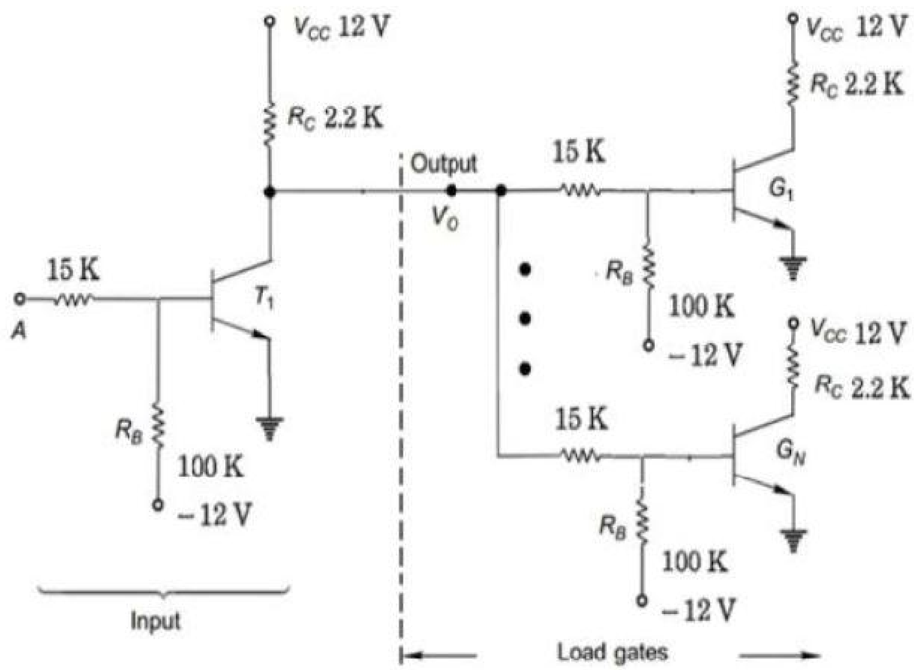
BRAC UNIVERSITY
Department of Computer Science & Engineering
Practice Problem sheet (Week 2)
CSE 350: Digital Electronics and Pulse Technique

- *Use activation voltage* $V_{\gamma}(diode) = \mathbf{0.6V}, V_{\gamma}(transistor) = \mathbf{0.5V}, V_{BE}(forward\ active) = 0.7V,$ $V_{D} = 0.7V$ *and* $V_{BE}(sat) = 0.8\,V$ *for all the questions.*

Question No. 1

For the given RTL inverter circuit assume V_{OH} =10 V and V_{OL}=0.2V.Also assume common emitter current gain, β_F=30.Assume for saturation mode V_{BE}=0.8V, V_{CE}=0.2V and cut in voltage for transistor $V\gamma$=0.5V.

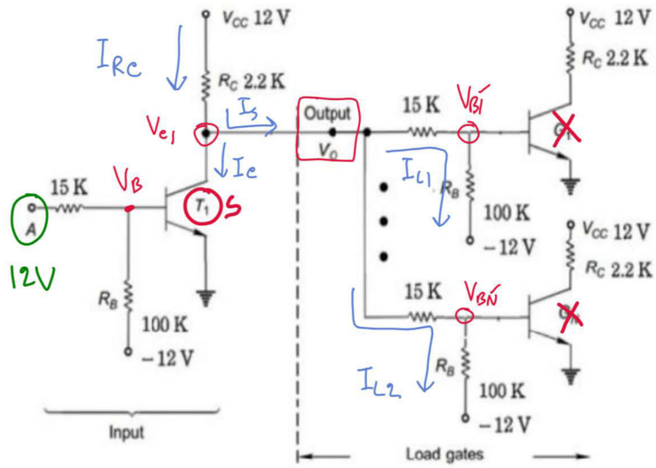
(a)	**Find the Maximum possible Fanout.**
(b)	**Find the value of Vo if Fanout, N=2 (2 Load gates are connected) and input of Driver is Low.**
(c)	**If Vin = High, find the power dissipation in the Driver circuit. (assume No Loads are connected)**
(d)	**If Vin = High, find the power dissipation in the Driver circuit. (assume 50 Loads are connected)**
(e)	**If Vin = Low and Fanout is 2, find the power dissipation in the Driver circuit.**



Solution:

(a) Case 1:

$V_{in} = \text{High} = 12V$



T_1 sat

$\therefore V_{c1} = 0.2 = V_o$

$\therefore$ Input of Load Gates $(G_1 \dots G_N)$

$= V_o = 0.2 = \text{Low}$

$\therefore G_1 \dots G_N$ in cutoff.

Now, $I_{Rc} = \dfrac{12 - V_o}{R_c} = \dfrac{12 - 0.2}{2.2k} = 5.3636\,mA$

We will Assume $I_c = 0 \longrightarrow$ To maximize I_s.

$\therefore I_{supply} = I_s = I_{Rc} = 5.3636\,mA$.

$\therefore$ Individual Load current $= I_L = I_{L1} = \dfrac{V_o - (-12)}{(100+15)\,k\Omega} = \dfrac{12.2}{115\,k\Omega} = 0.106\,mA$

$\therefore$ Total Demand " $= N I_L = N\,(0.106)\,mA$

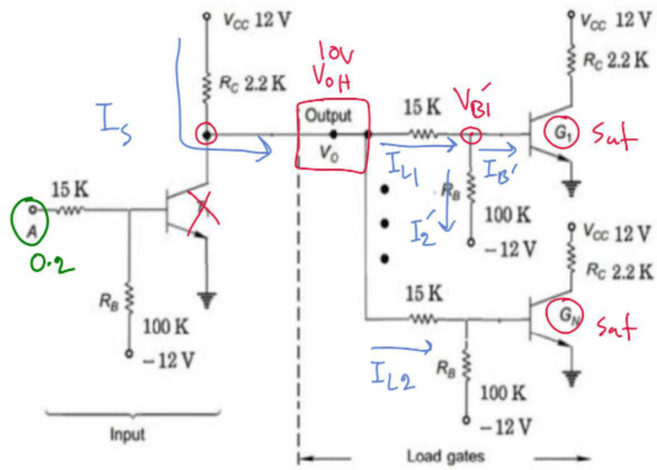
$I_{supply} = I_{Demand} \longrightarrow 5.3636\,mA = N\,(0.106\,mA) \rightarrow N = 50.6$

$\hookrightarrow$ Floor $\rightarrow N = 50$.

Case 02:

$V_{in} = Low = 0.2$

T_1 in cutoff.



$\therefore V_o = High$

$\therefore V_{in}$ of Load Gates is High

$\therefore G_1 \ldots G_N$ in saturation

Now, $V_o = High = V_{OH} = 10V$

As G_1 in sat $\rightarrow V_{B1}' = 0.8V$.

$\therefore$ Individual Load current, $I_{L1} = \dfrac{V_o - V_{B1}'}{15k\Omega} = \dfrac{10 - 0.8}{15k\Omega} = 0.6133mA$

Supply Current $\rightarrow I_s = \dfrac{12 - 10}{2.2k\Omega} = 0.909mA$

$\therefore$ Supply = Demand $\rightarrow I_s = N(I_L) \rightarrow 0.909 = N(0.6133)$

$\rightarrow N = 1.48$

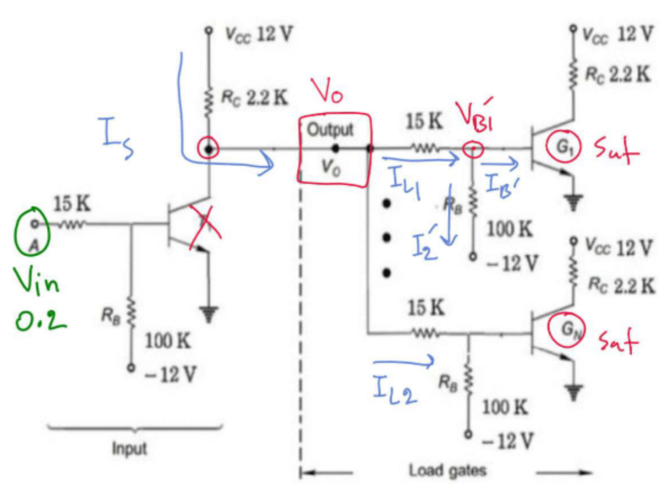
$\hookrightarrow$ Floor $\rightarrow N = 1$.

$\therefore$ Fanout = Min $(50, 1) = 1$ $\boxed{\text{Ans}}$

(b)	Find the value of Vo if Fanout, N=2 (2 Load gates are connected) and input of Driver is Low.

(b) Given, Fanout $= N = 2$

$V_{in} = Low = 0.2V$



$\therefore T_1$ cutoff

$V_o = High$

$\therefore G_1 \ldots G_N$ in saturation

Now,

Supply $\rightarrow I_s = \dfrac{12 - V_o}{2.2k\Omega}$

Individual Load current, $I_L = \dfrac{V_o - V_{B1}'}{\ldots}$ $\quad V_o - 0.8$

(c)	**If Vin = High, find the power dissipation in the Driver circuit. (assume No Loads are connected)**

Ans: $V_{in} = 12$

$\because T_1$ in sat.

$\therefore V_B = 0.8,\ V_c = 0.2$

Now, $I_1 = \dfrac{12 - 0.8}{15k\Omega} = 0.747mA$

$I_2 = \dfrac{0.8 - (-12)}{100k\Omega} = 0.128mA$

$I_B = I_1 - I_2 = 0.619\,mA$

$I_s = 0 \longrightarrow [\because$ No Loads are connected$]$

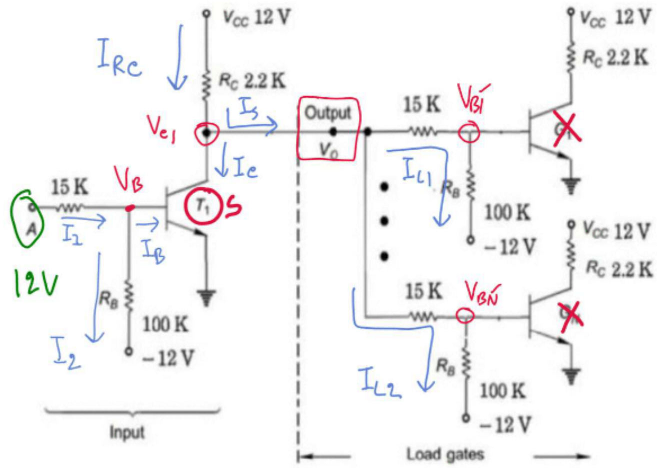
$I_{RC} = I_C = \dfrac{12 - 0.2}{2.2k\Omega} = 5.3636\,mA$

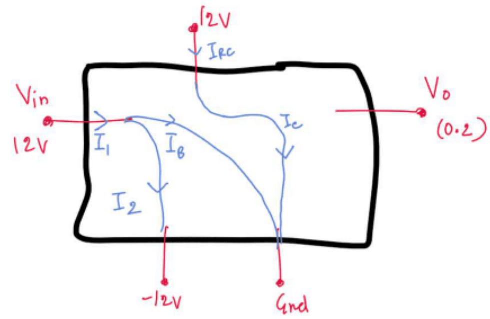
$\therefore$ Power $= \sum I\,\Delta V$

$= I_2(12+12)$

$+ I_B(12-0) + I_c(12-0)$

$= 74.8632\ mW.$





(d)	**If Vin = High, find the power dissipation in the Driver circuit. (assume 50 Loads are connected)**

Ans: $V_{in} = 12$

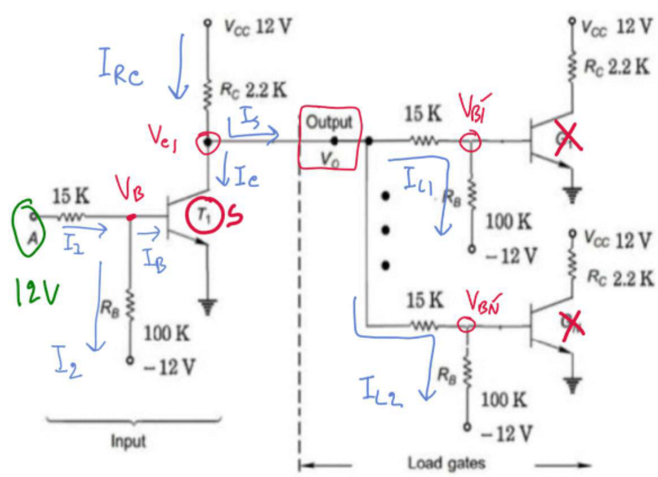
$\because T_1$ in sat.

$\therefore V_B = 0.8,\ V_c = 0.2$

Now, $I_1 = \dfrac{12 - 0.8}{15k\Omega} = 0.747mA$

$I_2 = \dfrac{0.8 - (-12)}{100k\Omega} = 0.128mA$

$I_B = I_1 - I_2 = 0.619\,mA$



From case (1) in ques. (a) →

$\therefore$ Individual Load current $= I_L = I_{L1} = \dfrac{V_o - (-12)}{(100+15)\,k\Omega} = \dfrac{12.2}{115k\Omega} = 0.106mA$

Total Load current $= I_s = N \times I_{L1} = 50(I_{L1}) = 5.3\ mA$

In Driver Circuit,

$I_{RC} = \dfrac{12 - 0.2}{2.2k\Omega} = 5.3636\,mA \longrightarrow$ And, $I_{RC} = I_c + I_s$

(e)	**If Vin = Low and Fanout is 2, find the power dissipation in the Driver circuit.**

$V_{in} = \text{Low} = 0.2$

T_1 in cutoff.

$\therefore V_o = \text{High}$

$\therefore G_1 \ldots G_N$ in saturation

Given, Fanout $= 2$

From (b) $\rightarrow V_o = 9.4597V$

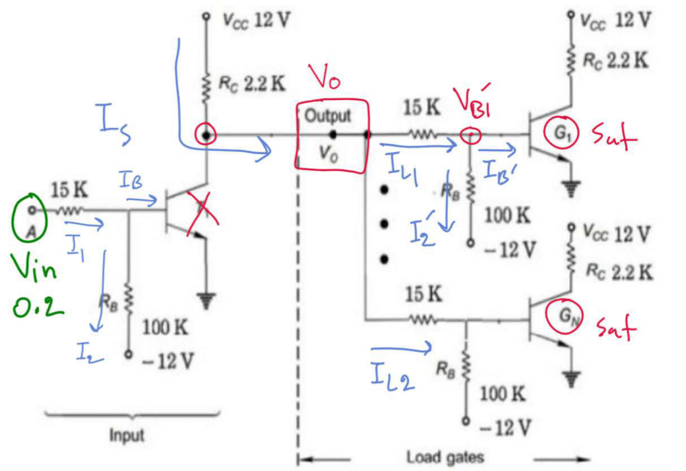
In Driver, $I_B = 0$

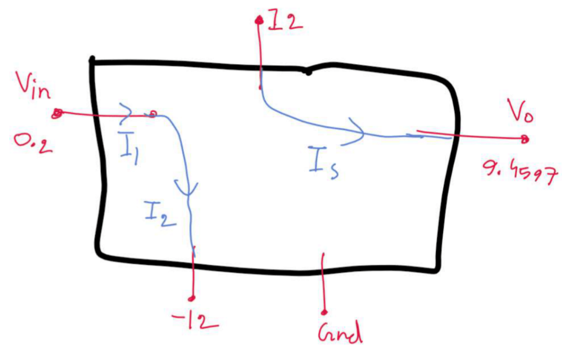
$$I_1 = I_2 = \frac{0.2 - (-12)}{115k\Omega} = 0.106\,mA$$

$$I_s = \frac{12 - 9.4597}{2.2k\Omega} = 1.1547\,mA$$

$$\text{Power} = I_1(12+12) + I_s(12 - 9.4597)$$

$$= 5.477\,mW$$

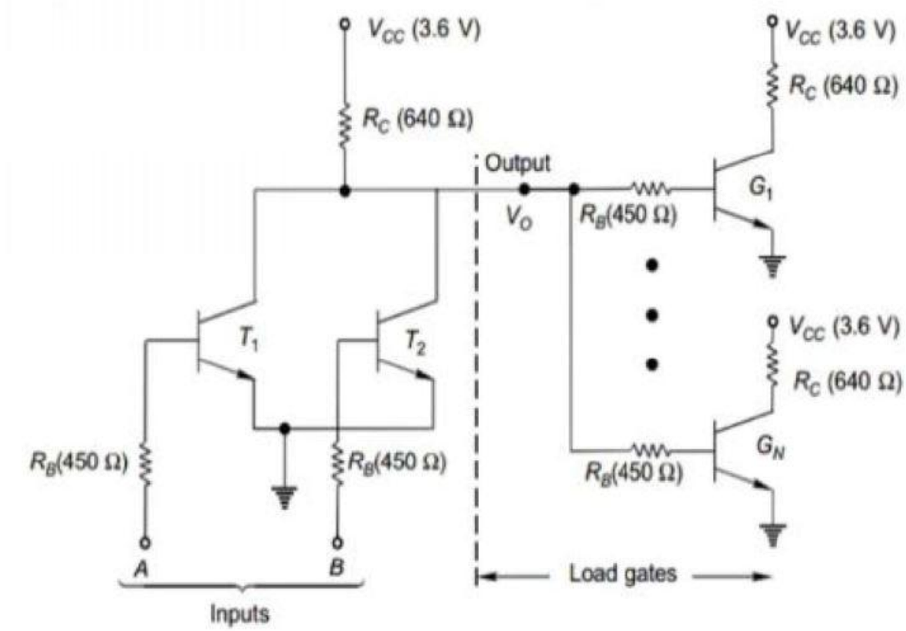




Question No. 2

For the given RTL NOR circuit assume $V_{OH} = 1.3\ V$ and $V_{OL} = 0.2V$. Also assume common emitter current gain, $\beta_F = 30$. Assume for saturation mode $V_{BE} = 0.8V$, $V_{CE} = 0.2V$ and cut in voltage for transistor $V_\gamma = 0.5V$.

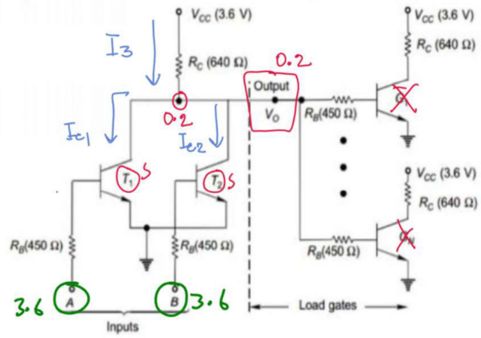
(a)	Find the value of **maximum fanout.**
(b)	**Find the value of *Vo (output of Driver),*** if Fanout(N)= 5 and Inputs A, B are Low.
(c)	**Find the value of *βmin (for Load Gates), and* Power dissipation in the Driver circuit** for the conditions in (b).
(d)	**Find the Power dissipation in the Driver circuit when both inputs (A and B) are High.**



V_{CC} (3.6 V)
R_C (640 Ω)
Output
V_O
R_B(450 Ω)
G_1
V_{CC} (3.6 V)
R_C (640 Ω)
T_1
T_2
R_B(450 Ω)
R_B(450 Ω)
G_N
R_B(450 Ω)
A
B
Inputs
Load gates

Solution:

(a)	Find the value of **maximum fanout.**



Case 1: A or B or both High = 3.6V

$\therefore T_1 \; T_2$ in Saturation

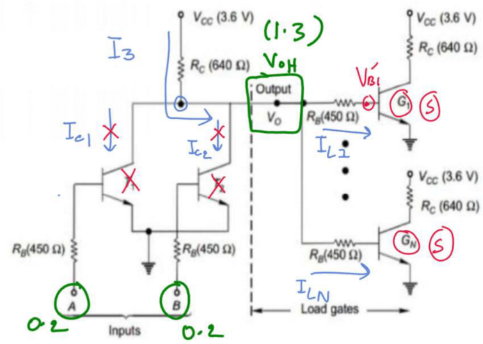
$V_{CE} = 0.2 \longrightarrow V_o = 0.2$

$\therefore$ Input of Load Gates $= V_o = 0.2 =$ Low

$\therefore G_1 \dots G_N$ in cutoff.

$\therefore$ No current flow between Driver and Load.

$\therefore$ Fanout $= \infty$.



Case 2: $A = B = 0.2V =$ Low

$T_1 \; T_2$ OFF.

$V_o =$ High $= V_{oH} = 1$

$\therefore$ Load Gates in Saturation

$$\therefore I_{supply} = I_3 = \frac{3.6 - V_{oH}}{640\Omega} = \frac{3.6 - 1.3}{640\Omega}$$

$$\therefore I_{supply} = 3.593 \text{ mA}$$

Individual Load current, $I_L = I_{L1} = \dfrac{V_o - V_{B1}'}{450\Omega} = \dfrac{1.3 - 0.8}{450\Omega}$ [$V_{BE} = 0.8$ in Sat]

$\hookrightarrow I_L = 1.111$ mA

Total Demand $= N(I_L)$

$\therefore I_{supply} = I_{Demand} \longrightarrow 3.593 = N(1.111)$

$\hookrightarrow N = 3.23 \longrightarrow \boxed{N = 3}$

$\therefore$ Max Fanout $= \text{Min}(\infty, 3) = 3$ $\boxed{\text{Ans}}$

(b) **Find the value of *Vo (output of Driver)*,** if Fanout(N)= 5 and Inputs A, B are Low.

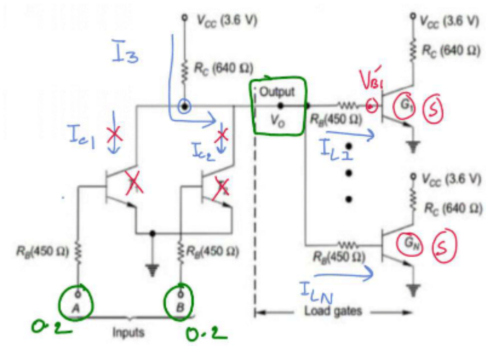
$A = B = 0.2V = \text{Low}$

$T_1 \; T_2$ OFF.

$V_o = \text{High}$

$\therefore$ Load Gates in Saturation

$\therefore I_{supply} = I_3 = \dfrac{3.6 - V_o}{640\Omega}$



Individual Load current, $I_L = I_{L1} = \dfrac{V_o - V_{B1}'}{450\Omega} = \dfrac{V_o - 0.8}{450\Omega}$ $[V_{BE} = 0.8 \text{ in sat}]$

Total Demand $= N(I_L)$

$\therefore I_{supply} = I_{Demand} \longrightarrow \boxed{\dfrac{3.6 - V_o}{640\Omega} = \dfrac{V_o - 0.8}{450\Omega} \times N}$

$$\frac{3.6 - V_o}{640} = \frac{V_o - 0.8}{450} \times 5$$

$$V_o = 1.145V \quad \boxed{\text{Ans.}}$$

(c) **Find the value of *βmin (for Load Gates), and* Power dissipation in the Driver circuit for** the conditions in (b).

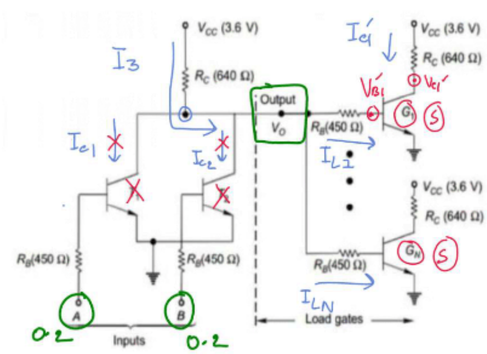
Soln: From (b) $\rightarrow V_o = 1.145v$

(i) Now, $\beta_{min} = \dfrac{I_c}{I_B}$ (sat)

Here, Load Gates are in saturation.

For Load Gate $G_1 \rightarrow$

$V_{B1}' = 0.8$ and, $V_{c1}' = 0.2$



$\therefore I_B = I_{L1} = \dfrac{V_o - V_{B1}'}{R_B} = \dfrac{1.145 - 0.8}{450\Omega}$

$\therefore I_B = 0.767mA$

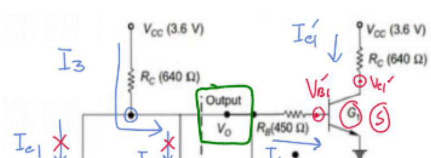
$I_c = I_{c1}' = \dfrac{3.6 - V_{c1}'}{640\Omega} = \dfrac{3.6 - 0.2}{640\Omega}$

$\therefore I_c = 5.3125mA$

$$\therefore \beta_{min} = \frac{I_c}{I_B} = \frac{5.3125}{0.767} = 6.9263 \quad \boxed{\text{Ans.}}$$

(ii) In Driver circuit,

$T_1 \; T_2$ OFF



(d)	**Find the Power dissipation in the Driver circuit when both inputs (A and B) are High.**

$V_A = V_B = Hi = 3.6$

$\therefore T_1 \ T_2$ in Saturation

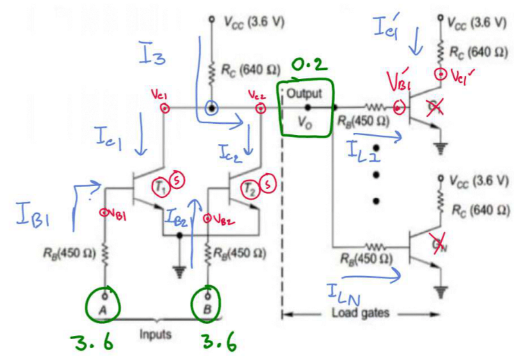
$V_{BE} = 0.8 \longrightarrow V_{B1} = V_{B2} = 0.8$

$V_{CE} = 0.2 \longrightarrow V_{C1} = V_{C2} = V_o = 0.2$

$\therefore$ Input of Load Gates $= V_o = 0.2 =$ Low

$\therefore G_1 \dots G_N$ in cutoff.

$\therefore$ No current flow between Driver and Load.

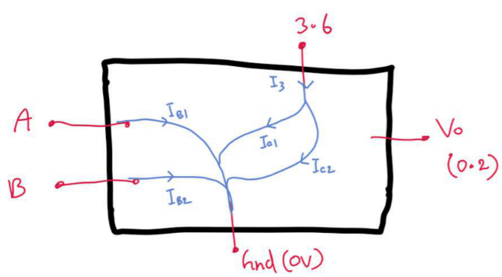


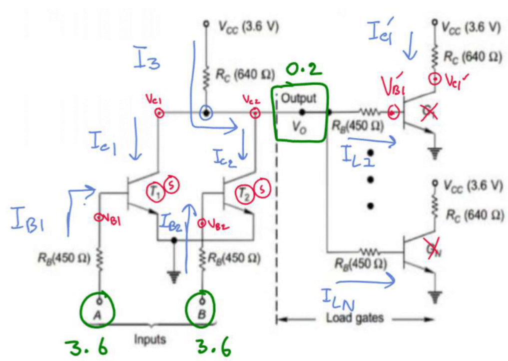
Now, $I_{B1} = \dfrac{3.6 - V_{B1}}{450\Omega} = \dfrac{3.6 - 0.8}{450\Omega} = 6.222\ mA$

$I_{B2} = \dfrac{3.6 - V_{B2}}{450\Omega} = \dfrac{3.6 - 0.8}{450\Omega} = 6.222\ mA$

$I_3 = \dfrac{3.6 - 0.2}{640} = 5.312\ mA$

$I_{C1} = I_{C2} = \dfrac{I_3}{2} = 2.656\ mA$





Power $= \Sigma \Delta V I = I_{B1}(V_{B1} - 0) + I_{B2}(V_{B2} - 0) + \underbrace{I_{C1}(3.6 - 0) + I_{C2}(3.6 - 0)}$

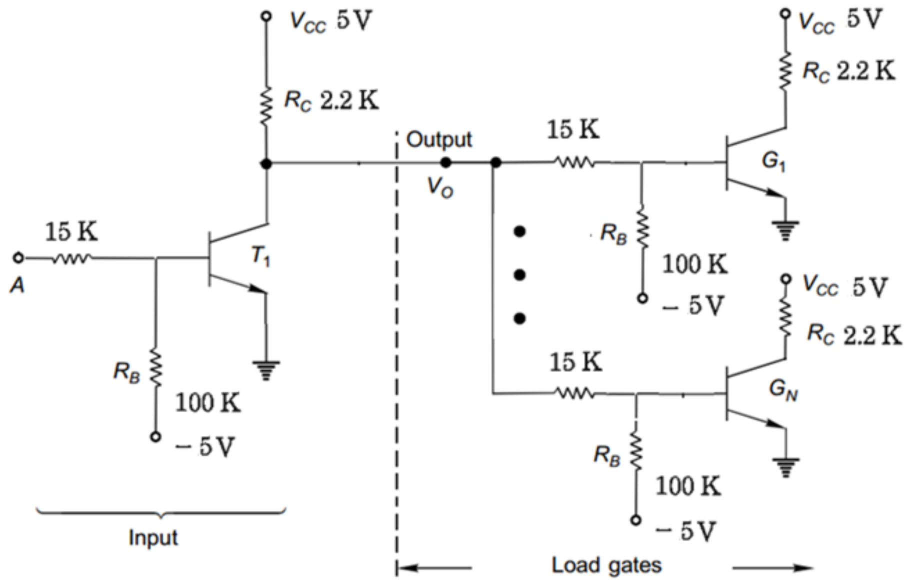
$= I_{B1}(V_{B1} - 0) + I_{B2}(V_{B2} - 0) + I_3(3.6 - 0)$

$= 63.922\ mW$

<u>Question No. 3</u>

For the given RTL inverter circuit assume $V_{OH} = 11.5\ V$ and $V_{OL} = 0.2V$. Also assume common emitter current gain, $\beta_F = 30$. Assume for saturation mode $V_{BE} = 0.8V$, $V_{CE} = 0.2V$ and cut in voltage for transistor $V\gamma_T = 0.5V$.

(a)	**Find the value of *VIL* in *V*.**
(b)	**Find the value of *VIH* in *V*.**
(c)	**Find the value of Noise margin, *VN* in *V*.**

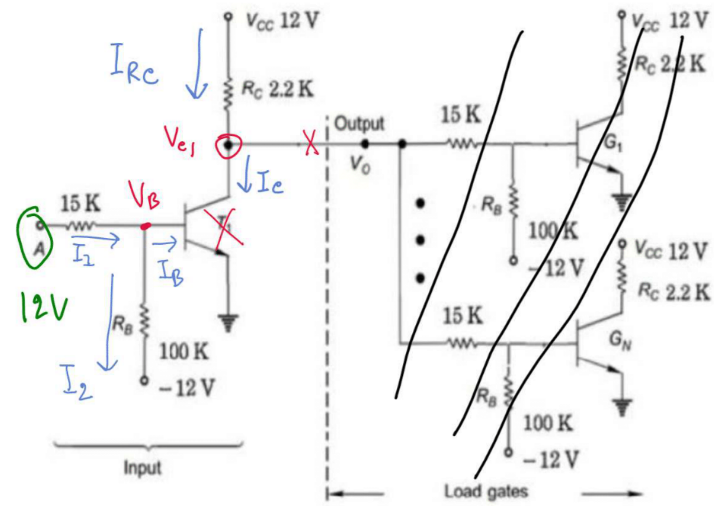


<u>Solution:</u>

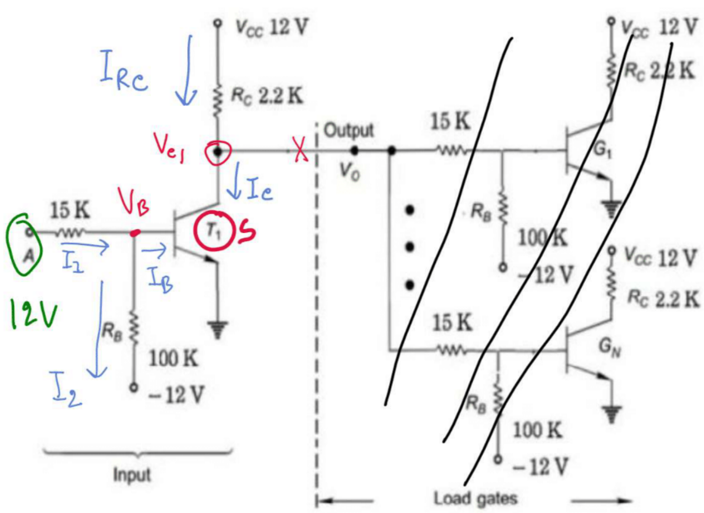
Soln: We can ignore Load Gates for noise margin calculation.

$V_{IL} \rightarrow T_1$ in cutoff

$\therefore I_{Rc} = I_c$.



$V_{IH} \rightarrow T_1$ in between Active and Saturation (edge of Saturation)



$V_{OL} = 0.2 \rightarrow V_{CE\,sat}$

$V_{OH} \rightarrow$ depends on design.

Will be given in question

Here, we will use ~~$V_{OH} = (12 - 0.5)$~~

$V_{OH} = 11.5\,V$

V_{IL} calculation $\rightarrow$

BJT just turns on for cut-in volt

$V_{BE} = 0.5$

$\hookrightarrow V_B = 0.5$

at this point, $I_B \approx 0A$.

$\therefore I_1 = I_2$ $\quad I_2 = \dfrac{0.5-(-12)}{100k} = 0.125mA$

$$I_1 = \frac{V_i - 0.5}{15k} = I_2 = 0.125mA$$

$\hookrightarrow V_i = 2.375 = V_{IL\,(max)}$

*V_{IH} calculation:

BJT going from saturation $\longleftrightarrow$ active

edge of saturation.

$\therefore$ Both formulas for sat and active mode can be applied.

$V_B = 0.8$

$I_c = \beta I_B$ (β → 30)

$V_c = 0.2$

$$I_c = \frac{12 - 0.2}{2.2k} = 5.3636\ mA$$

$$I_B = \frac{I_c}{\beta} = \frac{5.3636}{30} = 0.1788\ mA$$

$$I_2 = \frac{0.8 - (-12)}{100k} = 0.128\ mA$$

$$I_1 = I_2 + I_B = (0.128 + 0.1788)$$

$$= 0.3068\ mA$$

$$I_1 = \frac{V - 0.8}{15k} = 0.3068\ m$$

$$\hookrightarrow V = 5.4081\ v. = V_{IH}.$$

$$\therefore V_{NH} = \cancel{V_o}\ V_{OH} - V_{IH} = 11.5 - 5.4018\ v$$

$$= 6.0982\ V$$

$$V_{NL} = \underset{2.375}{V_{IL}} - \underset{0.2}{V_{OL}}$$

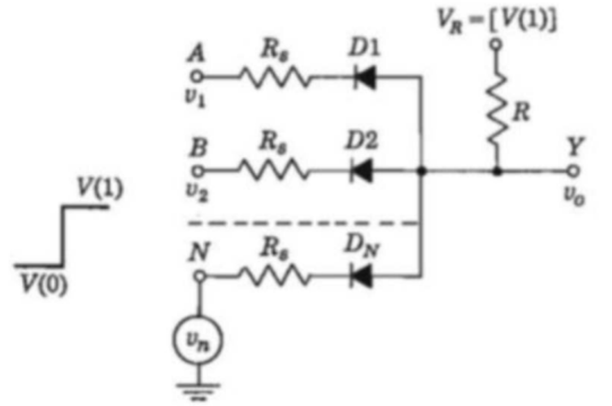
$$= 2.175\ V$$

Noise Margin = Minimum $\longrightarrow V_n = 2.175\ V$

$$= \text{Min}(6.098, 2.175) = 2.175\ V$$

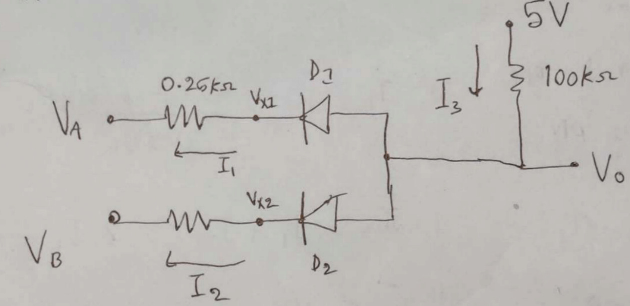
Question No. 4

AND Gate: If $V(0) = 0V$ and $V(1) = 5V$,
ans $R_S = 0.25\ k\,\Omega$, $R = 100\ k\,\Omega$. Fan In N = 2
(a) Find out the output voltage levels.
(b) Find out the maximum power dissipation.



Solution:

ⓐ ~~Case 1.~~ Fan in = 2



ⓐ Case 1: $V_A = V_B = 5V$

Then, D_1 D_2 OFF

Cause, cathode voltage Higher than anode voltage.

$\therefore I_1 = I_2 = I_3 = 0$

$\therefore$ No voltage Difference across '100 kΩ' resistor.

$\therefore V_o = 5V$

Ans.

Case 2: $V_A = 0V$, $V_B = 5V$

D_1 ON → cathode voltage < Anode voltage

D_2 OFF.

$\therefore I_2 = 0$ and, $I_1 = I_3$.

Now, $I_3 = \frac{5 - V_o}{100k\Omega}$

$I_1 = \frac{V_{x1} - 0}{0.25k\Omega}$

$\hookrightarrow I_1 = \frac{(V_o - 0.7) - 0}{0.25k\Omega}$

$\therefore I_1 = I_3 \rightarrow \frac{V_o - 0.7}{0.25k\Omega} = \frac{5 - V_o}{100k\Omega}$

$\hookrightarrow$ solving, $V_o = 0.7107V$

Ans.

Case 3: $V_B = 0, V_A = 5V$

Using same logic as case 2 → D_1 OFF, D_2 ON

$I_1 = 0$, $I_2 = I_3$

$$I_2 = \frac{V_{x2} - 0}{0.25k\Omega}$$

$$\hookrightarrow \frac{(V_o - 0.7)}{0.25k} = \frac{5 - V_o}{100k}$$

$\hookrightarrow V_o = 0.7107V$ $\boxed{\text{Ans.}}$

Case 4: $V_A = 0, V_B = 0$

D_1 D_2 ON

$$I_1 = I_2 = \frac{V_o - 0.7}{0.25k}$$

$$I_3 = I_1 + I_2 = 2I_1$$

$$\hookrightarrow \frac{5 - V_o}{100k} = 2 \times \frac{V_o - 0.7}{0.25k}$$

$\hookrightarrow V_o = 0.7054V.$ $\boxed{\text{Ans.}}$

(b) Max power dissipation happens when current is max. This happens when V_o is lowest (case 04).

$\therefore V_o = 0.7054V$ and, $I_3 = \frac{5 - 0.7054}{100k\Omega} = 0.0429mA.$

$$\therefore \text{Power Dissipation} = I_3[5 - V_A] = I_3[5 - V_B]$$

$$= I_1[5 - V_A] + I_2[5 - V_B]$$

$$\boxed{= 0.2147\ mW}$$