \frac{0.1}{(101)(0.5)}$$

$$= 0.00198 \text{ mA} \quad \text{(Negligible)}$$

$$i_{R2} = \frac{5-0.9}{0.9} = 4.56 \text{ mA}$$

$$\Rightarrow \underline{i_{C2} = 4.56 \text{ mA}}$$

$$i_{B3} = i_{B2} + i_{C2} - \frac{0.8}{1} = 0.475 + 4.56 - 0.8$$

$$\Rightarrow \underline{i_{B3} = 4.235 \text{ mA}}$$

b. $v_X = v_Y = v_Z = 0.1$ V

$$i_{B1} = \frac{5-(0.1+0.8)}{2} \Rightarrow \underline{i_{B1} = 2.05 \text{ mA}}$$

From part (a),

$$i_L' = \beta_R \cdot i_{B1} = (0.3)(0.25) = 0.075 \text{ mA}$$

Then

$$i_{B4} = \frac{5i_L'}{1+\beta_F} = \frac{5(0.075)}{101} \Rightarrow \underline{i_{B4} = 0.00371 \text{ mA}}$$

17.24

a. $v_X = v_Y = v_Z = 0.1$ V

$$i_{B1} = \frac{5-(0.1+0.8)}{R_{B1}} + i_{B3}$$

where

$$i_{B3} = \frac{(2-0.7)-(0.9)}{R_{B2}} = \frac{0.4}{1}$$

$$\Rightarrow \underline{i_{B3} = 0.4 \text{ mA}}$$

Then

$$i_{B1} = \frac{1.1}{1} + 0.4 \Rightarrow \underline{i_{B1} = 1.5 \text{ mA}}$$

$$\underline{i_{B2} = 0 = i_{C2}}$$

Q_3 in saturation $i_{C3} = 5i_L'$
For v_0 high.

$$v_{B1}' = 0.8 + 0.7 = 1.5 \text{ V} \Rightarrow Q_3' \text{ off}$$

$$i_{B1}' = \frac{2-1.5}{1} = 0.5 \text{ mA}$$

$$i_L' = \beta_R i_{B1}' = (0.2)(0.5) = 0.1 \text{ mA}$$

Then

$$\underline{i_{C3} = 0.5 \text{ mA}}$$

b. $v_X = v_Y = v_Z = 2$ V

From part (a),

$$\Rightarrow \underline{i_{B1} = 0.5 \text{ mA}}$$

$$\underline{i_{B3} = 0 = i_{C3}}$$

$$i_{B2} = i_{B1}(1+3\beta_R) = (0.5)(1+3[0.2])$$

$$\underline{i_{B2} = 0.8 \text{ mA}}$$

$i_{C2} = 5i_L'$, and from part (a), $i_L' = 1.5$ mA

So

$$\underline{i_{C2} = 7.5 \text{ mA}}$$

17.25

(a) $I_B + I_D = \dfrac{5.8-0.7}{10} = 0.51\,mA$

$I_C - I_D = \dfrac{5-(0.7-0.3)}{1} = 4.6\,mA$

Now

$I_D = 0.51 - I_B = 0.51 - \dfrac{I_C}{\beta} = 0.51 - \dfrac{I_C}{50}$

Then

$I_C - I_D = I_C - \left(0.51 - \dfrac{I_C}{50}\right) = I_C\left(1+\dfrac{1}{50}\right) - 0.51 = 4.6$

So $\underline{I_C = 5.01\,mA}$

$I_B = \dfrac{I_C}{\beta} = \dfrac{5.01}{50} \Rightarrow \underline{I_B = 0.1002\,mA}$

$I_D = 0.51 - 0.1002 \Rightarrow \underline{I_D = 0.4098\,mA}$

$\underline{V_{CE} = 0.4\,V}$

(b) $\underline{I_D = 0, V_{CE} = V_{CE}(sat) = 0.1\,V}$

$I_B = \dfrac{5.8-0.8}{10} \Rightarrow \underline{I_B = 0.5\,mA}$

$I_C = \dfrac{5-0.1}{1} \Rightarrow \underline{I_C = 4.9\,mA}$

17.26

a. $v_X = v_Y = 0.4$ V

$v_{B1} = 0.4 + 0.7 \Rightarrow \underline{v_{B1} = 1.1\text{ V}}$

$i_{B1} = \dfrac{5-1.1}{2.8} \Rightarrow \underline{i_{B1} = 1.39\text{ mA}}$

$v_{B2} = 0.4 + 0.4 \Rightarrow \underline{v_{B2} = 0.8\text{ V}}$

$i_{B2} = i_{C2} = i_{B0} = i_{C0} = i_{B5} = i_{C5}$

$= i_{B3} = i_{C3} = 0$ (No load)

$5 = i_{B4}R_2 + V_{BE} + (1+\beta)i_{B4}R_4$

$i_{B4} = \dfrac{5-0.7}{0.76 + (31)(3.5)}$

$\Rightarrow \underline{i_{B4} = 0.0394\text{ mA}}$

$i_{C4} = \beta_F i_{B4}$

$\Rightarrow \underline{i_{C4} = 1.18\text{ mA}}$

$v_{B4} = 5 - (0.0394)(0.76)$

$\Rightarrow \underline{v_{B4} = 4.97\text{ V}}$

b. $v_X = v_Y = 3.6$ V

$v_{B1} = 0.7 + 0.7 + 0.3 \Rightarrow \underline{v_{B1} = 1.7\text{ V}}$

$\underline{v_{B2} = 1.4\text{ V}}$

$\underline{v_{B0} = 0.7\text{ V}}$

$\underline{v_{C2} = 1.1\text{ V}}$

$i_{B1} = \dfrac{5-1.7}{2.8}$

$\Rightarrow \underline{i_{B1} = 1.18\text{ mA}}$

$i_{B2} = i_{B1}(1+2\beta_R) = 1.18(1+2[0.1])$

$\underline{i_{B2} = 1.42\text{ mA}}$

$i_{B4} = \dfrac{1.1-0.7}{(31)(3.5)}$

$\Rightarrow \underline{i_{B4} = 0.00369\text{ mA}}$

$i_{R2} = \dfrac{5-1.1}{0.76} = 5.13\text{ mA}$

$\Rightarrow \underline{i_{C2} \approx 5.13\text{ mA}}$

$i_{B0} \approx i_{B2} + i_{C2}$

$\underline{i_{B0} = 6.55\text{ mA}}$

17.27

a. Assuming the output transistor Q_2 is a Schottky transistor, then

$v_0 = 0.4$ V, $i'_L = \dfrac{2.5-(0.4+0.3)}{R_{B1}} = 0.5$

Then

$\underline{R_{B1} = 3.6\text{ k}\Omega}$

Then

$i_{B1} = \dfrac{2.5-(0.7+0.8)}{R_{B1}} = \dfrac{10}{3.6} = 0.278\text{ mA}$

$i_{B2} = 0.5\text{ mA},\ i_{E1} = 0.5 + \dfrac{0.7}{0.7} = 1.50\text{ mA}$

$i_{E1} = i_{B1} + i_{C1} \Rightarrow i_{C1} = 1.50 - 0.278 = 1.222\text{ mA}$

and $i_{C1} = \dfrac{2.5-(0.7+0.1)}{R_{C1}} = 1.222\text{ mA}$

$\Rightarrow \underline{R_{C1} = 1.39\text{ k}\Omega}$

b. $v_X = v_Y = 0.4$ V, $\underline{v_{B1} = 0.7\text{ V}}$

$v_{C2} = 2.5 - 0.7 \Rightarrow \underline{v_{C2} = 1.8\text{ V}}$

All transistor currents are zero.

c. $\underline{v_{B1} = 1.5\text{ V}}$, $\underline{v_{C1} = 0.8\text{ V}}$

Currents calculated in part (a).

d. $i_{B2} = 0.5$ mA, $i'_L = 0.5$ mA

$i_{C2}(\max) = \beta i_{B2} = N i'_L$ or $(50)(0.5) = N(0.5)$

So

$\underline{N = 50}$

17.28

a. For $v_X = v_Y = 3.6$ V

$v_{B1} = 3(0.7) = 2.1$

$\Rightarrow i_{B1} = \dfrac{5-2.1}{10} = 0.29\text{ mA}$

$v_{C1} = 0.7 + 0.7 + 0.4 = 1.8$ V

$\Rightarrow i_{C1} = \dfrac{5-1.8}{10} = 0.32\text{ mA}$

$i_{B2} = i_{B1} + i_{C1} - \dfrac{1.4}{15} = 0.29 + 0.32 - 0.0933$

So

$i_{B2} = 0.517$ mA

$v_{C2} = 0.7 + 0.4 = 1.1$ V

$$i_{C2} = \frac{5 - 1.1}{4.1} = 0.951 \text{ mA}$$

$$i_{B5} = i_{B2} + i_{C2} - \frac{0.7}{4} = 0.517 + 0.951 - 0.175$$

or $i_{B5} = 1.293$ mA

For $v_0 = 0.4$ V, $v'_{B1} = 0.4 + 0.7 = 1.1$ V

Then

$$i'_{B1} = \frac{1.1 - 0.7}{(31)(15)} = 0.00086 \text{ mA}$$

$$i'_L = \frac{5 - 1.1}{10} - 0.00086 \text{ or } i'_L \approx 0.39 \text{ mA}$$

So $i_{C5}(\max) = \beta i_{B5} = N i'_L$

$(30)(1.293) = N(0.39)$

$\Rightarrow \underline{N = 99}$

b. $P = (0.29 + 0.32 + 0.951)(5) + (99)(0.39)(0.4)$

$P = 7.805 + 15.444$ or $\underline{P = 23.2 \text{ mW}}$

(Assumming 99 load circuits which is unreasonably large.)

17.29

a. Assume no load. For v_X = logic 0 = 0.4 V

$$i_{B1} = \frac{5 - (0.4 + 0.7)}{40} = 0.0975 \text{ mA}$$

Essentially all of this current goes to ground from V_{CC}.

$P = i_{B1} \cdot V_{CC} = (0.0975)(5)$

$\Rightarrow \underline{P = 0.4875 \text{ mW}}$

b. $$i_{R1} = \frac{5 - (3)(0.7)}{40} = 0.0725 \text{ mA}$$

$$i_{R2} = \frac{5 - (0.7 + 0.7 + 0.4)}{50} = 0.064 \text{ mA}$$

$$i_{R3} = \frac{5 - (0.7 + 0.4)}{15} = 0.26 \text{ mA}$$

$P = (0.0725 + 0.064 + 0.26)(5)$

$\underline{P = 1.98 \text{ mW}}$

c. For $v_0 = 0$, $v_{C7} = 0.7 + 0.4 = 1.1$ V

$$i_{R7} = \frac{5 - 1.1}{0.050} \Rightarrow i_{R7} = \underline{78 \text{ mA} \approx i_{SC}}$$

17.30

(a) $v_I = v_O = 2.5\,V$; A transient situation

$v_{DS}(M_N) = 2.5 - 0.7 = 1.8\,V$

$v_{GS}(M_N) = 2.5 - 0.7 = 1.8\,V \Rightarrow M_N$ in saturation

$v_{SD}(M_P) = 5 - (2.5 + 0.7) = 1.8\,V$

$v_{SG}(M_P) 5 - 2.5 = 2.5\,V \Rightarrow M_P$ in saturation

$i_{DN} = K_n(v_{GSN} - V_{TN})^2 = (0.1)(1.8 - 0.8)^2 \Rightarrow$

$\underline{i_{DN} = 0.1\,mA}$

$i_{DP} = K_p(v_{SGP} + V_{TP})^2 = (0.1)(2.5 - 0.8)^2 \Rightarrow$

$\underline{i_{DP} = 0.289\,mA}$

$i_{C1} = \beta i_{DP} = (50)(0.289) \Rightarrow \underline{i_{C1} = 14.45\,mA}$

$i_{C2} = \beta i_{DN} = (50)(0.1) \Rightarrow \underline{i_{C2} = 5\,mA}$

Difference between i_{E1} and $i_{DN} + i_{C2}$ is a load current.

(b) Assume $i_{C1} = 14.45\,mA$ is a constant

$$V_C = \frac{1}{C}\int i_{C1}dt = \frac{i_{C1} \cdot t}{C} \Rightarrow t = \frac{(V_C)(C)}{i_{C1}}$$

$$t = \frac{(5)(15x10^{-12})}{14.45x10^{-3}} \Rightarrow \underline{t = 5.19\,ns}$$

(c) $$t = \frac{(5)(15x10^{-12})}{0.289x10^{-3}} \Rightarrow \underline{t = 260\,ns}$$

17.31

Let $R_1 = R_2 = 10\,k\Omega$

(a) $\underline{i_{DN} = 0.1\,mA,\ i_{DP} = 0.289\,mA}$

(Same as Problem 17.30)

$$i_{R1} = \frac{0.7}{10} = 0.07\,mA \Rightarrow i_{B1} = 0.289 - 0.07 = 0.219\,mA$$

$i_{C1} = (50)(0.219) \Rightarrow \underline{i_{C1} = 10.95\,mA}$

$$i_{R2} = \frac{0.7}{10} = 0.07\,mA \Rightarrow i_{B2} = 0.1 - 0.07 = 0.03\,mA$$

$i_{C2} = (50)(0.03) \Rightarrow \underline{i_{C2} = 1.5\,mA}$

(b) $$t = \frac{(5)(15x10^{-12})}{10.95x10^{-3}} \Rightarrow \underline{t = 6.85\,ns}$$

(c) $t = 260\,ns$ (Same as Problem 17.30)