



**THE DATASHEET OF
SN74LVTH646PWR**

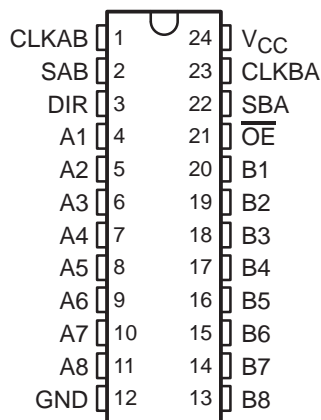


SN54LVTH646, SN74LVTH646 3.3-V ABT OCTAL BUS TRANSCEIVERS AND REGISTERS WITH 3-STATE OUTPUTS

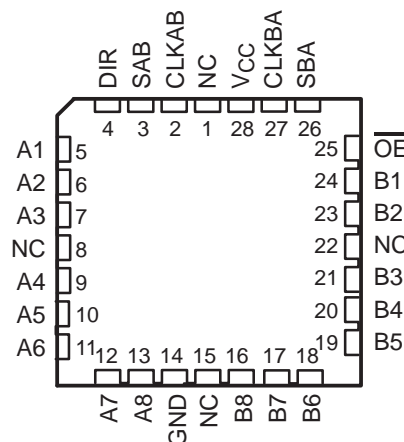
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- Support Mixed-Mode Signal Operation (5-V Input and Output Voltages With 3.3-V V_{CC})
- Support Unregulated Battery Operation Down to 2.7 V
- Typical V_{OLP} (Output Ground Bounce) <0.8 V at $V_{CC} = 3.3$ V, $T_A = 25^\circ\text{C}$
- I_{off} and Power-Up 3-State Support Hot Insertion
- Bus Hold on Data Inputs Eliminates the Need for External Pullup/Pulldown Resistors
- Latch-Up Performance Exceeds 500 mA Per JESD 17
- ESD Protection Exceeds JESD 22
 - 2000-V Human-Body Model (A114-A)
 - 200-V Machine Model (A115-A)

SN54LVTH646 . . . JT OR W PACKAGE
SN74LVTH646 . . . DB, DGV, DW, NS, OR PW PACKAGE
(TOP VIEW)



SN54LVTH646 . . . FK PACKAGE
(TOP VIEW)



NC – No internal connection

description/ordering information

These bus transceivers and registers are designed specifically for low-voltage (3.3-V) V_{CC} operation, but with the capability to provide a TTL interface to a 5-V system environment.

ORDERING INFORMATION

T_A	PACKAGE†	ORDERABLE PART NUMBER	TOP-SIDE MARKING	
–40°C to 85°C	SOIC – DW	Tube	SN74LVTH646DW	
		Tape and reel	SN74LVTH646DWR	
	SOP – NS	Tape and reel	SN74LVTH646NSR	LVTH646
	SSOP – DB	Tape and reel	SN74LVTH646DBR	LXH646
	TSSOP – PW	Tube	SN74LVTH646PW	LXH646
		Tape and reel	SN74LVTH646PWR	
	TVSOP – DGV	Tape and reel	SN74LVTH646DGV	LXH646
–55°C to 125°C	CDIP – JT	Tube	SNJ54LVTH646JT	SNJ54LVTH646JT
	CFP – W	Tube	SNJ54LVTH646W	SNJ54LVTH646W
	LCCC – FK	Tube	SNJ54LVTH646FK	SNJ54LVTH646FK

† Package drawings, standard packing quantities, thermal data, symbolization, and PCB design guidelines are available at www.ti.com/sc/package.



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PRODUCTION DATA information is current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.



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On products compliant to MIL-PRF-38535, all parameters are tested unless otherwise noted. On all other products, production processing does not necessarily include testing of all parameters.

SN54LVTH646, SN74LVTH646

3.3-V ABT OCTAL BUS TRANSCEIVERS AND REGISTERS WITH 3-STATE OUTPUTS

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description/ordering information (continued)

The 'LVTH646 devices consist of bus transceiver circuits, D-type flip-flops, and control circuitry arranged for multiplexed transmission of data directly from the input bus or from the internal registers. Data on the A or B bus is clocked into the registers on the low-to-high transition of the appropriate clock (CLKAB or CLKBA) input. Figure 1 illustrates the four fundamental bus-management functions that can be performed with the 'LVTH646.

Output-enable (\overline{OE}) and direction-control (DIR) inputs are provided to control the transceiver functions. In the transceiver mode, data present at the high-impedance port can be stored in either register or in both.

The select-control (SAB and SBA) inputs can multiplex stored and real-time (transparent mode) data. The direction control (DIR) determines which bus receives data when \overline{OE} is low. In the isolation mode (\overline{OE} high), A data can be stored in one register and/or B data can be stored in the other register.

When an output function is disabled, the input function still is enabled and can be used to store and transmit data. Only one of the two buses, A or B, can be driven at a time.

Active bus-hold circuitry is provided to hold unused or floating data inputs at a valid logic level. Use of pullup or pulldown resistors with the bus-hold circuitry is not recommended.

To ensure the high-impedance state during power up or power down, \overline{OE} should be tied to V_{CC} through a pullup resistor; the minimum value of the resistor is determined by the current-sinking capability of the driver.

These devices are fully specified for hot-insertion applications using I_{off} and power-up 3-state. The I_{off} circuitry disables the outputs, preventing damaging current backflow through the devices when they are powered down. The power-up 3-state circuitry places the outputs in the high-impedance state during power up and power down, which prevents driver conflict.

FUNCTION TABLE

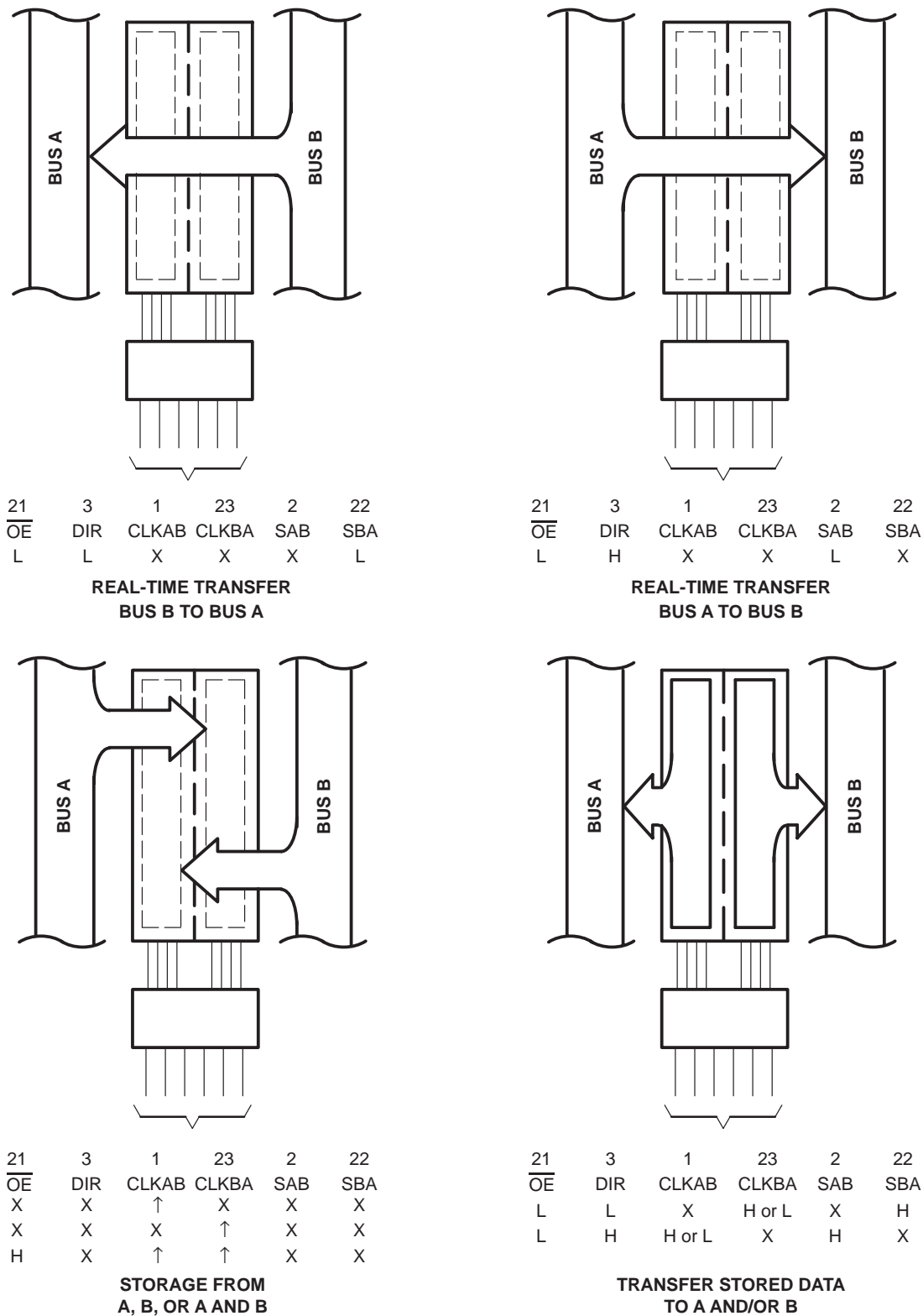
INPUTS						DATA I/Os		OPERATION OR FUNCTION
\overline{OE}	DIR	CLKAB	CLKBA	SAB	SBA	A1–A8	B1–B8	
X	X	↑	X	X	X	Input	Unspecified†	Store A, B unspecified†
X	X	X	↑	X	X	Unspecified†	Input	Store B, A unspecified†
H	X	↑	↑	X	X	Input	Input	Store A and B data
H	X	H or L	H or L	X	X	Input disabled	Input disabled	Isolation, hold storage
L	L	X	X	X	L	Output	Input	Real-time B data to A bus
L	L	X	H or L	X	H	Output	Input	Stored B data to A bus
L	H	X	X	L	X	Input	Output	Real-time A data to B bus
L	H	H or L	X	H	X	Input	Output	Stored A data to B bus

† The data-output functions can be enabled or disabled by various signals at \overline{OE} and DIR. Data-input functions always are enabled; i.e., data at the bus terminals is stored on every low-to-high transition of the clock inputs.



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Pin numbers shown are for the DB, DGV, DW, JT, NS, PW, and W packages.

Figure 1. Bus-Management Functions

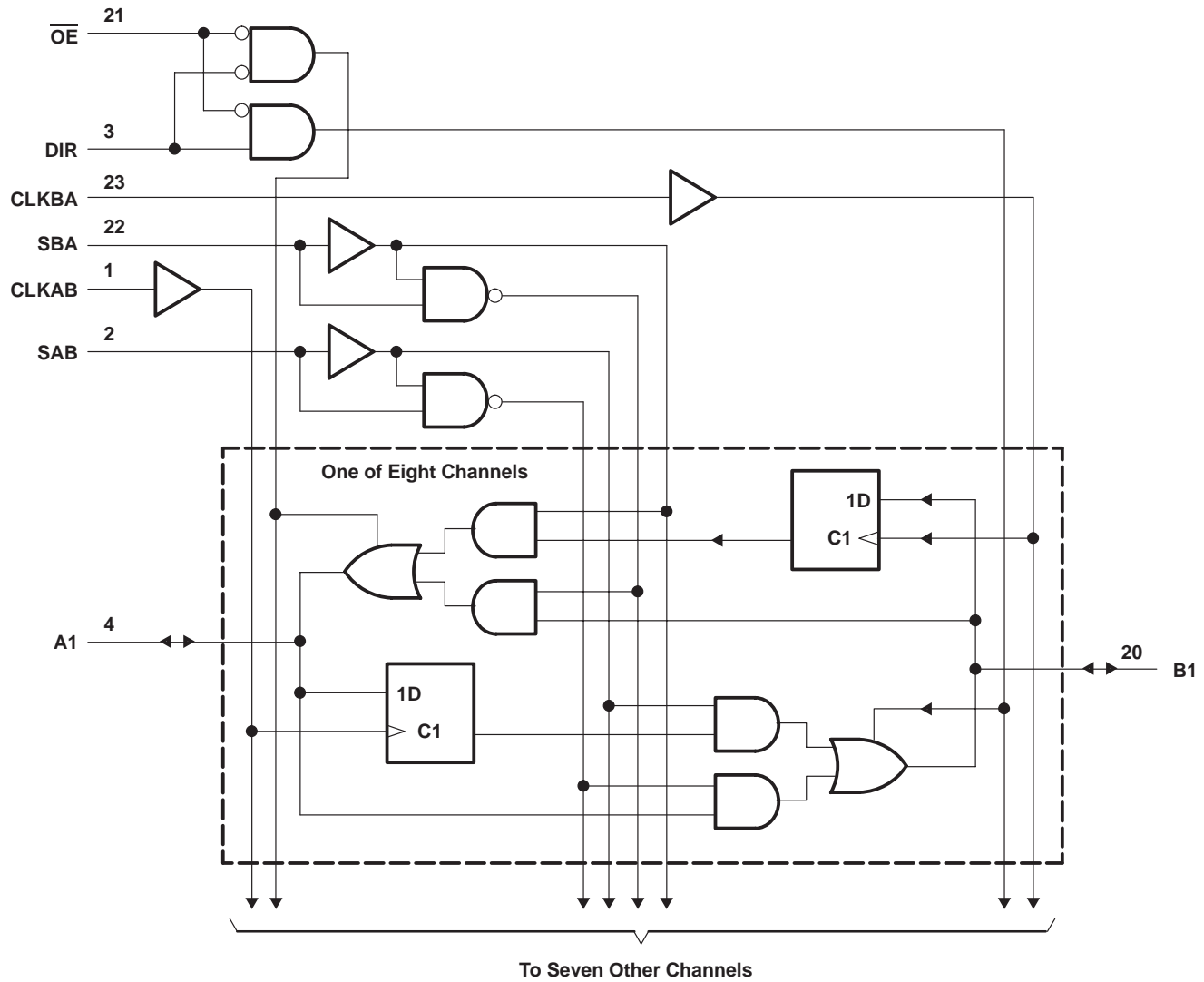
SN54LVTH646, SN74LVTH646

3.3-V ABT OCTAL BUS TRANSCEIVERS AND REGISTERS

WITH 3-STATE OUTPUTS

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logic diagram (positive logic)



Pin numbers shown are for the DB, DGV, DW, JT, NS, PW, and W packages.

SN54LVTH646, SN74LVTH646 3.3-V ABT OCTAL BUS TRANSCEIVERS AND REGISTERS WITH 3-STATE OUTPUTS

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absolute maximum ratings over operating free-air temperature range (unless otherwise noted)†

Supply voltage range, V_{CC}	–0.5 V to 4.6 V
Input voltage range, V_I (see Note 1)	–0.5 V to 7 V
Voltage range applied to any output in the high-impedance or power-off state, V_O (see Note 1)	–0.5 V to 7 V
Voltage range applied to any output in the high state, V_O (see Note 1)	–0.5 V to $V_{CC} + 0.5$ V
Current into any output in the low state, I_O : SN54LVTH646	96 mA
SN74LVTH646	128 mA
Current into any output in the high state, I_O (see Note 2): SN54LVTH646	48 mA
SN74LVTH646	64 mA
Input clamp current, I_{IK} ($V_I < 0$)	–50 mA
Output clamp current, I_{OK} ($V_O < 0$)	–50 mA
Package thermal impedance, θ_{JA} (see Note 3): DB package	63°C/W
DGV package	86°C/W
DW package	46°C/W
NS package	65°C/W
PW package	88°C/W
Storage temperature range, T_{stg}	–65°C to 150°C

† 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.

- NOTES: 1. The input and output negative-voltage ratings may be exceeded if the input and output clamp-current ratings are observed.
 2. This current flows only when the output is in the high state and $V_O > V_{CC}$.
 3. The package thermal impedance is calculated in accordance with JESD 51-7.

recommended operating conditions (see Note 4)

		SN54LVTH646		SN74LVTH646		UNIT
		MIN	MAX	MIN	MAX	
V_{CC}	Supply voltage	2.7	3.6	2.7	3.6	V
V_{IH}	High-level input voltage	2		2		V
V_{IL}	Low-level input voltage		0.8		0.8	V
V_I	Input voltage		5.5		5.5	V
I_{OH}	High-level output current		–24		–32	mA
I_{OL}	Low-level output current		48		64	mA
$\Delta t/\Delta v$	Input transition rise or fall rate	Outputs enabled		10	10	ns/V
$\Delta t/\Delta V_{CC}$	Power-up ramp rate	200		200		μs/V
T_A	Operating free-air temperature	–55	125	–40	85	°C

NOTE 4: All unused control inputs of the device must be held at V_{CC} or GND to ensure proper device operation. Refer to the TI application report, *Implications of Slow or Floating CMOS Inputs*, literature number SCBA004.



SN54LVTH646, SN74LVTH646

3.3-V ABT OCTAL BUS TRANSCEIVERS AND REGISTERS WITH 3-STATE OUTPUTS

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

PARAMETER	TEST CONDITIONS	SN54LVTH646			SN74LVTH646			UNIT
		MIN	TYP†	MAX	MIN	TYP†	MAX	
V_{IK}	$V_{CC} = 2.7\text{ V}$, $I_I = -18\text{ mA}$			-1.2			-1.2	V
V_{OH}	$V_{CC} = 2.7\text{ V to }3.6\text{ V}$, $I_{OH} = -100\text{ }\mu\text{A}$	$V_{CC}-0.2$			$V_{CC}-0.2$			V
	$V_{CC} = 2.7\text{ V}$, $I_{OH} = -8\text{ mA}$	2.4			2.4			
	$V_{CC} = 3\text{ V}$	2			2			
V_{OL}	$V_{CC} = 2.7\text{ V}$	$I_{OL} = 100\text{ }\mu\text{A}$		0.2			0.2	
		$I_{OL} = 24\text{ mA}$		0.5			0.5	
	$V_{CC} = 3\text{ V}$	$I_{OL} = 16\text{ mA}$		0.4			0.4	
		$I_{OL} = 32\text{ mA}$		0.5			0.5	
		$I_{OL} = 48\text{ mA}$		0.55			0.55	
I_I	Control inputs	$V_{CC} = 3.6\text{ V}$, $V_I = V_{CC}\text{ or GND}$		± 1			± 1	
		$V_{CC} = 0\text{ or }3.6\text{ V}$, $V_I = 5.5\text{ V}$		10			10	
	A or B ports‡	$V_{CC} = 3.6\text{ V}$, $V_I = 5.5\text{ V}$		20			20	
		$V_{CC} = 3.6\text{ V}$, $V_I = 0$		-5			-5	
I_{off}	$V_{CC} = 0$, $V_I\text{ or }V_O = 0\text{ to }4.5\text{ V}$					± 100		
$I_{I(\text{hold})}$	A or B ports	$V_{CC} = 3\text{ V}$, $V_I = 0.8\text{ V}$		75			75	
		$V_{CC} = 3\text{ V}$, $V_I = 2\text{ V}$		-75			-75	
		$V_{CC} = 3.6\text{ V}\S$, $V_I = 0\text{ to }3.6\text{ V}$					± 500	
I_{OZPU}	$V_{CC} = 0\text{ to }1.5\text{ V}$, $V_O = 0.5\text{ V to }3\text{ V}$, $OE = \text{don't care}$		± 100			± 100		
I_{OZPD}	$V_{CC} = 1.5\text{ V to }0$, $V_O = 0.5\text{ V to }3\text{ V}$, $OE = \text{don't care}$		± 100			± 100		
I_{CC}	$V_{CC} = 3.6\text{ V}$, $I_O = 0$, $V_I = V_{CC}\text{ or GND}$	Outputs high		0.19			0.19	
		Outputs low		5			5	
		Outputs disabled		0.19			0.19	
$\Delta I_{CC}\P$	$V_{CC} = 3\text{ V to }3.6\text{ V}$, One input at $V_{CC} - 0.6\text{ V}$, Other inputs at $V_{CC}\text{ or GND}$		0.2			0.2		
C_i	$V_I = 3\text{ V or }0$		4			4		
C_{io}	$V_O = 3\text{ V or }0$		9			9		

† All typical values are at $V_{CC} = 3.3\text{ V}$, $T_A = 25^\circ\text{C}$.

‡ Unused terminals at V_{CC} or GND

§ This is the bus-hold maximum dynamic current. It is the minimum overdrive current required to switch the input from one state to another.

¶ This is the increase in supply current for each input that is at the specified TTL voltage level, rather than V_{CC} or GND.



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timing requirements over recommended operating free-air temperature range (unless otherwise noted) (see Figure 2)

		SN54LVTH646				SN74LVTH646				UNIT
		V _{CC} = 3.3 V ± 0.3 V		V _{CC} = 2.7 V		V _{CC} = 3.3 V ± 0.3 V		V _{CC} = 2.7 V		
		MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	
f _{clock}	Clock frequency	150		150		150		150		MHz
t _w	Pulse duration, CLK high or low	3.3		3.3		3.3		3.3		ns
t _{su}	Setup time, A or B before CLKAB↑ or CLKBA↑	Data high	1.3	1.6	1.2	1.5			ns	
		Data low	1.9	2.6	1.6	2.2				
t _h	Hold time, A or B after CLKAB↑ or CLKBA↑	1.2		1.2		0.8		0.8		ns

switching characteristics over recommended operating free-air temperature range, C_L = 50 pF (unless otherwise noted) (see Figure 2)

PARAMETER	FROM (INPUT)	TO (OUTPUT)	SN54LVTH646				SN74LVTH646				UNIT	
			V _{CC} = 3.3 V ± 0.3 V		V _{CC} = 2.7 V		V _{CC} = 3.3 V ± 0.3 V			V _{CC} = 2.7 V		
			MIN	MAX	MIN	MAX	MIN	TYP†	MAX	MIN		MAX
f _{max}			150		150		150			150		MHz
t _{PLH}	CLKBA or CLKAB	A or B	1	5.3	5.9		1.8	3.1	4.7	5.6		ns
t _{PHL}			1.5	5	5.9		1.8	3.1	4.7	5.6		
t _{PLH}	A or B	B or A	1	4.9	5.6		1.3	2.3	3.5	4.1		ns
t _{PHL}			1.2	4.8	5		1.3	2.4	3.5	4.1		
t _{PLH}	SBA or SAB‡	A or B	1	5.3	6.3		1.5	3	4.9	6		ns
t _{PHL}			1.3	5.3	6.3		1.5	3.3	4.9	6		
t _{PZH}	$\overline{\text{OE}}$	A or B	1	5.4	6.7		1.1	3.1	5.2	6.5		ns
t _{PZL}			1	5.6	6.7		1.1	3.4	5.2	6.5		
t _{PHZ}	$\overline{\text{OE}}$	A or B	1.7	6.3	6.5		2.3	3.9	5.5	6.1		ns
t _{PLZ}			2.2	6.3	6.5		2.3	4	5.5	5.9		
t _{PZH}	DIR	A or B	1.2	5.6	6.8		1.3	3.4	5.2	6.6		ns
t _{PZL}			1.2	6.7	6.8		1.3	3.6	5.2	6.6		
t _{PHZ}	DIR	A or B	1.1	7.2	8.1		1.5	3.2	5.6	6.7		ns
t _{PLZ}			1.4	6.1	6.6		1.5	3.8	5.6	6.3		

† All typical values are at V_{CC} = 3.3 V, T_A = 25°C.

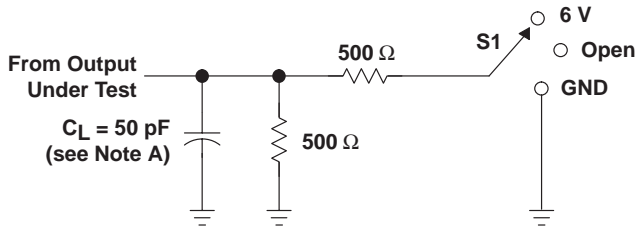
‡ These parameters are measured with the internal output state of the storage register opposite that of the bus input.

SN54LVTH646, SN74LVTH646

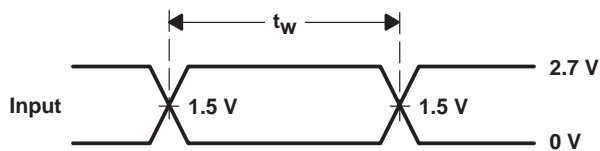
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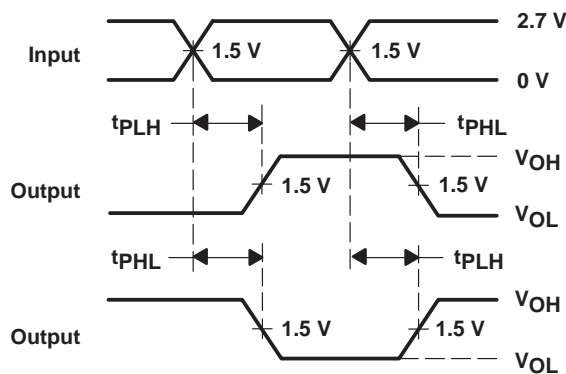
PARAMETER MEASUREMENT INFORMATION



LOAD CIRCUIT

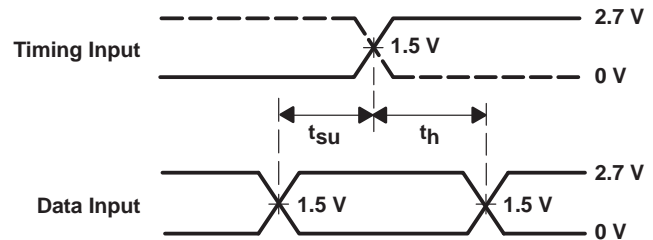


VOLTAGE WAVEFORMS
PULSE DURATION

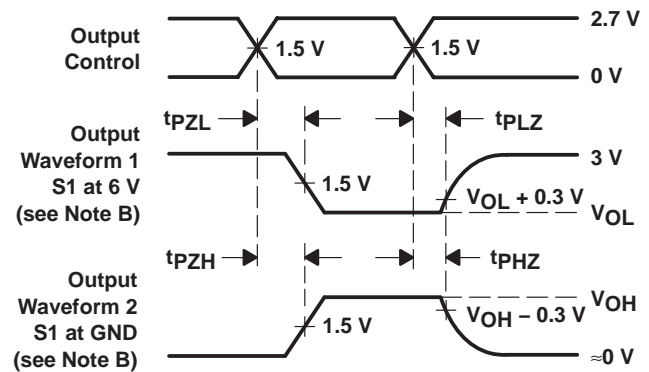


VOLTAGE WAVEFORMS
PROPAGATION DELAY TIMES
INVERTING AND NONINVERTING OUTPUTS

TEST	S1
t_{PLH}/t_{PHL}	Open
t_{PLZ}/t_{PZL}	6 V
t_{PHZ}/t_{PZH}	GND



VOLTAGE WAVEFORMS
SETUP AND HOLD TIMES



VOLTAGE WAVEFORMS
ENABLE AND DISABLE TIMES
LOW- AND HIGH-LEVEL ENABLING

- 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: $PRR \leq 10 \text{ MHz}$, $Z_O = 50 \Omega$, $t_r \leq 2.5 \text{ ns}$, $t_f \leq 2.5 \text{ ns}$.
 D. The outputs are measured one at a time, with one transition per measurement.
 E. All parameters and waveforms are not applicable to all devices.

Figure 2. Load Circuit and Voltage Waveforms

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
5962-9674801Q3A	ACTIVE	LCCC	FK	28	1	TBD	POST-PLATE	N / A for Pkg Type	-55 to 125	5962- 9674801Q3A SNJ54LVTH 646FK	Samples
SN74LVTH646DW	ACTIVE	SOIC	DW	24	25	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 85	LVTH646	Samples
SN74LVTH646DWG4	ACTIVE	SOIC	DW	24	25	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 85	LVTH646	Samples
SN74LVTH646PWR	ACTIVE	TSSOP	PW	24	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 85	LXH646	Samples
SNJ54LVTH646FK	ACTIVE	LCCC	FK	28	1	TBD	POST-PLATE	N / A for Pkg Type	-55 to 125	5962- 9674801Q3A SNJ54LVTH 646FK	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.

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.

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

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OTHER QUALIFIED VERSIONS OF SN54LVTH646, SN74LVTH646 :

- Catalog: [SN74LVTH646](#)

- Military: [SN54LVTH646](#)

NOTE: Qualified Version Definitions:

- Catalog - TI's standard catalog product

- Military - QML certified for Military and Defense 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
SN74LVTH646PWR	TSSOP	PW	24	2000	330.0	16.4	6.95	8.3	1.6	8.0	16.0	Q1

TAPE AND REEL BOX DIMENSIONS

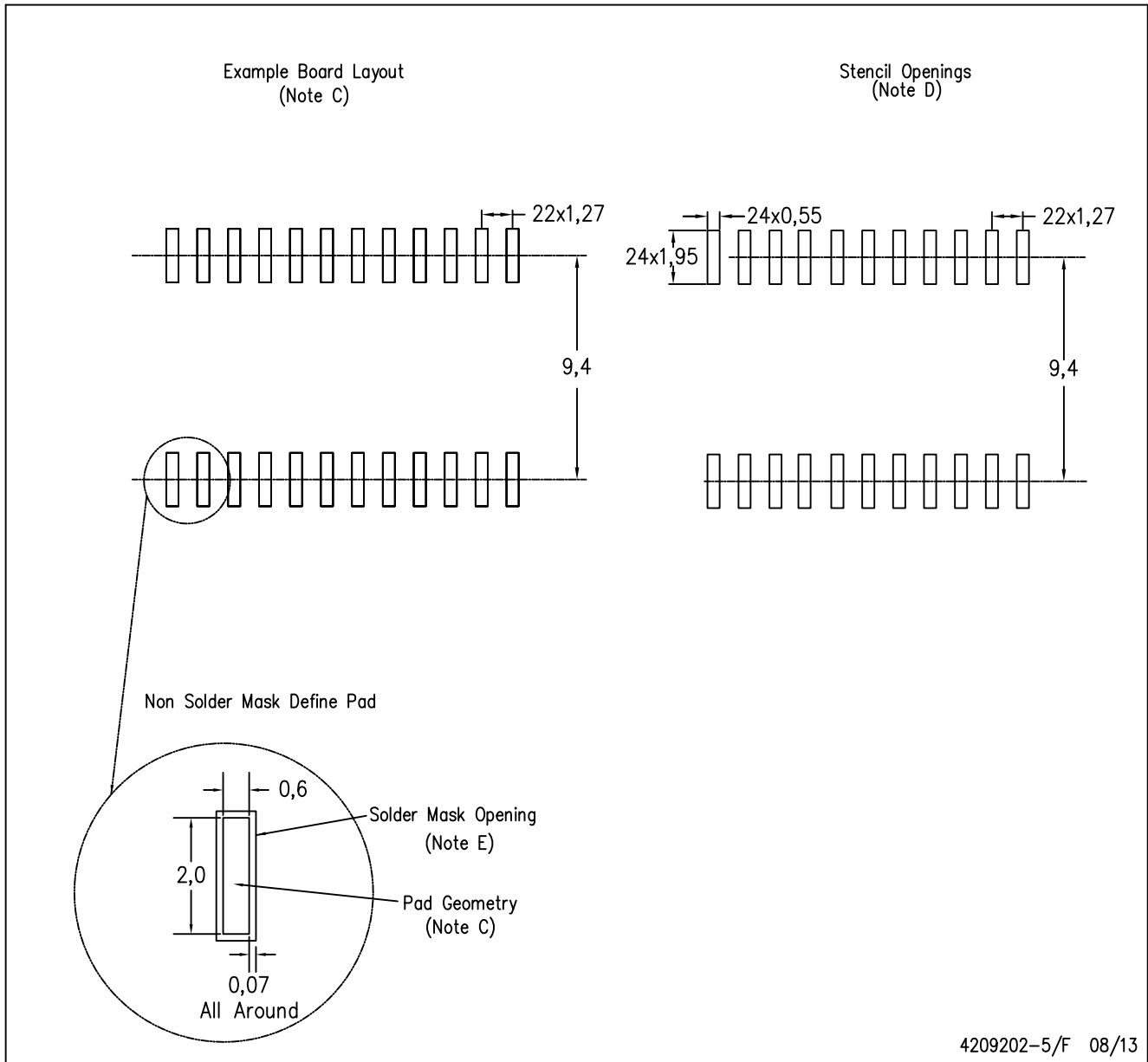


*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
SN74LVTH646PWR	TSSOP	PW	24	2000	367.0	367.0	38.0

DW (R-PDSO-G24)

PLASTIC SMALL OUTLINE



- NOTES:
- A. All linear dimensions are in millimeters.
 - B. This drawing is subject to change without notice.
 - C. Refer to IPC7351 for alternate board design.
 - D. Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Refer to IPC-7525
 - E. Customers should contact their board fabrication site for solder mask tolerances between and around signal pads.

FK (S-CQCC-N**)

LEADLESS CERAMIC CHIP CARRIER

28 TERMINAL SHOWN



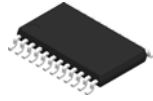
NO. OF TERMINALS **	A		B	
	MIN	MAX	MIN	MAX
20	0.342 (8,69)	0.358 (9,09)	0.307 (7,80)	0.358 (9,09)
28	0.442 (11,23)	0.458 (11,63)	0.406 (10,31)	0.458 (11,63)
44	0.640 (16,26)	0.660 (16,76)	0.495 (12,58)	0.560 (14,22)
52	0.740 (18,78)	0.761 (19,32)	0.495 (12,58)	0.560 (14,22)
68	0.938 (23,83)	0.962 (24,43)	0.850 (21,6)	0.858 (21,8)
84	1.141 (28,99)	1.165 (29,59)	1.047 (26,6)	1.063 (27,0)



4040140/D 01/11

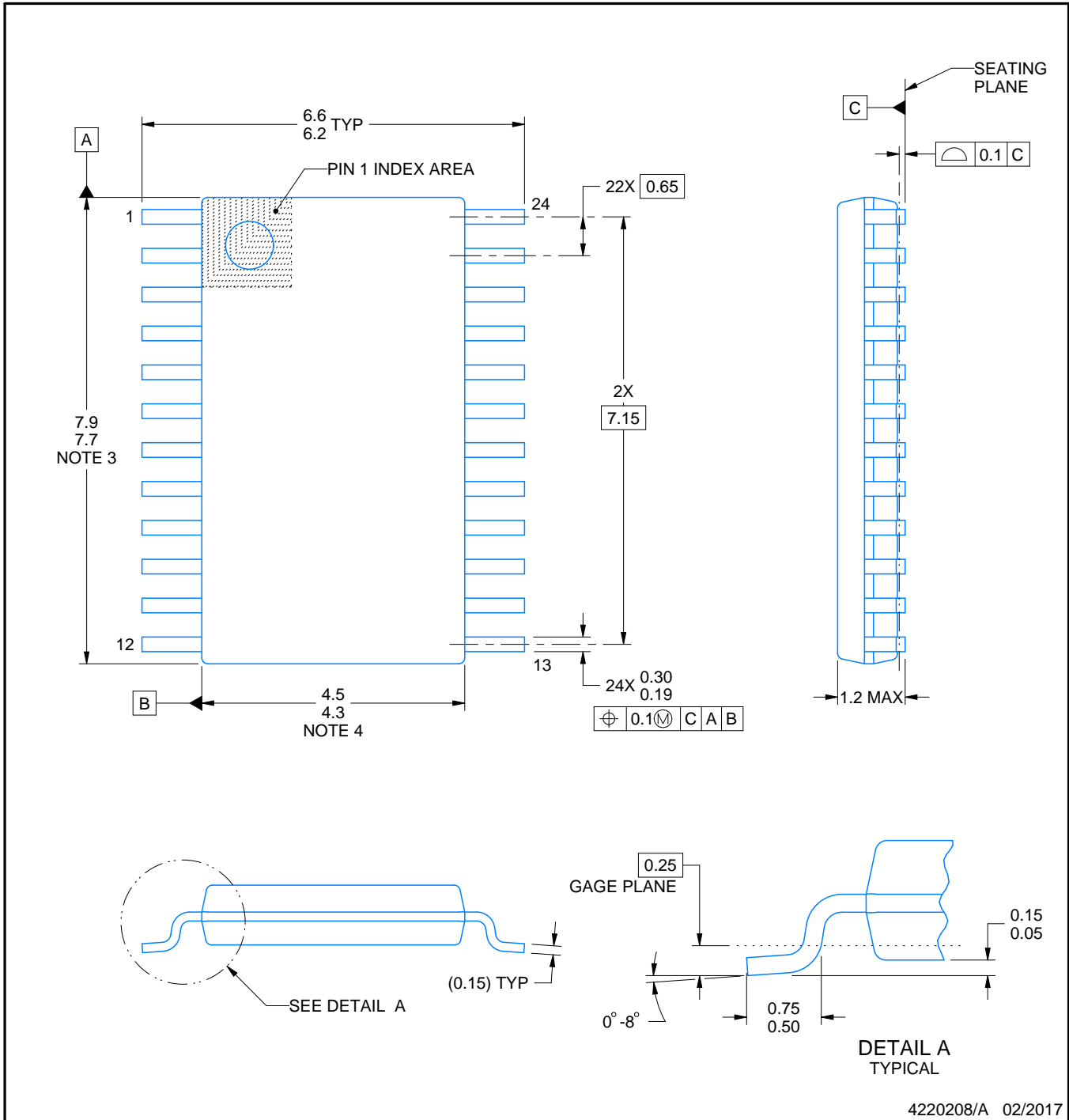
- NOTES:
- All linear dimensions are in inches (millimeters).
 - This drawing is subject to change without notice.
 - This package can be hermetically sealed with a metal lid.
 - Falls within JEDEC MS-004

PW0024A



PACKAGE OUTLINE
TSSOP - 1.2 mm max height

SMALL OUTLINE PACKAGE



4220208/A 02/2017

NOTES:

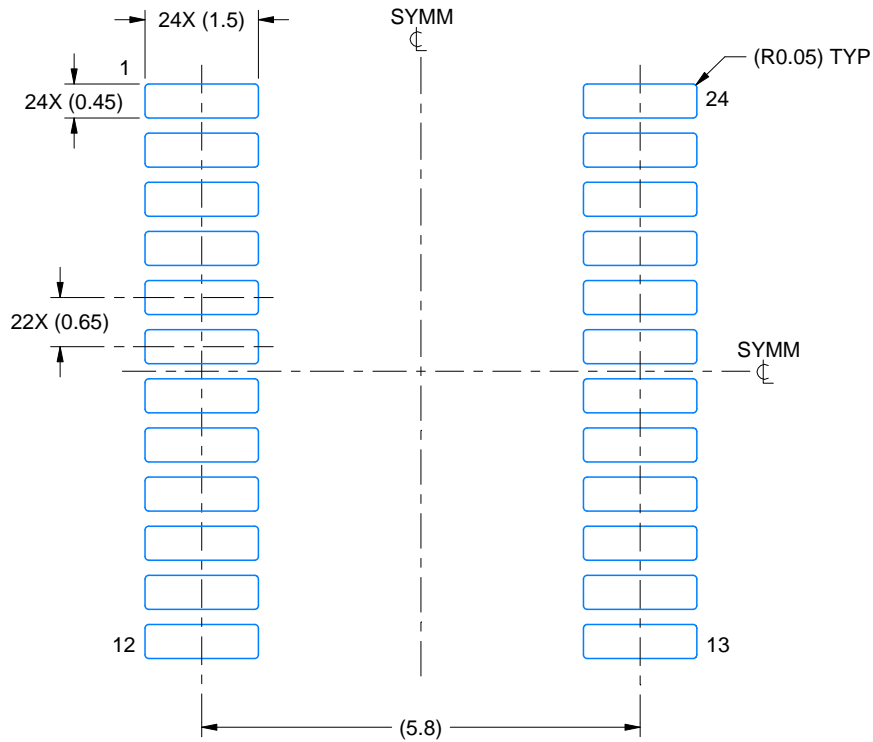
1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.15 mm per side.
4. This dimension does not include interlead flash. Interlead flash shall not exceed 0.25 mm per side.
5. Reference JEDEC registration MO-153.

EXAMPLE BOARD LAYOUT

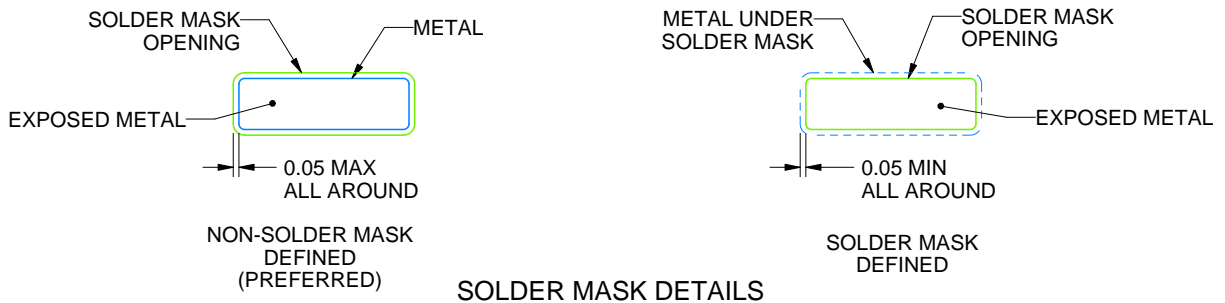
PW0024A

TSSOP - 1.2 mm max height

SMALL OUTLINE PACKAGE



LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE: 10X



SOLDER MASK DETAILS

4220208/A 02/2017

NOTES: (continued)

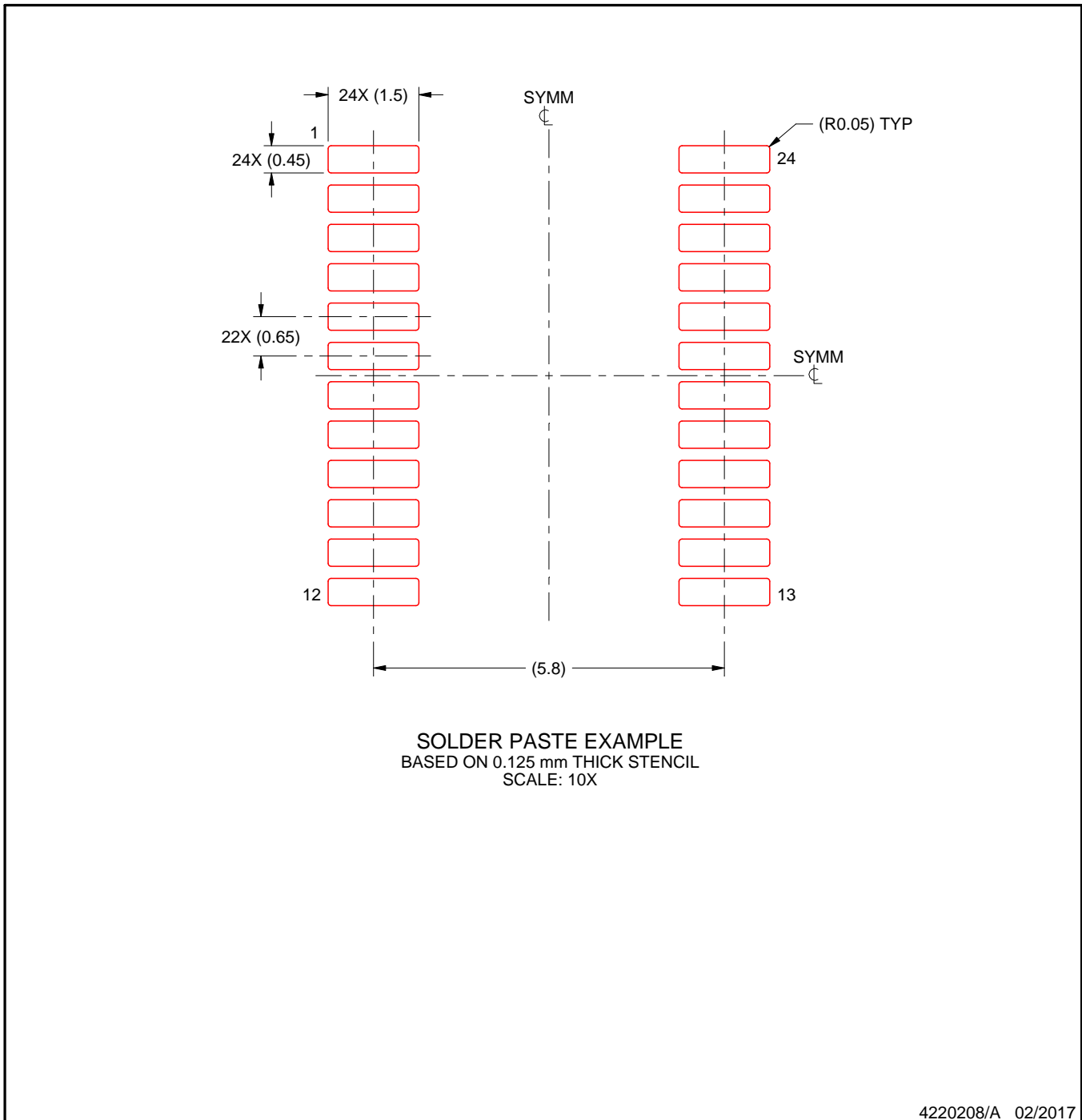
- 6. Publication IPC-7351 may have alternate designs.
- 7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.

EXAMPLE STENCIL DESIGN

PW0024A

TSSOP - 1.2 mm max height

SMALL OUTLINE PACKAGE



NOTES: (continued)

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

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