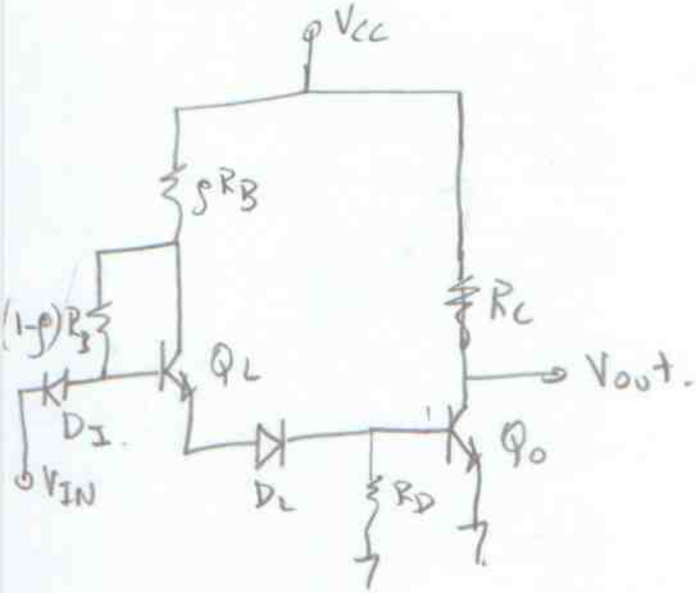
Modified DTL :



DTL with the following parameters is manufactured as 930 series.

$V_{CC} = 5V$

$\rho R_B = 1.75\,k\Omega$; $R_C = 6\,k\Omega$.

$(1-\rho) R_B = 2\,k\Omega$;

$R_D = 5\,k\Omega$;

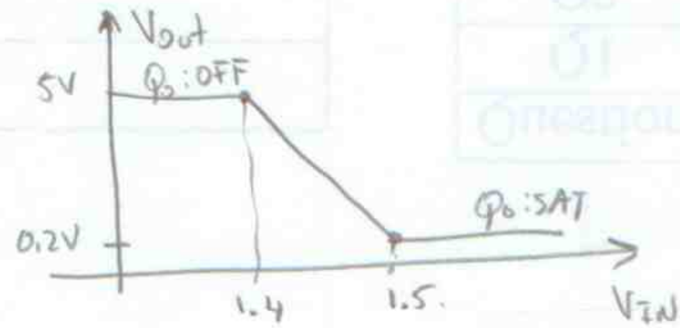
$(\rho = 7/15)$

$0 < \rho < 1$.

(Q_L: Level shifting transistor)

(1) Q_o turns ON when $V_{RD} = 0.7V$; $\rightarrow$ $V_{IN} = 1.4V$; ← edge of conduction

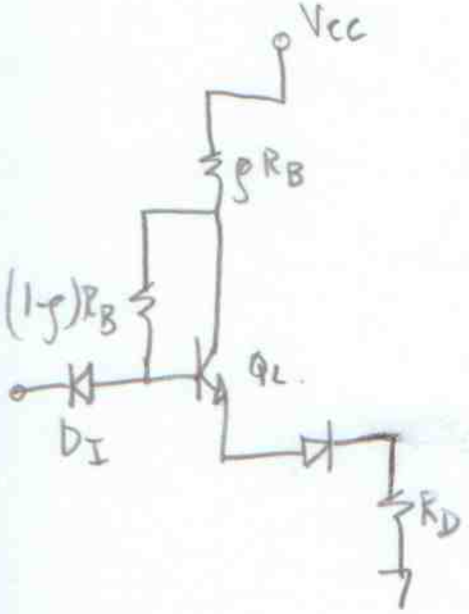
(2) Q_o saturates (at the edge) $V_{RD} = 0.8V$; $\rightarrow$ $V_{IN} = 1.5V$; ← edge of saturation.



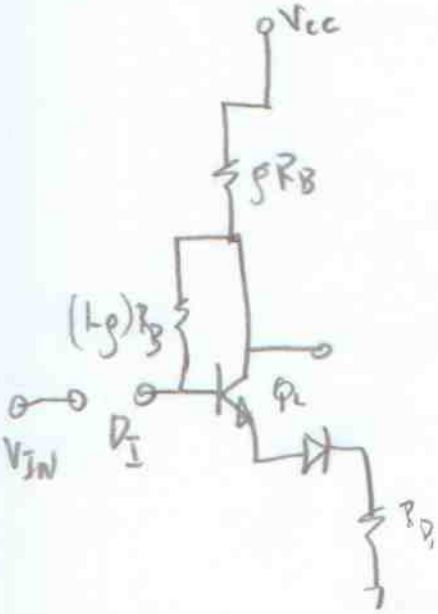
Q_L: provides more current to Q_o since it's adjusted (biased) in self-biased configuration and remains in FA when V_{IN} is in [0V, 5V].

(Current provided by Q_o improves Fan-out at OL.) "to be seen shortly"

Let's analyze self-biased configuration.

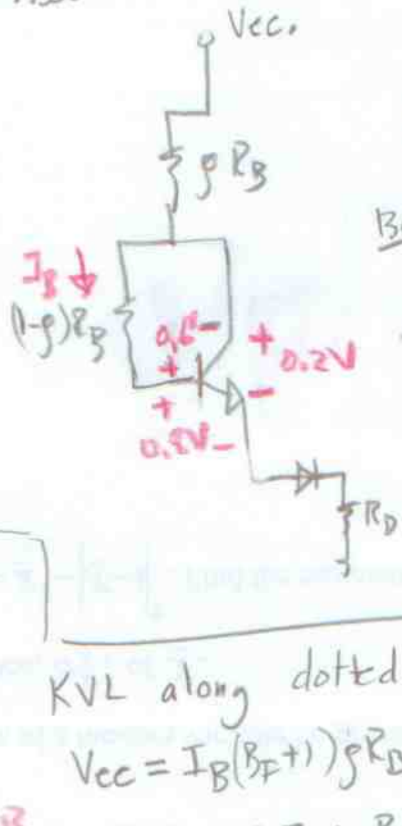


(1) Assume D_I: OFF



Q_L has to be in FA

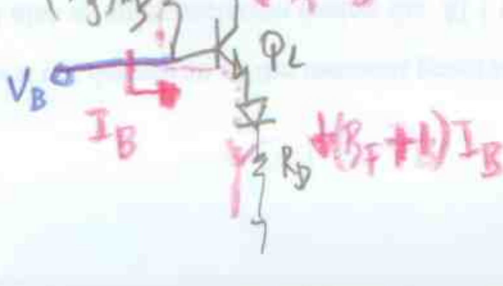
(since Assume SAT



$$I_B = \frac{-0.6}{(1-\rho)R_B} < 0$$

But $I_B > 0$ for the transistor to be ON. Hence SAT is not possible.)

With FA model:



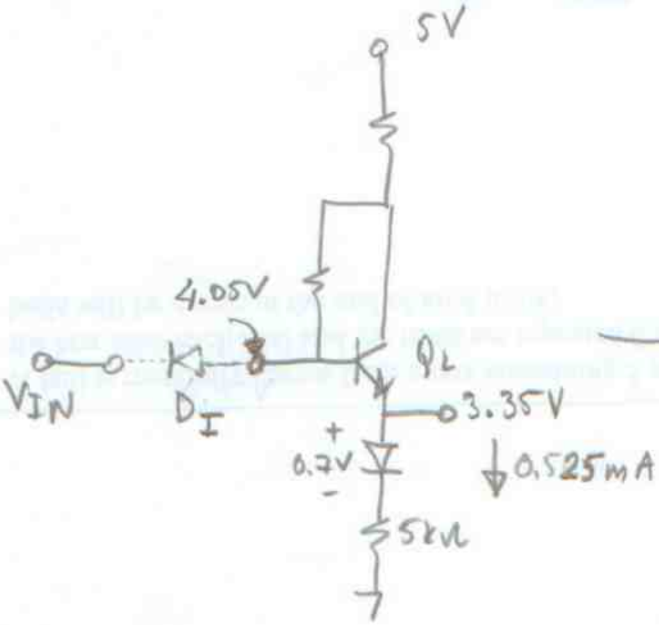
KVL along dotted line:

$$V_{cc} = I_B(\beta_F+1)\rho R_B + (1-\rho) R_B I_B + 0.7 + 0.7 + R_D(\beta_F+1) I_B$$

$$I_B = \frac{V_{cc} - 1.4}{(\beta_F+1)(\rho R_B + R_D) + (1-\rho)R_B}$$

Using 930 Series parameters ($\beta_F = 100$)

$$I_B = \frac{5 - 1.4}{(101)(6.75) + 2} \ mA = 5.25 \mu A$$

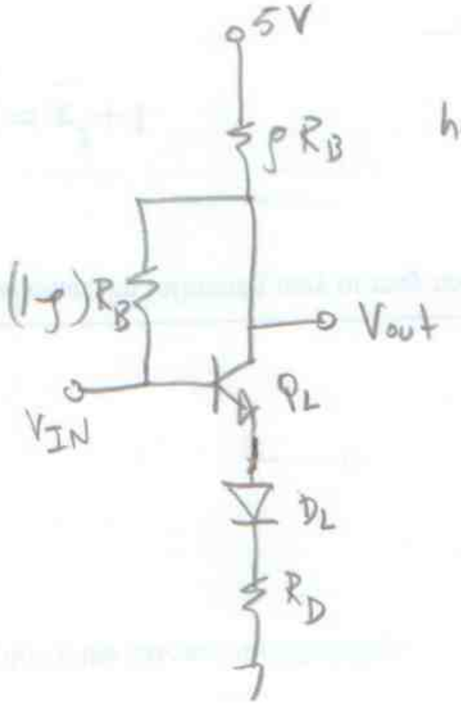


Then when

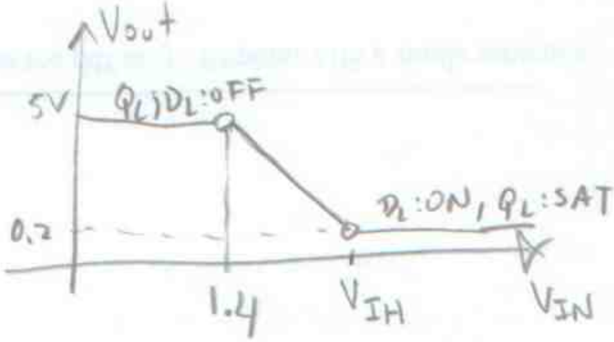
$\longrightarrow V_{IN} > 4.05 - 0.7 = 3.35$ V

D_I turns OFF and the contact of V_{IN} to Q_L is cut-off.

As an exercise, assume that D_I diode is removed and we have the following configuration.

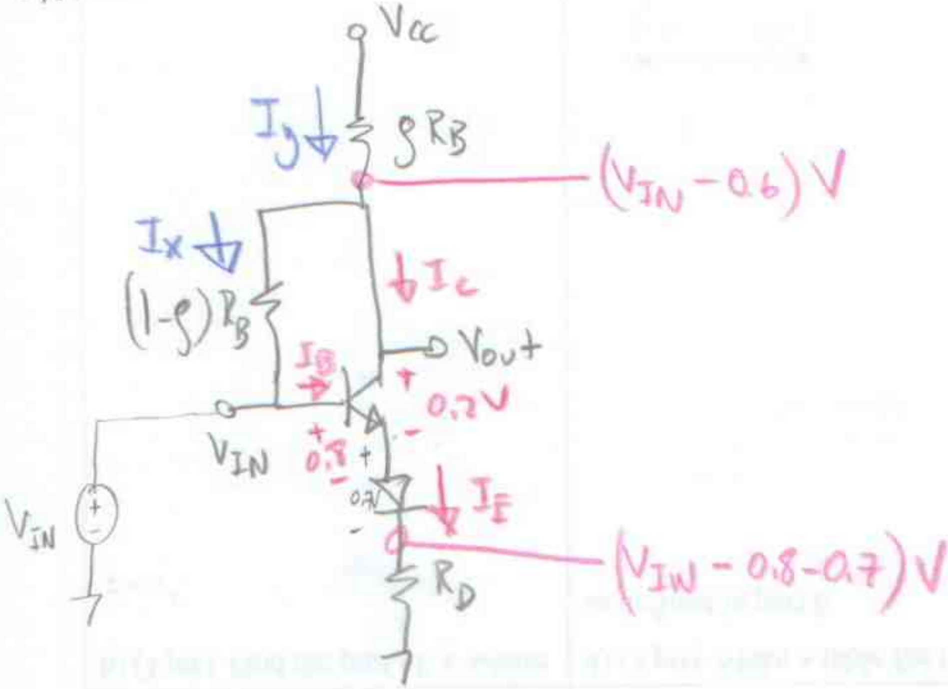


It's clear that the system has the following VTC.



Let's find V_{IH}:

Assume SAT



$$I_x = \frac{(V_{IN} - 0.6) - V_{IN}}{(1-\rho)R_B} = \frac{-0.6}{(1-\rho)R_B}\,A \quad ; \quad I_y = \frac{V_{CC} - (V_{IN} - 0.6)}{\rho R_B} = \frac{V_{CC} + 0.6 - V_{IN}}{\rho R_B}\,A$$

$$I_E = \frac{V_{IN} - 1.5}{R_D}\,A.$$

$$I_c = I_y - I_x = \frac{V_{CC} + 0.6 - V_{IN}}{\rho R_B} + \frac{0.6}{(1-\rho)R_B} = \frac{V_{CC} - V_{IN}}{\rho R_B} + \frac{0.6}{\rho(1-\rho)R_B}$$

$$I_B = I_E - I_c = \frac{V_{IN} - 1.5}{R_D} - \left(\frac{V_{CC} - V_{IN}}{\rho R_B} + \frac{0.6}{\rho(1-\rho)R_B}\right)$$

For SAT conditions are.

① $I_B > 0$ (ON)

② $\beta_F I_B > I_c$. (Not FA)

Using 930 Series parameters:

I_B:

$$I_B = \frac{V_{IN} - 1.5}{5} + \frac{V_{IN} - 5}{1.75} - \frac{0.6}{\frac{7}{15} \cdot 2} \ mA.$$

$$I_B = \frac{V_{IN}(7+20) - 100 - 10.5 - 22.5}{35} \ mA.$$

$$I_B = \frac{27}{35} V_{IN} - \frac{132.5}{35} \ mA$$

I_c:

$$I_c = \frac{5 - V_{IN}}{7/4} + \frac{0.6}{7/_{15} \cdot 2} \ mA = \frac{-4V_{IN} + 20 + 4.5}{7}$$

$$I_c = \frac{24.5}{7} - \frac{4}{7} V_{IN}$$

SAT condition:

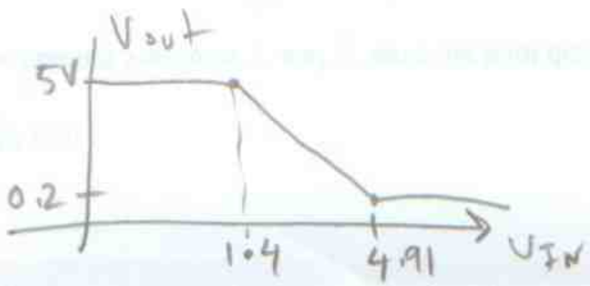
$$\beta_F I_B > I_c \longrightarrow \left(\frac{27}{35} V_{IN} - \frac{132.5}{35}\right) 100 > \left(\frac{24.5}{7} - \frac{4}{7} V_{IN}\right)$$

$$20(27 V_{IN} - 132.5) > (24.5 - 4V_{IN})$$

$$V_{IN} > \frac{20 \cdot (132.5) + 24.5}{544}$$

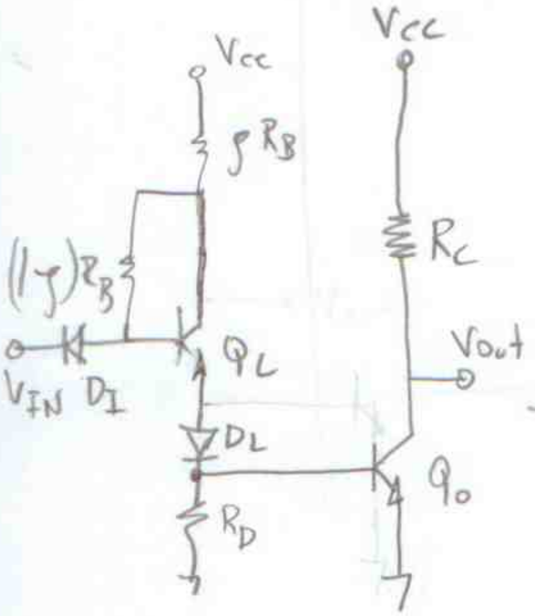
$$V_{IN} > 4.91 \, V$$

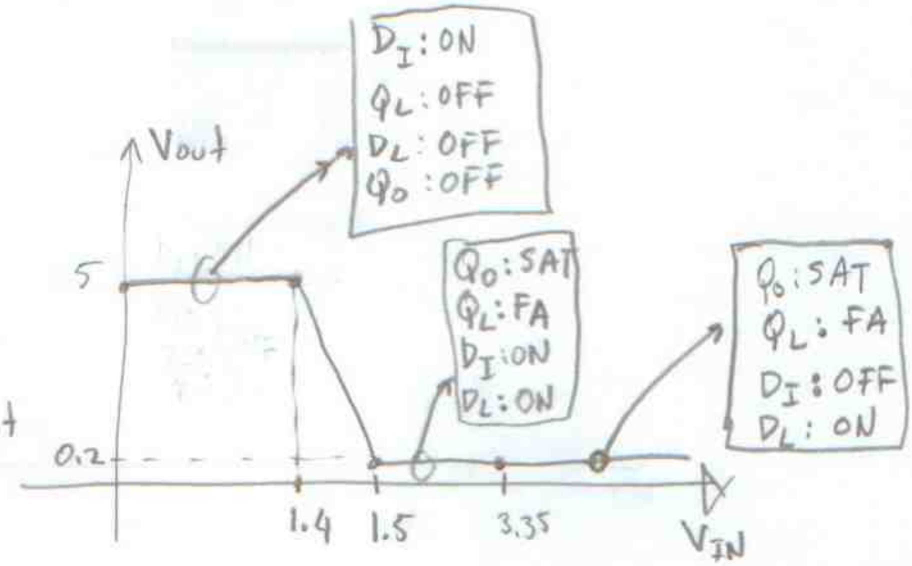
So



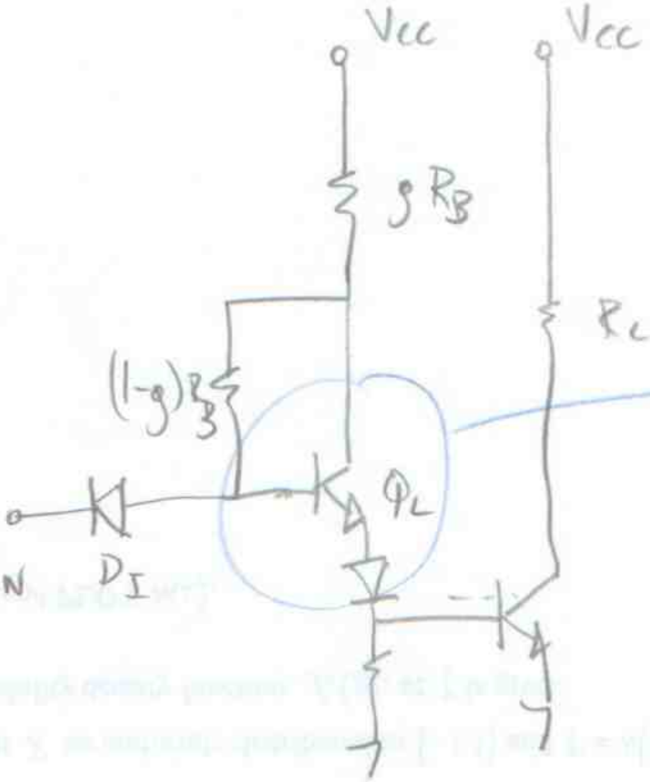
This concludes the exercise.

Thn





Note that



Q_L is in FA mode when it is ON.

(without D_I, Q_L saturates at 4.91V; but with D_I Q_L never saturates since V_{IN} is cut-off when $V_{IN} > 3.35V$)