

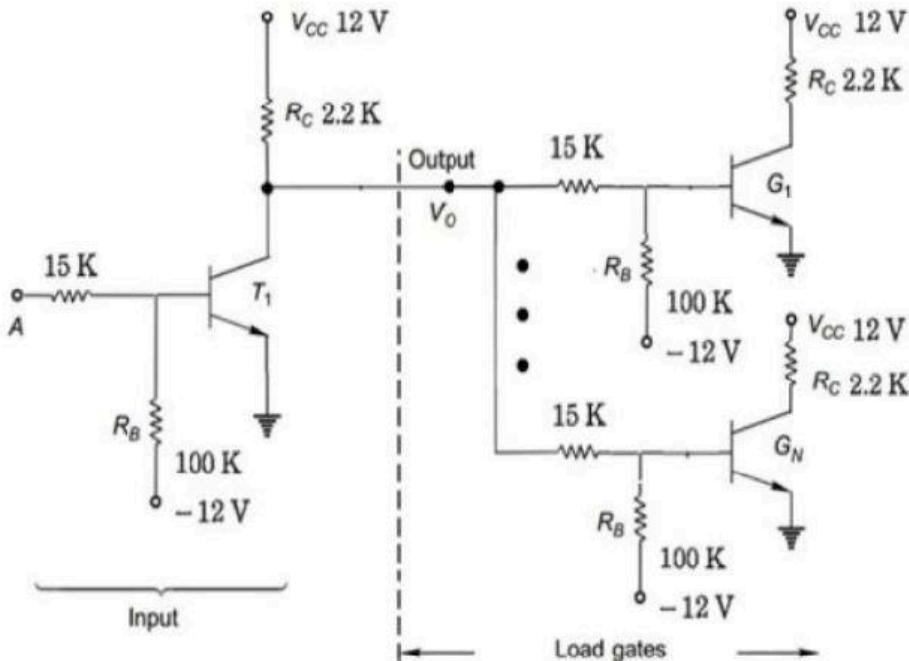
**BRAC UNIVERSITY**  
**Department of Computer Science & Engineering**  
**Practice Problem sheet (Week 2)**  
**CSE 350: Digital Electronics and Pulse Technique**

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

**Question No. 1**

For the given RTL inverter circuit assume  $V_{OH}=10V$  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 Maximum possible Fanout.
(b)	Find the value of $V_o$ if Fanout, $N=2$ (2 Load gates are connected) and input of Driver is Low.
(c)	If $V_{in}$ = High, find the power dissipation in the Driver circuit. (assume No Loads are connected)
(d)	If $V_{in}$ = High, find the power dissipation in the Driver circuit. (assume 50 Loads are connected)
(e)	If $V_{in}$ = 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 ( $h_1, \dots, h_N$ )

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

$\therefore h_1, \dots, h_N$  in cutoff.

$$\text{Now, } I_{RC} = \frac{12 - V_o}{R_C} = \frac{12 - 0.2}{2.2k} = 5.3636 \text{ mA}$$

We will Assume  $I_C = 0 \rightarrow$  To maximize  $I_S$ .

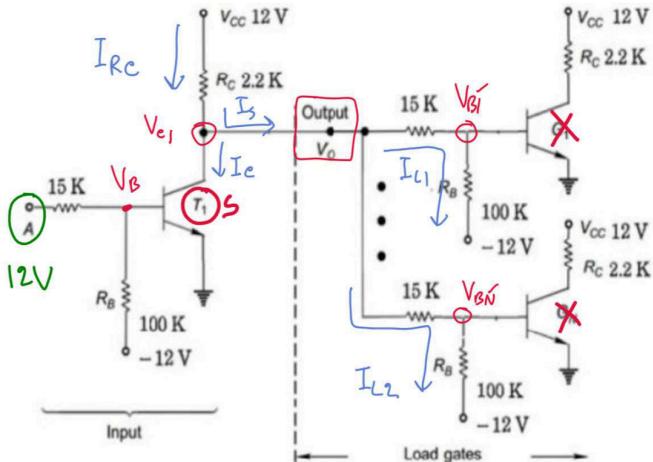
$$\therefore I_{\text{Supply}} = I_S = I_{RC} = 5.3636 \text{ mA}$$

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

$$\therefore \text{Total Demand} \quad \text{=} N I_L = N (0.106) \text{ mA}$$

$$I_{\text{Supply}} = I_{\text{Demand}} \rightarrow 5.3636 \text{ mA} = N (0.106 \text{ mA}) \rightarrow N = 50.6$$

└ Floor →  $N = 50$ .



### Case 02:

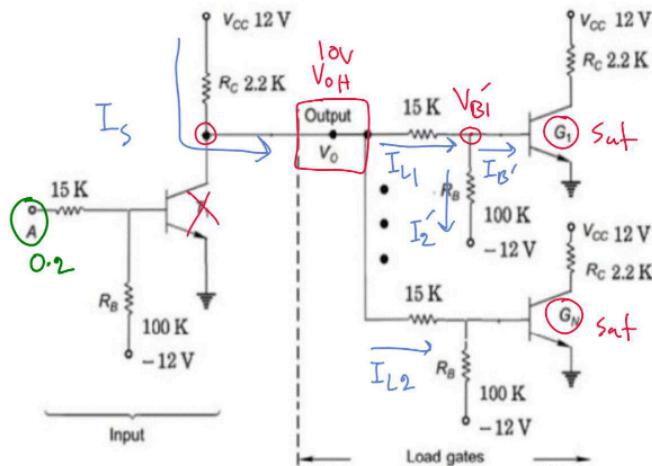
$$V_{in} = \text{Low} = 0.2$$

$T_1$  in cutoff.

$\therefore V_o = \text{High}$

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

$\therefore G_1 \dots G_N$  in saturation



$$\text{Now, } V_o = \text{High} = V_{0H} = 10V$$

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

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

$$\text{Supply current} \rightarrow I_s = \frac{12 - 10}{2.2k\Omega} = 0.909mA$$

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

$$\rightarrow N = 1.48$$

$$\hookrightarrow \text{Floor} \rightarrow N = 1.$$

$$\therefore \text{Fanout} = \text{Min}(G_0, 2) = 1 \quad [\text{Ans}]$$

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

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

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

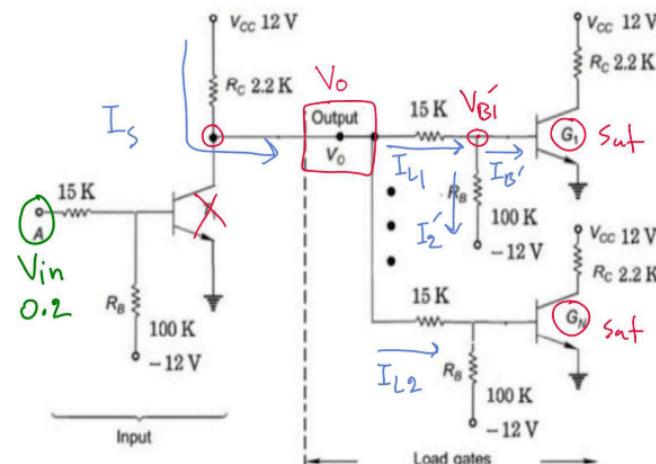
$\therefore T_1$  cutoff

$V_o = \text{High}$

$\therefore G_1 \dots G_N$  in saturation

Now,

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



$$\text{Individual Load currents, } I_L = \frac{V_o - V_{B1'}}{15k\Omega} = \frac{V_o - 0.8}{15k\Omega}$$

(c) If  $V_{in} = \text{High}$ , find the power dissipation in the Driver circuit. (assume No Loads are connected)

$$\text{Ans: } V_{in} = 12$$

$\therefore T_1$  in sat.

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

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

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

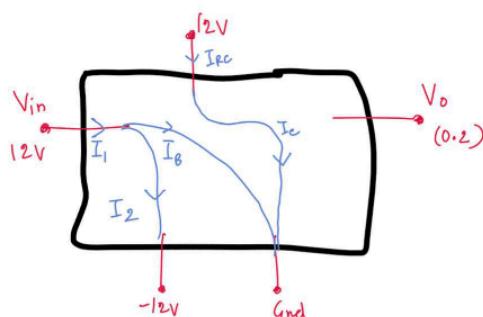
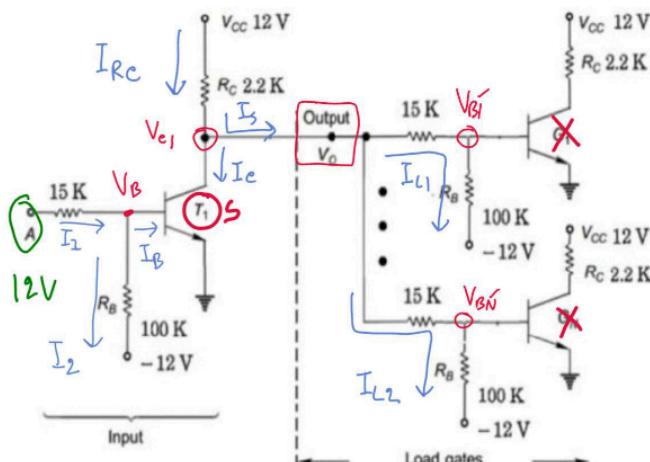
$$I_B = I_1 - I_2 = 0.619\text{mA}$$

$$I_S = 0 \rightarrow \{\text{No loads are connected}\}$$

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

$$\therefore \text{Power} = \sum I \Delta V$$

$$\begin{aligned} &= I_2(12+12) \\ &+ I_B(12-0) + I_C(12-0) \\ &= 74.8632\text{mW.} \end{aligned}$$



(d) If  $V_{in} = \text{High}$ , find the power dissipation in the Driver circuit. (assume 50 Loads are connected)

$$\text{Ans: } V_{in} = 12$$

$\therefore T_1$  in sat.

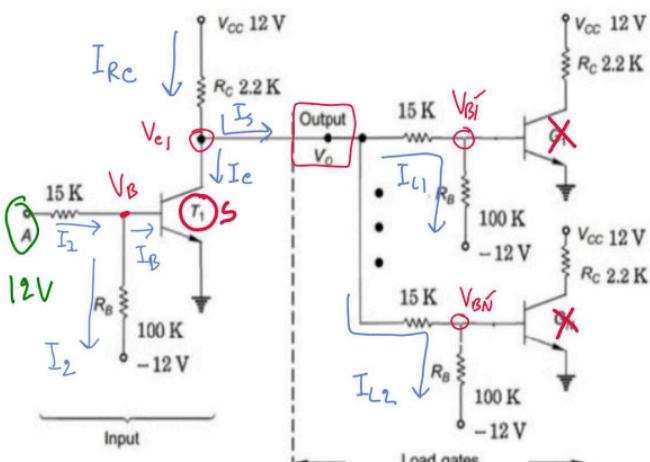
$$\therefore V_B = 0.8, V_C = 0.2$$

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

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

$$I_B = I_1 - I_2 = 0.619\text{mA}$$

From case (i) in ques. (a)  $\rightarrow$



$$\therefore \text{Individual Load current} = I_L = I_{L1} = \frac{V_0 - (-12)}{(100+15)\text{k}\Omega} = \frac{12-2}{115\text{k}\Omega} = 0.106\text{mA}$$

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

In Driver Circuit,

$$I_{RC} = \frac{12 - 0.2}{2.2\text{k}\Omega} = 5.3636\text{mA} \rightarrow \text{And, } I_{RC} = I_C + I_S$$

(e) If  $V_{in} = \text{Low} = 0.2$ , find the power dissipation in the Driver circuit.

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

$T_2$  in cutoff.

$\therefore V_o = \text{High}$

$\therefore G_1 \dots h_{FE}$  in saturation

Given, Fanout = 2

$$\text{From (b)} \rightarrow V_o = 9.4597V$$

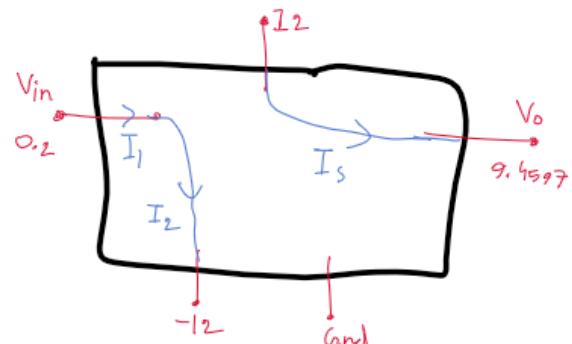
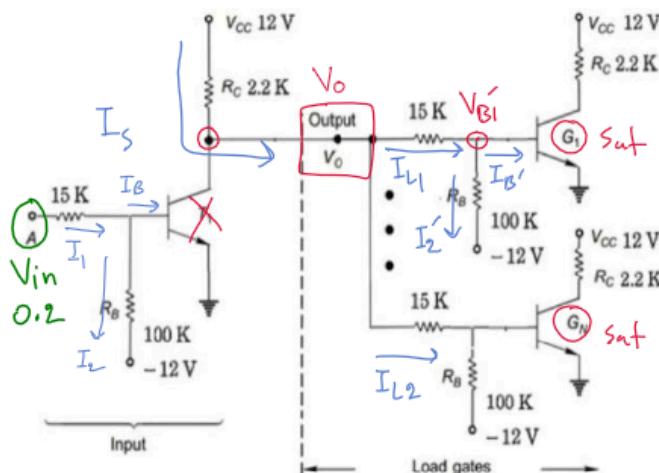
In Driver,  $I_B = 0$

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

$$I_S = \frac{|12 - 9.4597|}{2.2k\Omega} = 1.1547mA$$

$$\text{Power} = I_1(0.2 + 12) + I_S(|12 - 9.4597|)$$

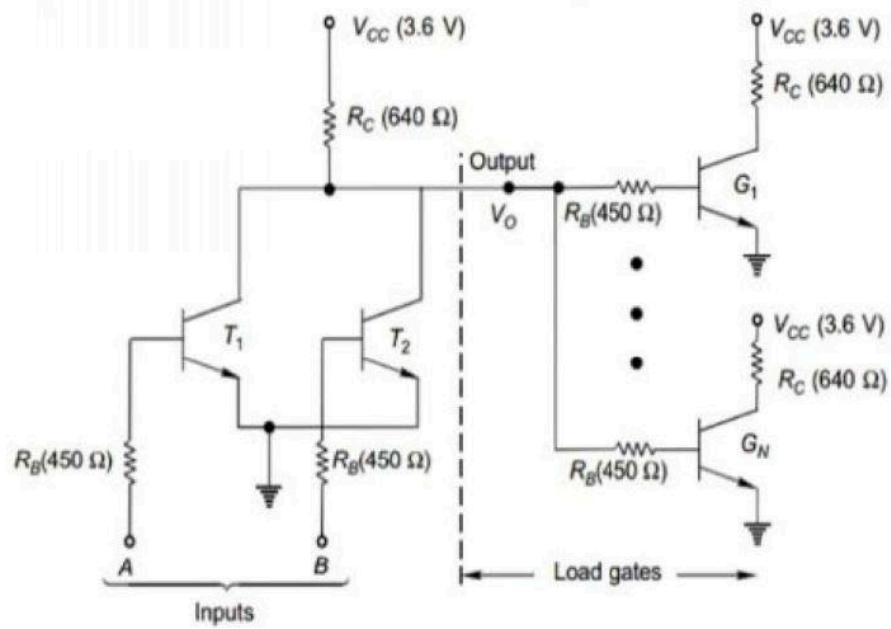
$$= 4.226 \text{ mW}$$



## Question No. 2

For the given RTL NOR circuit assume  $VOH = 1.3V$  and  $VOL = 0.2V$ . Also assume common emitter current gain,  $\beta_F = 30$ . Assume for saturation mode  $VBE = 0.8V$ ,  $VCE = 0.2V$  and cut in voltage for transistor  $V\gamma = 0.5V$ .

(a)	Find the value of <b>maximum fanout</b> .
(b)	Find the value of $V_o$ ( <i>output of Driver</i> ), if Fanout(N)= 5 and Inputs A, B are Low.
(c)	Find the value of $\beta_{min}$ ( <i>for Load Gates</i> ), 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.



### 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

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

$\therefore$  Input of Load Gates =  $V_o = 0.2$  = Low  
 $\therefore h_1, \dots, h_N$  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.

$$V_o = \text{High} = V_{OH} = 1$$

$\therefore$  Load Gates in Saturation

$$\therefore I_{\text{Supply}} = I_3 = \frac{3.6 - V_{OH}}{640\Omega} = \frac{3.6 - 2.3}{640\Omega}$$

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

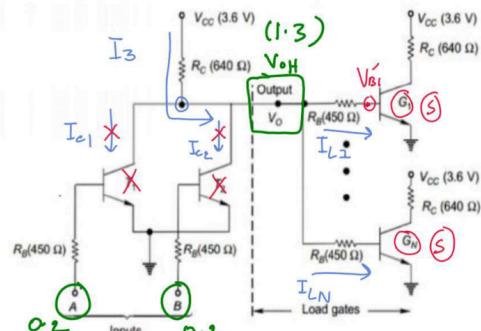
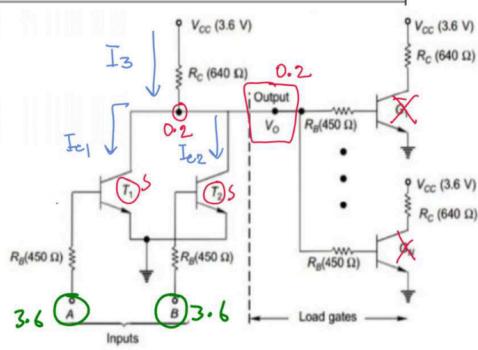
$$\text{Individual Load Current, } I_L = I_{L1} = \frac{V_o - V_{B1'}}{450\Omega} = \frac{1.3 - 0.8}{450\Omega} \quad [V_{BE} = 0.8 \text{ in sat}]$$

$$\therefore I_L = 1.111 \text{ mA}$$

$$\therefore I_{\text{Supply}} = I_{\text{Demand}} \rightarrow 3.593 = N(1.111)$$

$$\therefore N = 3.23 \rightarrow \boxed{N = 3}$$

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



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

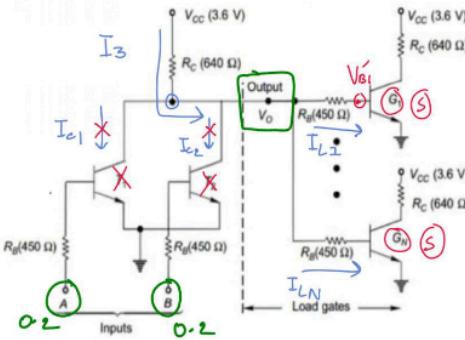
$$A=B=0.2V = \text{Low}$$

$T_1 T_2$  OFF.

$V_o = \text{High}$

∴ Load Gates in Saturation

$$\therefore I_{\text{Supply}} = I_3 = \frac{3.6 - V_o}{640\Omega}$$



$$\text{Individual Load current, } I_L = I_{L2} = \frac{V_o - V_{B1'}}{450\Omega} = \frac{V_o - 0.8}{450\Omega} \quad [V_{BE} = 0.8 \text{ in sat}]$$

Total Demand =  $N(I_L)$

$$\therefore I_{\text{Supply}} = I_{\text{Demand}} \rightarrow \frac{3.6 - V_o}{640\Omega} = \frac{V_o - 0.8}{450\Omega} \times N$$

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

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

(c) Find the value of  $\beta_{\min}$  (for Load Gates), and Power dissipation in the Driver circuit for the conditions in (b).

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

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

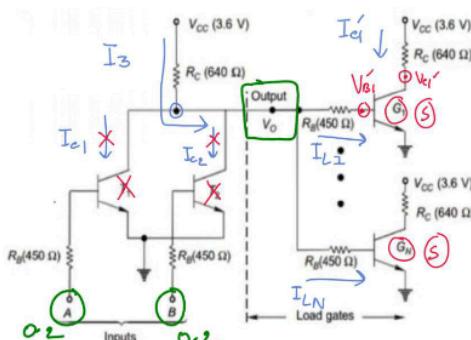
Hence, Load Gates are in saturation.

For Load Gate  $G_L1 \rightarrow$

$$V_{B1'} = 0.8 \quad \text{and,} \quad V_{ci} = 0.2$$

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

$$\therefore I_B = 0.767mA$$



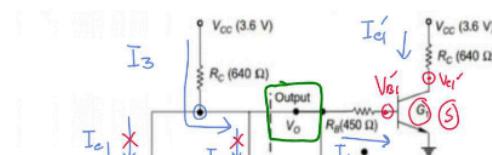
$$I_c = I_{ci} = \frac{3.6 - V_{ci}}{640\Omega} = \frac{3.6 - 0.2}{640\Omega}$$

$$\therefore I_c = 5.3125mA$$

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

(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.

$$V_A = V_B = H_i = 3.6$$

$\therefore T_1, T_2$  in saturation

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

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

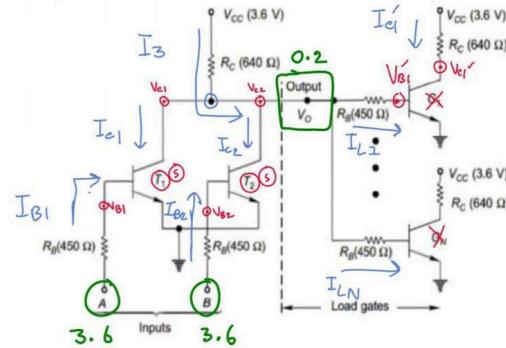
$\therefore$  Input of Load gates =  $V_o = 0.2$  = low

$\therefore h_1, \dots, h_N$  in cutoff.

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

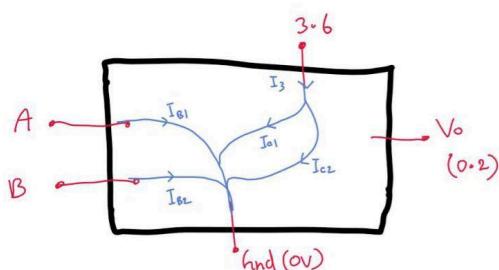
$$\text{Now, } I_{B1} = \frac{3.6 - V_{B1}}{450\Omega} = \frac{3.6 - 0.8}{450\Omega} = 6.222 \text{ mA}$$

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

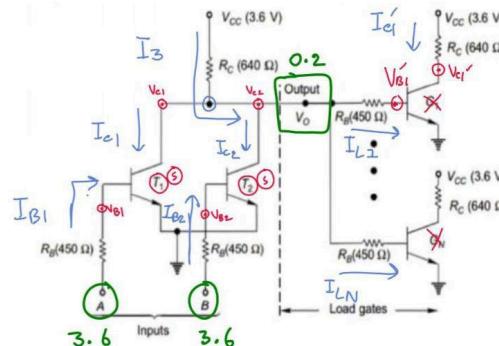


$$I_3 = \frac{3.6 - 0.2}{640} = 5.312 \text{ mA}$$

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



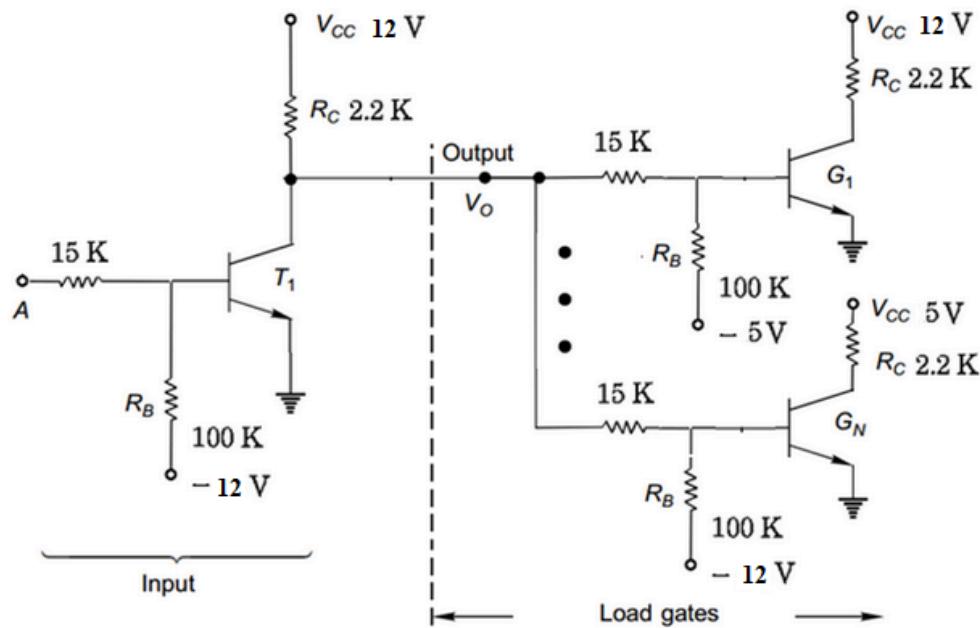
$$\begin{aligned} \text{Power} &= \sum \Delta VI = I_{B1}(V_A - 0) + I_{B2}(V_B - 0) + \underbrace{I_{C1}(3.6 - 0) + I_{C2}(3.6 - 0)}_0 \\ &= I_{B1}(3.6 - 0) + I_{B2}(3.6 - 0) + I_3(3.6 - 0) \\ &= 63.922 \text{ mW} \end{aligned}$$



### Question No. 3

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

(a)	Find the value of $V_{IL}$ in $V$ .
(b)	Find the value of $V_{IH}$ in $V$ .
(c)	Find the value of Noise margin, $V_N$ in $V$ .

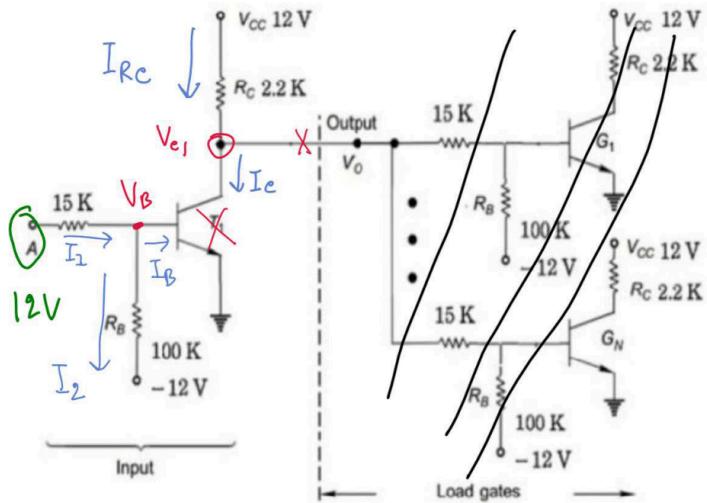


**Solution:**

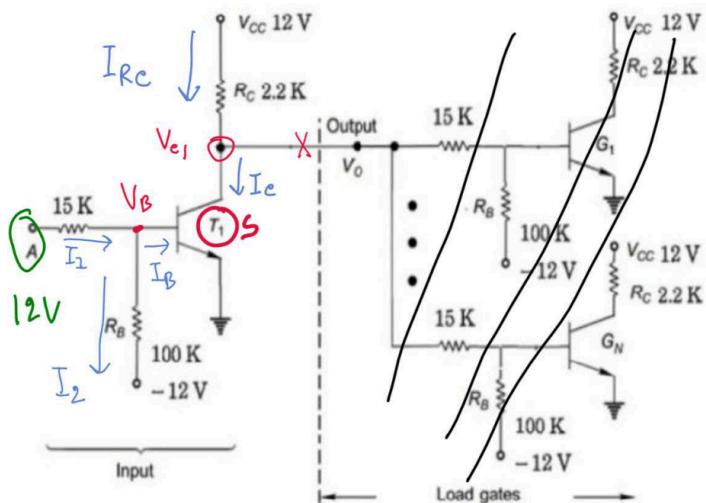
Soln: We can ignore Load gates for noise margin calculation.

$V_{IL} \rightarrow T_1$  in cutoff

$$\therefore I_{Rc} = I_c$$



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



$$V_{OL} = 0.2 \rightarrow V_{CEsat}$$

$V_{OH}$  → depends on design

Will be given in question

Here, we will use  $V_{OH} = \frac{12 - 0.5}{(12 - 0.5)} \times 12 = 11.5V$

$$V_{OH} = 11.5V$$

④  $V_{IL}$  calculation →

BJT just turns on for cut-in volt

$$V_{BE} = 0.5V$$

$$\hookrightarrow V_B = 0.5V$$

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

$$\therefore I_1 = I_2 \quad I_2 = \frac{0.5 - (-12)}{10k} = 0.125mA$$

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

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

\*  $V_{IH}$  calculation:

BJT going from saturation  $\xleftarrow{I} \rightarrow$  active

edge  $V_{IH}$  saturation

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

$$V_B = 0.8$$

$$V_C = 0.2 \quad I_C = \beta I_B$$

$\nearrow 30$   $\delta_{\text{aa}}$

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

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

$$I_2 = \frac{0.8 - (-0.2)}{100k} = 0.128 \text{ mA}$$

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

$$= 0.3068 \text{ mA}$$

$$I_{D_s} = \frac{V - 0.8}{15k} = 0.3068 \text{ mA}$$

$$\therefore V = 5.4081 \text{ V} = V_{IH}$$

$$\therefore V_{NH} = V_{IH} - V_{IL} = 7.5 - 5.4081 = 2.0919 \text{ V}$$

$$V_{NL} = \frac{V_{IL} - V_{OL}}{2.375 - 0.2} = \frac{7.5 - 5.4081}{2.175} = 2.175 \text{ V}$$

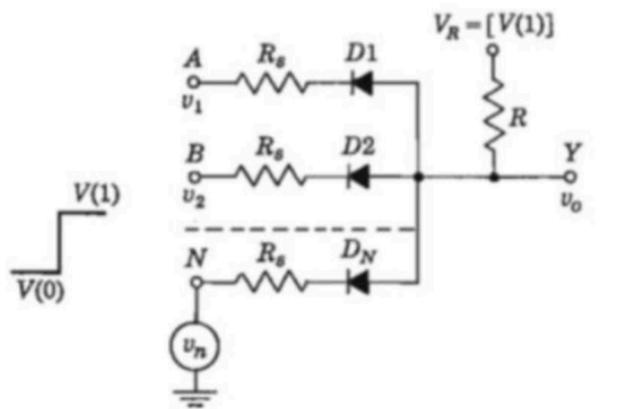
$$\text{Noise Margin} = \text{Minimum} \rightarrow V_h = 2.175 \text{ V}$$

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

### Question No. 4

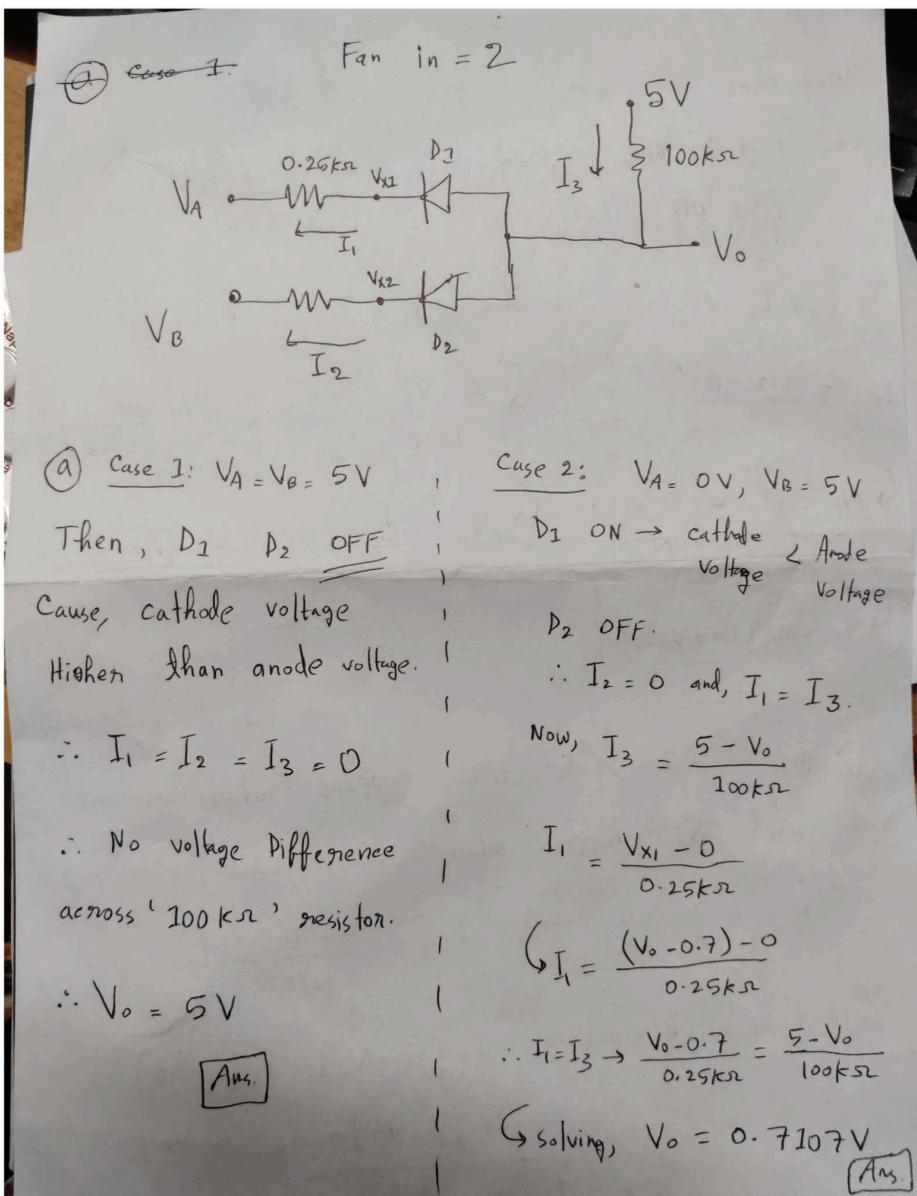
AND Gate: If  $V(0) = 0V$  and  $V(1) = 5V$ ,  
 ans  $R_s = 0.25 k\Omega$ ,  $R = 100 k\Omega$ . Fan In N = 2

- (a) Find out the output voltage levels.
- (b) Find out the maximum power dissipation.



**Solution:**

Activate Window



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

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

Using same logic as |  $D_1$   $D_2$  ON

case 2  $\rightarrow D_1$  OFF

$D_2$  ON

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

$$I_1 = 0, I_2 = I_3$$

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

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

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

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

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

$$\hookrightarrow V_o = 0.7107V$$

Ans.

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

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

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

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

$$= 0.2147 \text{ mW}$$

