

# SN74LVC1T45-Q1 Automotive 1.65V to 5.5V Single-Bit Dual-Supply Level Shifter

## 1 Features

- Qualified for automotive applications
- AEC-Q100 qualified with the following results:
  - Device temperature grade 1:  $-40^{\circ}\text{C}$  to  $+125^{\circ}\text{C}$  ambient operating temperature range
  - Device HBM ESD Classification Level H2
  - Device CDM ESD Classification Level C3B
- Fully configurable dual-rail design allows each port to operate over the full 1.65V to 5.5V power-supply range
- $V_{CC}$  isolation feature – if either  $V_{CC}$  input is at GND, both ports are in the high-impedance state
- DIR input circuit referenced to  $V_{CCA}$
- $\pm 24\text{mA}$  output drive at 3.3V
- $I_{off}$  supports partial-power-down mode operation
- Maximum data rates:
  - 420Mbps (3.3V to 5V translation)
  - 210Mbps (translate to 3.3V)
  - 140Mbps (translate to 2.5V)
  - 75Mbps (translate to 1.8V)

## 2 Applications

- [Head units](#)
- [ADAS – cameras](#)
- [Telematics](#)

## 3 Description

The SN74LVC1T45-Q1 device is a single-bit, noninverting bus transceiver that uses two separate configurable power supply rails. The A-port is designed to track  $V_{CCA}$ .  $V_{CCA}$  accepts any supply voltage from 1.65V to 5.5V. The B-port is designed to track  $V_{CCB}$ .  $V_{CCB}$  accepts any supply voltage from 1.65V to 5.5V. This allows for universal low-voltage bidirectional translation between any of the 1.8V, 2.5V, 3.3V, and 5V voltage nodes.

The SN74LVC1T45-Q1 device is a single-bit, non-inverting level translator. The fully configurable dual-rail design allows each port to operate over the full 1.65V to 5.5V power supply range. This device is an excellent choice for applications that need a wide bidirectional translation range.

The SN74LVC1T45-Q1 is designed so that the DIR input is powered by  $V_{CCA}$ .

This device is fully specified for partial-power-down applications using  $I_{off}$ . The  $I_{off}$  circuitry disables the outputs, preventing damaging current backflow through the device when it is powered down.

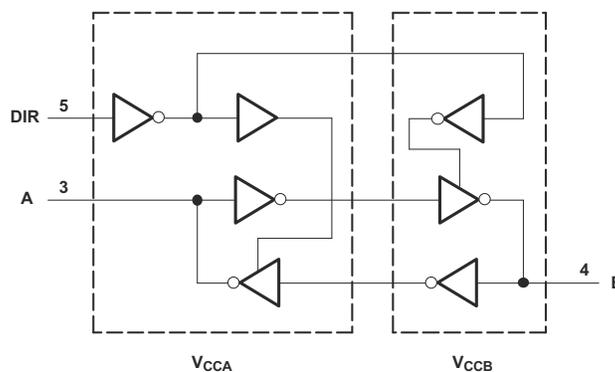
The  $V_{CC}$  isolation feature is designed so that if either  $V_{CC}$  input is at GND, then both ports are in the high-impedance state.

### Package Information

PART NUMBER	PACKAGE <sup>(1)</sup>	PACKAGE SIZE <sup>(2)</sup>
SN74LVC1T45-Q1	DCK (SC70, 6)	2mm × 2.1mm

(1) For more information, see [Section 9](#)

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



Copyright © 2016, Texas Instruments Incorporated

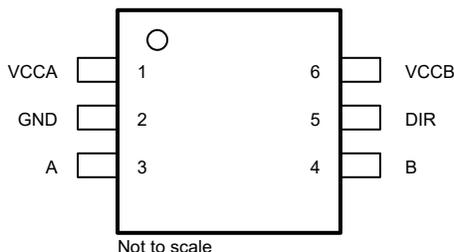
**Logic Diagram (Positive Logic)**



## Table of Contents

<b>1 Features</b> .....	<b>1</b>	<b>6 Detailed Description</b> .....	<b>12</b>
<b>2 Applications</b> .....	<b>1</b>	6.1 Overview.....	12
<b>3 Description</b> .....	<b>1</b>	6.2 Functional Block Diagram.....	12
<b>4 Pin Configuration and Functions</b> .....	<b>2</b>	6.3 Feature Description.....	12
<b>5 Specifications</b> .....	<b>3</b>	6.4 Device Functional Modes.....	12
5.1 Absolute Maximum Ratings.....	3	<b>7 Device and Documentation Support</b> .....	<b>17</b>
5.2 ESD Ratings.....	3	7.1 Documentation Support.....	17
5.3 Recommended Operating Conditions.....	3	7.2 Receiving Notification of Documentation Updates....	17
5.4 Thermal Information.....	4	7.3 Support Resources.....	17
5.5 Electrical Characteristics.....	5	7.4 Trademarks.....	17
5.6 Switching Characteristics: $V_{CCA} = 1.8V \pm 0.15V$ .....	6	7.5 Electrostatic Discharge Caution.....	17
5.7 Switching Characteristics: $V_{CCA} = 2.5V \pm 0.2V$ .....	6	7.6 Glossary.....	17
5.8 Switching Characteristics: $V_{CCA} = 3.3V \pm 0.3V$ .....	7	<b>8 Revision History</b> .....	<b>17</b>
5.9 Switching Characteristics: $V_{CCA} = 5V \pm 0.5V$ .....	7	<b>9 Mechanical, Packaging, and Orderable Information..</b>	<b>17</b>
5.10 Typical Characteristics.....	8		

## 4 Pin Configuration and Functions



See mechanical drawings for dimensions.

**Figure 4-1. DCK Package, 6-Pin SC70 (Top View)**

**Table 4-1. Pin Functions**

PIN		TYPE <sup>(1)</sup>	DESCRIPTION
NAME	NO.		
A	3	I/O	Output level depends on $V_{CC1}$ voltage
B	4	I/O	Input threshold value depends on $V_{CC2}$ voltage
DIR	5	I	GND (low level) determines B-port to A-port direction
GND	2	G	Device GND
$V_{CCA}$	1	P	SYSTEM-1 supply voltage (1.65V to 5.5V)
$V_{CCB}$	6	P	SYSTEM-2 supply voltage (1.65V to 5.5V)

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

## 5 Specifications

### 5.1 Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted)<sup>(1)</sup>

		MIN	MAX	UNIT
Supply voltage, $V_{CCA}$ , $V_{CCB}$		-0.5	6.5	V
Input voltage, $V_I$ <sup>(2)</sup>		-0.5	6.5	V
Voltage applied to any output in the high-impedance or power-off state, $V_O$ <sup>(2)</sup>		-0.5	6.5	V
Voltage applied to any output in the high or low state, $V_O$ <sup>(2)</sup> <sup>(3)</sup>	A port	-0.5	$V_{CCA} + 0.5$	V
	B port	-0.5	$V_{CCB} + 0.5$	
Input clamp current, $I_{IK}$ ( $V_I < 0$ )			-50	mA
Output clamp current, $I_{OK}$ ( $V_O < 0$ )			-50	mA
Continuous output current, $I_O$			±50	mA
Continuous current through $V_{CC}$ or GND			±100	mA
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) The input and output negative-voltage ratings may be exceeded if the input and output clamp-current ratings are observed.
- (3) The value of  $V_{CC}$  is provided in *Recommended Operating Conditions*.

### 5.2 ESD Ratings

		VALUE	UNIT
$V_{(ESD)}$ Electrostatic discharge	Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001 <sup>(1)</sup>	±2000	V
	Charged-device model (CDM), per JEDEC specification JESD22-C101 <sup>(2)</sup>	±750	

- (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

See<sup>(1)</sup> <sup>(2)</sup> <sup>(3)</sup>

		MIN	MAX	UNIT
$V_{CCA}$	Supply voltage	1.65	5.5	V
$V_{CCB}$	Supply voltage	1.65	5.5	V
$V_{IH}$	High-level input voltage, data inputs <sup>(4)</sup>	$V_{CCI} = 1.65V$ to $1.95V$	$V_{CCI} \times 0.65$	V
		$V_{CCI} = 2.3V$ to $2.7V$	1.7	
		$V_{CCI} = 3V$ to $3.6V$	2	
		$V_{CCI} = 4.5V$ to $5.5V$	$V_{CCI} \times 0.7$	
$V_{IL}$	Low-level input voltage, data inputs <sup>(4)</sup>	$V_{CCI} = 1.65V$ to $1.95V$	$V_{CCI} \times 0.35$	V
		$V_{CCI} = 2.3V$ to $2.7V$	0.7	
		$V_{CCI} = 3V$ to $3.6V$	0.8	
		$V_{CCI} = 4.5V$ to $5.5V$	$V_{CCI} \times 0.3$	
$V_{IH}$	High-level input voltage, DIR (referenced to $V_{CCA}$ ) <sup>(5)</sup>	$V_{CCI} = 1.65V$ to $1.95V$	$V_{CCA} \times 0.65$	V
		$V_{CCI} = 2.3V$ to $2.7V$	1.7	
		$V_{CCI} = 3V$ to $3.6V$	2	
		$V_{CCI} = 4.5V$ to $5.5V$	$V_{CCA} \times 0.7$	

### 5.3 Recommended Operating Conditions (continued)

See <sup>(1)</sup> <sup>(2)</sup> <sup>(3)</sup>

		MIN	MAX	UNIT	
V <sub>IL</sub>	Low-level input voltage, DIR (referenced to V <sub>CCA</sub> ) <sup>(5)</sup>	V <sub>CCI</sub> = 1.65V to 1.95V	V <sub>CCA</sub> × 0.35	V	
		V <sub>CCI</sub> = 2.3V to 2.7V	0.7		
		V <sub>CCI</sub> = 3V to 3.6V	0.8		
		V <sub>CCI</sub> = 4.5V to 5.5V	V <sub>CCA</sub> × 0.3		
V <sub>I</sub>	Input voltage	0	5.5	V	
V <sub>O</sub>	Output voltage	0	V <sub>CCO</sub>	V	
I <sub>OH</sub>	High-level output current	V <sub>CCO</sub> = 1.65V to 1.95V	–4	mA	
		V <sub>CCO</sub> = 2.3V to 2.7V	–8		
		V <sub>CCO</sub> = 3V to 3.6V	–24		
		V <sub>CCO</sub> = 4.5V to 5.5V	–32		
I <sub>OL</sub>	Low-level output current	V <sub>CCO</sub> = 1.65V to 1.95V	4	mA	
		V <sub>CCO</sub> = 2.3V to 2.7V	8		
		V <sub>CCO</sub> = 3V to 3.6V	24		
		V <sub>CCO</sub> = 4.5V to 5.5V	32		
Δt/Δv	Input transition rise or fall rate	Data inputs	V <sub>CCI</sub> = 1.65V to 1.95V	20	ns/V
			V <sub>CCI</sub> = 2.3V to 2.7V	20	
			V <sub>CCI</sub> = 3V to 3.6V	10	
			V <sub>CCI</sub> = 4.5V to 5.5V	5	
		Control inputs, V <sub>CCI</sub> = 1.65V to 5.5V	5		
T <sub>A</sub>	Operating free-air temperature	–40	125	°C	

(1) V<sub>CCI</sub> is the V<sub>CC</sub> associated with the input port.(2) V<sub>CCO</sub> is the V<sub>CC</sub> associated with the output port.(3) All unused data inputs of the device must be held at V<sub>CCI</sub> or GND for proper device operation. See [Implications of Slow or Floating CMOS Inputs](#) (SCBA004).(4) For V<sub>CCI</sub> values not specified in the data sheet, V<sub>IH</sub> min = V<sub>CCI</sub> × 0.7V, V<sub>IL</sub> max = V<sub>CCI</sub> × 0.3V.(5) For V<sub>CCI</sub> values not specified in the data sheet, V<sub>IH</sub> min = V<sub>CCA</sub> × 0.7V, V<sub>IL</sub> max = V<sub>CCA</sub> × 0.3V.

### 5.4 Thermal Information

THERMAL METRIC <sup>(1)</sup>		SN74LVC1T45-Q1	UNIT
		DCK (SC70)	
		6 PINS	
R <sub>θJA</sub>	Junction-to-ambient thermal resistance	210.9	°C/W
R <sub>θJC(top)</sub>	Junction-to-case (top) thermal resistance	139.2	°C/W
R <sub>θJB</sub>	Junction-to-board thermal resistance	72	°C/W
Ψ <sub>JT</sub>	Junction-to-top characterization parameter	54.9	°C/W
Ψ <sub>JB</sub>	Junction-to-board characterization parameter	71.7	°C/W
R <sub>θJC(bot)</sub>	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](#) application report.

## 5.5 Electrical Characteristics

over operating free-air temperature range with all limits at  $T_A = -40^\circ\text{C}$  to  $125^\circ\text{C}$  (unless otherwise noted)<sup>(1) (2)</sup>

PARAMETER	TEST CONDITIONS		MIN	TYP	MAX	UNIT	
$V_{OH}$	$V_I = V_{IH}$	$I_{OH} = -100\ \mu\text{A}$ , $V_{CCA} = 1.65\text{V to }4.5\text{V}$ , $V_{CCB} = 1.65\text{V to }4.5\text{V}$	$V_{CCO} - 0.1$			V	
		$I_{OH} = -4\text{mA}$ , $V_{CCA} = 1.65\text{V}$ , $V_{CCB} = 1.65\text{V}$	1.2				
		$I_{OH} = -8\text{mA}$ , $V_{CCA} = 2.3\text{V}$ , $V_{CCB} = 2.3\text{V}$	1.9				
		$I_{OH} = -24\text{mA}$ , $V_{CCA} = 3\text{V}$ , $V_{CCB} = 3\text{V}$	2.3				
		$I_{OH} = -32\text{mA}$ , $V_{CCA} = 4.5\text{V}$ , $V_{CCB} = 4.5\text{V}$	3.8				
$V_{OL}$	$V_I = V_{IL}$	$I_{OL} = 100\ \mu\text{A}$ , $V_{CCA} = 1.65\text{V to }4.5\text{V}$ , $V_{CCB} = 1.65\text{V to }4.5\text{V}$			0.1	V	
		$I_{OL} = 4\text{mA}$ , $V_{CCA} = 1.65\text{V}$ , $V_{CCB} = 1.65\text{V}$			0.45		
		$I_{OL} = 8\text{mA}$ , $V_{CCA} = 2.3\text{V}$ , $V_{CCB} = 2.3\text{V}$			0.4		
		$I_{OL} = 24\text{mA}$ , $V_{CCA} = 3\text{V}$ , $V_{CCB} = 3\text{V}$			0.65		
		$I_{OL} = 32\text{mA}$ , $V_{CCA} = 4.5\text{V}$ , $V_{CCB} = 4.5\text{V}$			0.65		
$I_I$	DIR at $V_I = V_{CCA}$ or GND, $V_{CCA} = 1.65\text{V to }5.5\text{V}$ , $V_{CCB} = 1.65\text{V to }5.5\text{V}$	$T_A = 25^\circ\text{C}$			$\pm 1$	$\mu\text{A}$	
		$T_A = -40^\circ\text{C to }125^\circ\text{C}$			$\pm 4$		
$I_{off}$	$V_I$ or $V_O = 0$ to $5.5\text{V}$	A port at $V_{CCA} = 0\text{V}$ , $V_{CCB} = 0$ to $5.5\text{V}$	$T_A = 25^\circ\text{C}$			$\pm 1$	$\mu\text{A}$
			$T_A = -40^\circ\text{C to }125^\circ\text{C}$			$\pm 10$	
		B port at $V_{CCA} = 0$ to $5.5\text{V}$ , $V_{CCB} = 0\text{V}$	$T_A = 25^\circ\text{C}$			$\pm 1$	
			$T_A = -40^\circ\text{C to }125^\circ\text{C}$			$\pm 10$	
$I_{OZ}$	A or B port at $V_O = V_{CCO}$ or GND, $V_{CCA} = 1.65\text{V to }5.5\text{V}$ , $V_{CCB} = 1.65\text{V to }5.5\text{V}$	$T_A = 25^\circ\text{C}$			$\pm 1$	$\mu\text{A}$	
		$T_A = -40^\circ\text{C to }125^\circ\text{C}$			$\pm 10$		
$I_{CCA}$	$V_I = V_{CCI}$ or GND, $I_O = 0$	$V_{CCA} = 1.65\text{V to }5.5\text{V}$ , $V_{CCB} = 1.65\text{V to }5.5\text{V}$			10	$\mu\text{A}$	
		$V_{CCA} = 5.5\text{V}$ , $V_{CCB} = 0\text{V}$			4		
		$V_{CCA} = 0\text{V}$ , $V_{CCB} = 5.5\text{V}$			-10		
$I_{CCB}$	$V_I = V_{CCI}$ or GND, $I_O = 0$	$V_{CCA} = 1.65\text{V to }5.5\text{V}$ , $V_{CCB} = 1.65\text{V to }5.5\text{V}$			10	$\mu\text{A}$	
		$V_{CCA} = 5.5\text{V}$ , $V_{CCB} = 0\text{V}$			-10		
		$V_{CCA} = 0\text{V}$ , $V_{CCB} = 5.5\text{V}$			4		
$I_{CCA} + I_{CCB}$	$V_I = V_{CCI}$ or GND, $I_O = 0$ , $V_{CCA} = 1.65\text{V to }5.5\text{V}$ , $V_{CCB} = 1.65\text{V to }5.5\text{V}$			20	$\mu\text{A}$		
$\Delta I_{CCA}$	$V_{CCA} = 3\text{V to }5.5\text{V}$ , $V_{CCB} = 3\text{V to }5.5\text{V}$	A port at $V_{CCA} - 0.6\text{V}$ , DIR at $V_{CCA}$ , B port = open			50	$\mu\text{A}$	
		DIR at $V_{CCA} - 0.6\text{V}$ , B port = open, A port at $V_{CCA}$ or GND			50		
$\Delta I_{CCB}$	B port at $V_{CCB} - 0.6\text{V}$ , DIR at GND, A port = open, $V_{CCA} = 3\text{V to }5.5\text{V}$ , $V_{CCB} = 3\text{V to }5.5\text{V}$			50	$\mu\text{A}$		
$C_i$	DIR at $V_I = V_{CCA}$ or GND, $T_A = 25^\circ\text{C}$ , $V_{CCA} = 3.3\text{V}$ , $V_{CCB} = 3.3\text{V}$			2.5	pF		
$C_{io}$	A or B port at $V_O = V_{CCA/B}$ or GND, $T_A = 25^\circ\text{C}$ , $V_{CCA} = 3.3\text{V}$ , $V_{CCB} = 3.3\text{V}$			6	pF		
$C_{pdA}$ <sup>(3)</sup>	$C_L = 0\text{pF}$ , $f = 10\text{MHz}$ , $t_r = t_f = 1\text{ns}$	A-port input, B-port output	$V_{CCA} = V_{CCB} = 1.8\text{V}$			3	pF
			$V_{CCA} = V_{CCB} = 2.5\text{V}$			4	
			$V_{CCA} = V_{CCB} = 3.3\text{V}$			4	
			$V_{CCA} = V_{CCB} = 5\text{V}$			4	
		B-port input, A-port output	$V_{CCA} = V_{CCB} = 1.8\text{V}$			18	
			$V_{CCA} = V_{CCB} = 2.5\text{V}$			19	
			$V_{CCA} = V_{CCB} = 3.3\text{V}$			20	
			$V_{CCA} = V_{CCB} = 5\text{V}$			21	

### 5.5 Electrical Characteristics (continued)

over operating free-air temperature range with all limits at  $T_A = -40^{\circ}\text{C}$  to  $125^{\circ}\text{C}$  (unless otherwise noted)<sup>(1) (2)</sup>

PARAMETER	TEST CONDITIONS			MIN	TYP	MAX	UNIT
$C_{pdB}$ <sup>(3)</sup>	$C_L = 0\text{pF}$ , $f = 10\text{MHz}$ , $t_r = t_f = 1\text{ns}$	A-port input, B-port output	$V_{CCA} = V_{CCB} = 1.8\text{V}$		18	pF	
			$V_{CCA} = V_{CCB} = 2.5\text{V}$		19		
			$V_{CCA} = V_{CCB} = 3.3\text{V}$		20		
			$V_{CCA} = V_{CCB} = 5\text{V}$		21		
		B-port input, A-port output	$V_{CCA} = V_{CCB} = 1.8\text{V}$		3		
			$V_{CCA} = V_{CCB} = 2.5\text{V}$		4		
			$V_{CCA} = V_{CCB} = 3.3\text{V}$		4		
			$V_{CCA} = V_{CCB} = 5\text{V}$		4		

- (1)  $V_{CCO}$  is the  $V_{CC}$  associated with the output port.
- (2)  $V_{CCI}$  is the  $V_{CC}$  associated with the input port.
- (3) Power dissipation capacitance per transceiver

### 5.6 Switching Characteristics: $V_{CCA} = 1.8\text{V} \pm 0.15\text{V}$

over operating free-air temperature range (unless otherwise noted; see Figure 6-1)

PARAMETER	FROM (INPUT)	TO (OUTPUT)	$V_{CCB} = 1.8\text{V} \pm 0.15\text{V}$		$V_{CCB} = 2.5\text{V} \pm 0.2\text{V}$		$V_{CCB} = 3.3\text{V} \pm 0.3\text{V}$		$V_{CCB} = 5\text{V} \pm 0.5\text{V}$		UNIT
			MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	
$t_{PLH}$	A	B	3	20.7	2.2	13.3	1.7	11.3	1.4	10.2	ns
$t_{PHL}$			2.8	17.3	2.2	11.5	1.8	10.1	1.7	10	
$t_{PLH}$	B	A	3	20.7	2.3	19	2.1	18.5	1.9	18.1	ns
$t_{PHL}$			2.8	17.3	2.1	15.9	2	15.6	1.8	15.2	
$t_{PHZ}$	DIR	A	5.2	22.7	4.8	21.5	4.7	21.4	5.1	20.1	ns
$t_{PLZ}$			2.3	13.5	2.1	13.5	2.4	13.7	3.1	13.9	
$t_{PHZ}$	DIR	B	5.2	27.9	4.9	14.5	3.6	13.3	2.3	11.2	ns
$t_{PLZ}$			4.2	19	2.2	12.2	2.3	11.4	2	9.4	
$t_{PZH}$ <sup>(1)</sup>	DIR	A		39.7		31.2		29.9		27.5	ns
$t_{PZL}$ <sup>(1)</sup>				45.2		30.4		28.9		26.4	
$t_{PZH}$ <sup>(1)</sup>	DIR	B		34.2		26.8		25		24.1	ns
$t_{PZL}$ <sup>(1)</sup>				40.7		33		31.5		30.1	

- (1) The enable time is a calculated value, derived using the formula shown in Section 7.1.1.

### 5.7 Switching Characteristics: $V_{CCA} = 2.5\text{V} \pm 0.2\text{V}$

over operating free-air temperature range (unless otherwise noted; see Figure 6-1)

PARAMETER	FROM (INPUT)	TO (OUTPUT)	$V_{CCB} = 1.8\text{V} \pm 0.15\text{V}$		$V_{CCB} = 2.5\text{V} \pm 0.2\text{V}$		$V_{CCB} = 3.3\text{V} \pm 0.3\text{V}$		$V_{CCB} = 5\text{V} \pm 0.5\text{V}$		UNIT
			MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	
$t_{PLH}$	A	B	2.3	19	1.5	11.5	1.3	9.4	1.1	8.1	ns
$t_{PHL}$			2.1	15.9	1.4	10.5	1.3	8.4	0.9	7.6	
$t_{PLH}$	B	A	2.2	13.3	1.5	11.5	1.4	11	1	10.5	ns
$t_{PHL}$			2.2	11.5	1.4	10.7	1.3	10	0.9	9.2	
$t_{PHZ}$	DIR	A	3	11.1	3.1	11.1	2.8	11.1	3.2	11.1	ns
$t_{PLZ}$			1.3	8.9	1.3	8.9	1.3	8.9	1	8.8	
$t_{PHZ}$	DIR	B	5.2	26.7	4.1	14.4	3.9	13.2	2.4	10.1	ns
$t_{PLZ}$			3.9	21.9	3.2	12.6	2.8	11.4	1.8	8.3	

### 5.7 Switching Characteristics: $V_{CCA} = 2.5V \pm 0.2V$ (continued)

over operating free-air temperature range (unless otherwise noted; see [Figure 6-1](#))

PARAMETER	FROM (INPUT)	TO (OUTPUT)	$V_{CCB} = 1.8V \pm 0.15V$		$V_{CCB} = 2.5V \pm 0.2V$		$V_{CCB} = 3.3V \pm 0.3V$		$V_{CCB} = 5V \pm 0.5V$		UNIT
			MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	
$t_{PZH}^{(1)}$	DIR	A	35.2		24.1		22.4		18.8		ns
$t_{PZL}^{(1)}$			38.2		24.9		23.2		19.3		
$t_{PZH}^{(1)}$	DIR	B	27.9		20.4		18.3		16.9		ns
$t_{PZL}^{(1)}$			27		21.6		19.5		18.7		

### 5.8 Switching Characteristics: $V_{CCA} = 3.3V \pm 0.3V$

over operating free-air temperature range (unless otherwise noted; see [Figure 6-1](#))

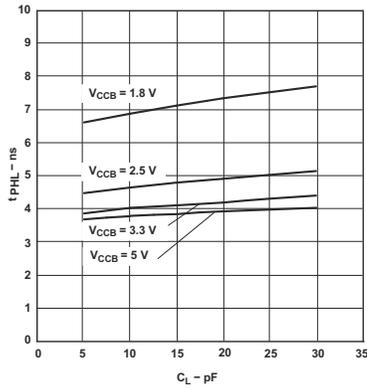
PARAMETER	FROM (INPUT)	TO (OUTPUT)	$V_{CCB} = 1.8V \pm 0.15V$		$V_{CCB} = 2.5V \pm 0.2V$		$V_{CCB} = 3.3V \pm 0.3V$		$V_{CCB} = 5V \pm 0.5V$		UNIT
			MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	
$t_{PLH}$	A	B	2.1	18.5	1.4	11	0.7	8.8	0.7	7.4	ns
$t_{PHL}$			2	15.6	1.3	10	0.8	8	0.7	7	
$t_{PLH}$	B	A	1.7	11.3	1.3	9.4	0.7	8.8	0.6	8.4	ns
$t_{PHL}$			1.8	10.1	1.3	8.4	0.8	8	0.7	7.5	
$t_{PHZ}$	DIR	A	2.9	10.3	3	10.3	2.8	10.3	3.4	10.3	ns
$t_{PLZ}$			1.8	8.6	1.6	8.6	2.2	8.7	2.2	8.7	
$t_{PHZ}$	DIR	B	5.4	27.5	3.9	13.1	2.9	11.8	2.4	9.8	ns
$t_{PLZ}$			3.3	17.5	2.9	10.8	2.4	10.1	1.7	7.9	
$t_{PZH}^{(1)}$	DIR	A	26.8		20.2		18.9		16.3		ns
$t_{PZL}^{(1)}$			37.6		21.5		19.8		17.3		
$t_{PZH}^{(1)}$	DIR	B	27.1		19.6		17.5		16.1		ns
$t_{PZL}^{(1)}$			25.9		20.3		18.3		17.3		

### 5.9 Switching Characteristics: $V_{CCA} = 5V \pm 0.5V$

over operating free-air temperature range (unless otherwise noted; see [Figure 6-1](#))

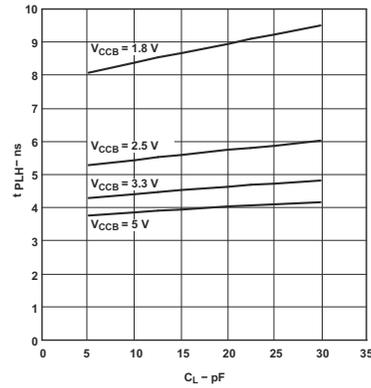
PARAMETER	FROM (INPUT)	TO (OUTPUT)	$V_{CCB} = 1.8V \pm 0.15V$		$V_{CCB} = 2.5V \pm 0.2V$		$V_{CCB} = 3.3V \pm 0.3V$		$V_{CCB} = 5V \pm 0.5V$		UNIT
			MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	
$t_{PLH}$	A	B	1.9	18.1	1	10.5	0.6	8.4	0.5	6.9	ns
$t_{PHL}$			1.8	15.2	0.9	9.2	0.7	7.5	0.5	6.5	
$t_{PLH}$	B	A	1.4	10.2	1	8.1	0.7	7.4	0.5	6.9	ns
$t_{PHL}$			1.7	10	0.9	7.6	0.7	7	0.5	6.5	
$t_{PHZ}$	DIR	A	2.1	8.4	2.2	8.4	2.2	8.5	2.2	8.4	ns
$t_{PLZ}$			0.9	6.8	1	6.8	0.7	6.7	0.7	6.7	
$t_{PHZ}$	DIR	B	4.8	26.2	2.5	14.8	1	11.5	2.5	9.5	ns
$t_{PLZ}$			3.2	17.8	2.5	10.4	2.5	10	1.6	7.5	
$t_{PZH}^{(1)}$	DIR	A	28		18.5		17.4		14.4		ns
$t_{PZL}^{(1)}$			36.2		22.4		18.5		16		
$t_{PZH}^{(1)}$	DIR	B	24.9		17.3		15.1		13.6		ns
$t_{PZL}^{(1)}$			23.6		17.6		16		14.9		

### 5.10 Typical Characteristics



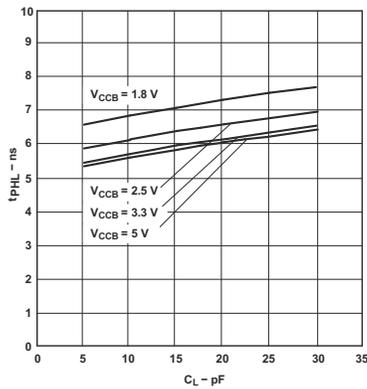
$T_A = 25^\circ\text{C}$ ,  $V_{CCA} = 1.8\text{V}$

**Figure 5-1. Typical Propagation Delay (A to B) vs Load Capacitance**



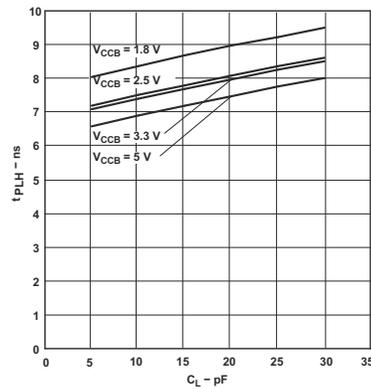
$T_A = 25^\circ\text{C}$ ,  $V_{CCA} = 1.8\text{V}$

**Figure 5-2. Typical Propagation Delay (A to B) vs Load Capacitance**



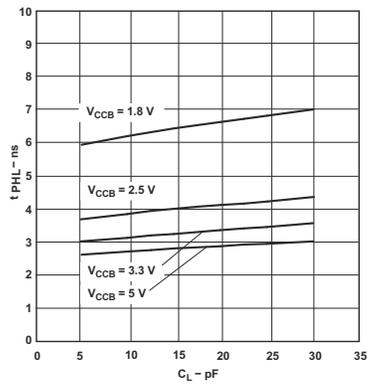
$T_A = 25^\circ\text{C}$ ,  $V_{CCA} = 1.8\text{V}$

**Figure 5-3. Typical Propagation Delay (B to A) vs Load Capacitance**



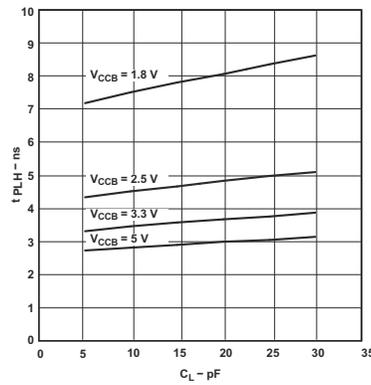
$T_A = 25^\circ\text{C}$ ,  $V_{CCA} = 1.8\text{V}$

**Figure 5-4. Typical Propagation Delay (B to A) vs Load Capacitance**



$T_A = 25^\circ\text{C}$ ,  $V_{CCA} = 2.5\text{V}$

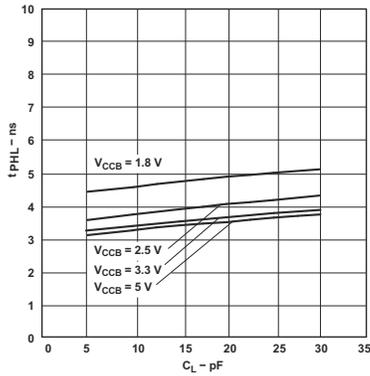
**Figure 5-5. Typical Propagation Delay (A to B) vs Load Capacitance**



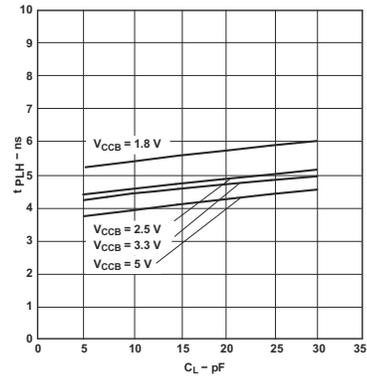
$T_A = 25^\circ\text{C}$ ,  $V_{CCA} = 2.5\text{V}$

**Figure 5-6. Typical Propagation Delay (A to B) vs Load Capacitance**

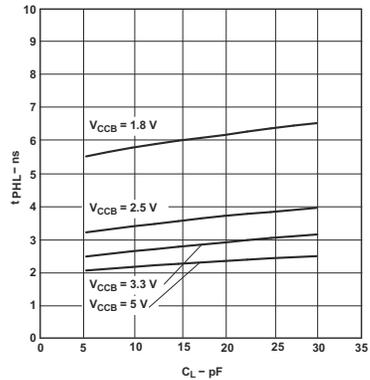
### 5.10 Typical Characteristics (continued)



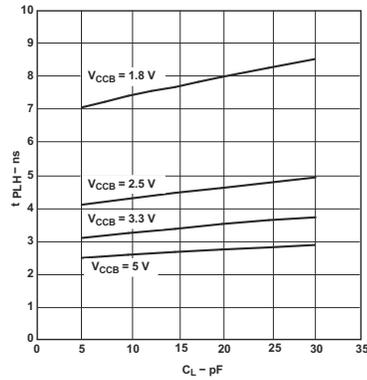
$T_A = 25^\circ\text{C}$ ,  $V_{CCA} = 2.5\text{V}$   
**Figure 5-7. Typical Propagation Delay (B to A) vs Load Capacitance**



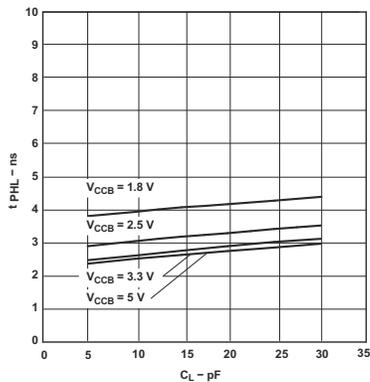
$T_A = 25^\circ\text{C}$ ,  $V_{CCA} = 2.5\text{V}$   
**Figure 5-8. Typical Propagation Delay (B to A) vs Load Capacitance**



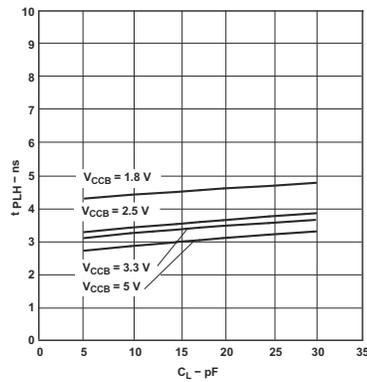
$T_A = 25^\circ\text{C}$ ,  $V_{CCA} = 3.3\text{V}$   
**Figure 5-9. Typical Propagation Delay (A to B) vs Load Capacitance**



$T_A = 25^\circ\text{C}$ ,  $V_{CCA} = 3.3\text{V}$   
**Figure 5-10. Typical Propagation Delay (A to B) vs Load Capacitance**

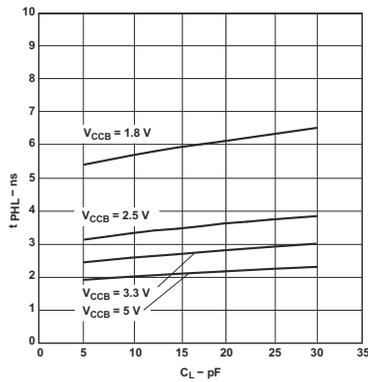


$T_A = 25^\circ\text{C}$ ,  $V_{CCA} = 3.3\text{V}$   
**Figure 5-11. Typical Propagation Delay (B to A) vs Load Capacitance**



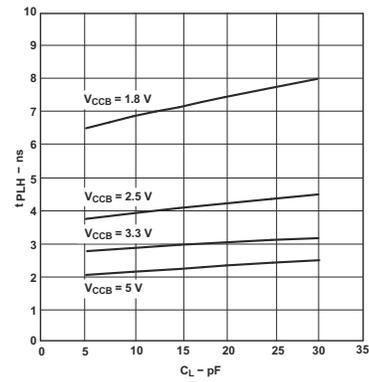
$T_A = 25^\circ\text{C}$ ,  $V_{CCA} = 3.3\text{V}$   
**Figure 5-12. Typical Propagation Delay (B to A) vs Load Capacitance**

**5.10 Typical Characteristics (continued)**



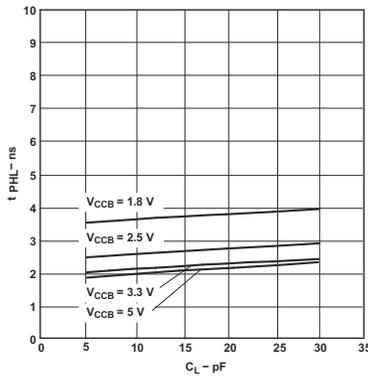
$T_A = 25^\circ\text{C}$ ,  $V_{CCA} = 5\text{V}$

**Figure 5-13. Typical Propagation Delay (A to B) vs Load Capacitance**



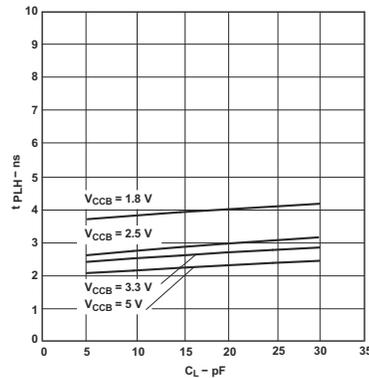
$T_A = 25^\circ\text{C}$ ,  $V_{CCA} = 5\text{V}$

**Figure 5-14. Typical Propagation Delay (A to B) vs Load Capacitance**



$T_A = 25^\circ\text{C}$ ,  $V_{CCA} = 5\text{V}$

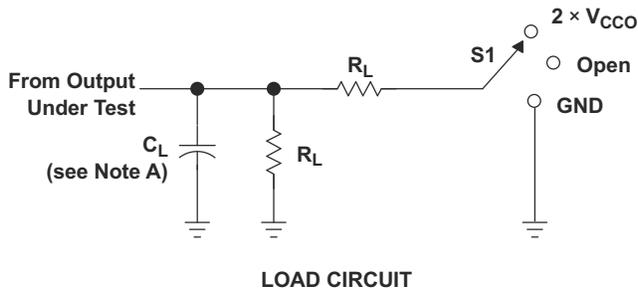
**Figure 5-15. Typical Propagation Delay (B to A) vs Load Capacitance**



$T_A = 25^\circ\text{C}$ ,  $V_{CCA} = 5\text{V}$

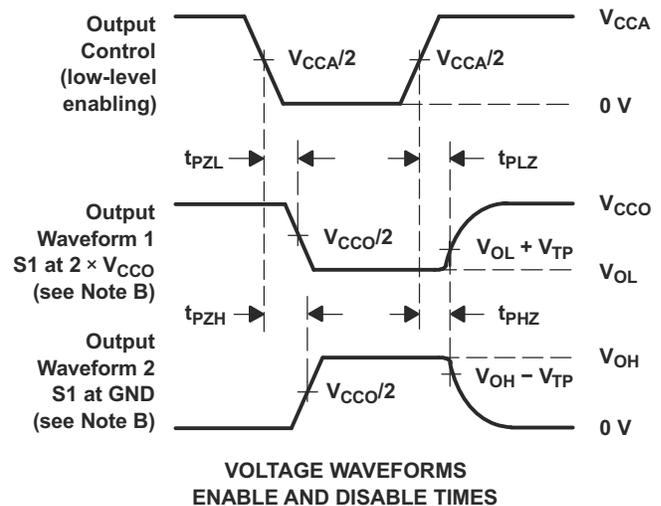
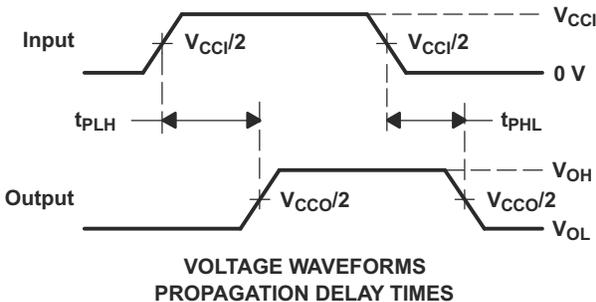
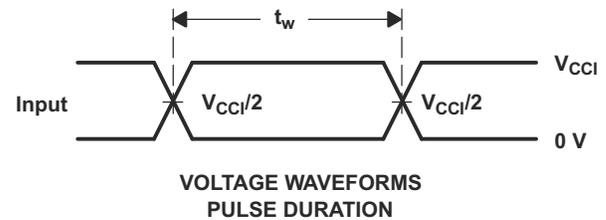
**Figure 5-16. Typical Propagation Delay (B to A) vs Load Capacitance**

## Parameter Measurement Information



TEST	S1
$t_{pd}$	Open
$t_{PLZ}/t_{PZL}$	$2 \times V_{CCO}$
$t_{PHZ}/t_{PZH}$	GND

$V_{CCO}$	$C_L$	$R_L$	$V_{TP}$
$1.8 \text{ V} \pm 0.15 \text{ V}$	15 pF	2 k $\Omega$	0.15 V
$2.5 \text{ V} \pm 0.2 \text{ V}$	15 pF	2 k $\Omega$	0.15 V
$3.3 \text{ V} \pm 0.3 \text{ V}$	15 pF	2 k $\Omega$	0.3 V
$5 \text{ V} \pm 0.5 \text{ V}$	15 pF	2 k $\Omega$	0.3 V



- NOTES:
- $C_L$  includes probe and jig capacitance.
  - Waveform 1 is for an output with internal conditions such that the output is low except when disabled by the output control. Waveform 2 is for an output with internal conditions such that the output is high, except when disabled by the output control.
  - All input pulses are supplied by generators having the following characteristics:  $PRR \leq 10 \text{ MHz}$ ,  $Z_O = 50 \Omega$ ,  $dv/dt \geq 1 \text{ V/ns}$ .
  - The outputs are measured one at a time, with one transition per measurement.
  - $t_{PLZ}$  and  $t_{PHZ}$  are the same as  $t_{dis}$ .
  - $t_{PZL}$  and  $t_{PZH}$  are the same as  $t_{en}$ .
  - $t_{PLH}$  and  $t_{PHL}$  are the same as  $t_{pd}$ .
  - $V_{CC1}$  is the  $V_{CC}$  associated with the input port.
  - $V_{CCO}$  is the  $V_{CC}$  associated with the output port.
  - All parameters and waveforms are not applicable to all devices.

**Figure 6-1. Load Circuit and Voltage Waveforms**

## 6 Detailed Description

### 6.1 Overview

The SN74LVC1T45-Q1 is single-bit, dual-supply, non-inverting voltage level translation. Pin A and that direction control pin (DIR) are supported by  $V_{CCA}$  and pin B is supported by  $V_{CCB}$ . The A port can accept I/O voltages ranging from 1.65V to 5.5V, while the B port can accept I/O voltages from 1.65V to 5.5V. The high on the DIR allows data transmissions from A to B and a low on the DIR allows data transmissions from B to A.

### 6.2 Functional Block Diagram

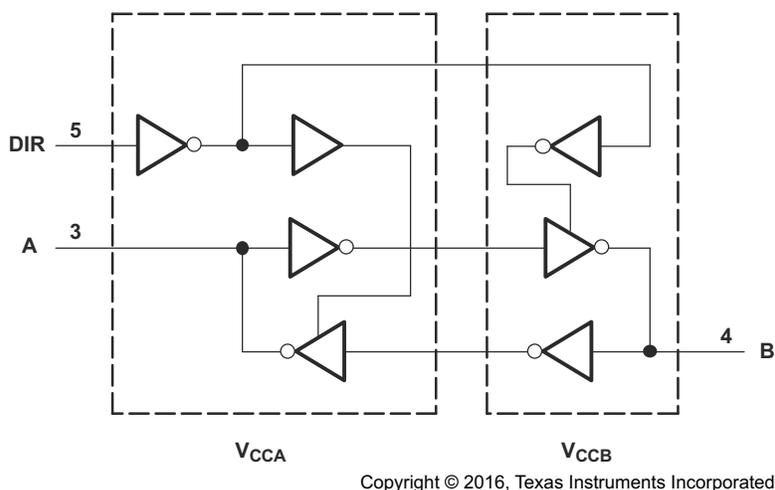


Figure 6-1. Logic Diagram (Positive Logic)

### 6.3 Feature Description

The SN74LVC1T45-Q1 has a fully configurable dual-rail design that allows each port to operate over the full 1.65V to 5.5V power-supply range. Both  $V_{CCA}$  and  $V_{CCB}$  can be supplied at any voltage between 1.65V and 5.5V, making the device suitable for translating between any of the voltage nodes (1.8V, 2.5V, 3.3V, and 5V).

SN74LVC1T45-Q1 can support high data rate applications. The translated signal data rate can be up to 420Mbps when the signal is translated from 3.3V to 5V.

$I_{off}$  prevents backflow current by disabling I/O output circuits when device is in partial-power-down mode.

#### 6.3.1 Glitch-Free Power Supply Sequencing

Either supply rail may be powered on or off in any order without producing a glitch on the I/Os (that is, where the output erroneously transitions to VCC when it should be held low or vice versa). Glitches of this nature can be misinterpreted by a peripheral as a valid data bit, which could trigger a false device reset of the peripheral, a false device configuration of the peripheral, or even a false data initialization by the peripheral.

### 6.4 Device Functional Modes

Table 6-1 lists the operational modes of SN74LVC1T45-Q1.

Table 6-1. Function Table<sup>(1)</sup>

INPUT DIR	OPERATION
L	B data to A bus
H	A data to B bus

(1) Input circuits of the data I/Os always are active.

## 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.

## 1 Application Information

The SN74LVC1T45-Q1 device can be used in level-translation applications for interfacing devices or systems operating at different interface voltages with one another. The maximum data rate can be up to 420Mbps when device translates signals from 3.3V to 5V.

### 1.1 Enable Times

Calculate the enable times for the SN74LVC1T45-Q1 using the following formulas:

- $t_{PZH} \text{ (DIR to A)} = t_{PLZ} \text{ (DIR to B)} + t_{PLH} \text{ (B to A)}$
- $t_{PZL} \text{ (DIR to A)} = t_{PHZ} \text{ (DIR to B)} + t_{PHL} \text{ (B to A)}$
- $t_{PZH} \text{ (DIR to B)} = t_{PLZ} \text{ (DIR to A)} + t_{PLH} \text{ (A to B)}$
- $t_{PZL} \text{ (DIR to B)} = t_{PHZ} \text{ (DIR to A)} + t_{PHL} \text{ (A to B)}$

In a bidirectional application, these enable times provide the maximum delay from the time the DIR bit is switched until an output is expected. For example, if the SN74LVC1T45-Q1 initially is transmitting from A to B, then the DIR bit is switched; the B port of the device must be disabled before presenting it with an input. After the B port has been disabled, an input signal applied to it appears on the corresponding A port after the specified propagation delay.

## 2 Typical Applications

### 2.1 Unidirectional Logic Level-Shifting Application

Figure 7-1 shows an example of the SN74LVC1T45-Q1 being used in a unidirectional logic level-shifting application.

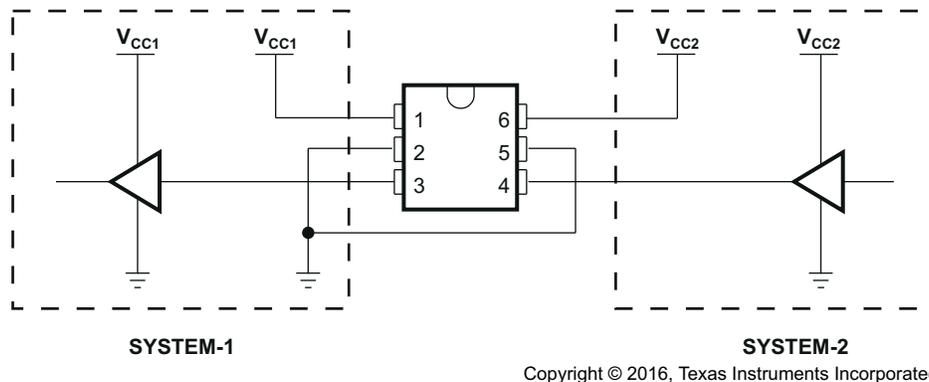


Figure 7-1. Unidirectional Logic Level-Shifting Application

#### 2.1.1 Design Requirements

For this design example, use the parameters listed in Table 7-1.

Table 7-1. Design Parameters

PARAMETER	VALUE
Input voltage	1.65V to 5.5V
Output voltage	1.65V to 5.5V

**SN74LVC1T45-Q1**

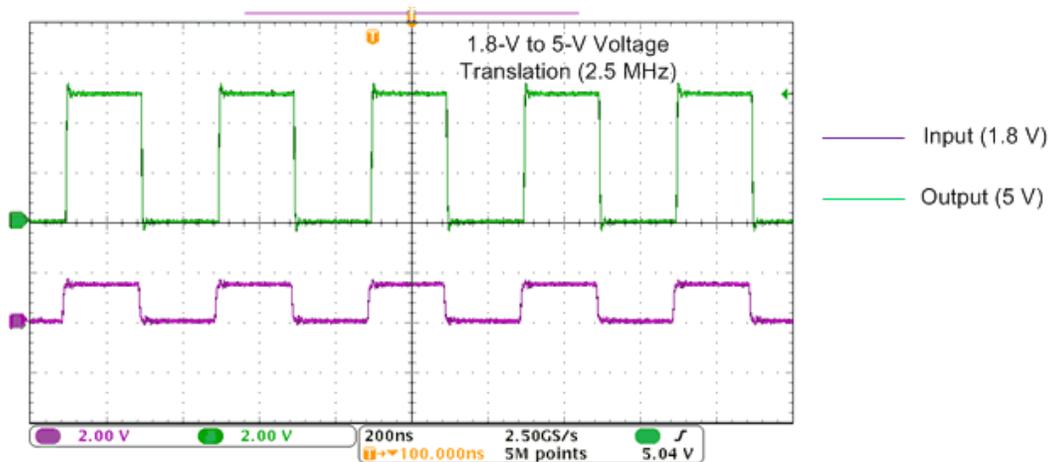
SCES677F – SEPTEMBER 2006 – REVISED JUNE 2024

**2.1.2 Detailed Design Procedure**

To begin the design process, determine the following:

- Input voltage range
  - Use the supply voltage of the device that is driving the SN74LVC1T45-Q1 device to determine the input voltage range. For a valid logic high the value must exceed the  $V_{IH}$  of the input port. For a valid logic low the value must be less than the  $V_{IL}$  of the input port.
- Output voltage range
  - Use the supply voltage of the device that the SN74LVC1T45-Q1 device is driving to determine the output voltage range.

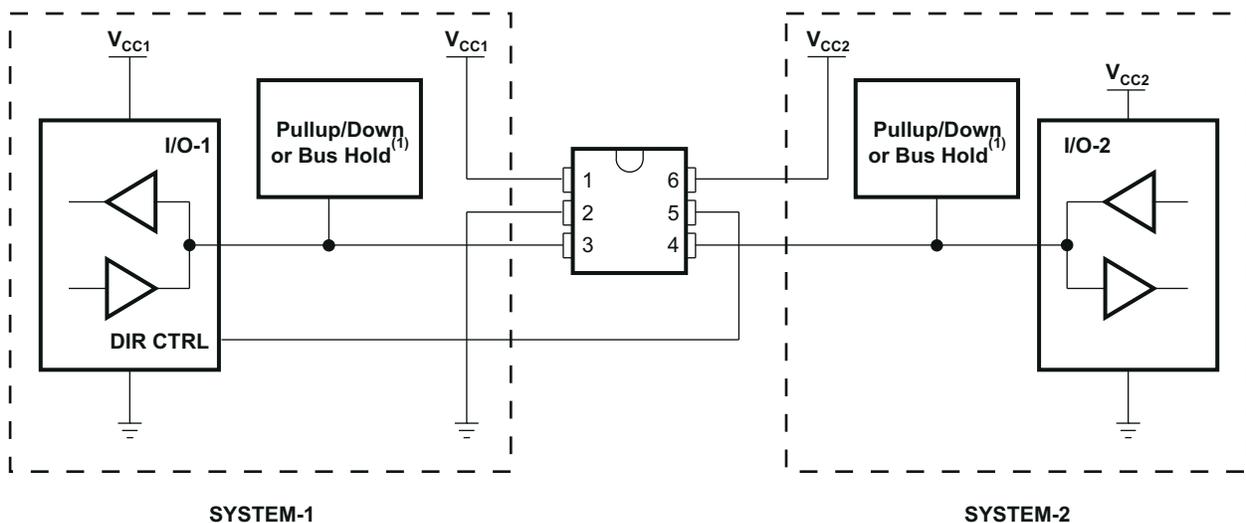
**2.1.3 Application Curves**



**Figure 7-2. Translation Up (1.8V to 5V) at 2.5MHz**

**2.2 Bidirectional Logic Level-Shifting Application**

Figure 7-3 shows the SN74LVC1T45-Q1 being used in a bidirectional logic level-shifting application. Because the SN74LVC1T45-Q1 does not have an output-enable (OE) pin, the system designer should take precautions to avoid bus contention between SYSTEM-1 and SYSTEM-2 when changing directions.



Copyright © 2016, Texas Instruments Incorporated

**Figure 7-3. Bidirectional Logic Level-Shifting Application**

### 2.2.1 Detailed Design Procedure

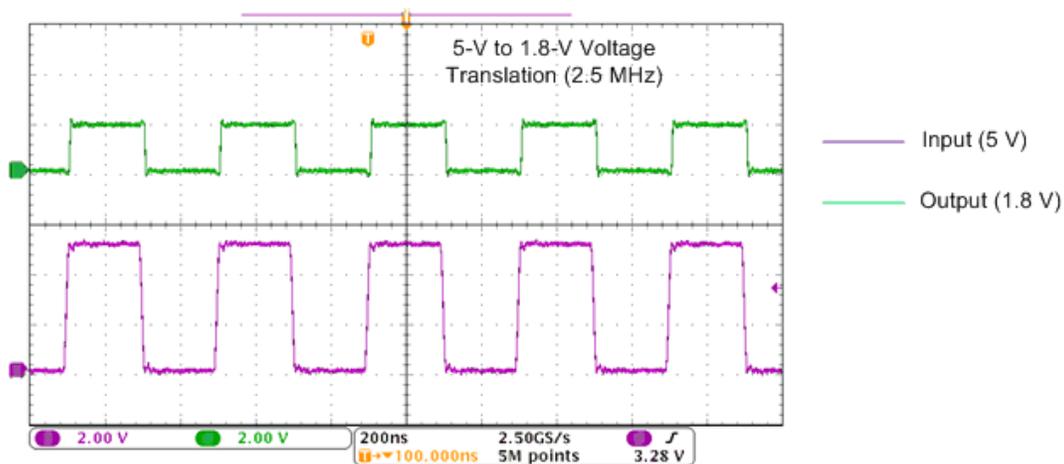
Table 7-2 shows data transmission from SYSTEM-1 to SYSTEM-2 and then from SYSTEM-2 to SYSTEM-1.

**Table 7-2. Data Transmission**

STATE	DIR CTRL	I/O-1	I/O-2	DESCRIPTION
1	H	Out	In	SYSTEM-1 data to SYSTEM-2
2	H	Hi-Z	Hi-Z	SYSTEM-2 is getting ready to send data to SYSTEM-1. I/O-1 and I/O-2 are disabled. The bus-line state depends on pullup or pulldown. <sup>(1)</sup>
3	L	Hi-Z	Hi-Z	DIR bit is flipped. I/O-1 and I/O-2 still are disabled. The bus-line state depends on pullup or pulldown. <sup>(1)</sup>
4	L	Out	In	SYSTEM-2 data to SYSTEM-1

(1) SYSTEM-1 and SYSTEM-2 must use the same conditions, that is, both pullup or both pulldown.

### 2.2.2 Application Curves



**Figure 7-4. Translation Down (5V to 1.8V) at 2.5MHz**

## 3 Power Supply Recommendations

Always apply a ground reference to the GND pins first. This device is designed for glitch free power sequencing without any supply sequencing requirements such as ramp order or ramp rate.

This device was designed with various power supply sequencing methods in mind to help prevent unintended triggering of downstream devices, as described in [Glitch-free Power Supply Sequencing](#).

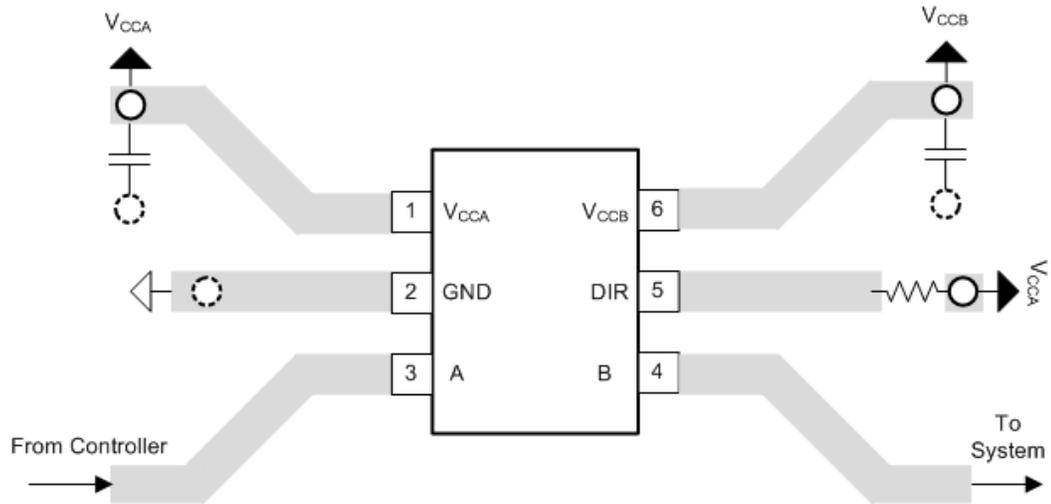
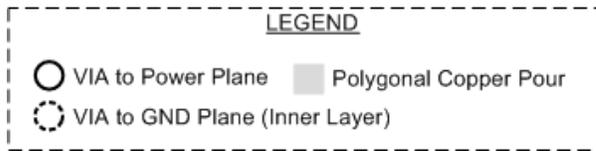
## 4 Layout

### 4.1 Layout Guidelines

For device reliability, the following common printed-circuit board layout guidelines are recommended:

- Bypass capacitors must be used on power supplies.
- Short trace lengths must be used to avoid excessive loading.
- Placing pads on the signal paths for loading capacitors or pullup resistors to help adjust rise and fall times of signals depends on the system requirements.

**4.2 Layout Example**



**Figure 7-5. Layout Schematic**

## 7 Device and Documentation Support

### 7.1 Documentation Support

#### 7.1.1 Related Documentation

For related documentation see the following:

- Texas Instruments, [Implications of Slow or Floating CMOS Inputs application note](#)

### 7.2 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.

### 7.3 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](#).

### 7.4 Trademarks

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

### 7.5 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.

### 7.6 Glossary

[TI Glossary](#) This glossary lists and explains terms, acronyms, and definitions.

## 8 Revision History

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

<b>Changes from Revision E (December 2022) to Revision F (June 2024)</b>	<b>Page</b>
• Updated <i>Package Information</i> table to include package lead size.....	1
• Updated the <i>Power Supply Recommendations</i> section.....	15

<b>Changes from Revision D (July 2017) to Revision E (December 2022)</b>	<b>Page</b>
• Updated the numbering format for tables, figures, and cross-references throughout the document.....	1
• Updated the thermals in the <i>Thermal Information</i> section.....	4
• Updated the <i>Switching Characteristics</i> sections: extended some minimum specifications for lower delays.....	6

## 9 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 Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead finish/ Ball material (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
SN74LVC1T45QDCKRQ1	ACTIVE	SC70	DCK	6	3000	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	-40 to 125	5TR	Samples

(1) The marketing status values are defined as follows:

**ACTIVE:** Product device recommended for new designs.

**LIFEBUY:** TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.

**NRND:** Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.

**PREVIEW:** Device has been announced but is not in production. Samples may or may not be available.

**OBSELETE:** TI has discontinued the production of the device.

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

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

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

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

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

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

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

**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.

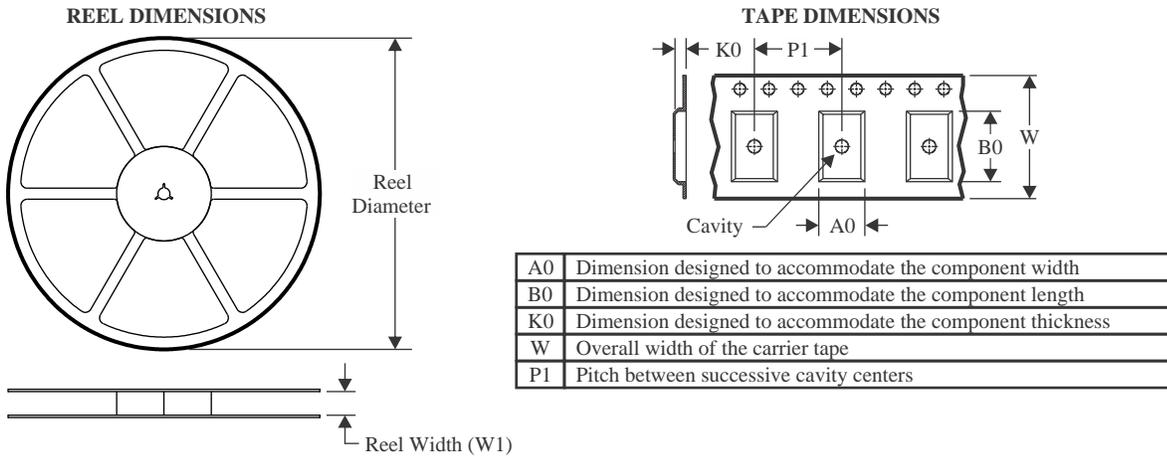
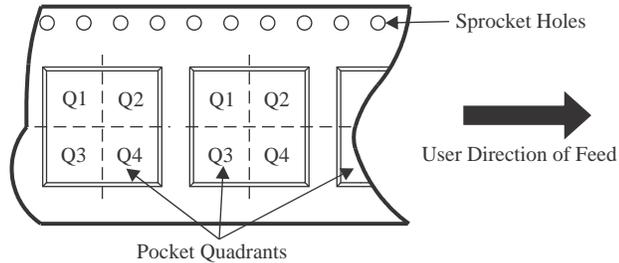
In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

**OTHER QUALIFIED VERSIONS OF SN74LVC1T45-Q1 :**

- Catalog : [SN74LVC1T45](#)
- Enhanced Product : [SN74LVC1T45-EP](#)

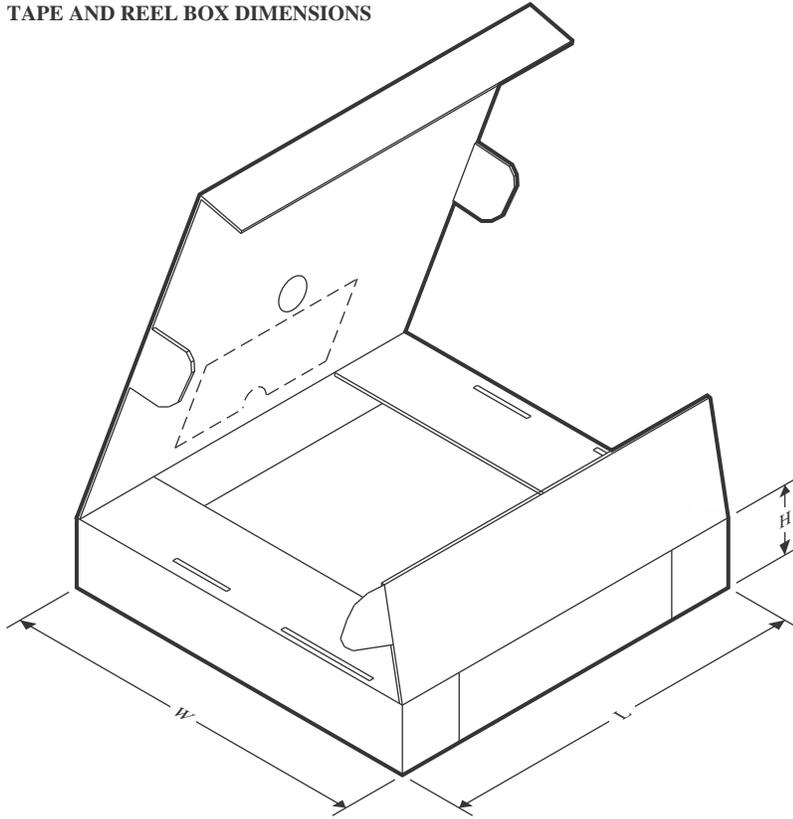
NOTE: Qualified Version Definitions:

- Catalog - TI's standard catalog product
- Enhanced Product - Supports Defense, Aerospace and Medical Applications

**TAPE AND REEL INFORMATION**

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


\*All dimensions are nominal

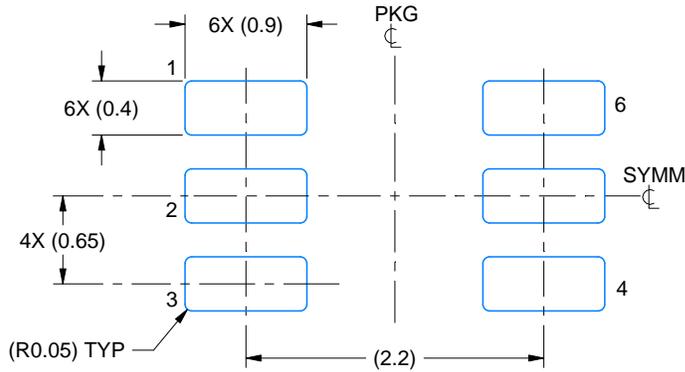
Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
SN74LVC1T45QDCKRQ1	SC70	DCK	6	3000	180.0	8.4	2.47	2.3	1.25	4.0	8.0	Q3

**TAPE AND REEL BOX DIMENSIONS**


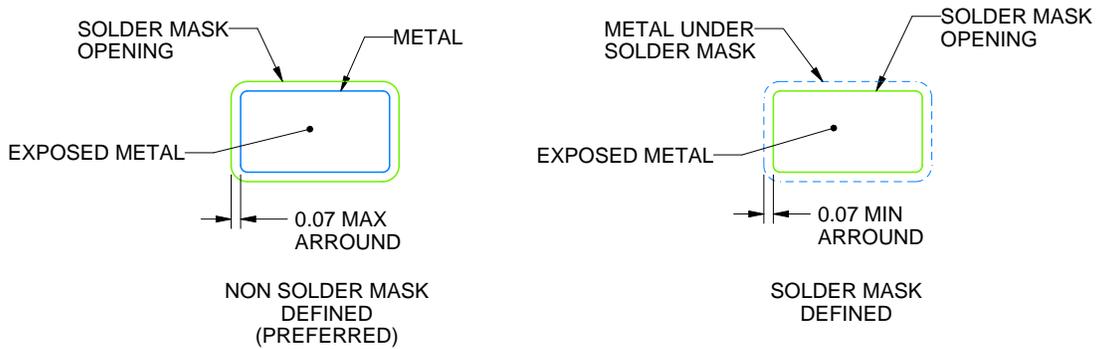
\*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
SN74LVC1T45QDCKRQ1	SC70	DCK	6	3000	202.0	201.0	28.0





LAND PATTERN EXAMPLE  
EXPOSED METAL SHOWN  
SCALE:18X

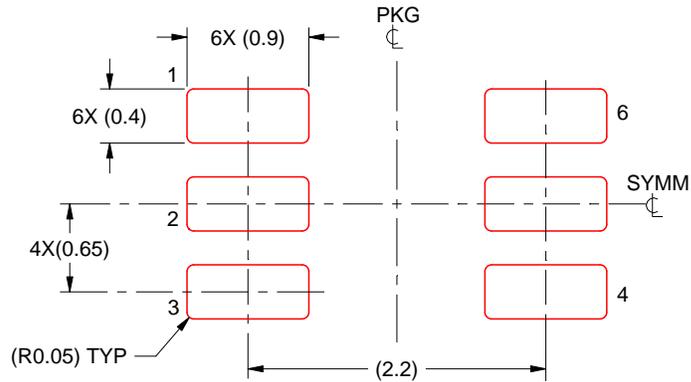


SOLDER MASK DETAILS

4214835/D 11/2024

NOTES: (continued)

- 5. Publication IPC-7351 may have alternate designs.
- 6. 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

4214835/D 11/2024

NOTES: (continued)

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

## IMPORTANT NOTICE AND DISCLAIMER

TI PROVIDES TECHNICAL AND RELIABILITY DATA (INCLUDING DATA SHEETS), 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 will 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](#) or other applicable terms available either on [ti.com](https://www.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.

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

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265

Copyright © 2025, Texas Instruments Incorporated