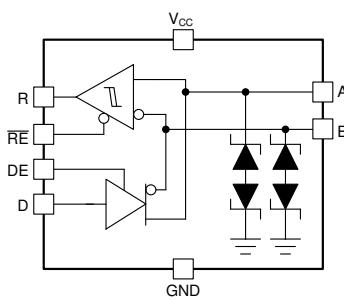


THVD24x9 3V to 5.5V RS-485 Transceivers With Integrated Surge and High Bus-Fault Protection in Small Packages

1 Features

- Meets or exceeds the requirements of the TIA/EIA-485A standard
- 3V to 5.5V Supply Voltage
- Industry's smallest surge-integrated RS-485 device in 9mm² package
- V_{IO} Support from 1.65V to V_{CC} supply level
- Bus I/O protection
 - ± 3kV/42Ω IEC 61000-4-5 1.2/50µs surge (SOIC)
 - ± 1.5kV/42Ω IEC 61000-4-5 1.2/50µs surge (VSON)
 - ± 8kV IEC 61000-4-2 Contact discharge
 - ± 4kV IEC 61000-4-4 Electrical fast transient
 - ± 15kV HBM ESD
 - ± 42V DC bus fault
- Available in two speed grades
 - THVD2419: 250kbps
 - THVD2429: 20Mbps
- Extended ambient temperature range: -40°C to 125°C
- Extended operational common-mode range: ± 25V
- Large receiver hysteresis for noise rejection
- Low power consumption in shutdown mode: < 5µA
- Glitch-free power-up and down for hot plug-in capability
- Open, short, and idle bus failsafe
- 1/8 Unit load (up to 256 bus nodes)
- Industry standard 8-pin SOIC for drop-in compatibility
- Small surge-integrated RS-485 device in 3mm x 3mm leadless (VSON) package



THVD24x9 Block Diagram (SOIC Package)

2 Applications

- Wireless infrastructure
- Factory automation
- Motor drives
- Building automation
- HVAC
- Grid infrastructure

3 Description

THVD24x9 devices are half-duplex RS-485 transceivers with integrated surge protection. Surge protection is achieved by integrating transient voltage suppressor (TVS) diodes in the standard 8-pin SOIC (D) package as well as small 10-pin VSON package. This feature increases the reliability by providing better immunity to noise transients coupled to the data cable which eliminates the need for external protection components.

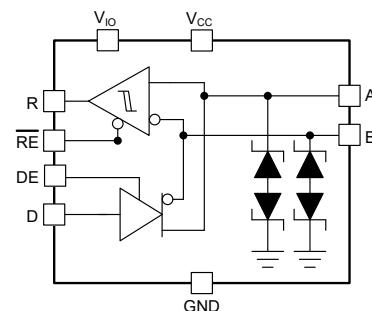
THVD24x9 devices in the standard pin-out SOIC package operate from a single 3.3V or 5V supply. In addition, THVD24x9 devices in 10-pin VSON package support an additional V_{IO} supply to operate the IOs from as low as 1.65V supply level. The devices in this family feature a wide common-mode voltage range making them suitable for multi-point applications over long cable runs.

Package Information

PART NUMBER	PACKAGE ⁽¹⁾	PACKAGE SIZE ⁽²⁾
THVD2419	SOIC (8)	4.9mm × 6mm
	VSON (10)	3mm × 3mm

(1) For more information, see [Section 12](#).

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



THVD24x9 Block Diagram (VSON Package)



An IMPORTANT NOTICE at the end of this data sheet addresses availability, warranty, changes, use in safety-critical applications, intellectual property matters and other important disclaimers. PRODUCTION DATA.

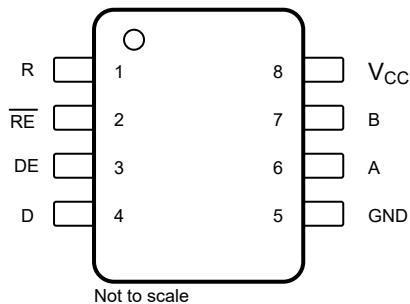
Table of Contents

1 Features	1	8.2 Functional Block Diagrams.....	14
2 Applications	1	8.3 Feature Description.....	14
3 Description	1	8.4 Device Functional Modes.....	18
4 Device Comparison Table	2	9 Application and Implementation	19
5 Pin Configuration and Functions	3	9.1 Application Information	19
6 Specifications	4	9.2 Typical Application.....	19
6.1 Absolute Maximum Ratings.....	4	9.3 Power Supply Recommendations.....	22
6.2 ESD Ratings	4	9.4 Layout.....	23
6.3 ESD Ratings - IEC Specifications.....	4	10 Device and Documentation Support	24
6.4 Recommended Operating Conditions.....	5	10.1 Device Support.....	24
6.5 Thermal Information.....	5	10.2 Receiving Notification of Documentation Updates.....	24
6.6 Power Dissipation.....	5	10.3 Support Resources.....	24
6.7 Electrical Characteristics.....	6	10.4 Trademarks.....	24
6.8 Switching Characteristics 250kbps.....	8	10.5 Electrostatic Discharge Caution.....	24
6.9 Switching Characteristics 20Mbps.....	8	10.6 Glossary.....	24
6.10 Typical Characteristics.....	10	11 Revision History	24
7 Parameter Measurement Information	12	12 Mechanical, Packaging, and Orderable Information	24
8 Detailed Description	14		
8.1 Overview.....	14		

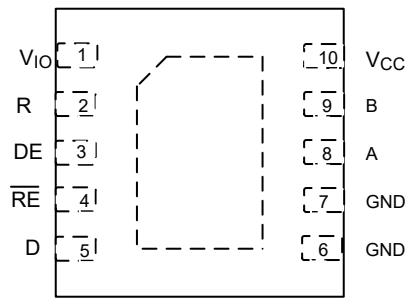
4 Device Comparison Table

PART NUMBER	PACKAGE	V _{IO}	SIGNALING RATE	NODES
THVD2419	SOIC-8	No	up to 250kbps	256
THVD2429			up to 20Mbps	
THVD2419	VSON-10	Yes	up to 250kbps	
THVD2429			up to 20Mbps	

5 Pin Configuration and Functions



**Figure 5-1. THVD2419, THVD2429, 8-Pin (SOIC)
(Top View)**



**Figure 5-2. THVD2419, THVD2429, 10-Pin (VSON)
(Top View)**

NAME	PIN		TYPE	DESCRIPTION
	SOIC-8	VSON-10		
V _{IO}	-	1	P	1.8V to 5V supply for R, D, and RE and DE
R	1	2	O	Receiver data output
RE	2	4	I	Receiver enable, active low (integrated pull-up)
DE	3	3	I	Driver enable, active high (integrated pull-down)
D	4	5	I	Driver data input (integrated pull-up)
GND	5	6, 7	-	Device ground
A	6	8	I/O	Bus I/O port, A (complementary to B)
B	7	9	I/O	Bus I/O port, B (complementary to A)
V _{CC}	8	10	P	3.3V to 5V supply for the device

6 Specifications

6.1 Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted)⁽¹⁾

		MIN	MAX	UNIT
Logic supply voltage	V_{IO}	-0.5	$V_{CC} + 0.2$	V
Bus supply voltage	V_{CC}	-0.5	6.5	V
Bus voltage	Range at any bus pin (A or B) as differential or common-mode with respect to GND	-42	42	V
Input voltage	Range at any logic pin (D, DE, SLR or \overline{RE}) for devices with VIO pin	-0.3	$V_{IO} + 0.2$	V
Input voltage	Range at any logic pin (D, DE, SLR or \overline{RE}) for devices with no VIO pin	-0.3	$V_{CC} + 0.2$	V
Receiver output current	I_O	-24	24	mA
Storage temperature	T_{STG}	-65	170	°C

(1) Operation outside the Absolute Maximum Ratings may cause permanent device damage. Absolute Maximum Ratings do not imply functional operation of the device at these or any other conditions beyond those listed under Recommended Operating Conditions. If used outside the Recommended Operating Conditions but within the Absolute Maximum Ratings, the device may not be fully functional, and this may affect device reliability, functionality, performance, and shorten the device lifetime.

6.2 ESD Ratings

			VALUE	UNIT
$V_{(ESD)}$	Electrostatic discharge	Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001 ⁽¹⁾	Bus terminals and GND	±16,000
		All pins except bus terminals and GND	±4,000	V
		Charged-device model (CDM), per JEDEC specification JESD22-C101 ⁽²⁾	±1,500	V

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

6.3 ESD Ratings - IEC Specifications

			VALUE	UNIT
$V_{(ESD)}$	Electrostatic discharge, bus terminals	Contact discharge, per IEC 61000-4-2 ⁽¹⁾	Bus terminals and GND	±8,000
		Air-gap discharge, per IEC 61000-4-2 ⁽¹⁾	Bus terminals and GND	±15,000
$V_{(SURGE)}$	Surge	Per IEC 61000-4-5, 1.2/50-8/20μs CWG (DRC Package)	Bus terminals and GND	±1500
$V_{(SURGE)}$	Surge	Per IEC 61000-4-5, 1.2/50-8/20μs CWG (D Package)	Bus terminals and GND	±3,000

(1) For optimised IEC ESD performance, it is recommended to have series resistor ($\geq 50 \Omega$) on all logic inputs to minimize transient currents going into or out of the logic pins.

6.4 Recommended Operating Conditions

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

			MIN	NOM	MAX	UNIT
V_{CC}	Supply voltage		3	5.5		V
V_{IO}	I/O supply voltage (devices with VIO pin)		1.65		V_{CC}	V
V_{IH}	High-level input voltage (D, DE, RE)	devices with VIO pin	0.7	1	V_{IO}	
V_{IL}	Low-level input voltage (D, DE, RE)		0	0.3	V_{IO}	
V_{IH}	High-level input voltage (D, DE, RE)	devices without VIO pin	0.7	1	V_{CC}	
V_{IL}	Low-level input voltage (D, DE, RE)		0	0.3	V_{CC}	
V_I	Input voltage at any bus terminal (separately or common mode) ⁽¹⁾		-25	25		V
V_{ID}	Differential input voltage		-25	25		V
I_O	Output current, driver		-60	60		mA
I_{OR}	Output current, receiver	$V_{IO} = 1.8V$ or $2.5V$ (devices with VIO pin)	-4	4		mA
I_{OR}	Output current, receiver	$V_{IO} = 3.3V$ or $5V$ (devices with VIO pin) or $V_{CC} = 3.3V$ or $5V$ (devices without VIO pin)	-8	8		mA
R_L	Differential load resistance		54	60		Ω
$1/t_{UI}$	Signaling rate	THVD2419			250	kbps
		THVD2429			20	Mbps
T_A	Operating ambient temperature		-40	125		$^{\circ}C$
T_J	Junction temperature		-40	150		$^{\circ}C$

(1) The algebraic convention, in which the least positive (most negative) limit is designated as minimum is used in this data sheet.

6.5 Thermal Information

THERMAL METRIC ⁽¹⁾		THVD2419, THVD2429		UNIT
		DRC (VSON)	D (SOIC)	
		10 PINS	8 PINS	
$R_{\theta JA}$	Junction-to-ambient thermal resistance	65.2	117.2	$^{\circ}C/W$
$R_{\theta JC(\text{top})}$	Junction-to-case (top) thermal resistance	41.7	40.2	$^{\circ}C/W$
$R_{\theta JB}$	Junction-to-board thermal resistance	36.4	65.3	$^{\circ}C/W$
Ψ_{JT}	Junction-to-top characterization parameter	1.4	3.3	$^{\circ}C/W$
Ψ_{JB}	Junction-to-board characterization parameter	36.3	64.4	$^{\circ}C/W$
$R_{\theta JC(\text{bot})}$	Junction-to-case (bottom) thermal resistance	24.9	N/A	$^{\circ}C/W$

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

6.6 Power Dissipation

PARAMETER		TEST CONDITIONS			VALUE	UNIT
P_D	Driver and receiver enabled, $V_{CC} = 5.5$ V, $T_A = 125$ $^{\circ}C$, square wave at 50% duty cycle	Unterminated $R_L = 300\Omega$, $C_L = 50pF$ (driver)	THVD2419	250kbps	180	mW
			THVD2429	20Mbps	310	
		RS-422 load $R_L = 100\Omega$, $C_L = 50pF$ (driver)	THVD2419	250kbps	180	mW
			THVD2429	20Mbps	310	
		RS-485 load $R_L = 54\Omega$, $C_L = 50pF$ (driver)	THVD2419	250kbps	270	mW
			THVD2429	20Mbps	325	

6.7 Electrical Characteristics

over operating free-air temperature range (unless otherwise noted). All typical values are at 25°C and supply voltage of $V_{CC} = 5V$, $V_{IO} = 3.3V$, unless otherwise noted.

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
Driver						
V_{OD}	Driver differential output voltage magnitude	$R_L = 60\Omega$, $-25V \leq V_{test} \leq 25V$ (See Figure 7-1)	1.5	2.8		V
		$R_L = 60\Omega$, $-25V \leq V_{test} \leq 25V$, $4.5V \leq V_{CC} \leq 5.5V$ (See Figure 7-1)	2.1	3.3		V
		$R_L = 100\Omega$ (See Figure 7-2)	2	2.9		V
		$R_L = 54\Omega$ (See Figure 7-2)	1.5	2.5		V
$\Delta V_{OD} $	Change in differential output voltage	$R_L = 54\Omega$ or 100Ω (See Figure 7-2)	-50	50		mV
V_{OC}	Common-mode output voltage		1	$V_{CC}/2$	3	V
$\Delta V_{OC(ss)}$	Change in steady-state common-mode output voltage		-50	50		mV
I_{OS}	Short-circuit output current	DE = V_{IO} , $-42V \leq (V_A \text{ or } V_B) \leq 42V$, or A shorted to B	-250	250		mA
Receiver						
I_I	Bus input current	DE = 0V, V_{CC} and $V_{IO} = 0V$ or 5.5V	$V_I = 12V$	90	125	μA
			$V_I = 25V$	200	250	μA
			$V_I = -7V$	-100	-80	μA
			$V_I = -25V$	-350	-240	μA
V_{TH+}	Positive-going input threshold voltage ⁽¹⁾	Over common-mode range of $\pm 25V$	20	125	200	mV
V_{TH-}	Negative-going input threshold voltage ⁽¹⁾		-200	-125	-20	mV
V_{HYS}	Input hysteresis		250			mV
V_{TH_FSH}	Input fail-safe threshold		-20		20	mV
$C_{A,B}$	Input differential capacitance	Measured between A and B, $f = 1MHz$	50			pF
V_{OH}	Output high voltage	$I_{OH} = -8mA$, $V_{IO} = 3$ to $3.6V$ or $4.5V$ to $5.5V$	$V_{IO} - 0.4$	$V_{IO} - 0.2$		V
V_{OL}	Output low voltage	$I_{OL} = 8mA$, $V_{IO} = 3$ to $3.6V$ or $4.5V$ to $5.5V$	0.2	0.4		V
V_{OH}	Output high voltage	$I_{OH} = -4mA$, $V_{IO} = 1.65$ to $1.95V$ or $2.25V$ to $2.75V$	$V_{IO} - 0.4$	$V_{IO} - 0.2$		V
V_{OL}	Output low voltage	$I_{OL} = 4mA$, $V_{IO} = 1.65$ to $1.95V$ or $2.25V$ to $2.75V$	0.2	0.4		V
I_{OZ}	Output high-impedance current, R pin	$V_O = 0V$ or V_{IO} , $\bar{RE} = V_{IO}$	-1	1		μA
Logic						
I_{IN}	Input current (DE, SLR)	DRC: $1.65V \leq V_{IO} \leq 5.5V$, $0V \leq V_{IN} \leq V_{IO}$ D: $3V \leq V_{CC} \leq 5.5V$, $0V \leq V_{IN} \leq 5.5V$		5		μA
I_{IN}	Input current (D, \bar{RE})	DRC: $1.65V \leq V_{IO} \leq 5.5V$, $0V \leq V_{IN} \leq V_{IO}$ D: $3V \leq V_{CC} \leq 5.5V$, $0V \leq V_{IN} \leq 5.5V$	-5			μA
Thermal Protection						
T_{SHDN}	Thermal shutdown threshold	Temperature rising	150	180		°C
T_{HYS}	Thermal shutdown hysteresis		10			°C
Supply						
UV_{VCC} (rising)	Rising under-voltage threshold on V_{CC}		2.3	2.6		V
UV_{VCC} (falling)	Falling under-voltage threshold on V_{CC}		1.95	2.2		V
$UV_{VCC(hys)}$	Hysteresis on under-voltage of V_{CC}		150			mV
UV_{VIO} (rising)	Rising under-voltage threshold on V_{IO}		1.4	1.6		V
UV_{VIO} (falling)	Falling under-voltage threshold on V_{IO}		1.2	1.3		V

6.7 Electrical Characteristics (continued)

over operating free-air temperature range (unless otherwise noted). All typical values are at 25°C and supply voltage of $V_{CC} = 5V$, $V_{IO} = 3.3V$, unless otherwise noted.

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
UV _{VIO(hys)}	Hysteresis on under-voltage of V_{IO}			120		mV
I _{CC}	Supply current (quiescent), $V_{CC} = 4.5V$ to $5.5V$	Driver and receiver enabled	$RE = 0V$, $DE = V_{IO}$, No load	3.5	5.7	mA
		Driver enabled, receiver disabled	$RE = V_{IO}$, $DE = V_{IO}$, No load	2.5	4.4	mA
		Driver disabled, receiver enabled	$RE = 0V$, $DE = 0V$, No load	1.8	2.4	mA
		Driver and receiver disabled (devices without VIO pin)	$RE = V_{CC}$, $DE = 0V$, $D = open$, No load	1.7	5	µA
		Driver and receiver disabled (devices with VIO pin)	$RE = V_{IO}$, $DE = 0V$, $D = open$, No load	0.1	3	µA
I _{CC}	Supply current (quiescent), $V_{CC} = 3V$ to $3.6V$	Driver and receiver enabled	$RE = 0V$, $DE = V_{IO}$, No load	3	4.6	mA
		Driver enabled, receiver disabled	$RE = V_{IO}$, $DE = V_{IO}$, No load	2.2	3.3	mA
		Driver disabled, receiver enabled	$RE = 0V$, $DE = 0V$, No load	1.6	2.2	mA
		Driver and receiver disabled (Devices without VIO pin)	$RE = V_{CC}$, $DE = 0V$, $D = open$, No load	1	4	µA
		Driver and receiver disabled (Devices with VIO pin)	$RE = V_{IO}$, $DE = 0V$, $D = open$, No load	1	2	µA
I _{IO}	Logic supply current (quiescent), $V_{IO} = 3$ to $3.6V$, Devices with VIO pin	Driver disabled, Receiver enabled	$DE = 0V$, $RE = 0V$, No load	3.3	8.4	µA
		Driver disabled, Receiver disabled	$DE = 0V$, $RE = V_{IO}$, No load	0.1	2	µA

(1) Under any specific conditions, V_{TH+} is assured to be at least V_{HYS} higher than V_{TH-} .

6.8 Switching Characteristics 250kbps

250kbps (THVD2419) over recommended operating conditions. All typical values are at 25°C and supply voltage of $V_{CC} = 5V$, $V_{IO} = 3.3V$, unless otherwise noted. (1)

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
Driver							
t_r, t_f	Differential output rise/fall time	$R_L = 54 \Omega, C_L = 50 \text{ pF}$ See Figure 7-3	$V_{CC} = 3 \text{ to } 3.6V, \text{ Typical at } 3.3V$	400	625	1200	ns
			$V_{CC} = 4.5 \text{ to } 5.5V, \text{ Typical at } 5V$	500	725	1200	ns
t_{PHL}, t_{PLH}	Propagation delay	$R_L = 54 \Omega, C_L = 50 \text{ pF}$ See Figure 7-3		510	750		ns
$t_{SK(P)}$	Pulse skew, $ t_{PHL} - t_{PLH} $			5	70		ns
t_{PHZ}, t_{PLZ}	Disable time	See Figure 7-4 and Figure 7-5	$\bar{RE} = X$	45	75		ns
t_{PZH}, t_{PZL}	Enable time		$\bar{RE} = 0V$	80	290		ns
			$\bar{RE} = V_{IO}$	2.5	4.5		μs
t_{SHDN}	Time to shutdown		$\bar{RE} = V_{IO}$	50	500		ns
Receiver							
t_r, t_f	Output rise/fall time	$C_L = 15 \text{ pF}$ See Figure 7-6		3	20		ns
t_{PHL}, t_{PLH}	Propagation delay			750	1270		ns
$t_{SK(P)}$	Pulse skew, $ t_{PHL} - t_{PLH} $			5	45		ns
t_{PHZ}, t_{PLZ}	Disable time	DE = X		30	40		ns
$t_{PZH(1)}$	Enable time			80	130		ns
$t_{PZL(1)}$	Enable time	See Figure 7-7		800	1320		ns
$t_{PZH(2)}, t_{PZL(2)}$	Enable time	See Figure 7-8	DE = 0V	3	5.4		μs
$t_{D(OFS)}$	Delay to enter fail-safe operation	See Figure 7-9	$C_L = 15 \text{ pF}$	7	11	18	μs
$t_{D(FSO)}$	Delay to exit fail-safe operation			540	750	1260	ns
t_{SHDN}	Time to shutdown	See Figure 7-8	DE = 0V	50	500		ns

(1) A, B are driver output and receiver input terminals for Half duplex devices. A, B are RX input, Y/Z are driver output terminals for Full duplex device

6.9 Switching Characteristics 20Mbps

20Mbps (THVD2429) over recommended operating conditions. All typical values are at 25°C and supply voltage of $V_{CC} = 5V$, $V_{IO} = 3.3V$, unless otherwise noted. (1)

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
Driver							
t_r, t_f	Differential output rise/fall time	$R_L = 54 \Omega, C_L = 50 \text{ pF}$ See Figure 7-3		3.5	5	15	ns
				6	15	30	ns
t_{PHL}, t_{PLH}	Propagation delay	$R_L = 54 \Omega, C_L = 50 \text{ pF}$ See Figure 7-3		0.5	3		ns
				20	35		ns
$t_{SK(P)}$	Pulse skew, $ t_{PHL} - t_{PLH} $	$R_L = 54 \Omega, C_L = 50 \text{ pF}$ See Figure 7-3		16	40		ns
				2.5	4.5		μs
t_{PHZ}, t_{PLZ}	Disable time	See Figure 7-4 and Figure 7-5	$\bar{RE} = X$	18	25		ns
t_{PZH}, t_{PZL}	Enable time		$\bar{RE} = 0V$	55	82		ns
t_{SHDN}	Time to shutdown		$\bar{RE} = V_{IO}$	50	500		ns
Receiver							
t_r, t_f	Output rise/fall time	$C_L = 15 \text{ pF}$, See Figure 7-6		1.5	6		ns
t_{PHL}, t_{PLH}	Propagation delay			25	35	60	ns
$t_{SK(P)}$	Pulse skew, $ t_{PHL} - t_{PLH} $			55			ns
t_{PHZ}, t_{PLZ}	Disable time	DE = X		18	25		ns
$t_{PZH(1)}, t_{PZL(1)}$	Enable time	See Figure 7-7	DE = V_{IO}	55	82		ns

6.9 Switching Characteristics 20Mbps (continued)

20Mbps (THVD2429) over recommended operating conditions. All typical values are at 25°C and supply voltage of $V_{CC} = 5$ V, $V_{IO} = 3.3$ V, unless otherwise noted. ⁽¹⁾

PARAMETER	TEST CONDITIONS		MIN	TYP	MAX	UNIT	
$t_{PZH(2)}$, $t_{PZL(2)}$	Enable time	See Figure 7-8	DE = 0V		2.5	4.5	μs
$t_{D(OFS)}$	Delay to enter fail-safe operation	See Figure 7-9	$C_L = 15pF$	7	10	18	μs
$t_{D(FSO)}$	Delay to exit fail-safe operation			19	35	50	ns
t_{SHDN}	Time to shutdown	See Figure 7-8	DE = 0V	50	500	ns	

(1) A, B are driver output and receiver input terminals for Half duplex devices. A, B are RX input, Y/Z are driver output terminals for Full duplex device

6.10 Typical Characteristics

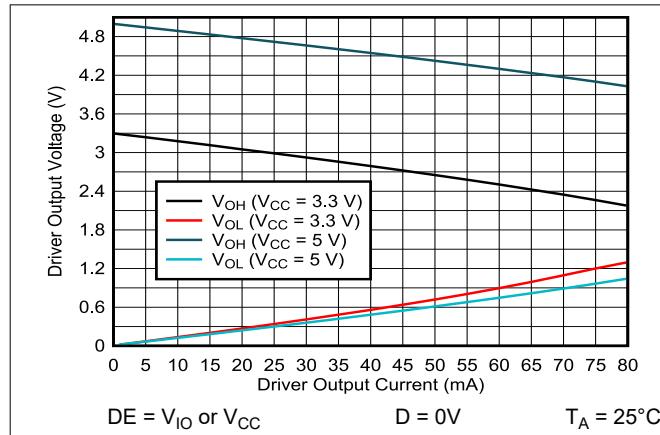


Figure 6-1. Driver Output Voltage vs Driver Output Current

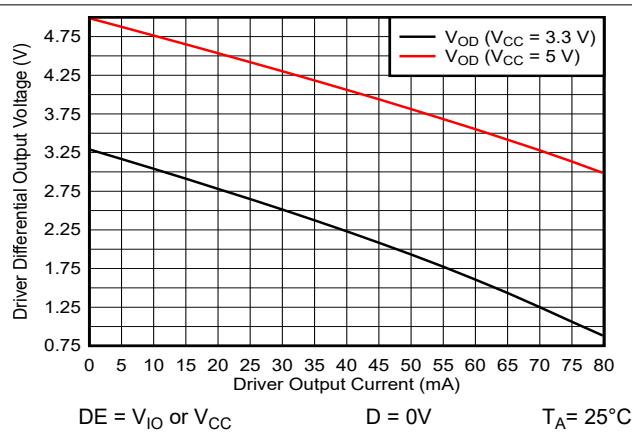


Figure 6-2. Driver Differential Output voltage vs Driver Output Current

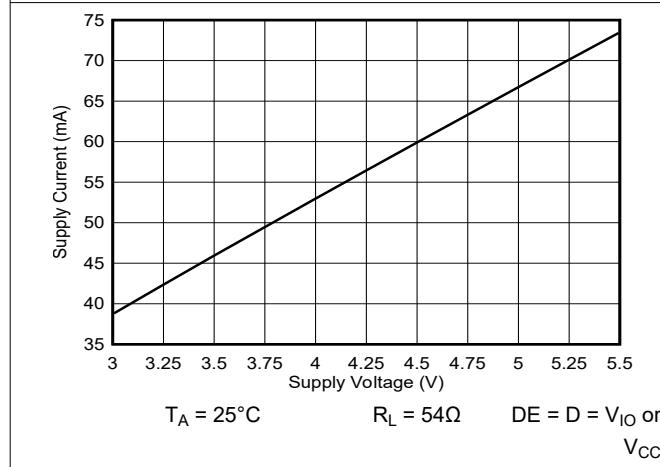


Figure 6-3. Driver Output Current vs Supply Voltage

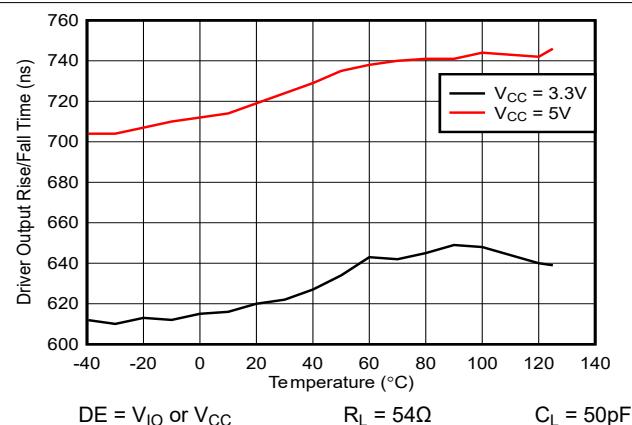


Figure 6-4. THVD2419 Driver Rise or Fall Time vs Temperature

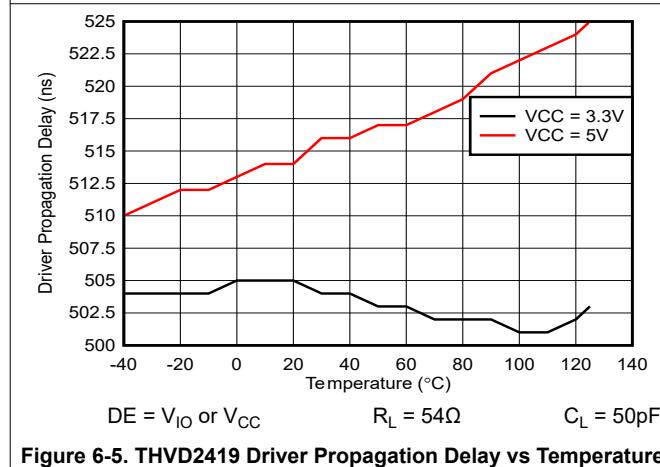


Figure 6-5. THVD2419 Driver Propagation Delay vs Temperature

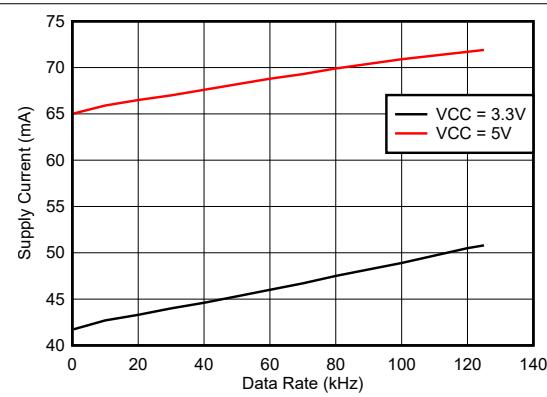
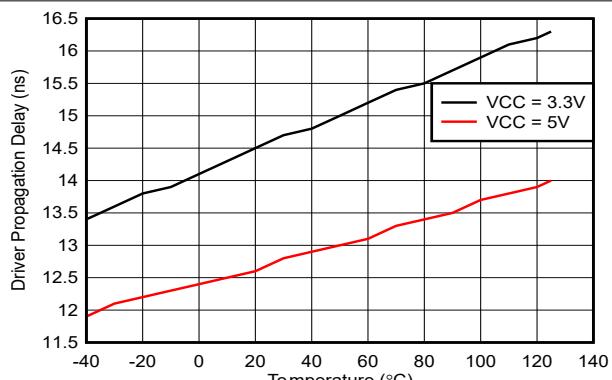


Figure 6-6. THVD2419 Supply Current vs Signal Rate

6.10 Typical Characteristics (continued)

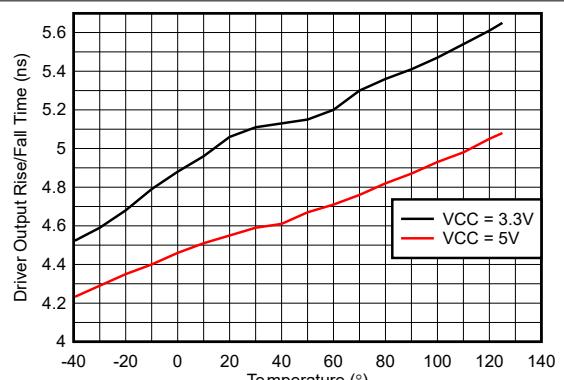


DE = V_{IO} or V_{CC}

$R_L = 50\Omega$

$C_L = 50\text{pF}$

Figure 6-7. THVD2429 Driver Propagation Delay vs Temperature

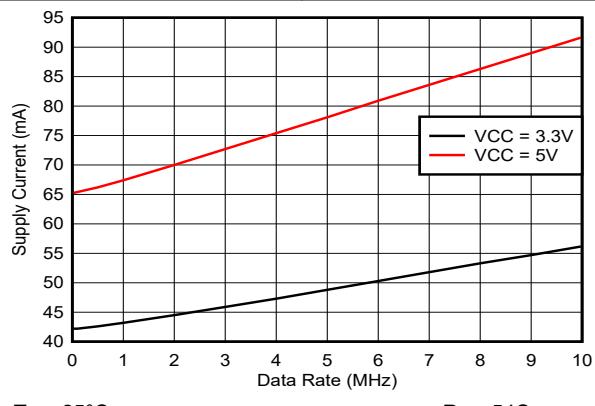


DE = V_{IO} or V_{CC}

$R_L = 50\Omega$

$C_L = 50\text{pF}$

Figure 6-8. THVD2429 Driver Rise or Fall Time vs Temperature



$T_A = 25^\circ\text{C}$

$R_L = 54\Omega$

Figure 6-9. THVD2429 Supply Current vs Signal Rate

7 Parameter Measurement Information

Note

Note: Digital input/output supply in the diagrams below could either be V_{CC} (devices without V_{IO} pin) or V_{IO} (devices with V_{IO} pin)

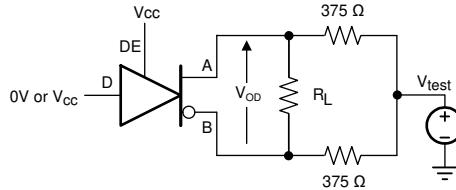


Figure 7-1. Measurement of Driver Differential Output Voltage With Common-Mode Load



Figure 7-2. Measurement of Driver Differential and Common-Mode Output With RS-485 Load

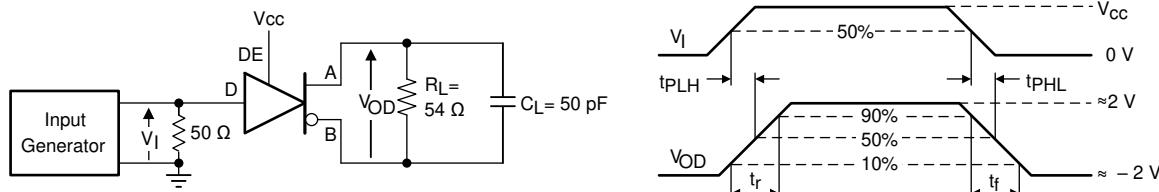


Figure 7-3. Measurement of Driver Differential Output Rise and Fall Times and Propagation Delays

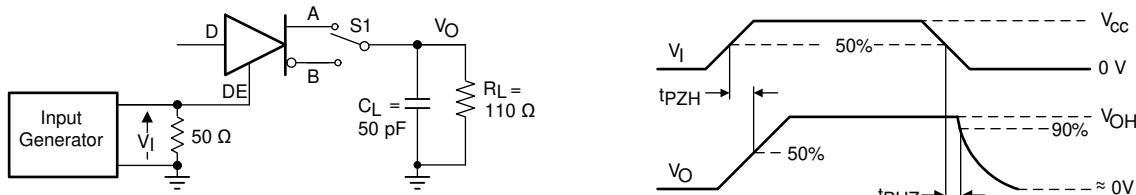


Figure 7-4. Measurement of Driver Enable and Disable Times With Active High Output and Pull-Down Load

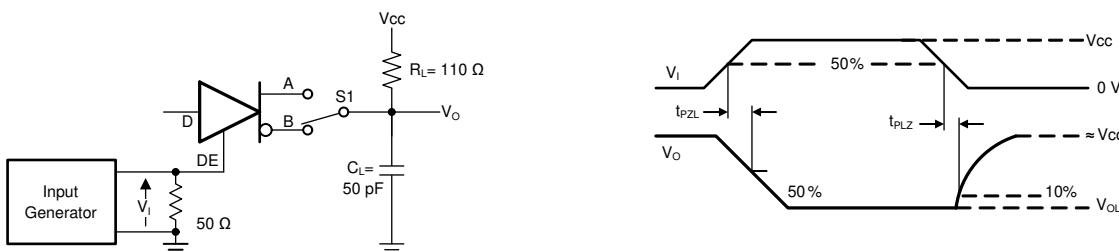


Figure 7-5. Measurement of Driver Enable and Disable Times With Active Low Output and Pull-up Load

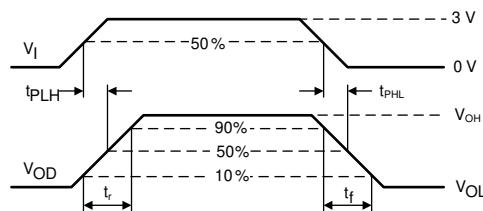
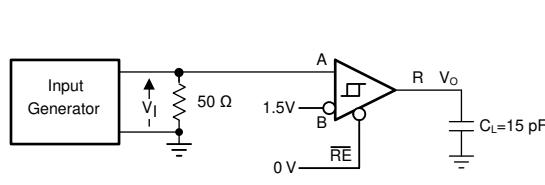


Figure 7-6. Measurement of Receiver Output Rise and Fall Times and Propagation Delays

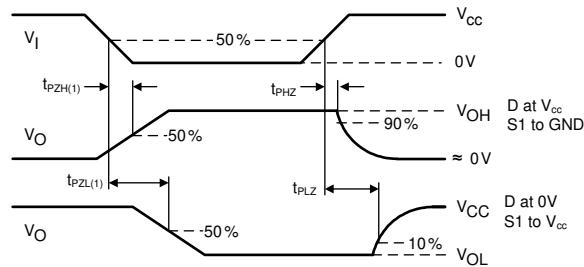
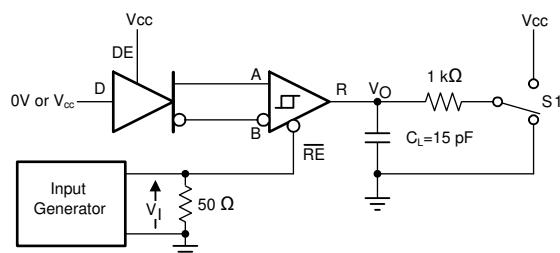


Figure 7-7. Measurement of Receiver Enable/Disable Times With Driver Enabled

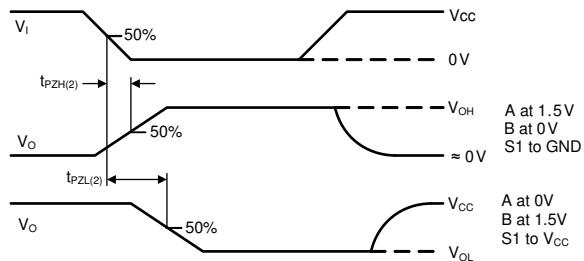
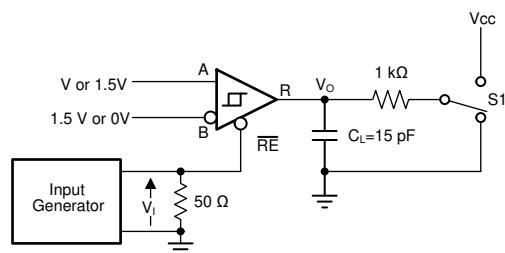
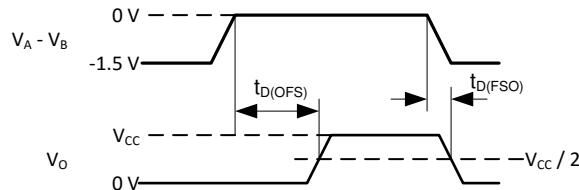
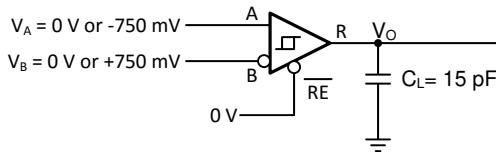


Figure 7-8. Measurement of Receiver Enable Times With Driver Disabled



Copyright © 2017, Texas Instruments Incorporated

Figure 7-9. Fail-Safe Delay Measurements

8 Detailed Description

8.1 Overview

THVD24x9 devices are surge-protected, half duplex RS-485 transceivers available in two speed grades suitable for data transmission up to 250kbps and 20Mbps respectively. Surge protection is achieved by integrating transient voltage suppressor (TVS) diodes in the standard 8-pin SOIC (D) package and a small 10-pin leadless package.

THVD2419 and THVD2429 devices have active-high driver enables and active-low receiver enables. A low standby current can be achieved by disabling both driver and receiver.

8.2 Functional Block Diagrams

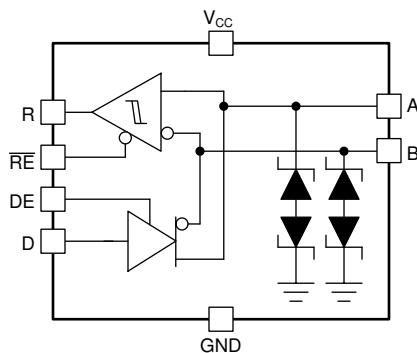


Figure 8-1. THVD2419 and THVD2429 Block Diagram (SOIC Package)

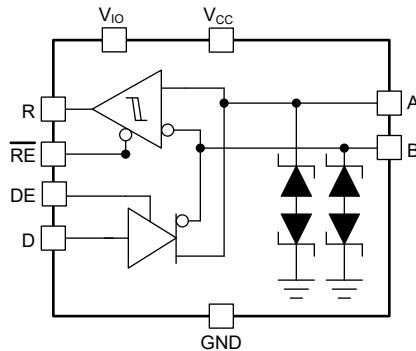


Figure 8-2. THVD2419 and THVD2429 Block Diagram (VSON Package)

8.3 Feature Description

8.3.1 Electrostatic Discharge (ESD) Protection

The bus pins of the THVD24x9 transceiver family include on-chip ESD protection against $\pm 15\text{kV}$ HBM and $\pm 8\text{kV}$ IEC 61000-4-2 contact discharge. The International Electrotechnical Commission (IEC) ESD test is far more severe than the HBM ESD test. The 50% higher charge capacitance, $C_{(S)}$, and 78% lower discharge resistance, $R_{(D)}$, of the IEC model produce significantly higher discharge currents than the HBM model. As stated in the IEC 61000-4-2 standard, contact discharge is the preferred transient protection test method.

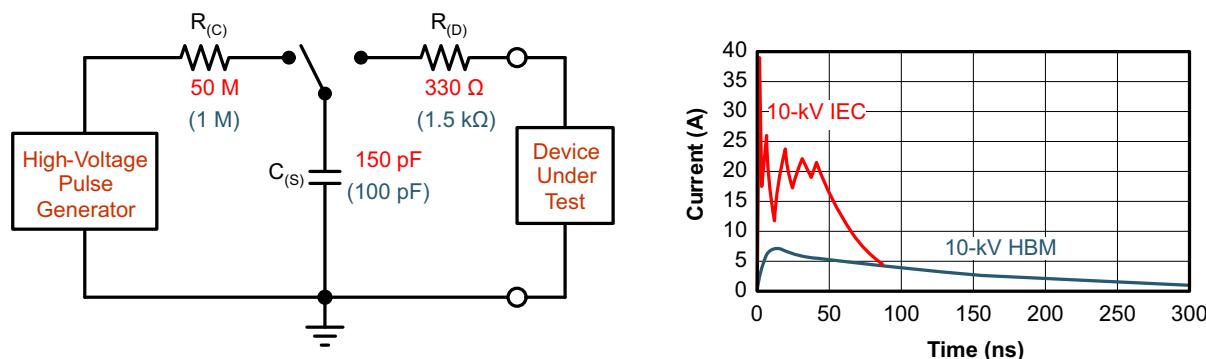


Figure 8-3. HBM and IEC ESD Models and Currents in Comparison (HBM Values in Parenthesis)

The on-chip implementation of IEC ESD protection significantly increases the robustness of equipment. Common discharge events occur because of human contact with connectors and cables.

8.3.2 Electrical Fast Transient (EFT) Protection

Inductive loads such as relays, switch contactors, or heavy-duty motors can create high-frequency bursts during transition. The IEC 61000-4-4 test is intended to simulate the transients created by such switching of inductive loads on AC power lines. Figure 8-4 shows the voltage waveforms in to 50Ω termination as defined by the IEC standard.

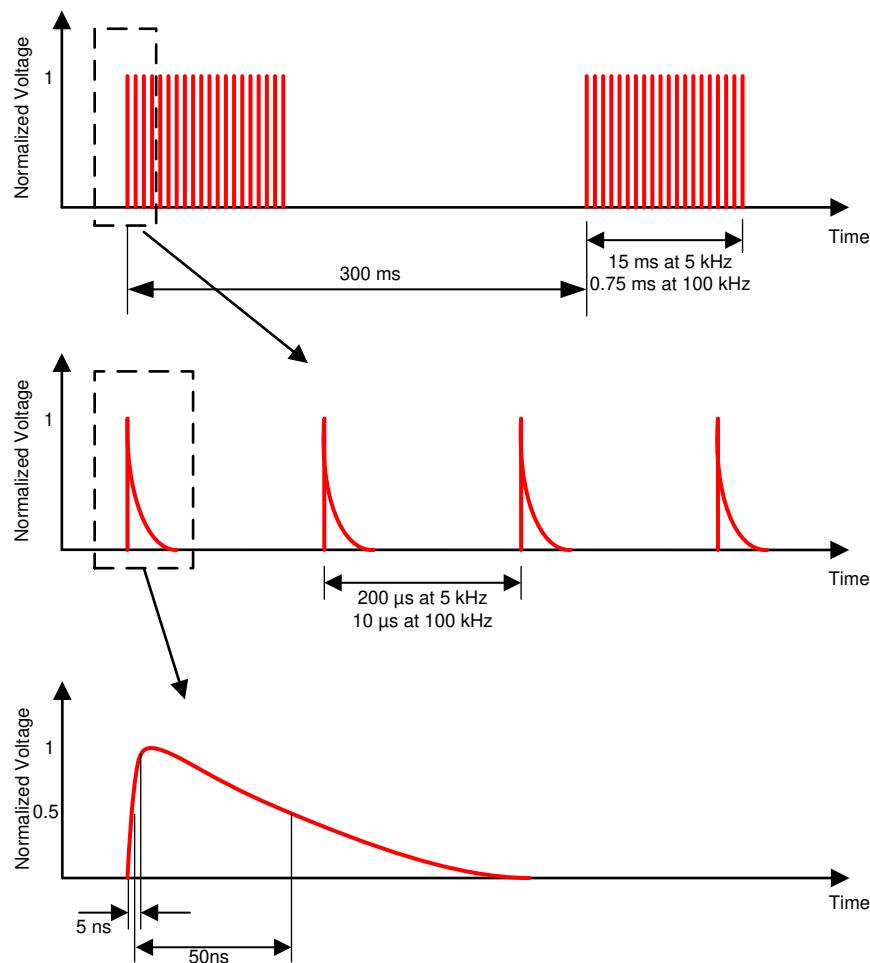


Figure 8-4. EFT Voltage Waveforms

Internal ESD protection circuits of the THVD24x9 protect the transceivers against $\pm 4\text{kV}$ EFT. With careful system design, one could achieve EFT Criterion A (no data loss when transient noise is present).

8.3.3 Surge Protection

Surge transients often result from lightning strikes (direct strike or an indirect strike which induce voltages and currents), or the switching of power systems, including load changes and short circuit switching. These transients are often encountered in industrial environments, such as factory automation and power-grid systems.

Figure 8-5 compares the pulse-power of the EFT and surge transients with the power caused by an IEC ESD transient. The diagram on the left shows the relative pulse-power for a 0.5kV surge transient and 4kV EFT transient, both of which dwarf the 10kV ESD transient visible in the lower-left corner. 500V surge transients are representative of events that may occur in factory environments in industrial and process automation.

The diagram on the right shows the pulse-power of a 6kV surge transient, relative to the same 0.5kV surge transient. 6kV surge transients are most likely to occur in power generation and power-grid systems.

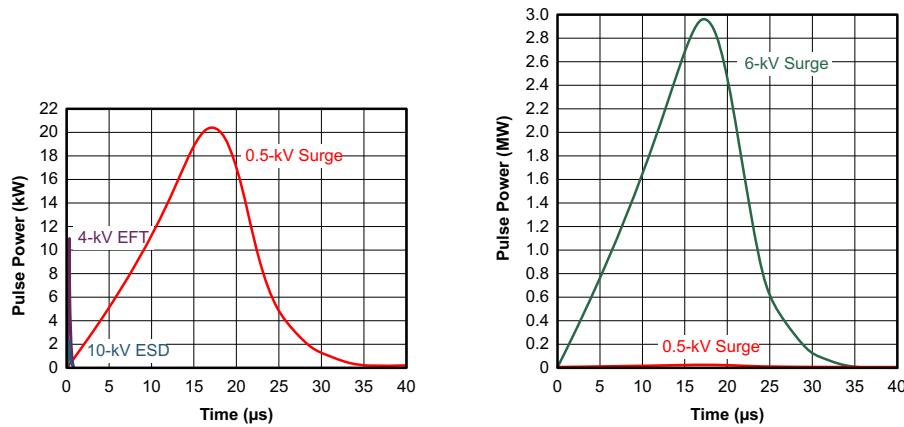


Figure 8-5. Power Comparison of ESD, EFT, and Surge Transients

Figure 8-6 shows the test setup used to validate THVD24x9 surge performance according to the IEC 61000-4-5 1.2/50μs surge pulse.

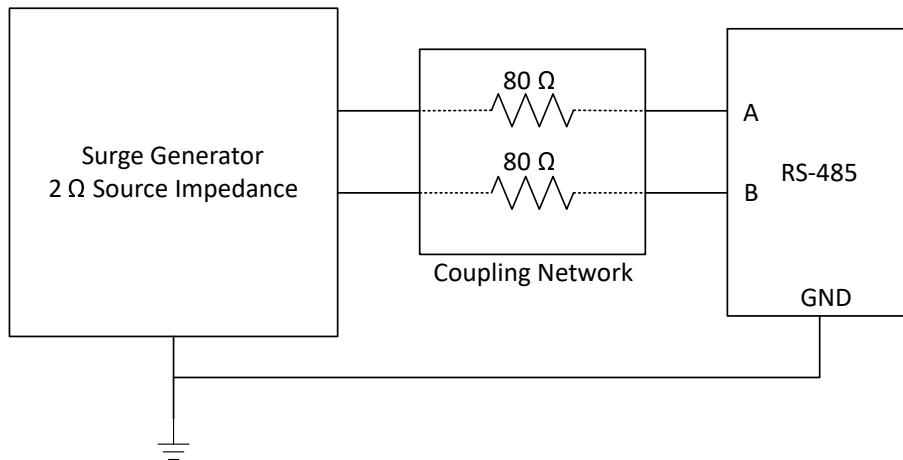


Figure 8-6. THVD24x9 Surge Test Setup

THVD24x9 product family is robust up to $\pm 3\text{kV}$ surge transients without the need for any external components. The bus pin voltage is clamped by the integrated surge protection diodes such that the internal circuitry is not damaged during the surge event.

8.3.4 Enhanced Receiver Noise Immunity

The differential receivers of THVD24x9 family feature fully symmetric thresholds to maintain duty cycle of the signal even with small input amplitudes. In addition, 250mV (typical) hysteresis displays excellent noise immunity.

8.3.5 Failsafe Receiver

The differential receivers of the THVD24x9 family are failsafe to invalid bus states caused by the following:

- Open bus conditions, such as a disconnected connector
- Shorted bus conditions, such as cable damage shorting the twisted-pair together
- Idle bus conditions that occur when no driver on the bus is actively driving

In any of these cases, the receiver outputs a fail-safe logic high state if the input amplitude stays for longer than $t_{D(OFS)}$ at less than $|V_{TH_FSH}|$.

8.4 Device Functional Modes

When the driver enable pin, DE, is logic high, the differential outputs A and B follow the logic states at data input D. A logic high at D causes A to turn high and B to turn low. The differential output voltage defined as $V_{OD} = V_A - V_B$ is positive. When D is low, the output states reverse: B turns high, A becomes low, and V_{OD} is negative.

When DE is low, both outputs turn high-impedance. In this condition the logic state at D is irrelevant. The DE pin has an internal pull-down resistor to ground. When left open the driver is disabled (high-impedance) by default. The D pin has an internal pull-up resistor to V_{CC} ; thus, when left open while the driver is enabled, output A turns high and B turns low.

Table 8-1. Driver Function Table

INPUT	ENABLE	OUTPUTS		FUNCTION
		A	B	
H	H	H	L	Actively drive bus high
L	H	L	H	Actively drive bus low
X	L	Z	Z	Driver disabled
X	OPEN	Z	Z	Driver disabled by default
OPEN	H	H	L	Actively drive bus high by default

When the receiver enable pin, \overline{RE} , is logic low, the receiver is enabled. When the differential input voltage defined as $V_{ID} = V_A - V_B$ is higher than the positive input threshold, V_{TH+} , the receiver output, R, turns high. When V_{ID} is lower than the negative input threshold, V_{TH-} , the receiver output, R, turns low. If V_{ID} is between V_{TH+} and V_{TH-} the output is indeterminate.

When \overline{RE} is logic high or left open, the receiver output is high-impedance and the magnitude and polarity of V_{ID} are irrelevant. Internal biasing of the receiver inputs causes the output to go failsafe-high when the transceiver is disconnected from the bus (open-circuit), the bus lines are shorted to one another (short-circuit), or the bus is not actively driven (idle bus).

Table 8-2. Receiver Function Table

DIFFERENTIAL INPUT	ENABLE	OUTPUT	FUNCTION
$V_{ID} = V_A - V_B$	\overline{RE}	R	
$V_{TH+} < V_{ID}$	L	H	Receive valid bus high
$V_{TH-} < V_{ID} < V_{TH+}$	L	Indeterminate	Indeterminate bus state
$V_{ID} < V_{TH-}$	L	L	Receive valid bus low
X	H	Z	Receiver disabled
X	OPEN	Z	Receiver disabled by default
Open-circuit bus	L	H	Fail-safe high output
Short-circuit bus	L	H	Fail-safe high output
Idle (terminated) bus	L	H	Fail-safe high output

9 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.

9.1 Application Information

THVD24x9 are half-duplex RS-485 transceivers with integrated system-level surge protection. Standard 8-pin SOIC (D) package allows drop-in replacement into existing systems and eliminate system-level protection components.

9.2 Typical Application

An RS-485 bus consists of multiple transceivers connecting in parallel to a bus cable. To eliminate line reflections, each cable end is terminated with a termination resistor, R_T , with a value that matches the characteristic impedance, Z_0 , of the cable. This method, known as parallel termination, allows for higher data rates over longer cable length.

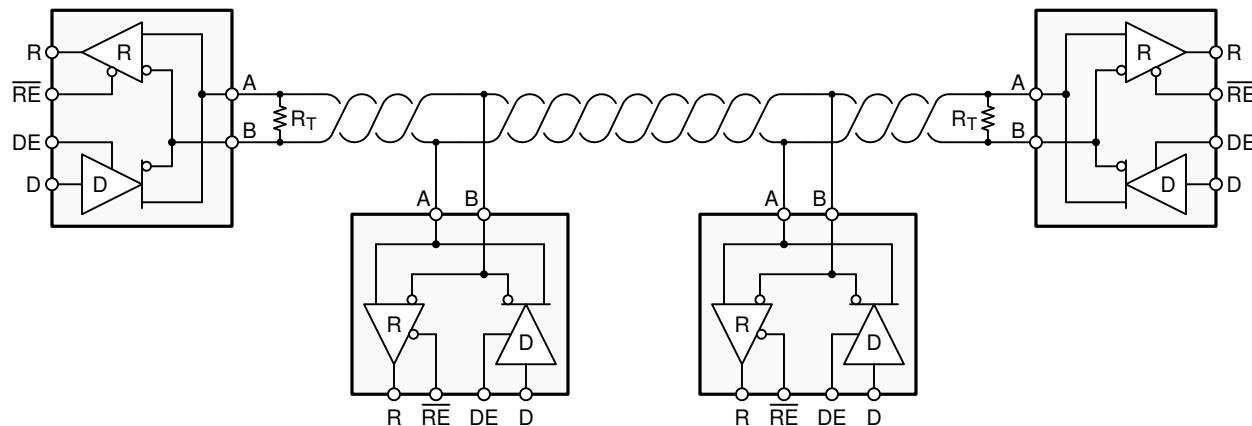


Figure 9-1. Typical RS-485 Network With Half-Duplex Transceivers

9.2.1 Design Requirements

RS-485 is a robust electrical standard suitable for long-distance networking that may be used in a wide range of applications with varying requirements, such as distance, data rate, and number of nodes.

9.2.1.1 Data Rate and Bus Length

There is an inverse relationship between data rate and cable length, which means the higher the data rate, the shorter the cable length; and conversely, the lower the data rate, the longer the cable length. While most RS-485 systems use data rates between 10kbps and 100kbps, some applications require data rates up to 250kbps at distances of 4000 feet and longer. Longer distances are possible by allowing for small signal jitter of up to 5 or 10%.

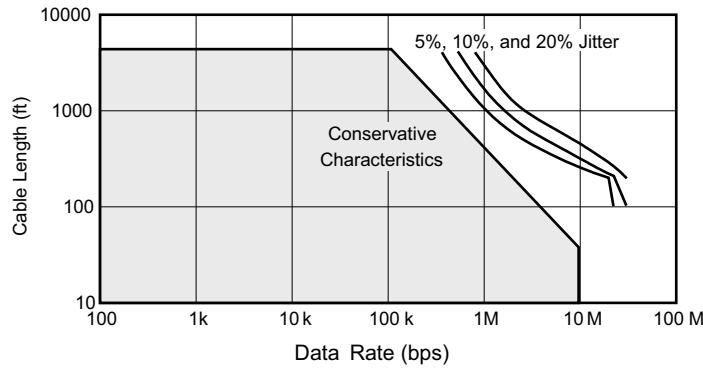


Figure 9-2. Cable Length vs Data Rate Characteristic

Even higher data rates are achievable (that is, 20Mbps for the THVD2429) in cases where the interconnect is short enough (or has suitably low attenuation at signal frequencies) to not degrade the data.

9.2.1.2 Stub Length

When connecting a node to the bus, the distance between the transceiver inputs and the cable trunk, known as the stub, should be as short as possible. Stubs present a non-terminated piece of bus line which can introduce reflections as the length of the stub increases. As a general guideline, the electrical length, or round-trip delay, of a stub should be less than one-tenth of the rise time of the driver, thus giving a maximum physical stub length as shown in [Equation 1](#).

$$L_{(STUB)} \leq 0.1 \times t_r \times v \times c \quad (1)$$

where

- t_r is the 10/90 rise time of the driver
- c is the speed of light (3×10^8 m/s)
- v is the signal velocity of the cable or trace as a factor of c

9.2.1.3 Bus Loading

The RS-485 standard specifies that a compliant driver must be able to drive 32 unit loads (UL), where 1 unit load represents a load impedance of approximately $12\text{k}\Omega$. Because the THVD24x9 devices consist of 1/8 UL transceivers, connecting up to 256 receivers to the bus is possible.

9.2.2 Detailed Design Procedure

RS-485 transceivers operate in noisy industrial environments typically require surge protection at the bus pins. Figure 9-3 compares the surge protection implementation with a regular RS-485 transceiver (a), against that with a surge-integrated RS-485 transceiver (b), such as the THVD24x9 family. The internal TVS protection of the THVD24x9 achieves up to $\pm 3\text{kV}$ IEC 61000-4-5 surge protection (SOIC package) without any additional external components, reducing system level bill of materials.

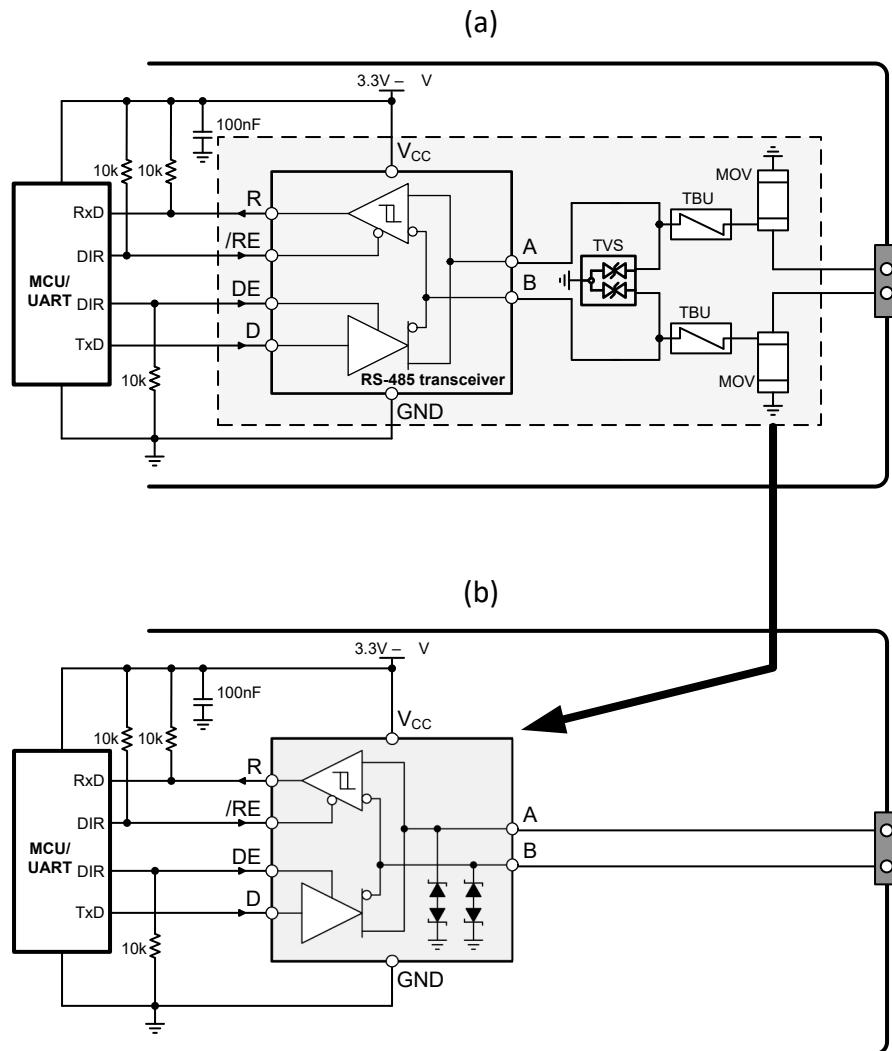
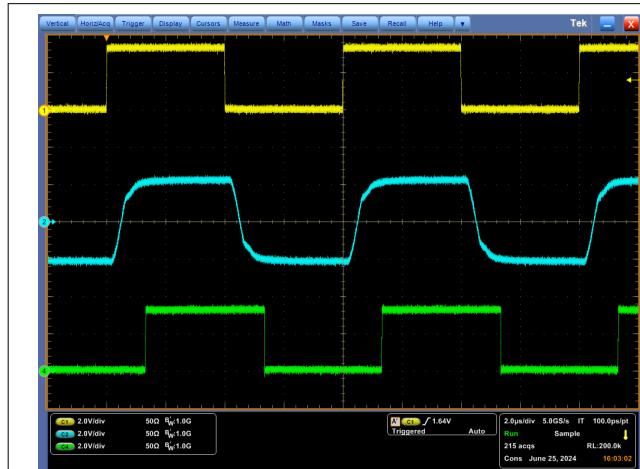


Figure 9-3. Implementation of System-Level Surge Protection Using THVD24x9

9.2.3 Application Curves



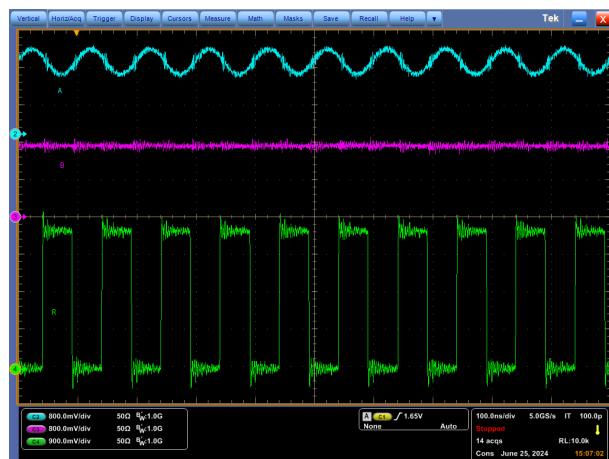
Ch 1: D Input, Ch2: V_A Ch3: V_B Ch4: R $V_{CC} = 3.3V$
 Output Data rate: 20Mbps

Figure 9-4. THVD2419 Waveforms with 54Ω Termination and $V_{CC} = 3.3V$



Ch 1: D Input, Ch2: V_A Ch3: V_B Ch4: R $V_{CC} = 3.3V$
 Output Data rate: 20Mbps

Figure 9-5. THVD2429 Waveforms with 54Ω Termination and $V_{CC} = 3.3V$



Ch 2: Input A ($\pm 200mV$ sine input over 1.5V DC offset)

Ch 3: Input B (1.5V)

Ch 4: Output R

Figure 9-6. THVD2429 Receiver Waveform with $\pm 200mV$ V_{ID}

9.3 Power Supply Recommendations

For reliable operation at all data rates and supply voltages, each supply should be decoupled with a 100nF ceramic capacitor located as close to the supply pins as possible. This helps to reduce supply voltage ripple present on the outputs of switched-mode power supplies and also helps to compensate for the resistance and inductance of the PCB power planes.

9.4 Layout

9.4.1 Layout Guidelines

Additional external protection components generally are not needed when using THVD24x9 transceivers.

1. Use V_{CC}/V_{IO} and ground planes to provide low-inductance. Note that high-frequency currents tend to follow the path of least impedance and not the path of least resistance. Apply 100nF to 220nF decoupling capacitors as close as possible to the V_{CC}/V_{IO} pins of transceiver, UART and/or controller ICs on the board.
2. Use at least two vias for V_{CC}/V_{IO} and ground connections of decoupling capacitors to minimize effective via inductance.
3. Use 1k Ω to 10k Ω pull-up and pull-down resistors for enable lines to limit noise currents in these lines during transient events.

9.4.2 Layout Example

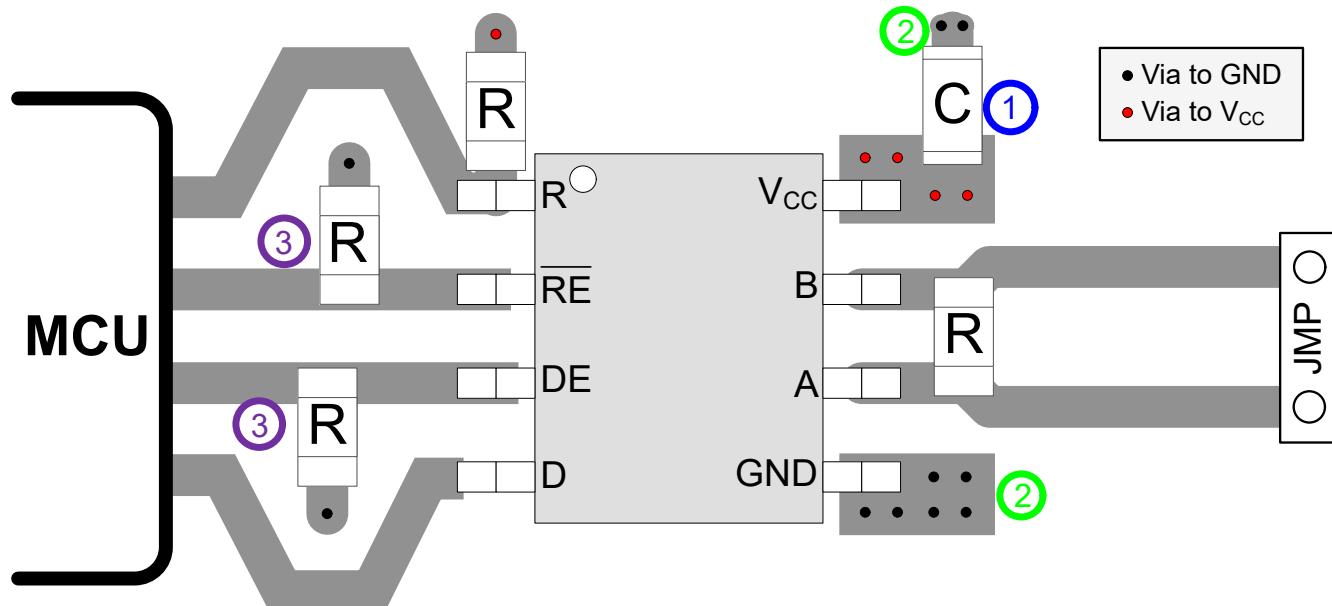


Figure 9-7. THVD2419, THVD2429 Layout Example (SOIC Package)

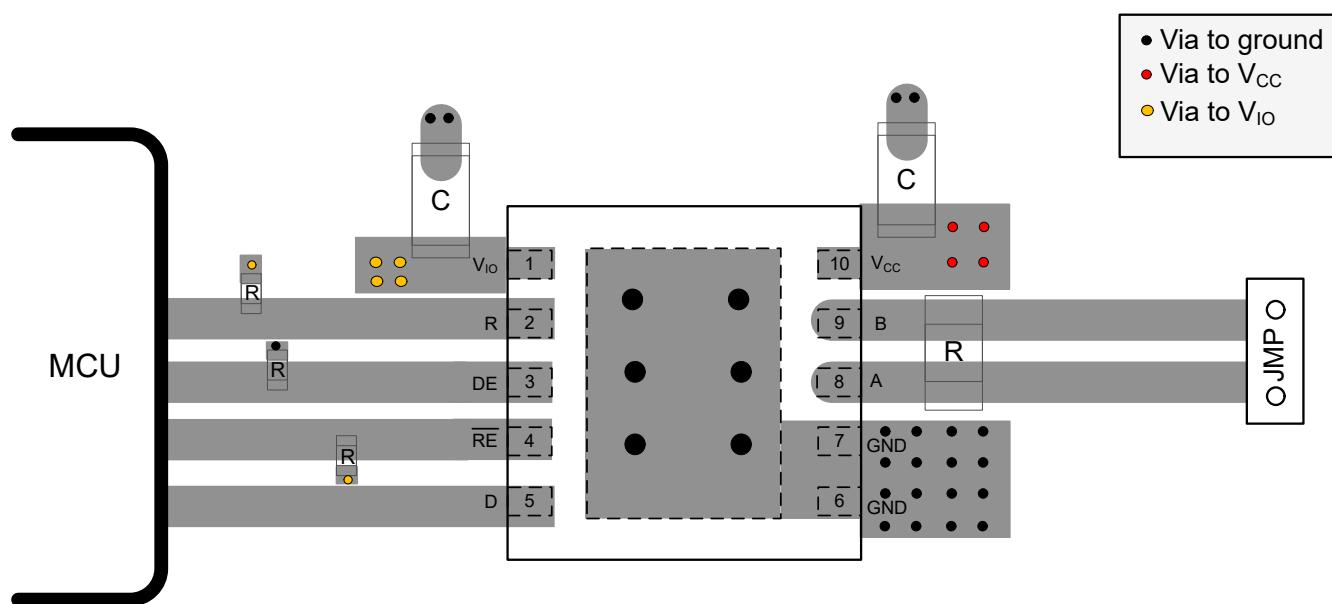


Figure 9-8. THVD2419, THVD2429 Layout Example (VSON Package)

10 Device and Documentation Support

10.1 Device Support

10.2 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.

10.3 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](#).

10.4 Trademarks

TI E2E™ is a trademark of Texas Instruments.

All trademarks are the property of their respective owners.

10.5 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.

10.6 Glossary

[TI Glossary](#)

This glossary lists and explains terms, acronyms, and definitions.

11 Revision History

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

Changes from Revision * (January 2024) to Revision A (August 2024)	Page
• Changed the document from Advanced Information to <i>Production</i> data.....	1

12 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)
THVD2419DR	Active	Production	SOIC (D) 8	2500 LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	TV2419 D2419
THVD2419DR.A	Active	Production	SOIC (D) 8	2500 LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	TV2419 D2419
THVD2419DRCR	Active	Production	VSON (DRC) 10	5000 LARGE T&R	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 125	T2419
THVD2419DRCR.A	Active	Production	VSON (DRC) 10	5000 LARGE T&R	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 125	T2419
THVD2429DR	Active	Production	SOIC (D) 8	2500 LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	TV2429 D2429
THVD2429DR.A	Active	Production	SOIC (D) 8	2500 LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	TV2429 D2429
THVD2429DRCR	Active	Production	VSON (DRC) 10	5000 LARGE T&R	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 125	T2429
THVD2429DRCR.A	Active	Production	VSON (DRC) 10	5000 LARGE T&R	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 125	T2429

⁽¹⁾ **Status:** For more details on status, see our [product life cycle](#).

⁽²⁾ **Material type:** When designated, preproduction parts are prototypes/experimental devices, and are not yet approved or released for full production. Testing and final process, including without limitation quality assurance, reliability performance testing, and/or process qualification, may not yet be complete, and this item is subject to further changes or possible discontinuation. If available for ordering, purchases will be subject to an additional waiver at checkout, and are intended for early internal evaluation purposes only. These items are sold without warranties of any kind.

⁽³⁾ **RoHS values:** Yes, No, RoHS Exempt. See the [TI RoHS Statement](#) for additional information and value definition.

⁽⁴⁾ **Lead finish/Ball material:** Parts may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.

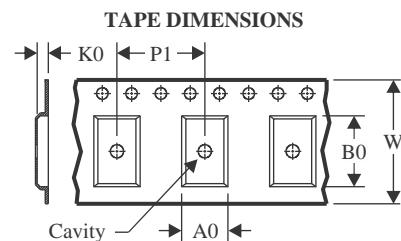
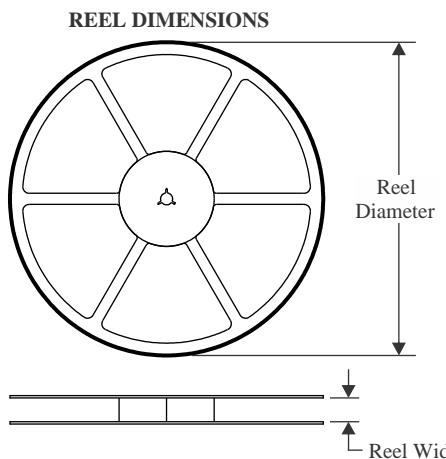
⁽⁵⁾ **MSL rating/Peak reflow:** The moisture sensitivity level ratings and peak solder (reflow) temperatures. In the event that a part has multiple moisture sensitivity ratings, only the lowest level per JEDEC standards is shown. Refer to the shipping label for the actual reflow temperature that will be used to mount the part to the printed circuit board.

⁽⁶⁾ **Part marking:** There may be an additional marking, which relates to the logo, the lot trace code information, or the environmental category of the part.

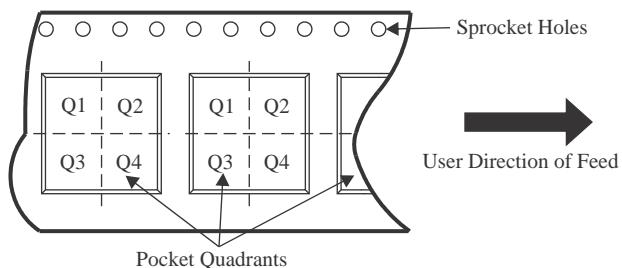
Multiple part markings will be inside parentheses. Only one part marking contained in parentheses and separated by a "~" will appear on a part. If a line is indented then it is a continuation of the previous line and the two combined represent the entire part marking for that device.

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

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

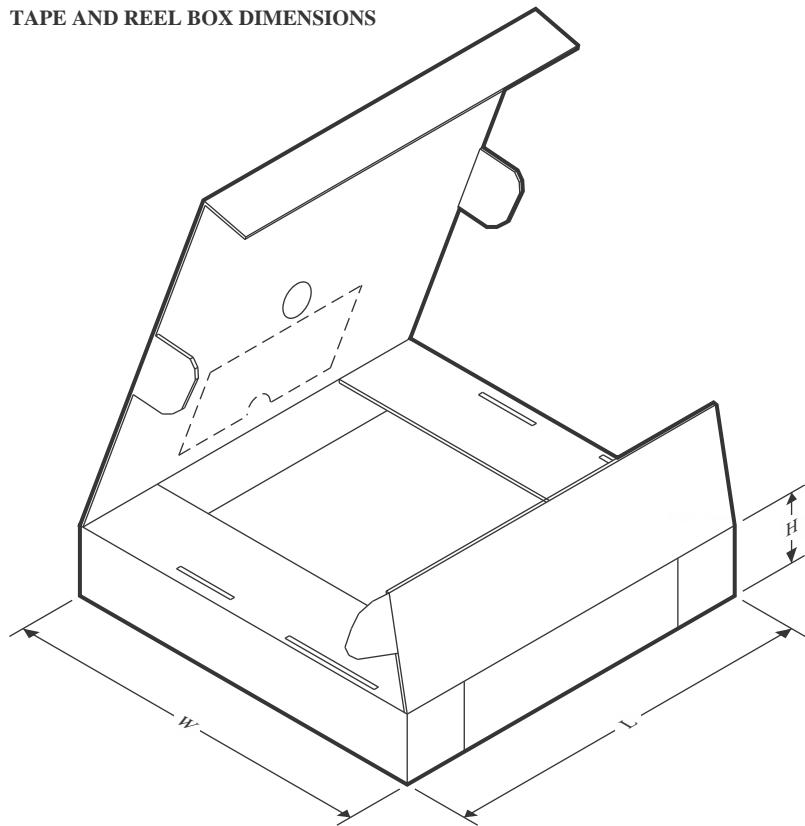
TAPE AND REEL INFORMATION


A0	Dimension designed to accommodate the component width
B0	Dimension designed to accommodate the component length
K0	Dimension designed to accommodate the component thickness
W	Overall width of the carrier tape
P1	Pitch between successive cavity centers

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
THVD2419DR	SOIC	D	8	2500	330.0	12.4	6.4	5.2	2.1	8.0	12.0	Q1
THVD2419DRCR	VSON	DRC	10	5000	330.0	12.4	3.3	3.3	1.1	8.0	12.0	Q2
THVD2429DR	SOIC	D	8	2500	330.0	12.4	6.4	5.2	2.1	8.0	12.0	Q1
THVD2429DRCR	VSON	DRC	10	5000	330.0	12.4	3.3	3.3	1.1	8.0	12.0	Q2

TAPE AND REEL BOX DIMENSIONS


*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
THVD2419DR	SOIC	D	8	2500	353.0	353.0	32.0
THVD2419DRCR	VSON	DRC	10	5000	367.0	367.0	35.0
THVD2429DR	SOIC	D	8	2500	353.0	353.0	32.0
THVD2429DRCR	VSON	DRC	10	5000	367.0	367.0	35.0

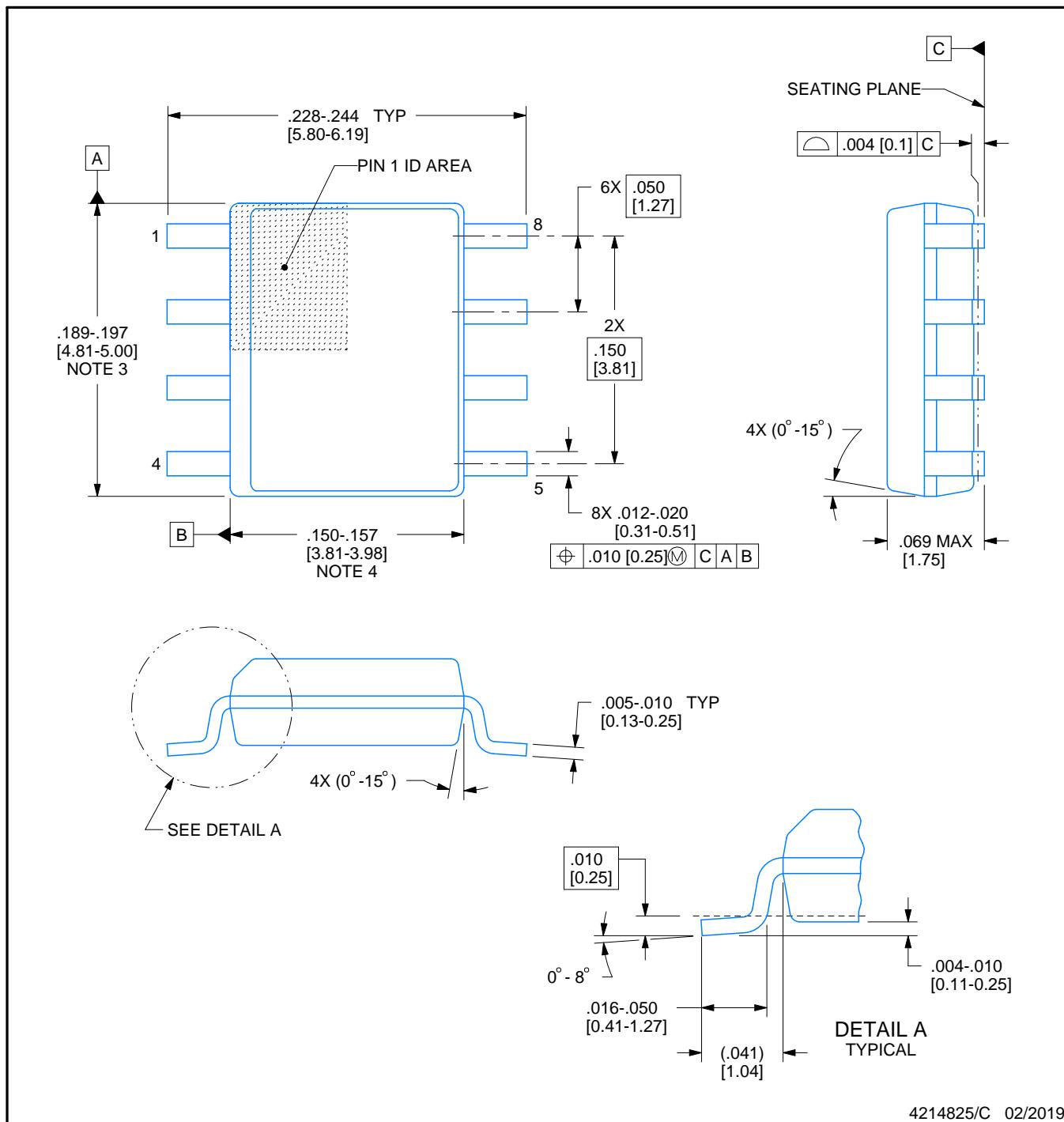


PACKAGE OUTLINE

D0008A

SOIC - 1.75 mm max height

SMALL OUTLINE INTEGRATED CIRCUIT



4214825/C 02/2019

NOTES:

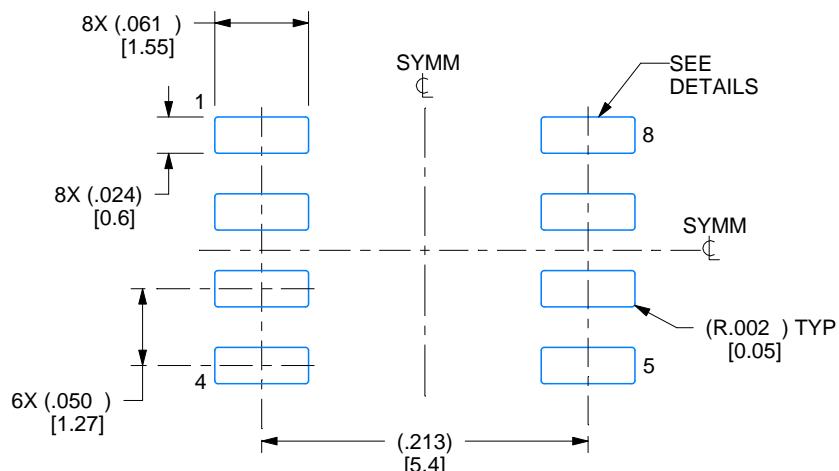
1. Linear dimensions are in inches [millimeters]. Dimensions in parenthesis are for reference only. Controlling dimensions are in inches. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed .006 [0.15] per side.
4. This dimension does not include interlead flash.
5. Reference JEDEC registration MS-012, variation AA.

EXAMPLE BOARD LAYOUT

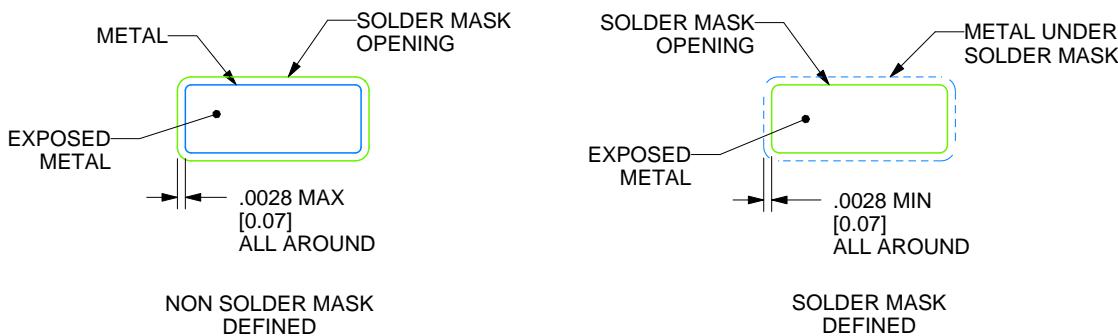
D0008A

SOIC - 1.75 mm max height

SMALL OUTLINE INTEGRATED CIRCUIT



LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE:8X



SOLDER MASK DETAILS

4214825/C 02/2019

NOTES: (continued)

6. Publication IPC-7351 may have alternate designs.

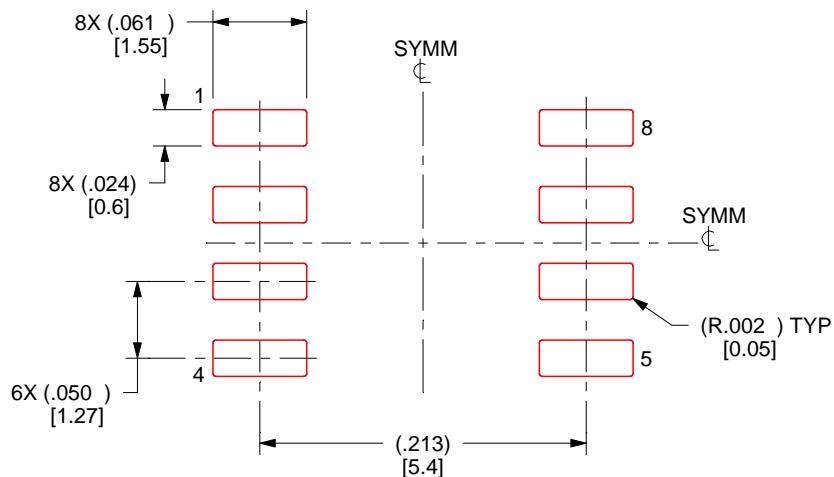
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.

EXAMPLE STENCIL DESIGN

D0008A

SOIC - 1.75 mm max height

SMALL OUTLINE INTEGRATED CIRCUIT



SOLDER PASTE EXAMPLE
BASED ON .005 INCH [0.125 MM] THICK STENCIL
SCALE:8X

4214825/C 02/2019

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.

GENERIC PACKAGE VIEW

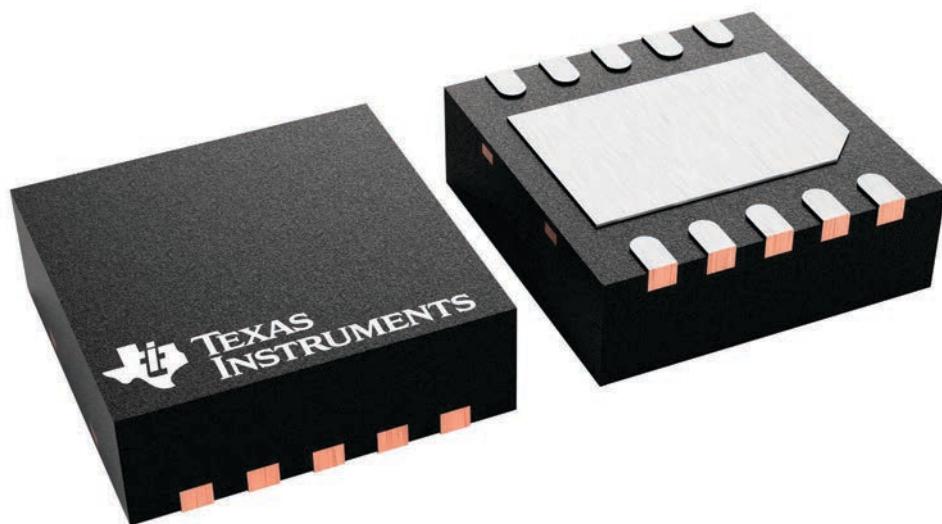
DRC 10

VSON - 1 mm max height

3 x 3, 0.5 mm pitch

PLASTIC SMALL OUTLINE - NO LEAD

This image is a representation of the package family, actual package may vary.
Refer to the product data sheet for package details.



4226193/A

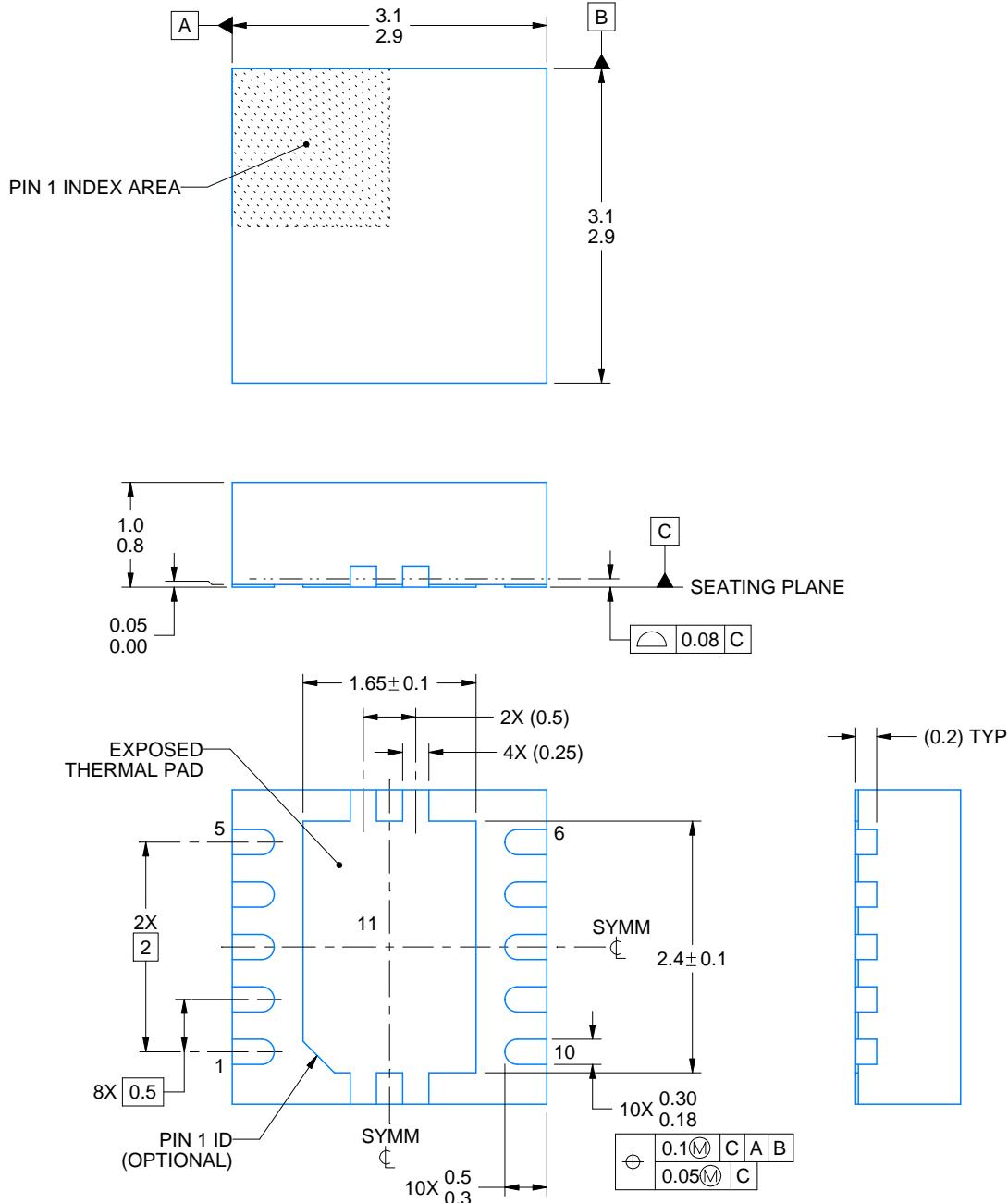
DRC0010J



PACKAGE OUTLINE

VSON - 1 mm max height

PLASTIC SMALL OUTLINE - NO LEAD



4218878/B 07/2018

NOTES:

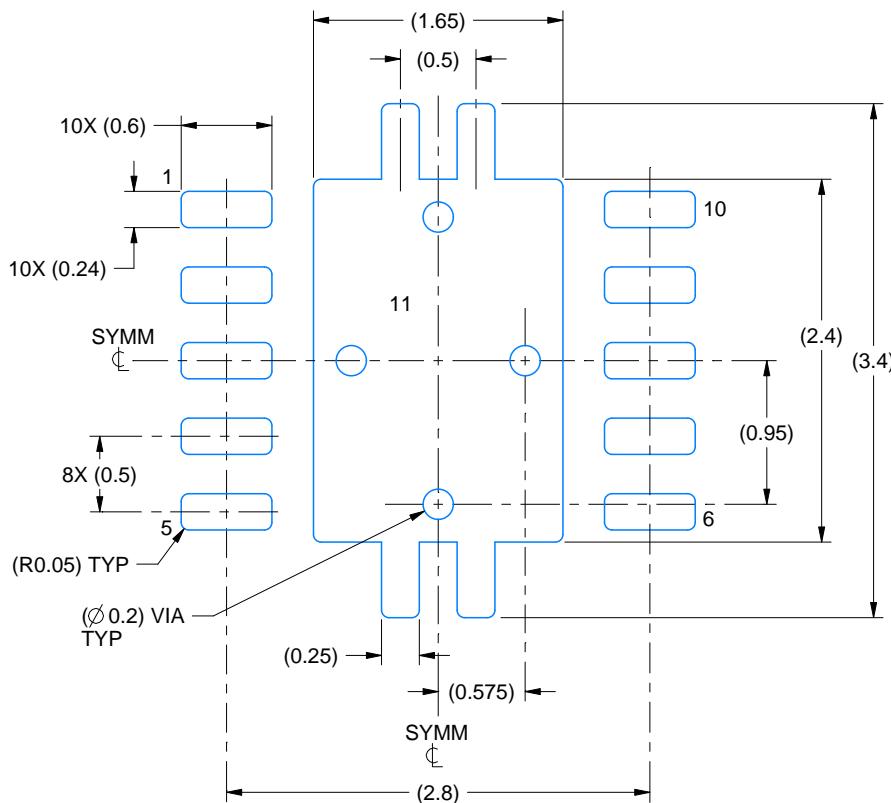
1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. The package thermal pad must be soldered to the printed circuit board for optimal thermal and mechanical performance.

EXAMPLE BOARD LAYOUT

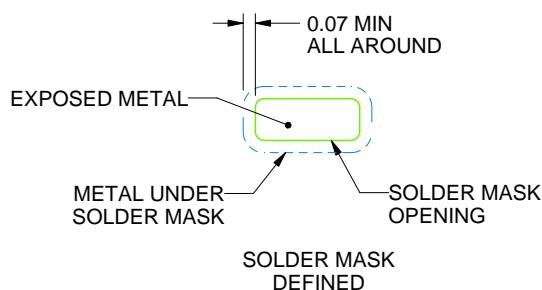
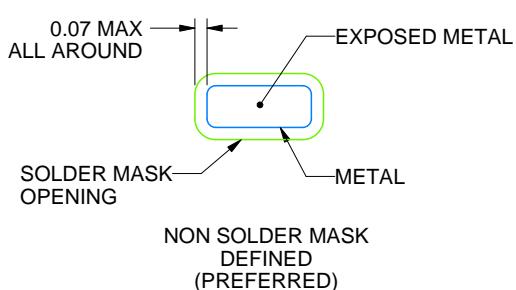
DRC0010J

VSON - 1 mm max height

PLASTIC SMALL OUTLINE - NO LEAD



LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE:20X



SOLDER MASK DETAILS

4218878/B 07/2018

NOTES: (continued)

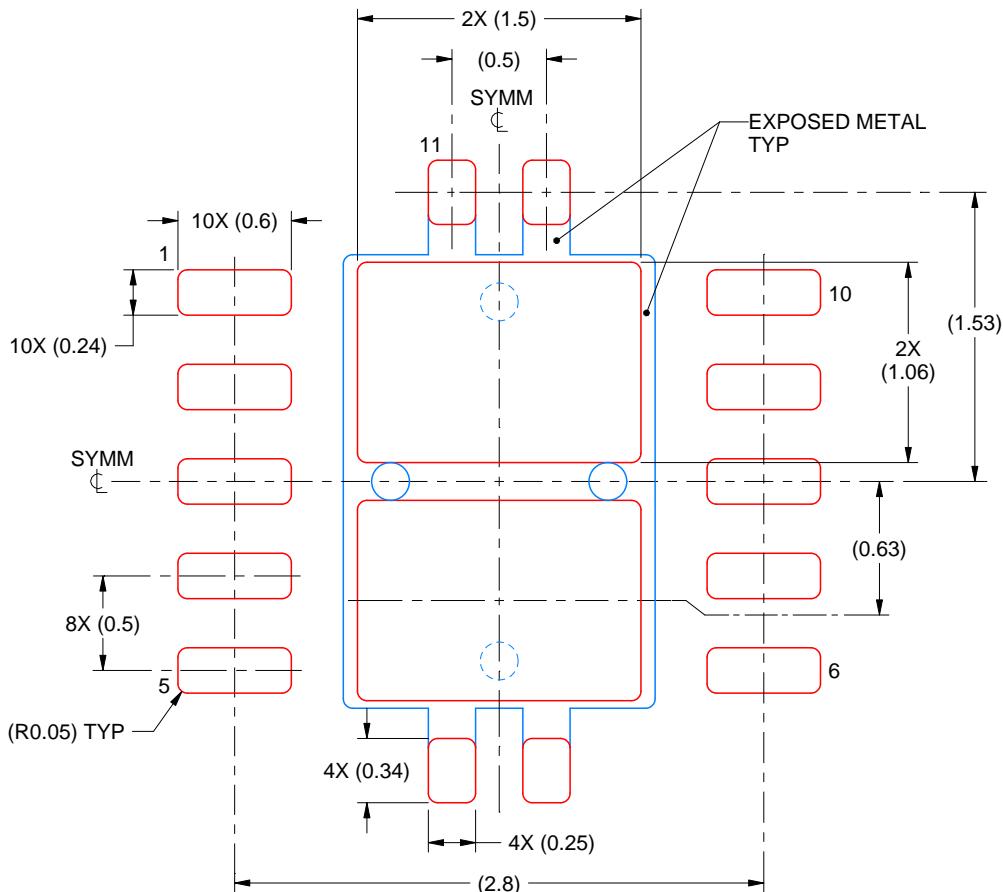
4. This package is designed to be soldered to a thermal pad on the board. For more information, see Texas Instruments literature number SLUA271 (www.ti.com/lit/slua271).
5. Vias are optional depending on application, refer to device data sheet. If any vias are implemented, refer to their locations shown on this view. It is recommended that vias under paste be filled, plugged or tented.

EXAMPLE STENCIL DESIGN

DRC0010J

VSON - 1 mm max height

PLASTIC SMALL OUTLINE - NO LEAD



SOLDER PASTE EXAMPLE
BASED ON 0.125 mm THICK STENCIL

EXPOSED PAD 11:
80% PRINTED SOLDER COVERAGE BY AREA
SCALE:25X

4218878/B 07/2018

NOTES: (continued)

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

IMPORTANT NOTICE AND DISCLAIMER

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

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

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

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

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

Copyright © 2026, Texas Instruments Incorporated

Last updated 10/2025