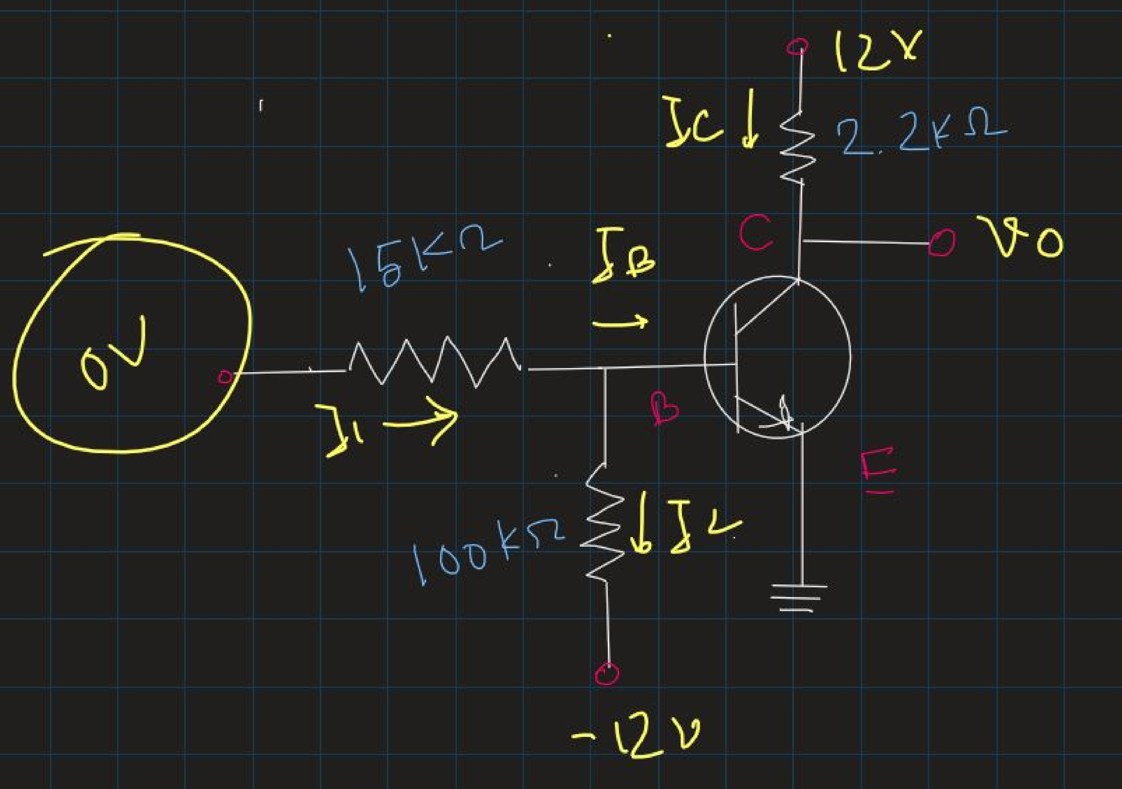
Power dissipation of RTL circuit

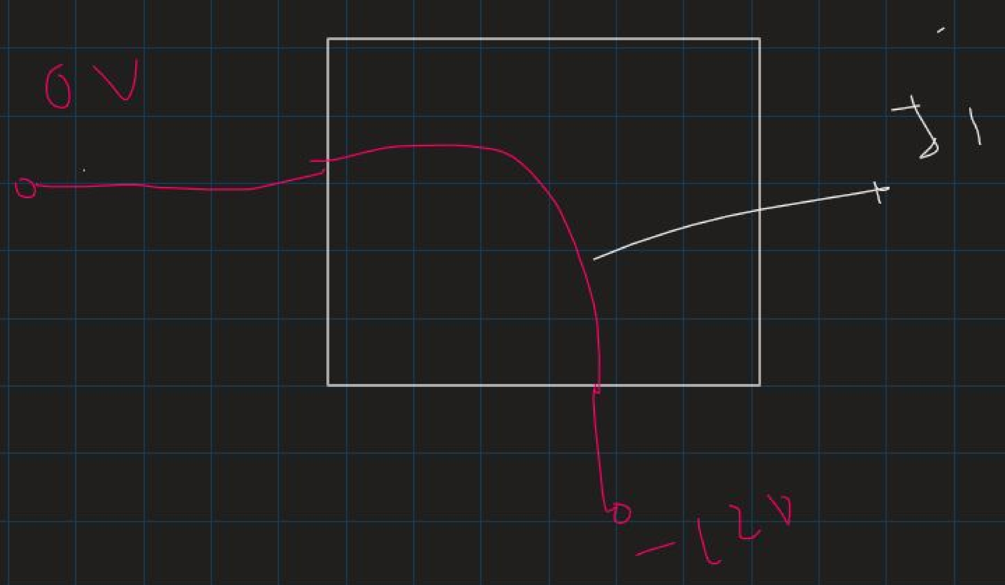
Case 1: When input is 0 V.

$i_C = i_B = i_E = 0$

$i_B = 0$

$I_1 = I_2 = \frac{0-(-12)}{100+15k} = 0.104\,mA$





$P = \Delta V \times I_1$

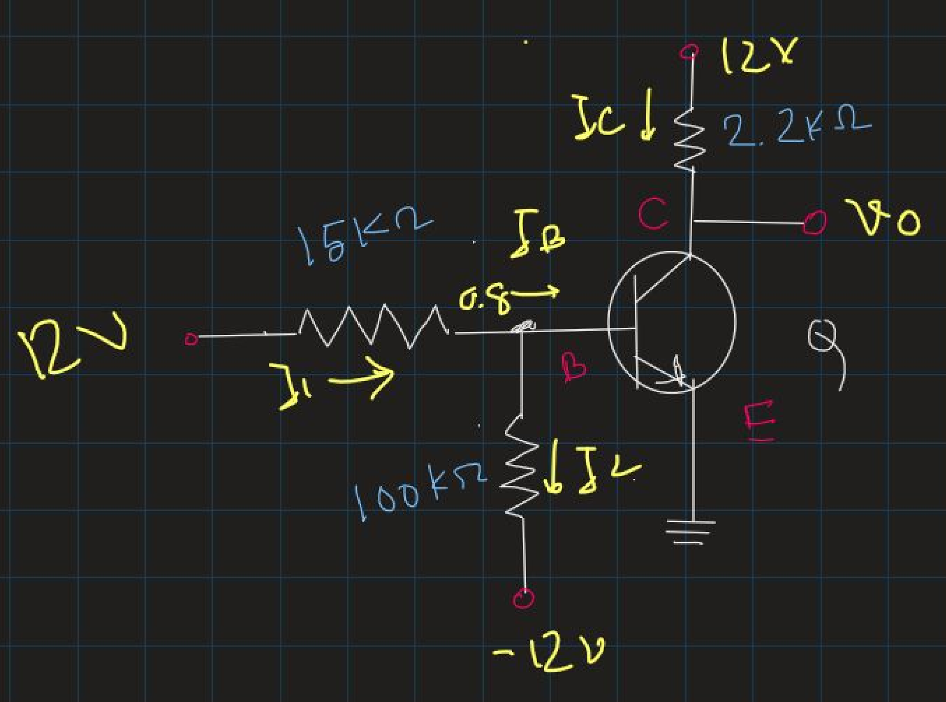
$= \{0-(-12)\} \times 0.104$ mW

$= 1.2521$ mW

Case 2: When input is 12 Volt!

Q → saturation

$V_B = 0.8\,Volt$, $V_C = 0.2\,Volt$ } $V_E = 0$



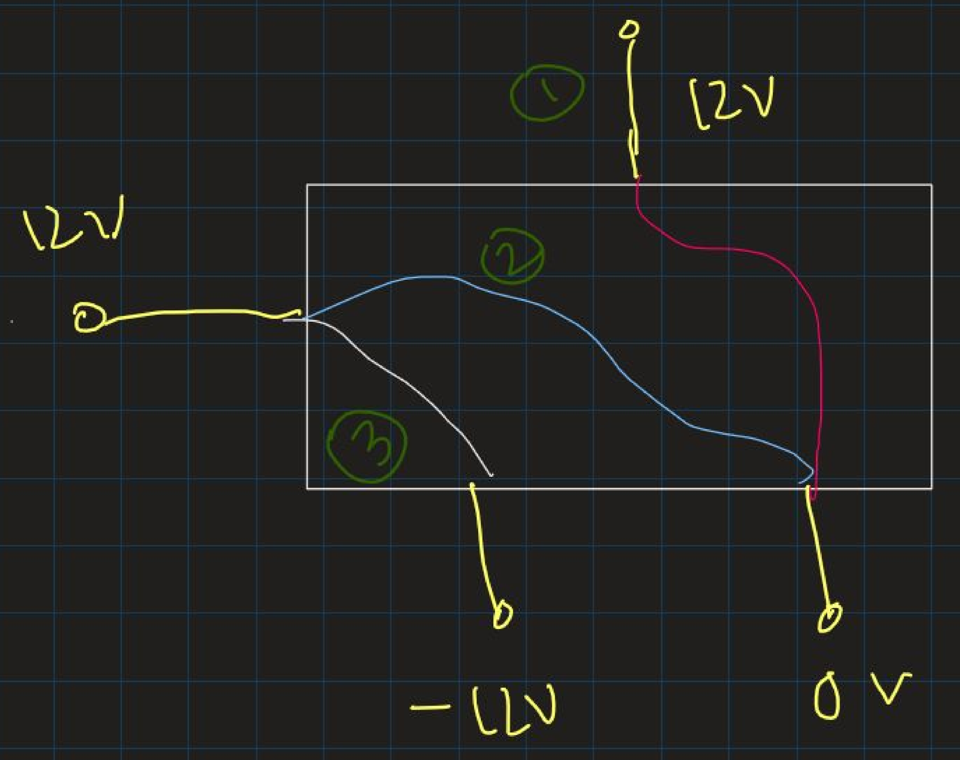
$i_C = \frac{12-0.2}{2.2K} = 5.3636\,mA$

$i_1 = \frac{12-0.8}{15K\Omega} = 0.7466\,mA$, $i_2 = \frac{0.8-(-12)}{100K\Omega} = 0.128\,mA$

using KCL,

$I_1 = I_2 + I_B$

$\Rightarrow I_B = I_1 - I_2 = 0.7466\,mA - 0.128\,mA = 0.6186\,mA$



$P_1 = \Delta V \times I_C$

$= (12-0) \times 5.3636$ mW

$= 64.3632$ mW

$P_2 = \Delta V \times I_B$

$= (12-0) \times 0.6186$ mW

$= 7.4323$ mW

$P_3 = \Delta V \times I_2$

$= \{12-(-12)\} \times 0.128$ mW

$= 3.072$ mW

$P = P_1 + P_2 + P_3 = 74.8584$ mW

Average Power Dissipation

$P = V_{CC} \times I_{CC}$

$P_{AV} = \frac{P_{C1} + P_{C2}}{2}$

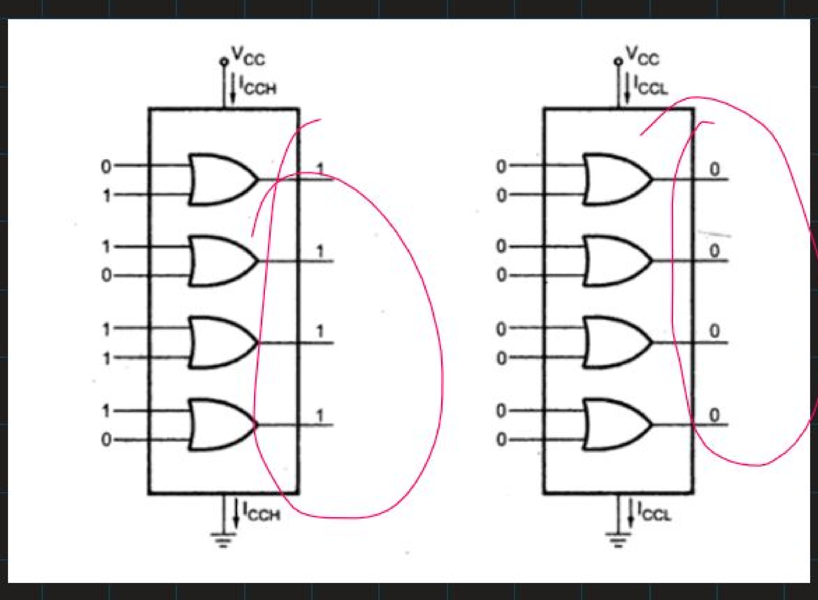
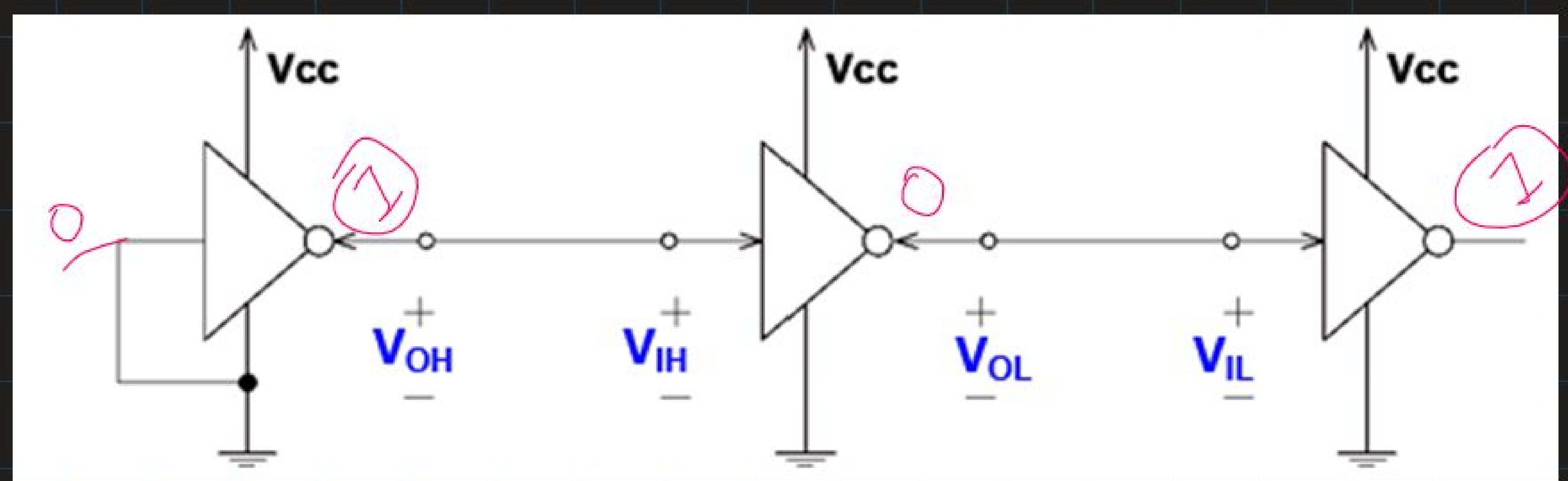


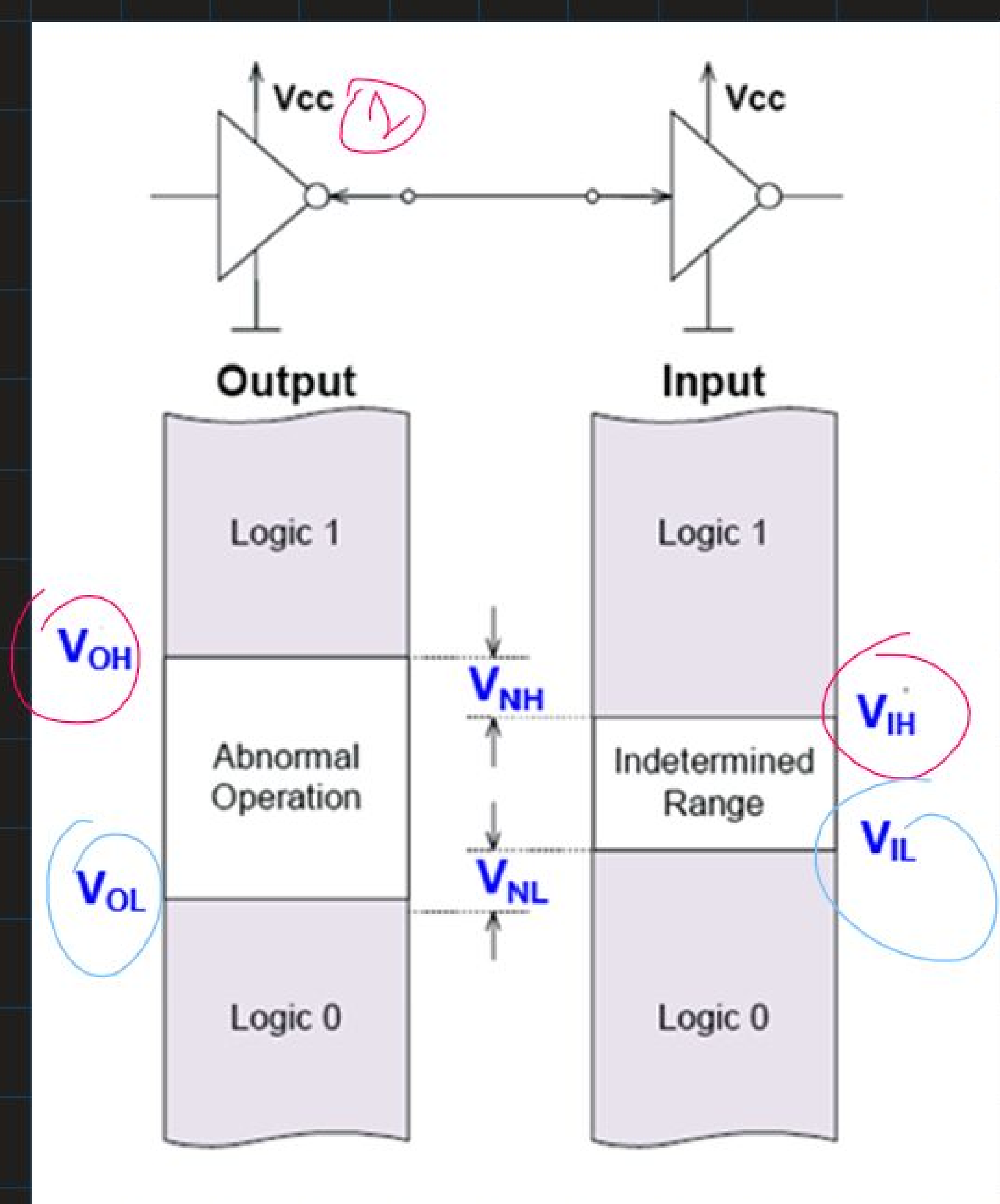
Figure of merit (PJ) = Propagation delay × power.

Lecture 4 Part 3

Thursday, June 17, 2021 1:40 PM

- V_{OH}(min) – The minimum voltage level at an output in the logical "1" state under defined load conditions
- V_{OL}(max) – The maximum voltage level at an output in the logical "0" state under defined load conditions
- V_{IH}(min) – The minimum voltage required at an input to be recognized as "1" logical state
- V_{IL}(max) – The maximum voltage required at an input that still will be recognized as "0" logical state





HIGH state noise margin:
$V_{NH} = V_{OH}(min) - V_{IH}(min)$

LOW state noise margin:
$V_{NL} = V_{IL}(max) - V_{OL}(max)$

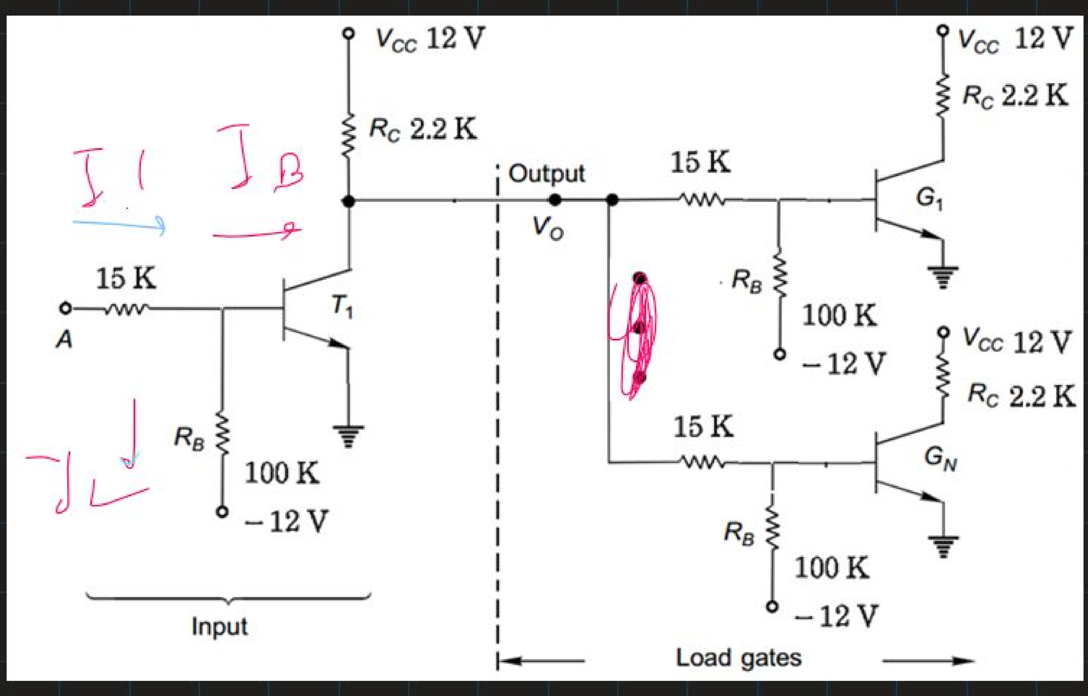
Noise margin:
$V_N = \min(V_{NH}, V_{NL})$

$V_{OH} > V_{IH}$
$V_{IL} > V_{OL}$

$V_{OL} = 0.2V$

$V_{OH} = (12 - 0.5)\,V$

$= 11.5V$



V_{IL} calculation

$I_B = 0$

$i_2 = \frac{0.5-(-12)V}{100K} = 0.125\ mA$

$i_1 = i_2$

$i_1 = \frac{v - 0.5}{15K} = 0.125\ mA$

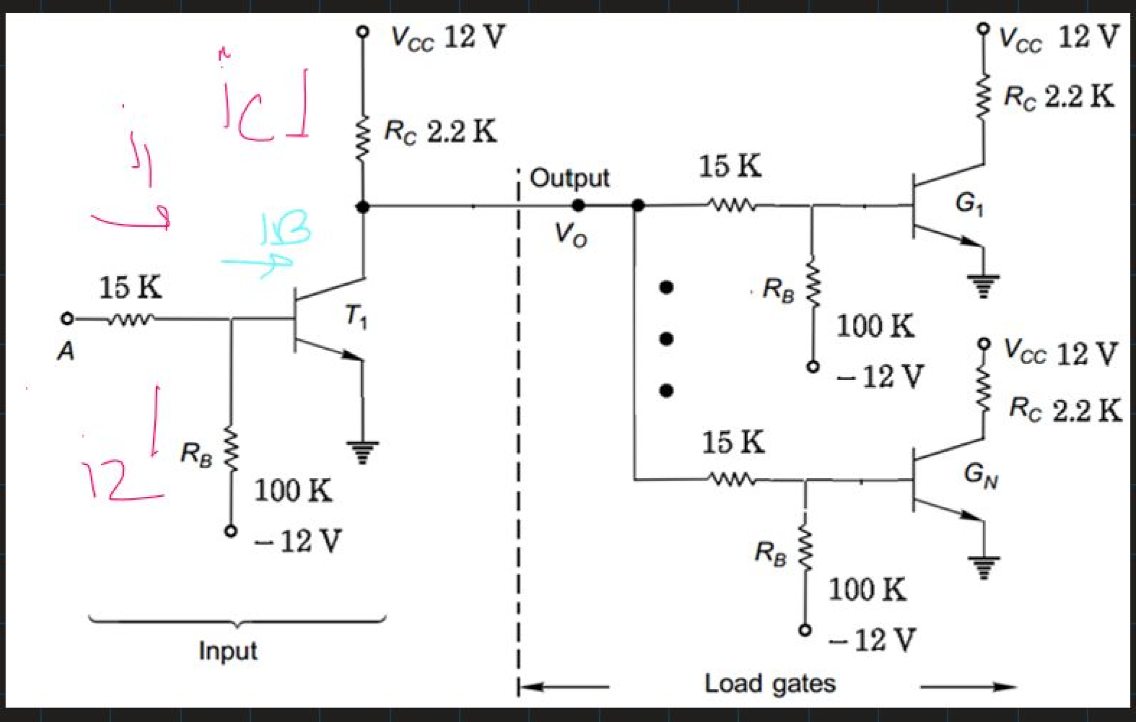
$v = 2.375$ Volt $= V_{IL}$

$V_{IH} = ?$

$T_1 \rightarrow$ saturation

saturation $\rightarrow$ active

$V_{IH} \rightarrow$ transition point



$V_B = 0.8V$

$i_C = \beta_F \times I_B$ 30

$V_C = 0.2V$

$i_c = \frac{12 - 0.2}{2.2K} = 5.3636\ mA$

$i_B = \frac{i_C}{\beta_F} = \frac{5.3636}{30}\ mA = 0.1788\ mA$

$i_2 = \frac{0.8-(-12)}{100K} = 0.128\ mA$

$i_1 = i_2 + i_B = (0.128 + 0.1788)\ mA$

$= 0.3068\ mA$

$i_1 = \frac{v - 0.8}{15K} = 0.3068\ mA$

$v = 5.4018V = V_{IH}$

HIGH state noise margin:
$V_{NH} = V_{OH}(min) - V_{IH}(min)$

LOW state noise margin:
$V_{NL} = V_{IL}(max) - V_{OL}(max)$

Noise margin:
$V_N = \min(V_{NH}, V_{NL})$

$V_N = 2.175$ Volt

$V_{NH} = 11.5V - 5.4018V$

$= 6.0982\ V$

$V_{NL} = 2.375\ V - 0.2V$

$= 2.175\ V$

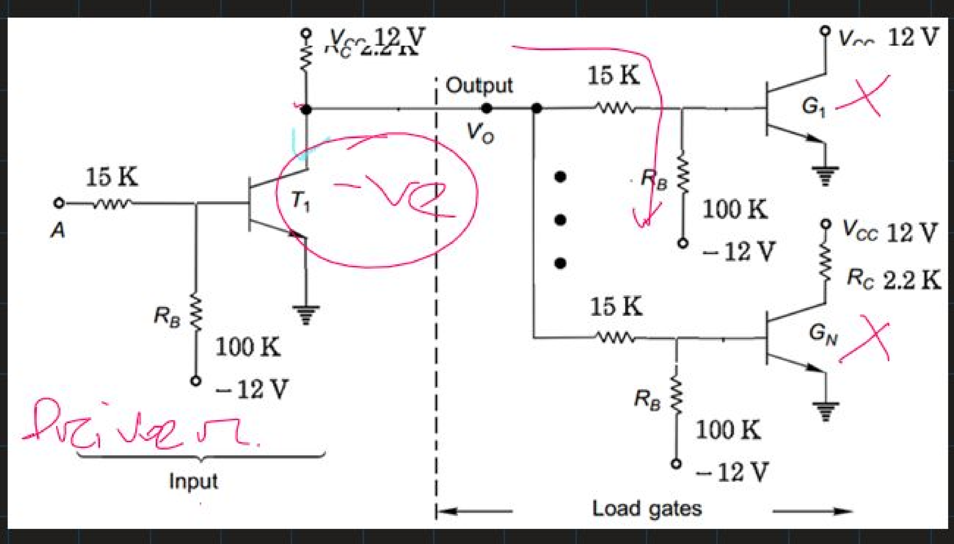
Lecture 4 part 5
Friday, June 18, 2021 03:04 PM

Fanout: the maximum number of logic inputs (of the same logic family) that an output can drive reliably

- I_{IH} – Current flowing into an input when driver's output is at logical high
- I_{IL} – Current flowing into an input when driver's output is at logical low
- I_{OH} – Current flowing into an output in the logical "1" state under specified load conditions
- I_{OL} – Current flowing into an output in the logical "0" state under specified load conditions

Calculate the fanout of this RTL circuit. Assume V_{OH} = 10 Volt

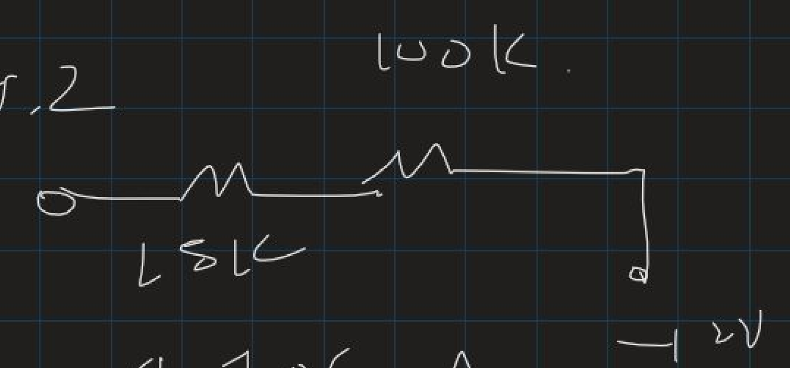
Case 1: When output is at 0.2 volt:



supply → driver

demand → load

Maximum total supply $= \dfrac{12 - 0.2}{2.2K} = 5.3636\ mA$



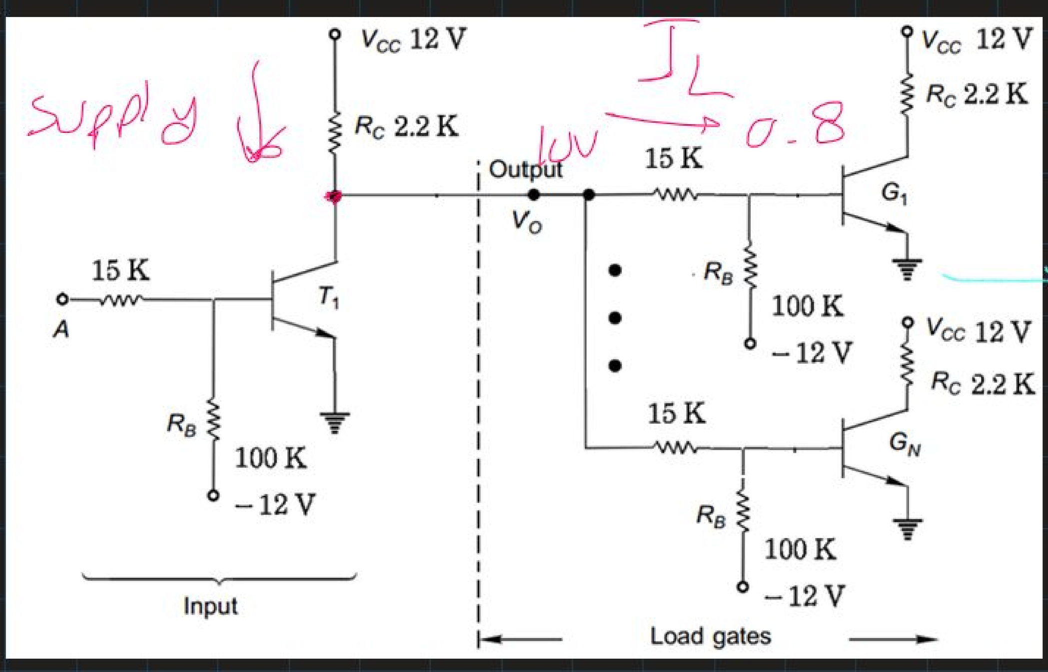
individual load current $= \dfrac{0.2 - (-12)}{(100+15)K} = 0.106\ mA$

Fanout $= \left\lfloor \dfrac{5.3636}{0.106} \right\rfloor = \lfloor 50.6 \rfloor = 50$

when driver is at logical low

2nd case

$V_{OH} = 10V$



F = 0

Maximum total supply $= \dfrac{12 - 10}{2.2K\Omega} = 0.909\ mA$

* load transistor will be in saturation

$V_{BE}(sat) = 0.8V$

* $V_B = 0.8V$.

* individual demand $= \dfrac{10 - 0.8}{15K} = 0.6133\ mA$

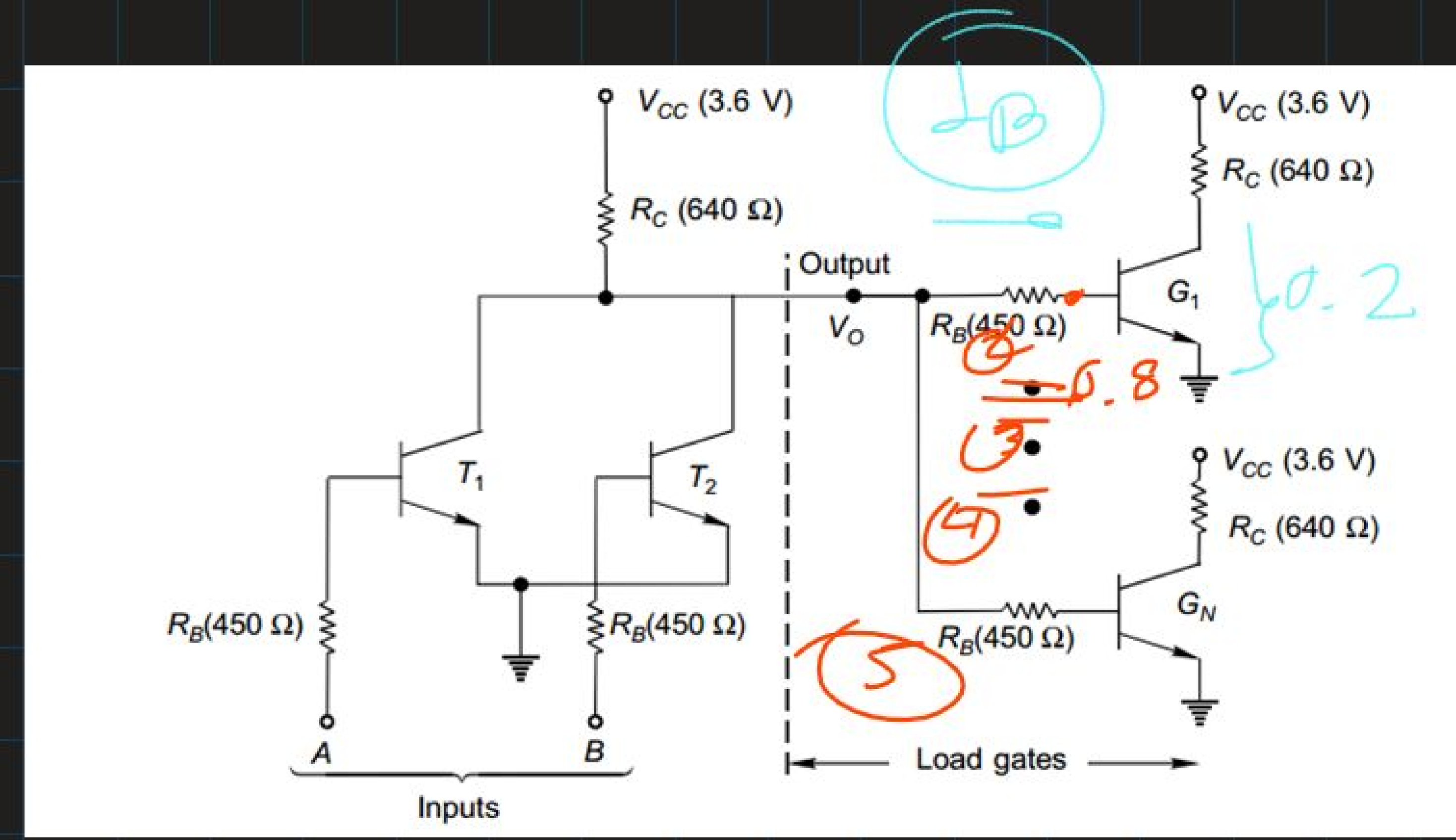
fanout $= \left\lfloor \dfrac{0.909}{0.6133} \right\rfloor = \lfloor 1.48 \rfloor = 1$

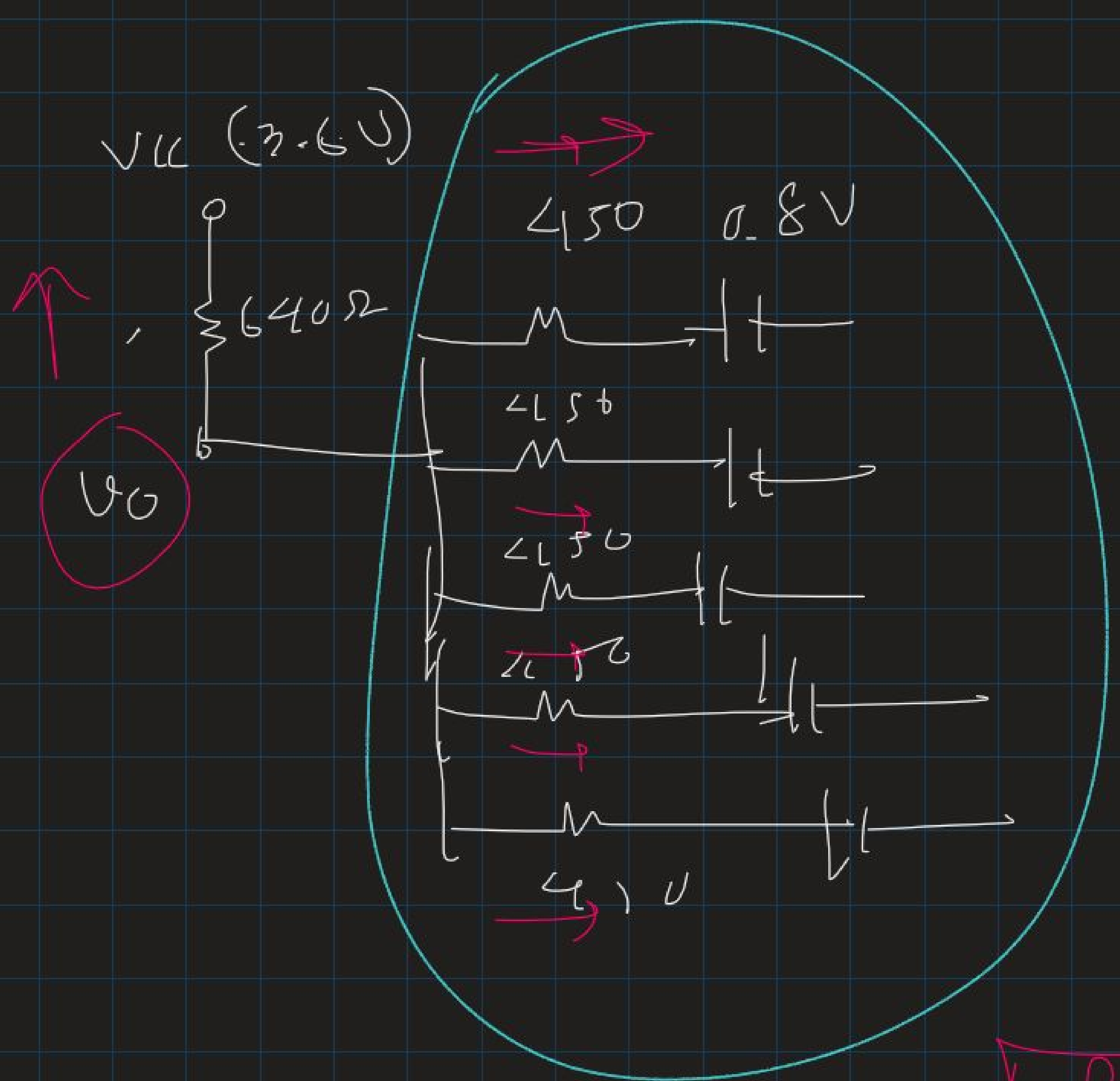
fanout → 50, 1

worst case scenario during fanout calculation

so, $\boxed{\text{Fanout} = 1}$

- If the number of FANOUT is 5, find the minimum value β_F so that these circuits operate as NOR gate. Assume all transistor have same value of β_F.





$$\frac{V_o - 3.6}{0.64k} + \frac{V_o - 0.8}{0.45k} \times 5 = 0$$

$$V_o = 1.1452\,V$$

$\boxed{\beta_{forced}}$

$$I_B = \frac{1.1452 - 0.8}{0.45k} = 0.767\,mA$$

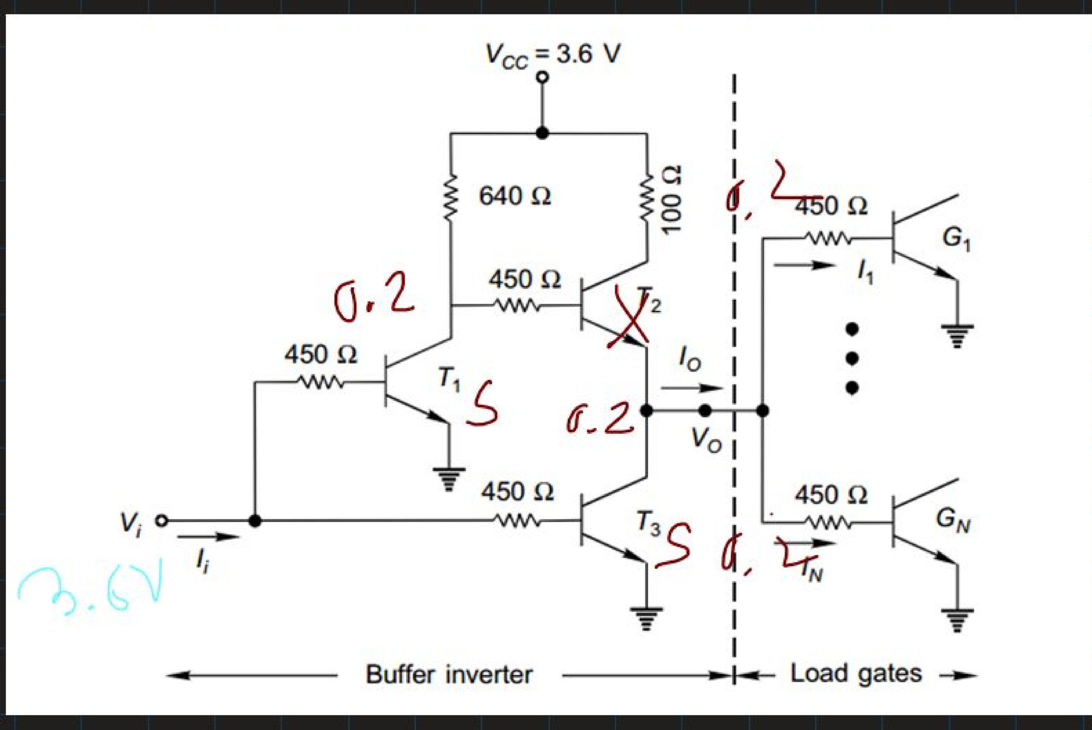
So, $V_C = 0.2V$

and so $I_C = \dfrac{3.6 - 0.2}{0.64\,k\Omega} = 5.3125\,mA$

$$\beta_{forced} = \frac{I_C}{I_B} = \frac{5.3125}{0.767} = 6.9263$$

$$\beta_F > 6.9263$$

- Find the value for maximum FANOUT if $V_{OH} = 2V$
  Given, $\beta_F = 30$.



1st case:

When $v_i = 3.6V$

$T_1 \rightarrow$ Satu
$T_3 \rightarrow$ saturation
$T_2 \rightarrow$ cutoff

all load transistor will be in cutoff

total demand = 0 mA

supply current = 0 mA

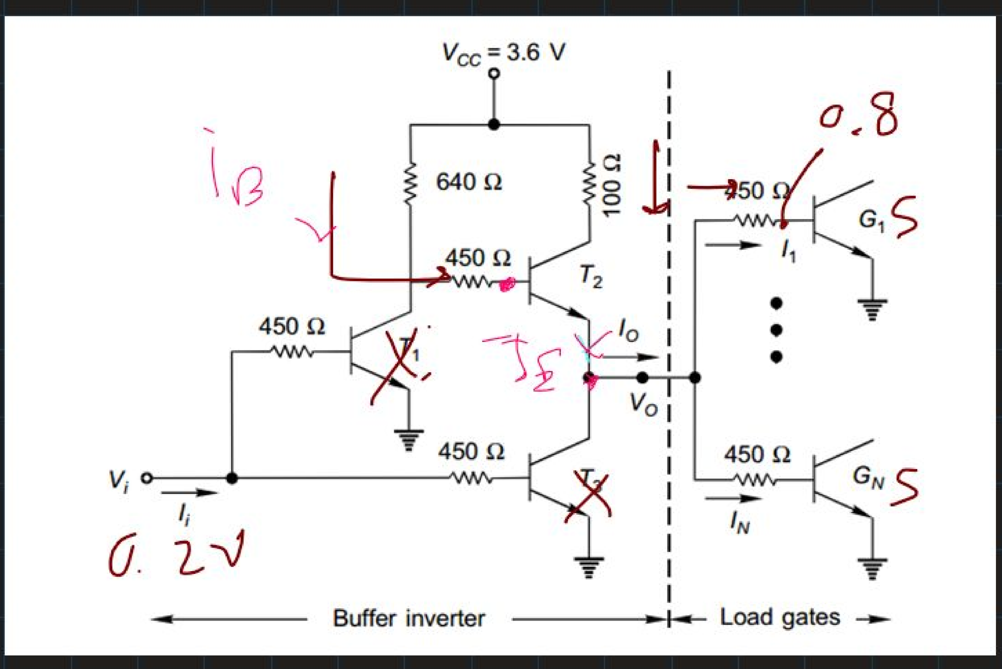
so, fanout $= \frac{0}{0}$

second case:

When $v_i = 0.2V$

$T_1 \rightarrow$ cutoff
$T_3 \rightarrow$ cutoff
$T_2 \rightarrow$?

$i_E = (\beta+1) i_B$



base voltage < collector voltage

$T_2 \rightarrow$ forward active mode.

$v_o \rightarrow$ logical high

demand of each load $= \frac{v_o - 0.8}{0.45k\Omega}$

Total demand will be $= N \times \frac{v_o - 0.8}{0.45k\Omega}$

$V_{BE} = 0.7V$ (Forward active)

$\Rightarrow V_B - V_E = 0.7V$

$\Rightarrow V_B - V_O = 0.7V$

$V_B = 0.7 + V_O$

$i_B = \frac{3.6 - (v_o + 0.7)}{1.09k}$

$i_E = (\beta+1) \times i_B$

$i_E = 31 \times \frac{3.6 - (v_o + 0.7)}{1.09k}$

total supply $= 31 \times \frac{3.6 - (v_o + 0.7)}{1.09K}$

v_o, N

$\downarrow$

$V_{OH} = 2$

$31 \times \frac{3.6 - (v_o + 0.7)}{1.09k} = N \times \frac{v_o - 0.8}{0.45K}$

$31 \times \frac{3.6 - (2 + 0.7)}{1.09K} = \frac{2 - 0.8}{0.45k} \times N$

$\Rightarrow 25.5963 = 2.667 \times N$

$\boxed{N = \lfloor 9.5986 \rfloor = 9}$

$V_B < V_C$

$\boxed{V_{BC} < 0}$

$\boxed{V_{BE} > 0}$