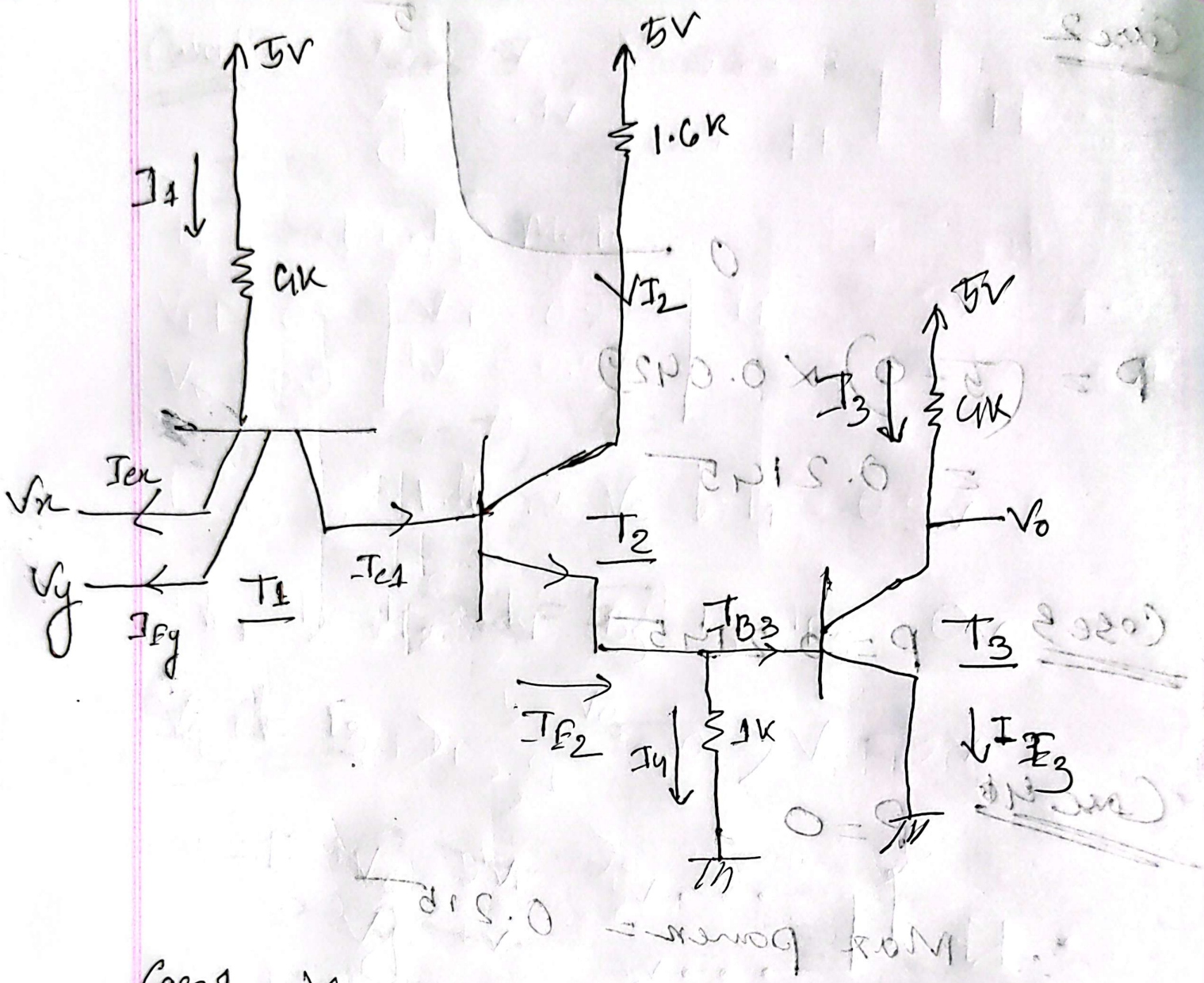
TTL



Case 1 $V_x = 0.1V$

$V_y = 0.1V$

$\therefore T_1$ is in Saturation mode

$\therefore V_{BE} = 0.8$

$V_B - V_E = 0.8$

$V_B - 0.1 = 0.8$

$\therefore V_B = 0.9$

$I_1 = \frac{5 - 0.2}{4}$

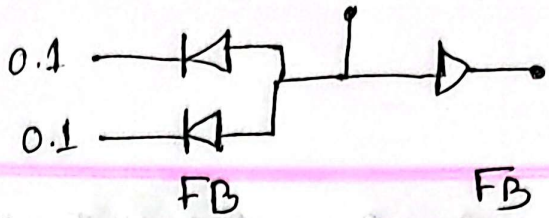
$= 1.025V$

$V_{CE} = 0.2$

$V_C - V_E = 0.2$

$V_C = 0.2 + 0.1$

$= 0.3V$



$\therefore$ T_2 and T_3 will be cutoff

Hence, $I_{C1} = I_2 = I_{E2} = I_4 = I_{B3} = I_3 = I_{E3} = 0V$

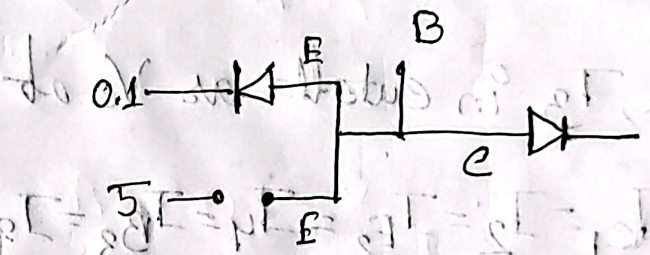
Output of T_3 $\Rightarrow \frac{5 - V_0}{4} = 0$

$\Rightarrow 5 - V_0 = 0$

$\Rightarrow V_0 = 5\,V$

Case 2 $V_x = 0.1V$

$V_y = 5V$



T_1 in saturation

$V_{BE} = 0.8$

$V_B - 0.1 = 0.8$

$V_B = 0.9$

$V_{ce} = 0.2$

$V_c = 0.2 + 0.1$

$= 0.3$

$I_1 = \frac{5 - 0.9}{4} = 1.025V$

$I_{Ex} = 1.025V$

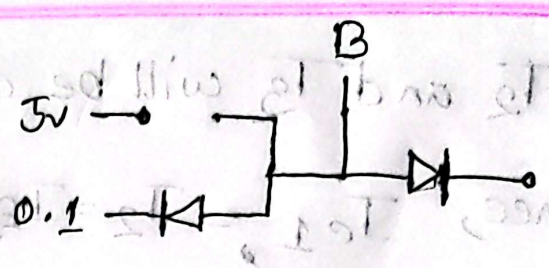
$I_{Ey} = 0V$

T_2, T_3 will be cut off

$I_{C1} = I_2 = I_{E2} = I_4 = I_{B3} = I_3 = I_{E3} = 0V$

$\therefore$ T_3 output $\Rightarrow \frac{5 - V_0}{4} = 0 \Rightarrow V_0 = 5\,V$

Case 3 $V_x = 5V$, $V_y = 0.1V$



T_1 in Saturation Mode

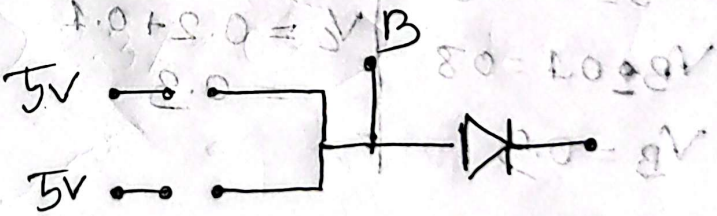
$V_{BE} = 0.8$, $V_B = 0.9$ | $V_{CE} = 0.2$, $V_C = 0.3$ | $I_1 = \frac{5 - 0.2}{4} = 1.025$ mA

T_2, T_3 in cutoff as V_C of $T_1 = 0.3V$

$\therefore I_{C_1} = I_2 = I_{E_2} = I_4 = I_{B_3} = I_3 = I_{E_3} = 0V$

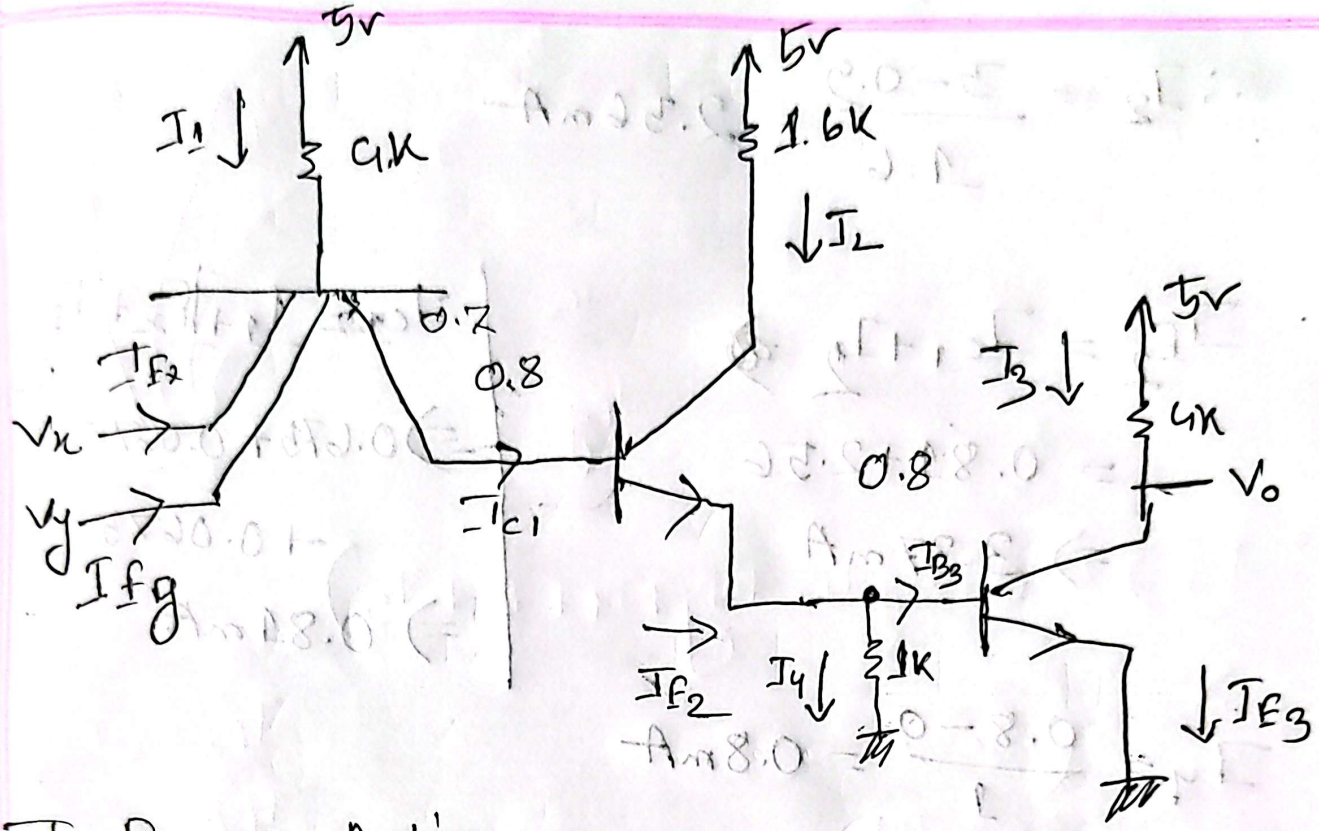
V_o of $T_3 \Rightarrow \frac{5 - V_o}{4} = 0 \Rightarrow V_o = 5V$

Case 4: $V_x = 5V$, $V_y = 5V$



T_1 is in Reverse Active

T_2, T_3 in Saturation mode



In Reverse Active

$$V_{BC} = 0.7$$

$$V_B = 0.7 + 0.8 + 0.8 \Rightarrow 2.3$$

$$I_1 = \frac{5 - 2.3}{4} = 0.675\,mA$$

$$I_{Ex} = \beta_0 I_B = (0.1 \times 0.675) \quad [\because I_1 = I_B]$$

$$= 0.0675\,mA$$

$$I_{Fy} = I_{Ex} = 0.0675\,mA$$

For T_2 in Saturation, $V_{BE} = 0.8$, $V_{CE} = 0.1$

$V_E = 0.8$; $V_B - V_E = 0.8$ $\therefore V_B = 1.6\,V$ | $V_C - V_E = 0.1$ $\therefore V_C = 0.9$

$$\therefore I_2 = \frac{5-0.9}{1.6} = 2.56\,mA$$

$$I_{E_2} = I_{C_1} + I_2$$

$$= 0.81 + 2.56$$

$$\Rightarrow 3.37\,mA$$

$$I_{C_1} = I_1 + I_{Bx} + I_{By}$$

$$\Rightarrow 0.675 + 0.0675 + 0.0675$$

$$\Rightarrow 0.81\,mA$$

$$I_4 = \frac{0.8-0}{1} = 0.8\,mA$$

$$I_{E_2} = I_4 + I_{B_3}$$

$$\therefore I_{B_3} = I_{E_2} - I_4 \Rightarrow 3.37 - 0.8 \Rightarrow 2.57\,mA$$

As T_3 is Saturation,

$V_{BE} = 0.8$, $V_{CE} = 0.2$

$V_B = 0.8$, $V_C = 0.2$

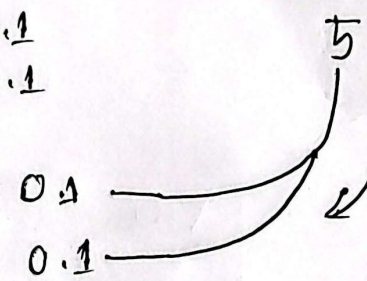
$$\therefore I_3 = \frac{5-0.2}{4} = 1.2\,mA$$

$$V_0 = V_C = 0.2$$

V_x	V_y	V_o
0.1	0.1	5
0.1	5	5
5	0.1	5
5	5	0.2

Power Consumption

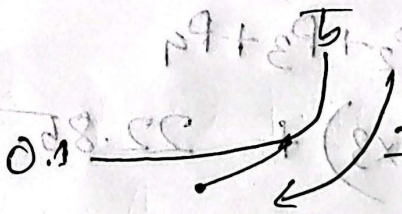
Case 1 $V_x = 0.1$, $V_y = 0.1$



$I_1 = 1.025\,mA$

$$P_1 = (5 - 0.1) \times I_1 = 5.0225\,mW$$

Case 2 $V_x = 0.1$, $V_y = 5$



$I_1 = 1.025\,mA$

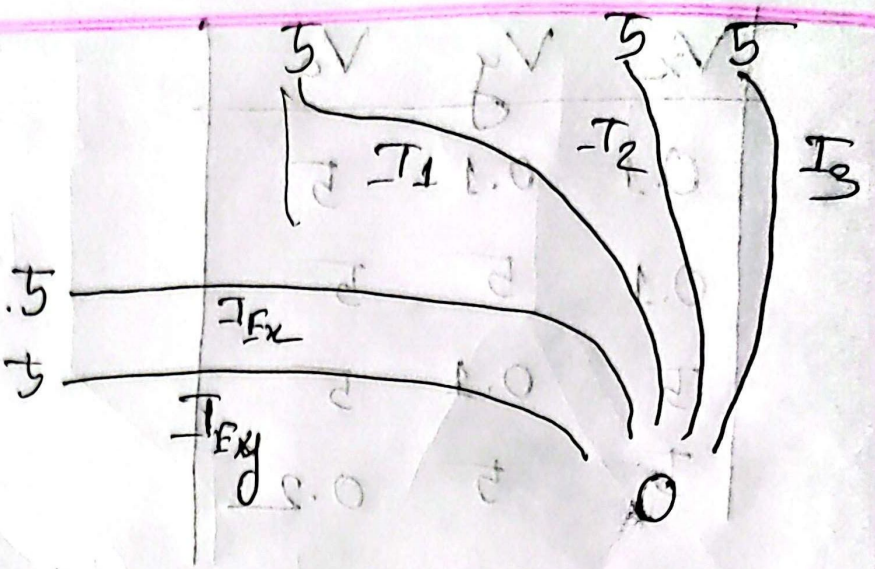
$$P_2 = (5 - 0.1) \times I_1 = 5.0225\,mW$$

Case 3

$I_1 = 1.025\,mA$

$$P_3 = (5 - 0.1) \times I_1 = 5.0225\,mA$$

Case 4



$$P_4 = (5-0) \times (-I_{Fx} + I_{Fy} + I_1 + I_2 + I_3)$$

$$\Rightarrow 5 \times \{4.57$$

$$= 22.85 \text{ mW}$$

$I_{Fx} = 0.0675 \text{ mA}$

$I_{Fy} = 0.0675 \text{ mA}$

$I_1 = 0.675 \text{ mA}$

$I_2 = 2.56 \text{ mA}$

$I_3 = -1.2 \text{ mA}$

Total power $\Rightarrow$

$\Rightarrow P_1 + P_2 + P_3 + P_4$

$\Rightarrow (5.0225 \times 3) + 22.85$

$\Rightarrow 37.92 \text{ mW}$

Avg $\Rightarrow \frac{37.92}{4} = 9.48 \text{ mW}$