TLV351x-Q1 6ns High-Speed Comparator with Rail-to-Rail Input

1 Features

removed

- Qualified for automotive applications
- AEC-Q100 qualified with the following results:
  - Device temperature grade 1: –40°C to 125°C ambient operating temperature range
  - Device HBM ESD classification level H1C
  - Device CDM ESD classification level C6
- Propagation delay: 6ns
- High toggle frequency: 180MHz
- Wide supply range: 2.7V to 5.5V
- Input offset voltage: +/- 1mV typical
- Low supply current: 1.1mA per channel
- Input voltage range extends 300mV beyond either rail
- Internal hysteresis: 2.3mV
- Power-on-reset provides a known startup condition
- Push-pull output
- Functional Safety-Capable
  - Documentation available to aid functional safety system design

2 Applications

- Telematics eCall
- Automotive head unit
- Instrument Cluster
- On-board (OBC) & wireless chargers

3 Description

The TLV351x-Q1 is a family of 5V single and dual channel comparators with push-pull outputs. The family has an excellent speed-to-power combination with a propagation delay of 6ns and a full supply voltage range of 2.7V to 5.5V with a quiescent supply current of only 1mA per channel.

All devices include a Power-On Reset (POR) feature. This makes sure the output is in a known state (output LOW) until the minimum supply voltage has been reached before the output responds to the inputs, thus preventing false outputs during system power-up and power-down.

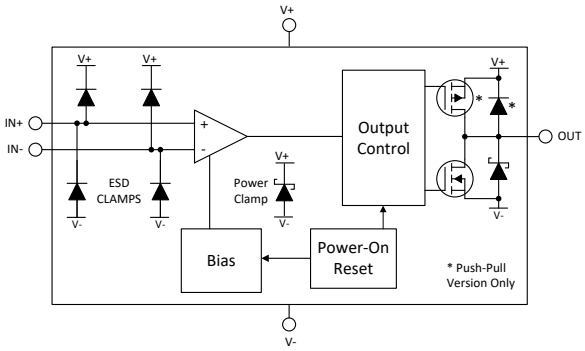
Likewise, the TLV351x-Q1 are conveniently available in standard leaded and leadless packages with features such as rail-to-rail inputs, low offset voltage, and large output drive current. These features along with fast response time make the comparators well-suited for current sensing, zero-cross detection, and a variety of other applications where precision and speed is critical.

All devices operate across the expanded temperature range of –40°C to 125°C.

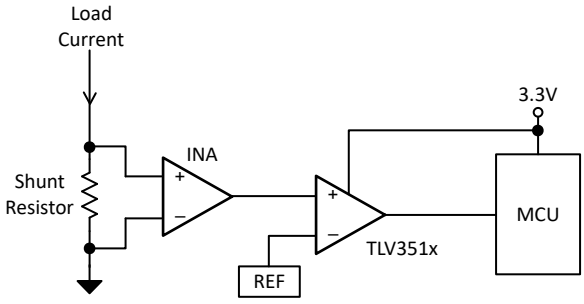
Device Information

PART NUMBER	PACKAGE(1)	PACKAGE SIZE(2)
TLV3511-Q1	DCK (SC-70, 5)	2mm × 2.1mm
	DBV (SOT-23, 5)	2.9mm × 2.8mm
	DRL (SOT, 5) (Preview)	1.6mm × 1.6mm
TLV3512-Q1	DGK (VSSOP, 8)	3.00mm × 4.9mm
	DSG (WSON, 8) (Preview)	2.00mm × 2.00mm

(1) For all available packages, see the orderable addendum at the end of the data sheet.
(2) The package size (length × width) is a nominal value and includes pins, where applicable.



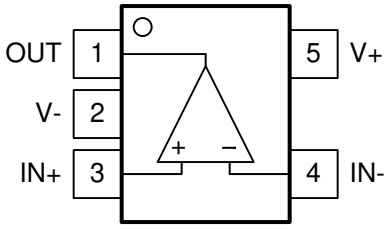
Block Diagram



Low-Side Current Sensing

Table of Contents

4 Pin Configuration and Functions



DCK, DBV, DRL Packages
SC70, SOT-23-5, SOT
Top View
(Standard "north west" pinout)

Table 4-1. Pin Functions: TLV3511-Q1

PIN		TYPE[1]	DESCRIPTION
NAME	NO.		
OUT	1	O	Output
V-	2	-	Negative supply voltage
IN+	3	I	Non-inverting (+) input
IN-	4	I	Inverting (-) input
V+	5	-	Positive supply voltage

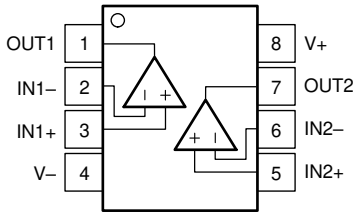


Figure 4-1. DGK Package
8-Pin VSSOP
Top View

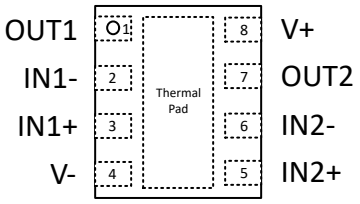


Figure 4-2. DSG Package
8-Pin WSON
Top View

Pin Functions: TLV3512-Q1

PIN		TYPE(1)	DESCRIPTION
NAME	NO.		
IN1+	1	I	Noninverting input, channel 1
IN1–	2	I	Inverting input, channel 1
IN2–	3	I	Inverting input, channel 2
IN2+	4	I	Noninverting input, channel 2
OUT1	7	O	Output, channel 1
OUT2	6	O	Output, channel 2
V-	5	-	Negative (lowest) supply or ground
V+	8	-	Positive (highest) supply

(1) I = input, O = output

5 Specifications

5.1 Absolute Maximum Ratings

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

	MIN	MAX	UNIT
Supply voltage V_S = (V+) - (V-)		6	V
Differential input voltage, VID	-6	6	V
Input pins (IN+, IN–) from (V-) (2)	– 0.5	(V+) + 0.5	V
Current into input pins (IN+, IN-)	-10	10	mA
Output (OUT) from (V-)	– 0.5	(V+) + 0.5	V
Output short-circuit current	-100	100	mA
Output short-circuit duration		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 (V–) and (V+). Input signals that can swing more than 0.5V beyond the supply rails must be current-limited to 10mA or less.

5.2 ESD Ratings

			VALUE	UNIT
$V_{(ESD)}$	Electrostatic discharge	Human-body model (HBM), per AEC Q100-002(1)	±2000	V
		Charged-device model (CDM), per AEC Q100-011	±1000	

(1) AEC Q100-002 indicates that HBM stressing shall be in accordance with the ANSI/ESDA/JEDEC JS-001 specification.

5.3 Recommended Operating Conditions

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

	MIN	MAX	UNIT
Supply voltage V_S = (V+) - (V-)	2.7	5.5	V
Input voltage range	(V-) - 0.3	(V+) + 0.3	V
Ambient temperature, T_A	–40	125	°C

5.4 Thermal Information. TLV3511

THERMAL METRIC (1)		TLV3511		UNIT
		DBV (SOT-23)	DCK (SC70)	
		5 PINS	5 PINS	
$R_{\theta JA}$	Junction-to-ambient thermal resistance	198.1	220.1	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	95.6	136.5	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	64.7	65.9	°C/W
Ψ_{JT}	Junction-to-top characterization parameter	32.1	34.5	°C/W
Ψ_{JB}	Junction-to-board characterization parameter	64.3	65.4	°C/W
$R_{\theta JC(bot)}$	Junction-to-case (bottom) thermal resistance	n/a	n/a	°C/W

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

5.5 Thermal Information, TLV3512

THERMAL METRIC (1)		TLV3512		UNIT
		DGK (VSSOP)	DSG (WSON)	
		8 PINS	8 PINS	
$R_{\theta JA}$	Junction-to-ambient thermal resistance	154.1		°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	48.6		°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	88.5		°C/W
Ψ_{JT}	Junction-to-top characterization parameter	1.7		°C/W
Ψ_{JB}	Junction-to-board characterization parameter	87.1		°C/W
$R_{\theta JC(bot)}$	Junction-to-case (bottom) thermal resistance	n/a		°C/W

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

5.6 Electrical Characteristics

V_S = 2.7V to 5V, V_{CM} = V_S / 2; at T_A = 25°C (unless otherwise noted).
Typical values are at T_A = 25°C.

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
DC Input Characteristics						
V_{IO}	Input Offset Voltage	V_S = 5V, V_{CM} = V_S / 2		±1	±5	mV
V_{IO}	Input Offset Voltage	V_S = 5V, V_{CM} = V_S / 2, T_A = -40 to 125℃			±6	mV
dV_{IO}/dT	Input Offset Voltage vs Temperature	V_S = 5V, V_{CM} = V_S / 2, T_A = -40 to 25℃ and 25 to 125℃		±2		µV/℃
V_{HYS}	Hysteresis	V_S = 5V, V_{CM} = V_S / 2		2.3		mV
V_{HYS}	Hysteresis	V_S = 5V, V_{CM} = V_S / 2, T_A = -40 to 125℃			3.5	mV
V_{CM}	Common-mode voltage range		(V-) - 0.2		(V+) + 0.2	V
I_B	Input bias current	V_S = 5V, V_{CM} = V_S / 2, T_A = -40 to 125℃			1.5	nA
I_{OS}	Input offset current	V_S = 5V, V_{CM} = V_S / 2			10	pA
C_{IN}	Input capacitance			4		pF
CMRR	Common-mode rejection ratio	V_{CM} = V_{EE} - 0.2V to V_{CC} + 0.2V		80		dB
DC Output Characteristics						
V_{OH}	Voltage swing from (V+)	V_S = 5V, I_{Source} = 4mA		120	225	mV
V_{OH}	Voltage swing from (V+)	V_S = 5V, I_{Source} = 4mA, -40 to 125C			250	mV
V_{OL}	Voltage swing from (V-)	V_S = 5V, I_{Sink} = 4mA		140	225	mV
V_{OL}	Voltage swing from (V-)	V_S = 5V, I_{Sink} = 4mA, -40 to 125C			250	mV
I_{SC}	Short-circuit current	V_S = 5V, sourcing		75		mA
		V_S = 5V, sinking		85		
Power Supply						
I_Q	Supply current / Channel	V_S = 2.7V and 5V, no load, output low, T_A = -40 to 125℃		1.1	2	mA
$V_{POR\ (postive)}$	Power-On Reset Voltage			2.2		V
PSRR	Power Supply Rejection Ratio	V_S = 2.7V to 5.5V, T_A = -40 to 125℃		93		dB

5.7 Switching Characteristics

For V_S = 5V, V_{CM} = V_S / 2; C_L = 15pF at T_A = 25°C (Unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
t_{PHL}	Propagation delay time, high to-low	Midpoint of input to midpoint of output, V_{OD} = 10mV		10		ns
t_{PHL}	Propagation delay time, high to-low	Midpoint of input to midpoint of output, V_{OD} = 50mV		6	7	ns
t_{PLH}	Propagation delay time, low-to high	Midpoint of input to midpoint of output, V_{OD} = 10mV		10		ns
t_{PLH}	Propagation delay time, low-to high	Midpoint of input to midpoint of output, V_{OD} = 50mV		6	7	ns
t_{PD} Skew	Propagation delay skew	Measured as absolute value of the difference between t_{PDLH} and t_{PDHL}		300		ps
t_{PD} ch-ch skew (dual only)	Channel-to-channel propagation delay skew	VCM = VCC/2, VOVERDRIVE = VUNDERDRIVE = 50mV, 10MHz Squarewave		100		ps
PWin	Minimum input pulse width	Voverdrive = Vunderdrive = 50mV PWout = 90% of PWin		3.5		ns
f_{TOGGLE}	Input toggle frequency	V_{IN} = 200mV_{PP} Sine Wave, When output high reaches 90% of V_{CC} - V_{EE} or output low reaches 10% of V_{CC} - V_{EE}		180		MHz
t_R	Rise time	Measured from 20% to 80%		1		ns
t_F	Fall time	Measured from 20% to 80%		1		ns

For V_S = 5V, V_{CM} = V_S / 2; C_L = 15pF at T_A = 25°C (Unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
t_{ON} (single)	Power-up time, single	During power on, (V+) must exceed 2.2V for 2.1µs before the output will reflect the input.		2.1		µs
t_{ON} (dual)	Power-up time, dual	During power on, (V+) must exceed 2.2V for 3µs before the output will reflect the input.		2.9		µs

5.8 Typical Characteristics

T_A = 25°C, V_S = 5V, C_L = 15pF, V_{CM} = V_S/2V, $V_{UNDERDRIVE}$ = 50mV, $V_{OVERDRIVE}$ = 50mV unless otherwise noted.

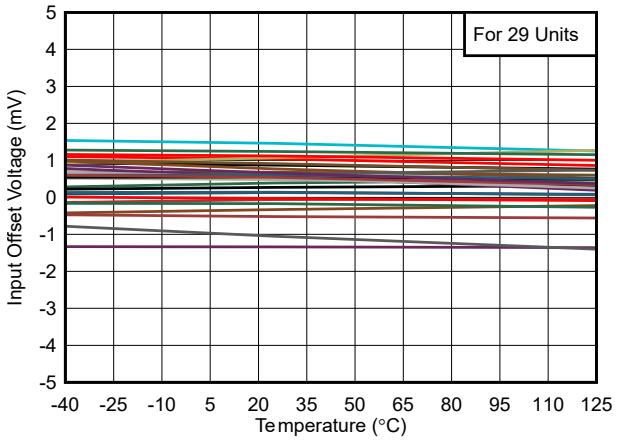


Figure 5-1. Offset vs. Temperature

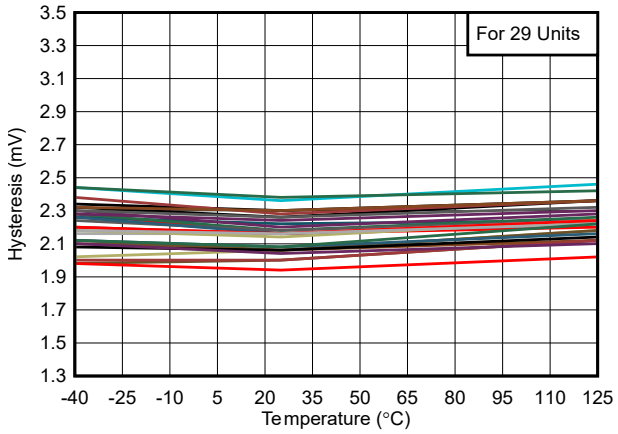


Figure 5-2. Hysteresis vs. Temperature

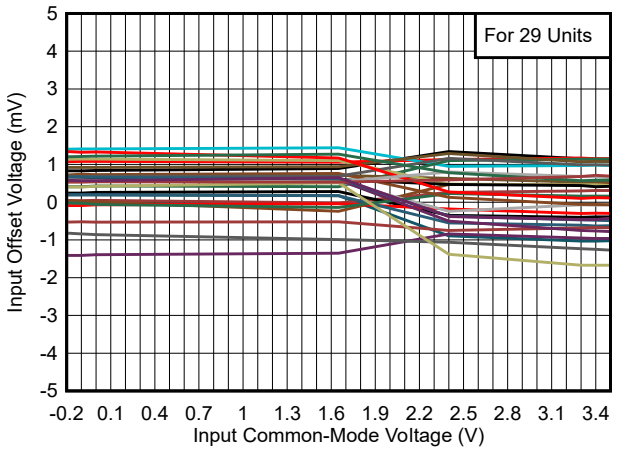


Figure 5-3. Offset vs. Common-Mode, 3.3V

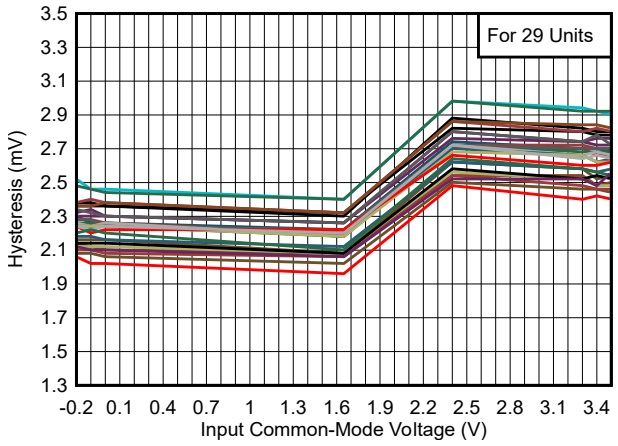


Figure 5-4. Hysteresis vs. Common-Mode, 3.3V

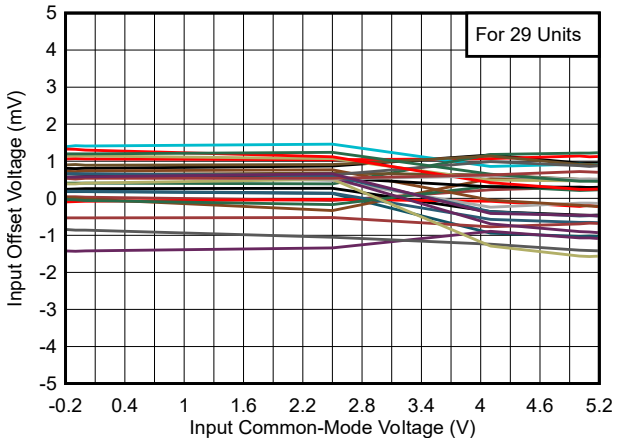


Figure 5-5. Offset vs. Common-Mode, 5V

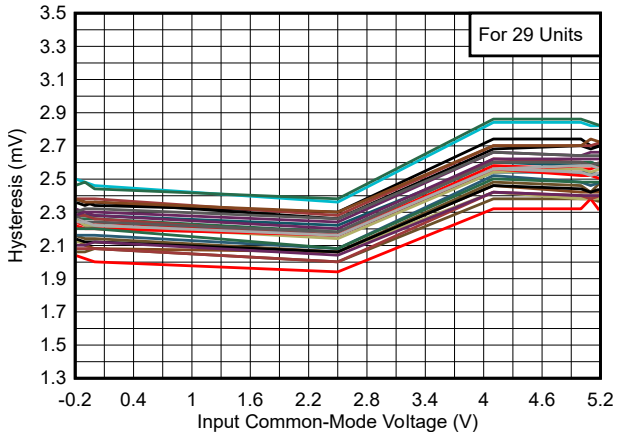


Figure 5-6. Hysteresis vs. Common-Mode, 5V

5.8 Typical Characteristics (continued)

T_A = 25°C, V_S = 5V, C_L = 15pF, V_{CM} = V_S/2V, $V_{UNDERDRIVE}$ = 50mV, $V_{OVERDRIVE}$ = 50mV unless otherwise noted.

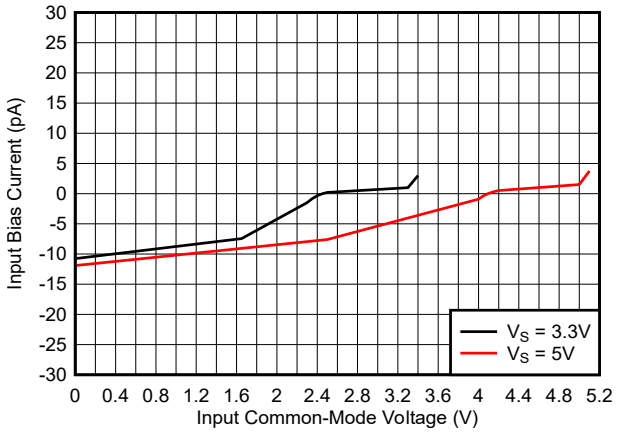


Figure 5-7. Bias Current vs. Common-Mode

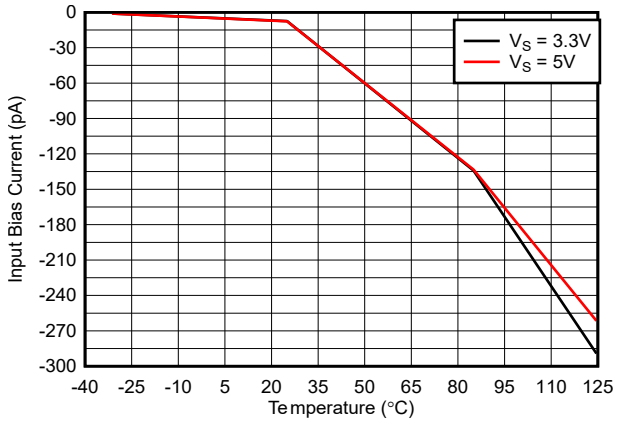


Figure 5-8. Bias Current vs. Temperature

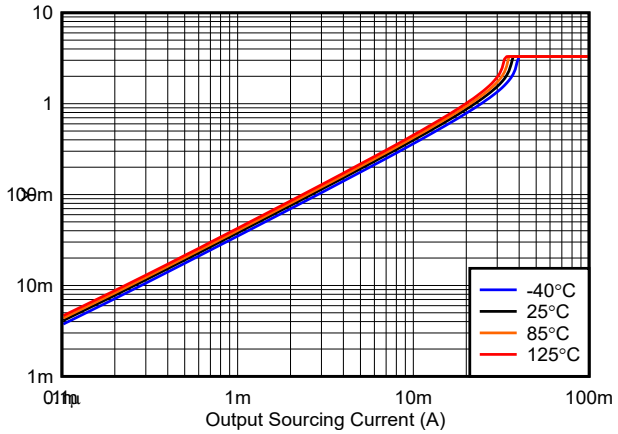


Figure 5-9. Output Voltage vs. Output Sourcing Current, 3.3V

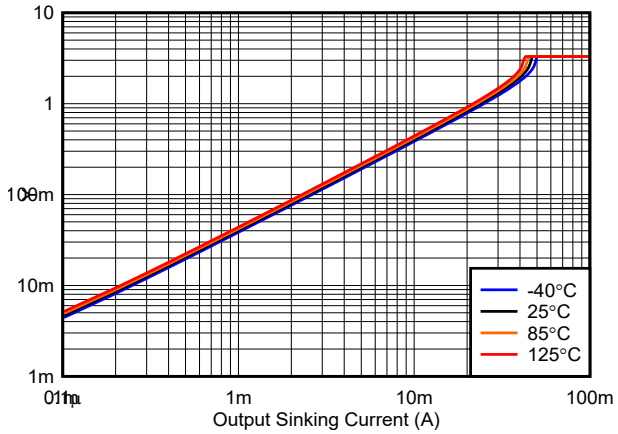


Figure 5-10. Output Voltage vs. Output Sinking Current, 3.3V

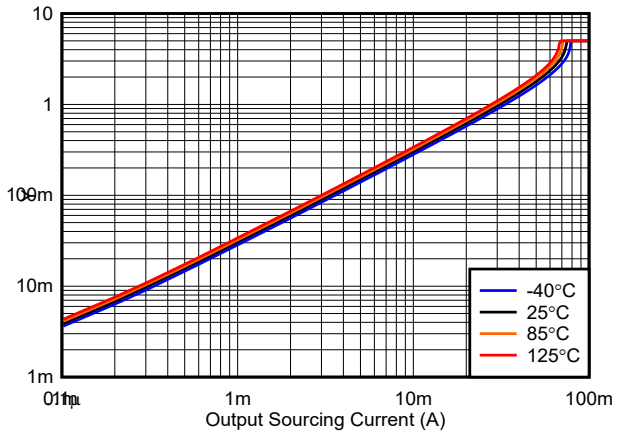


Figure 5-11. Output Voltage vs. Output Sourcing Current, 5V

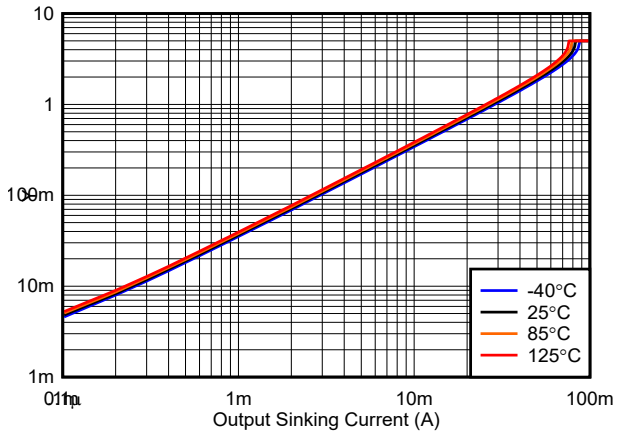


Figure 5-12. Output Voltage vs. Output Sinking Current, 5V

5.8 Typical Characteristics (continued)

T_A = 25°C, V_S = 5V, C_L = 15pF, V_{CM} = V_S/2V, $V_{UNDERDRIVE}$ = 50mV, $V_{OVERDRIVE}$ = 50mV unless otherwise noted.

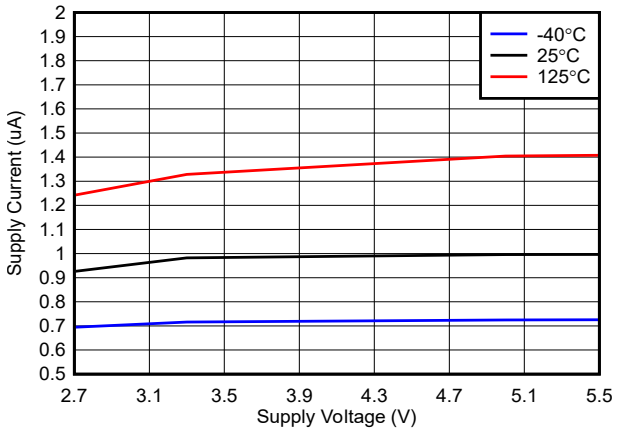


Figure 5-13. Supply Current vs. Supply Voltage (Output Low)

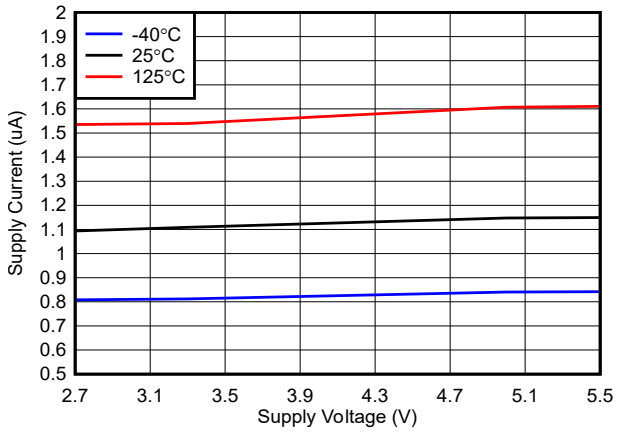


Figure 5-14. Supply Current vs. Supply Voltage (Output High)

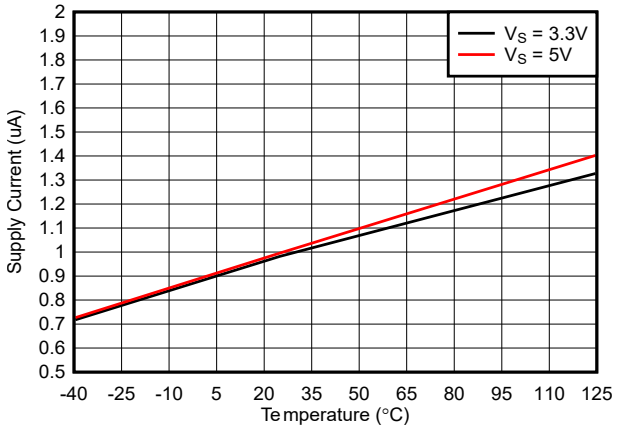


Figure 5-15. Supply Current vs. Temperature (Output Low)

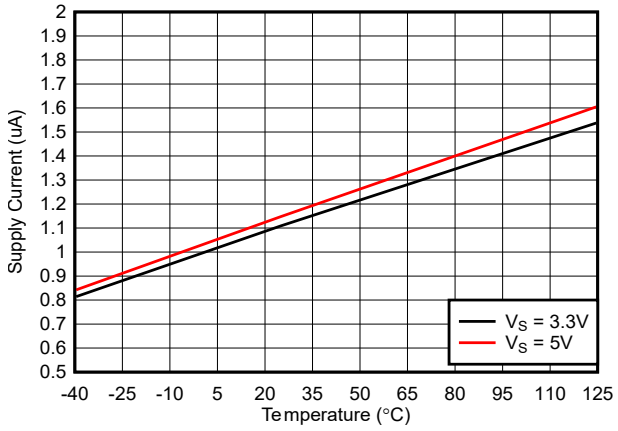


Figure 5-16. Supply Current vs. Temperature (Output High)

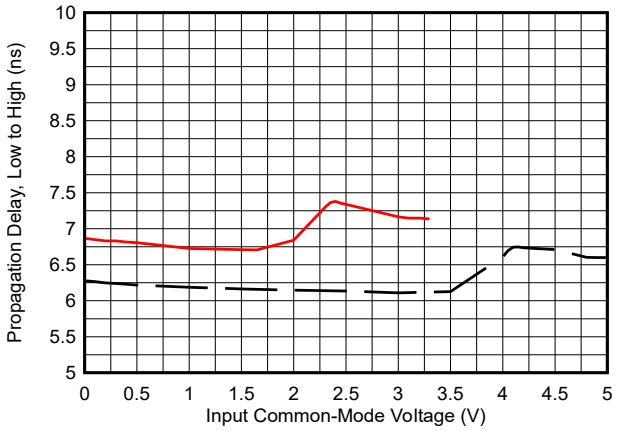


Figure 5-17. Propagation Delay (Low to High) vs. Common-Mode

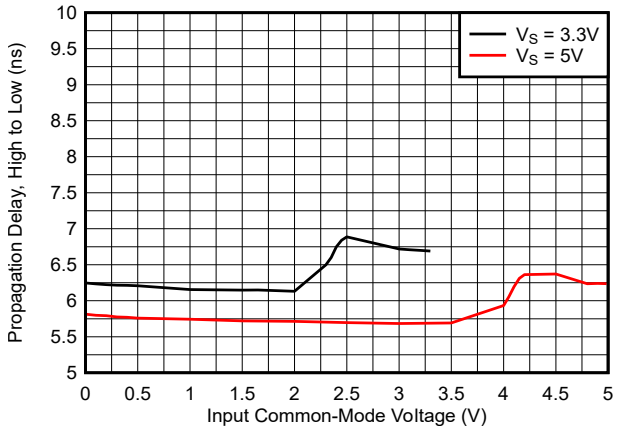


Figure 5-18. Propagation Delay (High to Low) vs. Common-Mode

5.8 Typical Characteristics (continued)

T_A = 25°C, V_S = 5V, C_L = 15pF, V_{CM} = V_S/2V, $V_{UNDERDRIVE}$ = 50mV, $V_{OVERDRIVE}$ = 50mV unless otherwise noted.

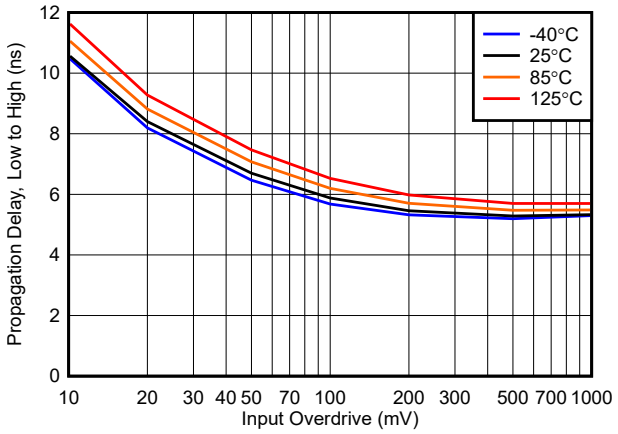


Figure 5-19. Propagation Delay (Low to High) vs. Overdrive (3.3V)

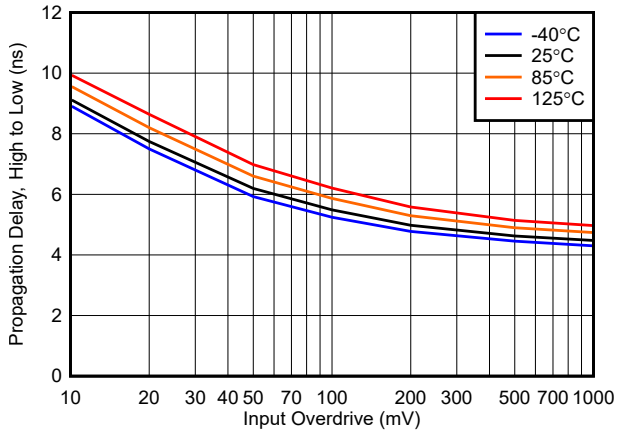


Figure 5-20. Propagation Delay (High to Low) vs. Overdrive (3.3V)

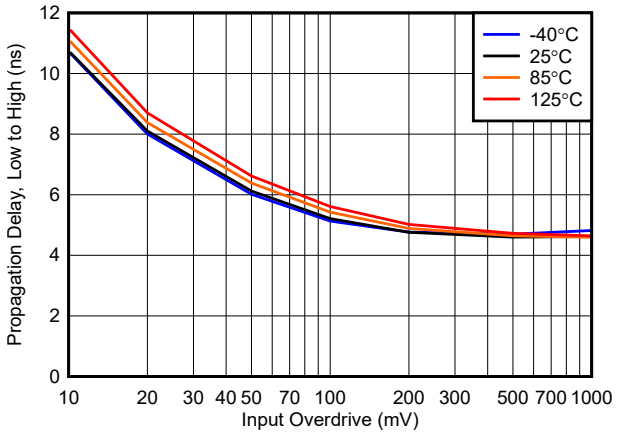


Figure 5-21. Propagation Delay (Low to High) vs. Overdrive (5V)

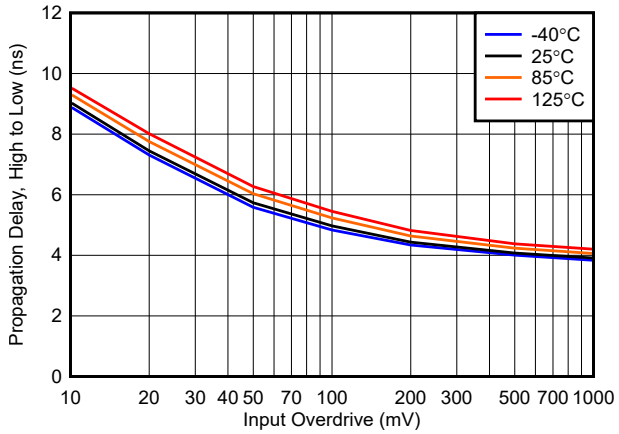


Figure 5-22. Propagation Delay (High to Low) vs. Overdrive (5V)

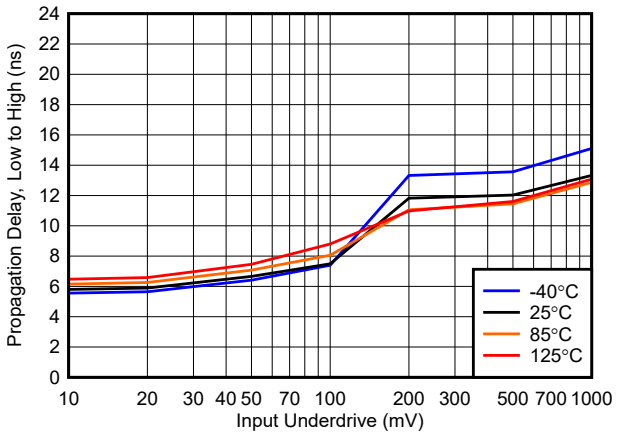


Figure 5-23. Propagation Delay (Low to High) vs. Underdrive (3.3V)

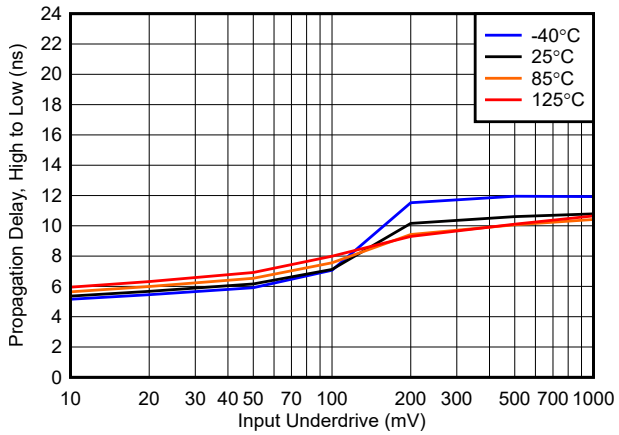


Figure 5-24. Propagation Delay (High to Low) vs. Underdrive (3.3V)

5.8 Typical Characteristics (continued)

T_A = 25°C, V_S = 5V, C_L = 15pF, V_{CM} = V_S/2V, $V_{UNDERDRIVE}$ = 50mV, $V_{OVERDRIVE}$ = 50mV unless otherwise noted.

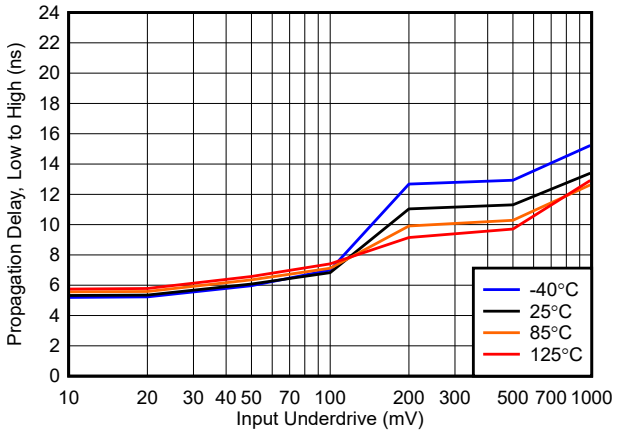


Figure 5-25. Propagation Delay (Low to High) vs. Underdrive (5V)

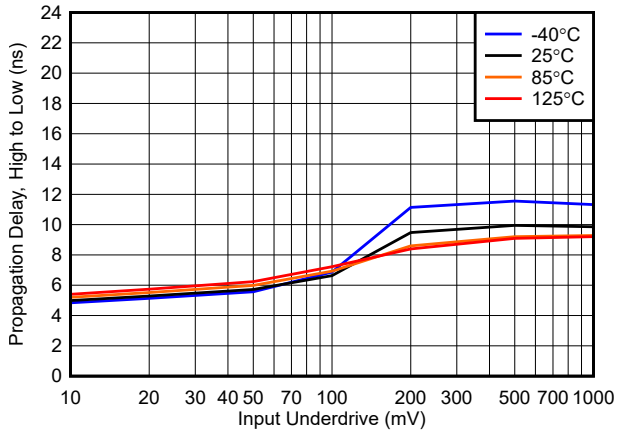


Figure 5-26. Propagation Delay (High to Low) vs. Underdrive (5V)

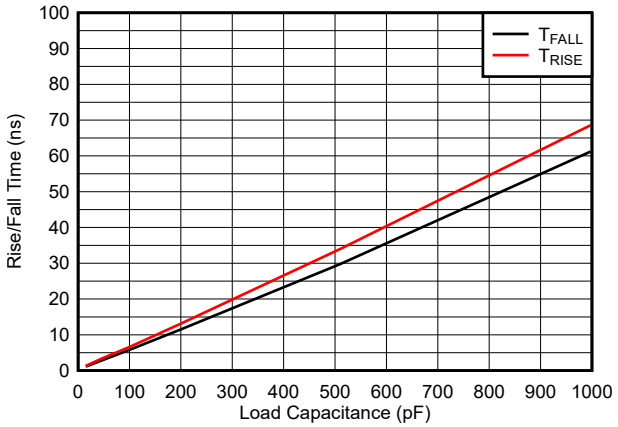


Figure 5-27. Rise and Fall Times vs. Capacitive Loads at 3.3V

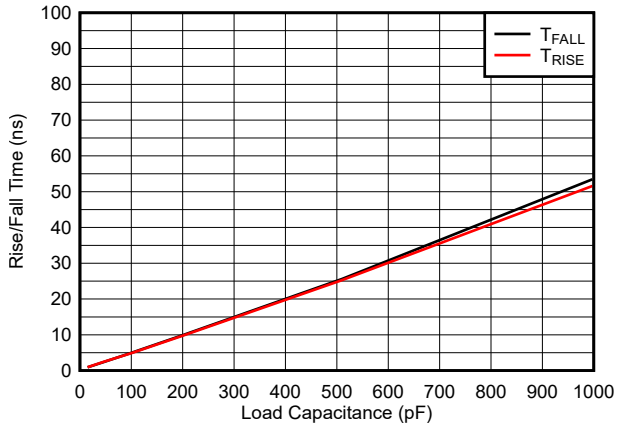


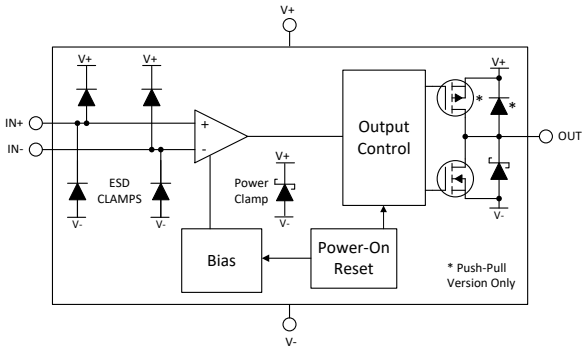
Figure 5-28. Rise and Fall Times vs. Capacitive Loads at 5V

6 Detailed Description

6.1 Overview

The TLV351x-Q1 devices are high-speed comparators consuming 1mA per channel with 6ns of propagation delay. The TLV351x-Q1 detects fast voltage and current transients while maintaining low power consumption with single-ended, push-pull outputs

6.2 Functional Block Diagram



6.3 Feature Description

The TLV351x-Q1 comparators feature rail-to-rail inputs with integrated hysteresis, single-ended, push-pull outputs, and a Power-ON-Reset function.

6.4 Device Functional Modes

6.4.1 Inputs

The inputs incorporate internal ESD protection circuits to (V+) and (V-). Voltages on the inputs are limited to 0.3V beyond the rails.

When connecting to a low impedance source such as a power supply or buffered reference line, TI recommends adding a current-limiting resistor in series with the input to limit any transient currents if the clamps conduct. Limit the current to 10mA or less. One form of series resistance is any resistive input dividers or networks.

When connecting to a higher impedance source such as a resistor divider to create a voltage reference or when multiple comparator inputs are connected in parallel, note that input bias current increases with temperature (see Bias Current vs. Temperature curve). Likewise, input bias current also increases when the input differential voltage is greater than 1V.

6.4.1.1 Unused Inputs

If a channel is not to be used, DO NOT tie the inputs together. Due to the high equivalent bandwidth and low offset voltage, tying the inputs directly together can cause high frequency oscillations as the device triggers on it's own internal wideband noise. Instead, the inputs can be tied to any available voltage that resides within the specified input voltage range and provides a minimum of 50mV differential voltage. For example, one input can be grounded and the other input connected to a reference voltage, or even (V+).

6.4.2 Internal Hysteresis

The device hysteresis transfer curve is shown below. 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.

  (typically 2mV for the TLV351x-Q1 family)

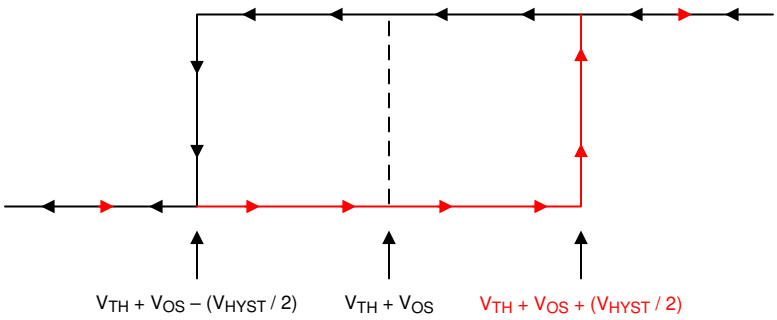


Figure 6-1. Hysteresis Transfer Curve

6.4.3 Outputs

The TLV351x-Q1 features a push-pull output stage capable of both sinking and sourcing current. This allows driving loads such as LED's and MOSFET gates, as well as eliminating the need for a power-wasting external pull-up resistor. The push-pull output must never be connected to another output.

Directly shorting the output to the supply rails ((V+) when output "low" or (V-) when output "High") can result in thermal runaway and eventual device destruction. If output shorts are possible, a series current limiting resistor is recommended to limit the power dissipation.

Unused push-pull outputs must be left floating, and never tied to a supply, ground, or another output.

6.4.4 ESD Protection

The inputs and outputs incorporate internal ESD protection circuits to (V+) and (V-).

Voltages on the inputs are limited to 0.3V beyond the rails. If the inputs are to be connected to a low impedance source, such as a power supply or buffered reference line, TI recommends adding a current-limiting resistor in series with the input to limit any transient currents in case the clamps conduct. Limit the current to 10mA or less.

6.4.5 Power-On Reset (POR)

The TLV351x-Q1 devices have an internal Power-on-Reset (POR) circuit for known start-up or power-down conditions. While the power supply (V+) is ramping up or ramping down, the POR circuitry is active for up to 2.1us after the V_{POR} of 2.2V is crossed. When the supply voltage is equal to or greater than the minimum supply voltage, and after the delay period, the comparator output reflects the state of the differential input (V_{ID}).

For the TLV351x-Q1 devices, the output is held low during the POR period (t_{on}) as shown below.

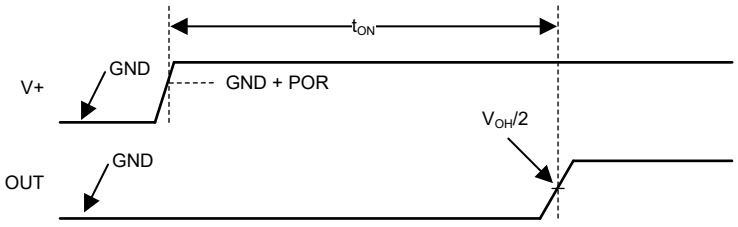


Figure 6-2. Power-On Reset Timing Diagram

7 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.

7.1 Application Information

7.1.1 Basic Comparator Definitions

7.1.1.1 Operation

The basic comparator compares the input voltage (V_{IN}) on one input to a reference voltage (V_{REF}) on the other input. In the example below, if V_{IN} is less than V_{REF}, the output voltage (V_O) is logic low (V_{OL}). If V_{IN} is greater than V_{REF}, the output voltage (V_O) is at logic high (V_{OH}). Likewise, the table below summarizes the output conditions. The output logic can be inverted by simply swapping the input pins.

Table 7-1. Output Conditions

Inputs Condition	Output
IN+ > IN-	HIGH (V_{OH})
IN+ = IN-	Indeterminate (chatters - see Hysteresis)
IN+ < IN-	LOW (V_{OL})

7.1.1.2 Propagation Delay

There is a delay between from when the input crosses the reference voltage and the output responds. This is called the Propagation Delay. Propagation delay can be different between high-to low and low-to-high input transitions. This is shown as t_{pLH} and t_{pHL} in the figure below and is measured from the mid-point of the input to the midpoint of the output.

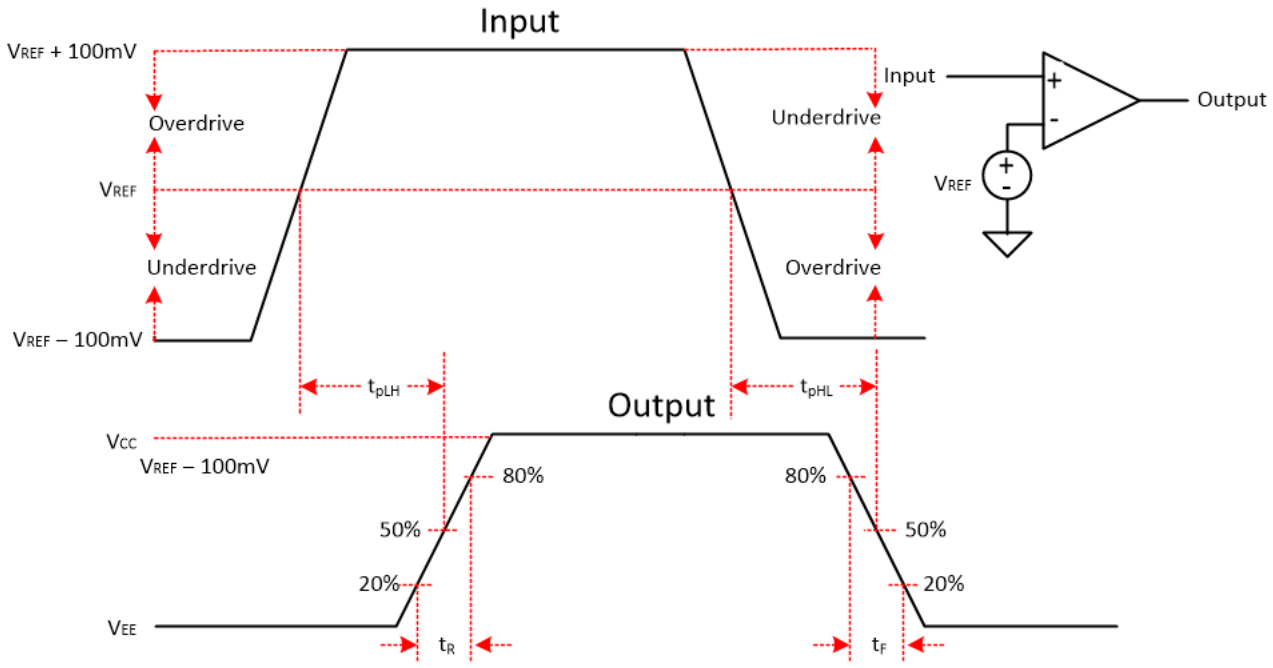


Figure 7-1. Comparator Timing Diagram

7.1.1.3 Overdrive Voltage

The overdrive voltage, V_{OD}, is the amount of input voltage beyond the reference voltage (and not the total input peak-to-peak voltage). The overdrive voltage is 100mV as shown in the above example. The overdrive voltage can influence the propagation delay (t_p). The smaller the overdrive voltage, the longer the propagation delay, particularly when <100mV. If the fastest speeds are desired, TI recommends appling the highest amount of overdrive possible.

The risetime (t_r) and falltime (t_f) is the time from the 20% and 80% points of the output waveform.

7.1.2 Hysteresis

The basic comparator configuration frequently produces a noisy "chatter" output if the applied differential input voltage is near the comparator's offset voltage. This can occur when the input signal is moving very slowly across the switching threshold of the comparator. This problem can be prevented by adding external hysteresis to the comparator.

Since the TLV351x-Q1 only have a minimal amount of internal hysteresis of 2mV, external hysteresis can be applied in the form of a positive feedback loop that adjusts the trip point of the comparator depending on the current output state.

The hysteresis transfer curve is shown below. 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 hysteresis (or trip window) that is designed to reduce comparator sensitivity to noise.

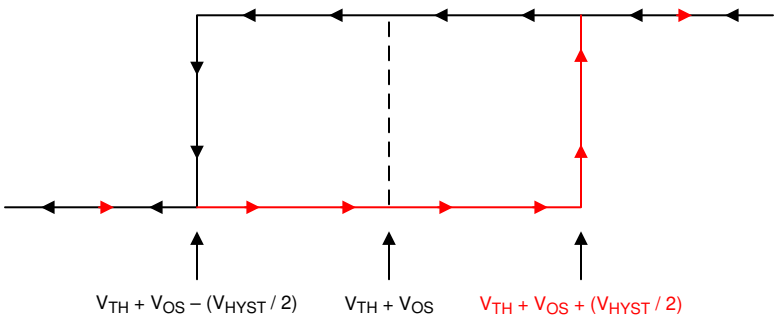


Figure 7-2. Hysteresis Transfer Curve

For more information, please see Application Note SBOA219 "Comparator with and without hysteresis circuit".

7.1.2.1 Inverting Comparator With Hysteresis

The inverting comparator with hysteresis requires a three-resistor network that is referenced to the comparator supply voltage (V_{CC}), as shown below.

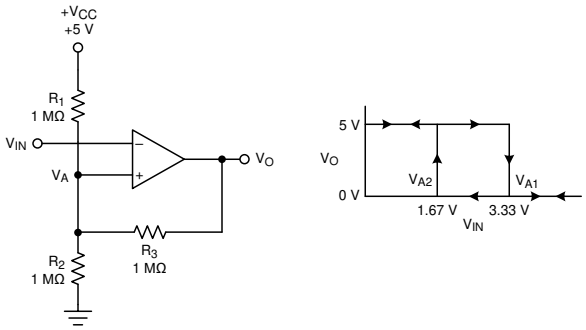


Figure 7-3. TLV3511-Q1 in an Inverting Configuration With Hysteresis

The equivalent resistor networks when the output is high and low are shown below.

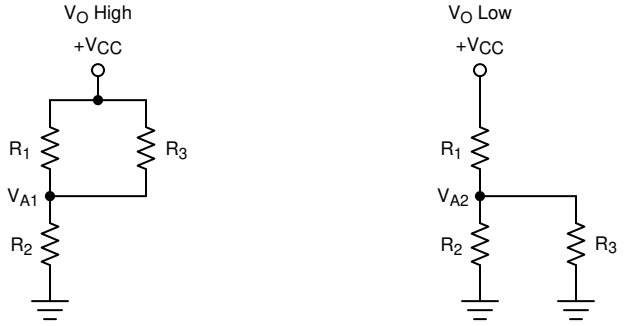


Figure 7-4. Inverting Configuration Resistor Equivalent Networks

When V_{IN} 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, as shown above on the left.

The equation below defines the high-to-low trip voltage (V_{A1}).

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

When V_{IN} is greater than V_A, the output voltage is low. In this case, the three network resistors can be presented as R2 || R3 in series with R1, as shown above on the right.

Use equation below to define the low to high trip voltage (V_{A2}).

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

The equation below defines the total hysteresis provided by the network.

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

7.1.2.2 Non-Inverting Comparator With Hysteresis

A non-inverting comparator with hysteresis requires a two-resistor network and a voltage reference (V_{REF}) at the inverting input, as shown below.

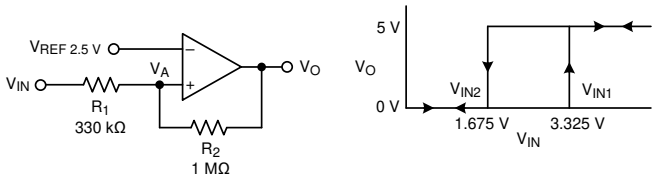


Figure 7-5. TLV3511-Q1 in a Non-Inverting Configuration With Hysteresis

The equivalent resistor networks when the output is high and low are shown below.

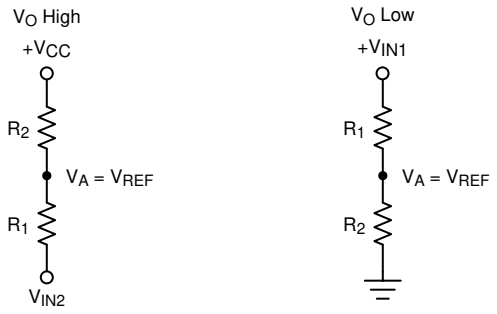


Figure 7-6. Non-Inverting Configuration Resistor Networks

When V_{IN} is less than V_{REF}, the output is low. For the output to switch from low to high, V_{IN} must rise above the V_{IN1} threshold. Use the equation below to calculate V_{IN1}.

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

When V_{IN} is greater than V_{REF}, the output is high. For the comparator to switch back to a low state, V_{IN} must drop below V_{IN2}. Use equation below 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 below.

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

For more information, please see Application Notes SNOA997 "Inverting comparator with hysteresis circuit" and SBOA313 "Non-Inverting Comparator With Hysteresis Circuit".

7.2 Typical Applications

7.2.1 Low-Side Current Sensing

The figure below shows a simple low-side current sensing circuit using a high-speed comparator. Since this design does not utilze an amplifier, the response time is only limited by the propagation delay of the comparator. With faster response time, the design is well-suited for short-circuit detection when speed is more important than accuracy. When the voltage across the shunt resistor reaches the critical over-current threshold created by R1 and R2, the comparator output changes state.

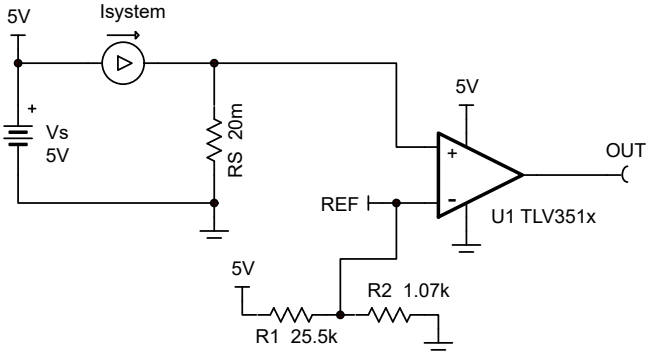


Figure 7-7. Current Sensing

7.2.1.1 Design Requirements

For this design, follow these design requirements:

- Alert (overcurrent) event occurs when system current (Isystem) reaches 10A
- Alert signal (OUT) is active high
- Operate from a 5V power supply

7.2.1.2 Detailed Design Procedure

To minimize power dissipation and voltage drop across the shunt resistor (RS), a value of 20mΩ is selected. Since the overcurrent level of 10A creates a 200mV drop across RS, R1 and R2 are calculated to create the voltage divider value of 200mV from the regulated 5V supply voltage. If the system is expected to operate close to the 10A maximum, hysteresis can be added to the design as shown in Non-Inverting Comparator With Hysteresis.

7.2.1.3 Application Curve

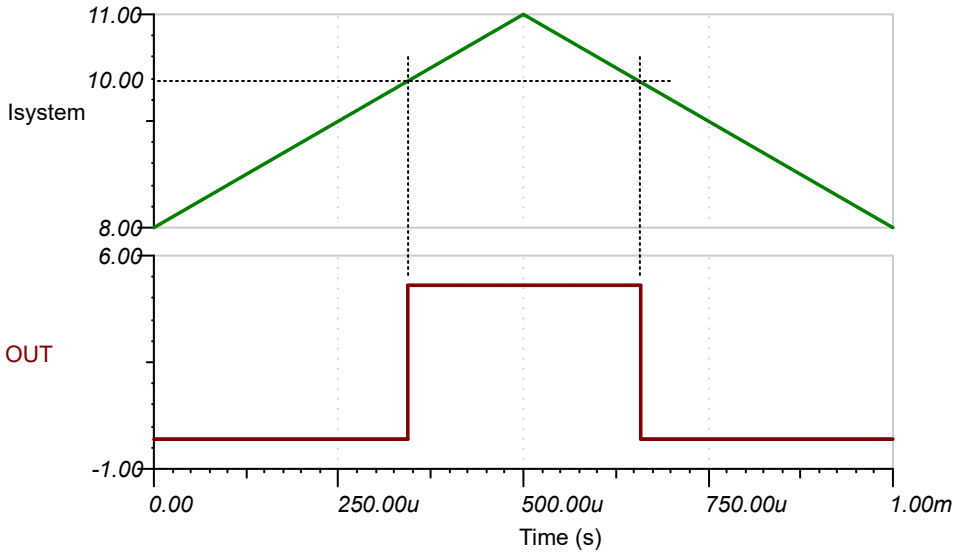


Figure 7-8. Current Sensing Results

7.3 Power Supply Recommendations

Due to the fast output edges, bypass capacitors are critical on the supply pin to prevent supply ringing and false triggers and oscillations. Bypass the supply directly at *each* device with a low ESR 0.1µF ceramic bypass capacitor directly between the (V+) pin and ground pins. Narrow peak currents are drawn during the output transition time, particularly for the push-pull output device. These narrow pulses cause un-bypassed supply lines and poor grounds to ring, possibly causing variation that limits the input voltage range and creates an inaccurate comparison or even oscillations.

The device is capable of being powered from both "split" supplies ((V+) &(V-)), or "single" supplies ((V+) and GND), with GND applied to the (V-) pin. Input signals must stay within the recommended input range for either type. Note that with a "split" supply the output now swings "low" (V_{OL}) to (V-) potential and not GND.

7.4 Layout

7.4.1 Layout Guidelines

For accurate comparator applications it is important to maintain a stable power supply with minimized noise and glitches. Output rise and fall times are in the tens of nanoseconds, and need to be treated as high speed logic devices. Place the bypass capacitor as close to the supply pin as possible and connect to a solid ground plane, directly between the (V+) and GND pins.

Minimize coupling between outputs and inputs to prevent output oscillations. Do not run output and input traces in parallel unless there is a (V+) or GND trace between output to reduce coupling. When series resistance is added to inputs, place resistor close to the device. A low value (<100 ohms) resistor added in series with the output dampens any ringing or reflections on long, non-impedance controlled traces. For best edge shapes, use controlled impedance traces with back-terminations when routing long distances.

7.4.2 Layout Example

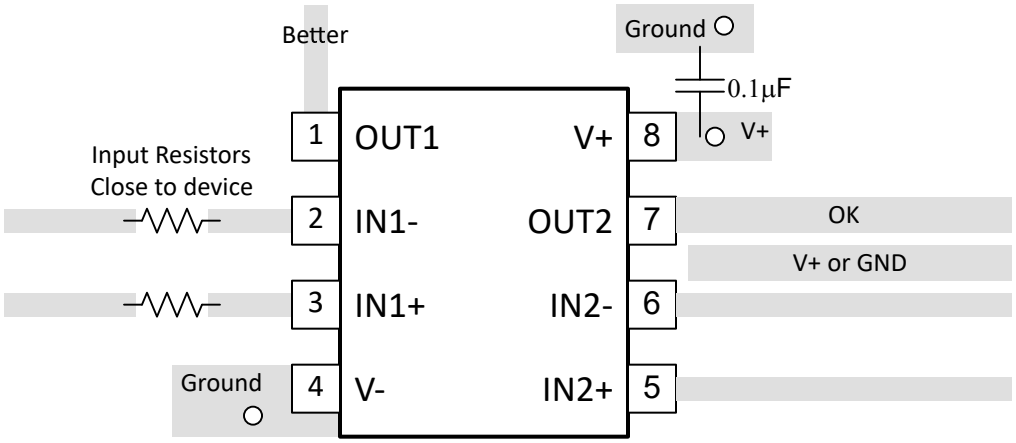


Figure 7-9. Dual Layout Example

8 Device and Documentation Support

8.1 Documentation Support

8.1.1 Related Documentation

- Texas Instruments, *Analog Engineers Circuit Cookbook: Amplifiers* (See Comparators section) - SLYY137
- Texas Instruments, *Precision Design, Comparator with Hysteresis Reference Design* design guide
- Texas Instruments, *Window comparator circuit* circuit design
- Texas Instruments, *Reference Design, Window Comparator Reference Design* design guide
- Texas Instruments, *Comparator with and without hysteresis circuit* analog engineer's circuit
- Texas Instruments, *Inverting comparator with hysteresis circuit* analog engineer's circuit
- Texas Instruments, *Non-Inverting Comparator With Hysteresis Circuit* analog engineer's circuit
- Texas Instruments, *A Quad of Independently Functioning Comparators* application note

8.2 Receiving Notification of Documentation Updates

To receive notification of documentation updates, navigate to the device product folder on ti.com. Click on *Notifications* 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.

8.3 Support Resources

TI E2E™ support forums are an engineer's go-to source for fast, verified answers and design help — straight from the experts. Search existing answers or ask your own question to get the quick design help you need.

Linked content is 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.

8.4 Trademarks

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

8.5 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.

8.6 Glossary

TI Glossary This glossary lists and explains terms, acronyms, and definitions.

9 Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

Changes from Revision A (April 2025) to Revision B (October 2025)	Page
• Removed preview note for TLV3512-Q1 DGK package	1
• Added typical VIO drift over temperature specification	1

Changes from Revision * (November 2024) to Revision A (April 2025)	Page
• Release of SOT23-5 package	1
• Added Functional Safety Capable feature	1

10 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

Orderable part number	Status (1)	Material type (2)	Package | Pins	Package qty | Carrier	RoHS (3)	Lead finish/ Ball material (4)	MSL rating/ Peak reflow (5)	Op temp (°C)	Part marking (6)
TLV3511QDBVRQ1	Active	Production	SOT-23 (DBV) | 5	3000 | LARGE T&R	Yes	SN	Level-1-260C-UNLIM	-40 to 125	3JHH
TLV3511QDCKRQ1	Active	Production	SC70 (DCK) | 5	3000 | LARGE T&R	Yes	SN	Level-1-260C-UNLIM	-40 to 125	1TI
TLV3512QDGKRQ1	Active	Production	VSSOP (DGK) | 8	2500 | LARGE T&R	-	NIPDAU	Level-1-260C-UNLIM	-	3VES

(1) **Status:** For more details on status, see our product life cycle.

(2) **Material type:** When designated, preproduction parts are prototypes/experimental devices, and are not yet approved or released for full production. Testing and final process, including without limitation quality assurance, reliability performance testing, and/or process qualification, may not yet be complete, and this item is subject to further changes or possible discontinuation. If available for ordering, purchases will be subject to an additional waiver at checkout, and are intended for early internal evaluation purposes only. These items are sold without warranties of any kind.

(3) **RoHS values:** Yes, No, RoHS Exempt. See the TI RoHS Statement for additional information and value definition.

(4) **Lead finish/Ball material:** Parts 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.

(5) **MSL rating/Peak reflow:** The moisture sensitivity level ratings and peak solder (reflow) temperatures. In the event that a part has multiple moisture sensitivity ratings, only the lowest level per JEDEC standards is shown. Refer to the shipping label for the actual reflow temperature that will be used to mount the part to the printed circuit board.

(6) **Part marking:** There may be an additional marking, which relates to the logo, the lot trace code information, or the environmental category of the part.

Multiple part markings will be inside parentheses. Only one part marking contained in parentheses and separated by a "~" will appear on a part. If a line is indented then it is a continuation of the previous line and the two combined represent the entire part marking for that device.

OTHER QUALIFIED VERSIONS OF TLV3511-Q1, TLV3512-Q1 :

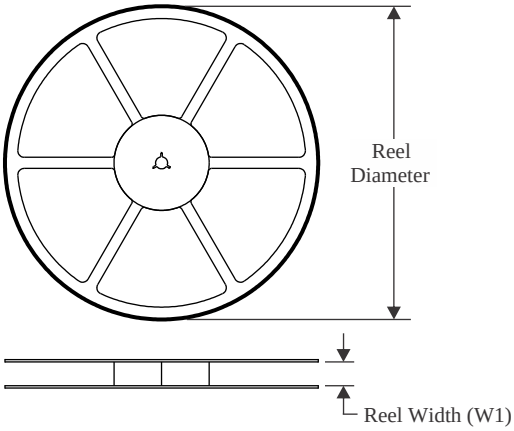
- Catalog : TLV3511, TLV3512

NOTE: Qualified Version Definitions:

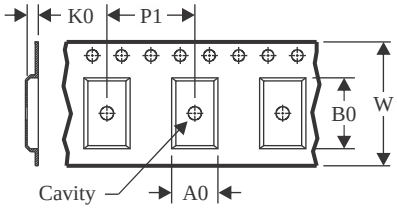
- Catalog - TI's standard catalog product

TAPE AND REEL INFORMATION

REEL DIMENSIONS

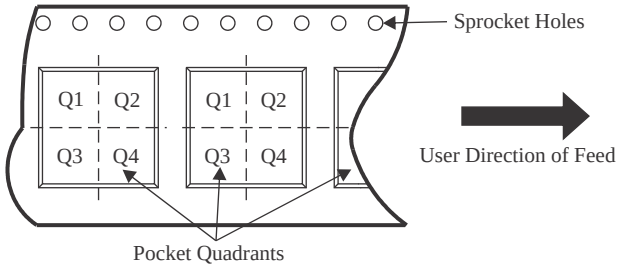


TAPE DIMENSIONS



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

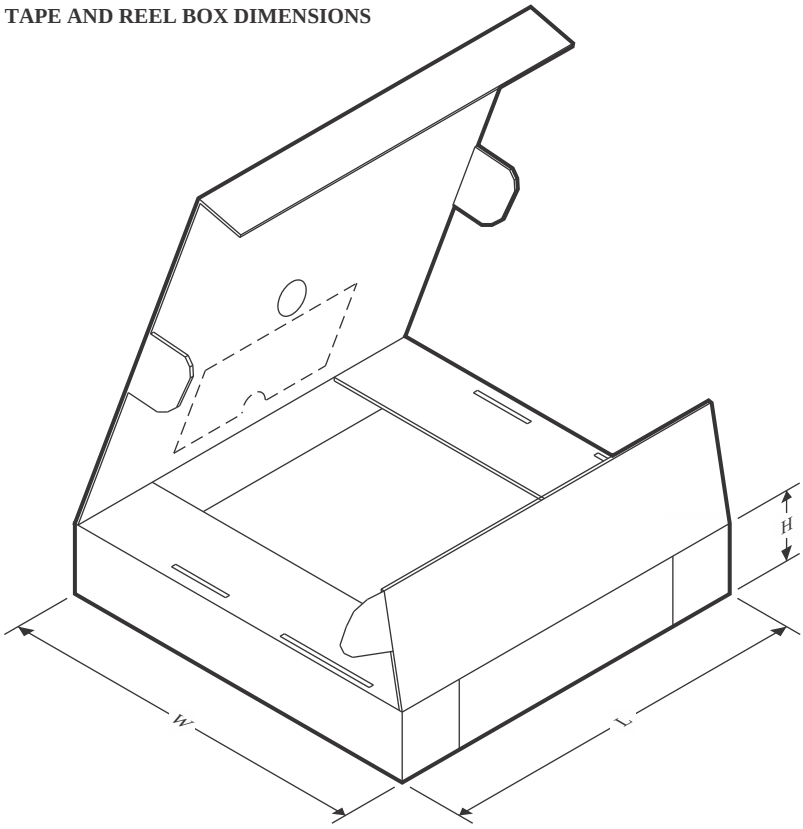
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
TLV3511QDBVRQ1	SOT-23	DBV	5	3000	180.0	8.4	3.2	3.2	1.4	4.0	8.0	Q3
TLV3511QDCKRQ1	SC70	DCK	5	3000	180.0	8.4	2.3	2.5	1.2	4.0	8.0	Q3

TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

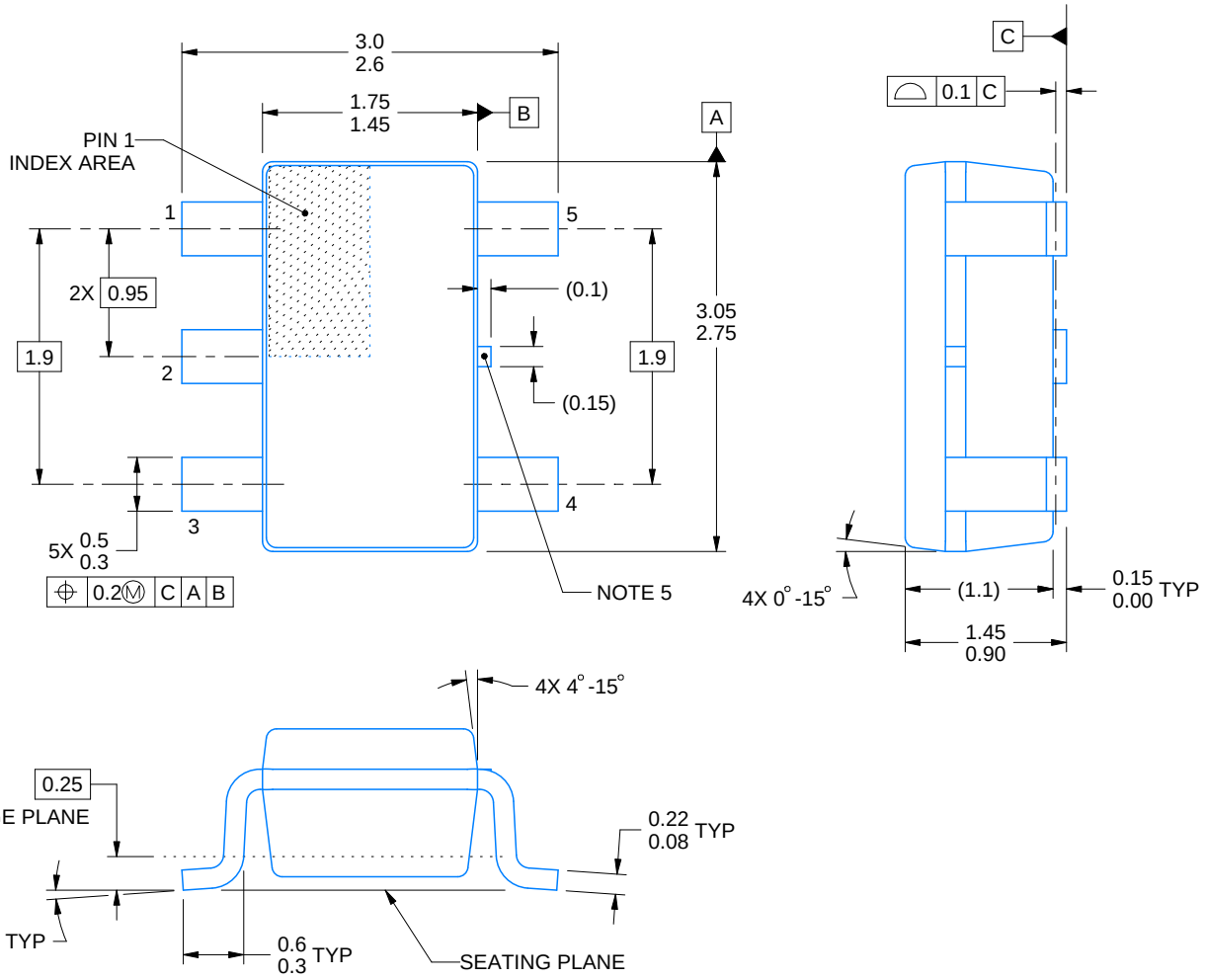
Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
TLV3511QDBVRQ1	SOT-23	DBV	5	3000	210.0	185.0	35.0
TLV3511QDCKRQ1	SC70	DCK	5	3000	210.0	185.0	35.0

PACKAGE OUTLINE

DBV0005A

SOT-23 - 1.45 mm max height

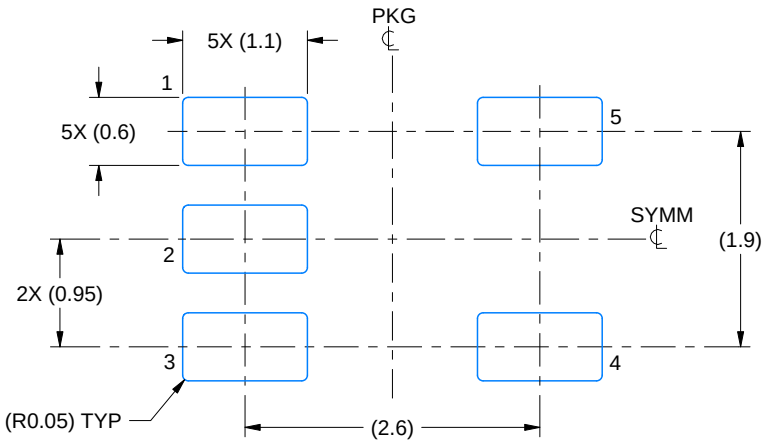
SMALL OUTLINE TRANSISTOR



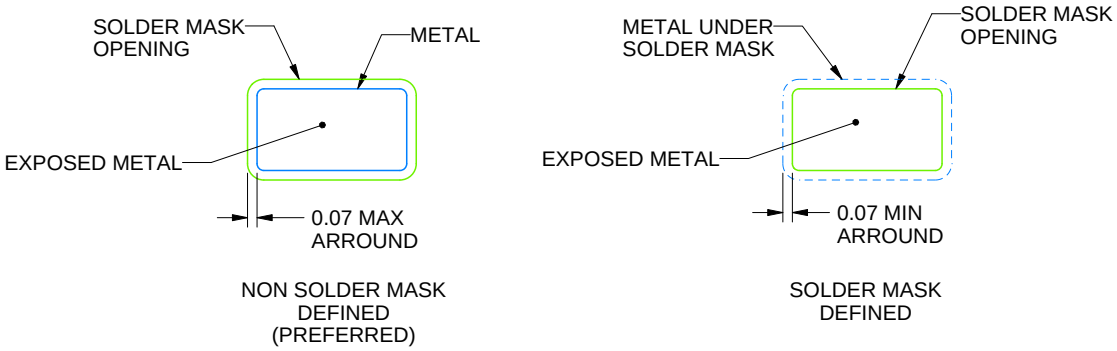
4214839/K 08/2024

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.
3. Refernce JEDEC MO-178.
4. Body dimensions do not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.25 mm per side.
5. Support pin may differ or may not be present.



LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE:15X

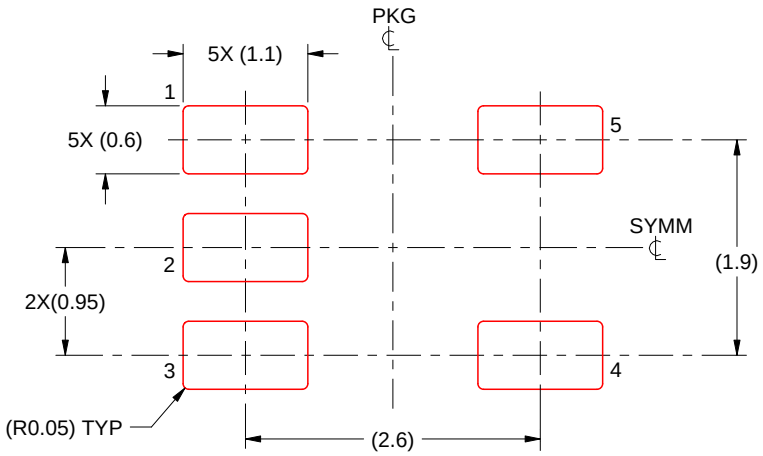


SOLDER MASK DETAILS

4214839/K 08/2024

NOTES: (continued)

6. Publication IPC-7351 may have alternate designs.
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.



SOLDER PASTE EXAMPLE
BASED ON 0.125 mm THICK STENCIL
SCALE:15X

4214839/K 08/2024

NOTES: (continued)

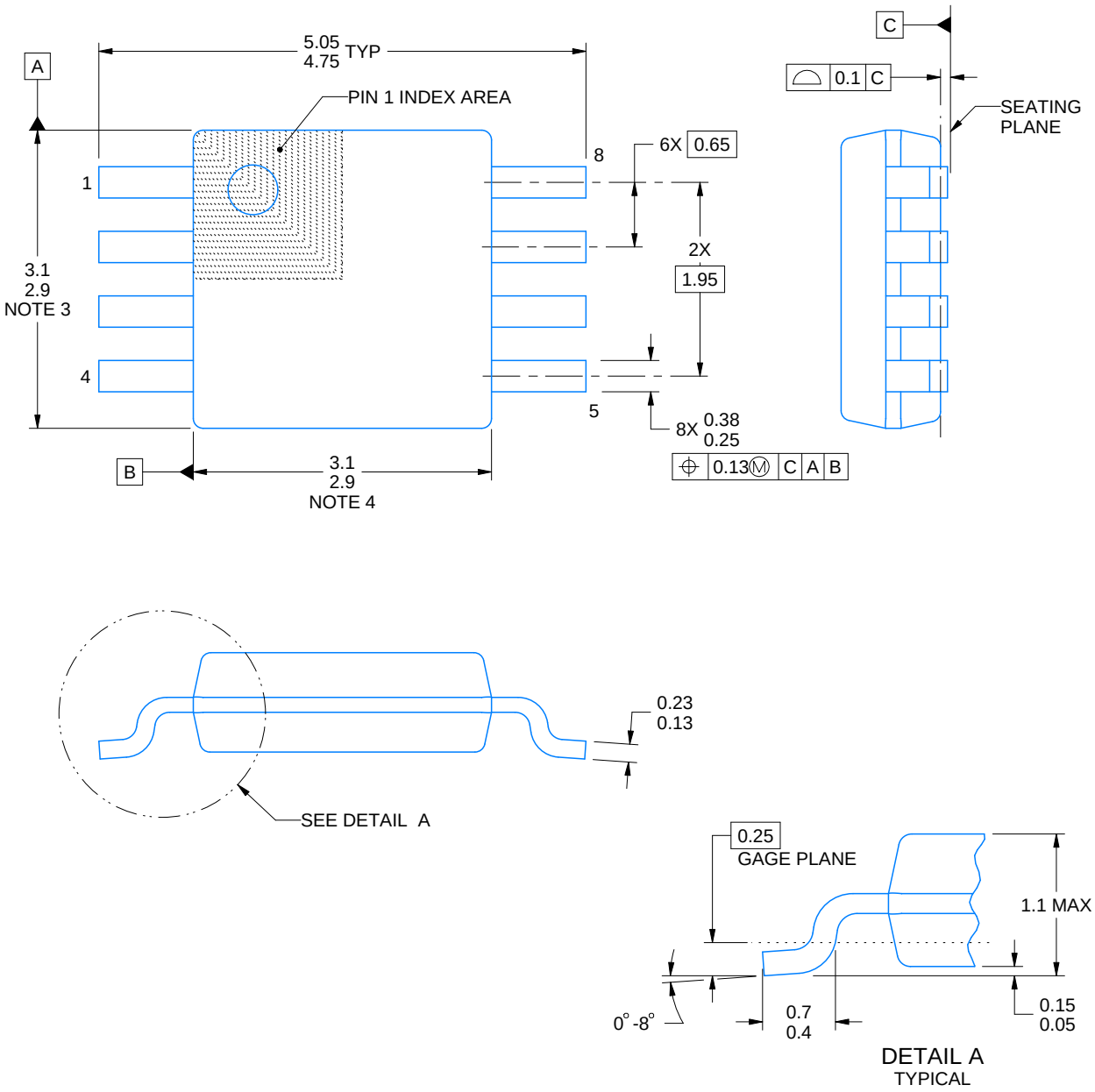
8. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
9. Board assembly site may have different recommendations for stencil design.

PACKAGE OUTLINE

DGK0008A

VSSOP - 1.1 mm max height

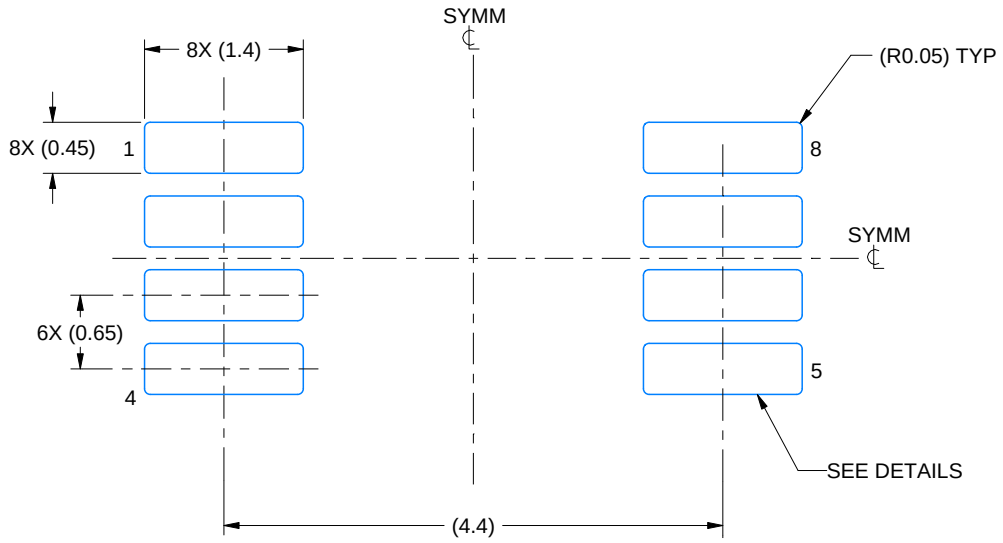
SMALL OUTLINE PACKAGE



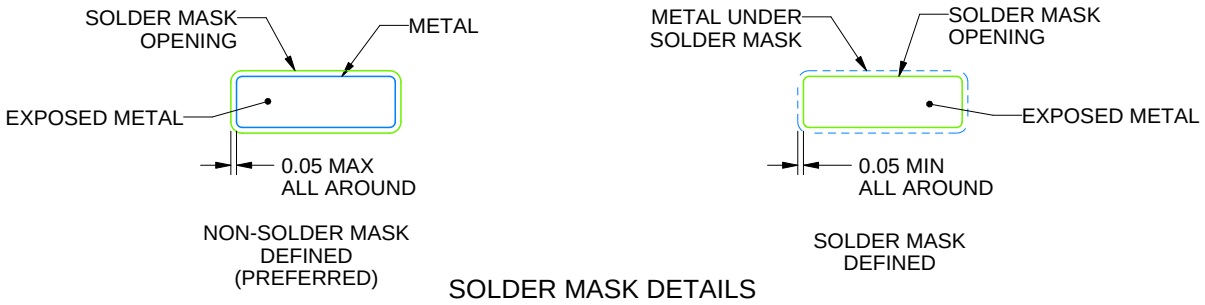
PowerPAD is a trademark of Texas Instruments.

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.
3. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.15 mm per side.
4. This dimension does not include interlead flash. Interlead flash shall not exceed 0.25 mm per side.
5. Reference JEDEC registration MO-187.



LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE: 15X

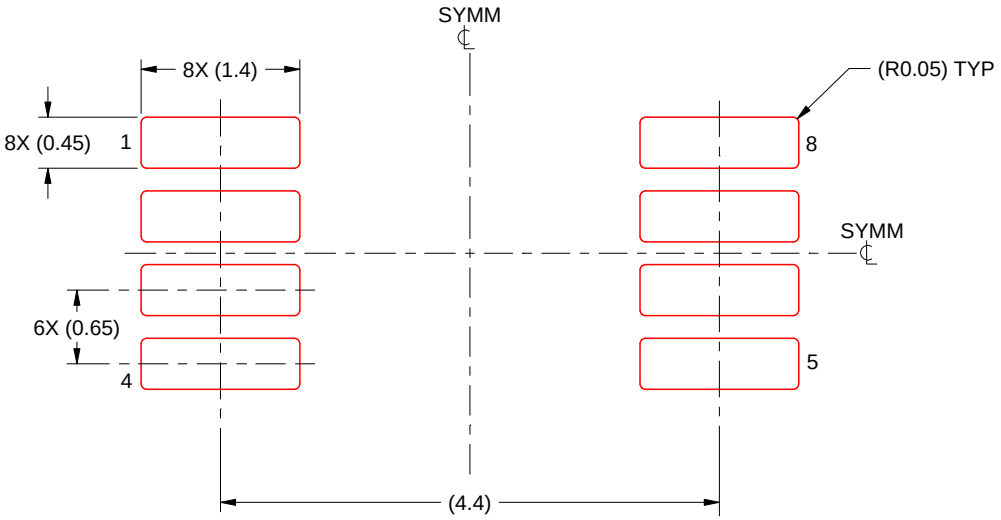


SOLDER MASK DETAILS

4214862/A 04/2023

NOTES: (continued)

6. Publication IPC-7351 may have alternate designs.
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.
8. Vias are optional depending on application, refer to device data sheet. If any vias are implemented, refer to their locations shown on this view. It is recommended that vias under paste be filled, plugged or tented.
9. Size of metal pad may vary due to creepage requirement.



SOLDER PASTE EXAMPLE
SCALE: 15X

4214862/A 04/2023

NOTES: (continued)

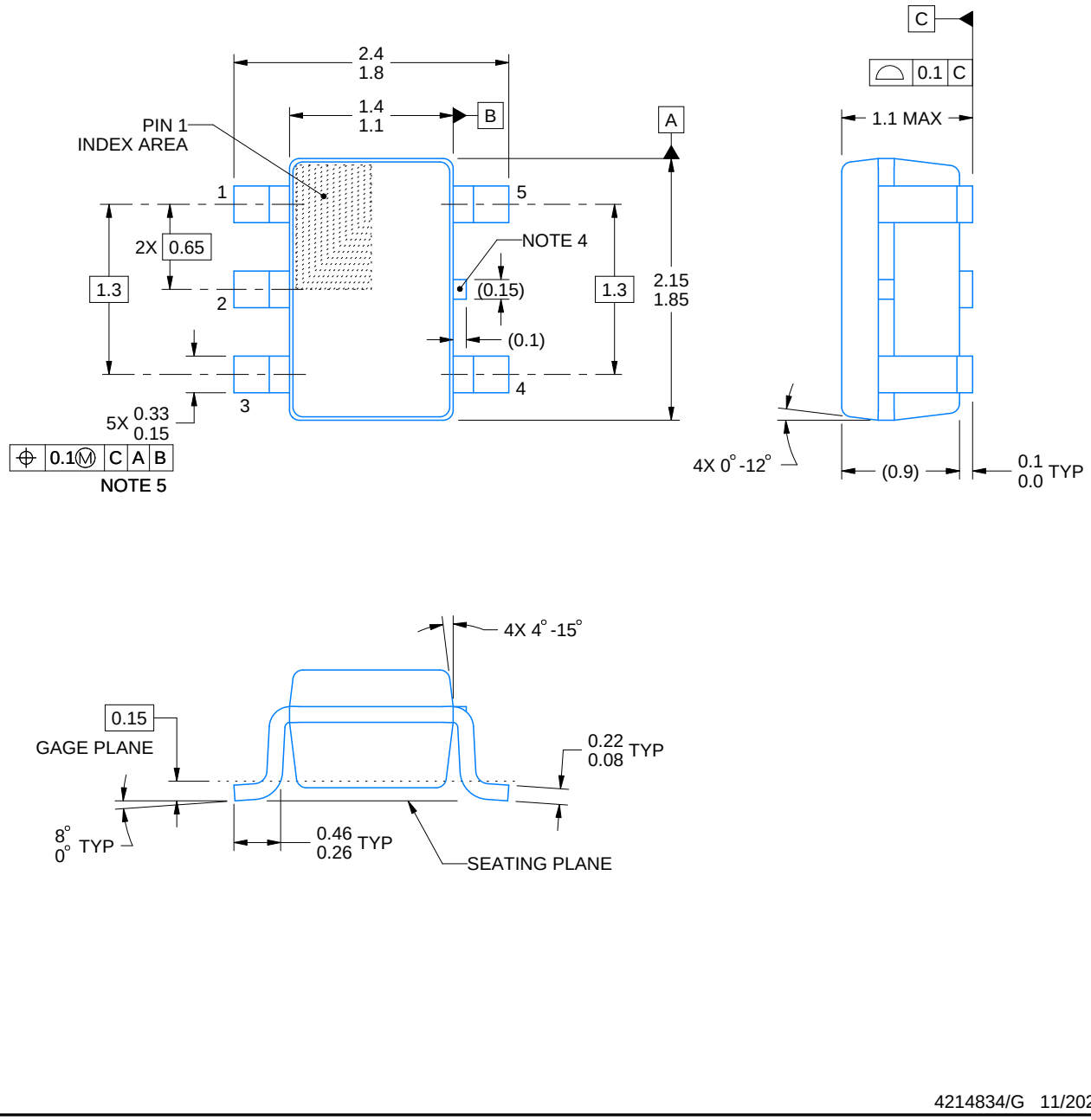
11. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
12. Board assembly site may have different recommendations for stencil design.

PACKAGE OUTLINE

DCK0005A

SOT - 1.1 max height

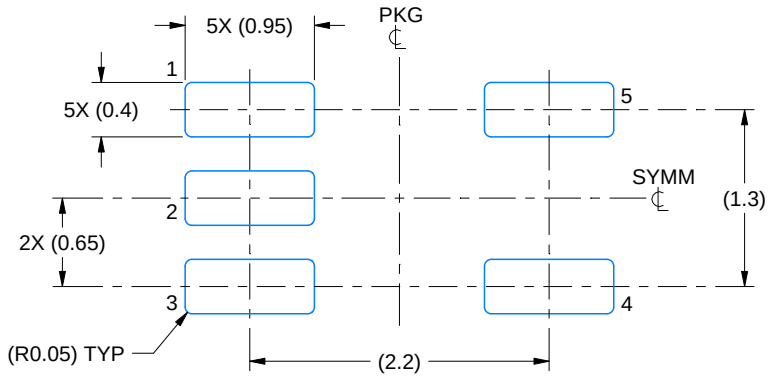
SMALL OUTLINE TRANSISTOR



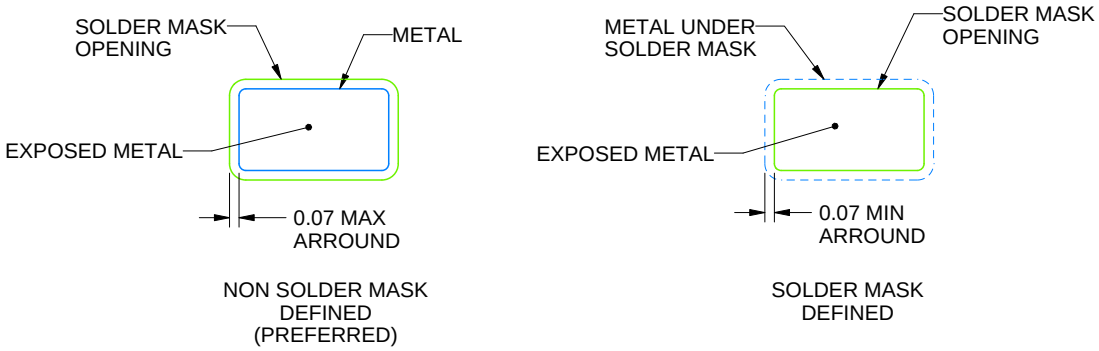
4214834/G 11/2024

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.
3. Refernce JEDEC MO-203.
4. Support pin may differ or may not be present.
5. Lead width does not comply with JEDEC.
6. Body dimensions do not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.25mm per side



LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE:18X

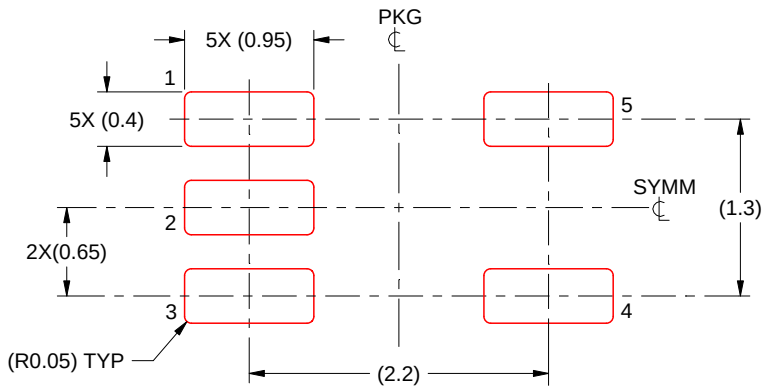


SOLDER MASK DETAILS

4214834/G 11/2024

NOTES: (continued)

7. Publication IPC-7351 may have alternate designs.
8. Solder mask tolerances between and around signal pads can vary based on board fabrication site.



SOLDER PASTE EXAMPLE
BASED ON 0.125 THICK STENCIL
SCALE:18X

4214834/G 11/2024

NOTES: (continued)

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

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