

**BRAC UNIVERSITY**  
**Department of Computer Science & Engineering**  
**Practice Problem sheet (Week 3)**  
**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.
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### 1 Question 1

For figure 1 assume common emitter current gain,  $\beta_F = 30$  and  $V_{OH} = 9.5 V$ ,  $V_{OL} = 0.1 V$ . Also assume for saturation mode  $V_{BE} = 0.8 V$ ,  $V_{CE(SAT)} = 0.1 V$  and cut in voltage for transistor  $V_{\gamma,T} = 0.5 V$ , cut in voltage for transistor  $V_{\gamma,D} = 0.6 V$ .

- Find the value of  $\beta_{min}$  when all inputs are logical High (10V).
- Find the maximum fanout. (Hint: find fanout for each case and calculate maximum fanout from it).
- Find the power dissipation for all cases. [Assume  $N$  load connected;  $N = \text{maximumFanout}$ ]
- If all the inputs are high ( $V_A = V_B = V_C = 10 V$ ), what is the magnitude of the **noise voltage in  $\mathbf{V}$**  at the *input A*, which will cause the gate to **malfunction**?
- If at least one input is low (0.1 V), what is the magnitude of the **noise voltage in  $\mathbf{V}$**  at the *input A*, which will cause the gate to **malfunction**?

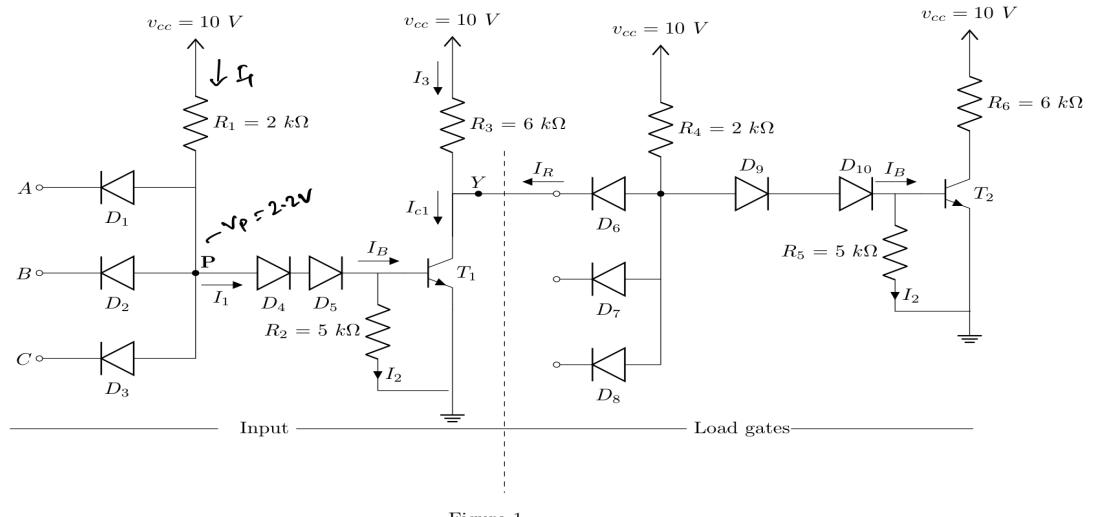


Figure 1

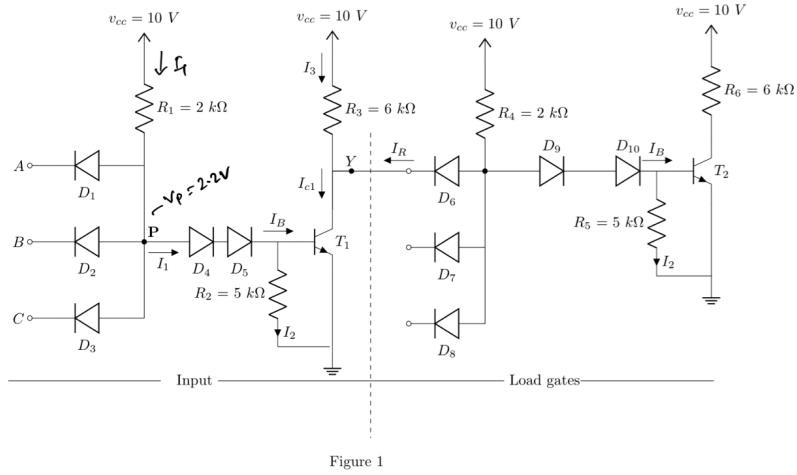


Figure 1

- (a) Find the value of  $\beta_{min}$  when all inputs are logical High (10V).

Assume  $T_1$  in saturation as we need to find  $\rho_{min}$ .

$$\text{at node } V_p, \text{ voltage} = 0.7 + 0.7 + 0.8V = 2.2V$$

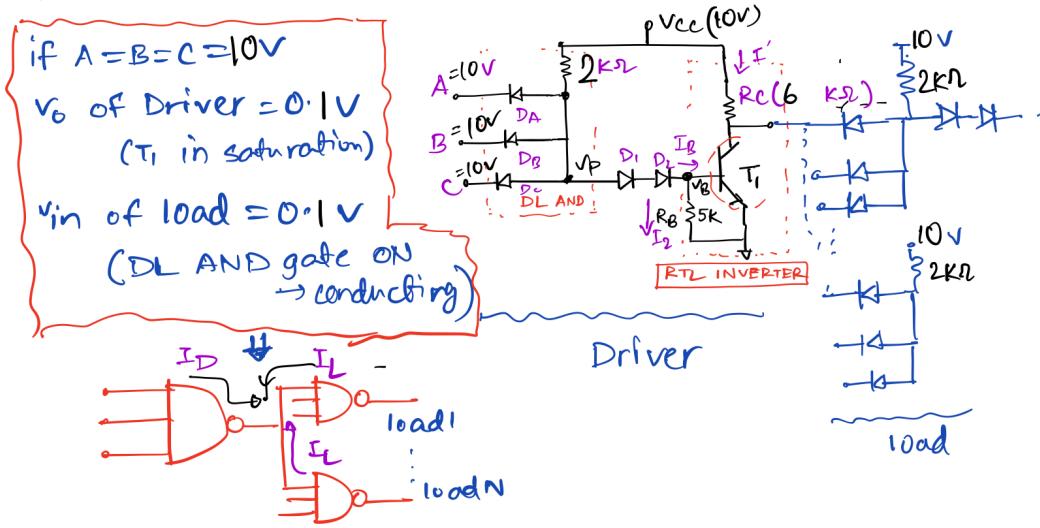
$$\left. \begin{aligned} I_1 &= \frac{(10 - 2 \cdot 2)V}{2K} = 3.9 \text{ mA} \\ I_2 &= \frac{0.8V}{5K} = 0.16 \text{ mA} \end{aligned} \right\} \quad \begin{aligned} I_{BT_1} &= I_1 - I_2 \\ &= 3.9 \text{ mA} - 0.16 \text{ mA} \\ I_{BT_1} &= 3.74 \text{ mA} \end{aligned}$$

$$I_{C_{T_1}} = \frac{(10 - 0.1)V}{6K} = 1.65 \text{ mA}$$

$$\beta_{\min} = \frac{I_{C_{T_1}}}{I_{B_{T_1}}} = 0.441 < \beta_{\text{forward}} = 30$$

(b) Find the maximum fanout. (Hint. find fanout for each case and calculate maximum fanout from it).

case I All input is logical high;  $A=B=C=10V$



$$I_C \text{ (with load)} \text{ at node } v_0 = I' \text{ (No load current)} + I_L \times N$$

$$I_C = I' + N \times I_L$$

$$\text{Now, } I' = \frac{V_{CC} - v_0}{6K} = \frac{(10 - 0.1)V}{6K} = 1.65 \text{ mA}$$

$$I_L \text{ (individual)} = \frac{V_{CC} - V_P}{5K} = \frac{10 - 0.8}{2K} = 4.6 \text{ mA}$$

$$I_C = 1.65 \text{ mA} + N \times 4.6 \text{ mA}$$

$$\frac{I_C}{I_B} < \beta_{\text{Forward}} \quad (\text{as } T_1 \text{ of Driver is in saturation.})$$

$$I_C < \beta_{\text{forward}} \times I_B$$

$$\Rightarrow I' + N \times I_L < \beta_{\text{forward}} \times I_B \quad [I_{B1} = 3.74 \text{ mA}]$$

$$\Rightarrow N < \frac{\beta_f I_B - I'}{I_L} \quad [\beta_f = 30]$$

$$\Rightarrow N < \frac{30 \times 3.74 \text{ mA} - 1.65 \text{ mA}}{4.6 \text{ mA}}$$

$$\Rightarrow N < [24.03] \approx 24. \quad [N = 24 \text{ when } A=B=C=5V]$$

case II

Any input low; Let's say  $A = 0.1V$ ;  $B = C = 10V$ ;  $V_P = 0.8V$

As,  $T_1$  is in cutoff,

$I' = 0$  (No load collector current)

$v_o$  (at the output of  $T_1$ )

$$= 10V \text{ so,}$$

Load AND gate is also in cutoff.

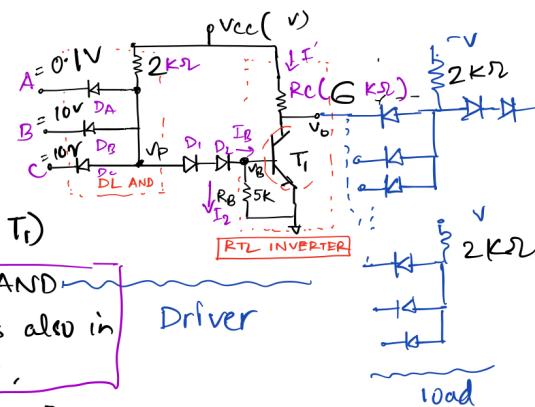
$$I_D = 0 \quad [T_1 \text{ in cutoff}]$$

$$\text{so, } \frac{I_C}{I_B} < \beta_f$$

$$\Rightarrow I_C = I' + N \times I_L < \beta_f I_B$$

$$\therefore 0 + N \times 0 = 0$$

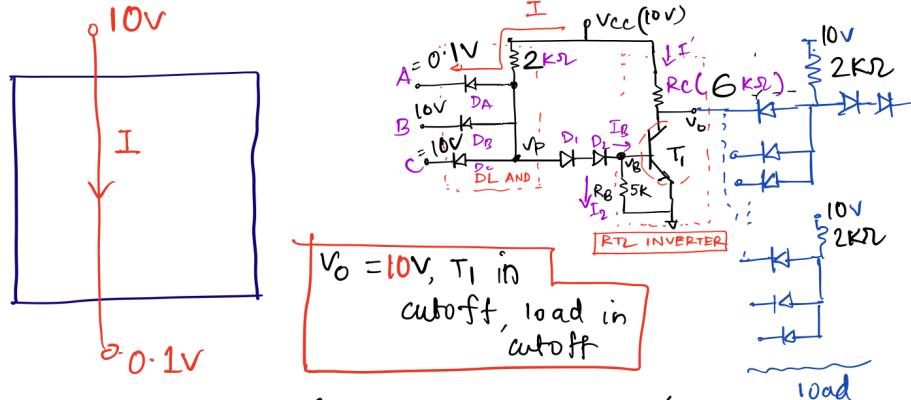
$$N = \frac{\beta_f I_B - I'}{I_L} = \frac{0 - 0}{0} = \infty$$



Maximum fanout:  $\min(24, \infty) = 24$

(c) Find the power dissipation for all cases. [Assume  $N$  load connected;  $N = \text{maximumFanout}$ ]

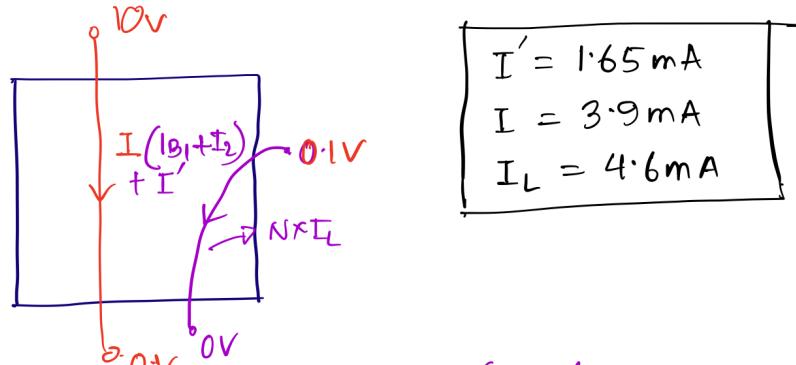
**Case I** Any input = 0.1V [LOAD CONDITION]  $N=24$



$$P = \Delta V \times I = (10 - 0.1)V \times \frac{(10 - 0.8)}{2k} = 45.54 \text{ mW}$$

$P = 45.54 \text{ mW}$  Any input = 0.1V

**Case II** All input = 10V [LOAD CONDITION]



$$\begin{aligned} P &= \Delta V \times I = (10 - 0)V \times (I + I') + (0.1 - 0)V \times N \times I_L \\ &= (10 - 0)V \times (3.9 + 1.65) \text{ mA} + 0.1 \times N \times I_L \\ P &= 66.54 \text{ mW} \end{aligned}$$

All input = 10V

- (d) If all the inputs are high ( $V_A = V_B = V_C = 10 \text{ V}$ ), what is the magnitude of the noise voltage in  $\mathbf{V}$  at the input  $A$ , which will cause the gate to malfunction?

$$V_A = 10 + V_N \text{ (Malfunction)}$$

$V_{DA} = 0.6 \text{ V}$  [Turns the Diode on]

$$V_A + V_{DA} = V_P = 2.2 \text{ V}$$

$$10 + V_N + V_{DA} = V_P$$

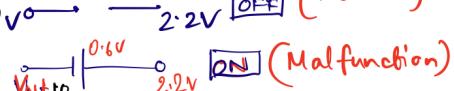
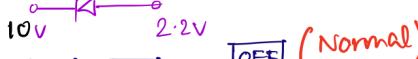
$$\Rightarrow 10 + V_N + 0.6 \text{ V} = 2.2 \text{ V}$$

$$\Rightarrow V_N = (2.2 - 10 - 0.6) \text{ V}$$

$$\boxed{V_N = -8.4 \text{ V}}$$

$$\text{Magnitude of } V_N = |V_N|$$

$$= |-8.4 \text{ V}| = 8.4 \text{ V}$$



$$V_A = 10 \text{ V} \quad [\text{NORMAL}]$$

$$V_P = 2.2 \text{ V}$$

As,  $D_A$  turns on and all the current flows through it,  $T_1$  goes to cutoff.

- (e) If at least one input is low ( $0.1 \text{ V}$ ), what is the magnitude of the noise voltage in  $\mathbf{V}$  at the input  $A$ , which will cause the gate to malfunction?

$$V_A = 0.1 + V_N \text{ (Malfunction)}$$

$V_{D1,2} = 0.6 \text{ V}$  [Turns the Diode on]

$$V_A + V_{DA} = V_P = V_N + 0.8 \text{ V}$$

$$\boxed{V_P = V_{D1} + V_{D2} + V_g \\ = 0.6 + 0.6 + 0.5 = 1.7 \text{ V}}$$

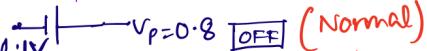
$$\Rightarrow \text{As, } V_P = V_N + 0.8 \text{ V}$$

$$V_N = V_P - 0.8 = (1.7 - 0.8) \text{ V}$$

$$\boxed{V_N = 0.9 \text{ V}}$$

$$\text{Magnitude of } V_N = |0.9 \text{ V}|$$

$$= 0.9 \text{ V}$$



$$V_A = 0.1 \text{ V} \quad [\text{NORMAL}]$$

$$V_P = 0.8 \text{ V}$$

As,  $T_1$  turns on and all the current flows through it,  $D_A$  goes to cutoff.

## 2 Question 2

For figure 2 assume common emitter current gain,  $\beta_F = 30$  and  $V_{OH} = 11.5 V$ ,  $V_{OL} = 0.1 V$ . Also assume for saturation mode  $V_{BE} = 0.8 V$ ,  $V_{CE(SAT)} = 0.1 V$  and cut in voltage for transistor  $V_{\gamma,T} = 0.5 V$ , cut in voltage for transistor  $V_{\gamma,D} = 0.6 V$ .

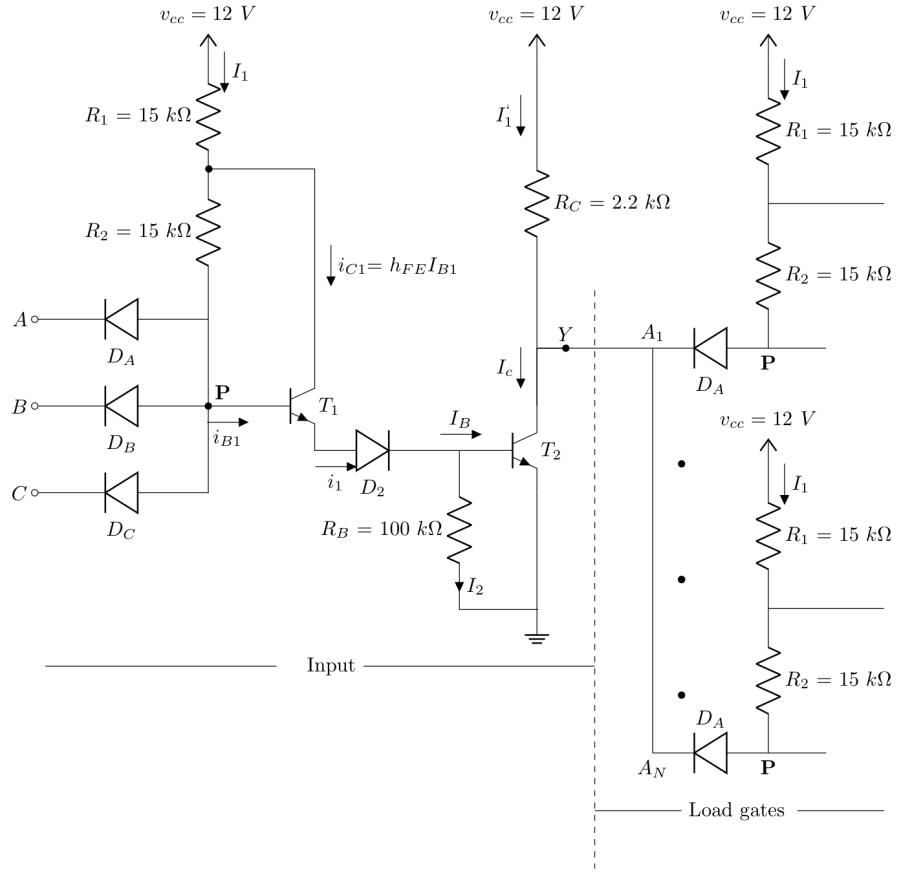


Figure 2

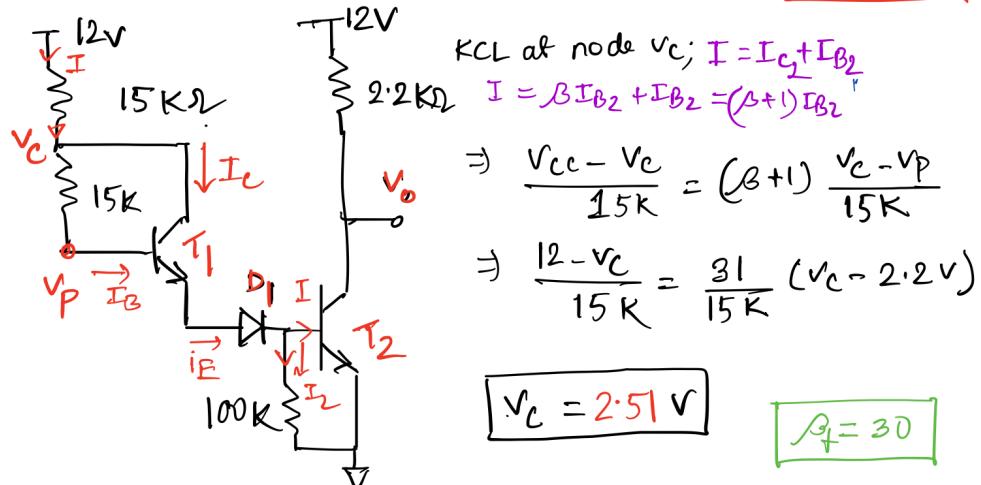
- (a) Find the value of  $\beta_{min}$  when all inputs are logical High (12V).

(a) Find the value of  $\beta_{min}$  when all inputs are logical High (12V).

Assume  $T_2$  in saturation as we need to find  $\beta_{min}$ .

at node  $V_p$ , voltage =  $0.7 + 0.7 + 0.8V = 2.2V$

$$V_{BE(T_2)} = 0.8V; V_{CE(sat)}_{T_1} = 0.1V; V_{BE(T_2)} = 0.7V \quad \boxed{\text{as } T_1 \text{ in RA}}$$



$$I = \frac{V_{CC} - V_C}{15k} = \frac{(12 - 2.51)V}{15k} = 0.633mA = I_{E_{T_2}}$$

$$I_{B_{T_2}} = I - I_2 = 0.633mA - \frac{0.8V}{100k} = 0.633mA - 0.008mA$$

$\Rightarrow I_{B_{T_2}} = 0.625mA$

$$I_2 = \frac{0.8}{100k} = 0.008mA$$

$$\boxed{I_{B_{T_2}} = 0.625mA}$$

$$\boxed{I_C = \frac{12 - 0.1}{2.2k} = 5.41mA}$$

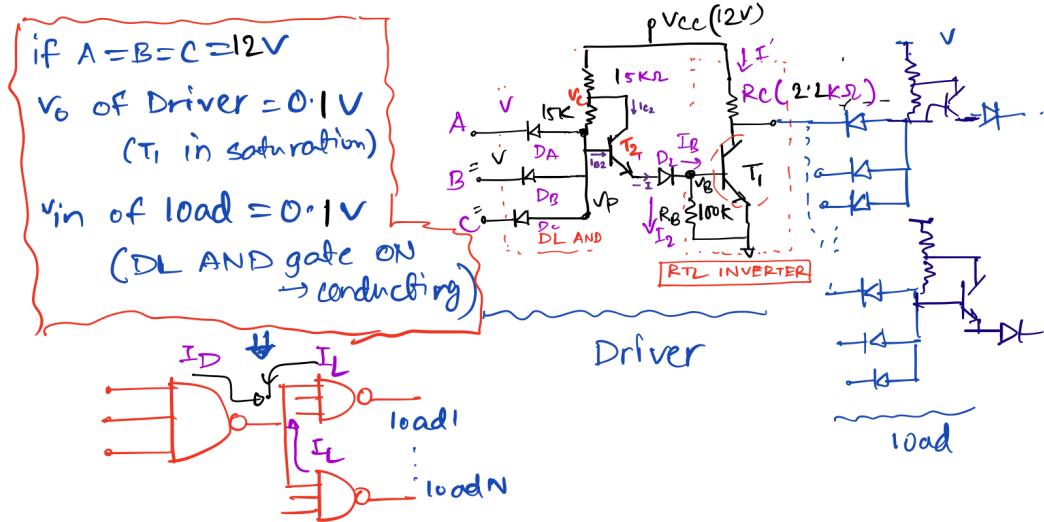
$$\beta_{min} = \frac{I_C}{I_B}$$

$$= \frac{5.41mA}{0.625mA}$$

$$\boxed{\beta_{min} = 8.659 < \beta_f (30)}$$

(b) Find the maximum fanout. (Hint. find fanout for each case and calculate maximum fanout from it).

case I All input is logical high;  $A = B = C = 12V$



$$I_C \text{ (with load)} \text{ at node } V_0 = I' \text{ (No load current)} + I_L \times N$$

$$I_C = I' + N \times I_L$$

$$\text{Now, } I' = \frac{V_{CC} - V_0}{2.2K} = \frac{12V - 0.1V}{2.2K} = 5.41 \text{ mA}$$

$$I_L \text{ (individual)} = \frac{V_{CC} - V_P}{(15+15)K} = \frac{(12 - 0.8)V}{30K}$$

$$I_C = 5.41 \text{ mA} + N \times 0.373 \text{ mA}$$

KCL at node  $v_C$ ;  $I = I_{C_1} + I_{B_2}$   
 $I = \beta I_{B_2} + I_{B_2} = (\beta + 1) I_{B_2}$

$$\Rightarrow \frac{V_{CC} - v_C}{K} = (\beta + 1) \frac{v_C - V_P}{K} \quad [\beta_f = 30]$$

$$\Rightarrow \frac{12 - v_C}{15K} = \frac{31}{15K} (v_C - 2.2V)$$

$$\Rightarrow 12 - v_C = \frac{15K \times 31}{15K} (v_C - 2.2V)$$

$$\Rightarrow v_C = 2.51V$$

$$I_e = \frac{V_{CC} - v_C}{15K\Omega} = 0.633mA = I_{E_2} = I_{B_1} + I_2$$

$$I_2 = 0.008mA \rightarrow I_{B_1} = 0.625mA$$

$\frac{I_C}{I_B} < \beta_{\text{Forward}}$  (as  $T_1$  of Driver is in saturation.)

$$I_C < \beta_{\text{forward}} \times I_B$$

$$\Rightarrow I' + N \times I_L < \beta_{\text{forward}} \times I_B$$

$$\Rightarrow N < \frac{\beta_f I_{B_2} - I'}{I_L}$$

$$\Rightarrow N < \frac{30 \times 0.625mA - 5.41mA}{0.373mA}$$

$$\Rightarrow N < [35.76] \approx 35. \quad [N = 35 \text{ when } A=B=C=10V]$$

### case II

Any input low; Let's say  $A = 0.1V$ ;  $B = C = 12V$

As,  $T_1$  is in cutoff,

$$I' = 0$$

(No load collector current)

$v_o$  (at the output of  $T_1$ )

$$= 12V \text{ so, } I_L = 0$$

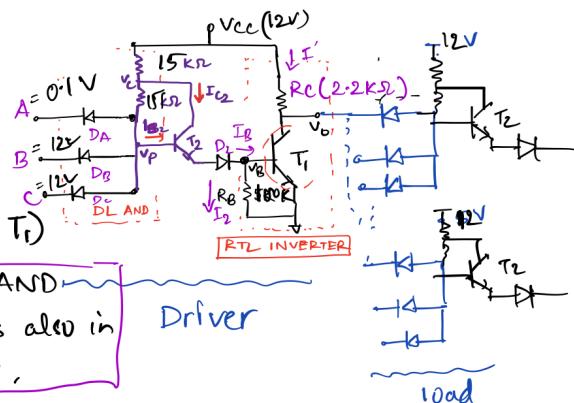
Load AND gate is also in cut off.

$$I_B = 0 \quad [T_1 \text{ in cutoff}]$$

$$so, \frac{I_c}{I_B} < \beta_f$$

$$\Rightarrow I_C = I_f + N \times \Sigma_L < \beta_f I_B$$

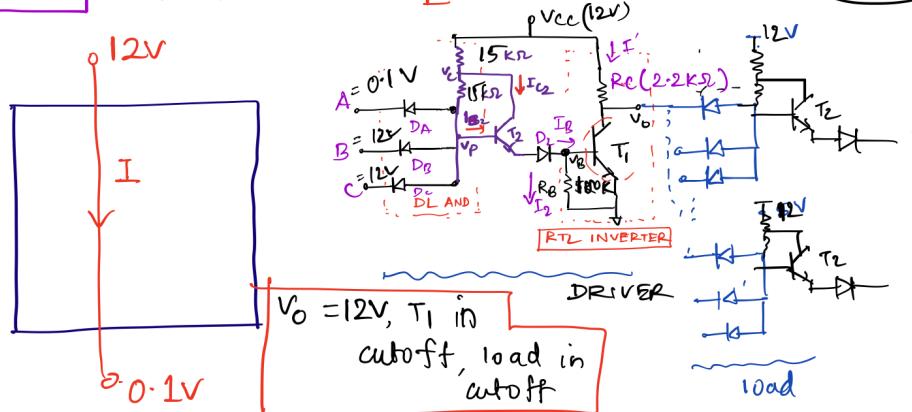
$$= 0 + 7 \times 0 = 0$$



$$\text{Maximum fanout} = \min(35, \infty) = 35$$

(c) Find the power dissipation for all cases. [Assume  $N$  load connected;  $N = \text{maximumFanout}$ ]

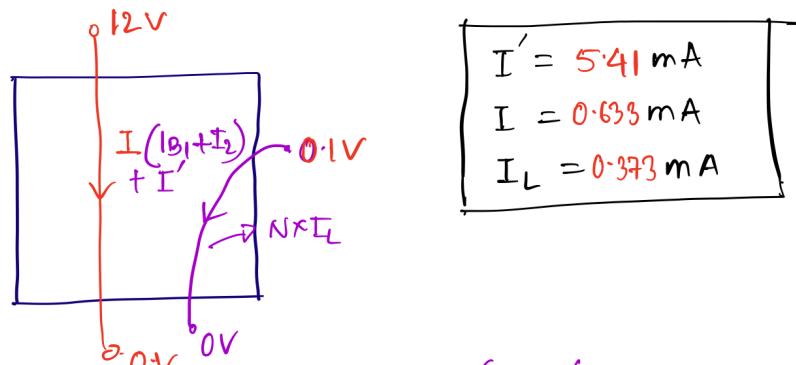
**Case I** Any input = 0.1V [LOAD CONDITION]  $N=35$



$$P = \Delta V \times I = (12 - 0.1) I = (12 - 0.1) V \cdot \frac{(12 - 0.8)}{30k}$$

$$P = 4.4387 \text{ mW} \quad \text{Any input} = 0.1V$$

**Case II** ALLinput = 12V [LOAD CONDITION]



$$P = \Delta V \times I = (12 - 0)V \times (I + I') + (0.1 - 0)N \times I_L$$

$$= (12 - 0)V \times (5.41 + 0.633) \text{ mA} + 0.1 \times N \times I_L$$

$$P = 73.82 \text{ mW} \quad \text{All input} = 12V$$

- (d) If all the inputs are high ( $V_A = V_B = V_C = 12V$ ), what is the magnitude of the noise voltage in  $V$  at the input  $A$ , which will cause the gate to malfunction?

$$V_A = 12 + V_N \text{ (Malfunction)}$$

$V_{DA} = 0.6V$  [Turns the Diode on]

$$V_A + V_{DA} = V_P = 2.2V$$

$$12 + V_N + V_{DA} = V_P$$

$$\Rightarrow 12 + V_N + 0.6V = 2.2V$$

$$\Rightarrow V_N = (2.2 - 12 - 0.6)V$$

$$\boxed{V_N = -10.4V}$$

$$\text{Magnitude of } V_N = |V_N|$$

$$= |-10.4V| = 10.4V$$

12V  $\xrightarrow{\text{K}} 2.2V$  (Normal)

12V  $\xrightarrow{\text{OFF}}$  2.2V (Malfunction)

$$V_A = 12V \quad [\text{NORMAL}]$$

$$V_P = 2.2V$$

As,  $D_A$  turns on and all the current flows through it,  $T_2$  goes to cutoff.

- (e) If at least one input is low (0.1 V), what is the magnitude of the noise voltage in  $V$  at the input  $A$ , which will cause the gate to malfunction?

$$V_A = 0.1 + V_N \text{ (Malfunction)}$$

$V_{D1} = 0.6V$  [Turns the Diode on]

$$V_A + V_{DA} = V_P = V_N + 0.8V$$

$$\Rightarrow V_P = V_{T_{R1}} + V_{D2} + V_{g_{T2}} \\ = 0.5 + 0.6 + 0.5 = 1.6V$$

$$\Rightarrow \text{As, } V_P = V_N + 0.8V$$

$$V_N = V_P - 0.8 = (1.6 - 0.8)V$$

$$\boxed{V_N = 0.8V}$$

$$\text{Magnitude of } V_N = |0.8V|$$

$$= 0.8V$$

0.1V  $\xrightarrow{\text{K}} 0.8V$

0.1V  $\xrightarrow{\text{OFF}}$   $V_P = 0.8V$  (Normal)

0.1V  $\xrightarrow{\text{ON}}$   $V_N + 0.8V$   $\xrightarrow{\text{K}_1}$   $V_N + 0.8V$   $\xrightarrow{\text{K}_2}$  0.5V 0.6V (Malfunction)

$$V_A = 0.1V \quad [\text{NORMAL}]$$

$$V_P = 0.8V$$

As,  $T_2$  turns on and all the current flows through it,  $D_A$  goes to cutoff.

### 3 Question 3

For figure 3 assume common emitter current gain,  $\beta_F = 30$ . Also assume for saturation mode  $V_{BE} = 0.8 \text{ V}$ ,  $V_{CE(SAT)} = 0.1 \text{ V}$  and cut in voltage for transistor  $V_{\gamma,T} = 0.5 \text{ V}$ , cut in voltage for transistor  $V_{\gamma,D} = 0.6 \text{ V}$ .

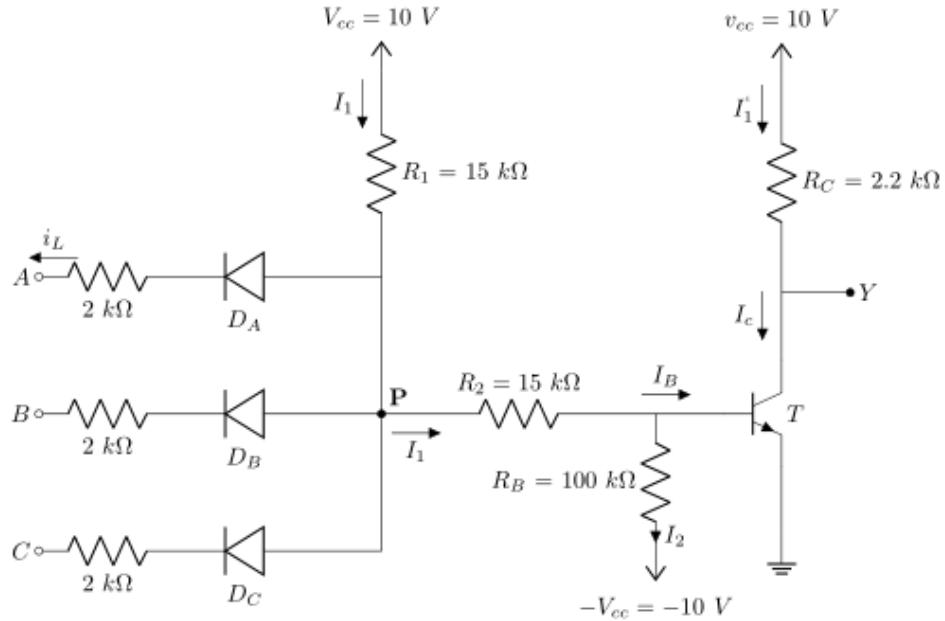


Figure 3

- (a) Find  $I_1$ ,  $I_2$ ,  $I_B$ ,  $I_C$  and  $I_L$  if any input is logical low ( $0.1 \text{ V}$ ).
- (b) Find  $I_1$ ,  $I_2$ ,  $I_B$ ,  $I_C$  and  $I_L$  if all inputs are logical high ( $10 \text{ V}$ ).
- (c) Find the value of  $\beta_{Min}$  when all inputs are logical High ( $10 \text{ V}$ ). ( Hint: find only for Transistor T of driver)
- (d) Find the power dissipation for the conditions of both (a) and (b) for the driver [Assume no load connected]
- (e) Find the maximum fanout (Hint: find fanout for each case and calculate maximum fanout from it)

④ If any input is low, that diode is in forward bias and the rest are in reverse bias.

$$i_1 = \frac{10 - V_p}{15k} \quad / \quad i_L = \frac{(V_p - 0.7) - 0.1}{2k} = \frac{V_p - 0.8}{2k}$$

since 'input low, assume transistor in cutoff.  $i_B = i_C = 0$

$$i_2 = \frac{V_p + 10}{115k}$$

$$i_1 = i_2 + i_L \Rightarrow \frac{10 - V_p}{15k} = \frac{V_p + 10}{115k} + \frac{V_p - 0.8}{2k}$$

$$\Rightarrow V_p = 1.703 \text{ V}$$

$$i_1 = 0.553 \text{ mA} / i_2 = 0.102 \text{ mA} / i_L = 0.4515 \text{ mA}$$

Base voltage

$$= V_p - i_2 \times 15k$$

$$= 1.703 - 15 \times 0.102$$

$$= 0.173 < V_T$$

thus, cutoff assumption true.

⑤ If all inputs logical high, all diodes reverse bias.

Assume transistor is in saturation mode.  $V_{BE} = 0.8V$

$$V_{CE} = 0.1V$$

$$V_{out} = 0.1V$$

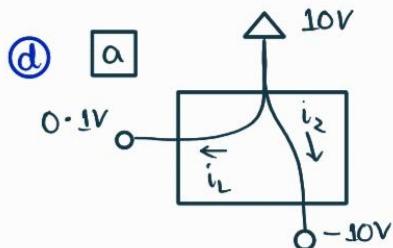
$$i_C = \frac{10 - 0.1}{2.2k} = 4.5 \text{ mA} \quad i_L = 0$$

$$i_2 = \frac{0.8 + 10}{100k} = 0.108 \text{ mA}$$

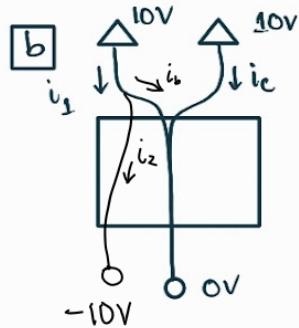
$$i_1 = \frac{10 - 0.8}{15k + 15k} = 0.307 \text{ mA}$$

$$i_B = i_1 - i_2 = 0.199 \text{ mA}$$

$$\textcircled{c} \quad \beta_{\text{forced}} = \beta_{\min} = \frac{i_C}{i_B} = \frac{4.5 \text{ mA}}{0.199 \text{ mA}} = 22.613$$



$$\begin{aligned} \text{power} &= (10 - 0.1)i_L + (10 + 10)i_2 \\ &= 9.9 \times 0.452 + 20 \times 0.102 \\ &= 6.515 \text{ mW} \end{aligned}$$



$$\begin{aligned}
 \text{Power} &= 10 \times (i_B + i_C) + (10 + 10)i_2 \\
 &= 10 \times (0.199 + 4.5) + 20 \times 0.108 \\
 &= 46.99 + 2.16 \\
 &= 49.15
 \end{aligned}$$

④ Case 1 - output low

Driver side base current,  $i_B = 0.199 \text{ mA}$   
 collector current,  $i_C = 4.5 \text{ mA}$   
 ↑  
 from ③

worst case load current,  $i_L = 0.452 \text{ mA}$   
 from ②

$$\begin{aligned}
 \text{we have, } \beta_F i_B &= i_C + n i_L \\
 \Rightarrow n &= \frac{\beta_F i_B - i_C}{i_L} = \frac{30 \times 0.199 - 4.5}{0.452} = \lfloor 3.25 \rfloor \\
 &= 3
 \end{aligned}$$

Case 2 - output high

worst case load current,  $i_L = 0$   
 $n = \infty$

Thus, fanout =  $\min(\infty, 3) = 3$