Modified DTL:

DTL with the following parameters is manufactured as 930 series.

\[ V_{CC} = 5V \]
\[ R_B = 1.75k\Omega \]
\[ R_C = 6k\Omega \]
\[ R_D = 5k\Omega \]

\( g = 7 \frac{1}{15} \)

0 < g < 1.

(\( Q_0 \): Level shifting transistor)

1. \( Q_0 \) turns ON when \( V_{RD} = 0.7V \) \( \rightarrow \) \( V_{IN} = 1.4V \) \( \rightarrow \) edge of conduction

2. \( Q_0 \) saturates (at the) \( V_{RD} = 0.8V \) \( \rightarrow \) \( V_{IN} = 1.5V \) \( \rightarrow \) edge of saturation.

\( Q_L \): provides more current to \( Q_0 \) since it's adjusted (biased) in self-biased configuration and remains in FA when \( V_{IN} \) is in \( [0V, 5V] \).

(Current provided by \( Q_0 \) improves Fan-out at \( O.L. \))

"to be seen shortly"
Let's analyze the self-biased configuration.

1. Assume \( D_I: \text{OFF} \)

\( Q_L \) has to be in FA

\[ I_B = \frac{-0.16}{(1-\gamma) R_B} \]

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

With FA model:

\[ I_B (B_T+1) \]

\[ R_B \]

KVL along dotted line:

\[ V_{cc} = I_B (B_T+1) g_R + (1-\gamma) R_B I_B + 0.7 \]

\[ +0.7 + R_D (B_T+1) I_B \]

\[ I_B = \frac{V_{cc} - 1.4}{(B_T+1)(g_R + R_D) + (1-\gamma) R_B} \]
Using 930 Series Parameters ($R_f=100$)

\[ J_B = \frac{5 - 1.4}{(101)(6.75) + 2} \text{ mA} = 5.25 \mu\text{A} \]

Then when

\[ V_{IN} > 4.05 - 0.17 = 3.88 \text{ V} \]

Diode $D_I$ 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

\[ I_X = \frac{(V_{IN} - 0.6) - V_{IN}}{(1-\eta)R_B} = -0.6 \text{ A} \]

\[ I_Y = \frac{V_{CC} - (V_{IN} - 0.6)}{g_{RB}} \]

\[ I_E = \frac{V_{IN} - 1.5}{R_D} \text{ A} \]

\[ I_E = I_Y - I_X = \frac{V_{CC} + 0.6 - V_{IN}}{g_{RB}} + \frac{0.6}{(1-\eta)R_B} = \frac{V_{CC} - V_{IN} + 0.6}{g_{RB}} + \frac{0.6}{g_{(1-\eta)R_B}} \]

\[ J_B = I_E - I_C = \frac{V_{IN} - 1.5}{R_D} - \left( \frac{V_{CC} - V_{IN} + 0.6}{g_{RB}} + \frac{0.6}{g_{(1-\eta)R_B}} \right) \]

For SAT condition are:

1. $I_B > 0$ (ON)
2. $B_T > I_C$ (Not FA)
Using 930 series parameters:

\[
I_B = \frac{V_{IN} - 1.5}{5} + \frac{V_{IN} - 5}{1.75} - \frac{0.6}{\frac{7}{15}} \text{ mA.}
\]

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

\[
I_B = \frac{27V_{IN} - 132.5}{35} \text{ mA.}
\]

\[
I_C = 5 - \frac{V_{IN}}{7/4} + \frac{0.6}{7/15} \text{ mA} = \frac{-4V_{IN} + 20 + 4.5}{7}
\]

\[
I_C = \frac{24.5}{7} - \frac{4V_{IN}}{7}
\]

SAT condition:

\[
P_F I_B > I_C \rightarrow \left( \frac{27V_{IN} - 132.5}{35} \right) 100 > \left( \frac{24.5}{7} - \frac{4V_{IN}}{7} \right)
\]

\[
20(27V_{IN} - 132.5) > (24.5 - 4V_{IN})
\]

\[
V_{IN} > \frac{20(132.5) + 24.5}{544}
\]

\[
V_{IN} > 4.91 \text{ V}
\]

This concludes the exercise.
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)