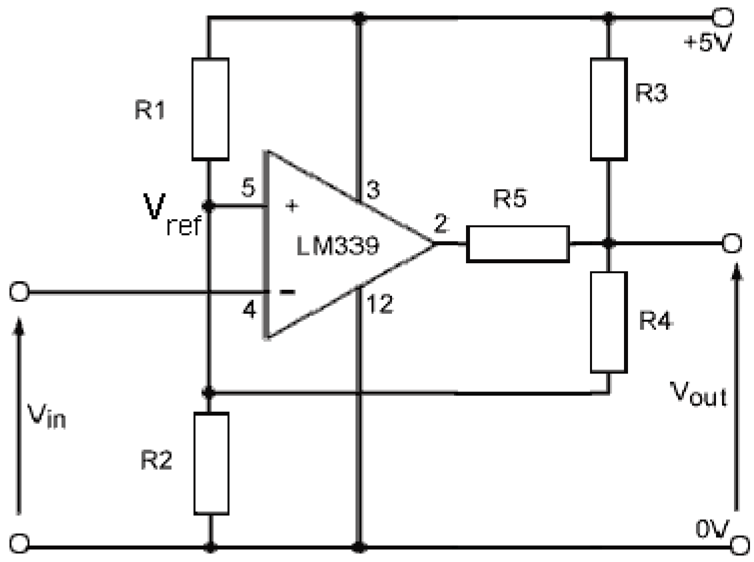
Open-Drain Schmitt Trigger with Programmable Low Level



Normalized High Output Voltage

Circuit equations for high output voltage case

Given

$$V_H\cdot\left(\frac{1}{R_3}+\frac{1}{R_4}\right)-\frac{V_{TH\uparrow}}{R_4}-\frac{1}{R_3}=0 \qquad V_{TH\uparrow}\cdot\left(1+\frac{1}{R_2}+\frac{1}{R_4}\right)-1-\frac{V_H}{R_4}=0$$

$$\mathbf{eq1} := \text{Find}(R_4, V_{TH\uparrow}) \rightarrow \begin{pmatrix} \dfrac{R_2\cdot V_H - R_2\cdot R_3 - R_2 + R_3\cdot V_H + R_2\cdot R_3\cdot V_H}{R_2 - V_H - R_2\cdot V_H + 1} \\ \dfrac{R_2 + R_2\cdot R_3 - R_2\cdot V_H}{R_3 + R_2\cdot R_3} \end{pmatrix}$$

Circuit equations for low output voltage case

Given

$$V_L\cdot\left(\frac{1}{R_3}+\frac{1}{R_4}+\frac{1}{R_5}\right)-\frac{V_{TH\downarrow}}{R_4}-\frac{1}{R_3}-\frac{V_{OL}}{R_5}=0 \qquad V_{TH\downarrow}\cdot\left(1+\frac{1}{R_2}+\frac{1}{R_4}\right)-1-\frac{V_L}{R_4}=0$$

$$\mathbf{eq2} := \text{Find}(R_5, V_{TH\downarrow}) \rightarrow \begin{pmatrix} -\dfrac{R_2\cdot R_3\cdot V_L + R_3\cdot R_4\cdot V_L - R_2\cdot R_3\cdot V_{OL} - R_3\cdot R_4\cdot V_{OL} + R_2\cdot R_3\cdot R_4\cdot V_L - R_2\cdot R_3\cdot R_4\cdot V_{OL}}{R_2\cdot V_L - R_4 - R_2\cdot R_3 - R_2\cdot R_4 - R_2 + R_3\cdot V_L + R_4\cdot V_L + R_2\cdot R_3\cdot V_L + R_2\cdot R_4\cdot V_L} \\ \dfrac{R_2\cdot R_4 + R_2\cdot V_L}{R_2 + R_4 + R_2\cdot R_4} \end{pmatrix}$$

Solve For Normalized Resistance Values

Given

$$R_4 = \frac{R_2\cdot V_H - R_2\cdot R_3 - R_2 + R_3\cdot V_H + R_2\cdot R_3\cdot V_H}{R_2 - V_H - R_2\cdot V_H + 1} \qquad V_{TH\downarrow} = \frac{R_2\cdot R_4 + R_2\cdot V_L}{R_2 + R_4 + R_2\cdot R_4}$$

$$V_{TH\uparrow} = \frac{R_2 + R_2\cdot R_3 - R_2\cdot V_H}{R_3 + R_2\cdot R_3}$$

$$\mathbf{eq1} := \text{Find}(R_2, R_3, R_4) \rightarrow \begin{pmatrix} -1 & \dfrac{V_H\cdot V_{TH\downarrow} - V_L\cdot V_{TH\uparrow}}{V_H - V_L - V_{TH\uparrow} + V_{TH\downarrow} - V_H\cdot V_{TH\downarrow} + V_L\cdot V_{TH\uparrow}} \\ V_H - 1 & \dfrac{V_H^2\cdot V_{TH\downarrow} - V_H\cdot V_{TH\downarrow} + V_L\cdot V_{TH\uparrow} - V_H\cdot V_L\cdot V_{TH\uparrow}}{V_{TH\uparrow}^2 - V_H\cdot V_{TH\uparrow} + V_H\cdot V_{TH\downarrow} - V_{TH\uparrow}\cdot V_{TH\downarrow}} \\ V_{TH\downarrow} - V_L & \dfrac{V_H\cdot V_{TH\downarrow} - V_L\cdot V_{TH\uparrow}}{V_{TH\uparrow} - V_{TH\downarrow}} \end{pmatrix}$$

extraneous solution   desired solution

$$R2(V_H, V_{TH\downarrow}, V_{TH\uparrow}, V_L, V_{OL}) := \frac{V_H\cdot V_{TH\downarrow} - V_L\cdot V_{TH\uparrow}}{V_H - V_L - V_{TH\uparrow} + V_{TH\downarrow} - V_H\cdot V_{TH\downarrow} + V_L\cdot V_{TH\uparrow}}$$

$$R3(V_H, V_{TH\downarrow}, V_{TH\uparrow}, V_L, V_{OL}) := \frac{V_H^2\cdot V_{TH\downarrow} - V_H\cdot V_{TH\downarrow} + V_L\cdot V_{TH\uparrow} - V_H\cdot V_L\cdot V_{TH\uparrow}}{V_{TH\uparrow}^2 - V_H\cdot V_{TH\uparrow} + V_H\cdot V_{TH\downarrow} - V_{TH\uparrow}\cdot V_{TH\downarrow}}$$

$$R4(V_H, V_{TH\downarrow}, V_{TH\uparrow}, V_L, V_{OL}) := \frac{V_H\cdot V_{TH\downarrow} - V_L\cdot V_{TH\uparrow}}{V_{TH\uparrow} - V_{TH\downarrow}}$$

Solving for R5 in terms of specification parameters did not prove workable. The expression was to large to display. I will instead compute R5 using a formula expressed in terms of other resistance values.

Explicit Formula for R5

$$R5\left(V_H, V_{TH\downarrow}, V_{TH\uparrow}, V_L, V_{OL}\right) := \left|\begin{array}{l} R_2 \leftarrow R2\left(V_H, V_{TH\downarrow}, V_{TH\uparrow}, V_L, V_{OL}\right) \\ R_3 \leftarrow R3\left(V_H, V_{TH\downarrow}, V_{TH\uparrow}, V_L, V_{OL}\right) \\ R_4 \leftarrow R4\left(V_H, V_{TH\downarrow}, V_{TH\uparrow}, V_L, V_{OL}\right) \\ -\dfrac{R_2 \cdot R_3 \cdot V_L + R_3 \cdot R_4 \cdot V_L - R_2 \cdot R_3 \cdot V_{OL} - R_3 \cdot R_4 \cdot V_{OL} + R_2 \cdot R_3 \cdot R_4 \cdot V_L - R_2 \cdot R_3 \cdot R_4 \cdot V_{OL}}{R_2 \cdot V_L - R_4 - R_2 \cdot R_3 - R_2 \cdot R_4 - R_2 + R_3 \cdot V_L + R_4 \cdot V_L + R_2 \cdot R_3 \cdot V_L + R_2 \cdot R_4 \cdot V_L} \end{array}\right.$$

Worked Example

$V_{CC} := 10 \quad V_H := \frac{8}{V_{CC}} = 0.8 \quad V_{TH\downarrow} := \frac{4 - 0.4}{V_{CC}} \quad V_{TH\uparrow} := \frac{4 + 0.4}{V_{CC}} \quad V_L := \frac{2}{V_{CC}} \quad V_{OL} := \frac{0}{V_{CC}}$

$r_1 := 1$

$r_2 := R2\left(V_H, V_{TH\downarrow}, V_{TH\uparrow}, V_L, V_{OL}\right) = 0.625000$

$r_3 := R3\left(V_H, V_{TH\downarrow}, V_{TH\uparrow}, V_L, V_{OL}\right) = 1.388889$

$r_4 := R4\left(V_H, V_{TH\downarrow}, V_{TH\uparrow}, V_L, V_{OL}\right) = 2.500000$

$r_5 := R5\left(V_H, V_{TH\downarrow}, V_{TH\uparrow}, V_L, V_{OL}\right) = 0.3125$

Unnormalized Values

$R_1 := 10K\Omega$

$R_2 := r_2 \cdot R_1 = 6.25 \cdot k\Omega$

$R_3 := r_3 \cdot R_1 = 13.88889 \cdot K\Omega$

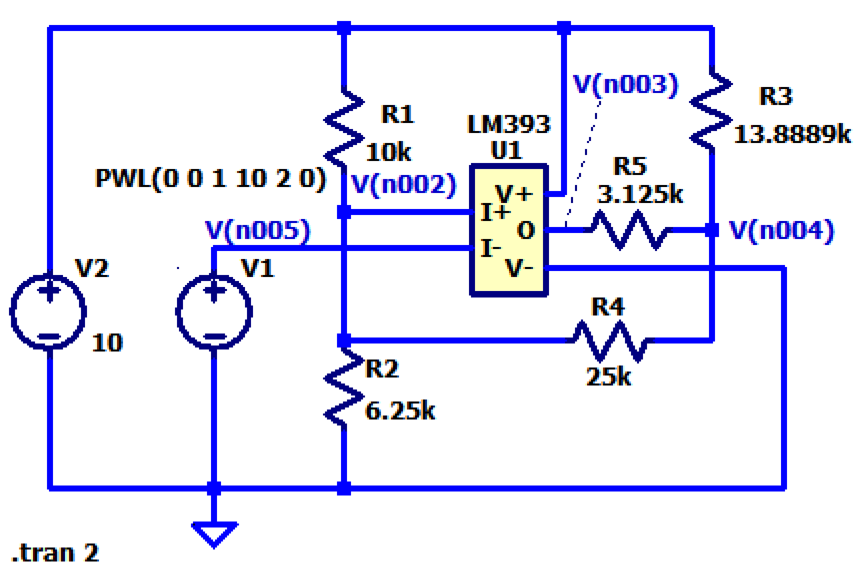
$R_4 := r_4 \cdot R_1 = 25.000000 \cdot k\Omega$

$R_5 := r_5 \cdot R_1 = 3.125 \cdot K\Omega$

$V_H := V_H \cdot V_{CC} = 8$

LTSpice Simulation of Real Comparator

LTSpice Circuit



LTSpice Simulation