

# LSF0002 Ultra-Small Auto-Bidirectional Translator for Open Drain or Push Pull Applications

## 1 Features

- Provide bidirectional voltage translation with no direction pin needed ( $V_{EXTA}$  needs to be 0.8V less than  $V_{EXTB}$  for best signal integrity)
- Supports switch configuration implementation when  $V_{EXTA} = V_{EXTB}$
- Supports up to 100MHz up translation and greater than 100MHz down translation at  $\leq 30\text{pF}$  capacitive load and up to 40MHz up or down translation at 50pF capacitive load
- Allows bidirectional voltage-level translation between
  - 0.95V  $\leftrightarrow$  1.8/2.5/3.3/5V
  - 1.2V  $\leftrightarrow$  1.8/2.5/3.3/5V
  - 1.8V  $\leftrightarrow$  2.5/3.3/5V
  - 2.5V  $\leftrightarrow$  3.3/5V
  - 3.3V  $\leftrightarrow$  5V
- Low standby current
- 5V tolerance I/O port to support TTL
- Low  $R_{ON}$  provides less signal distortion
- High-impedance I/O pins for EN = Low
- Flow-through pinout for easy PCB trace routing
- Latch-up performance  $>100\text{mA}$  per JESD 17
- $-40^{\circ}\text{C}$  to  $125^{\circ}\text{C}$  operating temperature range

## 2 Applications

- GPIO, MDIO, PMBus, SMBus, SDIO, UART, I<sup>2</sup>C, and other interfaces in telecom infrastructure
- [Enterprise systems](#)
- [Communications equipment](#)
- [Personal electronics](#)
- [Industrial applications](#)

## 3 Description

The LSF0002 supports bidirectional voltage translation without the need for DIR pin, which minimizes system effort (for PMBus, I<sup>2</sup>C, SMBus, and so forth). The LSF family of devices supports up to 100MHz up translation and greater than 100MHz down translation at  $\leq 30\text{pF}$  capacitive load and up to 40MHz up or down translation at 50pF capacitive load, which allows the LSF family to support more consumer or telecom interfaces (MDIO or SDIO).

LSF family supports 5V tolerance on I/O port, which makes it compatible with TTL levels in industrial and telecom applications. The LSF family can set up different voltage translation levels, which makes it very flexible.

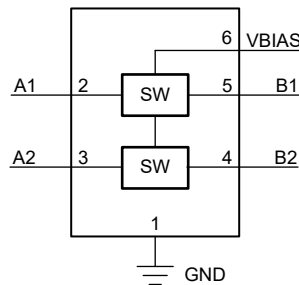
Unlike the LSF0x0x family, the LSF0002 does not require VREF\_A and VREF\_B power supplies and the 200k $\Omega$  bias resistor. The LSF0002 utilizes the V<sub>BIAS</sub> pin that enables translation by being biased to the same voltage as the lower power supply at the I/Os that is being translated to and from.

### Package Information

PART NUMBER	PACKAGE <sup>(1)</sup>	PACKAGE SIZE <sup>(2)</sup>
LSF0002	DTQ (X2SON, 6)	1mm $\times$ 0.8mm

(1) For more information, see [Section 11](#).

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



Functional Block Diagram

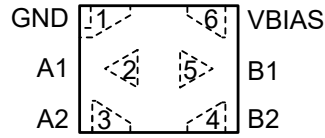


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## 4 Pin Configuration and Functions

Pinout drawings are not to scale



**Figure 4-1. LSF0002 DTQ Package, 6-Pin X2SON (Top View)**

**Table 4-1. Pin Functions**

PIN		TYPE <sup>(1)</sup>	DESCRIPTION
NAME	NO.		
A1	2	I/O	Auto-Bidirectional Data port
A2	3	I/O	
B1	5	I/O	
B2	4	I/O	
VBIAS	6	I	Enable input/ Supply Voltage
GND	1	—	Ground

(1) I = input, O = output

## 5 Specifications

### 5.1 Absolute Maximum Ratings

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

		MIN	MAX	UNIT
$V_I$	Input voltage <sup>(2)</sup>	-0.5	7	V
$V_{I/O}$	Input/output voltage <sup>(2)</sup>	-0.5	7	V
	Continuous channel current		128	mA
$I_{IK}$	Input clamp current	$V_I < 0$	-50	mA
$T_J$	Junction temperature		150	°C
$T_{stg}$	Storage temperature	-65	150	°C

- (1) Operation outside the *Absolute Maximum Rating* may cause permanent device damage. *Absolute Maximum Rating* do not imply functional operation of the device at these or any other conditions beyond those listed under *Recommended Operating Condition*. If used outside the *Recommended Operating Condition* but within the *Absolute Maximum Rating*, the device may not be fully functional, and this may affect device reliability, functionality, performance, and shorten the device lifetime.
- (2) The input and input/output voltage ratings may be exceeded if the input and input/output clamp-current ratings are observed.

### 5.2 ESD Ratings

			VALUE	UNIT
$V_{(ESD)}$	Electrostatic discharge	Human body model (HBM), per AEC Q100-002 <sup>(3)</sup>	±2000	V
$V_{(ESD)}$	Electrostatic discharge	Charged device model (CDM), per AEC Q100-001	±1000	V
$V_{(ESD)}$	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>	±1000	

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

### 5.3 Recommended Operating Conditions

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

PARAMETER			MIN	MAX	UNIT
$V_{BIAS}$	Reference Voltage		0	5.5	V
$V_{I/O}$	Input/Output voltage	A1, A2, B1, B2	0	5.5	V
$I_{PASS}$	Pass switch current			64	mA
$T_A$	Operating free-air temperature		-40	125	°C

## 5.4 Thermal Information

THERMAL METRIC <sup>(1)</sup>		LSF0002	UNIT
		DTQ (X2SON)	
		6 PINS	
$R_{\theta JA}$	Junction-to-ambient thermal resistance	294.4	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	188.9	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	216.8	°C/W
$\Psi_{JT}$	Junction-to-top characterization parameter	26.5	°C/W
$\Psi_{JB}$	Junction-to-board characterization parameter	216.0	°C/W
$R_{\theta JC(bot)}$	Junction-to-case (bottom) thermal resistance	n/a	°C/W

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

## 5.5 Electrical Characteristics

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

PARAMETER	TEST CONDITIONS			MIN	TYP <sup>(1)</sup>	MAX	UNIT
$V_{IK}$	$I_I = -18\text{mA}$	$EN = 0\text{V}$				-1.2	V
$I_{IH}$	$V_I = 5\text{V}$	$EN = 0\text{V}$				5.0	μA
$I_{CCBA}$	$V_{ref\_B} = V_{EN} = 5.5\text{V}$ , $V_{ref\_A} = 4.5\text{V}$ , $I_O = 0$ , $V_I = V_{CC}$ or GND				1		μA
$C_{I(ref\_A/B/EN)}$	$V_I = 3\text{V}$ or 0				11		pF
$C_{io(off)}$	$V_O = 3\text{V}$ or 0,	$V_{EN} = 0\text{V}$			4.0	6.0	pF
$C_{io(on)}$	$V_O = 3\text{V}$ or 0,	$V_{EN} = 3\text{V}$			10.5	12.5	pF
$r_{ON}$ <sup>(2)</sup>	$V_I = 0$ ,	$I_O = 64\text{mA}$	$V_{ref\_A} = 3.3\text{V}$ ; $V_{ref\_B} = V_{EN} = 5\text{V}$		8.0		Ω
			$V_{ref\_A} = 1.8\text{V}$ ; $V_{ref\_B} = V_{EN} = 5\text{V}$		9.0		
			$V_{ref\_A} = 1.0\text{V}$ ; $V_{ref\_B} = V_{EN} = 5\text{V}$		10		
	$V_I = 0$ ,	$I_O = 32\text{mA}$	$V_{ref\_A} = 1.8\text{V}$ ; $V_{ref\_B} = V_{EN} = 5\text{V}$		10		Ω
			$V_{ref\_A} = 2.5\text{V}$ ; $V_{ref\_B} = V_{EN} = 5\text{V}$		15		
	$V_I = 1.8\text{V}$ ,	$I_O = 15\text{mA}$	$V_{ref\_A} = 3.3\text{V}$ ; $V_{ref\_B} = V_{EN} = 5\text{V}$		9.0		Ω
	$V_I = 1.0\text{V}$ ,	$I_O = 10\text{mA}$	$V_{ref\_A} = 1.8\text{V}$ ; $V_{ref\_B} = V_{EN} = 3.3\text{V}$		18		Ω
	$V_I = 0\text{V}$ ,	$I_O = 10\text{mA}$	$V_{ref\_A} = 1.0\text{V}$ ; $V_{ref\_B} = V_{EN} = 3.3\text{V}$		20		Ω
$V_I = 0\text{V}$ ,	$I_O = 10\text{mA}$	$V_{ref\_A} = 1.0\text{V}$ ; $V_{ref\_B} = V_{EN} = 1.8\text{V}$		30		Ω	

(1) All typical values are at  $T_A = 25^\circ\text{C}$ .

(2) Measured by the voltage drop between the A and B pins at the indicated current through the switch. Minimum ON-state resistance is determined by the lowest voltage of the two (A or B) pins.

### 5.6 Switching Characteristics (Translating Down): $B_N = 3.3V$

over recommended operating free-air temperature range,  $B_N = 3.3V$ ,  $B_N = V_{IH} = A_N + 1$ ,  $V_{IL} = 0$ , and  $V_M = 0.5A_N$  (unless otherwise noted <sup>(1)</sup> <sup>(2)</sup>) (see Section 6)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
T <sub>PLH</sub>	Low-to-high propagation delay	From (input) A or B to (output) B or A	C <sub>L</sub> = 15pF	0.3	ns	
			C <sub>L</sub> = 30pF	0.7		
			C <sub>L</sub> = 50pF	1.1		
T <sub>PHL</sub>	High to low propagation delay		C <sub>L</sub> = 15pF	0.4	ns	
			C <sub>L</sub> = 30pF	0.8		
			C <sub>L</sub> = 50pF	1.2		

- (1) Specified by simulation, not tested in production.  
(2) Translating Down: the high-voltage side driving toward the low-voltage side.

### 5.7 Switching Characteristics (Translating Down): $B_N = 2.5V$

over recommended operating free-air temperature range,  $B_N = 2.5V$ ,  $B_N = V_{IH} = A_N + 1$ ,  $V_{IL} = 0$ , and  $V_M = 0.5A_N$  (unless otherwise noted <sup>(1)</sup> <sup>(2)</sup>) (see Section 6)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
T <sub>PLH</sub>	Low-to-high propagation delay	From (input) A or B to (output) B or A	C <sub>L</sub> = 15pF	0.35	ns	
			C <sub>L</sub> = 30pF	0.8		
			C <sub>L</sub> = 50pF	1.2		
T <sub>PHL</sub>	High to low propagation delay		C <sub>L</sub> = 15pF	0.5	ns	
			C <sub>L</sub> = 30pF	1		
			C <sub>L</sub> = 50pF	1.3		

- (1) Specified by simulation, not tested in production.  
(2) Translating Down: the high-voltage side driving toward the low-voltage side.

### 5.8 Switching Characteristics (Translating Up): $B_N = 3.3V$

over recommended operating free-air temperature range,  $B_N = 3.3V$ ,  $B_N = V_T = A_N + 1$ ,  $V_{ref\_A} = V_{IH}$ ,  $V_{IL} = 0$ ,  $V_M = 0.5A_N$  and  $R_L = 300$  (unless otherwise noted <sup>(1)</sup> <sup>(2)</sup>) (see Section 6)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
T <sub>PLH</sub>	Low-to-high propagation delay	From (input) A or B to (output) B or A	C <sub>L</sub> = 15pF	0.4	ns	
			C <sub>L</sub> = 30pF	0.8		
			C <sub>L</sub> = 50pF	1		
T <sub>PHL</sub>	High to low propagation delay		C <sub>L</sub> = 15pF	0.4	ns	
			C <sub>L</sub> = 30pF	0.9		
			C <sub>L</sub> = 50pF	1		

- (1) Specified by simulation, not tested in production.  
(2) Translating Down: the high-voltage side driving toward the low-voltage side.

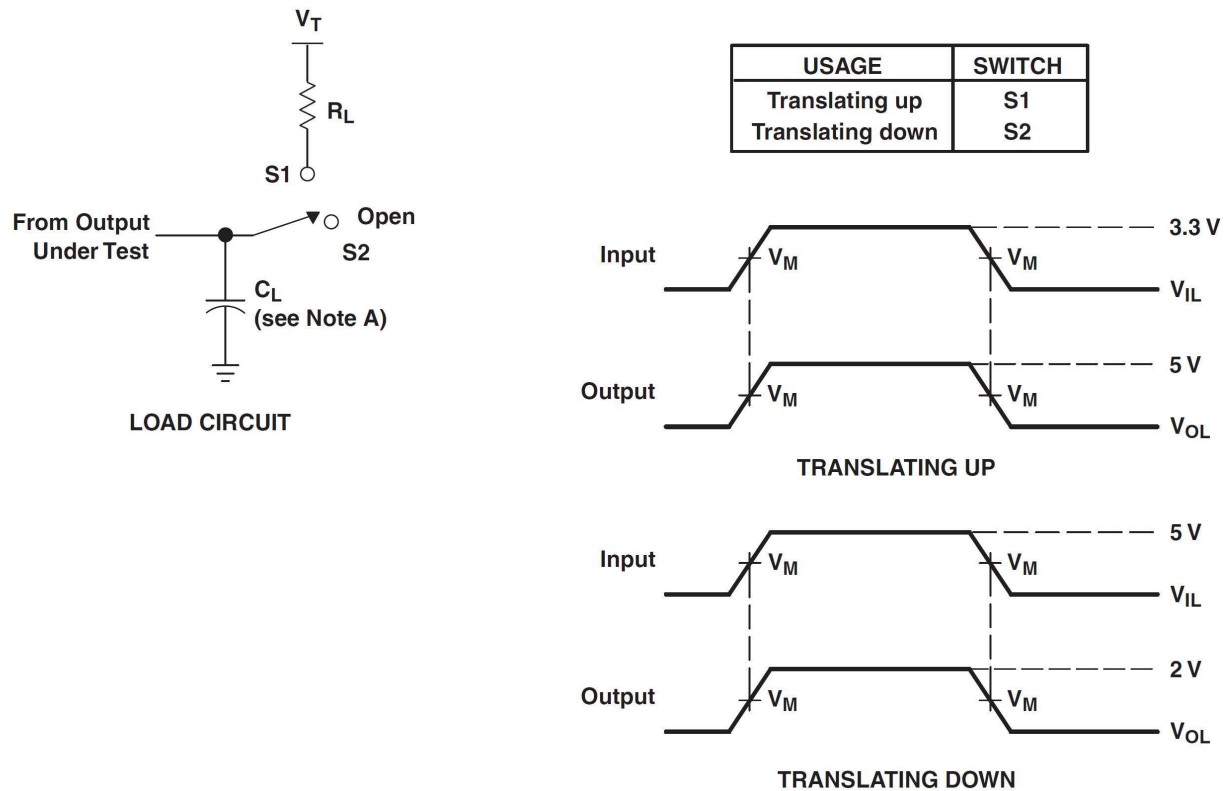
### 5.9 Switching Characteristics (Translating Up): $B_N = 2.5V$

over recommended operating free-air temperature range,  $B_N = 2.5V$ ,  $B_N = V_T = A_N + 1$ ,  $A_N = V_{IH}$ ,  $V_{IL} = 0$ ,  $V_M = 0.5A_N$  and  $R_L = 300$  (unless otherwise noted <sup>(1)</sup> <sup>(2)</sup>) (see [Section 6](#))

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
T <sub>PLH</sub>	Low-to-high propagation delay	From (input) A or B to (output) B or A	C <sub>L</sub> = 15pF	0.45		ns
			C <sub>L</sub> = 30pF	0.9		
			C <sub>L</sub> = 50pF	1.1		
T <sub>PHL</sub>	High to low propagation delay	From (input) A or B to (output) B or A	C <sub>L</sub> = 15pF	0.6		ns
			C <sub>L</sub> = 30pF	1.1		
			C <sub>L</sub> = 50pF	1.3		

- (1) Specified by simulation, not tested in production.  
 (2) Translating Down: the high-voltage side driving toward the low-voltage side.

## 6 Parameter Measurement Information



- A.  $C_L$  includes probe and jig capacitance.
- B. Generators that have the following characteristics generate all input pulses:  $PRR \leq 10\text{MHz}$ ,  $Z_O = 50\Omega$ ,  $t_r \leq 2\text{ns}$ ,  $t_f \leq 2\text{ns}$ .
- C. The outputs are measured one at a time, with one transition per measurement.

**Figure 6-1. Load Circuit for Outputs**

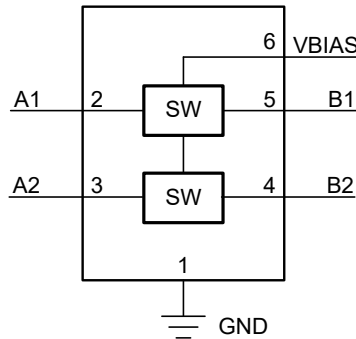


## 7 Detailed Description

### 7.1 Overview

The LSF0002 can be used in level-translation applications for interfacing devices or systems operating with one another that operate at different interface voltages as well as for switching applications where  $V_{EXTA} = V_{EXTB}$ . This allows the I/Os of the LSF0002 to be placed in HIGH-Z when the device is set to enabled/ disabled. The LSF family is an excellent choice for use in applications where an open-drain driver is connected to the data I/Os. With appropriate pull-up resistors and layout, LSF can achieve 100MHz. The LSF family can also be used in applications where a push-pull driver is connected to the data I/Os. For an overview of device setup and operation, see [The Logic Minute](#) training series on [Understanding the LSF Family of Bidirectional, Multi-Voltage Level Translators](#).

### 7.2 Functional Block Diagram



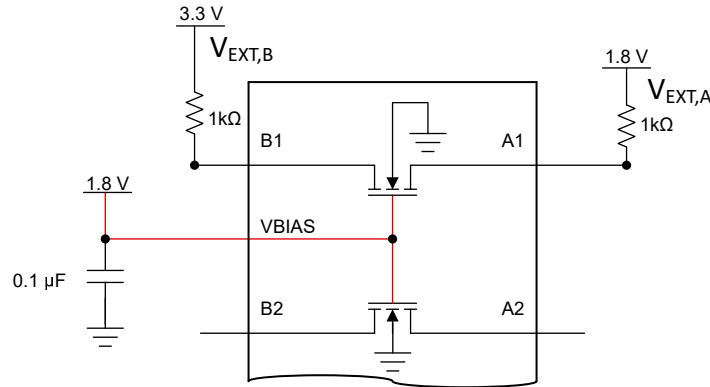
### 7.3 Feature Description

#### 7.3.1 Auto Bidirectional Voltage Translation

The LSF family is an auto bidirectional voltage level translator that is operational from 0.95 to 5.5V. This allows for bidirectional voltage translation between 0.95V and 5.5V without the need for a direction pin in open-drain or push-pull applications. The LSF family supports level translation applications with transmission speeds greater than 100Mbps for open-drain systems using a 30pF capacitance and 250Ω pullup resistor. Both the output driver of the controller and the peripheral device output can be push-pull or open-drain (pull-up resistors may be required). In both up and down translation, the B-side is often referred to as the high side and refers to devices connected to the B ports. The A-side can be referred to as the low side.

### 7.3.2 $V_{BIAS}$ / Enable

To enable the I/O pins, the  $V_{BIAS}$  input should be referenced towards the lower power supply (in the following example,  $V_{EXT,A}$ ) during voltage translation. To be in the high impedance state during power-up, power-down, or during operation, the  $V_{BIAS}$  pin must be pulled low and at GND or disabled by an open-drain driver without a pullup resistor. Use the  $V_{BIAS}$  pin to properly bias the I/O channels. A filter capacitor on  $V_{BIAS}$  is also recommended for a stable supply at the device.



**Figure 7-1.  $V_{BIAS}$  Tied to Lower Power Supply**

The supply voltage of open drain I/O devices can be completely different from the supplies used for the LSF and has no impact on the operation. For additional details on how to use the enable pin, see the [Using the Enable Pin with the LSF Family video](#).

**Table 7-1. Enable Pin Function Table**

INPUT $V_{BIAS}$ PIN	Data Port State
Tied directly to $V_{BIAS}$	$A_n = B_n$
L	Hi-Z

### 7.4 Device Functional Modes

For each channel (n), when either the  $A_n$  or  $B_n$  port is LOW, the switch provides a low impedance path between the  $A_n$  and  $B_n$  ports; the corresponding  $B_n$  or  $A_n$  port will be pulled LOW. The low  $R_{ON}$  of the switch allows connections to be made with minimal propagation delay and signal distortion.

[Table 7-1](#) provides a summary of device operation. For additional details on the functional operation of the LSF family of devices, see the [Down Translation with the LSF Family](#) and [Up Translation with the LSF Family](#) videos.

**Table 7-2. Device Functionality**

Signal Direction <sup>(1)</sup>	Input State	Switch State	Functionality
B to A (Down Translation)	B = LOW	ON (Low Impedance)	A-side voltage is pulled low through the switch to the B-side voltage
	B = HIGH	OFF (High Impedance)	A-side voltage is clamped at $V_{EXT,A}$ <sup>(2)</sup>
A to B (Up Translation)	A = LOW	ON (Low Impedance)	B-side voltage is pulled low through the switch to the A-side voltage
	A = HIGH	OFF (High Impedance)	B-side voltage is clamped at $V_{EXT,A}$ and then pulled up to the $V_{EXT,B}$ supply voltage

- (1) The downstream channel should not be actively driven through a low impedance driver, or else bus contention may occur.
- (2) The A-side can have a pullup to  $V_{EXT,A}$  for additional current drive capability or may also be pulled above  $V_{EXT,A}$  with a pullup resistor. Specifications in the [Recommended Operating Conditions](#) section should always be followed.

## 8 Application and Implementation

### Note

Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI's customers are responsible for determining suitability of components for their purposes, as well as validating and testing their design implementation to confirm system functionality.

### 8.1 Application Information

The LSF devices can perform voltage translation for open-drain or push-pull interfaces. Table 8-1 provides common interfaces and the corresponding device recommendation from the LSF family, which supports the corresponding bit count.

**Table 8-1. Voltage Translator for Common Interfaces**

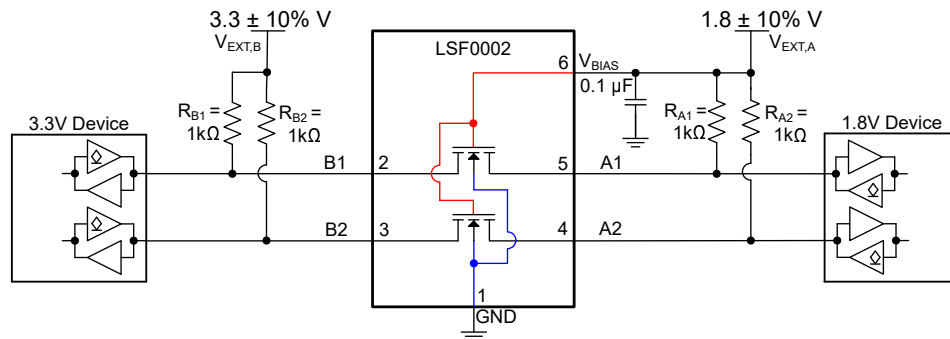
Part Name	Channel Number	Interface
LSF0002	2	GPIO, MDIO, SMBus, PMBus, and I <sup>2</sup> C

Some important reminders regarding the LSF0002 are as follows:

- LSF devices are switch-based, not buffer-based (for more information, see the TXB family for buffer-based devices).
- Specific data rates cannot be calculated by using  $1/T_{pd}$ .
- $V_{EXT,A}/V_{EXT,B}$  are referenced to the external power supplies at the I/Os.
- $V_{BIAS}$  should be tied towards the lowest voltage being translated to at the I/Os.

### 8.2 Typical Applications

#### 8.2.1 Open-Drain Interface (I<sup>2</sup>C, PMBus, SMBus, and GPIO)



**Figure 8-1. Typical Application Circuit for Open-Drain Translation (MDIO Shown as an Example)**

### 8.2.1.1 Design Requirements

#### 8.2.1.1.1 Enable and Disable Guidelines

In the previous figure,  $V_{BIAS}$  is referenced to the lower power supply ( $V_{EXT,A}$ ) of 1.8V power supply and  $V_{EXT,B}$  is set to 3.3V. The A1 and A2 channels have a maximum output voltage equal to  $V_{EXT,A}$  and the B1 and B2 channels have a maximum output voltage equal to  $V_{EXT,B}$ .

The LSF0002 has an  $V_{BIAS}$  input that is used to disable the device by driving this node LOW to GND, placing all I/Os in the high-impedance state. Since the LSF family of devices are switch-type voltage translators, the power consumption is very low. TI recommends always enabling the LSF family for bidirectional applications (I<sup>2</sup>C, SMBus, PMBus, or MDIO).

#### Note

The 200kΩ, bias resistor is not required for the LSF0002

**Table 8-2. Application Operating Condition (Level Shift Configuration,  $V_{EXT,A} \neq V_{EXT,B}$ )**

PARAMETER		MIN	TYP	MAX	UNIT
$V_{EXT,A}$ <sup>(1)</sup>	reference voltage (A)	0.9		5.5	V
$V_{EXT,B}$	reference voltage (B)	$V_{EXT,A} + 0.8$		5.5	V
$V_{BIAS}$	input voltage on $V_{BIAS}$ pin	$V_{EXT,A}$		$V_{EXT,A} + 0.8$	V
$V_{PU}$	pull-up supply voltage	0		$V_{EXT,B}$	V

(1)  $V_{EXT,A}$  is required to be the lowest voltage level across all inputs and outputs.

**Table 8-3. Application Operating Condition (Switch Configuration,  $V_{EXT,A} = V_{EXT,B}$ )**

PARAMETER		MIN	TYP	MAX	UNIT
$V_{EXT,A}=V_{EXT,B}$	reference voltage (A) reference voltage (B)	0.9		5.5	V
$V_{BIAS}$	input voltage on $V_{BIAS}$ pin	$V_{EXT,A}$		$V_{EXT,A} + 0.8$	V
$V_{PU}$	pull-up supply voltage	0		$V_{EXT,B}$	V

### 8.2.1.2 Detailed Design Procedure

#### 8.2.1.2.1 Bidirectional Translation

For the bidirectional translation configuration (higher voltage to lower voltage or lower voltage to higher voltage), the  $V_{BIAS}$  input must be connected to  $V_{EXT,A}$ . This allows  $V_{BIAS}$  to regulate the bias of the I/O channels for proper translation. A filter capacitor on  $V_{BIAS}$  is recommended for a stable supply at the device. The controller output driver can be push-pull or open-drain (pull-up resistors may be required) and the peripheral device output can be push-pull or open-drain (pull-up resistors are required to pull the Bn outputs to  $V_{PU}$ ).

#### Note

If either output is push-pull, data must be unidirectional or the outputs must be tri-state and be controlled by some direction-control mechanism to prevent HIGH-to-LOW bus contention in either direction. If both outputs are open-drain, no direction control is needed.

#### 8.2.1.2.2 Pull-Up Resistor Sizing

The pull-up resistor value needs to limit the current through the pass transistor when it is in the ON state to about 15mA. Doing this causes a voltage drop of 260mV to 350mV to have a valid LOW signal on the downstream channel. If the current through the pass transistor is higher than 15mA, then the voltage drop is also higher in the ON state. To set the current through each pass transistor at 15mA, calculate the pull-up resistor value using the following equation:

$$R_{pu} = \frac{(V_{pu} - 0.35 V)}{0.015 A} \quad (1)$$

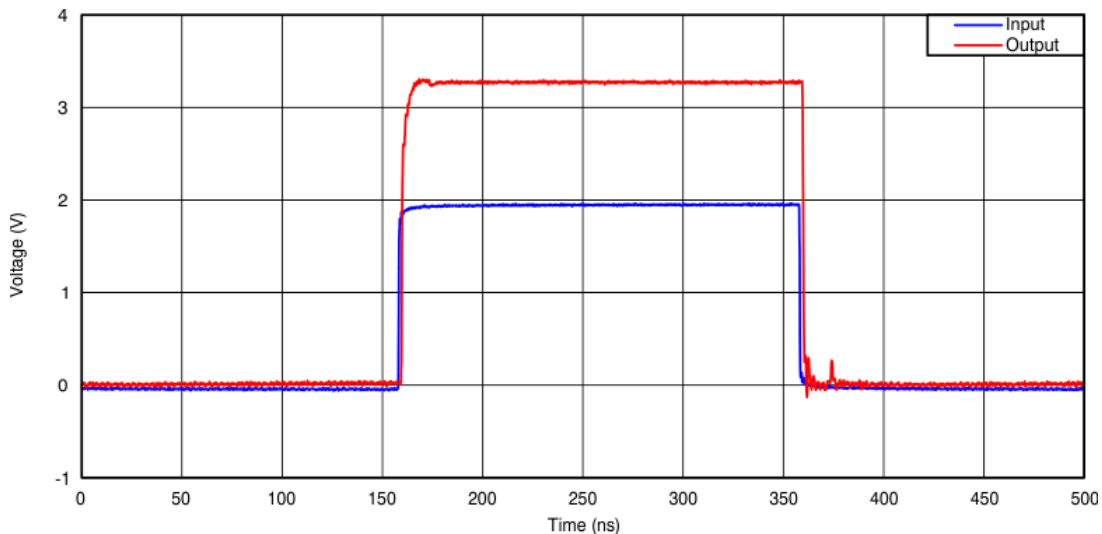
Table 8-4 provides resistor values, reference voltages, and currents at 8mA, 5mA, and 3mA. The resistor value shown in the +10% column (or a larger value) should be used so that the voltage drop across the transistor is 350mV or less. The external driver must be able to sink the total current from the resistors on both sides of the LSF family device at 0.175V, although the 15mA applies only to current flowing through the LSF family device. The device driving the low state at 0.175V must sink current from one or more of the pull-up resistors and maintain  $V_{OL}$ . A decrease in resistance will increase current, and thus result in increased  $V_{OL}$ .

**Table 8-4. Pull-Up Resistor Values**

$V_{PU}$ (1) (2)	8mA		5mA		3mA	
	NOMINAL ( $\Omega$ )	+10% <sup>(3)</sup> ( $\Omega$ )	NOMINAL ( $\Omega$ )	+10% <sup>(3)</sup> ( $\Omega$ )	NOMINAL ( $\Omega$ )	+10% <sup>(3)</sup> ( $\Omega$ )
5V	581	639	930	1023	1550	1705
3.3V	369	406	590	649	983	1082
2.5V	269	296	430	473	717	788
1.8V	181	199	290	319	483	532
1.5V	144	158	230	253	383	422
1.2V	106	117	170	187	283	312

- (1) Calculated for  $V_{OL} = 0.35V$
- (2) Assumes output driver  $V_{OL} = 0.175V$  at stated current
- (3) +10% to compensate for  $V_{DD}$  range and resistor tolerance

**8.2.1.3 Application Curve**



**Figure 8-2. Open Drain Translation (1.8V to 3.3V at 2.5MHz)**

**8.2.2 Mixed-Mode Voltage Translation**

The supply voltage ( $V_{EXT,A,B}$ ) for each channel can be individually set with a pull-up resistor. Figure 8-3 shows an example of this mixed-mode multi-voltage translation. For additional details on multi-voltage translation, see the [Multi-voltage Translation with the LSF Family](#) video.

With  $V_{EXT,B}$  pulled up to 5V and  $V_{EXT,A}$  connected to 1.2V, all channels will be clamped to 1.2V at which point a pullup can be used to define the high level voltage for a given channel.

- **Push-Pull Down Translation (5V to 1.2V):** Channel 2 is an example of this setup. When B2 is 5V (HIGH), A2 is clamped to 1.2V, and when B2 is 0V (LOW), A2 is driven LOW through the switch.
- **Push-Pull Up Translation (1.2V to 3.3V):** Channel 1 is an example of this setup. When A1 is 1.2V, the switch is high impedance and B1 channel is pulled up to 3.3V through RB1. When A1 is LOW, B1 is driven LOW through the switch.

- **Push-Pull Down Translation (3.3V to 1.2V):** Channels 1 is an example of this setup. When B1 is driven to 3.3V, A1 is clamped to 1.2V, and when B1 is LOW, A1 is driven LOW through the switch.

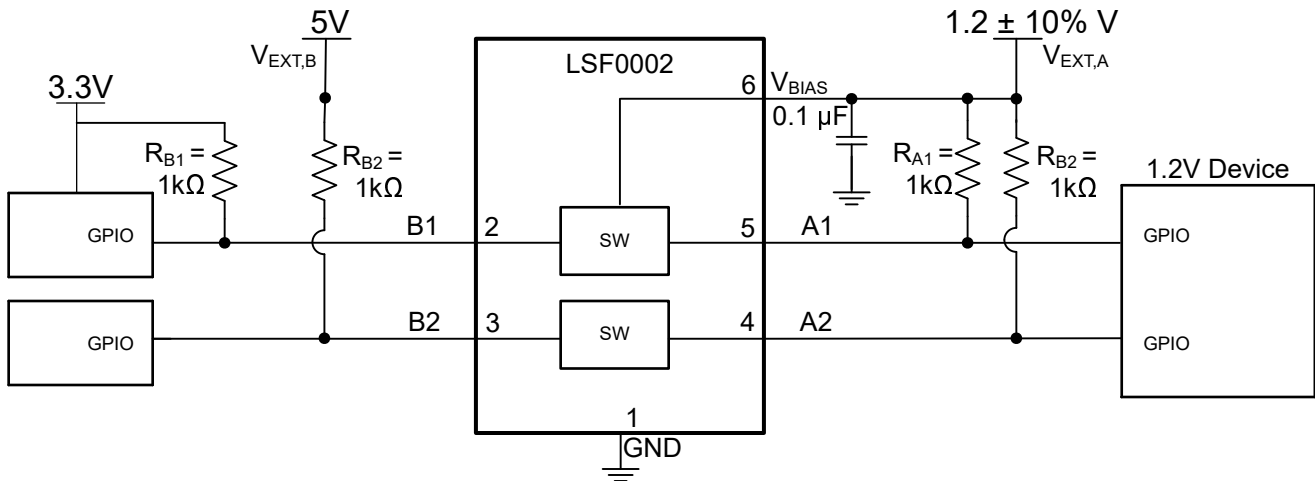


Figure 8-3. Multi-Voltage Translation Example with the LSF Translators

### 8.2.3 Voltage Translation for $V_{ref\_B} < V_{ref\_A} + 0.8V$

As described in the *Enable and Disable Guidelines* section, it is generally recommended that  $V_{EXT,B} > V_{EXT,A} + 0.8V$ ; however, the device can still operate in the condition where  $V_{EXT,B} < V_{EXT,A} + 0.8V$  as long as additional considerations are made for the design.

**Typical Operation ( $V_{EXT,B} > V_{EXT,A} + 0.8V$ ):** in this scenario, pullup resistors are not required on the A-side for proper down-translation. When down translating from B to A, the A-side I/O ports will clamp at  $V_{EXT,A}$  to provide proper voltage translation. For further explanation of device operation, see the [Down Translation with the LSF Family](#) video.

**Requirements for  $V_{EXT,B} < V_{EXT,A} + 0.8V$  Operation:** in this scenario, there is not a large enough voltage difference between  $V_{EXT,A}$  and  $V_{EXT,B}$  so that the A side I/O ports will be clamped at  $V_{EXT,A}$ , but rather at a voltage approximately equal to  $V_{EXT,B} - 0.8V$ . For example, if  $V_{EXT,B} = 1.8V$  and  $V_{EXT,A} = 1.2V$ , the A-side I/Os will clamp to a voltage around 1.0V. Therefore, to operate in such a condition, the following additional design considerations must be met:

- $V_{EXT,B}$  must be greater than  $V_{EXT,A}$  during operation ( $V_{EXT,B} > V_{EXT,A}$ )
- Pullup resistors should be populated on A-side I/O ports for the line to be fully pulled up to the desired voltage.

Figure 8-4 shows an example of this setup, where 1.2V ↔ 1.8V translation is achieved with the LSF0002. This type of setup also applies for other voltage nodes such as 1.8V ↔ 2.5V, 1.05V ↔ 1.5V, and others as long as the [Recommended Operating Conditions](#) table is followed.

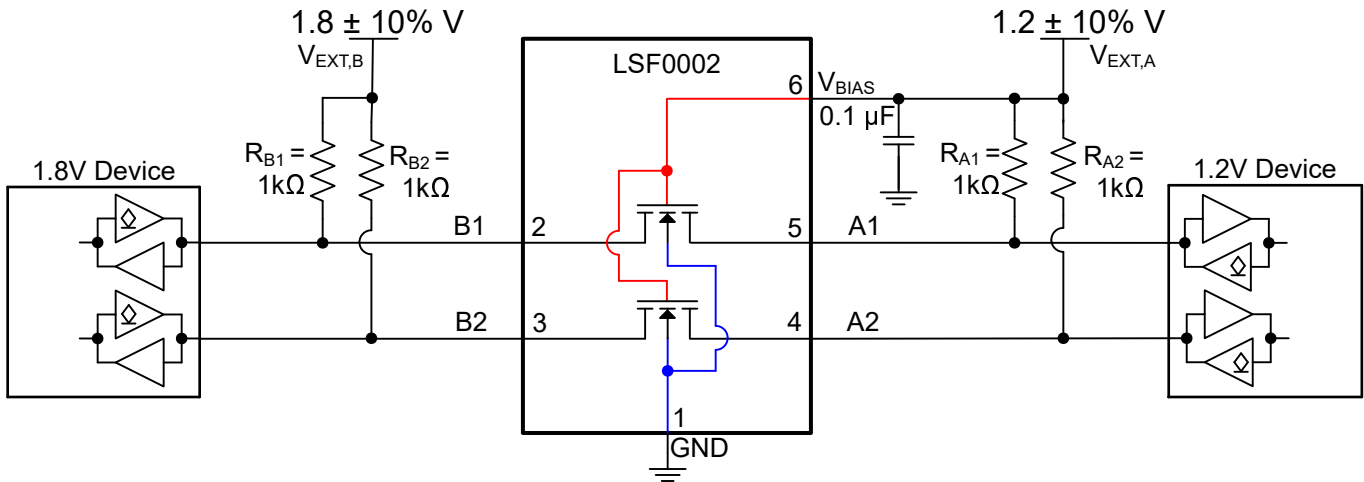


Figure 8-4. 1.2V to 1.8V Level Translation with LSF0002

### 8.3 Power Supply Recommendations

There are no power sequence requirements for the LSF family. Table 8-5 provides recommended operating voltages for all supply and input pins.

Table 8-5. Recommended Operating Voltages

PARAMETER		MIN	TYP	MAX	UNIT
$V_{EXT,A}$ <sup>(1)</sup>	reference voltage (A)	0.9		5.5	V
$V_{EXT,B}$	reference voltage (B)	$V_{EXT,A} + 0.8$		5.5	V
$V_{BIAS}$	input voltage on EN pin	$V_{EXT,A}$		$V_{EXT,A} + 0.8$	V
$V_{PU}$	pull-up supply voltage	0		$V_{EXT,B}$	V

(1)  $V_{EXT,A}$  is required to be the lowest voltage level across all inputs and outputs.

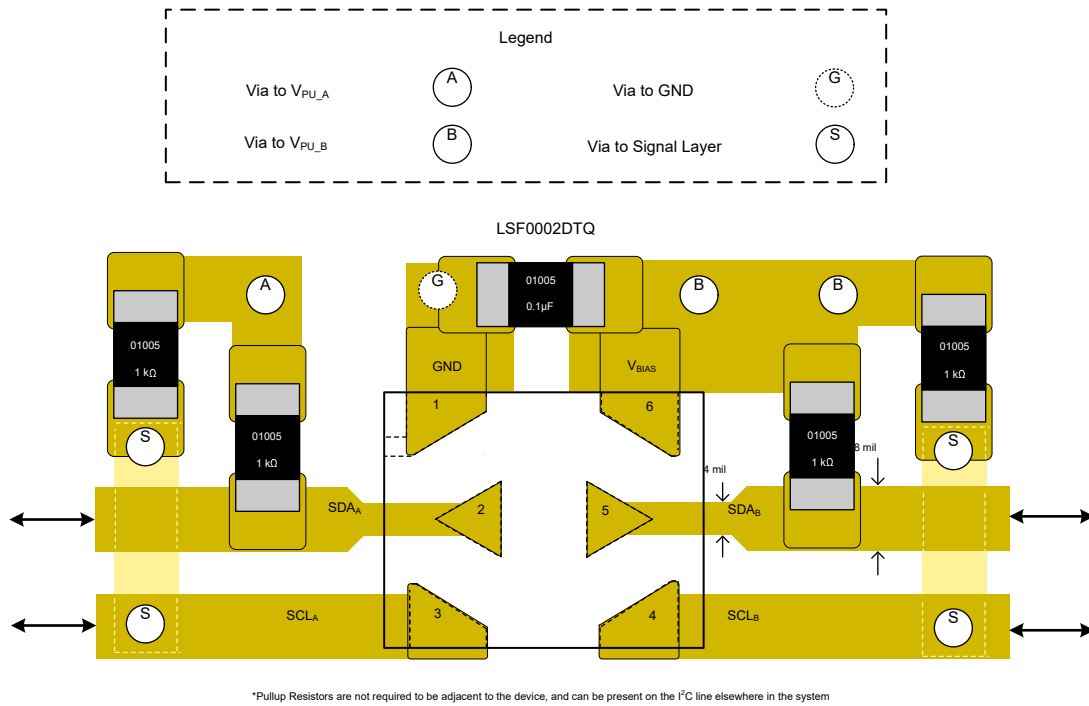
### 8.4 Layout

#### 8.4.1 Layout Guidelines

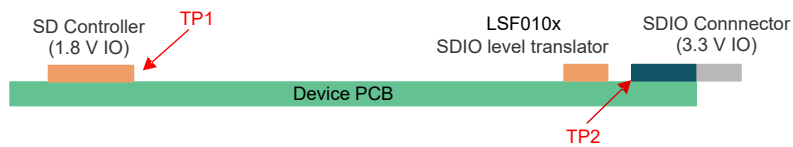
Because the LSF family is a switch-type level translator, the signal integrity is highly related with a pull-up resistor and PCB capacitance condition. Therefore, do as follows:

- Short the signal trace as short as possible to reduce capacitance and minimize stub from the pull-up resistor.
- Place the LSF device as close to the high voltage side as possible.
- Select the appropriate pull-up resistor that applies to translation levels and the driving capability of the transmitter.

### 8.4.2 Layout Example



**Figure 8-5. Short Trace Layout**



**Figure 8-6. Device Placement**



## 9 Device and Documentation Support

### 9.1 Related Documentation

For related documentation, see the following:

- Texas Instruments, [LSF Translator Family Evaluation Module user's guide](#)
- Texas Instruments, [Biasing Requirements for TXS, TXB, and LSF Auto-Bidirectional Translators application note](#)
- Texas Instruments, [Voltage Level Translation with the LSF Family application note](#)
- The Logic Minute Video Training Series on Understanding the LSF Family of Devices:
  - Texas Instruments, [Introduction - Voltage Level Translation with the LSF Family](#)
  - Texas Instruments, [Understanding the Bias Circuit for the LSF Family](#)
  - Texas Instruments, [Using the Enable Pin with the LSF Family](#)
  - Texas Instruments, [Translation Basics with the LSF Family](#)
  - Texas Instruments, [Down Translation with the LSF Family](#)
  - Texas Instruments, [Up Translation with the LSF Family](#)
  - Texas Instruments, [Multi-Voltage Translation with the LSF Family](#)
  - Texas Instruments, [Single Supply Translation with the LSF Family](#)

### 9.2 Receiving Notification of Documentation Updates

To receive notification of documentation updates, navigate to the device product folder on [ti.com](https://www.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.

### 9.3 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.

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### 9.5 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.

### 9.6 Glossary

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

## 10 Revision History

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

<b>Changes from Revision * (April 2024) to Revision A (September 2025)</b>	<b>Page</b>
• Updated <i>Features</i> to include switch configuration.....	1
• Updated <i>Guaranteed by simulation</i> to <i>Specified by simulation</i> in table notes for all Switching Characteristics tables.....	6
• Updated <a href="#">Figure 8-1</a> .....	11
• Added <a href="#">Table 8-3</a> .....	12
• Updated <a href="#">Figure 8-3</a> .....	13
• Updated <a href="#">Figure 8-4</a> .....	14

DATE	REVISION	NOTES
April 2024	*	Initial Release

## 11 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)
<a href="#">LSF0002DTQR</a>	Active	Production	X2SON (DTQ)   6	12000   LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	J
LSF0002DTQR.A	Active	Production	X2SON (DTQ)   6	12000   LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	J

(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.

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**TAPE AND REEL INFORMATION**

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

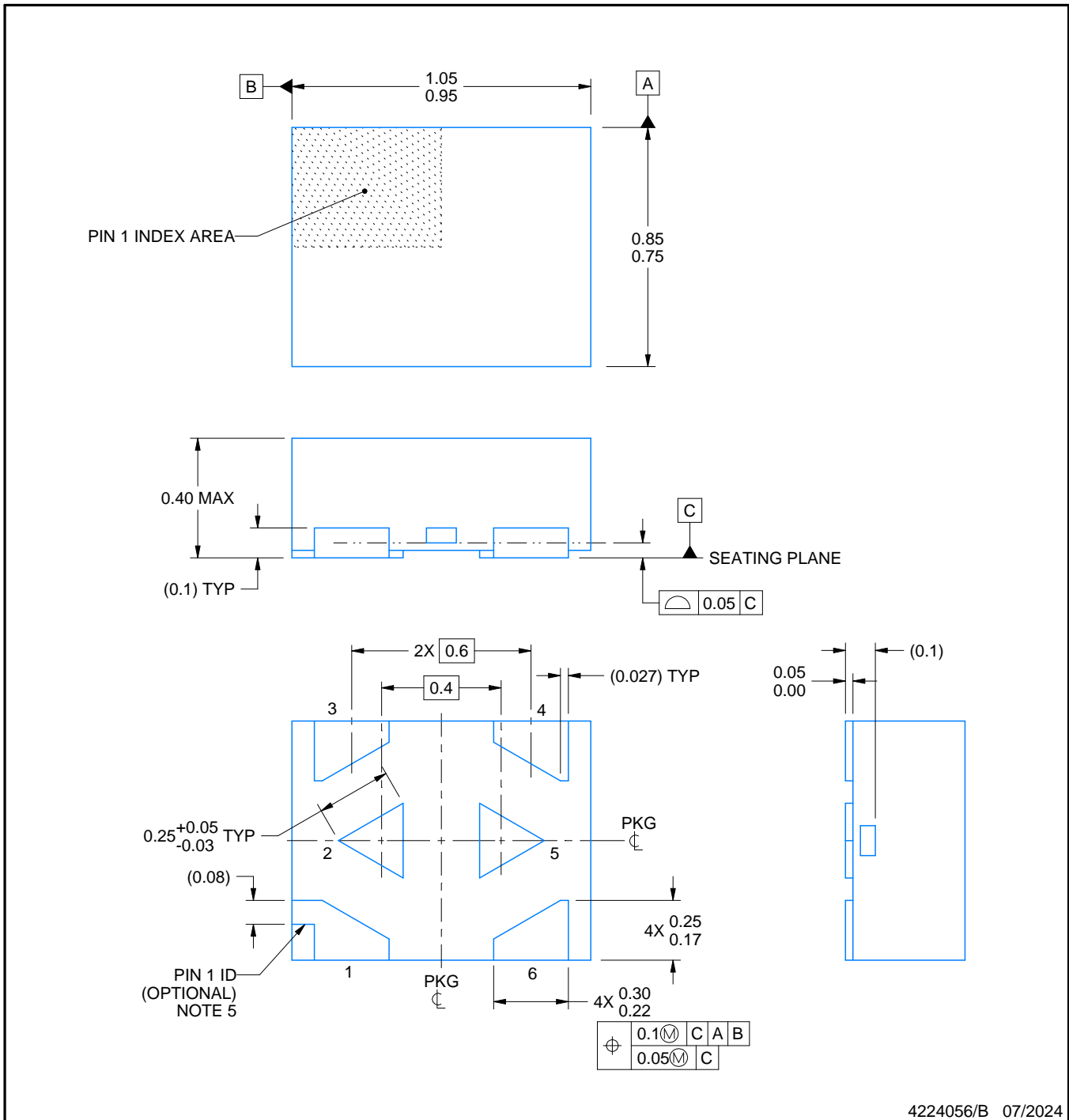

\*All dimensions are nominal

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
LSF0002DTQR	X2SON	DTQ	6	12000	180.0	8.4	0.92	1.12	0.47	2.0	8.1	Q2

**TAPE AND REEL BOX DIMENSIONS**


\*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
LSF0002DTQR	X2SON	DTQ	6	12000	182.0	182.0	20.0



NOTES:

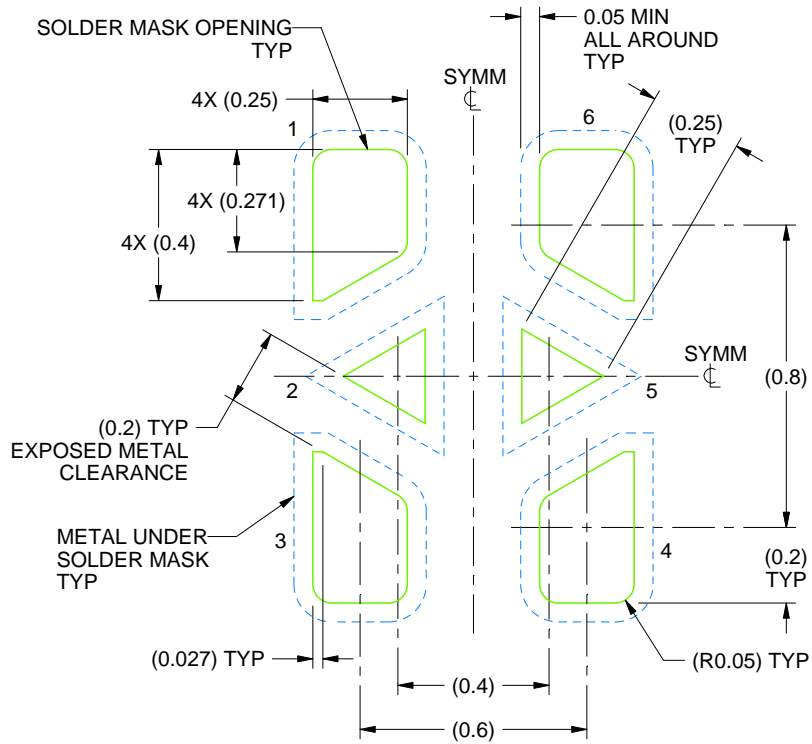
1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. The package thermal pads must be soldered to the printed circuit board for optimal thermal and mechanical performance.
4. The size and shape of this feature may vary.
5. Features may not exist. Recommend use of pin 1 marking on top of package for orientation purposes.

# EXAMPLE BOARD LAYOUT

DTQ0006A

X2SON - 0.4 mm max height

PLASTIC SMALL OUTLINE - NO LEAD



LAND PATTERN EXAMPLE  
SOLDER MASK DEFINED  
SCALE:50X

4224056/B 07/2024

NOTES: (continued)

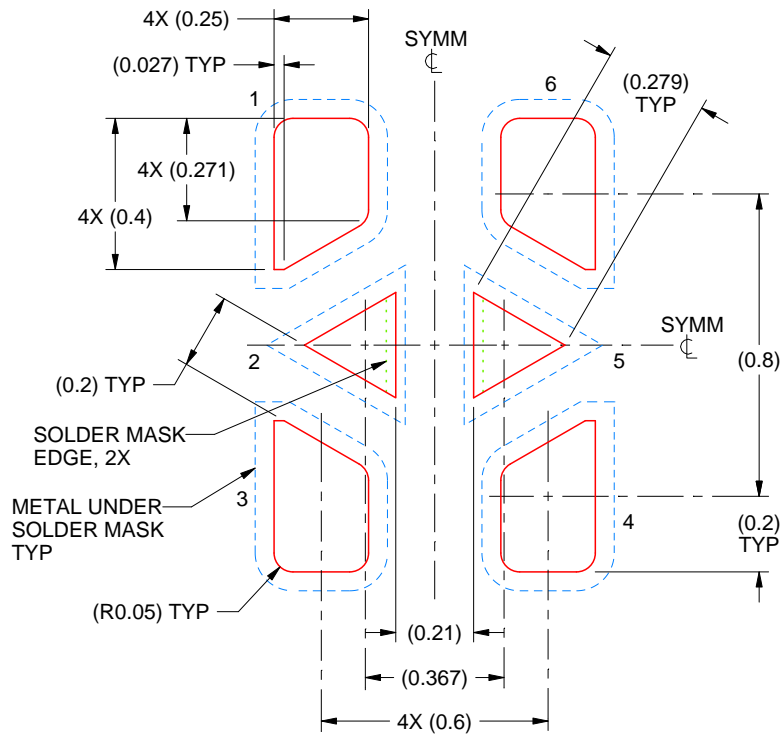
6. This package is designed to be soldered to a thermal pads on the board. For more information, see Texas Instruments literature number SLUA271 ([www.ti.com/lit/slua271](http://www.ti.com/lit/slua271)).
7. Vias are optional depending on application, refer to device data sheet. If some or all are implemented, recommended via locations are shown.

# EXAMPLE STENCIL DESIGN

DTQ0006A

X2SON - 0.4 mm max height

PLASTIC SMALL OUTLINE - NO LEAD



SOLDER PASTE EXAMPLE  
BASED ON 0.07 mm THICK STENCIL

PRINTED SOLDER COVERAGE BY AREA UNDER PACKAGE  
SCALE:50X

4224056/B 07/2024

NOTES: (continued)

8. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.



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