Analog Engineer's Circuit
# Non-Inverting Comparator with Hysteresis Circuit

TEXAS INSTRUMENTS

Design Goals

Output		Thresholds			Supply		
V_o = HIGH	V_o = LOW	V_H	V_L	V_{HYS}	V_{cc}	V_{pu}	V_{ref}
$V_i > V_H$	$V_i < V_L$	1.7 V	1.3 V	400 mV	3 V	3 V	3 V

Design Description

Comparators are used to differentiate between two different signal levels. With noise, signal variation, or slow-moving signals, undesirable transitions at the output can be observed with a constant threshold. Setting upper and lower hysteresis thresholds eliminates these undesirable output transitions. This circuit example will focus on the steps required to design the positive feedback resistor network necessary to obtain the desired hysteresis for a non-inverting comparator application.
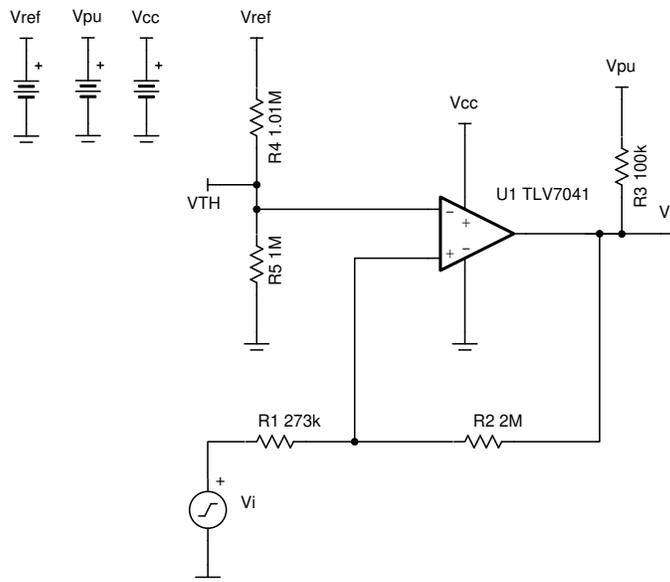

Design Notes

1. The accuracy of the hysteresis threshold voltages are related to the tolerance of the resistors used in the circuit, the selected comparator's input offset voltage specification, and any internal hysteresis of the device.
2. The TLV7041 has an open-drain output stage, so a pull-up resistor is needed.

Design Steps

1. Select the switching thresholds for when the comparator will transition from high to low (V_L) and low to high (V_H). V_L is the necessary input voltage for the comparator output to transition low and V_H is the required input voltage for the comparator to output high.

V_L ⟶ V_H
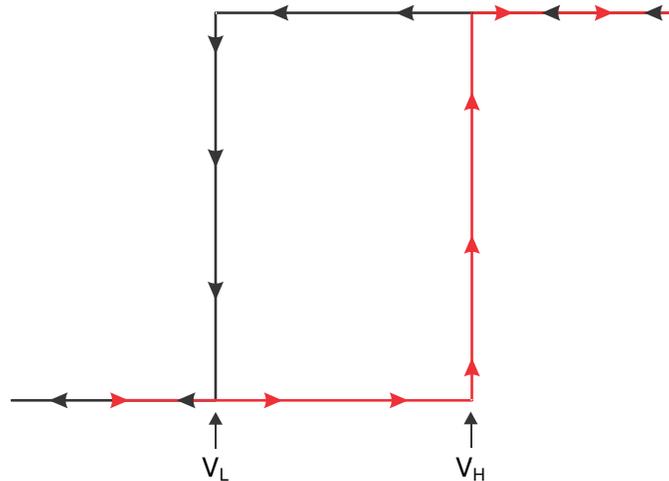
$V_L=1.3V$ and $V_H=1.7V$

2. Analyze the circuit when the input voltage is V_H. At this point, $V_o=0V$ and the transition to a logic high is initiated in the comparator output. Solve for the voltage seen by the comparator's non-inverting pin, V_{TH}.

(Non-Inverting Input Pin)
V_{TH}

Logic Low Output

COMP OUT

V_H — R1 — R2
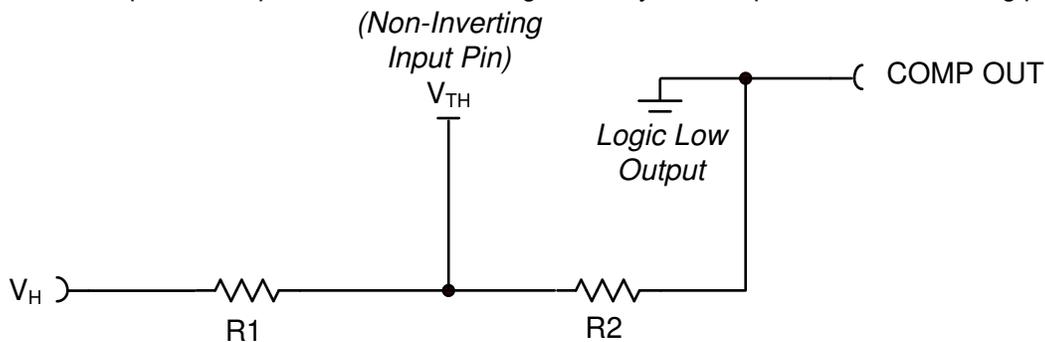
$$V_{TH} = V_H \times \left(\frac{R_2}{R_1 + R_2} \right)$$

3. Analyze the circuit when the input voltage is V_L. At this point, $V_o=V_{pu}$ (or $V_o=V_{cc}$ if the comparator has a push-pull output stage) and the transition to a logic low is initiated in the comparator output. Using superposition, solve for V_{TH}.
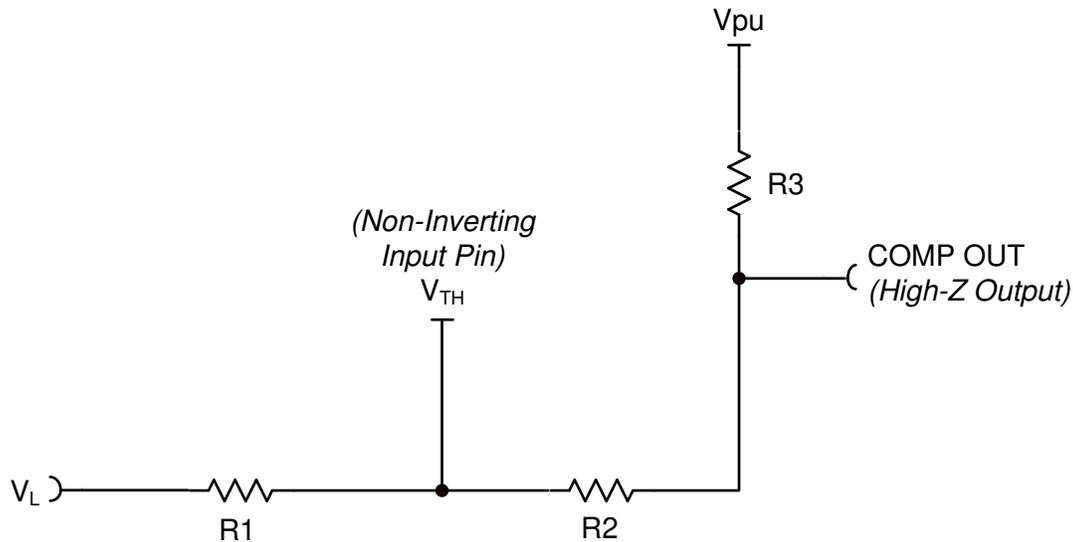
$$V_{TH} = V_L \times \left(\frac{R_2 + R_3}{R_1 + R_2 + R_3} \right) + V_{pu} \times \left(\frac{R_1}{R_1 + R_2 + R_3} \right)$$

4. Set R_2 to be large for power conservation. This resistance can be changed to meet certain design specifications but it was selected to be 2 MΩ. Now set the two V_{TH} equations equal and solve for R_1.

$$0 = (V_{PU}) \times R_1{}^2 + [V_{PU} \times R_2 + V_L \times (R_2 + R_3) - V_H \times R_2] \times R_1 + (V_L - V_H) \times \left(R_2{}^2 + R_2 \times R_3 \right)$$

$$R_1 = 273.19\text{k}\Omega \cong \mathbf{273k\Omega}$$

5. Calculate V_{TH} using the equation derived in step 2.

$$V_{TH} = V_H \times \left(\frac{R_2}{R_1 + R_2} \right)$$

$$V_{TH} = \mathbf{1.4958V}$$

6. Assuming a value for R_5 of 1 MΩ for reduced power consumption, calculate R_4 using the following relationship developed from a basic voltage divider of the reference voltage V_{REF}. The voltage at the inverting terminal is V_{TH}.

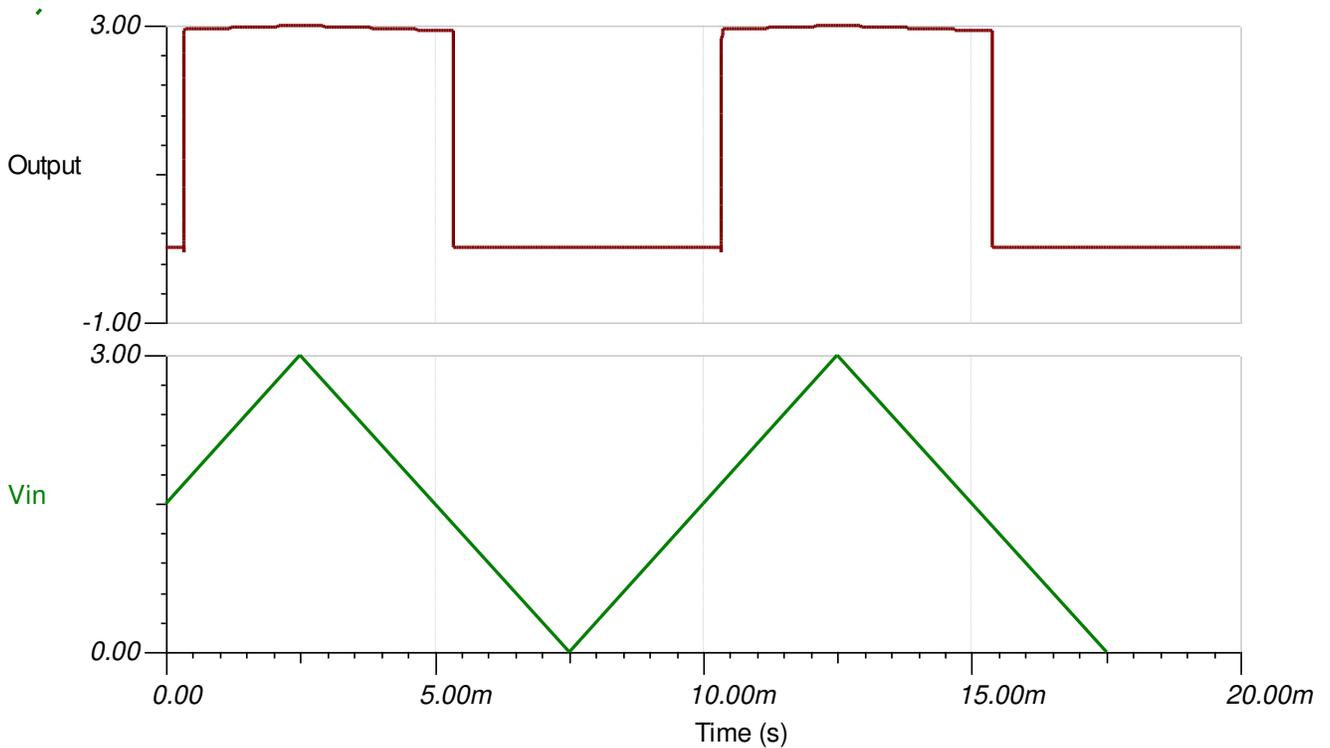$$V_{TH} = V_{REF} \times \left(\frac{R_5}{R_4 + R_5} \right)$$

$$\Rightarrow R_4 = 1.0056\text{M}\Omega \cong \mathbf{1.01M\Omega}$$

Design Simulations

DC Transfer Simulation Results
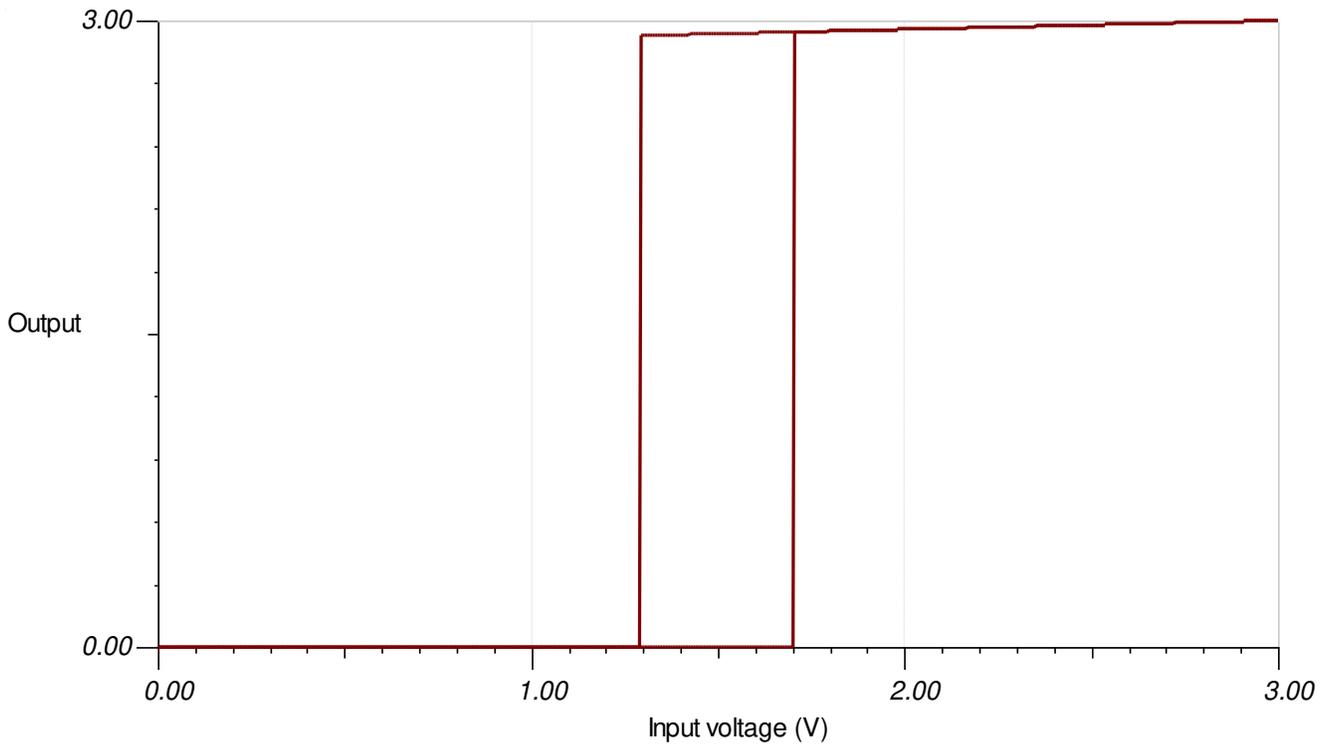
Transient Simulation Results

Design References

See *Analog Engineer's Circuit Cookbooks* for TI's comprehensive circuit library.

See Circuit SPICE Simulation File SLVMCR2.

For more information on many comparator topics including hysteresis, propagation delay and input common mode range please see TI Precision Labs - Op amps.

Design Featured Comparator

TLV7031, TLV7041	
Output Type	PP (7031), OD (7041)
V_{cc}	1.6 V to 6.5 V
V_{inCM}	Rail-to-rail
V_{os}	±100 µV
V_{HYS}	7 mV
I_q	335 nA/Ch
t_{pd}	3 µs
#Channels	1 and 2
TLV7041 Product Page	

Design Alternate Comparator

	TLV1701	TLV7011, TLV7011
Output Type	Open Collector	PP (7011), OD (7021)
V_{cc}	2.2 V to 36 V	1.6 V to 5.5 V
V_{inCM}	Rail-to-rail	Rail-to-rail
V_{HYS}	N/A	4.2 mV
V_{os}	±500 µV	±500 µV
I_q	55 µA/Ch	335 nA/Ch
t_{pd}	560 ns	3 µs
#Channels	1, 2, and 4	1 and 2
	TLV1701 Product Page	TLV7011 Product Page

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