TPS3701 36-V Window Comparator with Internal Reference for Over- and Undervoltage Detection

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 (typ)
- High Threshold Accuracy:
  - 0.75% Over Temperature
  - 0.25% (typ)
- Internal Hysteresis: 5.5 mV (typ)
- 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 comparator 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 comparator 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(1)

<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 datasheet.

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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4 Revision History

<table>
<thead>
<tr>
<th>DATE</th>
<th>REVISION</th>
<th>NOTES</th>
</tr>
</thead>
<tbody>
<tr>
<td>November 2014</td>
<td>*</td>
<td>Initial release</td>
</tr>
</tbody>
</table>
5 Pin Configuration and Functions

<table>
<thead>
<tr>
<th>PIN</th>
<th>NAME</th>
<th>NO.</th>
<th>I/O</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>GND</td>
<td>2</td>
<td>—</td>
<td></td>
<td>Ground</td>
</tr>
<tr>
<td>INA</td>
<td>3</td>
<td>I</td>
<td></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>I</td>
<td></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>O</td>
<td></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>O</td>
<td></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>I</td>
<td></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.

<table>
<thead>
<tr>
<th>VALUE</th>
<th>MIN</th>
<th>MAX</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>VDD</td>
<td>–0.3</td>
<td>+40</td>
<td>V</td>
</tr>
<tr>
<td>VOUTA, VOUTB</td>
<td>–0.3</td>
<td>+28</td>
<td>V</td>
</tr>
<tr>
<td>VINA, VINB</td>
<td>–0.3</td>
<td>+7</td>
<td>V</td>
</tr>
<tr>
<td>Current</td>
<td>40</td>
<td></td>
<td>mA</td>
</tr>
<tr>
<td>Temperature</td>
<td>–40</td>
<td>+125</td>
<td>°C</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 Handling Ratings

<table>
<thead>
<tr>
<th>VALUE</th>
<th>MIN</th>
<th>MAX</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tstg</td>
<td>–65</td>
<td>+150</td>
<td>°C</td>
</tr>
<tr>
<td>V(ESD)</td>
<td>–2000</td>
<td>+2000</td>
<td>V</td>
</tr>
<tr>
<td></td>
<td>–500</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>VALUE</th>
<th>MIN</th>
<th>NOM</th>
<th>MAX</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>VDD</td>
<td>1.8</td>
<td></td>
<td>36</td>
<td>V</td>
</tr>
<tr>
<td>VIN</td>
<td>0</td>
<td>1.7</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>VOUT</td>
<td>0</td>
<td>25</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>IOUT</td>
<td>0</td>
<td>10</td>
<td>mA</td>
<td></td>
</tr>
<tr>
<td>TJ</td>
<td>–40</td>
<td>+25</td>
<td>+125</td>
<td>°C</td>
</tr>
</tbody>
</table>

6.4 Thermal Information

<table>
<thead>
<tr>
<th>THERMAL METRIC(1)</th>
<th>TPS3701 DDC (SOT)</th>
<th>UNITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>RθJA</td>
<td>201.6</td>
<td>°C/W</td>
</tr>
<tr>
<td>RθJC(top)</td>
<td>47.8</td>
<td></td>
</tr>
<tr>
<td>RθJB</td>
<td>51.2</td>
<td></td>
</tr>
<tr>
<td>ψJT</td>
<td>0.7</td>
<td></td>
</tr>
<tr>
<td>ψJB</td>
<td>50.8</td>
<td></td>
</tr>
<tr>
<td>RθJC(bot)</td>
<td>N/A</td>
<td></td>
</tr>
</tbody>
</table>

(1) For more information about traditional and new thermal metrics, see the 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 pullup 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>$V_{DD}$ Supply voltage range</td>
<td></td>
<td>1.8</td>
<td>36</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>$V_{(POR)}$ Power-on reset voltage(\text{(1)})</td>
<td>$V_{OL} \leq 0.2 \text{ V}$</td>
<td>0.8</td>
<td></td>
<td>0.8</td>
<td>V</td>
</tr>
<tr>
<td>$V_{IT-\text{(INA)}}$ INA pin negative input threshold voltage</td>
<td>$V_{DD} = 1.8 \text{ V} \text{ to } 36 \text{ V}$</td>
<td>397</td>
<td>400</td>
<td>403</td>
<td>mV</td>
</tr>
<tr>
<td>$V_{IT+\text{(INA)}}$ INA pin positive input threshold voltage</td>
<td>$V_{DD} = 1.8 \text{ V} \text{ to } 36 \text{ V}$</td>
<td>400</td>
<td>405.5</td>
<td>413</td>
<td>mV</td>
</tr>
<tr>
<td>$V_{HYS\text{(INA)}}$ INA pin hysteresis voltage (HYS = $V_{IT+\text{(INA)}} - V_{IT-\text{(INA)}}$)</td>
<td></td>
<td>2</td>
<td>5.5</td>
<td>12</td>
<td>mV</td>
</tr>
<tr>
<td>$V_{IT-\text{(INB)}}$ INB pin negative input threshold voltage</td>
<td>$V_{DD} = 1.8 \text{ V} \text{ to } 36 \text{ V}$</td>
<td>387</td>
<td>394.5</td>
<td>400</td>
<td>mV</td>
</tr>
<tr>
<td>$V_{IT+\text{(INB)}}$ INB pin positive input threshold voltage</td>
<td>$V_{DD} = 1.8 \text{ V} \text{ to } 36 \text{ V}$</td>
<td>397</td>
<td>400</td>
<td>403</td>
<td>mV</td>
</tr>
<tr>
<td>$V_{HYS\text{(INB)}}$ INB pin hysteresis voltage (HYS = $V_{IT+\text{(INB)}} - V_{IT-\text{(INB)}}$)</td>
<td></td>
<td>2</td>
<td>5.2</td>
<td>12</td>
<td>mV</td>
</tr>
<tr>
<td>$V_{OL}$ 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></td>
<td>mV</td>
</tr>
<tr>
<td></td>
<td>$V_{DD} = 5 \text{ V}, I_{OUT} = 5 \text{ mA}$</td>
<td>150</td>
<td>250</td>
<td></td>
<td>mV</td>
</tr>
<tr>
<td>$I_{IN}$ Input current (at INA, INB pins)</td>
<td>$V_{DD} = 1.8 \text{ V} \text{ and } 36 \text{ V}, V_{INA}, V_{INB} = 6.5 \text{ V}$</td>
<td>$-25$</td>
<td>+1</td>
<td>$+15$</td>
<td>nA</td>
</tr>
<tr>
<td></td>
<td>$V_{DD} = 1.8 \text{ V} \text{ and } 36 \text{ V}, V_{INA}, V_{INB} = 0.1 \text{ V}$</td>
<td>$-15$</td>
<td>+1</td>
<td>$+15$</td>
<td>nA</td>
</tr>
<tr>
<td>$I_{(leak)}$ Open-drain output leakage current</td>
<td>$V_{DD} = 1.8 \text{ V} \text{ and } 36 \text{ V}, V_{OUT} = 25 \text{ V}$</td>
<td>10</td>
<td>300</td>
<td></td>
<td>nA</td>
</tr>
<tr>
<td>$I_{DD}$ Supply current</td>
<td>$V_{DD} = 1.8 \text{ V} \text{ to } 36 \text{ V}$</td>
<td>8</td>
<td>11</td>
<td></td>
<td>µA</td>
</tr>
<tr>
<td>UVLO Undervoltage lockout(\text{(2)})</td>
<td>$V_{DD}$ falling</td>
<td>1.3</td>
<td>1.5</td>
<td>1.7</td>
<td>V</td>
</tr>
</tbody>
</table>

\(1\) The lowest supply voltage ($V_{DD}$) at which output is active; $t_{(VDD)} > 15 \mu\text{V/V}$. 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 $V_{(POR)}$. 
### 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>
</table>
| $t_{pd(HL)}$ (High-to-low propagation delay)

(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 (typ) before the output state reflects the input condition. |
| $V_{DD} = 24$ V, ±10-mV input overdrive, $R_L = 100$ kΩ, $V_{OH} = 0.9 \times V_{DD}$, $V_{OL} = 250$ mV | 9.9  | µs   |      |      |
| $t_{pd(LH)}$ (Low-to-high propagation delay)

(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 (typ) before the output state reflects the input condition. |
| $V_{DD} = 24$ V, ±10-mV input overdrive, $R_L = 100$ kΩ, $V_{OH} = 0.9 \times V_{DD}$, $V_{OL} = 250$ mV | 28.1 | µs   |      |      |
| $t_{d(start)}$ (Startup delay)

(2) During power on, $V_{DD}$ must exceed 1.8 V for at least 150 µs (typ) before the output state reflects the input condition. |
| $V_{DD} = 5$ V | 155 | µs |      |      |
| $t_r$ (Output rise time) |
| $V_{DD} = 12$ V, 10-mV input overdrive, $R_L = 100$ kΩ, $C_L = 10$ pF, $V_O = (0.1$ to $0.9) \times V_{DD}$ | 2.7  | µs  |      |      |
| $t_f$ (Output fall time) |
| $V_{DD} = 12$ V, 10-mV input overdrive, $R_L = 100$ kΩ, $C_L = 10$ pF, $V_O = (0.9$ to $0.1) \times V_{DD}$ | 0.12 | µs |      |      |

![Figure 1. Timing Diagram](image-url)
6.7 Typical Characteristics

At $T_J = 25^\circ C$ 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)

(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 $T_J = 25^\circ C$ 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. Startup Delay vs Temperature

Figure 17. Startup Delay

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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 comparator, use the two input pins and three resistors (see the Window Comparator 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+}(INA)</td>
<td>OUTA high</td>
<td>Output A high impedance</td>
</tr>
<tr>
<td>INA &lt; V_{IT-}(INA)</td>
<td>OUTA low</td>
<td>Output A asserted</td>
</tr>
<tr>
<td>INB &gt; V_{IT+}(INB)</td>
<td>OUTB low</td>
<td>Output B asserted</td>
</tr>
<tr>
<td>INB &lt; V_{IT-}(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 comparator. Both comparators also have built-in hysteresis that proves immunity to noise and ensures stable operation.

The comparator 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-detection function as described in the Window Comparator 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 pullup resistors to hold these lines high when the output goes to a high-impedance state. Connect pullup 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 pullup resistor values. The pullup 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 supervisor in several different configurations. The monitored voltage (\(V_{\text{MON}}\)), VDD voltage, and output pullup 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 Comparator Considerations

The inverting and noninverting configuration of the comparators forms a window-comparator detection 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 Comparator Block Diagram

Figure 20. Window Comparator Timing Diagram
Application Information (continued)

The TPS3701 flags the overvoltage or undervoltage condition with the greatest accuracy. The highest accuracy threshold voltages are $V_{IT-(INA)}$ and $V_{IT+(INB)}$, 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 $V_{MON(UV)}$ and $V_{MON(OV)}$ trigger voltages, respectively. If the monitored voltage is outside of the valid window ($V_{MON}$ is less than the undervoltage limit, $V_{MON(UV)}$, or greater than overvoltage limit, $V_{MON(OV)}$), then the input threshold voltages to re-enter the valid window are $V_{IT+(INA)}$ or $V_{IT-(INB)}$, and correspond with the $V_{MON(UV_HYS)}$ and $V_{MON(OV_HYS)}$ monitored voltages, respectively.

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

$$R_{TOTAL} = R_1 + R_2 + R_3$$

(1)

Choose an $R_{TOTAL}$ 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 SLVA450, Optimizing Resistor Dividers at a Comparator Input, for details on sizing input resistors.

$R_3$ is determined by Equation 2:

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

(2)

where

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

$R_2$ is determined by either Equation 3 or Equation 4:

$$R_2 = \left\{ \frac{R_{TOTAL}}{V_{MON(UV_HYS)}} \cdot V_{IT+(INA)} \right\} - R_3$$

(3)

where

- $V_{MON(UV_HYS)}$ is the target voltage at which an undervoltage condition is removed as $V_{MON}$ rises.

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

(4)

where

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

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

![Comparator Circuit Diagram]

Figure 25. 24-V, 10% Window Comparator

8.2.1 Design Requirements

Table 2. Design Parameters

<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_MON(OV)) and falling (V_MON(UV)) threshold ±10% nominal</td>
<td>V_MON(OV) = 26.4 V ±2.7%, V_MON(UV) = 21.6 V ±2.7%</td>
</tr>
<tr>
<td></td>
<td>(26.4 V and 21.6 V, respectively)</td>
<td></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, care should be taken 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.

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

   where
   
   • \( V_{MON(OV)} \) is the target voltage at which an overvoltage condition is detected as \( V_{MON} \) rises.
   
   • \( I \) is the current flowing through the resistor network. \hspace{5cm} (5)

2. After \( R_{TOTAL} \) 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.

   \[ R_3 = \frac{R_{TOTAL}}{V_{MON(OV)}} \times V_{IT(NB)} = \frac{2.03 \text{ M}\Omega}{26.4 \text{ V}} \times 0.4 \text{ V} = 30.7 \text{ k}\Omega \]

   \hspace{5cm} (6)

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.

   \[ R_2 = \frac{R_{TOTAL}}{V_{MON(UV)}} \times V_{IT(NA)} - R_3 = \frac{2.03 \text{ M}\Omega}{21.6 \text{ V}} \times 26.4 \text{ V} - 30.9 \text{ k}\Omega = 6.69 \text{ k}\Omega \]

   \hspace{5cm} (7)

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.

   \[ R_1 = R_{TOTAL} - R_2 - R_3 = 2.03 \text{ M}\Omega - 6.81 \text{ k}\Omega - 30.9 \text{ k}\Omega = 1.99 \text{ M}\Omega \]

   \hspace{5cm} (8)
5. The worst-case tolerance can be calculated by referring to Equation 13 in application report SLVA450, Optimizing Resistor Dividers at a Comparator Input. 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
- $\%\ \text{TOL}(V_{\text{IT+INB}})$ is the tolerance of the INB positive threshold.
- $\%\ \text{ACC}$ is the total tolerance of the $V_{\text{MON(OV)}}$ voltage.
- $\%\ \text{TOL}_R$ 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 pullup resistance and the capacitance on the node. Choose pullup resistors that satisfy the downstream timing requirements; 100-kΩ resistors are a good choice for low-capacitive loads.

8.2.3 Application Curves

![Figure 26. 24-V Window Monitor Output Response](image-url)
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.

![Diagram of RC Filter Circuit](image)

Figure 27. Using an RC Filter to Remove High-Frequency Disturbances on VDD
10 Layout

10.1 Layout Guidelines

- Place $R_1$, $R_2$, and $R_3$ 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 ($C_{VDD}$), 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

![Recommended Layout Diagram](image-url)

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 SLVA600—Using the TPS3700 as a Negative Rail Over- and Undervoltage Detector.
- Application report SLVA450—Optimizing Resistor Dividers at a Comparator Input.
- User guide SLVU683—TPS3700EVM-114 Evaluation Module.

11.2 Trademarks
All trademarks are the property of their respective owners.

11.3 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.

11.4 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</th>
<th>Package Type</th>
<th>Package Drawing</th>
<th>PIns</th>
<th>Package Qty</th>
<th>Eco Plan</th>
<th>Lead/Ball Finish</th>
<th>MSL Peak Temp</th>
<th>Op Temp (°C)</th>
<th>Device Marking</th>
<th>Samples</th>
</tr>
</thead>
<tbody>
<tr>
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<td>ACTIVE</td>
<td>SOT-23-THIN</td>
<td>DDC</td>
<td>6</td>
<td>3000</td>
<td>Green (RoHS &amp; no Sb/Br)</td>
<td>CU NIPDAU</td>
<td>Level-2-260C-1 YEAR</td>
<td>ZABO</td>
<td>Samples</td>
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<td>Level-2-260C-1 YEAR</td>
<td>ZABO</td>
<td>Samples</td>
<td></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) Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check [http://www.ti.com/productcontent](http://www.ti.com/productcontent) for the latest availability information and additional product content details.

**TBD:** The Pb-Free/Green conversion plan has not been defined.

**Pb-Free (RoHS):** TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.

**Pb-Free (RoHS Exempt):** This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.

**Green (RoHS & no Sb/Br):** TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material).

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

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TAPE AND REEL INFORMATION

*All dimensions are nominal.

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<th>SPQ</th>
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<th>A0 (mm)</th>
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<th>K0 (mm)</th>
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<td>1.4</td>
<td>4.0</td>
<td>8.0</td>
<td>Q3</td>
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**TAPE AND REEL BOX DIMENSIONS**

*All dimensions are nominal*

<table>
<thead>
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<th>Device</th>
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</table>
NOTES:
A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Body dimensions do not include mold flash or protrusion.
D. Falls within JEDEC MO-193 variation AA (6 pin).
NOTES:
A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Publication IPC-7351 is recommended for alternate designs.
D. Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Example stencil design based on a 50% volumetric metal load solder paste. Refer to IPC-7525 for other stencil recommendations.
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