TLV7011 and TLV7021 Micro-Package, Micro-Power, Low-Voltage Comparators

1 Features

- Ultra-Small X2SON Package (0.8 mm × 0.8 mm × 0.4 mm)
- Wide Supply Voltage Range of 1.4 V to 5.5 V
- Quiescent Supply Current of 5 µA
- Low Propagation Delay of 300 ns
- Rail-to-Rail Common-Mode Input Voltage
- Internal Hysteresis
- Push-Pull and Open-Drain Output Options
- No Phase Reversal for Overdriven Inputs
- –40°C to 125°C Operating Ambient Temperature

2 Applications

- Mobile Phones and Tablets
- Portable and Battery-Powered Devices
- IR Receivers
- Level Translators
- Threshold Detectors and Discriminators
- Window Comparators
- Zero-Crossing Detectors

3 Description

The TLV7011 is a single-channel, micro-power comparator that features low-voltage operation with rail-to-rail input capability. These comparators are available in an ultra-small, leadless package measuring 0.8 mm × 0.8 mm, making them applicable for space-critical designs like smartphones and other portable or battery-powered applications.

The TLV7011 and TLV7021 offer an excellent speed-to-power combination with a propagation delay of 300 ns and a quiescent supply current of 5 µA. This combination of fast response time at micropower enables power conscious systems to monitor and respond quickly to fault conditions. With an operating voltage range of 1.4 V to 5.5 V, these comparators are compatible with 3-V and 5-V systems.

These comparators also feature no output phase inversion with overdriven inputs and internal hysteresis. These features make this family of comparators well suited for precision voltage monitoring in harsh, noisy environments where slow-moving input signals must be converted into clean digital outputs.

The TLV7011 has a push-pull output stage capable of sinking and sourcing milliamps of current when controlling an LED or driving a capacitive load. The TLV7021 has an open-drain output stage that can be pulled beyond V_{CC}, making it appropriate for level translators and bipolar to single-ended converters.

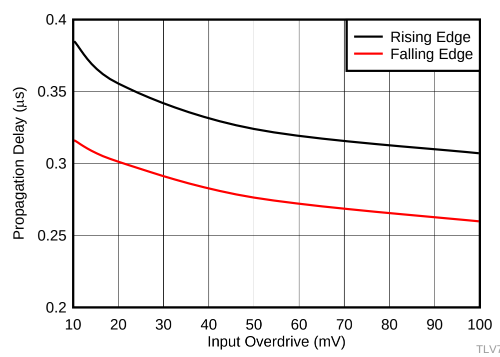
Device Information(1)

PART NUMBER	PACKAGE (PINS)	BODY SIZE (NOM)
TLV7011	X2SON (5)	0.80 mm × 0.80 mm
TLV7021		

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

X2SON Package vs SOT23 and US Dime

Propagation Delay vs. Overdrive (TLV7011)



T_A = 25°C, V_{CC} = 5 V, C_L = 15 pF

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4 Revision History

DATE	REVISION	NOTES
May 2017	*	Initial release.

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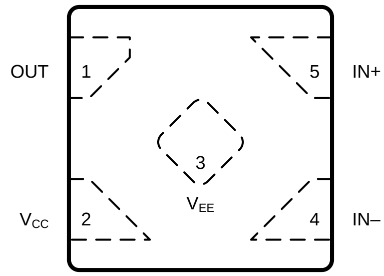
5 Pin Configuration and Functions

DPW Package
5-Pin X2SON
Top View



Not to scale

Pin Functions

PIN		I/O(1)	DESCRIPTION
NO.	NAME		
1	OUT	O	Output
2	V_{CC}	P	Positive (highest) power supply
3	V_{EE}	P	Negative (lowest) power supply
4	IN–	I	Inverting input
5	IN+	I	Noninverting input

(1) I = Input, O = Output, P = Power

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6 Specifications

6.1 Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted)[1]

		MIN	MAX	UNIT
Supply voltage ($V_S = V_{CC} – V_{EE}$)			6	V
Input pins (IN+, IN–)[2]		V_{EE} – 0.3	V_{CC} + 0.3	V
Current into Input pins (IN+, IN–)[2]			±10	mA
Output (OUT)	TLV7011	V_{EE} – 0.3	V_{CC} + 0.3	V
	TLV7021	V_{EE} – 0.3	6	
Output short-circuit duration[3]			10	s
Junction temperature, T_J			150	°C
Storage temperature, T_{stg}		–65	150	°C

(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) Input terminals are diode-clamped to the power-supply rails. Input signals that can swing more than 0.3V beyond the supply rails must be current-limited to 10mA or less.
(3) Short-circuit to ground, one comparator per package.

6.2 ESD Ratings

			VALUE	UNIT
$V_{(ESD)}$	Electrostatic discharge	Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001[1]	±1000	V
		Charged-device model (CDM), per JEDEC specification JESD22-C101[2]	±250	

(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 free-air temperature range (unless otherwise noted)

	MIN	NOM	MAX	UNIT
Supply voltage ($V_S = V_{CC} – V_{EE}$)	1.4		5.5	V
Ambient temperature, T_A	–40		125	°C

6.4 Thermal Information

THERMAL METRIC[1]		TLV7011/TLV7021	UNIT
		DPW (X2SON)	
		5 PINS	
$R_{\theta JA}$	Junction-to-ambient thermal resistance	497.5	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	275.5	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	372.2	°C/W
ψ_{JT}	Junction-to-top characterization parameter	55.5	°C/W
ψ_{JB}	Junction-to-board characterization parameter	370.3	°C/W
$R_{\theta JC(bot)}$	Junction-to-case (bottom) thermal resistance	165.1	°C/W

(1) For more information about traditional and new thermal metrics, see the *Semiconductor and IC Package Thermal Metrics* application report.

6.5 Electrical Characteristics

V_S = 1.4 V to 5 V, V_{CM} = V_S / 2; minimum and maximum values are at T_A = –40°C to +125°C (unless otherwise noted). Typical values are at T_A = 25°C.

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
V_{IO}	Input offset voltage	V_S = 1.4 V and 5 V, V_{CM} = V_S / 2		±3	±8	mV
V_{HYS}	Hysteresis	V_S = 1.4 V and 5 V, V_{CM} = V_S / 2	2.5	6	14	mV
V_{CM}	Common-mode voltage range		V_{EE}		V_{CC} + 0.1	V
I_B	Input bias current			5		pA
I_{OS}	Input offset current			1		pA
V_{OH}	Output voltage high (for TLV7011 only)	V_S = 5 V, I_O = 3 mA	4.7	4.8		V
V_{OL}	Output voltage low	V_S = 5 V, I_O = 3 mA		120	220	mV
I_{LKG}	Open-drain output leakage current (TLV7021 only)	V_S = 5 V, V_{ID} = +0.1 V (output high), V_{PULLUP} = V_{CC}		100		pA
CMRR	Common-mode rejection ratio	V_{EE} < V_{CM} < V_{CC}, V_S = 5 V		70		dB
PSRR	Power supply rejection ratio	V_S = 1.4 V to 5 V, V_{CM} = V_S / 2		78		dB
I_{SC}	Short-circuit current	V_S = 5 V, sourcing		65		mA
		V_S = 5 V, sinking		44		
I_{CC}	Supply current	V_S = 1.4 V, no load, V_{ID} = –0.1 V (Output Low)		5	10	µA

6.6 Switching Characteristics

Typical values are at T_A = 25°C, V_{CC} = 5 V, V_{CM} = 2.5 V; C_L = 15 pF, input overdrive = 100 mV (unless otherwise noted).

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
t_{PHL}	Propagation delay time, high-to-low (R_P = 2.5 kΩ TLV7021 only)	Midpoint of input to midpoint of output		0.3		µs
t_{PLH}	Propagation delay time, low-to-high (R_P = 2.5 kΩ TLV7021 only)	Midpoint of input to midpoint of output		0.35		µs
t_R	Rise time (for TLV7011 only)	10% to 90%		5		ns
t_F	Fall time	10% to 90%		5		ns
t_{ON}	Power-up time			20		µs

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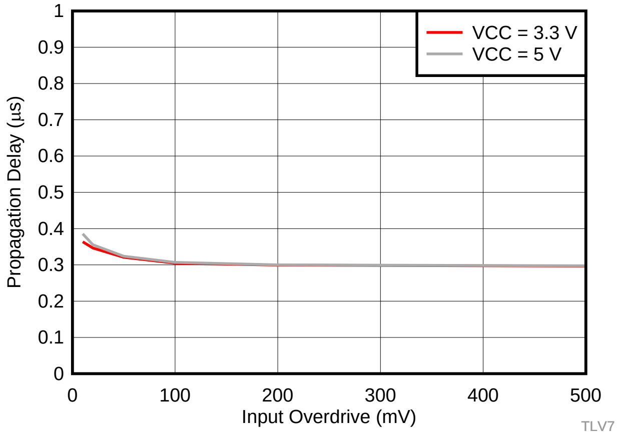
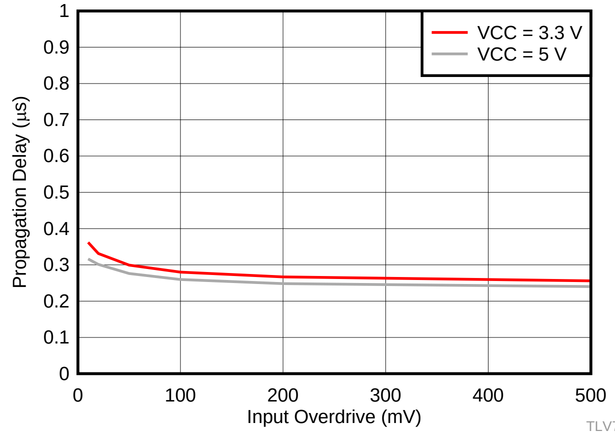
6.7 Typical Characteristics

T_A = 25°C, V_S = 5 V, V_S / 2 = 2.5 V



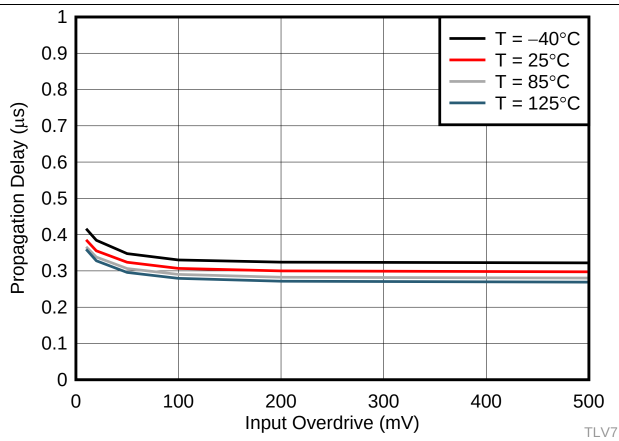
T_A = 25°C, V_{CM} = V_{CC}/2, C_L = 15 pF

Figure 1. TLV7011 Propagation Delay (L-H) vs. Input Overdrive



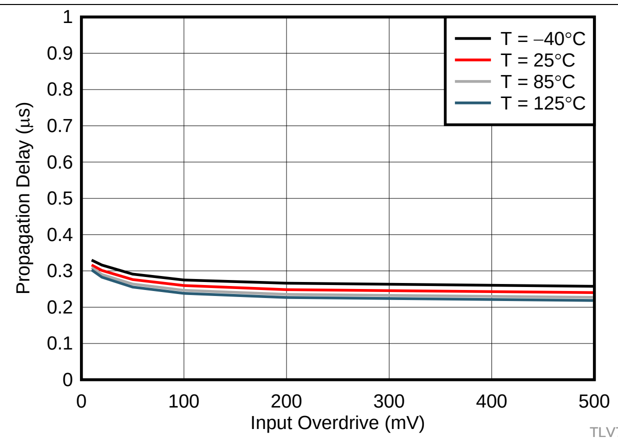
T_A = 25°C, V_{CM} = V_{CC}/2, C_L = 15 pF

Figure 2. TLV7011 Propagation Delay (H-L) vs. Input Overdrive



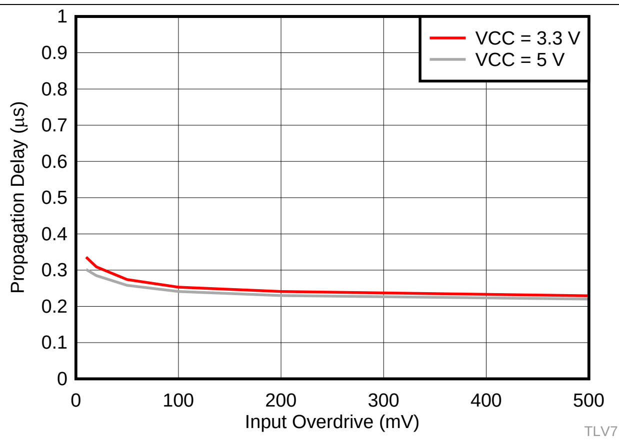
V_{CC} = 5 V, V_{CM} = V_{CC}/2, C_L = 15 pF

Figure 3. TLV7011 Propagation Delay (L-H) vs. Input Overdrive



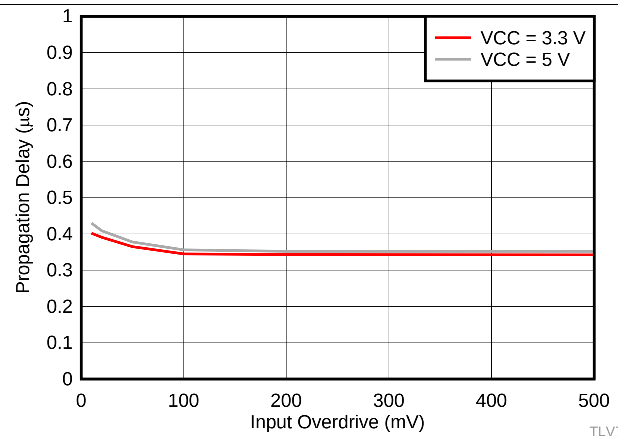
V_{CC} = 5 V, V_{CM} = V_{CC}/2, C_L = 15 pF

Figure 4. TLV7011 Propagation Delay (H-L) vs. Input Overdrive



T_A = 25°C, V_{CM} = V_{CC}/2, C_L = 15 pF

Figure 5. TLV7021 Propagation Delay (L-H) vs. Input Overdrive

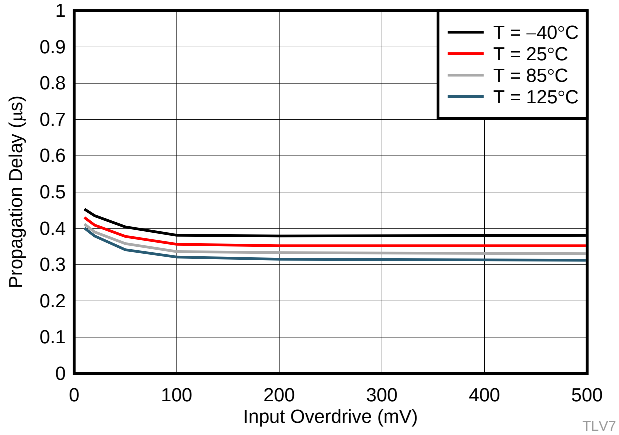


T_A = 25°C, V_{CM} = V_{CC}/2, C_L = 15 pF

Figure 6. TLV7021 Propagation Delay (H-L) vs. Input Overdrive

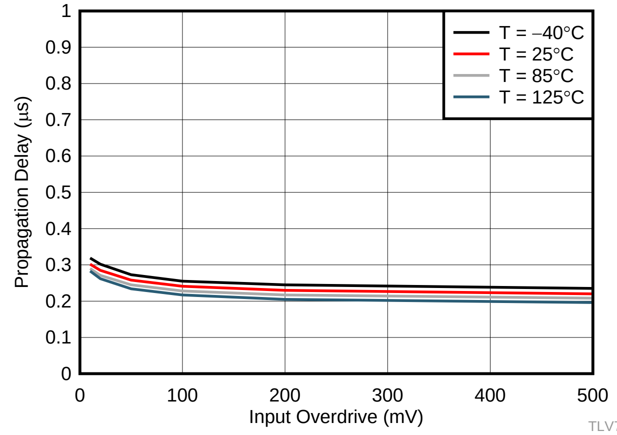
Typical Characteristics (continued)

T_A = 25°C, V_S = 5 V, V_S / 2 = 2.5 V



V_{CC} = 5 V, V_{CM} = V_{CC}/2, C_L = 15 pF

Figure 7. TLV7021 Propagation Delay (L-H) vs. Input Overdrive



V_{CC} = 5 V, V_{CM} = V_{CC}/2, C_L = 15 pF

Figure 8. TLV7021 Propagation Delay (H-L) vs. Input Overdrive

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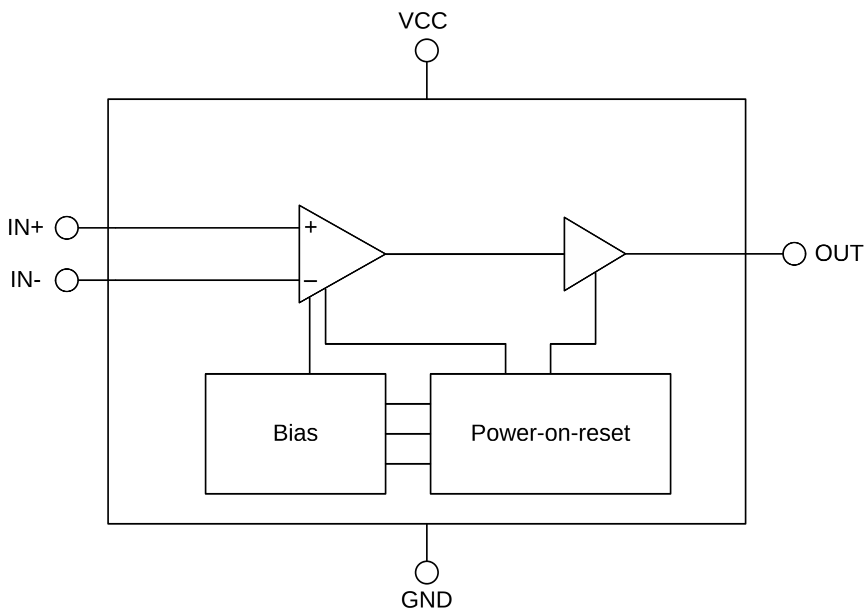
7 Detailed Description

7.1 Overview

The TLV7011 and TLV7021 devices are single-channel, micro-power comparators with push-pull and open-drain outputs. Operating from 1.4 V to 5.5 V and consuming only 5 µA, the TLV7011 and TLV7021 are ideally suited for portable and industrial applications. The TLV7011 and TLV7021 are available in an ultra-small X2SON package (0.8 × 0.8 mm) to offer significant board space saving in space-challenged designs.

7.2 Functional Block Diagram



7.3 Feature Description

The TLV7011 and TLV7021 devices are micro-power comparators that are capable of operating at low voltages. The TLV7011 and TLV7021 feature a rail-to-rail input stage capable of operating up to 100 mV beyond the VCC power supply rail. The TLV7011 and TLV7021 also feature a push-pull and open-drain output stage with internal hysteresis.

7.4 Device Functional Modes

The TLV7011 and TLV7021 have two functional modes. The first functional mode is called Power-on-Reset (POR) Mode. While the power supply (V_S) is ramping up to the recommended operating voltage or ramping down, the POR circuitry will hold the output of the comparator at V_{EE}. The second functional mode is called Normal Mode. Normal Mode is defined as the mode when V_S is greater than or equal to the recommended operating voltage. During Normal Mode, the comparator output reflects the state of the differential input (VID).

7.4.1 Inputs

The TLV7011 and TLV7021 input common-mode extends from V_{EE} to 100 mV above V_{CC}. The differential input voltage (V_{ID}) can be any voltage within these limits. No phase-inversion of the comparator output will occur when the input pins exceed V_{CC} and V_{EE}.

The input bias current is typically 1 pA for input voltages between V_{CC} and V_{EE}. The comparator inputs are protected from overvoltage and undervoltage by internal diodes connected to V_{CC} and V_{EE}. As the input voltage exceeds V_{CC} and V_{EE}, the protection diodes become forward biased and begin to conduct causing the input bias current to increase exponentially.

Device Functional Modes (continued)

7.4.2 Internal Hysteresis

The device hysteresis transfer curve is shown in Figure 9. This curve is a function of three components: V_{TH}, V_{OS}, and V_{HYST}:

- V_{TH} is the actual set voltage or threshold trip voltage.
- V_{OS} is the internal offset voltage between V_{IN+} and $V_{IN–}$. This voltage is added to V_{TH} to form the actual trip point at which the comparator must respond to change output states.
- V_{HYST} is the internal hysteresis (or trip window) that is designed to reduce comparator sensitivity to noise (6 mV for the TLV3691).

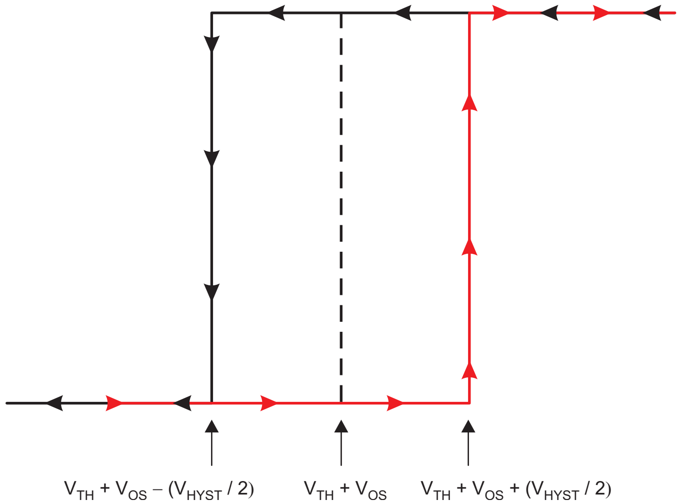


Figure 9. Hysteresis Transfer Curve

7.4.3 Output

The TLV7011 features a push-pull output stage eliminating the need for an external pullup resistor. On the other hand, the TLV7021 features an open-drain output stage enabling the output logic levels to be compatible with the receiving device.

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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 TLV7011 and TLV7021 are micro-power comparators with nano-power response time. The comparators have a rail-to-rail input stage that can monitor signals beyond the positive supply rail with integrated hysteresis. When higher levels of hysteresis are required, positive feedback can be externally added. The push-pull output stage of the TLV7011 is optimal for reduced power budget applications and features no shoot-through current. When level shifting or wire-ORing of the comparator outputs is needed, the TLV7021 with its open-drain output stage is well suited to meet the system needs. In either case, the wide operating voltage range, low quiescent current, and micro-package of the TLV7011 and TLV7021 make these comparators excellent candidates for battery-operated and portable, handheld designs.

8.1.1 Inverting Comparator With Hysteresis for TLV7011

The inverting comparator with hysteresis requires a three-resistor network that is referenced to the comparator supply voltage (V_{CC}), as shown in Figure 10. When V_{IN} at the inverting input is less than V_A, the output voltage is high (for simplicity, assume V_O switches as high as V_{CC}). The three network resistors can be represented as R1 || R3 in series with R2. Equation 1 defines the high-to-low trip voltage (V_{A1}).

$$V_{A1} = V_{CC} \times \frac{R2}{(R1 \,||\, R3) + R2} \quad (1)$$

When V_{IN} is greater than V_A, the output voltage is low, very close to ground. In this case, the three network resistors can be presented as R2 || R3 in series with R1. Use Equation 2 to define the low to high trip voltage (V_{A2}).

$$V_{A2} = V_{CC} \times \frac{R2 \,||\, R3}{R1 + (R2 \,||\, R3)} \quad (2)$$

Equation 3 defines the total hysteresis provided by the network.

$$\Delta V_A = V_{A1} - V_{A2} \quad (3)$$

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Application Information (continued)

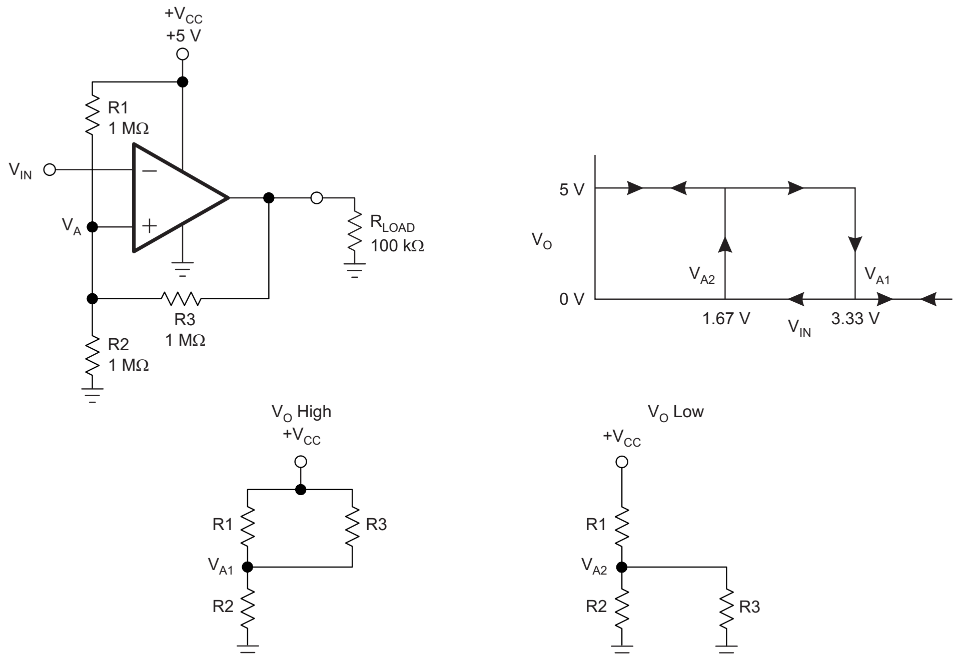

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Figure 10. TLV7011 in an Inverting Configuration With Hysteresis

8.1.2 Noninverting Comparator With Hysteresis for TLV7011

A noninverting comparator with hysteresis requires a two-resistor network, as shown in Figure 11, and a voltage reference (V_{REF}) at the inverting input. When V_{IN} is low, the output is also low. For the output to switch from low to high, V_{IN} must rise to V_{IN1}. Use Equation 4 to calculate V_{IN1}.

$$V_{IN1} = R1 \times \frac{V_{REF}}{R2} + V_{REF} \tag{4}$$

When V_{IN} is high, the output is also high. For the comparator to switch back to a low state, V_{IN} must drop to V_{IN2} such that V_A is equal to V_{REF}. Use Equation 5 to calculate V_{IN2}.

$$V_{IN2} = \frac{V_{REF}\,(R1 + R2) - V_{CC} \times R1}{R2} \tag{5}$$

The hysteresis of this circuit is the difference between V_{IN1} and V_{IN2}, as shown in Equation 6.

$$\Delta V_{IN} = V_{CC} \times \frac{R1}{R2} \tag{6}$$

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Application Information (continued)

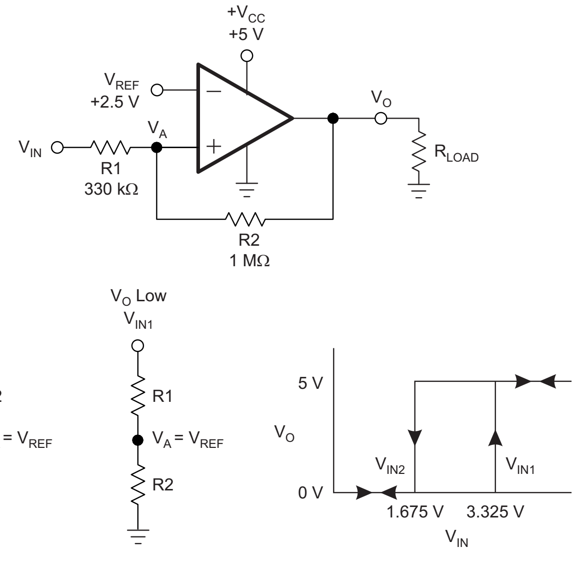

Figure 11. TLV7011 in a Noninverting Configuration With Hysteresis

8.2 Typical Application

8.2.1 Window Comparator

Window comparators are commonly used to detect undervoltage and overvoltage conditions. Figure 12 illustrates a simple window comparator circuit.

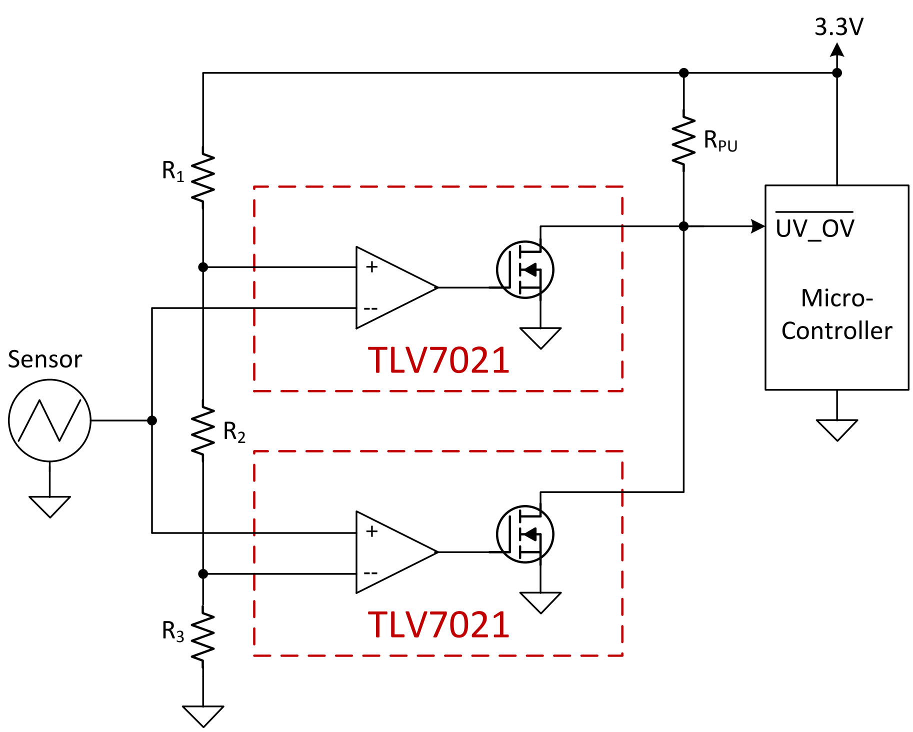

Figure 12. Window Comparator

Typical Application (continued)

8.2.1.1 Design Requirements

For this design, follow these design requirements:

- Alert (logic low output) when an input signal is less than 1.1 V
- Alert (logic low output) when an input signal is greater than 2.2 V
- Alert signal is active low
- Operate from a 3.3-V power supply

8.2.1.2 Detailed Design Procedure

Configure the circuit as shown in Figure 12. Connect V_{CC} to a 3.3-V power supply and V_{EE} to ground. Make R1, R2 and R3 each 10-MΩ resistors. These three resistors are used to create the positive and negative thresholds for the window comparator (V_{TH+} and V_{TH-}). With each resistor being equal, V_{TH+} is 2.2 V and V_{TH-} is 1.1 V. Large resistor values such as 10-MΩ are used to minimize power consumption. The sensor output voltage is applied to the inverting and noninverting inputs of the two TLV7021's. The TLV7021 is used for its open-drain output configuration. Using the TLV7021 allows the two comparator outputs to be Wire-Ored together. The respective comparator outputs will be low when the sensor is less than 1.1 V or greater than 2.2 V. V_{OUT} will be high when the sensor is in the range of 1.1 V to 2.2 V.

8.2.1.3 Application Curve

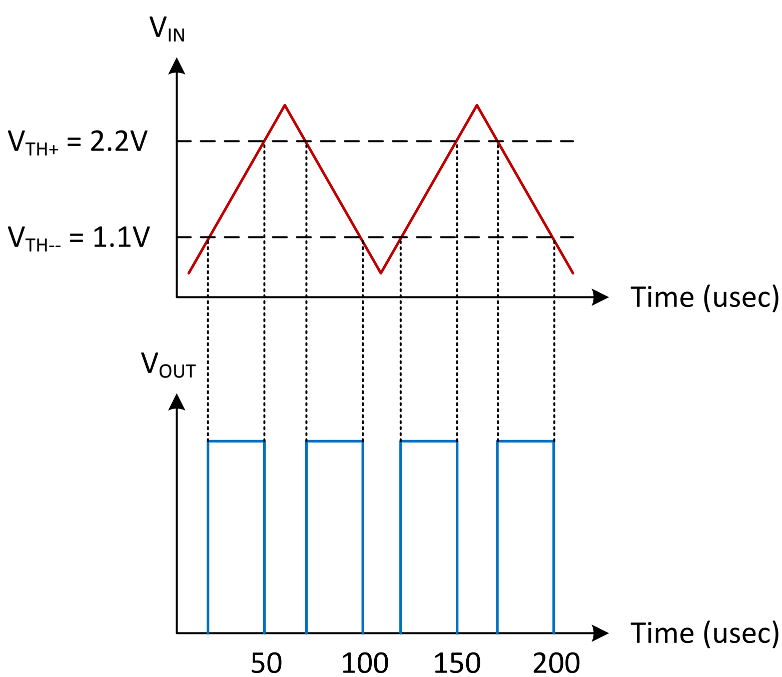

Figure 13. Window Comparator Results

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9 Power Supply Recommendations

The TLV7011 and TLV7021 have a recommended operating voltage range (V_S) of 1.4 V to 5.5 V. V_S is defined as V_{CC} – V_{EE}. Therefore, the supply voltages used to create V_S can be single-ended or bipolar. For example, single-ended supply voltages of 5 V and 0 V and bipolar supply voltages of +2.5 V and –2.5 V create comparable operating voltages for V_S. However, when bipolar supply voltages are used, it is important to realize that the logic low level of the comparator output is referenced to V_{EE}.

10 Layout

10.1 Layout Guidelines

A power-supply bypass capacitor of 100 nF is recommended when supply output impedance is high, supply traces are long, or when excessive noise is expected on the supply lines. Bypass capacitors are also recommended when the comparator output drives a long trace or is required to drive a capacitive load. Due to the fast rising and falling edge rates and high-output sink and source capability of the TLV7011 and TLV7021 output stages, higher than normal quiescent current can be drawn from the power supply. Under this circumstance, the system would benefit from a bypass capacitor across the supply pins.

10.2 Layout Example

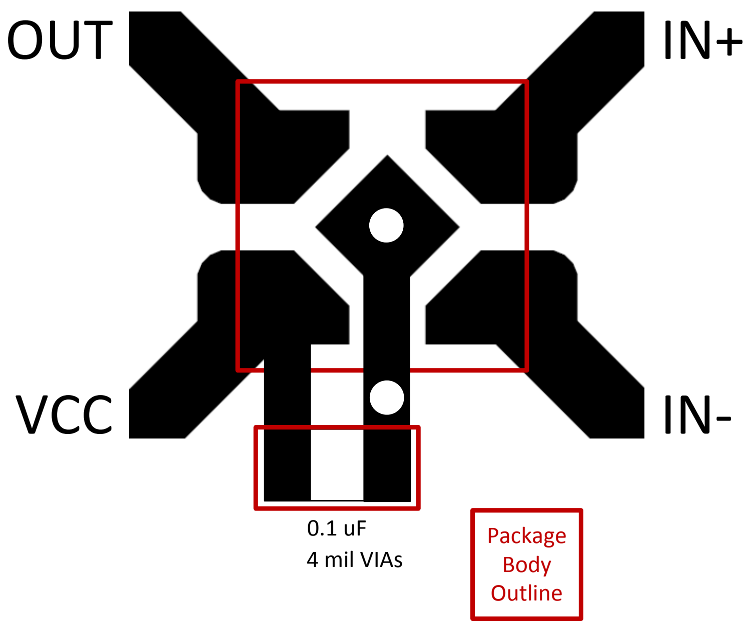

Figure 14. Layout Example

11 Device and Documentation Support

11.1 Related Links

The table below lists quick access links. Categories include technical documents, support and community resources, tools and software, and quick access to sample or buy.

Table 1. Related Links

PARTS	PRODUCT FOLDER	SAMPLE & BUY	TECHNICAL DOCUMENTS	TOOLS & SOFTWARE	SUPPORT & COMMUNITY
TLV7011	Click here	Click here	Click here	Click here	Click here
TLV7021	Click here	Click here	Click here	Click here	Click here

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.

TI E2E™ Online Community ***TI's Engineer-to-Engineer (E2E) Community.*** Created to foster collaboration among engineers. At e2e.ti.com, you can ask questions, share knowledge, explore ideas and help solve problems with fellow engineers.

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

11.4 Trademarks

E2E is a trademark of Texas Instruments.
All other trademarks are the property of their respective owners.

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.

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PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
PTLV7011DPWR	ACTIVE	X2SON	DPW	5	3000	TBD	Call TI	Call TI	-40 to 125		Samples
TLV7011DPWR	PREVIEW	X2SON	DPW	5	3000	TBD	Call TI	Call TI	-40 to 125		
TLV7021DPWR	PREVIEW	X2SON	DPW	5	3000	TBD	Call TI	Call TI	-40 to 125		

(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/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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Images above are just a representation of the package family, actual package may vary.
Refer to the product data sheet for package details.

IMPORTANT NOTICE

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