







THVD2419, THVD2429 SLLSFP5A - JANUARY 2024 - REVISED AUGUST 2024

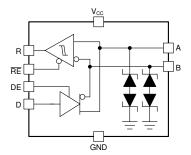
THVD24x9 3V to 5.5V RS-485 Transceivers With Integrated Surge and High Bus-Fault **Protection in Small Packages**

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

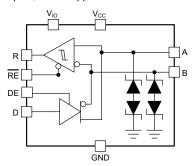
THVD24x9 devices are half-duplex RS-485 transceivers with integrated surge protection. Surge protection is achieved by integrating transient voltage suppressor (TVS) diodes in the standard 8-pin SOIC (D) package as well as small 10-pin VSON package. This feature increases the reliability by providing 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
THVD2429	VSON (10)	3mm × 3mm

- For more information, see Section 12.
- The package size (length × width) is a nominal value and includes pins, where applicable.



THVD24x9 Block Diagram (VSON Package)



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4 Device Comparison Table

PART NUMBER	PACKAGE	V _{IO}	SIGNALING RATE	NODES
THVD2419	SOIC-8	No	up to 250kbps	
THVD2429	5010-0	No	up to 20Mbps	256
THVD2419	VSON-10	Yes	up to 250kbps	250
THVD2429	V30N-10	165	up to 20Mbps	



5 Pin Configuration and Functions

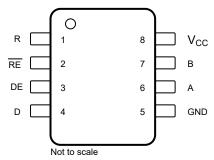


Figure 5-1. THVD2419, THVD2429, 8-Pin (SOIC) (Top View)

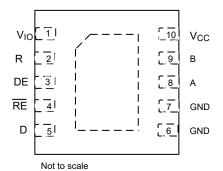


Figure 5-2. THVD2419, THVD2429, 10-Pin (VSON) (Top View)

	PIN		TYPE	DESCRIPTION	
NAME	SOIC-8	VSON-10	ITPE	DESCRIPTION	
V _{IO}	-	1	Р	1.8V to 5V supply for R, D, and RE and DE	
R	1	2	0	Receiver data output	
RE	2	4	I	Receiver enable, active low (integrated pull-up)	
DE	3	3	ı	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)	
В	7	9	I/O	Bus I/O port, B (complementary to A)	
V _{CC}	8	10	Р	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 $\overline{\text{RE}}$) 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	lo	-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
		Human-body model (HBM), per ANSI/ESDA/	Bus terminals and GND	±16,000	V
V _(ESD)	Electrostatic discharge	JEDEC JS-001 ⁽¹⁾	All pins except bus terminals and GND	±16,000 ±4,000	V
		Charged-device model (CDM), per JEDEC specific	±1,500	V	

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

6.3 ESD Ratings - IEC Specifications

				VALUE	UNIT
\ <u>\</u>	/(ESD) Electrostatic discharge, bus terminals	Contact discharge, per IEC 61000-4-2 (1)	Bus terminals and GND	±8,000	V
V (ESD)		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	٧
V _(SURGE)	Surge	Per IEC 61000-4-5, 1.2/50-8/20μs CWG (D Package)	Bus terminals and GND	±3,000	V

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

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



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	I/O supply voltage (devices with VIO pin) High-level input voltage (D. DE RE)			V _{CC}	V
V _{IH}	High-level input voltage (D, DE, RE)	viere with MO min	0.7		1	V _{IO}
V _{IL}	Low-level input voltage (D, DE, RE)	devices with VIO pin	0		0.3	V _{IO}
V _{IH}	High-level input voltage (D, DE, RE)	diib4\/10 -i-	0.7		1	V _{CC}
V _{IL}	Low-level input voltage (D, DE, RE)	vices without VIO pin	0		0.3	V _{CC}
VI	Input voltage at any bus terminal (separately or common mode)(1)		-25		25	V
V _{ID}	Differential input voltage		-25		25	V
Io	Output current, driver	Output current, driver			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
4.4	Cinnalia a nata	THVD2419			250	kbps
1/t _{UI}	Signaling rate	THVD2429			20	Mbps
T _A	Operating ambient temperature	,	-40		125	°C
TJ	Junction temperature		-40	,	150	°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

			THVD2419, THVD2429		
	THERMAL METRIC ⁽¹⁾	DRC (VSON)	D (SOIC)	UNIT	
		10 PINS	8 PINS		
$R_{\theta JA}$	Junction-to-ambient thermal resistance	65.2	117.2	°C/W	
R _{0JC(top)}	Junction-to-case (top) thermal resistance	41.7	40.2	°C/W	
R _{0JB}	Junction-to-board thermal resistance	36.4	65.3	°C/W	
ΨЈТ	Junction-to-top characterization parameter	1.4	3.3	°C/W	
ΨЈВ	Junction-to-board characterization parameter	36.3	64.4	°C/W	
R _{0JC(bot)}	Junction-to-case (bottom) thermal resistance	24.9	N/A	°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 CON	TEST CONDITIONS			UNIT
	Unterminated	THVD2419	250kbps	180	mW	
		$R_L = 300\Omega$, $C_L = 50pF$ (driver)	THVD2429	20Mbps	310	IIIVV
	Driver and receiver enabled,	RS-422 load	THVD2419	250kbps	180	ma\A/
PD	P_D $V_{CC} = 5.5 \text{ V}, T_A = 125 ^{\circ}\text{C},$ square wave at 50% duty cycle	$R_L = 100\Omega$, $C_L = 50pF$ (driver)	THVD2429	20Mbps	310	- mW
		RS-485 load	THVD2419	250kbps	270	ma\A/
		$R_L = 54\Omega$, $C_L = 50pF$ (driver)	THVD2429	20Mbps	325	mW



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							
		$R_L = 60\Omega$, $-25V \le V_{test} \le 25V$ (See Figure 7-1)		1.5	2.8		V
	Driver differential output	$R_L = 60\Omega$, $-25V \le V_{test} \le 25V$, $4.5V \le V_{CC} \le 5.5V$ (See	2.1	3.3		V	
V _{OD}	voltage magnitude	$R_L = 100\Omega$ (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			-50		50	mV
V _{OC}	Common-mode output voltage	R_L = 54Ω or 100Ω (See Figure 7-2)		1	V _{CC} /2	3	V
$\Delta V_{OC(SS)}$	Change in steady-state common-mode output voltage			-50		50	mV
Ios	Short-circuit output current	DE = V _{IO} , -42V ≤ (V _A or V _B) ≤42 V, or A shorted to B	1	-250		250	mA
Receiver							
			V _I = 12V		90	125	μA
L	Puo input aurent	DE = 0\/ \/ \ and \/ \ = 0\/ ar 5 5\/	V _I = 25V		200	250	μA
l _l	Bus input current	DE = 0V, V_{CC} and V_{IO} = 0V or 5.5V	V _I = -7V	-100	-80		μA
			V _I = -25V	-350	-240		μA
V _{TH+}	Positive-going input threshold voltage ⁽¹⁾			20	125	200	mV
V _{TH-}	Negative-going input threshold voltage ⁽¹⁾	Over common-mode range of ± 25V		-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	$V_O = 0V \text{ or } V_{IO}, \overline{RE} = V_{IO}$		-1		1	μA
Logic							
I _{IN}	Input current (DE , SLR)	DRC: $1.65V \le V_{IO} \le 5.5V$, $0V \le V_{IN} \le V_{IO}$ D: $3V \le V_{CC} \le 5.5V$, $0V \le V_{IN} \le 5.5V$				5	μA
I _{IN}	Input current (D, RE)	DRC: $1.65V \le V_{IO} \le 5.5V$, $0V \le V_{IN} \le V_{IO}$ D: $3V \le V_{CC} \le 5.5V$, $0V \le V_{IN} \le 5.5V$		-5			μΑ
Thermal F	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	٧
UV _{VCC} (falling)	Falling under-voltage threshold on V _{CC}			1.95	2.2		٧
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 under-voltage threshold on V _{IO}			1.2	1.3		V

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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		PARAMETER TEST CONDITIONS		MIN	TYP	MAX	UNIT
UV _{VIO(hys)}	Hysteresis on under-voltage of V _{IO}				120		mV
		Driver and receiver enabled	RE = 0V, DE = V _{IO} , No load		3.5	5.7	mA
		Driver enabled, receiver disabled	$\overline{RE} = V_{IO}$, DE = V_{IO} , No load		2.5	4.4	mA
Supply current (quiescent), V _{CC} = 4.5 V to 5.5 V	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
		Driver and receiver enabled	RE = 0V, DE = V _{IO} , No load		3	4.6	mA
		Driver enabled, receiver disabled	$\overline{RE} = V_{IO}$, DE = V_{IO} , No load		2.2	3.3	mA
СС	Supply current (quiescent), V _{CC} = 3 V to 3.6 V	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
Logic supply current	Logic supply current (quiescent), V _{IO} = 3 to 3.6	Driver disabled, Receiver enabled	DE = 0V, RE = 0V, No load		3.3	8.4	μA
I _{IO}	V, Devices with VIO pin	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 CONE	MIN	TYP	MAX	UNIT	
Driver			<u> </u>				
t _r , t _f Differential output rise/fall time		R _L = 54 Ω, C _L = 50 pF	V _{CC} = 3 to 3.6V, Typical at 3.3V	400	625	1200	ns
t _r , t _f	Dinerential output fise/fail time	See Figure 7-3	V _{CC} = 4.5 to 5.5V, Typical at 5V	500	725	1200	ns
t _{PHL} , t _{PLH}	Propagation delay	R _L = 54 Ω, C _L = 50 pF			510	750	ns
t _{SK(P)}	Pulse skew, t _{PHL} - t _{PLH}	See Figure 7-3			5	70	ns
t _{PHZ} , t _{PLZ}	Disable time		RE = X		45	75	ns
	Enable time	See Figure 7-4 and Figure 7-5	RE = 0V		80	290	ns
t _{PZH} , t _{PZL}	Enable time	See Figure 7-4 and Figure 7-5	RE = V _{IO}		2.5	4.5	μs
t _{SHDN}	Time to shutdown		RE = V _{IO}	50		500	ns
Receiver							
t _r , t _f	Output rise/fall time				3	20	ns
t _{PHL} , t _{PLH}	Propagation delay	C _L = 15 pF See Figure 7-6			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	DL - X			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 ₁ = 15pF	7	11	18	μs
t _{D(FSO)}	Delay to exit fail-safe operation	Oce i igule 1-9	Ο _L – 13μ1	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} = 5 V, V_{IO} = 3.3 V, unless otherwise noted. (1)

PARAMETER		TEST CONI	MIN	TYP	MAX	UNIT	
Driver							
t _r , t _f	Differential output rise/fall time	$R_L = 54\Omega$, $C_L = 50pF$ See Figure 7-3		3.5	5	15	ns
t _{PHL} , t _{PLH}	Propagation delay	$R_L = 54\Omega$, $C_L = 50pF$ See Figure 7-3		6	15	30	ns
t _{SK(P)}	Pulse skew, t _{PHL} - t _{PLH}	$R_L = 54\Omega$, $C_L = 50pF$ See Figure 7-3			0.5	3	ns
t _{PHZ} , t _{PLZ}	Disable time		RE = X		20	35	ns
	Enable time	Can Figure 7.4 and Figure 7.5	RE = 0V		16	40	ns
t _{PZH} , t _{PZL}	Enable lime	See Figure 7-4 and Figure 7-5	RE = V _{IO}		2.5	4.5	μs
t _{SHDN}	Time to shutdown		RE = V _{IO}	50		500	ns
Receiver							
t _r , t _f	Output rise/fall time				1.5	6	ns
t _{PHL} , t _{PLH}	Propagation delay	C _L = 15pF, See Figure 7-6		25	35	60	ns
t _{SK(P)}	Pulse skew, t _{PHL} - t _{PLH}					5.5	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 CONDIT	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 _I = 15pF	7	10	18	μs
t _{D(FSO)}	Delay to exit fail-safe operation	See Figure 7-9	OL - 150F	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

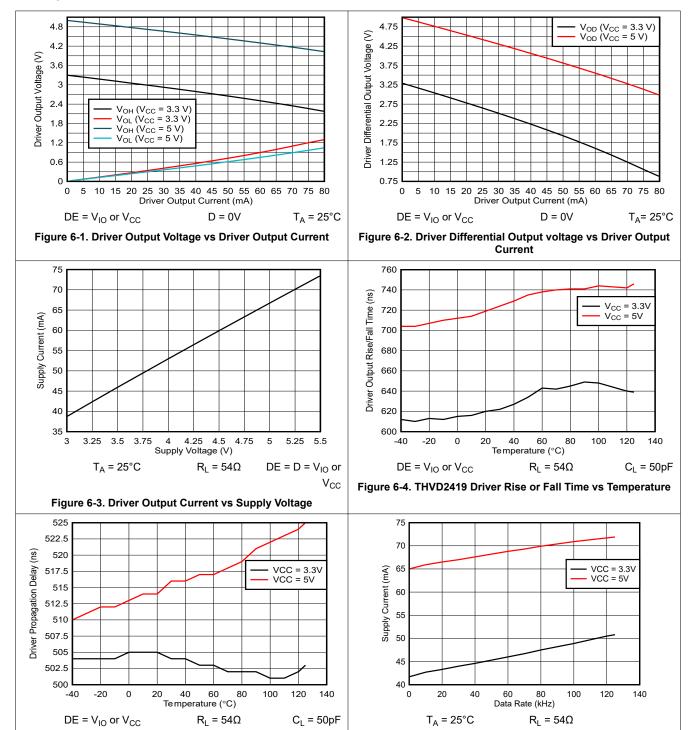
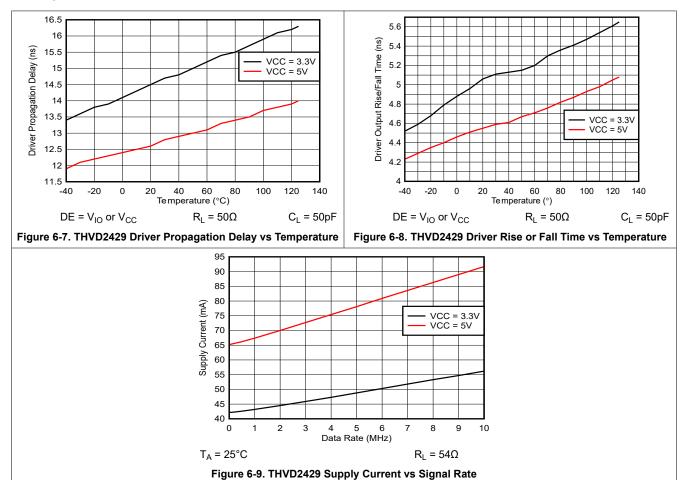


Figure 6-5. THVD2419 Driver Propagation Delay vs Temperature

Figure 6-6. THVD2419 Supply Current vs Signal Rate



6.10 Typical Characteristics (continued)





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 VIO pin)

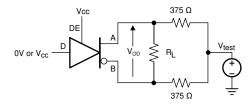


Figure 7-1. Measurement of Driver Differential Output Voltage With Common-Mode Load

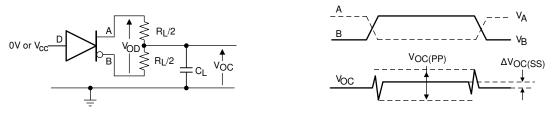


Figure 7-2. Measurement of Driver Differential and Common-Mode Output With RS-485 Load

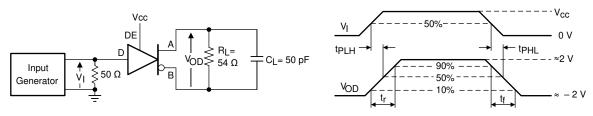


Figure 7-3. Measurement of Driver Differential Output Rise and Fall Times and Propagation Delays

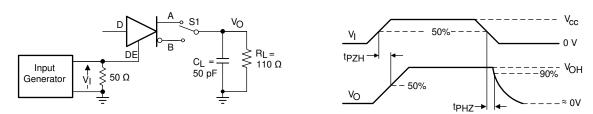


Figure 7-4. Measurement of Driver Enable and Disable Times With Active High Output and Pull-Down Load

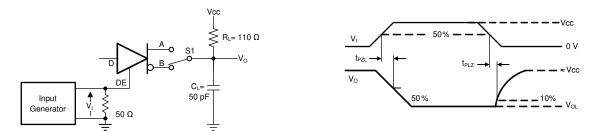
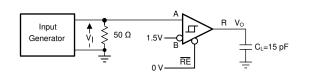


Figure 7-5. Measurement of Driver Enable and Disable Times With Active Low Output and Pull-up Load





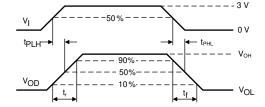
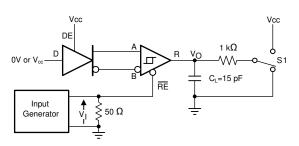


Figure 7-6. Measurement of Receiver Output Rise and Fall Times and Propagation Delays



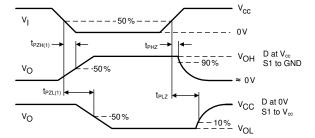
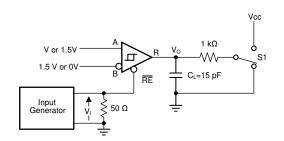


Figure 7-7. Measurement of Receiver Enable/Disable Times With Driver Enabled



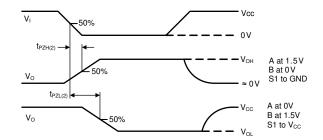
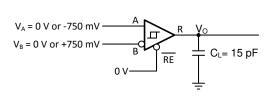
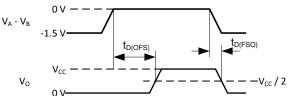


Figure 7-8. Measurement of Receiver Enable Times With Driver Disabled





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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

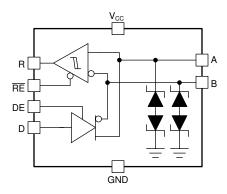


Figure 8-1. THVD2419 and THVD2429 Block Diagram (SOIC Package)

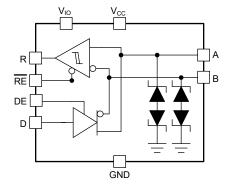


Figure 8-2. THVD2419 and THVD2429 Block Diagram (VSON Package)

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 ± 15 kV HBM and ± 8 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.



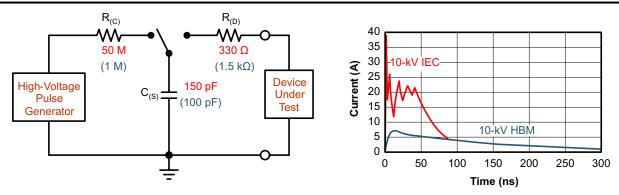


Figure 8-3. HBM and IEC ESD Models and Currents in Comparison (HBM Values in Parenthesis)

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.

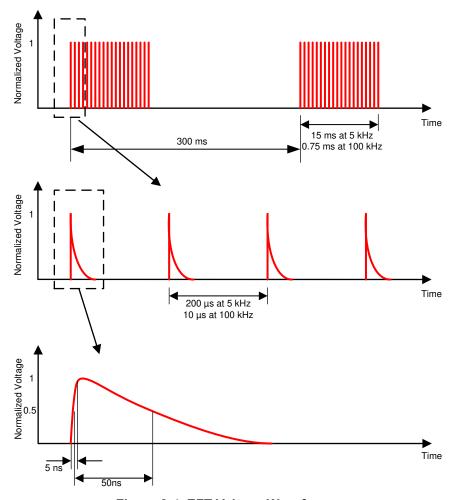


Figure 8-4. EFT Voltage Waveforms

Internal ESD protection circuits of the THVD24x9 protect the transceivers against ±4kV 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.

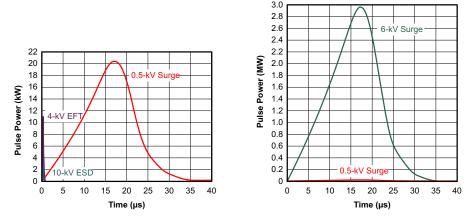


Figure 8-5. Power Comparison of ESD, EFT, and Surge Transients

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.

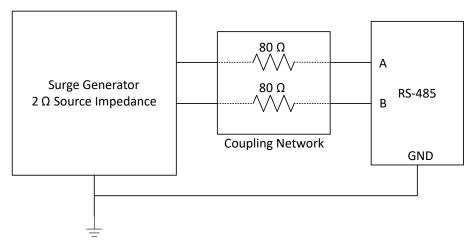


Figure 8-6. THVD24x9 Surge Test Setup

THVD24x9 product family is robust up to ±3kV 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 0-1. Driver i direttori fable											
INPUT	ENABLE	OUTI	PUTS	FUNCTION							
D	DE	A B		FUNCTION							
Н	Н	Н	L	Actively drive bus high							
L	Н	L	Н	Actively drive bus low							
Х	L	L Z Z		Driver disabled							
Х	OPEN	Z	Z	Driver disabled by default							
OPEN	Н	Н	L	Actively drive bus high by default							

Table 8-1. Driver Function Table

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).

ENABLE	OUTPUT	FUNCTION								
RE	R	FONCTION								
L	Н	Receive valid bus high								
L	Indeterminate	Indeterminate bus state								
L	L	Receive valid bus low								
Н	Z	Receiver disabled								
OPEN	Z	Receiver disabled by default								
L	Н	Fail-safe high output								
L	Н	Fail-safe high output								
L	Н	Fail-safe high output								
	RE L L L	RE R L H L Indeterminate L L H Z OPEN Z L H L H L H								

Table 8-2. Receiver Function Table

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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.

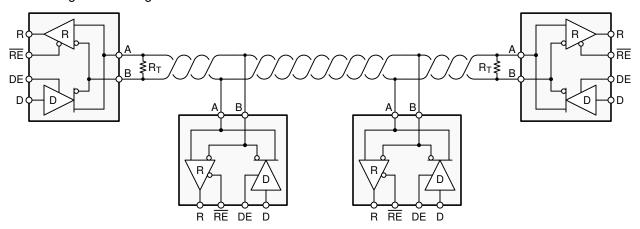


Figure 9-1. Typical RS-485 Network With Half-Duplex Transceivers

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 short 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%.



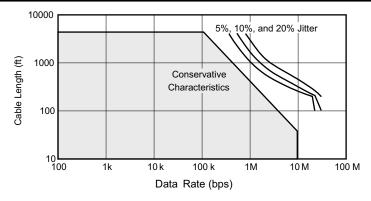


Figure 9-2. Cable Length vs Data Rate Characteristic

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.

$$L_{(STUB)} \le 0.1 \times t_r \times v \times c \tag{1}$$

where

- t_r is the 10/90 rise time of the driver
- c is the speed of light (3 × 10⁸ 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 driver 32 unit loads (UL), where 1 unit load represents a load impedance of approximately $12k\Omega$. Because the THVD24x9 devices consist of 1/8 UL transceivers, connecting up to 256 receivers to the bus is possible.

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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 ±3kV IEC 61000-4-5 surge protection (SOIC package) without any additional external components, reducing system level bill of materials.

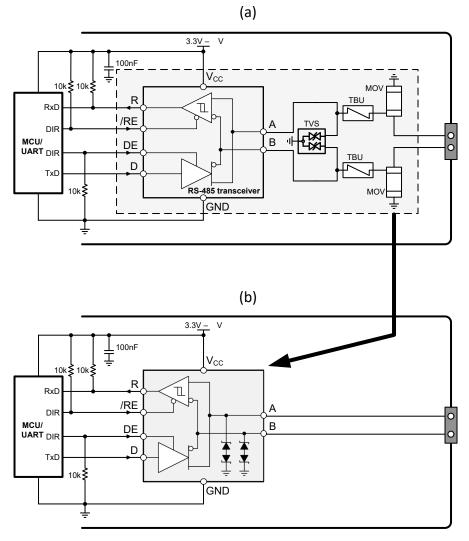


Figure 9-3. Implementation of System-Level Surge Protection Using THVD24x9



9.2.3 Application Curves



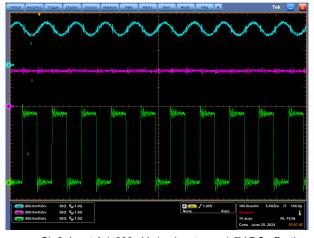
Ch 1: D Input, Ch2: V_A Ch3: V_B Ch4: R V_{CC} = 3.3V Output Data rate: 20Mbps

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 (±200mV sine input over 1.5V DC offset)
Ch3: Input B (1.5V)

Ch 4: Output R

Figure 9-6. THVD2429 Receiver Waveform with ±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 $1k\Omega$ to $10k\Omega$ pull-up and pull-down resistors for enable lines to limit noise currents in these lines during transient events.

9.4.2 Layout Example

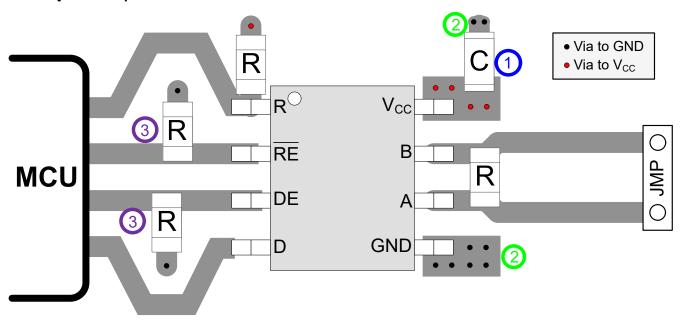


Figure 9-7. THVD2419, THVD2429 Layout Example (SOIC Package)

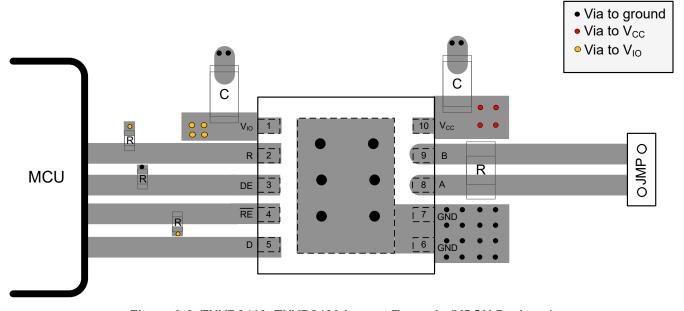


Figure 9-8. THVD2419, THVD2429 Layout Example (VSON Package)



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

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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

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.

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8-Nov-2025

PACKAGING INFORMATION

Orderable part number	Status	Material type	Package Pins	Package qty Carrier	RoHS	Lead finish/ Ball material	MSL rating/ Peak reflow	Op temp (°C)	Part marking
						(4)	(5)		
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
THVD2419DR.B	Active	Production	SOIC (D) 8	2500 LARGE T&R	-	Call TI	Call TI	-40 to 125	
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
THVD2419DRCR.B	Active	Production	VSON (DRC) 10	5000 LARGE T&R	-	Call TI	Call TI	-40 to 125	
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
THVD2429DR.B	Active	Production	SOIC (D) 8	2500 LARGE T&R	-	Call TI	Call TI	-40 to 125	
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
THVD2429DRCR.B	Active	Production	VSON (DRC) 10	5000 LARGE T&R	-	Call TI	Call TI	-40 to 125	

⁽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.



PACKAGE OPTION ADDENDUM

www.ti.com 8-Nov-2025

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

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PACKAGE MATERIALS INFORMATION

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TAPE AND REEL INFORMATION





A0	Dimension designed to accommodate the component width
В0	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		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



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*All dimensions are nominal

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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



SMALL OUTLINE INTEGRATED CIRCUIT



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.



SMALL OUTLINE INTEGRATED CIRCUIT



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.



SMALL OUTLINE INTEGRATED CIRCUIT



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.



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.



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PLASTIC SMALL OUTLINE - NO LEAD



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.



PLASTIC SMALL OUTLINE - NO LEAD



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.



PLASTIC SMALL OUTLINE - NO LEAD



NOTES: (continued)

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



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Last updated 10/2025