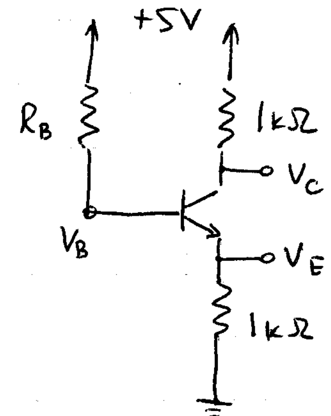
Problem 4.99



Find V_B, V_C, V_E for a) $R_B = 100\,k\Omega$
b) $R_B = 10\,k\Omega$
c) $R_B = 1\,k\Omega$

$\beta = 100$

a) $R_B = 100\,k\Omega$.

Let's check first the operation mode.

Assume that transistor is in the active mode. Then:

$$5V = I_B R_B + 0.7V + I_E R_E \quad \text{or} \quad I_E = \frac{5V - 0.7V}{R_E + \frac{R_B}{\beta + 1}}$$

$$I_E = \frac{4.3\,V}{1k\Omega + \frac{100k\Omega}{101}} = \underline{\underline{2.16\,mA}} \; ; \; V_E = I_E R_E = \underline{\underline{2.16\,V}} \; ; \; V_B = \underline{\underline{2.86\,V}}$$

$$V_C = 5V - I_C R_C = 5V - \alpha I_E R_C = 5V - 0.99 \cdot 2.16\,mA \cdot 1k\Omega = \underline{\underline{2.86\,V}}$$

Transistor is still in the active mode as was assumed.

$$V_E = 2.16\,V \; ; \; V_B = 2.86\,V \; ; \; V_C = 2.86\,V.$$

b) $R_B = 10\,k\Omega$. Let's again check the operation mode.

Assume that it's in the active mode. Then:

$$I_E = \frac{4.3\,V}{1k\Omega + \frac{10k\Omega}{101}} = 3.91\,mA \; ; \; V_E = I_E R_E = 3.91\,V \; ; \; V_B = \underline{4.61\,V}$$

$$V_C = 5V - \alpha I_E R_C = 5V - 0.99 \cdot 3.91\,mA \cdot 1k\Omega = \underline{1.13\,V}$$

Since $V_C < V_B$, the assumption is incorrect, and transistor is in saturation mode.

Then we can write for currents: $I_E = I_B + I_C$ or:

$$\frac{V_E}{1k\Omega} = \frac{5V - (V_E + 0.7V)}{10k\Omega} + \frac{5V - (V_E + V_{CE}^{sat})}{1k\Omega}, \text{ where } V_{CE}^{sat} = 0.2\,V$$

We can solve for $V_E = \frac{52.3}{21}\,V = \underline{\underline{2.49\,V}}$

$$V_B = V_E + 0.7\,V = \underline{\underline{3.19\,V}} \qquad V_C = V_E + V_{CE}^{sat} = \underline{\underline{2.69\,V}}$$

$$I_C / I_B = \frac{2.31\,mA}{0.181\,mA} = 12.76 < 100 \qquad \beta_{forced} = 12.76$$

c) $R_B = 1\,k\Omega$. Since for $R_B = 10\,k\Omega$ the transistor was already in saturation mode, it will be for $R_B = 1\,k\Omega$

Writing again $I_E = I_B + I_C$

$$\frac{V_E}{1\,k\Omega} = \frac{5V - V_E - 0.7V}{1\,k\Omega} + \frac{5V - V_E - V_{CE}^{sat}}{1\,k\Omega} \quad \text{or:}$$

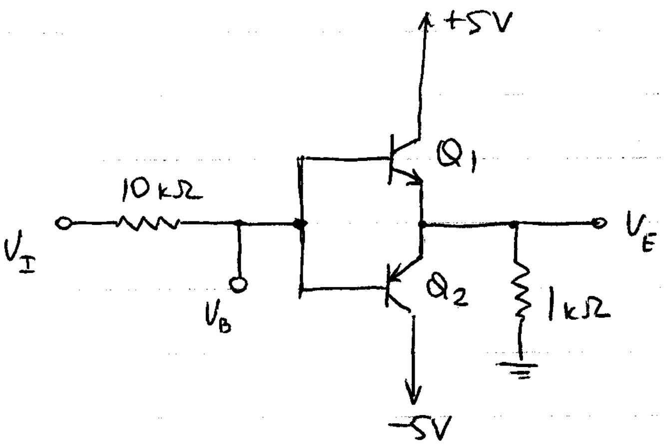
$$V_E = \frac{9.1V}{3} = \underline{\underline{3.03\,V}}$$

$V_B = V_E + 0.7V = \underline{3.73\,V}$ $\qquad V_C = V_E + V_{CE}^{sat} = \underline{\underline{3.23\,V}}$

$I_C / I_B = {1.77mA}/{1.27mA} = 1.39 < 100$

$\beta_{forced} = 1.39$

Problem 4.100



Find V_B and V_E for
a) $V_I = 0$
b) $V_I = 3V$
c) $V_I = -5V$
d) $V_I = -10V$

$\beta = 100$

Q_1 (npn) Q_2 (pnp)

a) $V_I = 0$. Let's suppose there is a current in the base. Since $V_I = 0$, the base voltage is negative. Then V_E^{Q1} should be even more negative, and the current should go in the emitter through $1\,k\Omega$. This doesn't hold, and hence Q1 is off. The same reasons apply for Q_2, and Q_2 is off.
Then $I_B = I_C = I_E = 0$, therefore $V_E = V_B = 0$

b) $V_I = 3V$. Let's suppose Q_2 is on. Then for pnp the current goes out of the base and $V_B > 3V$ and $V_E > 3V + 0.7V$. This means that the current goes out of emitter to ground through $1\,k\Omega$. This doesn't hold and $\underline{Q_2 \text{ is off}}$
Assume Q_1 is on. Then $V_I - 0 = I_B \cdot 10k\Omega + 0.7V + I_E \cdot 1k\Omega$, or

$$I_E = \frac{V_I - 0.7V}{1k\Omega + \frac{10k\Omega}{101}} = \frac{2.3\,V}{1.099\,k\Omega} = 2.09\,mA \quad . \text{ Then } \underline{V_E = I_E R_E} = \underline{2.09\,V}$$

$$\underline{V_B} = V_E + 0.7\,V = \underline{2.79\,V}$$

c) $V_I = -5V$. Analogous to b) it can be shown that this time Q_1 is off. Indeed, if $V_I = -5V$, $V_B < -5V$ and $V_E < -5V - 0.7V$, and the current goes into the emitter that doesn't hold for npn.

Assume Q_2 is on, and in active mode. Then

$$V_I = I_B \cdot 10k\Omega + 0.7V + I_E \cdot 1k\Omega, \text{ or } I_E = \frac{5V - 0.7V}{1.099\,k\Omega} = 3.91\,mA$$

$$V_E = 0 - I_E R_E = \underline{\underline{-3.91\,V}} \qquad V_B = V_E - 0.7V = \underline{\underline{-4.61\,V}}$$

$V_B > V_C = -5V$, so transistor is still in active mode, and on, as assumed.

d) $V_I = -10\,V$. Identical to c), Q_1 is off.

Assume Q_2 is on, and in active mode. Then

$$V_I = I_B \cdot 10k\Omega + 0.7V + I_E \cdot 1k\Omega \quad \text{or } I_E = \frac{10V - 0.7V}{1.099k\Omega} = 8.46\,mA$$

$$V_E = 0 - I_E R_E = \underline{-8.46\,V} \qquad V_B = V_E - 0.7V = -9.16\,V$$

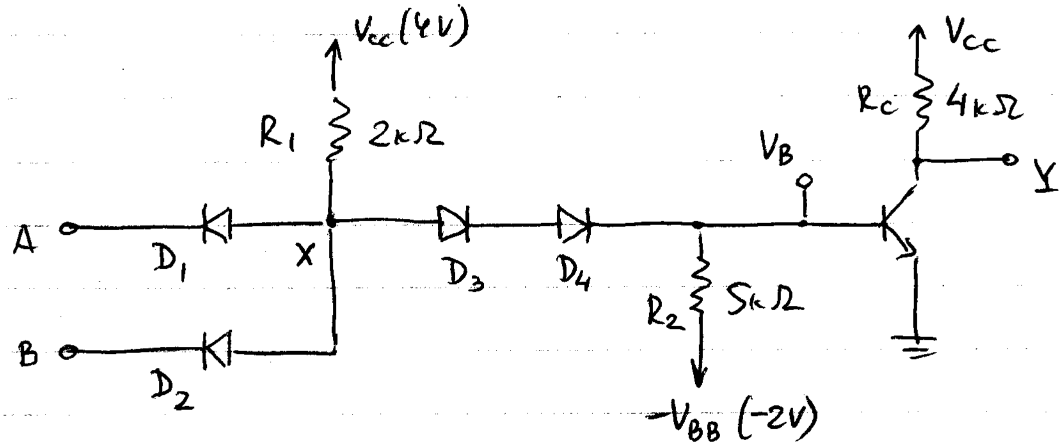
$V_B < V_C = -5V$, and transistor is in saturation.

So, our assumption was wrong. Therefore, we can write for ~~currents~~ V_E:

$$V_E = -5V + V_{CE}^{sat} = -5V + 0.2V = \underline{\underline{-4.8\,V}}$$

$$V_B = V_E - 0.7V = \underline{\underline{-5.5V}}$$

Exercise 14.3



All conducting junctions drop 0.7V
$V_{CE}^{sat} = 0.2V$

a) $V_A = 0.2V$ $V_B = 4V$
Find I_{D_1}, V_B

b) $V_A = V_B = 4V$
Find I_B, β forced.

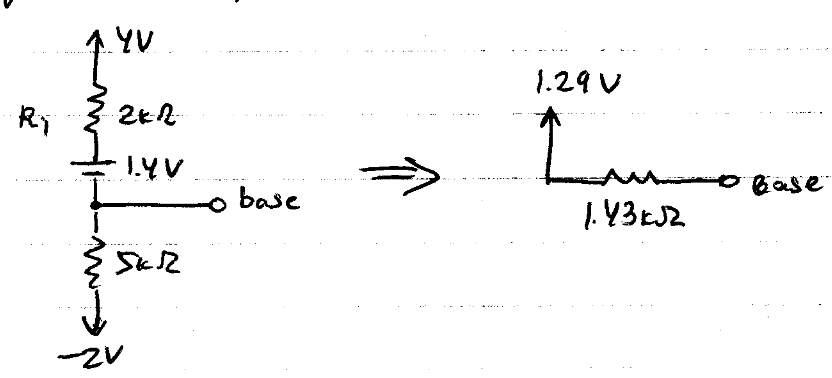
a) When V_A is low, V_B is high, D_1 is conducting, D_2 is off.
Since D_1 is conducting, $V_X = V_A + 0.7V = 0.2V + 0.7V = 0.9V$
Voltage 1.4 V drops on $D_3 + D_4$, and it gives $V_B = V_X - 1.4V = -0.5V$.
So, $\underline{V_B = -0.5V}$, and it's negative with respect to emitter (grounded)
Transistor is off. The diode current can be determined from:

$$I_{D_1} = I_{R_1} - I_{(D_3+D_4)} \qquad I_{R_1} = \frac{V_{CC} - V_X}{R_1} = \frac{4V - 0.9V}{2k\Omega} = 1.55mA$$

$$I_{(D_3+D_4)} = \frac{V_B - (-V_{BB})}{R_2} = \frac{-0.5V + 2V}{5k\Omega} = \frac{1.5V}{5k\Omega} = 0.3mA$$

$$I_{D_1} = 1.55mA - 0.3mA = 1.25mA.$$

b) When both V_A and V_B are high, ~~the~~ D_1 and D_2 are off. The we can find the equivalent V_S and R_S at the base to determine I_B.



If transistor is on, $V_B = 0.7V$
and $\underline{\underline{I_B}} = \frac{1.29V - 0.7V}{1.43k\Omega} =$
$= \underline{\underline{0.413mA}}$

over

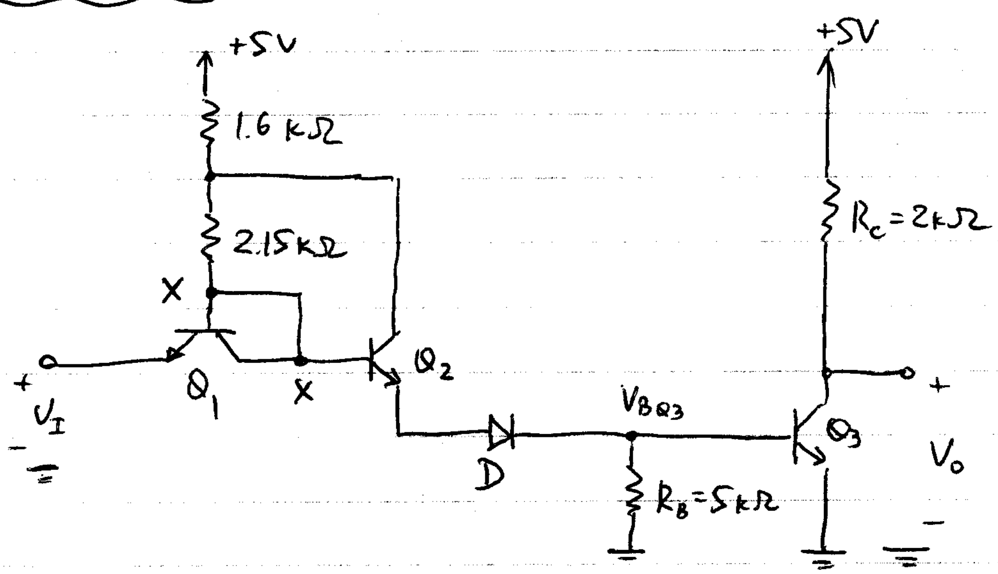
Assume, transistor is in active mode. For β large enough (~ 100), $V_c = V_Y < V_B$, and thus means that transistor in saturation.

Then $V_Y = V_E + V_{CE}^{sat} = 0.2\,V$ and $I_c = \frac{V_{cc} - V_Y}{R_c} = \frac{4V - 0.2V}{4 k\Omega} =$

$= \underline{\underline{0.95\ mA}}$.

$\underline{\underline{\beta_{forced}}} = \frac{I_c}{I_B} = \frac{0.95 mA}{0.413 mA} = \underline{\underline{2.3}}$

Exercise 14.4



$\beta(Q_2) = \beta(Q_3) = 50$

a) $V_I = 0.2V$. Find I_I

b) $V_I = 5V$

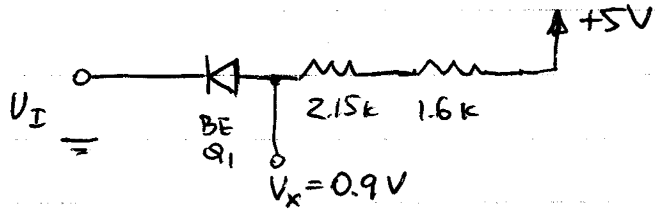
Find I_{BQ3}

Transistor Q_1 works like voltage-regulated diode.

a) If $V_I = 0.2\,V$ (low), the BE junction of Q_1 is conducting, and $V_X = V_I + 0.7V = 0.9V$. Let's assume Q_2 is on. Then $V_{BQ3} = V_X \underbrace{-0.7V}_{BE\ of\ Q_2} - \underbrace{0.7V}_{D} = 0.9V - 1.4V = -0.5V$. Then current goes into the emitter of Q_2 through $R_B = 5k\Omega$, since Q_3 is ~~on~~ off ($V_{BQ3} < V_{EQ3} = 0$)

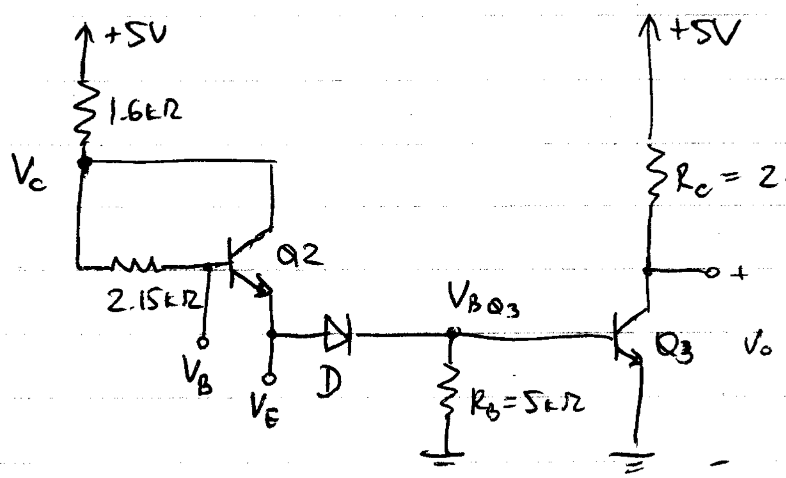
This doesn't hold, and it means that Q_2 and Q_3 are both $\underline{\underline{off}}$.

In this case, the equivalent circuit will be:



$$V_I = \frac{5V - 0.9V}{2.15k\Omega + 1.6k\Omega} = \underline{\underline{1.093\ mA}}$$

b) If $V_I = 5V$, BE junction of Q_1 is not conducting, and we have



Assume Q_3 is conducting, then $V_{BQ_3} = 0.7V$ and $V_E = 0.7V + 0.7V = 1.4V$

$V_B = V_E + 0.7V = 2.1\ V$ (if Q_2 is conducting).

For transistor Q_2 : $I_{1.6k\Omega} = I_{B_{Q_2}} + I_{C_{Q_2}} = (\beta + 1)\, I_B$, or:

$$\frac{5V - V_C}{1.6k\Omega} = (\beta+1)\frac{V_C - V_B}{2.15k\Omega} = 51 \cdot \frac{V_C - 2.1V}{2.15k\Omega}, \text{ and } \underline{V_C = 2.17\ V}$$

From this equation we can find $I_{BQ_2} = \dfrac{2.17V - 2.1V}{2.15k\Omega} = 0.0346\ mA$

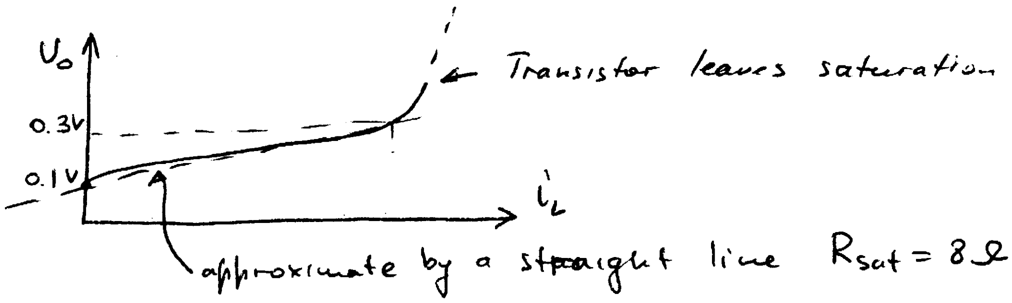
$$I_{BQ_3} = I_{EQ_2} - I_{R_B} = (\beta+1)\, I_{BQ_2} - \frac{V_{BQ_3} - 0}{5k\Omega} = 51 \cdot 0.0346\ mA - \frac{0.7V}{5k\Omega} =$$

$$= 1.76\ mA - 0.14\ mA = \underline{\underline{1.62\ mA}}$$

a) $V_I = 1.093\ mA$
b) $V_{BQ_3} = 1.62\ mA$

Homework #8

Ex 14.5



$R_{sat} = 8\Omega$

The maximum allowed current is $(i_{MAX} - 0) \cdot 8\Omega = 0.3V - 0.1V$

It follows, $i_{MAX} = \frac{0.2V}{8\Omega} = \underline{\underline{25mA}}$

Ex 14.6. Input current is 1mA when $V_I = 0.2$ $\therefore$ $\frac{25mA}{1mA} = 25$ (fanout)

Ex. 14.16

① Third state is high, Brings Q_5 into reverse active mode (Base-collector junction in forward Bias). The Base current into Q_6 then will be $\frac{5V - 2.1V}{4k\Omega} \approx .73mA$. that is too large for Q_6 to remain in active mode. It turns out that Q_6 is saturated. This means that $V_C(Q6) = V_E(Q6) + 0.2V$. This 0.2V difference is not enough to open base-emitter junction of Q_7 that is in cut-off. Therefore, there is no current in the base of Q_4 from the collector of Q_7. On the other hand, high third state will have no influence on Q_1 if either of the two logic inputs is low (Q_1 saturated). When two logic inputs are high, and the third state is high, Q_1 will be in reverse active, saturating Q_2, Q_3, turning off Q_4, and the output will be low, as in the case with normal NAND gate.

(2) Third state is low, Q_5 remains forward biased (saturated), that makes the base voltage of Q_6 to be $V_B(Q6) = 0.2V + 0.7V = 0.9V$, This voltage is not enough of Q_6 to operate (it requires 1.4V). So, Q_6 is cut off, that connects $4k\Omega$ resistor directly to the base of Q_7 with $V_B(Q7) = 1.4V$. The base current then $i_B(Q7) = \frac{5V - 1.4V}{4k\Omega} = 0.9mA$, that is too large for Q_7 to remain in active mode. So, it's saturated with collector voltage $V_C(Q7) \approx 0.9V$. This voltage is not enough to drive Q_4, since it requires 1.4V to operate. Q_4 turns off. So, Q_4 is always off, and, for any combination of two logic inputs, Q_1 is saturated, turning off Q_2 and Q_3.

Therefore, if third state is low, Q_3 and Q_4 are both off. The output floats.