

Non-Inverting Comparator with Hysteresis Circuit

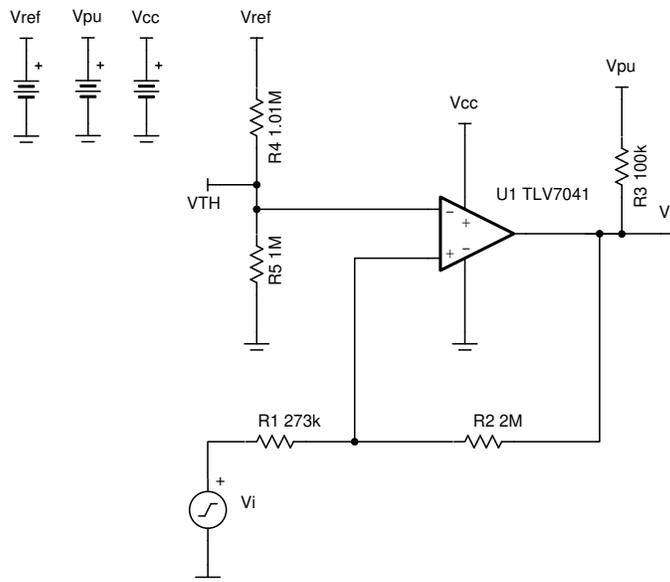


Design Goals

| Output | | Thresholds | | | Supply | | |
|---------------------|--------------------|------------|-------|------------------|-----------------|-----------------|------------------|
| $V_o = \text{HIGH}$ | $V_o = \text{LOW}$ | 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.

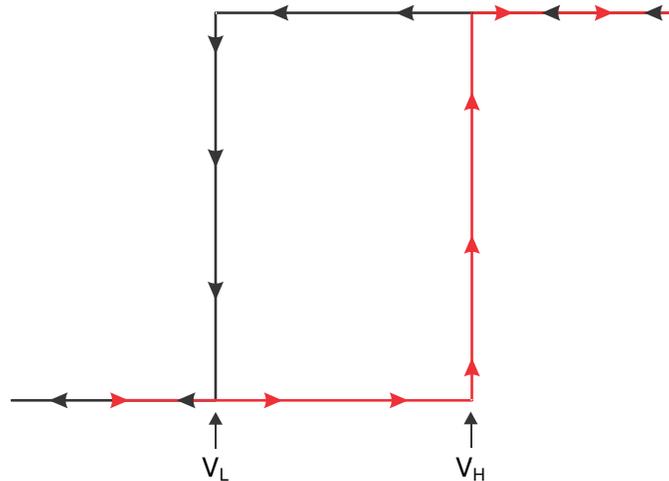


Design Notes

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.

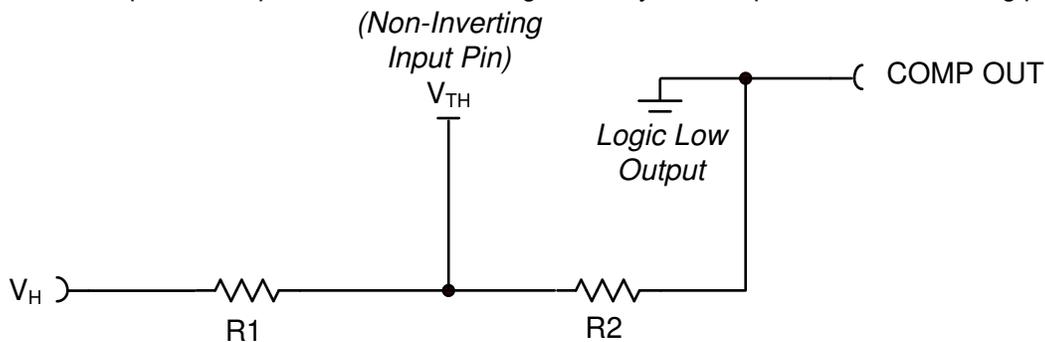
Design Steps

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.



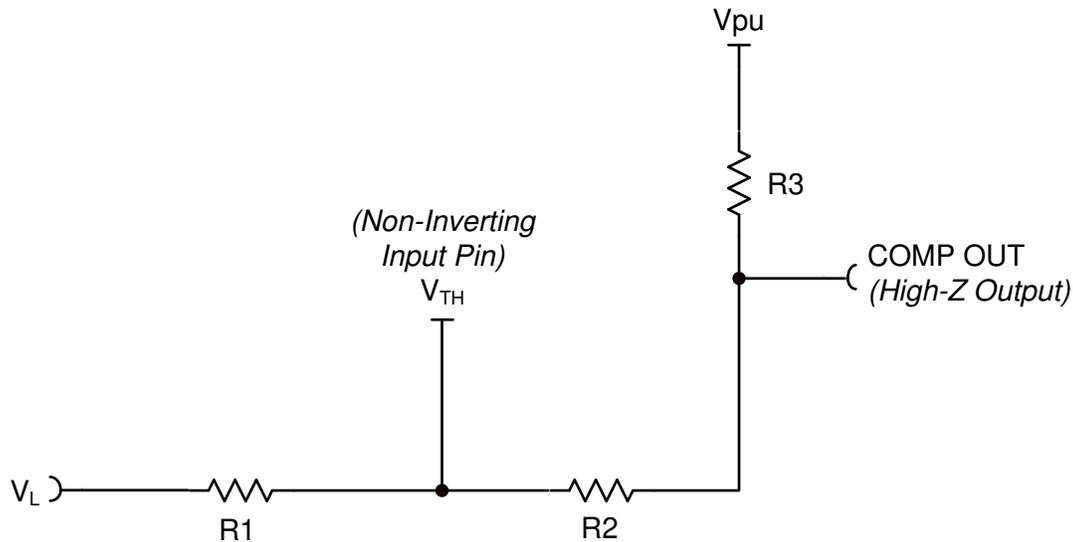
$$V_L=1.3V \text{ and } V_H=1.7V$$

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 input pin, V_{TH} .



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

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 M Ω . Now set the two V_{TH} equations equal and solve for R_1 .

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

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

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

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

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

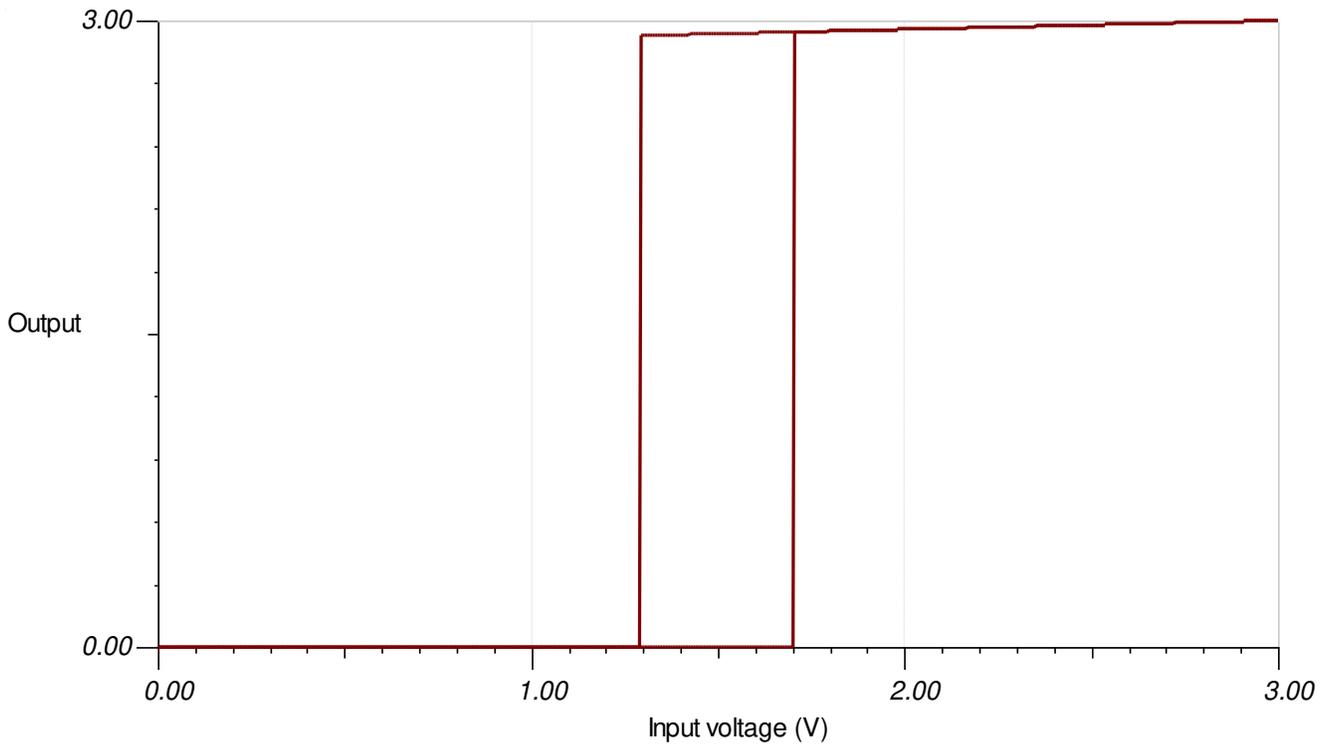
6. Assuming a value for R_5 of 1 M Ω for reduced power consumption, calculate R_4 using the following relationship developed from a basic voltage divider of the reference voltage V_{REF} . The voltage at the inverting terminal is V_{TH} .

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

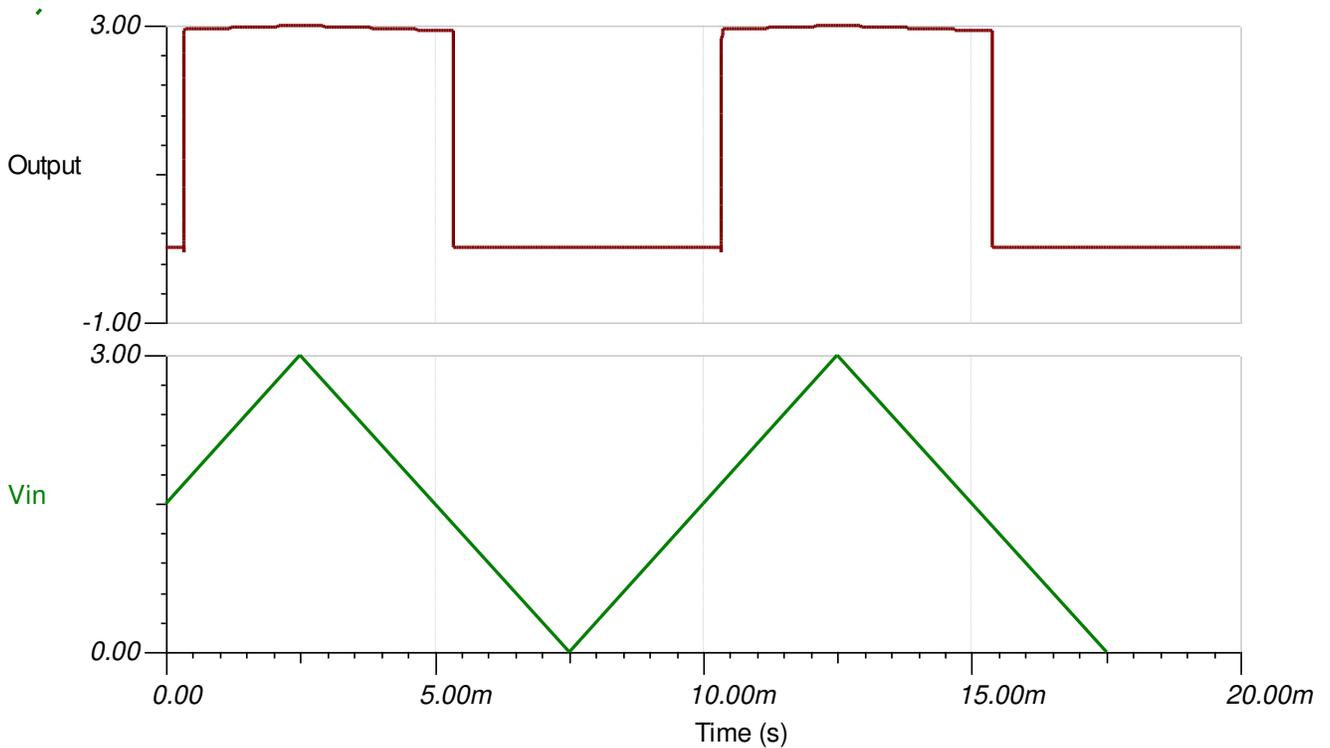
$$\Rightarrow R_4 = 1.0056M\Omega \cong \mathbf{1.01M\Omega}$$

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 |

IMPORTANT NOTICE AND DISCLAIMER

TI PROVIDES TECHNICAL AND RELIABILITY DATA (INCLUDING DATA SHEETS), DESIGN RESOURCES (INCLUDING REFERENCE DESIGNS), APPLICATION OR OTHER DESIGN ADVICE, WEB TOOLS, SAFETY INFORMATION, AND OTHER RESOURCES "AS IS" AND WITH ALL FAULTS, AND DISCLAIMS ALL WARRANTIES, EXPRESS AND IMPLIED, INCLUDING WITHOUT LIMITATION ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

These resources are intended for skilled developers designing with TI products. You are solely responsible for (1) selecting the appropriate TI products for your application, (2) designing, validating and testing your application, and (3) ensuring your application meets applicable standards, and any other safety, security, regulatory or other requirements.

These resources are subject to change without notice. TI grants you permission to use these resources only for development of an application that uses the TI products described in the resource. Other reproduction and display of these resources is prohibited. No license is granted to any other TI intellectual property right or to any third party intellectual property right. TI disclaims responsibility for, and you will fully indemnify TI and its representatives against, any claims, damages, costs, losses, and liabilities arising out of your use of these resources.

TI's products are provided subject to [TI's Terms of Sale](#) or other applicable terms available either on [ti.com](https://www.ti.com) or provided in conjunction with such TI products. TI's provision of these resources does not expand or otherwise alter TI's applicable warranties or warranty disclaimers for TI products.

TI objects to and rejects any additional or different terms you may have proposed.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265
Copyright © 2023, Texas Instruments Incorporated