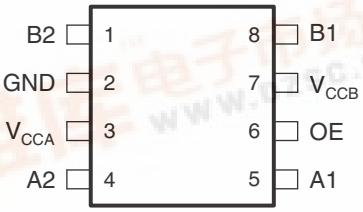
TXS0102
2-BIT BIDIRECTIONAL VOLTAGE-LEVEL TRANSLATOR FOR OPEN-DRAIN APPLICATIONS

SCES640 – JANUARY 2007

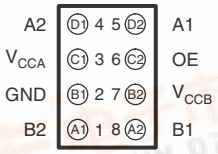
FEATURES

- **Available in the Texas Instruments NanoStar™ and NanoFree™ Packages**
- **1.65 V to 3.6 V on A port and 2.3 V to 5.5 V on B port ($V_{CCA} \leq V_{CCB}$)**
- **V_{CC} Isolation Feature – If Either V_{CC} Input Is at GND, Both Ports Are in the High-Impedance State**
- **I_{off} Supports Partial-Power-Down Mode Operation**
- **Latch-Up Performance Exceeds 100 mA Per JESD 78, Class II**
- **ESD Protection Exceeds JESD 22**
  - **A Port**
    - **2500-V Human-Body Model (A114-B)**
    - **250-V Machine Model (A115-A)**
    - **1500-V Charged-Device Model (C101)**
  - **B Port**
    - **8-kV Human-Body Model (A114-B)**
    - **250-V Machine Model (A115-A)**
    - **1500-V Charged-Device Model (C101)**

DCT OR DCU PACKAGE
(TOP VIEW)



YZP PACKAGE
(BOTTOM VIEW)



DESCRIPTION/ORDERING INFORMATION

This two-bit noninverting translator uses two separate configurable power-supply rails. The A port is designed to track V_{CCA}. V_{CCA} accepts any supply voltage from 1.65 V to 3.6 V. The B port is designed to track V_{CCB}. V_{CCA} must be less than or equal to V_{CCB}. V_{CCB} accepts any supply voltage from 2.3 V to 5.5 V. This allows for low-voltage bidirectional translation between any of the 1.8-V, 2.5-V, 3.3-V, and 5-V voltage nodes.

When the output-enable (OE) input is low, all outputs are placed in the high-impedance state.

To ensure the high-impedance state during power up or power down, OE should be tied to GND through a pulldown resistor; the minimum value of the resistor is determined by the current-sourcing capability of the driver.

ORDERING INFORMATION

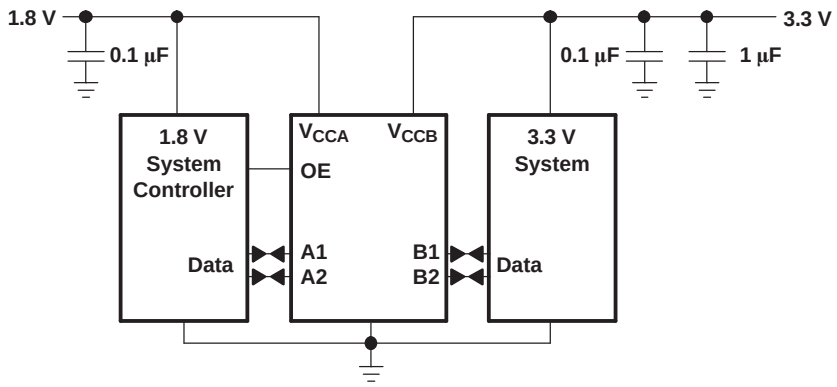
T_A	PACKAGE(1)		ORDERABLE PART NUMBER	TOP-SIDE MARKING(2)
–40°C to 85°C	NanoStar™ – WCSP (DSBGA) 0.23-mm Large Bump – YZP	Reel of 3000	TXS0102YZPR	
	SSOP – DCT	Reel of 3000	TXS0102DCTR	NFEZ_ _ _
		Tube of 250	TXS0102DCTT	NFEZ _ _ _
	VSSOP – DCU	Reel of 3000	TXS0102DCUR	_ _ NFE

(1) Package drawings, standard packing quantities, thermal data, symbolization, and PCB design guidelines are available at www.ti.com/sc/package.
(2) DCT: The actual top-side marking has three additional characters that designate the year, month, and assembly/test site.
DCU: The actual top-side marking has one additional character that designates the assembly/test site.
YZP: The actual top-side marking has three preceding characters to denote year, month, and sequence code, and one following character to designate the assembly/test site. Pin 1 identifier indicates solder-bump composition (1 = SnPb, • = Pb-free).

PIN DESCRIPTION (DCT AND DCU PACKAGES)

NO.	NAME	FUNCTION
1	B2	Input/output B. Referenced to V_{CCB}.
2	GND	Ground
3	V_{CCA}	A-port supply voltage. 1.65 V ≤ V_{CCA} ≤ 3.6 V and V_{CCA} ≤ V_{CCB}
4	A2	Input/output A. Referenced to V_{CCA}.
5	A1	Input/output A. Referenced to V_{CCA}.
6	OE	3-state output mode enable. Pull OE low to place all outputs in 3-state mode. Referenced to V_{CCA}.
7	V_{CCB}	B-port supply voltage. 2.3 V ≤ V_{CCB} ≤ 5.5 V
8	B1	Input/output B. Referenced to V_{CCB}.

TYPICAL OPERATING CIRCUIT



Absolute Maximum Ratings(1)

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

			MIN	MAX	UNIT
V_{CCA}	Supply voltage range		–0.5	4.6	V
V_{CCB}	Supply voltage range		–0.5	6.5	V
V_I	Input voltage range(2)	A port	–0.5	4.6	V
		B port	–0.5	6.5	
V_O	Voltage range applied to any output in the high-impedance or power-off state(2)	A port	–0.5	4.6	V
		B port	–0.5	6.5	
V_O	Voltage range applied to any output in the high or low state(2)(3)	A port	–0.5	V_{CCA} + 0.5	V
		B port	–0.5	V_{CCB} + 0.5	
I_{IK}	Input clamp current	V_I < 0		–50	mA
I_{OK}	Output clamp current	V_O < 0		–50	mA
I_O	Continuous output current			±50	mA
	Continuous current through V_{CCA}, V_{CCB}, or GND			±100	mA
θ_{JA}	Package thermal impedance(4)	DCT package		220	°C/W
		DCU package		227	
		YZP package		102	
T_{stg}	Storage temperature range		–65	150	°C

(1) Stresses beyond those listed under "absolute maximum ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under "recommended operating conditions" is not implied. 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 current ratings are observed.
(3) The value of V_{CCA} and V_{CCB} are provided in the recommended operating conditions table.
(4) The package thermal impedance is calculated in accordance with JESD 51-7.

Recommended Operating Conditions[1][2]

			V_{CCA}	V_{CCB}	MIN	MAX	UNIT
V_{CCA}	Supply voltage[3]				1.65	3.6	V
V_{CCB}					2.3	5.5	
V_{IH}	High-level input voltage	A-port I/Os	1.65 V to 1.95 V	2.3 V to 5.5 V	V_{CCI} – 0.2	V_{CCI}	V
			2.3 V to 3.6 V		V_{CCI} – 0.4	V_{CCI}	
		B-port I/Os	1.65 V to 3.6 V	2.3 V to 5.5 V	V_{CCI} – 0.4	V_{CCI}	
		OE input			$V_{CCA} \times 0.65$	5.5	
V_{IL}	Low-level input voltage	A-port I/Os	1.65 V to 3.6 V	2.3 V to 5.5 V	0	0.15	V
		B-port I/Os			0	0.15	
		OE input			0	$V_{CCA} \times 0.35$	
$\Delta t/\Delta v$	Input transition rise or fall rate	A-port I/Os, push-pull driving	1.65 V to 3.6 V	2.3 V to 5.5 V		10	ns/V
		B-port I/Os, push-pull driving				10	
		Control input				10	
T_A	Operating free-air temperature				–40	85	°C

(1) V_{CCI} is the supply voltage associated with the input port.
(2) V_{CCO} is the supply voltage associated with the output port.
(3) V_{CCA} must be less than or equal to V_{CCB}, and V_{CCA} must not exceed 3.6 V.

Electrical Characteristics[1][2][3]

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

PARAMETER		TEST CONDITIONS	V_{CCA}	V_{CCB}	T_A = 25°C			–40°C to 85°C		UNIT
					MIN	TYP	MAX	MIN	MAX	
V_{OHA}		I_{OH} = –20 µA, $V_{IB} \geq V_{CCB}$ – 0.4 V	1.65 V to 3.6 V	2.3 V to 5.5 V				$V_{CCA} \times 0.67$		V
V_{OLA}		I_{OL} = 1 mA, $V_{IB} \leq$ 0.15 V	1.65 V to 3.6 V	2.3 V to 5.5 V					0.4	V
V_{OHB}		I_{OH} = –20 µA, $V_{IA} \geq V_{CCA}$ – 0.2 V	1.65 V to 3.6 V	2.3 V to 5.5 V				$V_{CCB} \times 0.67$		V
V_{OLB}		I_{OL} = 1 mA, $V_{IA} \leq$ 0.15 V	1.65 V to 3.6 V	2.3 V to 5.5 V					0.4	V
I_I	OE		1.65 V to 5.5 V	1.65 V to 5.5 V			±1		±2	µA
I_{off}	A port		0 V	0 to 5.5 V			±1		±2	µA
	B port		0 to 3.6 V	0 V			±1		±2	µA
I_{OZ}	A or B port		1.65 V to 5.5 V	2.3 V to 5.5 V			±1		±2	µA
I_{CCA}		$V_I = V_O$ = open, I_O = 0	1.65 V to V_{CCB}	2.3 V to 5.5 V					2.4	µA
			3.6 V	0 V					2.2	
			0 V	5.5 V					–1	
I_{CCB}		$V_I = V_O$ = open, I_O = 0	1.65 V to V_{CCB}	2.3 V to 5.5 V					12	µA
			3.6 V	0 V					–1	
			0 V	5.5 V					1	
$I_{CCA} + I_{CCB}$		$V_I = V_{CCI}$ or GND, I_O = 0	1.65 V to V_{CCB}	2.3 V to 5.5 V					14.4	µA
C_I	OE		3.3 V	3.3 V		2.5			3.5	pF
C_{io}	A or B port		3.3 V	3.3 V		10				pF
	A port					5		6		
	B port					6		7.5		

(1) V_{CCI} is the V_{CC} associated with the input port.
(2) V_{CCO} is the V_{CC} associated with the output port.
(3) V_{CCA} must be less than or equal to V_{CCB}, and V_{CCA} must not exceed 3.6 V.

Timing Requirements

over recommended operating free-air temperature range, V_{CCA} = 1.8 V ± 0.15 V (unless otherwise noted)

				V_{CCB} = 2.5 V ± 0.2 V		V_{CC} = 3.3 V ± 0.3 V		V_{CC} = 5 V ± 0.5 V		UNIT
				MIN	MAX	MIN	MAX	MIN	MAX	
Data rate		Push-pull driving			21		22		24	Mbps
		Open-drain driving			1		1		1	
t_w	Pulse duration	Push-pull driving	Data inputs	47		45		41		ns
		Open-drain driving		500		500		500		

Timing Requirements

over recommended operating free-air temperature range, V_{CCA} = 2.5 V ± 0.2 V (unless otherwise noted)

				V_{CCB} = 2.5 V ± 0.2 V		V_{CC} = 3.3 V ± 0.3 V		V_{CC} = 5 V ± 0.5 V		UNIT
				MIN	MAX	MIN	MAX	MIN	MAX	
Data rate		Push-pull driving			20		22		24	Mbps
		Open-drain driving			1		1		1	
t_w	Pulse duration	Push-pull driving	Data inputs	50		45		41		ns
		Open-drain driving		500		500		500		

Timing Requirements

over recommended operating free-air temperature range, V_{CCA} = 3 V ± 0.3 V (unless otherwise noted)

			V_{CC} = 3.3 V ± 0.3 V		V_{CC} = 5 V ± 0.5 V		UNIT
			MIN	MAX	MIN	MAX	
Data rate	Push-pull driving			23		24	Mbps
	Open-drain driving			1		1	
t_w Pulse duration	Push-pull driving	Data inputs	43		41		ns
	Open-drain driving		500		500		

Switching Characteristics

over recommended operating free-air temperature range, V_{CCA} = 1.8 V ± 0.15 V (unless otherwise noted)

PARAMETER	FROM (INPUT)	TO (OUTPUT)	TEST CONDITIONS	V_{CCB} = 2.5 V ± 0.2 V		V_{CCB} = 3.3 V ± 0.3 V		V_{CCB} = 5 V ± 0.5 V		UNIT
				MIN	MAX	MIN	MAX	MIN	MAX	
t_{PHL}	A	B	Push-pull driving		5.3		5.4		6.8	ns
			Open-drain driving	2.3	8.8	2.4	9.6	2.6	10	
t_{PLH}			Push-pull driving		6.8		7.1		7.5	
			Open-drain driving	45	260	36	208	27	198	
t_{PHL}	B	A	Push-pull driving		4.4		4.5		4.7	ns
			Open-drain driving	1.9	5.3	1.1	4.4	1.2	4	
t_{PLH}			Push-pull driving		5.3		4.5		0.5	
			Open-drain driving	45	175	36	140	27	102	
t_{en}	OE	A or B			200		200		200	ns
t_{dis}	OE	A or B			50		40		35	ns
t_{rA}	A-port rise time		Push-pull driving	3.2	9.5	2.3	9.3	2	7.6	ns
			Open-drain driving	38	165	30	132	22	95	
t_{rB}	B-port rise time		Push-pull driving	4	10.8	2.7	9.1	2.7	7.6	ns
			Open-drain driving	34	145	23	106	10	58	
t_{fA}	A-port fall time		Push-pull driving	2	5.9	1.9	6	1.7	13.3	ns
			Open-drain driving	4.4	6.9	4.3	6.4	4.2	6.1	
t_{fB}	B-port fall time		Push-pull driving	2.9	13.8	2.8	16.2	2.8	16.2	
			Open-drain driving	6.9	13.8	7.5	16.2	7	16.2	
$t_{SK(O)}$	Channel-to-channel skew				0.7		0.7		0.7	ns
Max data rate			Push-pull driving	21		22		24		Mbps
			Open-drain driving	1		1		1		

Switching Characteristics

over recommended operating free-air temperature range, V_{CCA} = 2.5 V ± 0.2 V (unless otherwise noted)

PARAMETER	FROM (INPUT)	TO (OUTPUT)	TEST CONDITIONS	V_{CCB} = 2.5 V ± 0.2 V		V_{CCB} = 3.3 V ± 0.3 V		V_{CCB} = 5 V ± 0.5 V		UNIT
				MIN	MAX	MIN	MAX	MIN	MAX	
t_{PHL}	A	B	Push-pull driving		3.2		3.7		3.8	ns
			Open-drain driving	1.7	6.3	2	6	2.1	5.8	
t_{PLH}			Push-pull driving		3.5		4.1		4.4	
			Open-drain driving	43	250	36	206	27	190	
t_{PHL}	B	A	Push-pull driving		3		3.6		4.3	ns
			Open-drain driving	1.8	4.7	2.6	4.2	1.2	4	
t_{PLH}			Push-pull driving		2.5		1.6		1	
			Open-drain driving	44	170	37	140	27	103	
t_{en}	OE	A or B			200		200		200	ns
t_{dis}	OE	A or B			50		40		35	ns
t_{rA}	A-port rise time		Push-pull driving	2.8	7.4	2.6	6.6	1.8	5.6	ns
			Open-drain driving	34	149	28	121	24	89	
t_{rB}	B-port rise time		Push-pull driving	3.2	8.3	2.9	7.2	2.4	6.1	ns
			Open-drain driving	35	151	24	112	12	64	
t_{fA}	A-port fall time		Push-pull driving	1.9	5.7	1.9	5.5	1.8	5.3	ns
			Open-drain driving	4.4	6.9	4.3	6.2	4.2	5.8	
t_{fB}	B-port fall time		Push-pull driving	2.2	7.8	2.4	6.7	2.6	6.6	ns
			Open-drain driving	5.1	8.8	5.4	9.4	5.4	10.4	
$t_{SK(O)}$	Channel-to-channel skew				0.7		0.7		0.7	ns
Max data rate			Push-pull driving	20		22		24		Mbps
			Open-drain driving	1		1		1		

Switching Characteristics

over recommended operating free-air temperature range, V_{CCA} = 3.3 V ± 0.3 V (unless otherwise noted)

PARAMETER	FROM (INPUT)	TO (OUTPUT)	TEST CONDITIONS	V_{CCB} = 3.3 V ± 0.3 V		V_{CCB} = 5 V ± 0.5 V		UNIT
				MIN	MAX	MIN	MAX	
t_{PHL}	A	B	Push-pull driving		2.4		3.1	ns
			Open-drain driving	1.3	4.2	1.4	4.6	
t_{PLH}			Push-pull driving		4.2		4.4	
			Open-drain driving	36	204	28	165	
t_{PHL}	B	A	Push-pull driving		2.5		3.3	ns
			Open-drain driving	1	124	1	97	
t_{PLH}			Push-pull driving		2.5		2.6	
			Open-drain driving	3	139	3	105	
t_{en}	OE	A or B			200		200	ns
t_{dis}	OE	A or B			40		35	ns
t_{rA}	A-port rise time		Push-pull driving	2.3	5.6	1.9	4.8	ns
			Open-drain driving	25	116	19	85	
t_{rB}	B-port rise time		Push-pull driving	2.5	6.4	2.1	7.4	ns
			Open-drain driving	26	116	14	72	
t_{fA}	A-port fall time		Push-pull driving	2	5.4	1.9	5	ns
			Open-drain driving	4.3	6.1	4.2	5.7	
t_{fB}	B-port fall time		Push-pull driving	2.3	7.4	2.4	7.6	ns
			Open-drain driving	5	7.6	4.8	8.3	
$t_{SK(O)}$	Channel-to-channel skew				0.7		0.7	ns
Max data rate			Push-pull driving	23		24		Mbps
			Open-drain driving	1		1		

PRINCIPLES OF OPERATION

Applications

The TXS0102 can be used in level-translation applications for interfacing devices or systems operating at different interface voltages with one another. The TXS0102 is ideal for use in applications where an open-drain driver is connected to the data I/Os. The TXS0102 can also be used in applications where a push-pull driver is connected to the data I/Os, but the TXB0102 might be a better option for such push-pull applications.

Architecture

The TXS0102 architecture (see Figure 1) does not require a direction-control signal to control the direction of data flow from A to B or from B to A.

PRINCIPLES OF OPERATION (continued)

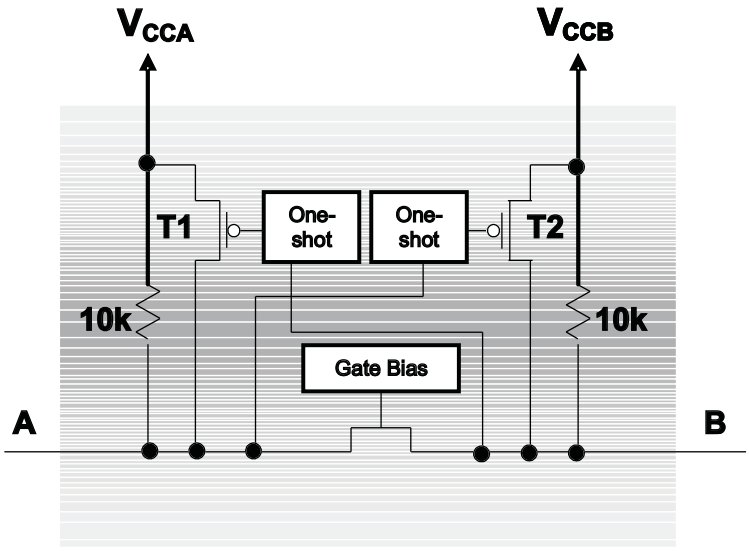


Figure 1. Architecture of a TXS01xx Cell

Each A-port I/O has an internal 10-kΩ pullup resistor to V_{CCA}, and each B-port I/O has an internal 10-kΩ pullup resistor to V_{CCB}. The output one-shots detect rising edges on the A or B ports. During a rising edge, the one-shot turns on the PMOS transistors (T1,T2) for a short duration, which speeds up the low-to-high transition.

Input Driver Requirements

The fall time (t_{fA}, t_{fB}) of a signal depends on the output impedance of the external device driving the data I/Os of the TXS0102. Similarly, the t_{PHL} and max data rates also depend on the output impedance of the external driver. The values for t_{fA}, t_{fB}, t_{PHL}, and maximum data rates in the data sheet assume that the output impedance of the external driver is less than 50 Ω.

Power Up

During operation, ensure that $V_{CCA} \leq V_{CCB}$ at all times. During power-up sequencing, $V_{CCA} \geq V_{CCB}$ does not damage the device, so any power supply can be ramped up first.

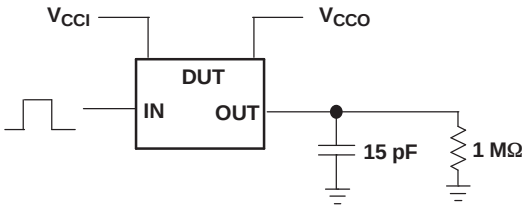
Enable and Disable

The TXS0102 has an OE input that is used to disable the device by setting OE low, which places all I/Os in the Hi-Z state. The disable time (t_{dis}) indicates the delay between the time when OE goes low and when the outputs actually get disabled (Hi-Z). The enable time (t_{en}) indicates the amount of time the user must allow for the one-shot circuitry to become operational after OE is taken high.

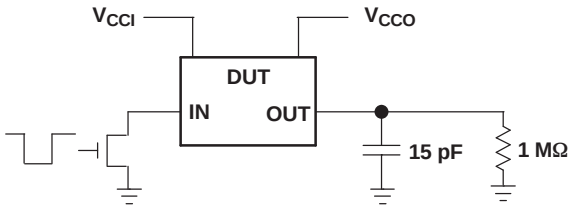
Pullup or Pulldown Resistors on I/O Lines

Each A-port I/O has an internal 10-kΩ pullup resistor to V_{CCA}, and each B-port I/O has an internal 10-kΩ pullup resistor to V_{CCB}. If a smaller value of pullup resistor is required, an external resistor must be added from the I/O to V_{CCA} or V_{CCB} (in parallel with the internal 10-kΩ resistors).

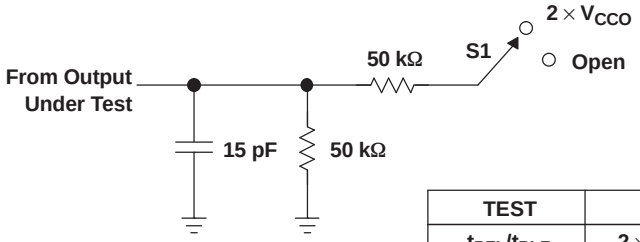
PARAMETER MEASUREMENT INFORMATION



DATA RATE, PULSE DURATION, PROPAGATION DELAY, OUTPUT RISE AND FALL TIME MEASUREMENT USING A PUSH-PULL DRIVER

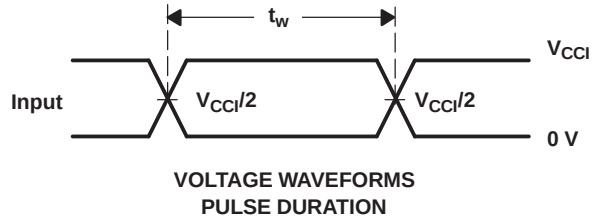


DATA RATE, PULSE DURATION, PROPAGATION DELAY, OUTPUT RISE AND FALL TIME MEASUREMENT USING AN OPEN-DRAIN DRIVER

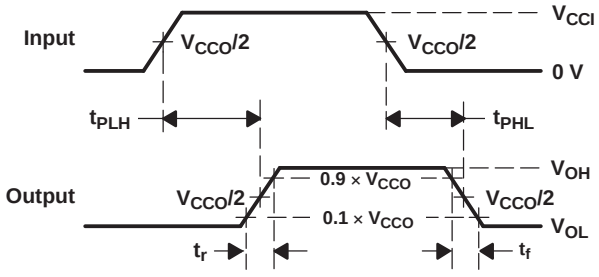


LOAD CIRCUIT FOR ENABLE/DISABLE TIME MEASUREMENT

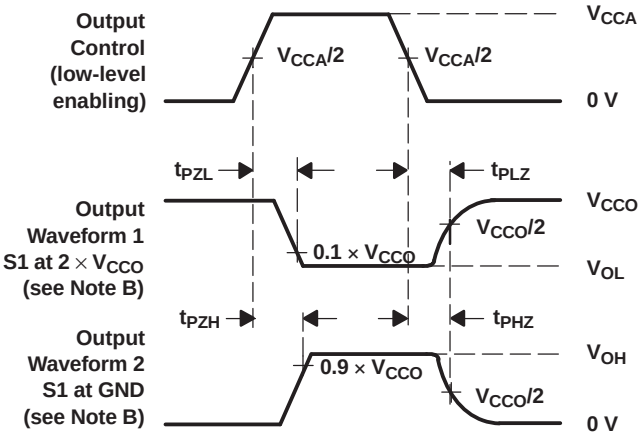
TEST	S1
t_{PZL}/t_{PLZ} t_{PHZ}/t_{PZH}	$2 \times V_{CCO}$ Open



VOLTAGE WAVEFORMS PULSE DURATION



VOLTAGE WAVEFORMS PROPAGATION DELAY TIMES



VOLTAGE WAVEFORMS ENABLE AND DISABLE TIMES

NOTES:
A. C_L includes probe and jig capacitance.
B. 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.
C. All input pulses are supplied by generators having the following characteristics: PRR ≤ 10 MHz, Z_O = 50 Ω, dv/dt ≥ 1 V/ns.
D. The outputs are measured one at a time, with one transition per measurement.
E. t_{PLZ} and t_{PHZ} are the same as t_{dis}.
F. t_{PZL} and t_{PZH} are the same as t_{en}.
G. t_{PLH} and t_{PHL} are the same as t_{pd}.
H. V_{CCI} is the V_{CC} associated with the input port.
I. V_{CCO} is the V_{CC} associated with the output port.
J. All parameters and waveforms are not applicable to all devices.

Figure 2. Load Circuit and Voltage Waveforms

PACKAGE OPTION ADDENDUM

PACKAGING INFORMATION

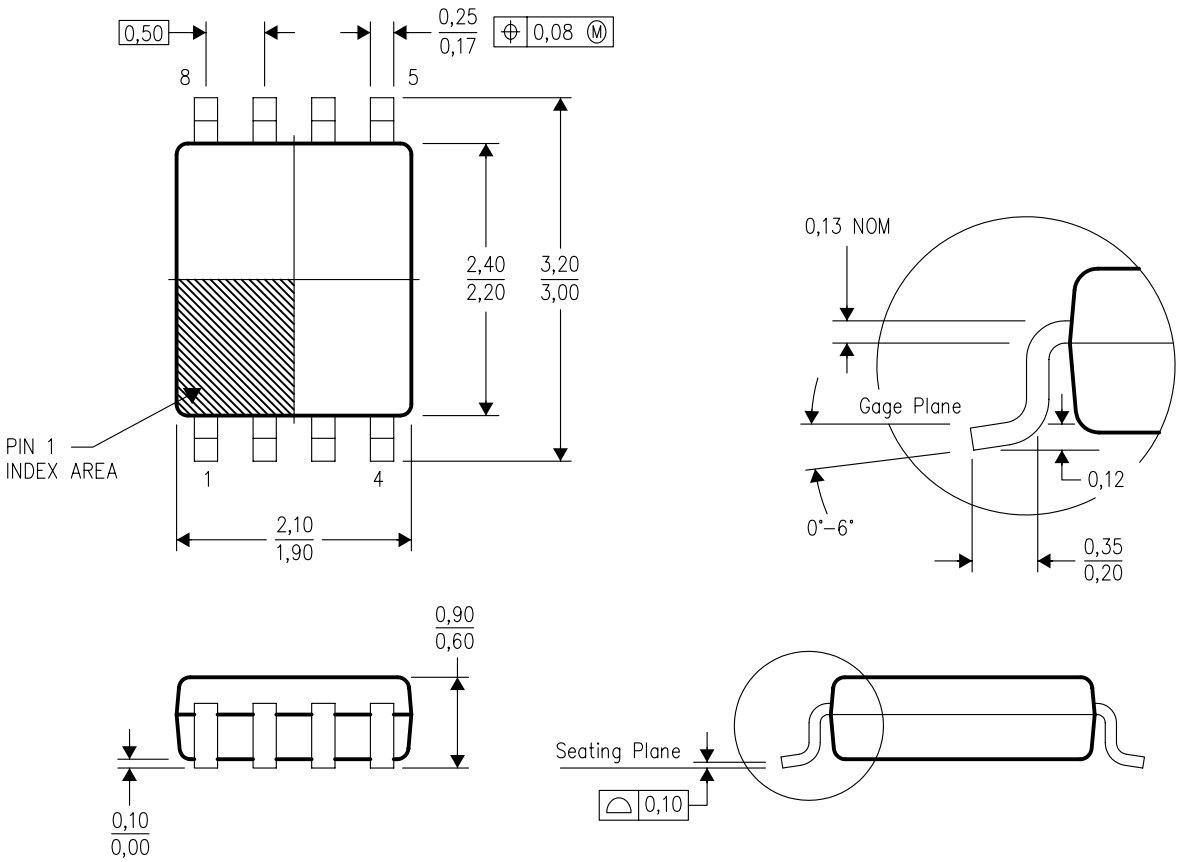
Orderable Device	Status [1]	Package Type	Package Drawing	Pins	Package Qty	Eco Plan [2]	Lead/Ball Finish	MSL Peak Temp [3]
TXS0102DCUR	ACTIVE	US8	DCU	8	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM

[1] The marketing status values are defined as follows:
ACTIVE: Product device recommended for new designs.
LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.
NRND: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.
PREVIEW: Device has been announced but is not in production. Samples may or may not be available.
OBSOLETE: TI has discontinued the production of the device.

[2] Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check http://www.ti.com/productcontent for the latest availability information and additional product content details.
TBD: The Pb-Free/Green conversion plan has not been defined.
Pb-Free (RoHS): TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.
Pb-Free (RoHS Exempt): This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.
Green (RoHS & no Sb/Br): TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

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

DCU (R–PDSO–G8) PLASTIC SMALL–OUTLINE PACKAGE (DIE DOWN)



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NOTES:
A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Body dimensions do not include mold flash or protrusion. Mold flash and protrusion shall not exceed 0.15 per side.
D. Falls within JEDEC MO–187 variation CA.

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