TPS3701 High voltage (36V) window voltage detector with internal reference for over and undervoltage monitoring

1 Features
- Wide supply voltage range: 1.8 V to 36 V
- Adjustable threshold: down to 400 mV
- Open-drain outputs for over- and undervoltage detection
- Low quiescent current: 7 µA (Typical)
- High threshold accuracy:
  - 0.75% Over temperature
  - 0.25% (Typical)
- Internal hysteresis: 5.5 mV (typical)
- Temperature range: −40°C to 125°C
- Package:
  - SOT-6

2 Applications
- Industrial control systems
- Embedded computing modules
- DSPs, microcontrollers, and microprocessors
- Notebook and desktop computers
- Portable- and battery-powered products
- FPGA and ASIC systems

3 Description
The TPS3701 wide-supply voltage window detector operates over a 1.8-V to 36-V range. The device has two precision comparators with an internal 400-mV reference and two open-drain outputs (OUTA and OUTB) rated to 25 V for over- and undervoltage detection. Use the TPS3701 as a window voltage detector or as two independent voltage monitors; set the monitored voltage with the use of external resistors.

OUTA is driven low when the voltage at the INA pin drops below the negative threshold, and goes high when the voltage returns above the positive threshold. OUTB is driven low when the voltage at the INB pin rises above the positive threshold, and goes high when the voltage drops below the negative threshold. Both comparators in the TPS3701 include built-in hysteresis for noise rejection, thereby ensuring stable output operation without false triggering.

The TPS3701 is available in a SOT-6 package and is specified over the junction temperature range of −40°C to 125°C.

Device Information

<table>
<thead>
<tr>
<th>PART NUMBER</th>
<th>PACKAGE</th>
<th>BODY SIZE (NOM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TPS3701</td>
<td>SOT (6)</td>
<td>2.90 mm × 1.60 mm</td>
</tr>
</tbody>
</table>

(1) For all available packages, see the package option addendum at the end of the data sheet.

An IMPORTANT NOTICE at the end of this data sheet addresses availability, warranty, changes, use in safety-critical applications, intellectual property matters and other important disclaimers. PRODUCTION DATA.
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Revised February 2019

Changes from Revision B (June 2018) to Revision C Page

• Changed the text “supervisor” to “voltage detector” ................................................................. 1
• Changed “supervisor” to “voltage detector” ................................................................................. 12

Changes from Revision A (November 2017) to Revision B Page

• Changed the text ‘window comparator’ to ‘window supervisor’ throughout the data sheet .................... 1

Changes from Original (November 2014) to Revision A Page

• Changed input pin voltage maximum from: 1.7 V to: 6.5 V ............................................................ 4
• Added a tablenote for the input pin voltage maximum ................................................................. 4
• Changed Figure 19 ...................................................................................................................... 12
5 Pin Configuration and Functions

![Pin Configuration Diagram]

### Pin Functions

<table>
<thead>
<tr>
<th>PIN</th>
<th>I/O</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>GND</td>
<td>2</td>
<td>Ground</td>
</tr>
<tr>
<td>INA</td>
<td>3</td>
<td>Comparator A input. This pin is connected to the voltage to be monitored with the use of an external resistor divider. When the voltage at this terminal drops below the threshold voltage $V_{IT-(INA)}$, OUTA is driven low.</td>
</tr>
<tr>
<td>INB</td>
<td>4</td>
<td>Comparator B input. This pin is connected to the voltage to be monitored with the use of an external resistor divider. When the voltage at this terminal exceeds the threshold voltage $V_{IT+(INB)}$, OUTB is driven low.</td>
</tr>
<tr>
<td>OUTA</td>
<td>1</td>
<td>INA comparator open-drain output. OUTA is driven low when the voltage at this comparator is less than $V_{IT-(INA)}$. The output goes high when the sense voltage rises above $V_{IT+(INA)}$.</td>
</tr>
<tr>
<td>OUTB</td>
<td>6</td>
<td>INB comparator open-drain output. OUTB is driven low when the voltage at this comparator exceeds $V_{IT+(INB)}$. The output goes high when the sense voltage falls below $V_{IT-(INB)}$.</td>
</tr>
<tr>
<td>VDD</td>
<td>5</td>
<td>Supply voltage input. Connect a 1.8-V to 36-V supply to VDD to power the device. It is good analog design practice to place a 0.1-µF ceramic capacitor close to this pin.</td>
</tr>
</tbody>
</table>
6 Specifications

6.1 Absolute Maximum Ratings
Over operating junction temperature range, unless otherwise noted.\(^{(1)}\)

<table>
<thead>
<tr>
<th>Voltage(^{(2)})</th>
<th>MIN</th>
<th>MAX</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>(V_{DD})</td>
<td>−0.3</td>
<td>+40</td>
<td>V</td>
</tr>
<tr>
<td>(V_{OUTA}, V_{OUTB})</td>
<td>−0.3</td>
<td>+28</td>
<td>V</td>
</tr>
<tr>
<td>(V_{INA}, V_{INB})</td>
<td>−0.3</td>
<td>+7</td>
<td>V</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Current</th>
<th></th>
<th></th>
<th>mA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output pin current</td>
<td>40</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Temperature</th>
<th></th>
<th></th>
<th>°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating junction, (T_J)</td>
<td>−40</td>
<td>+125</td>
<td></td>
</tr>
<tr>
<td>Storage temperature, (T_{stg})</td>
<td>−65</td>
<td>+150</td>
<td></td>
</tr>
</tbody>
</table>

\(^{(1)}\) Stresses beyond those listed under Absolute Maximum Ratings may cause permanent damage to the device. These are stress ratings only, which do not imply functional operation of the device at these or any other conditions beyond those indicated under Recommended Operating Conditions. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

\(^{(2)}\) All voltages are with respect to network ground terminal.

6.2 ESD Ratings

<table>
<thead>
<tr>
<th>(V_{(ESD)}) Electrostatic discharge</th>
<th>VALUE</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001(^{(1)})</td>
<td>±2000</td>
<td>V</td>
</tr>
<tr>
<td>Charged-device model (CDM), per JEDEC specification JESD22-C101(^{(2)})</td>
<td>±500</td>
<td>V</td>
</tr>
</tbody>
</table>

\(^{(1)}\) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process.

\(^{(2)}\) JEDEC document JEP157 states that 250-V CDM allows safe manufacturing with a standard ESD control process.

6.3 Recommended Operating Conditions
over operating junction temperature range (unless otherwise noted)

<table>
<thead>
<tr>
<th>(V_{DD}) Supply pin voltage</th>
<th>MIN</th>
<th>NOM</th>
<th>MAX</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>(V_{INA}, V_{INB}) Input pin voltage</td>
<td>0</td>
<td>6.5</td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>(V_{OUTA}, V_{OUTB}) Output pin voltage</td>
<td>0</td>
<td>25</td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>(I_{OUTA}, I_{OUTB}) Output pin current</td>
<td>0</td>
<td>10</td>
<td></td>
<td>mA</td>
</tr>
<tr>
<td>(T_J) Junction temperature</td>
<td>−40</td>
<td>+25</td>
<td>+125</td>
<td>°C</td>
</tr>
</tbody>
</table>

\(^{(1)}\) Operating \(V_{INA}\) or \(V_{INB}\) at 2.4 V or higher and at 125°C continuously for 10 years or more would cause a degradation of accuracy spec to 1.5% maximum.

6.4 Thermal Information

<table>
<thead>
<tr>
<th>THERMAL METRIC(^{(1)})</th>
<th>TPS3701</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 PINS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(R_{UA}) Junction-to-ambient thermal resistance</td>
<td>201.6</td>
<td>°C/W</td>
</tr>
<tr>
<td>(R_{UIC(top)}) Junction-to-case (top) thermal resistance</td>
<td>47.8</td>
<td>°C/W</td>
</tr>
<tr>
<td>(R_{UJB}) Junction-to-board thermal resistance</td>
<td>51.2</td>
<td>°C/W</td>
</tr>
<tr>
<td>(\psi_{JT}) Junction-to-top characterization parameter</td>
<td>0.7</td>
<td>°C/W</td>
</tr>
<tr>
<td>(\psi_{JB}) Junction-to-board characterization parameter</td>
<td>50.8</td>
<td>°C/W</td>
</tr>
<tr>
<td>(R_{UIC(bot)}) Junction-to-case (bottom) thermal resistance</td>
<td>N/A</td>
<td>°C/W</td>
</tr>
</tbody>
</table>

\(^{(1)}\) For more information about traditional and new thermal metrics, see the Semiconductor and IC Package Thermal Metrics application report (SPRA953).
### 6.5 Electrical Characteristics

Over the operating temperature range of $T_J = -40^\circ$C to $+125^\circ$C, $1.8 \text{ V} \leq V_{DD} < 36 \text{ V}$, and pull-up resistors $R_{P1,2} = 100 \text{ k}\Omega$, unless otherwise noted. Typical values are at $T_J = 25^\circ$C and $V_{DD} = 12 \text{ V}$.

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>TEST CONDITIONS</th>
<th>MIN</th>
<th>TYP</th>
<th>MAX</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_{DD}$</td>
<td>Supply voltage range</td>
<td>1.8</td>
<td>36</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>$V_{(POR)}$</td>
<td>Power-on reset voltage$^{(1)}$</td>
<td>$V_{OL} \leq 0.2 \text{ V}$</td>
<td>0.8</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>$V_{IT-}(INA)$</td>
<td>INA pin negative input threshold voltage</td>
<td>$V_{DD} = 1.8 \text{ V to 36 V}$</td>
<td>397</td>
<td>400</td>
<td>403</td>
</tr>
<tr>
<td>$V_{IT+}(INA)$</td>
<td>INA pin positive input threshold voltage</td>
<td>$V_{DD} = 1.8 \text{ V to 36 V}$</td>
<td>400</td>
<td>405.5</td>
<td>413</td>
</tr>
<tr>
<td>$V_{HYS(INA)}$</td>
<td>INA pin hysteresis voltage $\left(\text{HYS} = V_{IT+}(INA) - V_{IT-}(INA)\right)$</td>
<td>2</td>
<td>5.5</td>
<td>12</td>
<td>mV</td>
</tr>
<tr>
<td>$V_{IT-}(INB)$</td>
<td>INB pin negative input threshold voltage</td>
<td>$V_{DD} = 1.8 \text{ V to 36 V}$</td>
<td>387</td>
<td>394.5</td>
<td>400</td>
</tr>
<tr>
<td>$V_{IT+}(INB)$</td>
<td>INB pin positive input threshold voltage</td>
<td>$V_{DD} = 1.8 \text{ V to 36 V}$</td>
<td>397</td>
<td>400</td>
<td>403</td>
</tr>
<tr>
<td>$V_{HYS(INB)}$</td>
<td>INB pin hysteresis voltage $\left(\text{HYS} = V_{IT+}(INB) - V_{IT-}(INB)\right)$</td>
<td>2</td>
<td>5.2</td>
<td>12</td>
<td>mV</td>
</tr>
<tr>
<td>$V_{OL}$</td>
<td>Low-level output voltage</td>
<td>$V_{DD} = 1.8 \text{ V, } I_{OUT} = 3 \text{ mA}$</td>
<td>130</td>
<td>250</td>
<td>mV</td>
</tr>
<tr>
<td>$V_{OL}$</td>
<td>Low-level output voltage</td>
<td>$V_{DD} = 5 \text{ V, } I_{OUT} = 5 \text{ mA}$</td>
<td>150</td>
<td>250</td>
<td>mV</td>
</tr>
<tr>
<td>$I_{IN}$</td>
<td>Input current (at INA, INB pins)</td>
<td>$V_{DD} = 1.8 \text{ V and 36 V, } V_{INA}, V_{INB} = 6.5 \text{ V}$</td>
<td>$-25$</td>
<td>$+1$</td>
<td>$+25$</td>
</tr>
<tr>
<td>$I_{IN}$</td>
<td>Input current (at INA, INB pins)</td>
<td>$V_{DD} = 1.8 \text{ V and 36 V, } V_{INA}, V_{INB} = 0.1 \text{ V}$</td>
<td>$-15$</td>
<td>$+1$</td>
<td>$+15$</td>
</tr>
<tr>
<td>$I_{D(\text{leak})}$</td>
<td>Open-drain output leakage current</td>
<td>$V_{DD} = 1.8 \text{ V and 36 V, } V_{OUT} = 25 \text{ V}$</td>
<td>10</td>
<td>300</td>
<td>nA</td>
</tr>
<tr>
<td>$I_{DD}$</td>
<td>Supply current</td>
<td>$V_{DD} = 1.8 \text{ V - 36 V}$</td>
<td>8</td>
<td>11</td>
<td>μA</td>
</tr>
<tr>
<td>UVLO</td>
<td>Undervoltage lockout$^{(2)}$</td>
<td>$V_{DD}$ falling</td>
<td>1.3</td>
<td>1.5</td>
<td>1.7</td>
</tr>
</tbody>
</table>

$^{(1)}$ The lowest supply voltage ($V_{DD}$) at which output is active: $t_{r(VDD)} > 15 \mu$s/V. If less than $V_{(POR)}$, the output is undetermined.

$^{(2)}$ When $V_{DD}$ falls below UVLO, OUTA is driven low and OUTB goes to high impedance. The outputs cannot be determined if less than $V_{(POR)}$. 

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Product Folder Links: TPS3701
6.6 Timing Requirements

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>TEST CONDITION</th>
<th>MIN</th>
<th>TYP</th>
<th>MAX</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>$t_{pd(HL)}$ High-to-low propagation delay$^{(1)}$</td>
<td>$V_{DD} = 24$ V, ±10-mV input overdrive, $R_L = 100$ kΩ, $V_{OH} = 0.9 \times V_{DD}$, $V_{OL} = 250$ mV</td>
<td>9.9</td>
<td>µs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$t_{pd(LH)}$ Low-to-high propagation delay$^{(1)}$</td>
<td>$V_{DD} = 24$ V, ±10-mV input overdrive, $R_L = 100$ kΩ, $V_{OH} = 0.9 \times V_{DD}$, $V_{OL} = 250$ mV</td>
<td>28.1</td>
<td>µs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$t_{d(start)}$ Startup delay</td>
<td>$V_{DD} = 5$ V</td>
<td>155</td>
<td>µs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$t_r$ Output rise time</td>
<td>$V_{DD} = 12$ V, 10-mV input overdrive, $R_L = 100$ kΩ, $C_L = 10$ pF, $V_O = (0.1$ to $0.9) \times V_{DD}$</td>
<td>2.7</td>
<td>µs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$t_f$ Output fall time</td>
<td>$V_{DD} = 12$ V, 10-mV input overdrive, $R_L = 100$ kΩ, $C_L = 10$ pF, $V_O = (0.9$ to $0.1) \times V_{DD}$</td>
<td>0.12</td>
<td>µs</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(1) High-to-low and low-to-high refers to the transition at the input pins (INA and INB).
(2) During power on, $V_{DD}$ must exceed 1.8 V for at least 150 µs (typical) before the output state reflects the input condition.

Figure 1. Timing Diagram
6.7 Typical Characteristics

At \( T_J = 25°C \) and \( V_{DD} = 12 \) V, unless otherwise noted.

![Graph 1: Supply Current vs Supply Voltage](D001)

![Graph 2: Minimum Pulse Duration vs Threshold Overdrive Voltage](D011)

![Graph 3: INA Positive Input Threshold Voltage \( (V_{IT+}(INA)) \) vs Temperature](D005)

![Graph 4: INA Negative Input Threshold Voltage \( (V_{IT-}(INA)) \) vs Temperature](D002)

![Graph 5: INB Positive Input Threshold Voltage \( (V_{IT+}(INB)) \) vs Temperature](D004)

![Graph 6: INB Negative Input Threshold Voltage \( (V_{IT-}(INB)) \) vs Temperature](D003)

The graphs illustrate the typical characteristics of the TPS3701, including supply current, minimum pulse duration, and input threshold voltages at various temperatures and supply voltages. The graphs show how these parameters change with temperature and supply voltage, which is crucial for understanding the device's performance under different conditions.

(1) Minimum pulse duration required to trigger output high-to-low transition. INA = negative spike below \( V_{IT+} \) and INB = positive spike above \( V_{IT+} \).
Typical Characteristics (continued)

At $T_J = 25°C$ and $V_{DD} = 12$ V, unless otherwise noted.

Figure 8. INA Positive Input Threshold Voltage ($V_{IT+}(INA)$) Distribution

Figure 9. INA Negative Input Threshold Voltage ($V_{IT-}(INA)$) Distribution

Figure 10. INB Positive Input Threshold Voltage ($V_{IT+}(INB)$) Distribution

Figure 11. INB Negative Input Threshold Voltage ($V_{IT-}(INB)$) Distribution

Figure 12. Propagation Delay vs Temperature (High-to-Low Transition at the Inputs)

Figure 13. Propagation Delay vs Temperature (Low-to-High Transition at the Inputs)
Typical Characteristics (continued)

At $T_J = 25^\circ$C and $V_{DD} = 12$ V, unless otherwise noted.

**Figure 14. Output Voltage Low vs Output Sink Current**

**Figure 15. Output Voltage Low vs Output Sink Current**

**Figure 16. Start-Up Delay vs Temperature**

**Figure 17. Start-Up Delay**

**Figure 18. Start-Up Delay**
7 Detailed Description

7.1 Overview

The TPS3701 combines two comparators (referred to as A and B) and a precision reference for over- and undervoltage detection. The TPS3701 features a wide supply voltage range (1.8 V to 36 V) and high-accuracy window threshold voltages of 400 mV (0.75% over temperature) with built-in hysteresis. The outputs are rated to 25 V and can sink up to 10 mA.

Set each input pin (INA, INB) to monitor any voltage above 0.4 V by using an external resistor divider network. Each input pin has very low input leakage current, allowing the use of large resistor dividers without sacrificing system accuracy. To form a window voltage detector, use the two input pins and three resistors (see the Window Voltage Detector Considerations section). In this configuration, the TPS3701 is designed to assert the output signals when the monitored voltage is within the window band. Each input can also be used independently. The relationship between the inputs and the outputs is shown in Table 1. Broad voltage thresholds are supported that enable the device to be used in a wide array of applications.

<table>
<thead>
<tr>
<th>CONDITION</th>
<th>OUTPUT</th>
<th>STATUS</th>
</tr>
</thead>
<tbody>
<tr>
<td>INA &gt; ( V_{IT-}^{\text{INA}} )</td>
<td>OUTA high</td>
<td>Output A high impedance</td>
</tr>
<tr>
<td>INA &lt; ( V_{IT+}^{\text{INA}} )</td>
<td>OUTA low</td>
<td>Output A asserted</td>
</tr>
<tr>
<td>INB &gt; ( V_{IT-}^{\text{INB}} )</td>
<td>OUTB low</td>
<td>Output B asserted</td>
</tr>
<tr>
<td>INB &lt; ( V_{IT+}^{\text{INB}} )</td>
<td>OUTB high</td>
<td>Output B high impedance</td>
</tr>
</tbody>
</table>

7.2 Functional Block Diagram

![Functional Block Diagram](image-url)
7.3 Feature Description

7.3.1 Inputs (INA, INB)

The TPS3701 combines two comparators with a precision reference voltage. Each comparator has one external input; the other input is connected to the internal reference. The rising threshold on INB and the falling threshold on INA are designed and trimmed to be equal to the reference voltage (400 mV). This configuration optimizes the device accuracy when used as a window voltage detector. Both comparators also have built-in hysteresis that proves immunity to noise and ensures stable operation.

The INA and INB inputs swings from ground to 1.7 V (7.0 V absolute maximum), regardless of the device supply voltage used. Although not required in most cases, it is good analog design practice to place a 1-nF to 10-nF bypass capacitor at the comparator input for noisy applications in order to reduce sensitivity to transient voltage changes on the monitored signal.

For comparator A, the corresponding output (OUTA) is driven to logic low when the input INA voltage drops below $V_{IT-(INA)}$. When the voltage exceeds $V_{IT+(INA)}$, OUTA goes to a high-impedance state; see Figure 1.

For comparator B, the corresponding output (OUTB) is driven to logic low when the voltage at input INB exceeds $V_{IT+(INB)}$. When the voltage drops below $V_{IT-(INB)}$, OUTB goes to a high-impedance state; see Figure 1. Together, these two comparators form a window voltage detector function as described in the Window Voltage Detector Considerations section.

7.3.2 Outputs (OUTA, OUTB)

In a typical TPS3701 application, the outputs are connected to a reset or enable input of the processor [such as a digital signal processor (DSP), application-specific integrated circuit (ASIC), or other processor type] or the outputs are connected to the enable input of a voltage regulator [such as a DC-DC converter or low-dropout regulator (LDO)].

The TPS3701 provides two open-drain outputs (OUTA and OUTB); use pull-up resistors to hold these lines high when the output goes to a high-impedance state. Connect pull-up resistors to the proper voltage rails to enable the outputs to be connected to other devices at correct interface voltage levels. The TPS3701 outputs can be pulled up to 25 V, independent of the device supply voltage. To ensure proper voltage levels, give some consideration when choosing the pull-up resistor values. The pull-up resistor value is determined by $V_{OL}$, output capacitive loading, and output leakage current ($I_{D(leak)}$). These values are specified in the Electrical Characteristics table. Use wired-OR logic to merge OUTA and OUTB into one logic signal.

Table 1 and the Inputs (INA, INB) section describe how the outputs are asserted or high impedance. See Figure 1 for a timing diagram that describes the relationship between threshold voltages and the respective output.

7.4 Device Functional Modes

7.4.1 Normal Operation ($V_{DD} > UVLO$)

When the voltage on VDD is greater than 1.8 V for at least 155 µs, the OUTA and OUTB signals correspond to the voltage on INA and INB as listed in Table 1.

7.4.2 Undervoltage Lockout ($V_{(POR)} < V_{DD} < UVLO$)

When the voltage on VDD is less than the device UVLO voltage, and greater than the power-on-reset voltage, $V_{(POR)}$, the OUTA and OUTB signals are asserted and high impedance, respectively, regardless of the voltage on INA and INB.

7.4.3 Power-On-Reset ($V_{DD} < V_{(POR)}$)

When the voltage on VDD is lower than the required voltage to internally pull the asserted output to GND ($V_{(POR)}$), both outputs are in a high-impedance state.
8 Application and Implementation

NOTE
Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI’s customers are responsible for determining suitability of components for their purposes. Customers should validate and test their design implementation to confirm system functionality.

8.1 Application Information

The TPS3701 is used as a precision dual-voltage detector in several different configurations. The monitored voltage (V\text{MON}), VDD voltage, and output pull-up voltage can be independent voltages or connected in any configuration. The following sections show the connection configurations and the voltage limitations for each configuration.

8.1.1 Window Voltage Detector Considerations

The inverting and noninverting configuration of the comparators forms a window voltage detector circuit using a resistor divider network, as shown in Figure 19 and Figure 20. The input pins can monitor any system voltage above 400 mV with the use of a resistor divider network. INA and INB monitor for undervoltage and overvoltage conditions, respectively.

![Figure 19. Window Voltage Detector Block Diagram](image)

![Figure 20. Window Voltage Detector Timing Diagram](image)
Application Information (continued)

The TPS3701 flags the overvoltage or undervoltage condition with the greatest accuracy. The highest accuracy threshold voltages are \( V_{\text{IT}-(\text{INA})} \) and \( V_{\text{IT}+(\text{INB})} \), and correspond with the falling undervoltage flag, and the rising overvoltage flag, respectively. These thresholds represent the accuracy when the monitored voltage is within the valid window (both OUTA and OUTB are in a high-impedance state), and correspond to the \( V_{\text{MON(UV)}} \) and \( V_{\text{MON(OV)}} \) trigger voltages, respectively. If the monitored voltage is outside of the valid window (\( V_{\text{MON}} \) is less than the undervoltage limit, \( V_{\text{MON(UV)}} \), or greater than overvoltage limit, \( V_{\text{MON(OV)}} \)), then the input threshold voltages to re-enter the valid window are \( V_{\text{IT}+(\text{INA})} \) or \( V_{\text{IT}-(\text{INB})} \), and correspond with the \( V_{\text{MON(UV)_HYS}} \) and \( V_{\text{MON(OV)_HYS}} \) monitored voltages, respectively.

The resistor divider values and target threshold voltage can be calculated by using Equation 1 through Equation 4:

\[
R_{\text{TOTAL}} = R_1 + R_2 + R_3
\]  

Choose an \( R_{\text{TOTAL}} \) value so that the current through the divider is approximately 100 times higher than the input current at the INA and INB pins. Resistors with high values minimize current consumption; however, the input bias current degrades accuracy if the current through the resistors is too low. See application report \textit{SLVA450, Optimizing Resistor Dividers at a Comparator Input} (SLVA450), for details on sizing input resistors.

\( R_3 \) is determined by Equation 2:

\[
R_3 = \frac{R_{\text{TOTAL}}}{V_{\text{MON(OV)}}} \cdot V_{\text{IT}+(\text{INB})}
\]

where

- \( V_{\text{MON(OV)}} \) is the target voltage at which an overvoltage condition is detected.  

(2)

\( R_2 \) is determined by either Equation 3 or Equation 4:

\[
R_2 = \left[ \frac{R_{\text{TOTAL}}}{V_{\text{MON(UV)_HYS}}} \cdot V_{\text{IT}-(\text{INA})} \right] - R_3
\]

where

- \( V_{\text{MON(UV)_HYS}} \) is the target voltage at which an undervoltage condition is removed as \( V_{\text{MON}} \) rises.  

(3)

\[
R_2 = \left[ \frac{R_{\text{TOTAL}}}{V_{\text{MON(UV)}}} \cdot V_{\text{IT}-(\text{INB})} \right] - R_3
\]

where

- \( V_{\text{MON(UV)}} \) is the target voltage at which an undervoltage condition is detected.  

(4)

8.1.2 Input and Output Configurations

Figure 21 to Figure 24 show examples of the various input and output configurations.
Application Information (continued)

Figure 21. Interfacing to Voltages Other than $V_{DD}$

Figure 22. Monitoring the Same Voltage as $V_{DD}$
Application Information (continued)

NOTE: The inputs can monitor a voltage higher than \( V_{DD} \) (max) with the use of an external resistor divider network.

**Figure 23. Monitoring a Voltage Other than \( V_{DD} \)**

NOTE: In this case, OUTA is driven low when an undervoltage condition is detected at the 5-V rail and OUTB is driven low when an overvoltage condition is detected at the 12-V rail.

**Figure 24. Monitoring Overvoltage for One Rail and Undervoltage for a Different Rail**

### 8.1.3 Immunity to Input Pin Voltage Transients

The TPS3701 is immune to short voltage transient spikes on the input pins. Sensitivity to transients depends on both transient duration and amplitude; see **Figure 3, Minimum Pulse Duration vs Threshold Overdrive Voltage**.
8.2 Typical Application

![Diagram of 24-V, 10% Window Voltage Detector](image)

Figure 25. 24-V, 10% Window Voltage Detector

8.2.1 Design Requirements

Table 2 lists the design parameters for this example.

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>DESIGN REQUIREMENT</th>
<th>DESIGN RESULT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monitored voltage</td>
<td>24-V nominal, rising (V\textsubscript{MON(OV)}) and falling (V\textsubscript{MON(UV)}) threshold ±10% nominal (26.4 V and 21.6 V, respectively)</td>
<td>V\textsubscript{MON(OV)} = 26.4 V ±2.7%, V\textsubscript{MON(UV)} = 21.6 V ±2.7%</td>
</tr>
<tr>
<td>Output logic voltage</td>
<td>3.3-V CMOS</td>
<td>3.3-V CMOS</td>
</tr>
<tr>
<td>Maximum current consumption</td>
<td>30 µA</td>
<td>24 µA</td>
</tr>
</tbody>
</table>

8.2.2 Detailed Design Procedure

1. Determine the minimum total resistance of the resistor network necessary to achieve the current consumption specification by using Equation 1. For this example, the current flow through the resistor network was chosen to be 13 µA; a lower current can be selected. However, take care to avoid leakage currents that are artifacts of the manufacturing process. Leakage currents significantly impact the accuracy if they are greater than 1% of the resistor network current.

   \[ R_{\text{TOTAL}} = \frac{V_{\text{MON(OV)}}}{I} = \frac{26.4 \text{ V}}{13 \mu\text{A}} = 2.03 \text{ MΩ} \]

   where
   
   - \( V_{\text{MON(OV)}} \) is the target voltage at which an overvoltage condition is detected as \( V_{\text{MON}} \) rises.
   - \( I \) is the current flowing through the resistor network.

2. After \( R_{\text{TOTAL}} \) is determined, \( R_3 \) can be calculated using Equation 6. Select the nearest 1% resistor value for \( R_3 \). In this case, 30.9 kΩ is the closest value.

   \[ R_3 = \frac{R_{\text{TOTAL}} \cdot V_{\text{IT+(INB)}}}{V_{\text{MON(OV)}}} = \frac{2.03 \text{ MΩ}}{26.4 \text{ V}} \cdot 0.4 \text{ V} = 30.7 \text{ kΩ} \]

3. Use Equation 7 to calculate \( R_2 \). Select the nearest 1% resistor value for \( R_2 \). In this case, 6.81 kΩ is the closest value.

   \[ R_2 = \frac{R_{\text{TOTAL}} \cdot V_{\text{IT-(INA+)}}}{V_{\text{MON(UV)}}} = \frac{2.03 \text{ MΩ}}{21.6 \text{ V}} \cdot 0.4 \text{ V} - 30.9 \text{ kΩ} = 6.69 \text{ kΩ} \]

4. Use Equation 8 to calculate \( R_1 \). Select the nearest 1% resistor value for \( R_1 \). In this case, 2 MΩ is the closest value.
\[ R_1 = R_{\text{TOTAL}} - R_2 - R_3 = 2.03 \, \text{M}\Omega - 6.81 \, \text{k}\Omega - 30.9 \, \text{k}\Omega = 1.99 \, \text{M}\Omega \]  

(8)

5. The worst-case tolerance can be calculated by referring to Equation 13 in application report *Optimizing Resistor Dividers at a Comparator Input* (SLVA450). An example of the rising threshold error, \( V_{\text{MON(OV)}} \), is given in Equation 9:

\[
\% \text{ACC} = \% \text{TOL}(V_{\text{IT+(INB)}}) + 2 \cdot \left(1 - \frac{V_{\text{IT+(INB)}}}{V_{\text{MON(OV)}}} \right) \cdot \% \text{TOL}_R = 0.75 \% + 2 \cdot \left(1 - \frac{0.4}{26.4} \right) \cdot 1\% = 2.72 \%
\]

where

- \% TOL\((V_{\text{IT+(INB)}})\) is the tolerance of the INB positive threshold.
- \% ACC is the total tolerance of the \( V_{\text{MON(OV)}} \) voltage.
- \% TOL\(_R\) is the tolerance of the resistors selected.  

(9)

6. When the outputs switch to the high-Z state, the rise time of the OUTA or OUTB node depends on the pull-up resistance and the capacitance on the node. Choose pull-up resistors that satisfy the downstream timing requirements; 100-kΩ resistors are a good choice for low-capacitive loads.

8.2.3 Application Curve

![Diagram](image)

Figure 26. 24-V Window Monitor Output Response
9 Power Supply Recommendations

The TPS3701 has a 40-V absolute maximum rating on the VDD pin, with a recommended operating condition of 36 V. If the voltage supply that is providing power to VDD is susceptible to any large voltage transient that may exceed 40 V, or if the supply exhibits high voltage slew rates greater than 1 V/µs, take additional precautions. Place an RC filter between the supply and VDD to filter any high-frequency transient surges on the VDD pin. A 100-Ω resistor and 0.01-µF capacitor is required in these cases, as shown in Figure 27.

![Figure 27. Using an RC Filter to Remove High-Frequency Disturbances on VDD](image-url)
10 Layout

10.1 Layout Guidelines

- Place R₁, R₂, and R₃ close to the device to minimize noise coupling into the INA and INB nodes.
- Place the VDD decoupling capacitor close to the device.
- Avoid using long traces for the VDD supply node. The VDD capacitor (CᵥDD), along with parasitic inductance from the supply to the capacitor, may form an LC tank and create ringing with peak voltages above the maximum VDD voltage. If this is unavoidable, see Figure 27 for an example of filtering VDD.

10.2 Layout Example

Figure 28. Recommended Layout
11 Device and Documentation Support

11.1 Documentation Support

11.1.1 Related Documentation
For related documentation see the following application reports and user guide (available through the TI website):

- Application report *Using the TPS3700 as a negative rail over- and undervoltage detector* (SLVA600).
- Application report *Optimizing resistor dividers at a comparator input* (SLVA450).
- User guide *TPS3700EVM-114 Evaluation module* (SLVU683).

11.2 Receiving Notification of Documentation Updates
To receive notification of documentation updates, navigate to the device product folder on ti.com. In the upper right corner, click on Alert me to register and receive a weekly digest of any product information that has changed. For change details, review the revision history included in any revised document.

11.3 Community Resources
The following links connect to TI community resources. Linked contents are provided “AS IS” by the respective contributors. They do not constitute TI specifications and do not necessarily reflect TI’s views; see TI’s Terms of Use.

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**Design Support**  *TI’s Design Support*  Quickly find helpful E2E forums along with design support tools and contact information for technical support.

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11.5 Electrostatic Discharge Caution
This integrated circuit can be damaged by ESD. Texas Instruments recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

11.6 Glossary
*SLYZ022 — TI Glossary.*
This glossary lists and explains terms, acronyms, and definitions.

12 Mechanical, Packaging, and Orderable Information
The following pages include mechanical, packaging, and orderable information. This information is the most current data available for the designated devices. This data is subject to change without notice and revision of this document. For browser-based versions of this data sheet, refer to the left-hand navigation.
**PACKAGING INFORMATION**

<table>
<thead>
<tr>
<th>Orderable Device</th>
<th>Status (1)</th>
<th>Package Type</th>
<th>Package Drawing</th>
<th>PIns</th>
<th>Package Qty</th>
<th>Eco Plan (2)</th>
<th>Lead finish/ Ball material</th>
<th>MSL Peak Temp (3)</th>
<th>Op Temp (°C)</th>
<th>Device Marking (4/5)</th>
<th>Samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>TPS3701DDCR</td>
<td>ACTIVE</td>
<td>SOT-23-THIN</td>
<td>DDC</td>
<td>6</td>
<td>3000</td>
<td>RoHS &amp; Green</td>
<td>NIPDAU</td>
<td>Level-2-260C-1 YEAR</td>
<td>-40 to 125</td>
<td>ZABO</td>
<td>Samples</td>
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<td>DDC</td>
<td>6</td>
<td>250</td>
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<td>-40 to 125</td>
<td>ZABO</td>
<td>Samples</td>
</tr>
</tbody>
</table>

(1) The marketing status values are defined as follows:
- **ACTIVE**: Product device recommended for new designs.
- **LIFEBUY**: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.
- **NRND**: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.
- **PREVIEW**: Device has been announced but is not in production. Samples may or may not be available.
- **OBSOLETE**: TI has discontinued the production of the device.

(2) **RoHS**: TI defines "RoHS" to mean semiconductor products that are compliant with the current EU RoHS requirements for all 10 RoHS substances, including the requirement that RoHS substance do not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, "RoHS" products are suitable for use in specified lead-free processes. TI may reference these types of products as "Pb-Free".

**RoHS Exempt**: TI defines "RoHS Exempt" to mean products that contain lead but are compliant with EU RoHS pursuant to a specific EU RoHS exemption.

**Green**: TI defines "Green" to mean the content of Chlorine (Cl) and Bromine (Br) based flame retardants meet JS709B low halogen requirements of <=1000ppm threshold. Antimony trioxide based flame retardants must also meet the <=1000ppm threshold requirement.

(3) MSL, Peak Temp. - The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

(5) Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

(6) Lead finish/Ball material - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.

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### TAPE AND REEL INFORMATION

<table>
<thead>
<tr>
<th>Device</th>
<th>Package Type</th>
<th>Package Drawing</th>
<th>Pins</th>
<th>SPQ</th>
<th>Reel Diameter (mm)</th>
<th>Reel Width W1 (mm)</th>
<th>A0 (mm)</th>
<th>B0 (mm)</th>
<th>K0 (mm)</th>
<th>P1 (mm)</th>
<th>W (mm)</th>
<th>Pin 1 Quadrant</th>
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<td>8.0</td>
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<td>3.2</td>
<td>1.4</td>
<td>4.0</td>
<td>8.0</td>
<td>Q3</td>
</tr>
</tbody>
</table>

*All dimensions are nominal.

A0: Dimension designed to accommodate the component width
B0: Dimension designed to accommodate the component length
K0: Dimension designed to accommodate the component thickness
W: Overall width of the carrier tape
P1: Pitch between successive cavity centers

---

**TAPE DIMENSIONS**

- **A0**: Dimension designed to accommodate the component width
- **B0**: Dimension designed to accommodate the component length
- **K0**: Dimension designed to accommodate the component thickness
- **W**: Overall width of the carrier tape
- **P1**: Pitch between successive cavity centers

**QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE**

- **Q1**, **Q2**, **Q3**, **Q4**: Pocket Quadrants
- **Sprocket Holes**: User Direction of Feed

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*www.ti.com 7-Jan-2021*
### TAPE AND REEL BOX DIMENSIONS

*All dimensions are nominal*

<table>
<thead>
<tr>
<th>Device</th>
<th>Package Type</th>
<th>Package Drawing</th>
<th>Pins</th>
<th>SPQ</th>
<th>Length (mm)</th>
<th>Width (mm)</th>
<th>Height (mm)</th>
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</thead>
<tbody>
<tr>
<td>TPS3701DDCR</td>
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<td>213.0</td>
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<td>35.0</td>
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</tbody>
</table>
NOTES:

1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
NOTES: (continued)

4. Publication IPC-7351 may have alternate designs.
5. Solder mask tolerances between and around signal pads can vary based on board fabrication site.
NOTES: (continued)

6. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
7. Board assembly site may have different recommendations for stencil design.
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