

TLV321x and TLV322x 40ns High-Speed Comparators with Rail-to-Rail Input

1 Features

- Propagation delay: 40ns
- Low supply current: 40µA per channel
- Input offset voltage: ±5mV maximum
- Internal hysteresis: 1.8mV
- Input voltage range extends 200mV beyond rails
- Power-on Reset (POR) for known start-up
- Push-pull output option (TLV321x)
- Open-drain output option (TLV322x)

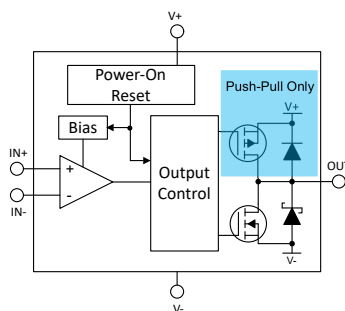
2 Applications

- [Motor drives](#)
- [Appliances](#)
- [Grid infrastructure](#)
- [Factory automation and control](#)
- [Traction inverter](#)

3 Description

The TLV321x and TLV322x are a family of 5V single, dual and quad channel high-speed comparators with push-pull or open-drain output options. The family has an excellent speed-to-power combination with a propagation delay of 40ns and a full supply voltage range of 1.8V to 5V with a quiescent supply current of only 40µA per channel.

These features, along with fast response time, rail-to-rail inputs, low offset voltage and large output drive current make the family well suited for current sensing, zero-cross detection, and a variety of other applications where speed is critical.



Block Diagram

The family also includes a Power-on Reset (POR) feature that holds the output in a known state until the minimum supply voltage has been reached to prevent output transients during system power-up and power-down.

The TLV321x have a push-pull output stage capable of sinking and sourcing large currents for symmetrical rise and fall times and quickly driving capacitive loads such as MOSFET gates.

The TLV322x have an open-drain output that can be pulled-up below or beyond the supply voltage. These devices are designed for low voltage logic translators or combined ORed logic lines.

All devices are specified for operation across the expanded temperature range of –40°C to 125°C.

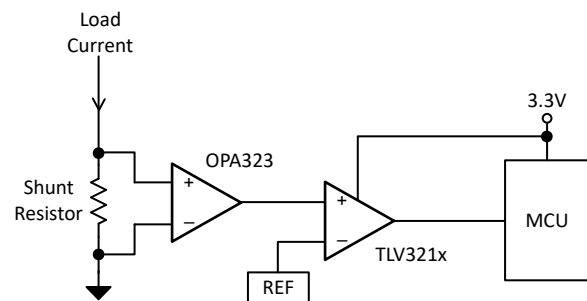
Package Information

PART NUMBER	PACKAGE ⁽¹⁾	PACKAGE SIZE ⁽²⁾
TLV3211, TLV3221 ⁽³⁾ (Single)	DCK (SOT-SC70, 5)	2mm × 2.1mm
	DBV (SOT-23, 5)	2.9mm × 2.8mm
TLV3212, TLV3222 ⁽³⁾ (Dual)	D (SOIC, 8) ⁽³⁾	4.9mm × 6mm
	DGK (VSSOP, 8)	3.0mm × 4.9mm
	DSG (WSON, 8) ⁽³⁾	2mm × 2mm
TLV3214 (Quad)	PW (TSSOP, 14)	5mm × 6.4mm
	RTE (WQFN, 16) ⁽³⁾	3mm × 3mm

(1) For more information, see [Section 10](#).

(2) The package size (length × width) is a nominal value and includes pins, where applicable.

(3) Preview information (not Production Data).



Low-Side Current Sensing

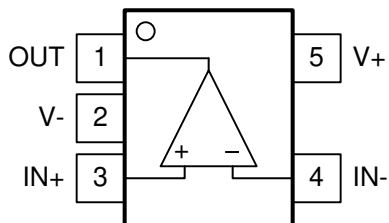


Table of Contents

1 Features	1	6.2 Functional Block Diagrams.....	18
2 Applications	1	6.3 Feature Description.....	18
3 Description	1	6.4 Device Functional Modes.....	18
4 Pin Configuration and Functions	3	7 Application and Implementation	21
4.1 Pin Configuration: TLV3211, TLV3221	3	7.1 Application Information.....	21
4.2 Pin Configurations: TLV3212, TLV3222	4	7.2 Typical Applications.....	24
4.3 Pin Configurations: TLV3214	5	7.3 Power Supply Recommendations.....	25
5 Specifications	6	7.4 Layout.....	26
5.1 Absolute Maximum Ratings.....	6	8 Device and Documentation Support	27
5.2 ESD Ratings.....	6	8.1 Documentation Support.....	27
5.3 Recommended Operating Conditions.....	6	8.2 Receiving Notification of Documentation Updates....	27
5.4 Thermal Information - Single.....	7	8.3 Support Resources.....	27
5.5 Thermal Information - Dual.....	7	8.4 Trademarks.....	27
5.6 Thermal Information - Quad.....	7	8.5 Electrostatic Discharge Caution.....	27
5.7 Electrical Characteristics.....	8	8.6 Glossary.....	27
5.8 Switching Characteristics.....	9	9 Revision History	27
5.9 Typical Characteristics.....	10	10 Mechanical, Packaging, and Orderable	
6 Detailed Description	18	Information	28
6.1 Overview.....	18		

4 Pin Configuration and Functions

4.1 Pin Configuration: TLV3211, TLV3221



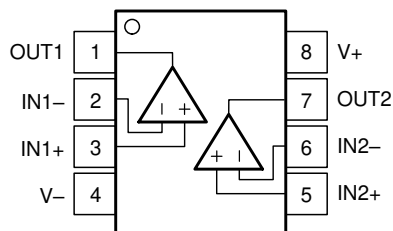
DCK, DBV Packages
SC70, SOT-23-5
Top View
(North West Pinout)

Table 4-1. Pin Functions: TLV3211, TLV3221

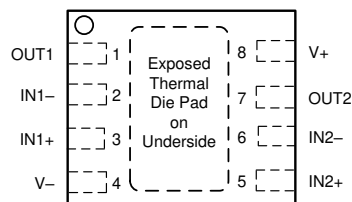
PIN		TYPE ⁽¹⁾	DESCRIPTION
NAME	NO.		
OUT	1	O	Output
V-	2	—	Negative supply voltage
IN+	3	I	Non-inverting (+) input
IN-	4	I	Inverting (-) input
V+	5	-	Positive supply voltage

(1) I = input, O = output

4.2 Pin Configurations: TLV3212, TLV3222



D, DGK Packages
8-Pin SOIC, VSSOP
Top View



NOTE: Connect exposed thermal pad directly to V- pin.

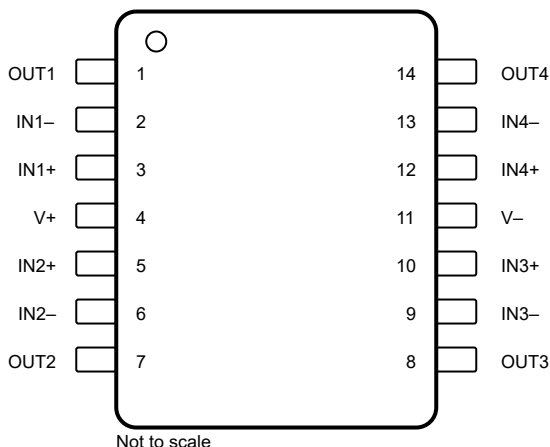
DSG Package
8-Pad WSON With Exposed Thermal Pad
Top View

Table 4-2. Pin Functions: TLV3212, TLV3222

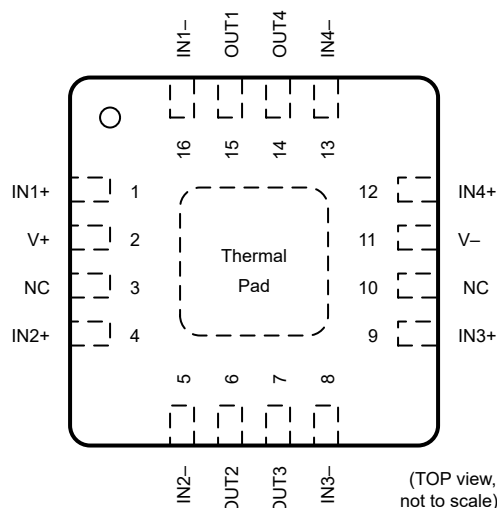
PIN		TYPE ⁽¹⁾	DESCRIPTION
NAME	NO.		
OUT1	1	O	Output pin of the comparator 1
IN1–	2	I	Inverting input pin of comparator 1
IN1+	3	I	Noninverting input pin of comparator 1
V–	4	—	Negative supply voltage
IN2+	5	I	Noninverting input pin of comparator 2
IN2–	6	I	Inverting input pin of comparator 2
OUT2	7	O	Output pin of the comparator 2
V+	8	—	Positive supply voltage
Thermal Pad	—	—	Connect directly to V- pin

(1) I = input, O = output

4.3 Pin Configurations: TLV3214



**Figure 4-1. PW Package
14-Pin TSSOP
Top View**



NOTE: Connect exposed thermal pad directly to V- pin.

**Figure 4-2. RTE Package
16-Pin WQFN With Exposed Thermal Pad
Top View**

Table 4-3. Pin Functions: TLV3214

PIN			TYPE ⁽¹⁾	DESCRIPTION
NAME	TSSOP	WQFN		
IN1–	2	16	I	Inverting input, channel A
IN1+	3	1	I	Noninverting input, channel A
IN2–	6	5	I	Inverting input, channel B
IN2+	5	4	I	Noninverting input, channel B
IN3–	9	8	I	Inverting input, channel C
IN3+	10	9	I	Noninverting input, channel C
IN4–	13	13	I	Inverting input, channel D
IN4+	12	12	I	Noninverting input, channel D
NC	—	3, 10	—	No internal connection
OUT1	1	15	O	Output, channel A
OUT2	7	6	O	Output, channel B
OUT3	8	7	O	Output, channel C
OUT4	14	14	O	Output, channel D
V–	11	11	—	Negative (lowest) supply or ground (for single-supply operation)
V+	4	2	—	Positive (highest) supply
Thermal Pad	—	Pad	—	Thermal Pad - Connect directly to V–

(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 $V_S = (V+) - (V-)$		6.5	V
Differential input voltage, V_{ID}	-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* can 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 can 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 ANSI/ESDA/JEDEC JS-001 ⁽¹⁾	±2000	V
$V_{(ESD)}$	Electrostatic discharge	Charged-device model (CDM), per JEDEC specification JESD22-C101 ⁽²⁾	±1000	V

- (1) JEDEC document JEP155 states that 500V HBM allows safe manufacturing with a standard ESD control process.
- (2) JEDEC document JEP157 states that 250V CDM allows safe manufacturing with a standard ESD control process.

5.3 Recommended Operating Conditions

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

	MIN	MAX	UNIT
Supply voltage $V_S = (V+) - (V-)$	1.8	5.5	V
Input voltage range	(V-) - 0.2	(V+) + 0.2	V
Ambient temperature, T_A	-40	125	°C

5.4 Thermal Information - Single

THERMAL METRIC ⁽¹⁾		TLV3211, TLV3221		UNIT
		DCK (SC70)	DBV (SOT-23)	
		5 PINS	5 PINS	
R _{θJA}	Junction-to-ambient thermal resistance	222.0	203.0	°C/W
R _{θJC(top)}	Junction-to-case (top) thermal resistance	126.2	96.8	°C/W
R _{θJB}	Junction-to-board thermal resistance	56.1	62.4	°C/W
Ψ _{JT}	Junction-to-top characterization parameter	29.6	32.2	°C/W
Ψ _{JB}	Junction-to-board characterization parameter	56.0	62.0	°C/W
R _{θJC(bot)}	Junction-to-case (bottom) thermal resistance	–	–	°C/W

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

5.5 Thermal Information - Dual

THERMAL METRIC ⁽¹⁾		TLV3212, TLV3222			UNIT
		DGK (VSSOP)	DSG (WSON)	D (SOIC)	
		8 PINS	8 PINS	8 PINS	
R _{θJA}	Junction-to-ambient thermal resistance	141.7	–	–	°C/W
R _{θJC(top)}	Junction-to-case (top) thermal resistance	59.9	–	–	°C/W
R _{θJB}	Junction-to-board thermal resistance	78.8	–	–	°C/W
Ψ _{JT}	Junction-to-top characterization parameter	6.0	–	–	°C/W
Ψ _{JB}	Junction-to-board characterization parameter	78.1	–	–	°C/W
R _{θJC(bot)}	Junction-to-case (bottom) thermal resistance	–	–	–	°C/W

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

5.6 Thermal Information - Quad

THERMAL METRIC ⁽¹⁾		TLV3214		UNIT
		PW (TSSOP)	RTE (WQFN)	
		14 PINS	16 PINS	
R _{θJA}	Junction-to-ambient thermal resistance	114.8	–	°C/W
R _{θJC(top)}	Junction-to-case (top) thermal resistance	49.9	–	°C/W
R _{θJB}	Junction-to-board thermal resistance	70.7	–	°C/W
Ψ _{JT}	Junction-to-top characterization parameter	5.8	–	°C/W
Ψ _{JB}	Junction-to-board characterization parameter	70.0	–	°C/W
R _{θJC(bot)}	Junction-to-case (bottom) thermal resistance	–	–	°C/W

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

5.7 Electrical Characteristics

$V_S = 1.8V$ to $5V$, $V_{CM} = V_S / 2$; at $T_A = 25^\circ C$ (unless otherwise noted). Typical values are at $T_A = 25^\circ C$.

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
DC Input Characteristics						
V_{IO}	Input Offset Voltage	$V_S = 5V$, $V_{CM} = V_S / 2$, $T_A = -40$ to $125^\circ C$		± 1	± 6	mV
dV_{OS}/dT	Input offset voltage drift	$V_S = 5V$, $V_{CM} = V_S / 2$, $T_A = -40$ to $125^\circ C$		1		$\mu V/^\circ C$
V_{HYS}	Hysteresis	$V_S = 5V$, $V_{CM} = V_S / 2$		1.8		mV
V_{HYS}	Hysteresis	$V_S = 5V$, $V_{CM} = V_S / 2$, $T_A = -40$ to $125^\circ C$			4	mV
V_{CM}	Common-mode voltage range		$(V_-) - 0.2$		$(V_+) + 0.2$	V
I_B	Input bias current	$V_S = 5V$, $V_{CM} = V_S / 2$		1	5	pA
I_B	Input bias current	$V_S = 5V$, $V_{CM} = V_S / 2$, $T_A = -40$ to $125^\circ C$			1200	pA
I_{OS}	Input offset current	$V_S = 5V$, $V_{CM} = V_S / 2$		0.1	2.5	pA
I_{OS}	Input offset current	$V_S = 5V$, $V_{CM} = V_S / 2$, $T_A = -40$ to $125^\circ C$			250	pA
C_{IN}	Input capacitance			1.5		pF
R_{DM}	Input differential mode resistance			1600		G Ω
R_{CM}	Input common mode resistance			550		G Ω
CMRR	Common-mode rejection ratio	$V_{CM} = (V_-) - 0.2$ to $(V_+) + 0.2$		76		dB
DC Output Characteristics						
V_{OH}	Voltage swing from (V+)	$V_S = 5V$, $I_{Source} = 4mA$ (push-pull only)		135	165	mV
V_{OH}	Voltage swing from (V+)	$V_S = 5V$, $I_{Source} = 4mA$, -40 to $125^\circ C$ (push-pull only)			200	mV
V_{OL}	Voltage swing from (V-)	$V_S = 5V$, $I_{Sink} = 4mA$		120	160	mV
V_{OL}	Voltage swing from (V-)	$V_S = 5V$, $I_{Sink} = 4mA$, -40 to $125^\circ C$			180	mV
I_{SC}	Short-circuit current	$V_S = 5V$, sourcing		87		mA
		$V_S = 5V$, sourcing, -40 to $125^\circ C$			110	
I_{SC}	Short-circuit current	$V_S = 5V$, sinking		96		mA
		$V_S = 5V$, sinking, -40 to $125^\circ C$			120	
I_{LKG}	Open-drain output leakage current	$V_{PULLUP} = V_S$ (open-drain only)		50		pA
Power Supply						
I_Q	Supply current / Channel (SINGLE and DUAL)	$V_S = 2.7V$ and $5V$, no load, $V_{ID} = -0.1V$ (Output Low), -40 to $125^\circ C$		46	53	μA
I_Q	Supply current / Channel (QUAD)	$V_S = 2.7V$ and $5V$, no load, $V_{ID} = -0.1V$ (Output Low), -40 to $125^\circ C$		42	48	μA
I_Q	Supply current / Channel (SINGLE)	$V_S = 2.7V$ and $5V$, no load, $V_{ID} = +0.1V$ (Output High), $T_A = -40$ to $125^\circ C$		48	60	μA
I_Q	Supply current / Channel (DUAL and QUAD)	$V_S = 2.7V$ and $5V$, no load, $V_{ID} = +0.1V$ (Output High), $T_A = -40$ to $125^\circ C$		44	60	μA
V_{POR} (postive)	Power-On Reset Voltage			1.65		V
PSRR	Power Supply Rejection Ratio	$V_S = 1.8V$ to $5.5V$, no load, $V_{ID} = +0.1V$, $T_A = -40$ to $125^\circ C$		77		dB

5.8 Switching Characteristics

For $V_S = 5V$, $V_{CM} = V_S / 2$; $C_L = 15pF$ at $T_A = 25^\circ C$ (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, $V_{OD} = 20mV$		56		ns
t_{PHL}	Propagation delay time, high to-low	Midpoint of input to midpoint of output, $V_{OD} = 20mV$ ($R_P = 2.5k\Omega$ for open-drain only)		56		ns
t_{PHL}	Propagation delay time, high to-low	Midpoint of input to midpoint of output, $V_{OD} = 50mV$		42		ns
t_{PHL}	Propagation delay time, high to-low	Midpoint of input to midpoint of output, $V_{OD} = 50mV$ ($R_P = 2.5k\Omega$ for open-drain only)		42		ns
t_{PHL}	Propagation delay time, high to-low	Midpoint of input to midpoint of output, $V_{OD} = 100mV$		34	40	ns
t_{PHL}	Propagation delay time, high to-low	Midpoint of input to midpoint of output, $V_{OD} = 100mV$ ($R_P = 2.5k\Omega$ for open-drain only)		34	40	ns
t_{PHL}	Propagation delay time, high to-low	Midpoint of input to midpoint of output, $V_{OD} = 100mV$, -40 to $125^\circ C$			50	ns
t_{PLH}	Propagation delay time, low-to-high	Midpoint of input to midpoint of output, $V_{OD} = 20mV$ (push-pull only)		54		ns
t_{PLH}	Propagation delay time, low-to-high	Midpoint of input to midpoint of output, $V_{OD} = 50mV$ (push-pull only)		39		ns
t_{PLH}	Propagation delay time, low-to-high	Midpoint of input to midpoint of output, $V_{OD} = 100mV$ (push-pull only)		32	39	ns
t_{PLH}	Propagation delay time, low-to-high	Midpoint of input to midpoint of output, $V_{OD} = 100mV$, -40 to $125^\circ C$ (push-pull only)			50	ns
t_{PD} Skew	Propagation delay skew	Measured as absolute value of the difference between t_{PDLH} and t_{PDHL} , $V_{OD} = 100mV$		3.5		ns
t_{PD} ch-ch skew	Channel-to-channel propagation delay skew (dual and quad only)	$V_{CM} = V_S/2$, $V_{OVERDRIVE} = V_{UNDERDRIVE} = 50mV$, 10MHz Squarewave		1.3		ns
f_{TOGGLE}	Input toggle frequency	$V_{IN} = 200mV_{PP}$ Sine Wave, When output high reaches 90% of (V_+) - (V_-) or output low reaches 10% of (V_+) - (V_-)		12		MHz
t_R	Rise time	Measured from 20% to 80% (for push-pull only)		1.5		ns
t_F	Fall time	Measured from 20% to 80%		1.5		ns
t_{ON}	Power-up time	During power on, (V_+) must exceed 1.65V for 32 μs before the output reflects the input		32		μs

5.9 Typical Characteristics

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

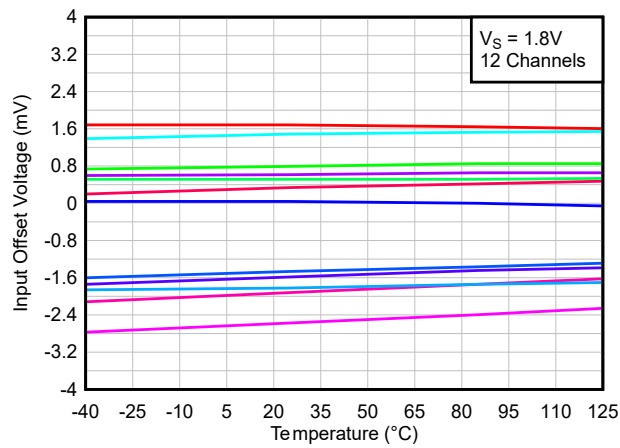


Figure 5-1. Offset Voltage vs. Temperature, 1.8V

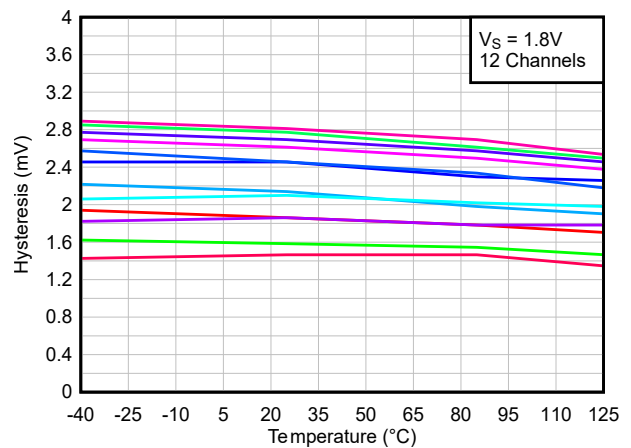


Figure 5-2. Hysteresis vs. Temperature, 1.8V

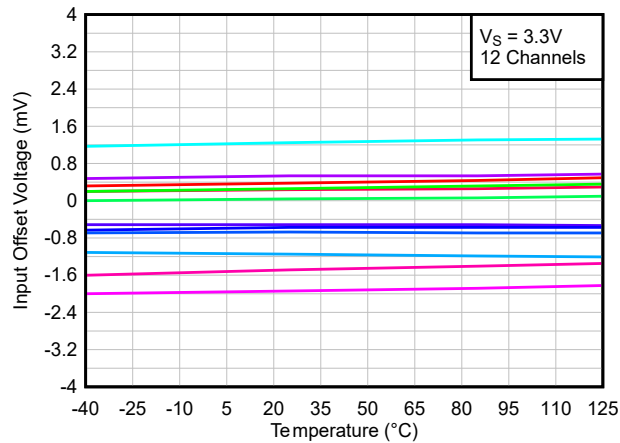


Figure 5-3. Offset Voltage vs. Temperature, 3.3V

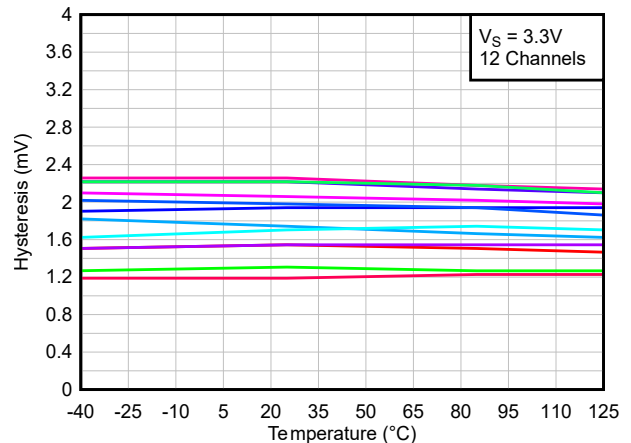


Figure 5-4. Hysteresis vs. Temperature, 3.3V

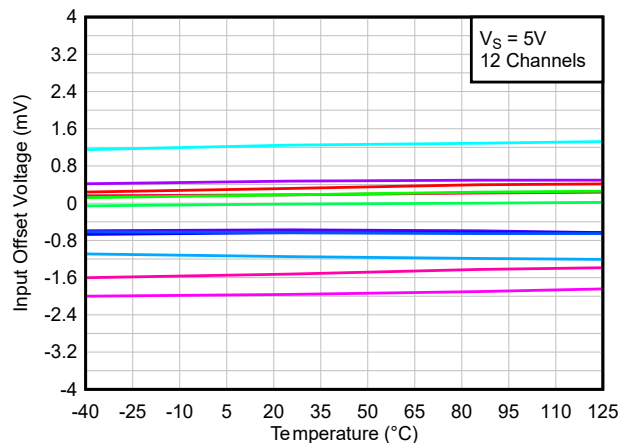


Figure 5-5. Offset Voltage vs. Temperature, 5V

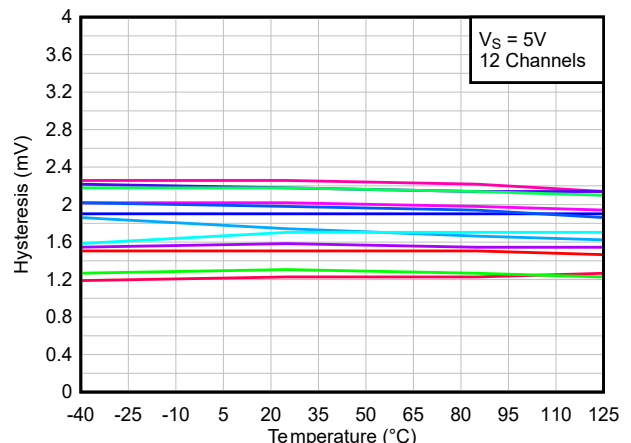


Figure 5-6. Hysteresis vs. Temperature, 5V

5.9 Typical Characteristics (continued)

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

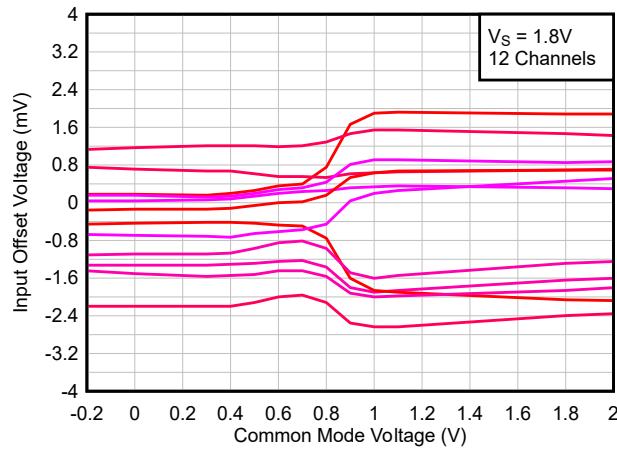


Figure 5-7. Offset Voltage vs. Common-Mode, 1.8V

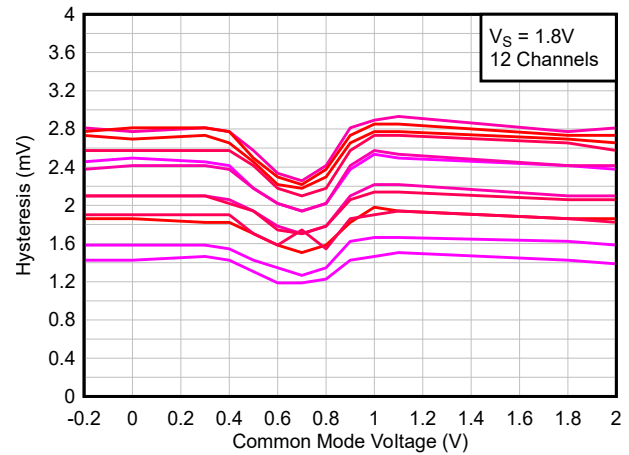


Figure 5-8. Hysteresis vs. Common-Mode, 1.8V

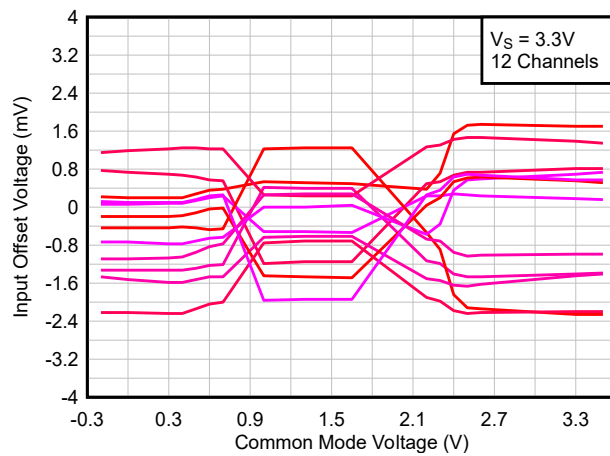


Figure 5-9. Offset vs. Common-Mode, 3.3V

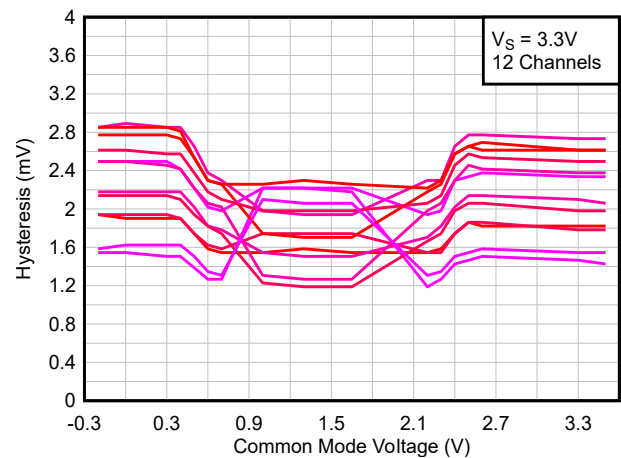


Figure 5-10. Hysteresis vs. Common-Mode, 3.3V

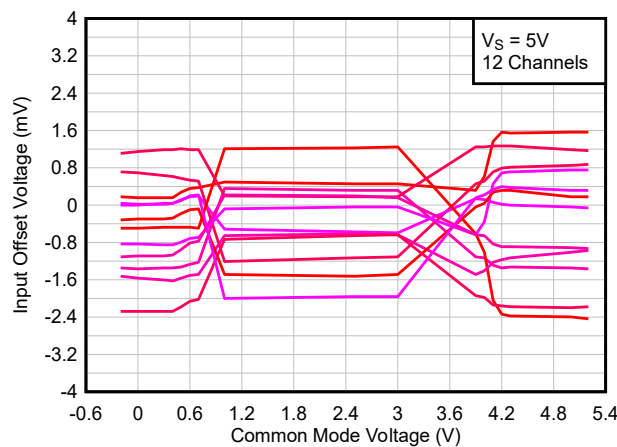


Figure 5-11. Offset Voltage vs. Common-Mode, 5V

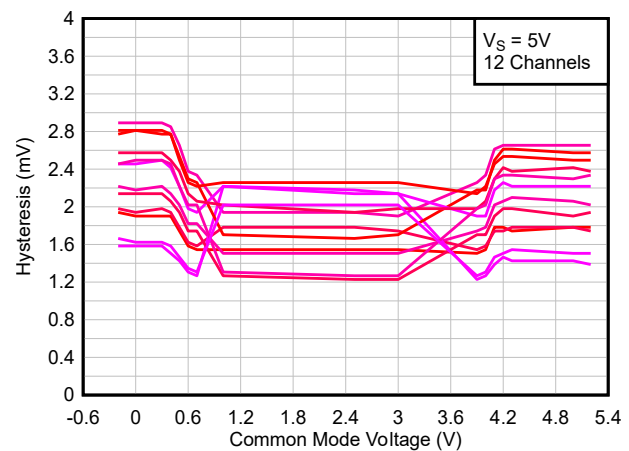


Figure 5-12. Hysteresis vs. Common-Mode, 5V

5.9 Typical Characteristics (continued)

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

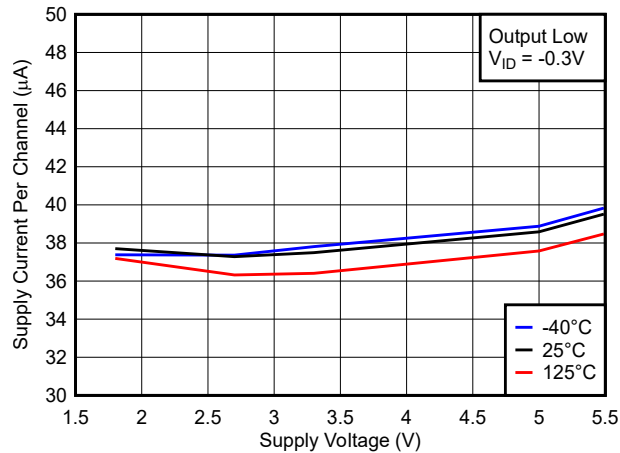


Figure 5-13. Supply Current vs. Supply Voltage (Output Low)

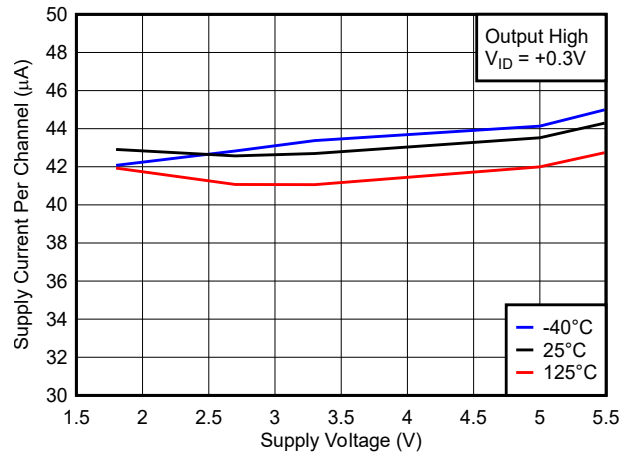


Figure 5-14. Supply Current vs. Supply Voltage (Output High)

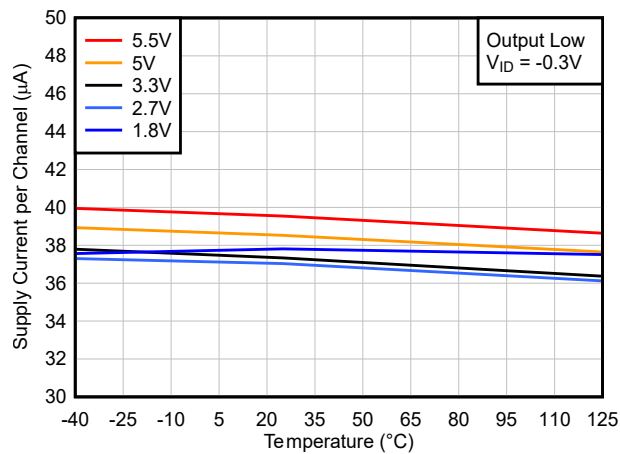


Figure 5-15. Supply Current vs. Temperature (Output Low)

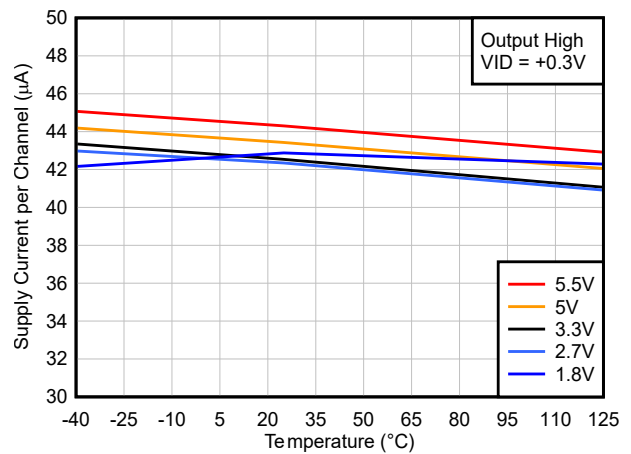


Figure 5-16. Supply Current vs. Temperature (Output High)

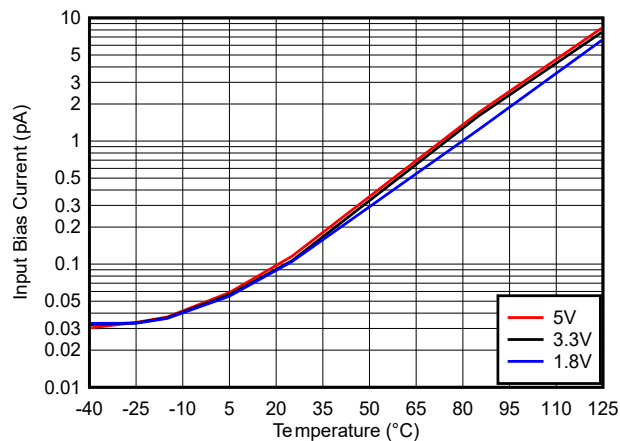


Figure 5-17. Input Bias Current vs. Temperature

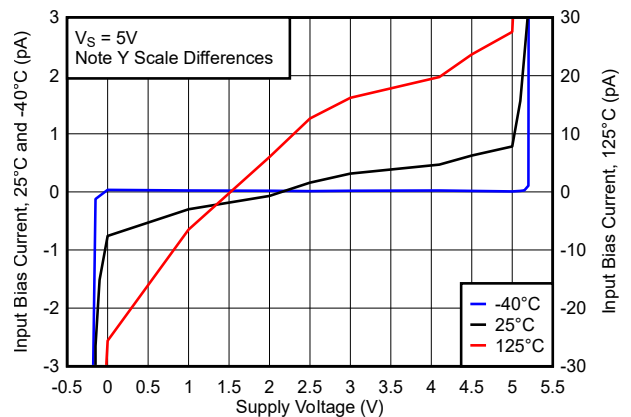


Figure 5-18. Input Bias Current vs. Common-Mode, 5V

5.9 Typical Characteristics (continued)

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

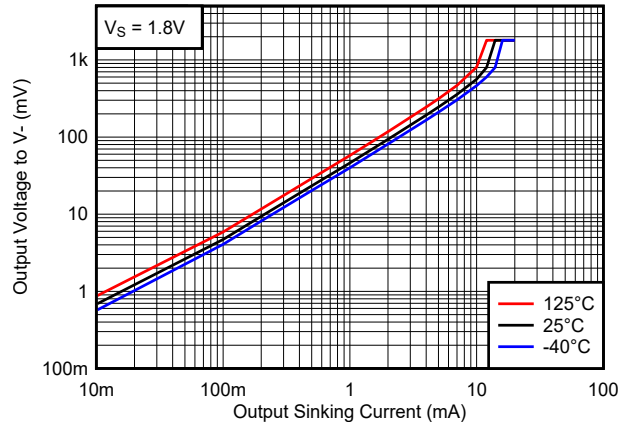


Figure 5-19. Output Voltage vs. Output Sinking Current, 1.8V

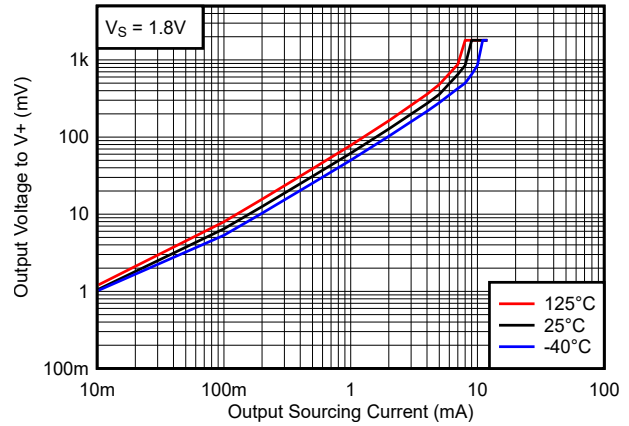


Figure 5-20. Output Voltage vs. Output Sourcing Current (Push-Pull Only), 1.8V

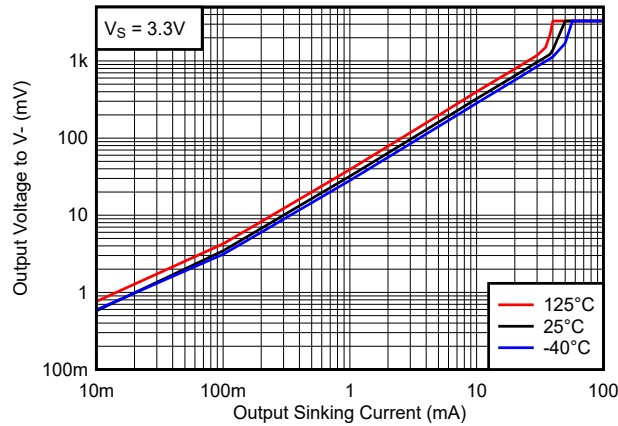


Figure 5-21. Output Voltage vs. Output Sinking Current, 3.3V

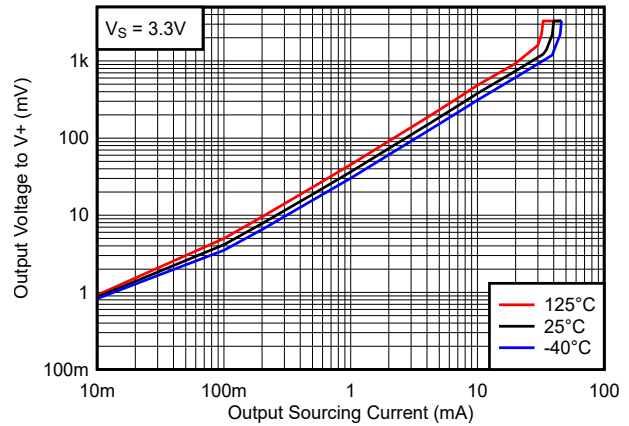


Figure 5-22. Output Voltage vs. Output Sourcing Current (Push-Pull Only), 3.3V

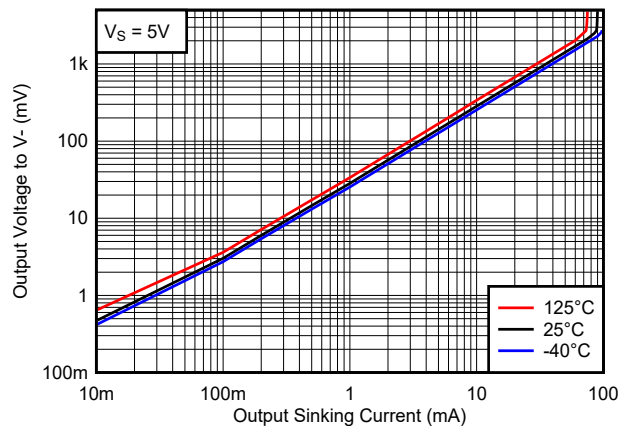


Figure 5-23. Output Voltage vs. Output Sinking Current, 5V

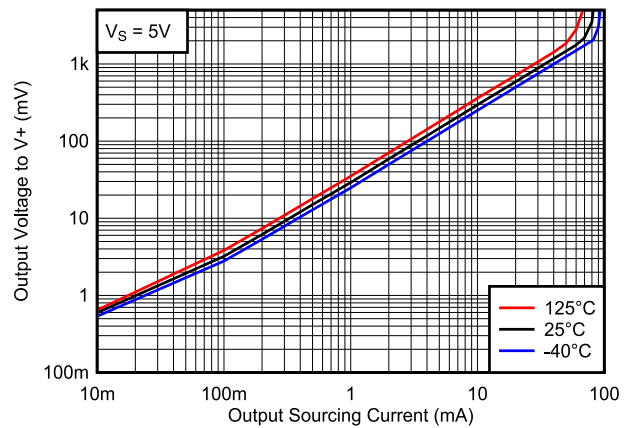


Figure 5-24. Output Voltage vs. Output Sourcing Current (Push-Pull Only), 5V

5.9 Typical Characteristics (continued)

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

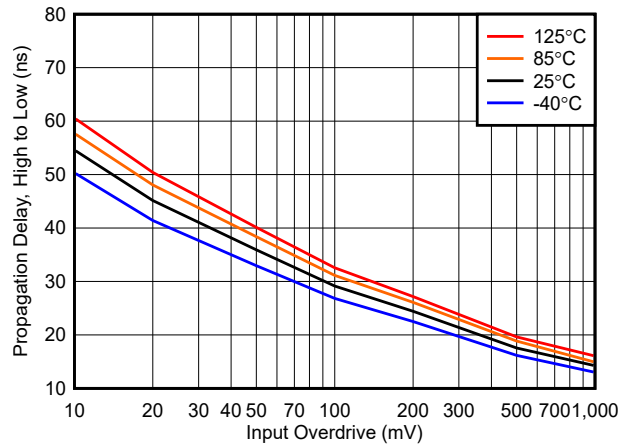


Figure 5-25. Propagation Delay, High to Low vs. Overdrive at 1.8V

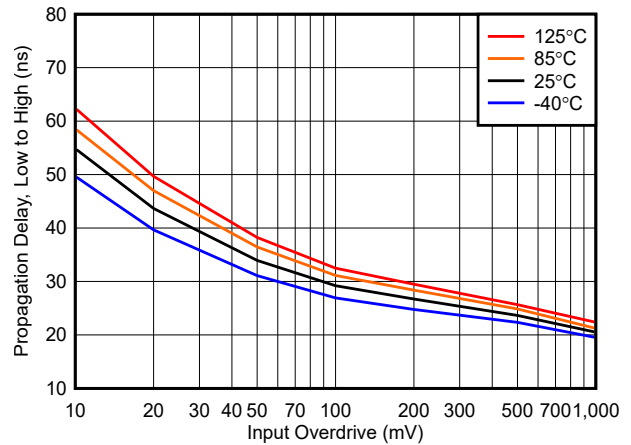


Figure 5-26. Propagation Delay, Low to High vs. Overdrive at 1.8V

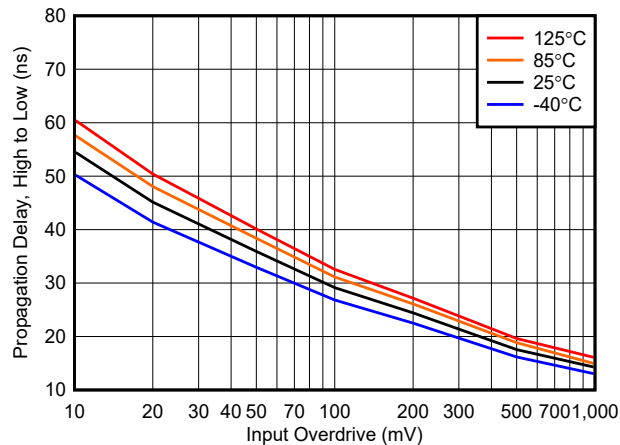


Figure 5-27. Propagation Delay, High to Low vs. Overdrive at 3.3V

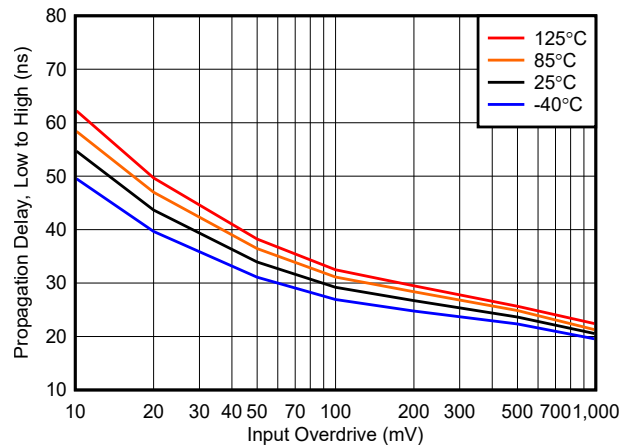


Figure 5-28. Propagation Delay, Low to High vs. Overdrive at 3.3V

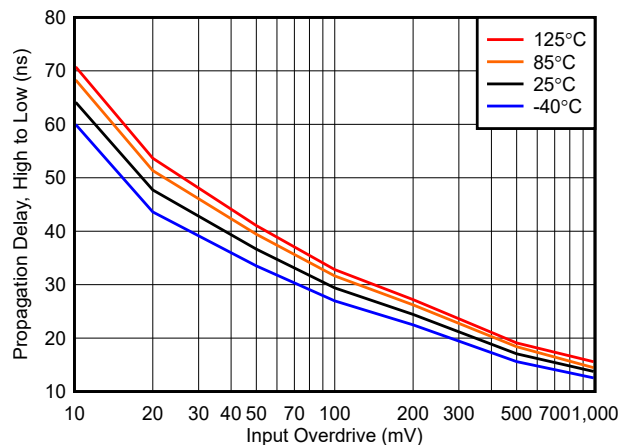


Figure 5-29. Propagation Delay, High to Low vs. Overdrive at 5V

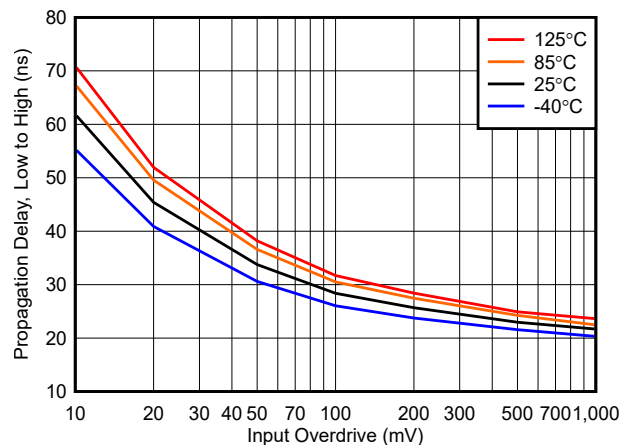


Figure 5-30. Propagation Delay, Low to High vs. Overdrive at 5V

5.9 Typical Characteristics (continued)

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

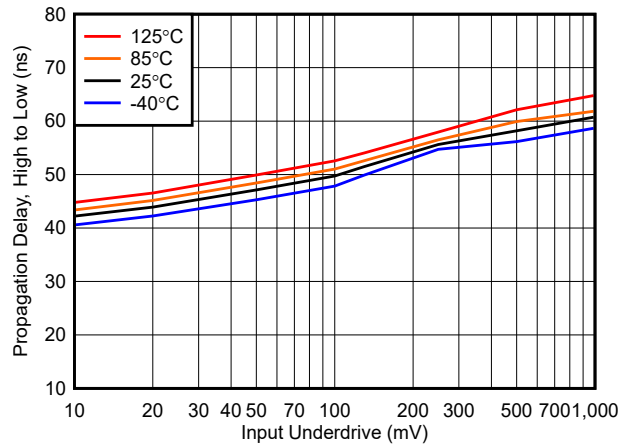


Figure 5-31. Propagation Delay, High to Low vs. Underdrive at 1.8V

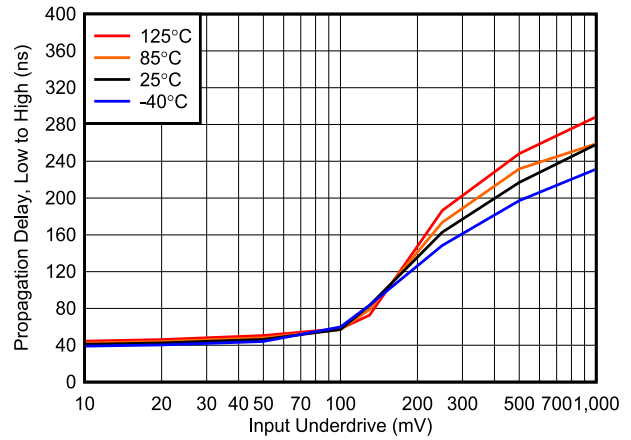


Figure 5-32. Propagation Delay, Low to High vs. Underdrive at 1.8V

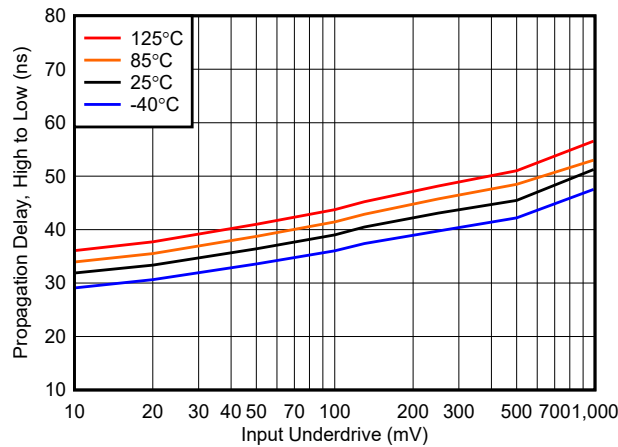


Figure 5-33. Propagation Delay, High to Low vs. Underdrive at 3.3V

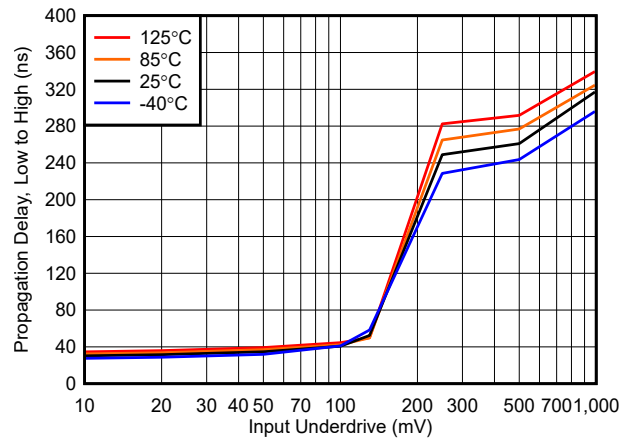


Figure 5-34. Propagation Delay, Low to High vs. Underdrive at 3.3V

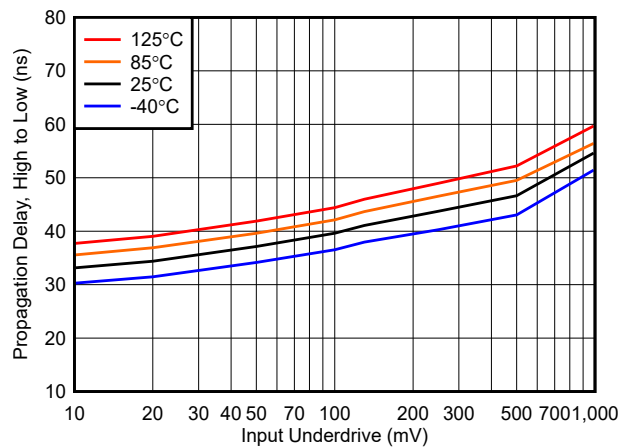


Figure 5-35. Propagation Delay, High to Low vs. Underdrive at 5V

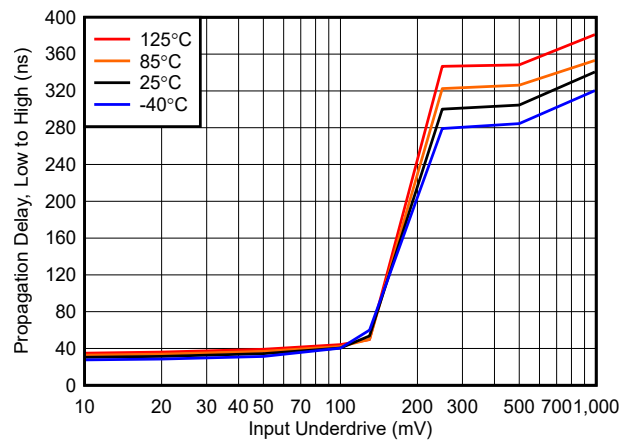


Figure 5-36. Propagation Delay, Low to High vs. Underdrive at 5V

5.9 Typical Characteristics (continued)

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

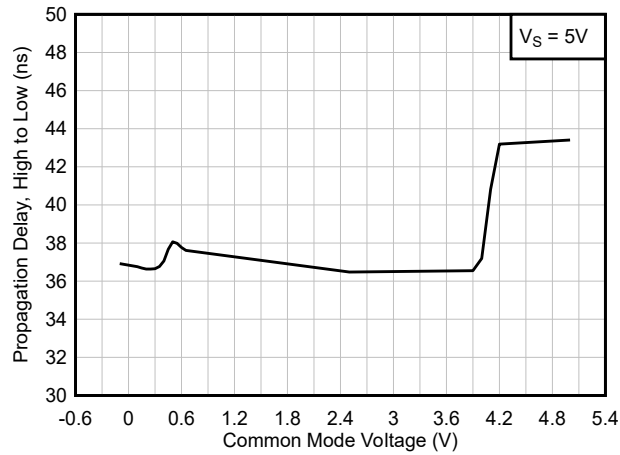


Figure 5-37. Propagation Delay, High to Low vs. Common Mode at 5V

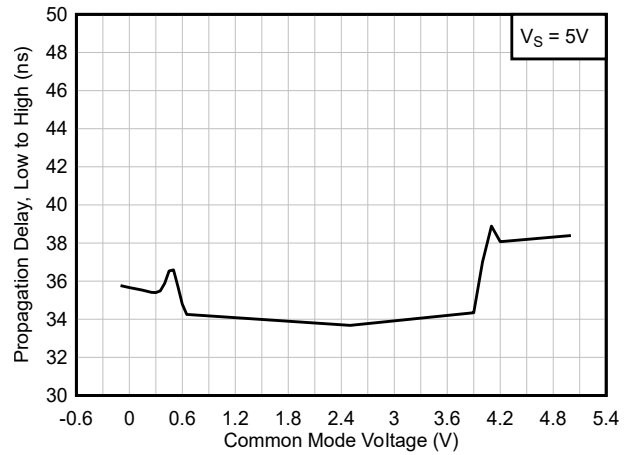


Figure 5-38. Propagation Delay, Low to High vs. Common Mode at 5V

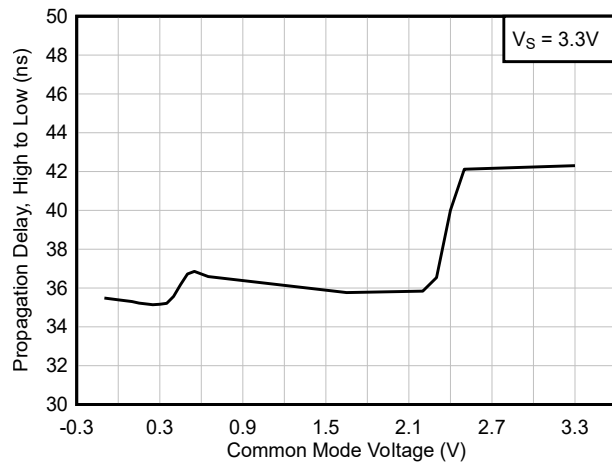


Figure 5-39. Propagation Delay, High to Low vs. Common Mode at 3.3V

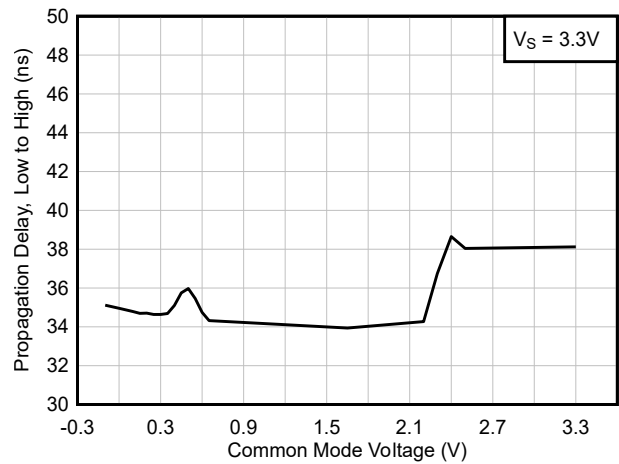


Figure 5-40. Propagation Delay, Low to High vs. Common Mode at 3.3V

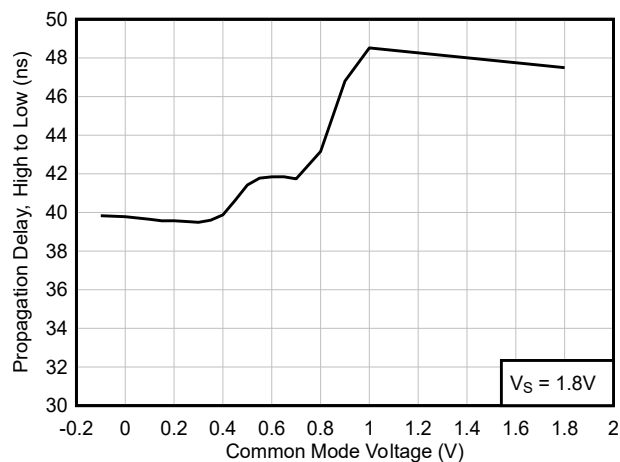


Figure 5-41. Propagation Delay, High to Low vs. Common Mode at 1.8V

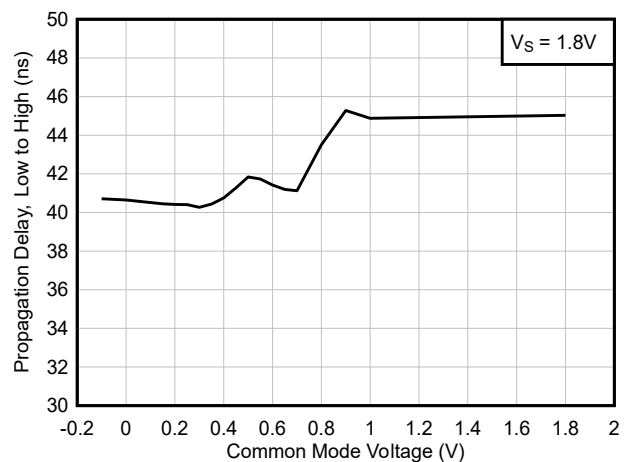


Figure 5-42. Propagation Delay, Low to High vs. Common Mode at 1.8V

5.9 Typical Characteristics (continued)

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

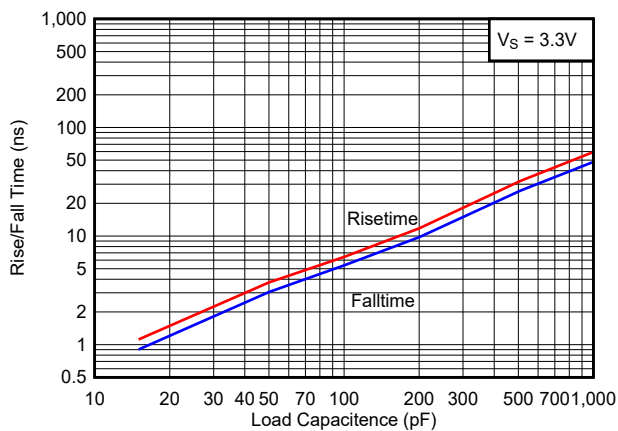


Figure 5-43. Rise and Fall Times vs. Capacitive Load

6 Detailed Description

6.1 Overview

The TLV321x devices are 40ns comparators with push-pull output.

6.2 Functional Block Diagrams

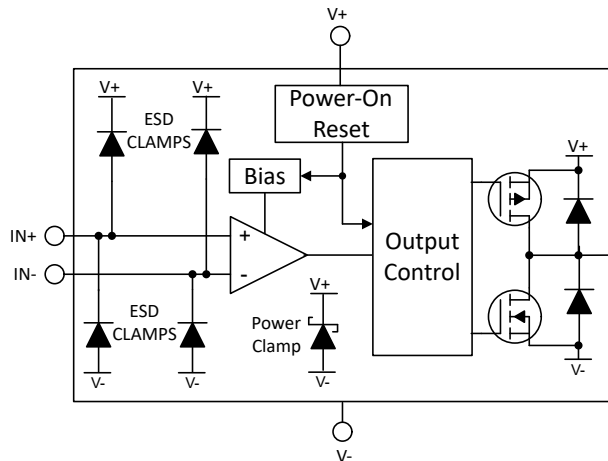


Figure 6-1. TLV321x Push-Pull Block Diagram

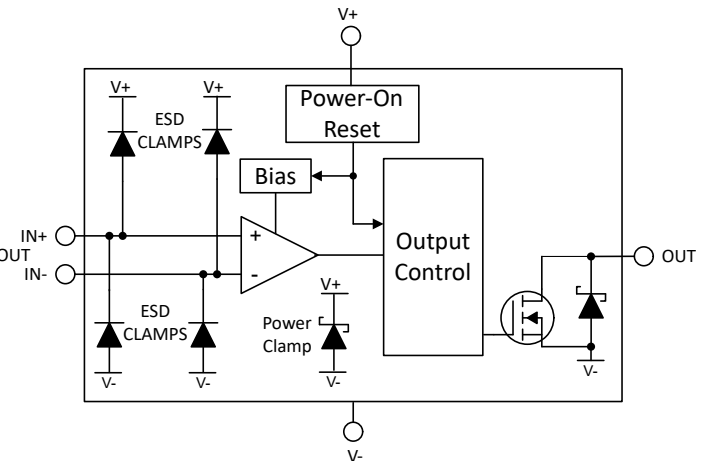


Figure 6-2. TLV322x Open-Drain Block Diagram

6.3 Feature Description

The TLV321/2x consumes only 40uA per channel with 40ns of propagation delay, detecting fast voltage and current transients while maintaining low power consumption.

The TLV321/2x family has two output options:

The TLV321x has a **push-pull** (sink-source) output.

The TLV322x has a **open-drain** (sink only) output, capable of being pulled-up to any voltage up to 5.5V, independent of comparator supply voltage.

6.4 Device Functional Modes

6.4.1 Inputs

The TLV32xx input voltage range extends from 200mV below V_- to 200mV above V_+ . The differential input voltage (V_{ID}) can be any voltage within these limits. No phase-inversion of the comparator output occurs when the input voltages stay within the specified range.

The Rail-to-Rail input does have an ESD clamp to the V_+ supply line and therefore the input voltage must not exceed the supply voltages by more than 200mV. TI does not recommend applying signals to the inputs with no supply voltage.

Limit the current to 10mA or less. TI recommends adding a resistance in series with the inputs to limit current during transients or faults. Any resistive voltage dividers or networks on the input can be part of this series resistance.

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 chatter as the device triggers on it's own internal wideband noise. Instead, the inputs must 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+ (as long as the input is directly connected to the V+ pin to avoid transients).

6.4.2 Internal Hysteresis

The TLV32xx family contains 1.8mV of 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.

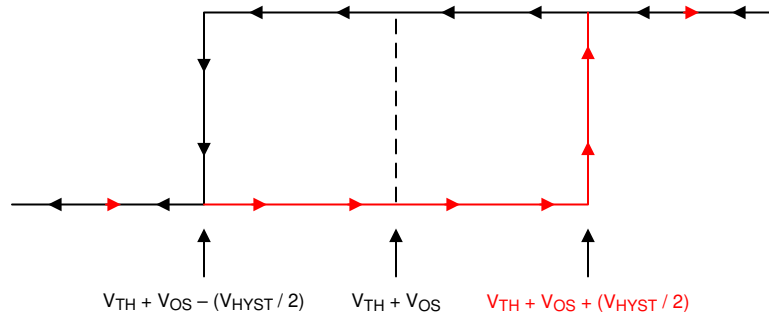


Figure 6-3. Hysteresis Transfer Curve

6.4.3 Outputs

The TLV321/2x family is available in both Push-Pull and Open-Drain output options.

The output must be treated as a high speed digital device and proper high-speed digital PCB layout and routing techniques are recommended.

6.4.3.1 TLV321x Push-Pull Output

The TLV321x features a push-pull output stage capable of both sinking and sourcing current. This allows quickly and symmetrically driving loads such as 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 opposite supply rail (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.

6.4.3.2 TLV322x Open Drain Output

The TLV322x features an open-drain (also commonly called open collector) sinking-only output stage enabling the output logic levels to be pulled up to an external voltage from 0V up to 5.5V, independent of the comparator supply voltage (V+). The open-drain output allows logical OR'ing of multiple open drain outputs and logic level translation.

TI recommends setting the pull-up resistor current to between 100uA and 1mA. Lower value pull-up resistor values can help increase the rising edge rise-time, but at the expense of increasing V_{OL} and higher power dissipation. The rise-time is dependent on the time constant of the total pull-up resistance and total load capacitance. Large value pull-up resistors (>1MΩ) creates an exponential rising edge due to the output RC time constant and increase the rise-time.

Directly shorting the output to a voltage source 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 open drain outputs can be left floating, or can be tied to the V- pin if floating pins are not desired.

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 0.2V 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 if the clamps conduct. Limit the current to 10mA or less.

6.4.5 Power-On Reset (POR)

The TLV321x devices have an internal Power-on-Reset (POR) circuit for known start-up conditions. While the power supply (V+) is ramping up, the POR circuitry is activated for up to 32us after the V_{POR} of 1.65V 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}).

The output is held low during the POR period (t_{on}). This is true for both the Open-Drain and Push-Pull output options.

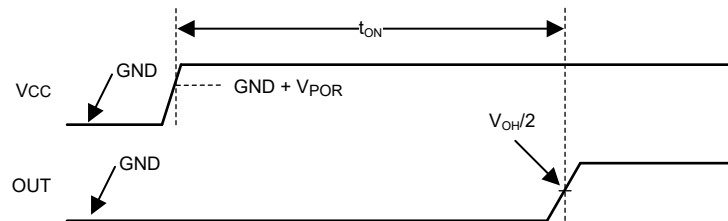


Figure 6-4. Power-On Reset Timing Diagram

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 [Figure 7-1](#) 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}). [Table 7-1](#) 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 [Figure 7-1](#) and is measured from the mid-point of the input to the midpoint of the output.

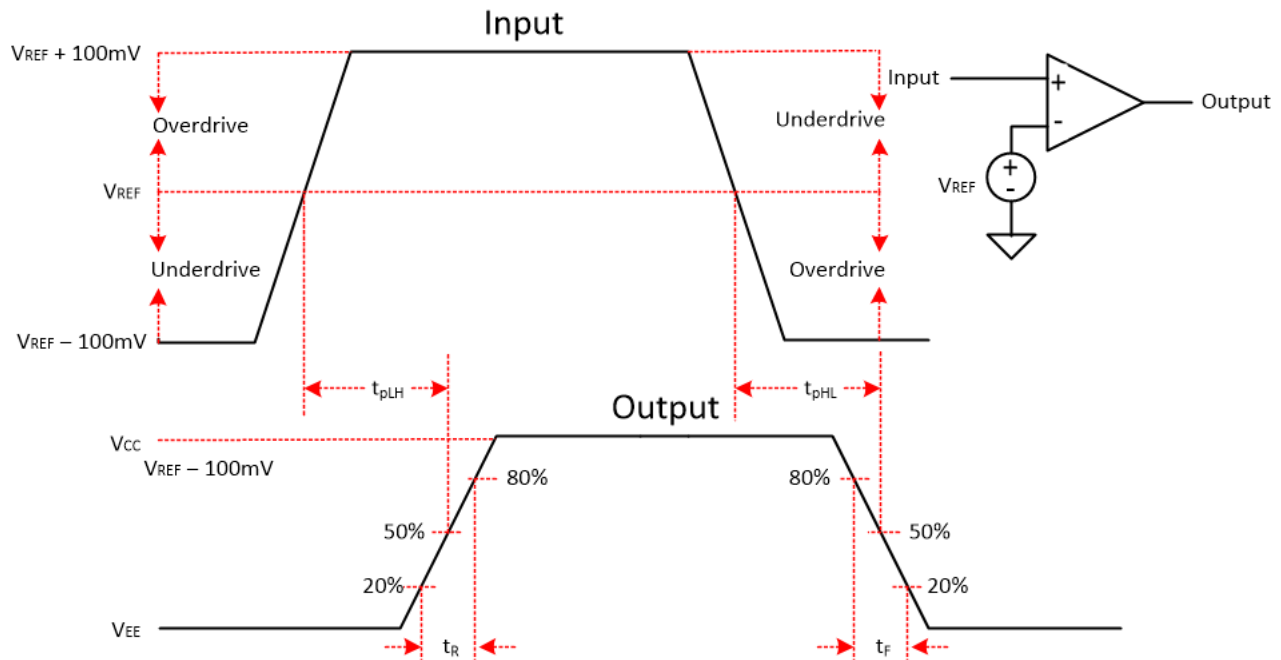


Figure 7-1. Comparator Timing Diagram

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 can influence the propagation delay (t_p). The smaller the overdrive voltage, the longer the propagation delay, particularly when $<100\text{mV}$. If the fastest speeds are desired, apply 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 External Hysteresis

The basic comparator configuration can produce a noisy "chatter" output if the applied differential input voltage is near the comparator offset voltage. This typically occurs 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 TLV321x devices only have 1.8mV of internal hysteresis, 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. External hysteresis adds to the internal hysteresis.

The hysteresis transfer curve is shown in [Figure 7-2](#). 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.

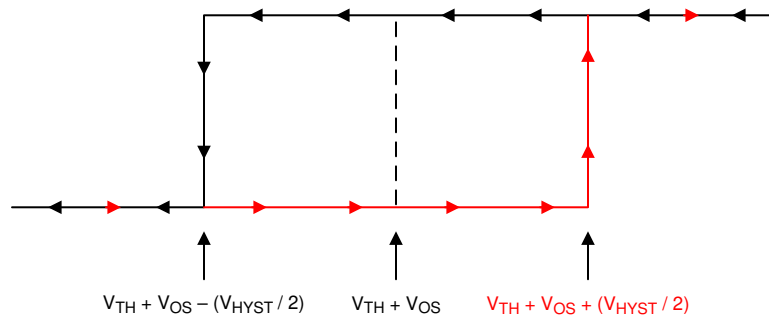


Figure 7-2. Hysteresis Transfer Curve

For more information, please see the [Comparator with and without hysteresis circuit](#) application note.

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 in [Figure 7-3](#).

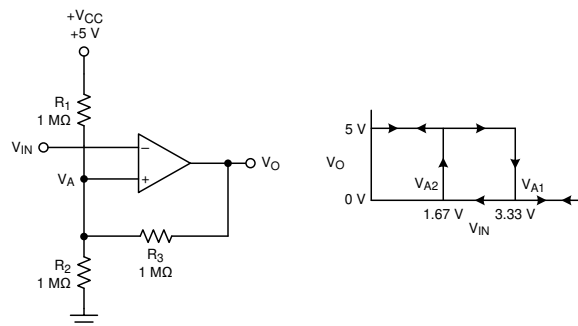


Figure 7-3. TLV321x in an Inverting Configuration With Hysteresis

The equivalent resistor networks when the output is high and low are shown in [Figure 7-3](#).

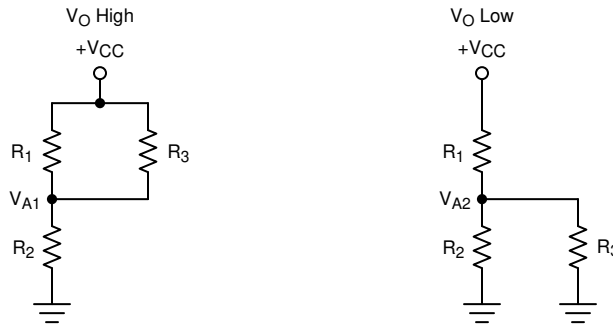


Figure 7-4. Inverting Configuration Resistor Equivalent Networks

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 $R1 \parallel R3$ in series with $R2$, as shown in [Figure 7-4](#).

[Equation 1](#) 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 $R2 \parallel R3$ in series with $R1$, as shown in [Equation 2](#).

Use [Equation 2](#) to define the low to high trip voltage (V_{A2}).

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

[Equation 3](#) 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 in [Figure 7-5](#),

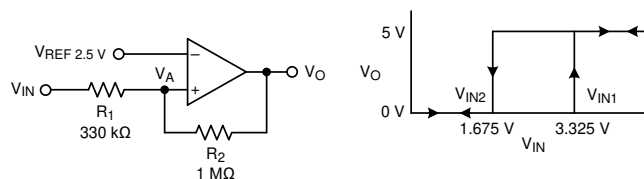


Figure 7-5. TLV321x in a Non-Inverting Configuration With Hysteresis

The equivalent resistor networks when the output is high and low are shown in [Figure 7-6](#).

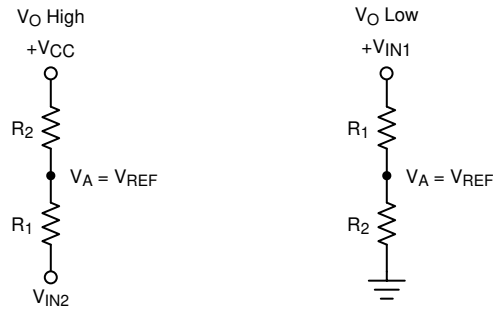


Figure 7-6. Non-Inverting Configuration Resistor Networks

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 [Equation 4](#) to calculate V_{IN1} .

$$V_{IN1} = R1 \times \frac{V_{REF}}{R2} + V_{REF} \quad (4)$$

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 5](#) to calculate V_{IN2} .

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

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

$$\Delta V_{IN} = V_{CC} \times \frac{R1}{R2} \quad (6)$$

For more information, please see [Inverting comparator with hysteresis circuit](#) and [Non-Inverting Comparator With Hysteresis Circuit](#) application notes.

7.2 Typical Applications

7.2.1 Low-Side Current Sensing

[Figure 7-7](#) shows a simple low-side current sensing circuit using an amplifier and a high-speed comparator. The amplifier is used to amplify the voltage drop across the shunt resistor. When the voltage at the output reaches the critical over-current threshold, the comparator output changes state.

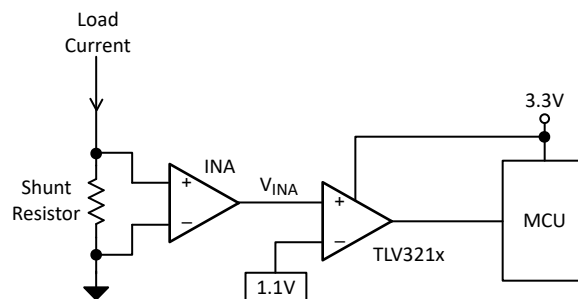


Figure 7-7. Current Sensing

7.2.1.1 Design Requirements

For this design, follow these design requirements:

- Alert (logic high output) when the amplifier output is greater than 1.1V
- Alert signal is active high
- Operate from a 3.3V power supply

7.2.1.2 Detailed Design Procedure

Configure the circuit as shown in [Figure 7-7](#).

7.2.1.3 Application Curve

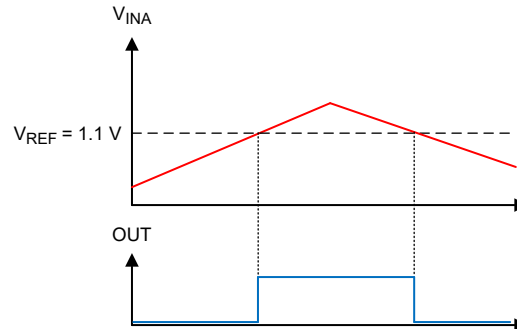


Figure 7-8. overcurrent Results

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 can cause un-bypassed supply lines and poor grounds to ring, possibly causing variation that can eat into the input voltage range and create an inaccurate comparison or even oscillations.

The device can be 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, a stable power supply with minimized noise and glitches is important. Output rise and fall times are in the tens of nanoseconds, and must be treated as high speed logic devices. The bypass capacitor must be as close to the supply pin as possible and connected to a solid ground plane, and preferably 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 ($<100\Omega$) resistor can also be added in series with the output to dampen any ringing or reflections on long, non-impedance controlled traces. For best edge shapes, controlled impedance traces with back-terminations can be used when routing long distances.

7.4.2 Layout Example

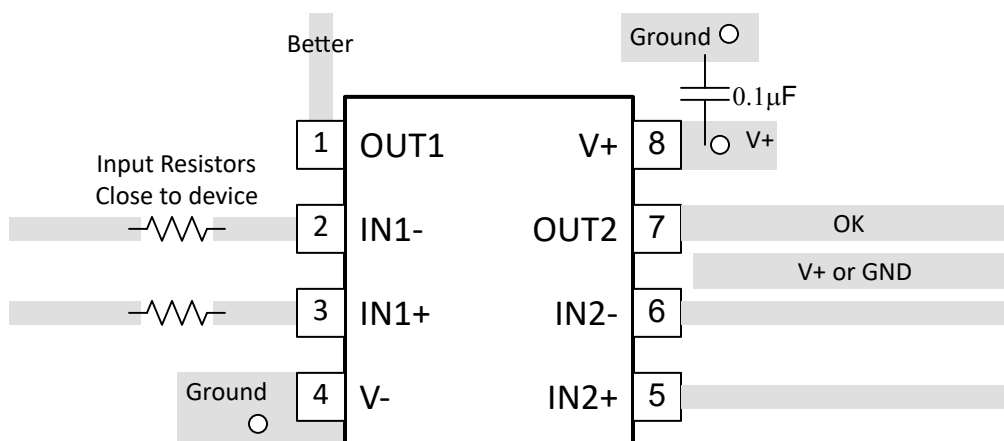


Figure 7-9. Dual Layout Example

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— TIDU020](#)
- Texas Instruments, [Comparator with and without hysteresis circuit - SBOA219](#)
- Texas Instruments, [Inverting comparator with hysteresis circuit - SNOA997](#)
- Texas Instruments, [Non-Inverting Comparator With Hysteresis Circuit - SBOA313](#)

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 (November 2025) to Revision B (December 2025)	Page
• Corrected dual supply current.....	8

Changes from Revision * (September 2025) to Revision A (November 2025)	Page
• Removed Previews from Single and Dual P-P.....	1

DATE	REVISION	NOTES
September 2025	*	Initial Release

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)
TLV3211DCKR	Active	Production	SC70 (DCK) 5	3000 LARGE T&R	-	SN	Level-1-260C-UNLIM	-	1ZW
TLV3214PWR	Active	Production	TSSOP (PW) 14	3000 LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	TLV3214

⁽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.

Important Information and Disclaimer:The information provided on this page represents TI's knowledge and belief as of the date that it is provided. TI bases its knowledge and belief on information provided by third parties, and makes no representation or warranty as to the accuracy of such information. Efforts are underway to better integrate information from third parties. TI has taken and continues to take reasonable steps to provide representative and accurate information but may not have conducted destructive testing or chemical analysis on incoming materials and chemicals. TI and TI suppliers consider certain information to be proprietary, and thus CAS numbers and other limited information may not be available for release.

In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

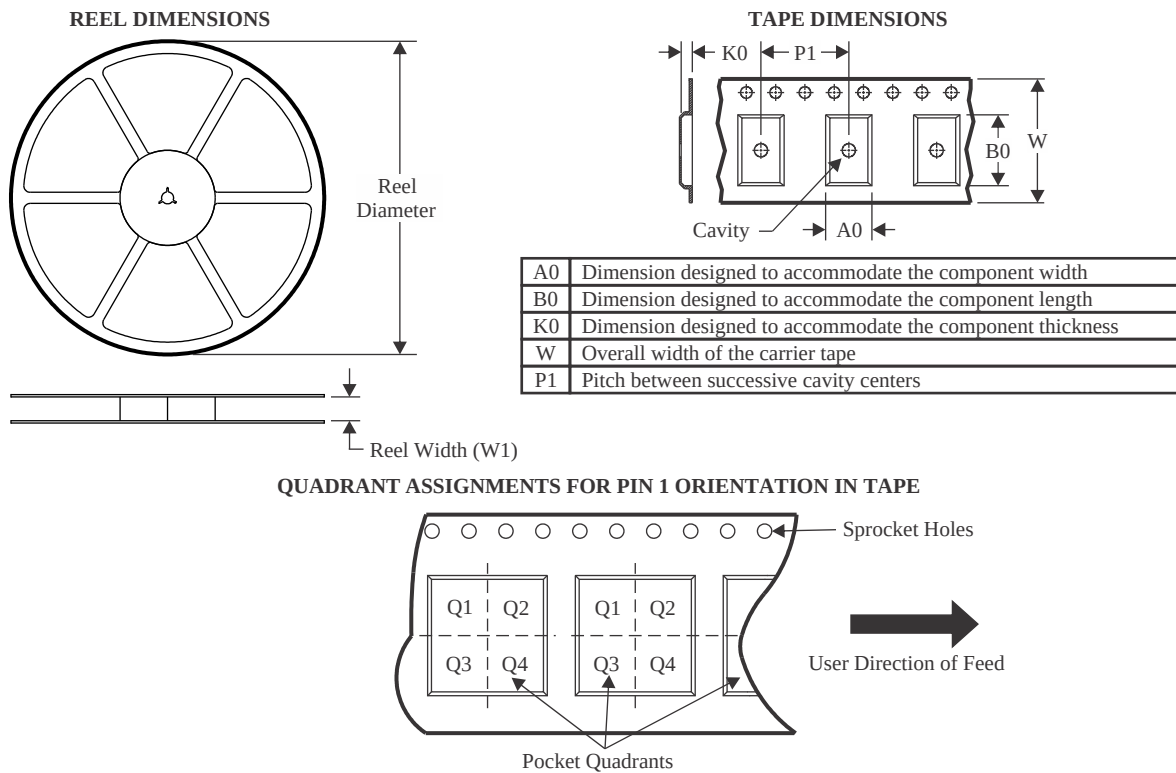
OTHER QUALIFIED VERSIONS OF TLV3214 :

- Automotive : [TLV3214-Q1](#)

NOTE: Qualified Version Definitions:

- Automotive - Q100 devices qualified for high-reliability automotive applications targeting zero defects

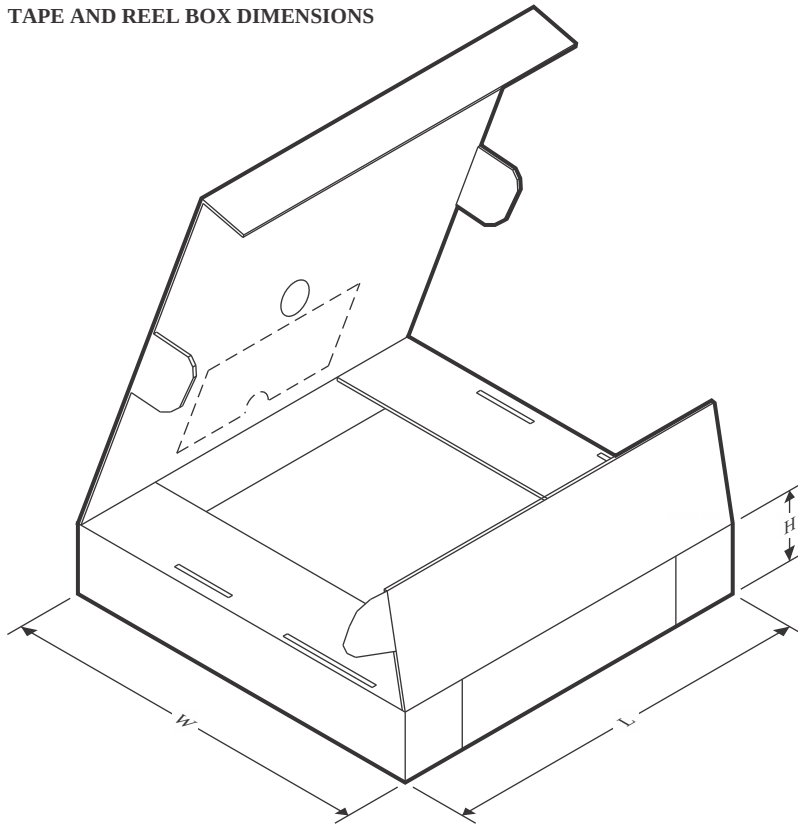
TAPE AND REEL INFORMATION



*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
TLV3211DCKR	SC70	DCK	5	3000	180.0	8.4	2.3	2.5	1.2	4.0	8.0	Q3
TLV3214PWR	TSSOP	PW	14	3000	330.0	12.4	6.9	5.6	1.6	8.0	12.0	Q1

TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
TLV3211DCKR	SC70	DCK	5	3000	210.0	185.0	35.0
TLV3214PWR	TSSOP	PW	14	3000	353.0	353.0	32.0



SOT - 1.1 max height

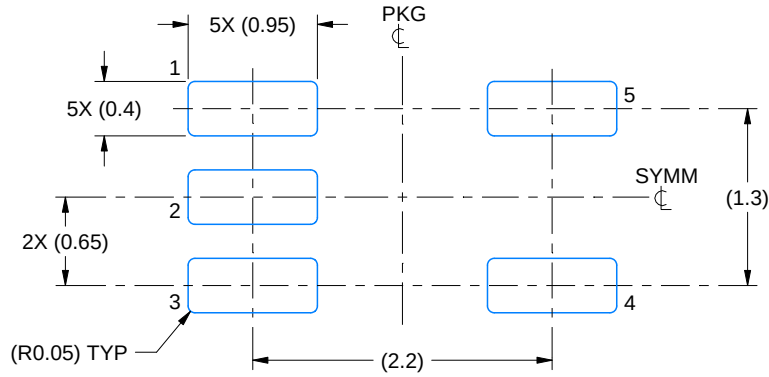
1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. Reference JEDEC MO-203.
4. Support pin may differ or may not be present.
5. Lead width does not comply 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

EXAMPLE BOARD LAYOUT

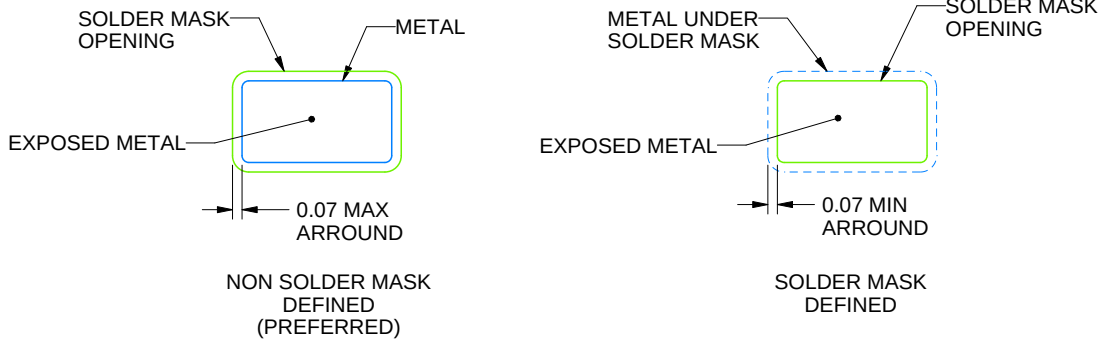
DCK0005A

SOT - 1.1 max height

SMALL OUTLINE TRANSISTOR



LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE:18X

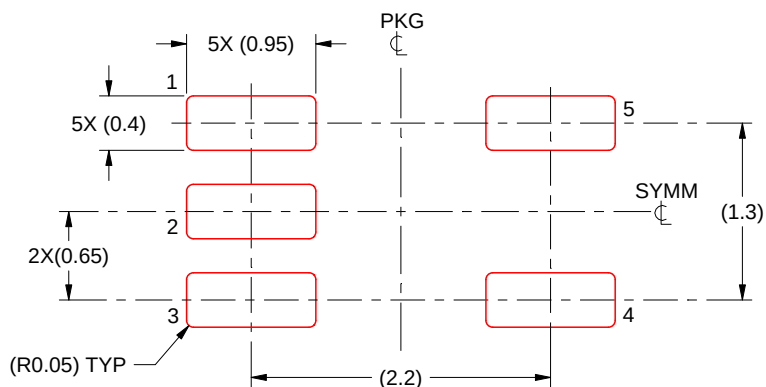


SOLDER MASK DETAILS

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)

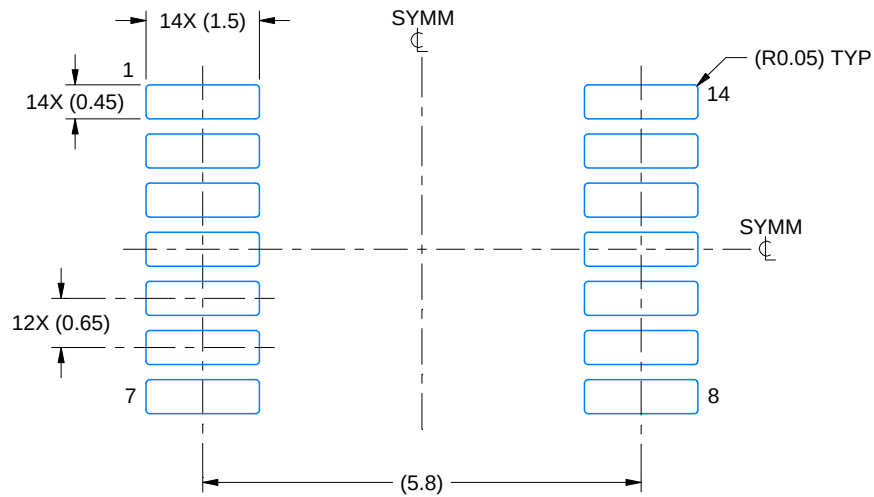
9. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
10. Board assembly site may have different recommendations for stencil design.

EXAMPLE BOARD LAYOUT

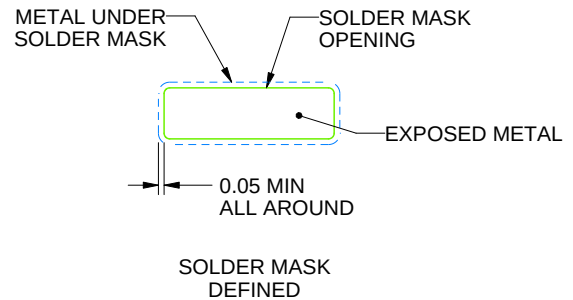
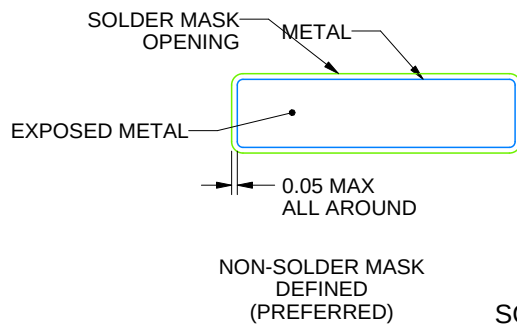
PW0014A

TSSOP - 1.2 mm max height

SMALL OUTLINE PACKAGE



LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE: 10X



SOLDER MASK DETAILS

4220202/B 12/2023

NOTES: (continued)

6. Publication IPC-7351 may have alternate designs.

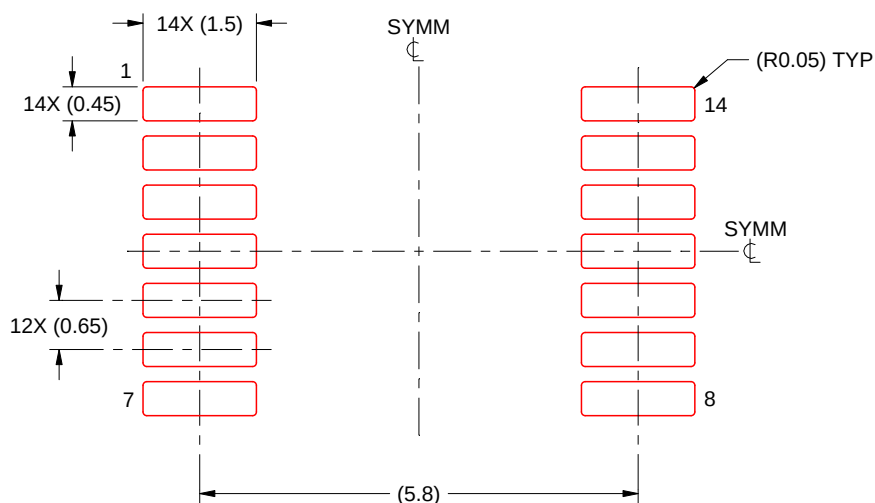
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.

EXAMPLE STENCIL DESIGN

PW0014A

TSSOP - 1.2 mm max height

SMALL OUTLINE PACKAGE



SOLDER PASTE EXAMPLE
BASED ON 0.125 mm THICK STENCIL
SCALE: 10X

4220202/B 12/2023

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.

IMPORTANT NOTICE AND DISCLAIMER

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

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

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

TI's products are provided subject to [TI's Terms of Sale](#), [TI's General Quality Guidelines](#), or other applicable terms available either on [ti.com](#) or provided in conjunction with such TI products. TI's provision of these resources does not expand or otherwise alter TI's applicable warranties or warranty disclaimers for TI products. Unless TI explicitly designates a product as custom or customer-specified, TI products are standard, catalog, general purpose devices.

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

Copyright © 2025, Texas Instruments Incorporated

Last updated 10/2025