THVD9491-SEP Radiation Tolerant 3V to 5.5V RS-485 Transceiver with Flexible I/O Supply and IEC ESD Protection

1 Features

- VID V62/24626
- Meets or exceeds the requirements of the TIA/EIA-485A and TIA/EIA-422B standards
- Total ionizing dose (TID) characterized up to 30krad (Si)
  - Total ionizing dose radiation lot acceptance testing (TID RLAT) for every wafer lot to 30krad (Si)
- Single-event effects (SEE) characterized
  - Single event latch-up (SEL) immune to linear energy transfer (LET) = 43MeV·cm2 /mg at 125°C
- Space enhanced plastic (Space EP)
  - Controlled baseline
  - One assembly and test site
  - One fabrication site
  - Gold bond wire
  - NiPdAu lead finish
  - Military temp range (-55°C to 125°C)
  - Extended product life cycle
  - Product traceability
  - Meets the NASA ASTM E595 outgassing specification
- 3V to 5.5V supply voltage
- 1.65V to 5.5V Supply for data and enable signals
- SLR Pin Selectable Data Rates:
  - 20Mbps and 50Mbps
- Bus I/O protection
  - ±40V DC bus fault
  - ±16kV HBM ESD
  - ±8kV IEC 61000-4-2 contact discharge
  - ±4kV IEC 61000-4-4 fast transient burst
- Symmetric common mode range: ±12V
- Enhanced receiver hysteresis for noise immunity
- Glitch-free power-up or down for hot plug-in capability
- Open, short, and idle bus failsafe
- 1/8 unit load (up to 256 bus nodes)
- Leaded 14-pin SOIC package

2 Applications

- Low Earth Orbit (LEO) space applications
- Command & data handling
- Communications payload systems
- Optical imaging
- Radar imaging payload

3 Description

THVD9491-SEP is a space enhanced, ±40V fault-protected full-duplex RS-422/RS-485 transceiver using a 1.65V to 5.5V logic supply for data and enable logic signals, and a 3V to 5.5V bus side supply. The device has a slew rate select feature that enables the use at two maximum speeds based on the SLR pin setting.

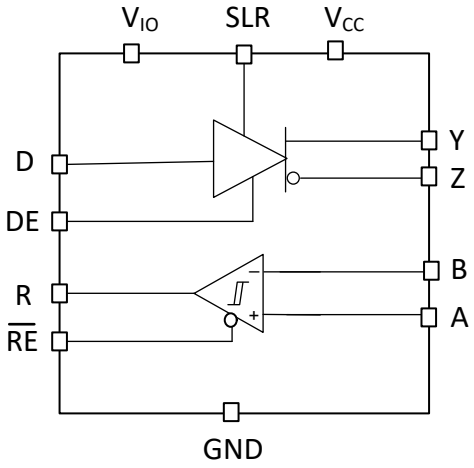
The device features integrated IEC ESD protection, eliminating the need for external system-level protection components. The ±12V input common-mode range makes reliable data communication over longer cable run lengths and/or in the presence of large ground loop voltages. Enhanced 250mV receiver hysteresis provides high noise rejection. In addition, the receiver fail-safe feature makes sure of a logic high when the inputs are open or shorted together.

THVD9491-SEP device is available in a standard 14-pin SOIC package.

Package Information

PART NUMBER	PACKAGE(1)	PACKAGE SIZE(2)
THVD9491-SEP	SOIC (D, 14)	8.65mm × 6mm

(1) For more information, see Section 11.
(2) The package size (length × width) is a nominal value and includes pins, where applicable.



Simplified Schematic

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4 Pin Configuration and Functions

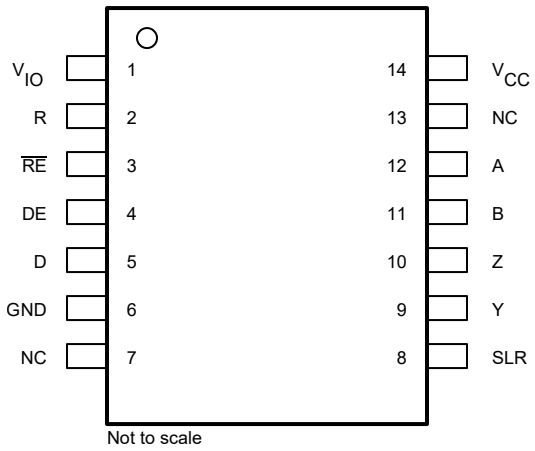


Figure 4-1. D (SOIC) Package 14-Pin (Top View)

Table 4-1. Pin Functions

NAME	NO.	TYPE	DESCRIPTION
V_{IO}	1	Logic Supply	1.65V to 5.5V supply for logic I/O signals (R, $\overline{RE}$, D, DE, and SLR)
R	2	Digital Output	Receive data output
$\overline{RE}$	3	Digital Input	Receiver enable input
DE	4	Digital Input	Driver enable input
D	5	Digital Input	Transmission data input
GND	6	Reference Potential	Local device ground
NC	7,13	No Connect	Not connected internally.
SLR	8	Digital Input	Slew rate selection pin: Low = 50Mbps, High = 20Mbps. Defaults to 50Mbps if left floating.
Y	9	Bus Output	RS-485 bus output, Y
Z	10	Bus Output	RS-485 bus output, Z
B	11	Bus Input	RS-485 bus input, B
A	12	Bus Input	RS-485 bus input, A
V_{CC}	14	Bus Supply	3V to 5.5V supply for A and B bus lines

5 Specifications

5.1 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	-40	40	V
Input voltage	Range at any logic pin (D, DE, SLR or $\overline{RE}$)	–0.3	V_{IO} + 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.

5.2 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	V
			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.

5.3 ESD Ratings [IEC]

				VALUE	UNIT
$V_{(ESD)}$	Electrostatic discharge	Contact discharge, per IEC 61000-4-2 (1)	Bus terminals and GND	±8,000	V
		Air-gap discharge, per IEC 61000-4-2 (1)	Bus terminals and GND	±8,000	
$V_{(EFT)}$	Electrical fast transient	Per IEC 61000-4-4	Bus terminals	±4,000	V

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

5.4 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		1.65		V_{CC}	V
V_I	Input voltage at any bus terminal (separately or common mode)(1)		–12		12	V
V_{IH}	High-level input voltage (driver, driver enable, receiver enable and slew rate select inputs)		0.7*V_{IO}		V_{IO}	V
V_{IL}	Low-level input voltage (driver, driver enable, receiver enable and slew rate select inputs)		0		0.3*V_{IO}	V
V_{ID}	Differential input voltage		–12		12	V
I_O	Output current, driver		–60		60	mA
I_{OR}	Output current, receiver	V_{IO} = 1.8 V or 2.5 V	–4		4	mA
I_{OR}	Output current, receiver	V_{IO} = 3.3 V or 5 V	–8		8	mA
R_L	Differential load resistance		54	60		Ω
$1/t_{UI}$	Signaling rate	SLR = V_{IO}			20	Mbps
		SLR = 0 or floating			50	Mbps
T_A	Operating ambient temperature		-55		125	°C
T_J	Junction temperature		-55		150	°C

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

5.5 Thermal Information

THERMAL METRIC(1)		THVD9491-SEP D (SOIC) 14-PINS	UNIT
$R_{\theta JA}$	Junction-to-ambient thermal resistance	87.5	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	43.7	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	41.8	°C/W
Ψ_{JT}	Junction-to-top characterization parameter	8.1	°C/W
Ψ_{JB}	Junction-to-board characterization parameter	43.3	°C/W
$R_{\theta JC(bot)}$	Junction-to-case (bottom) thermal resistance	N/A	°C/W

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

5.6 Power Dissipation

PARAMETER		TEST CONDITIONS		VALUE	UNIT
P_D	Driver and receiver enabled, loopback for full duplex devices (A connected to Y, B connected to Z) V_{CC} = 5.5 V, T_A = 125 °C, square wave at 50% duty cycle	Unterminated R_L = 300 Ω, C_L = 50 pF (driver)	20Mbps	335	mW
			50 Mbps	571	
		RS-422 load R_L = 100 Ω, C_L = 50 pF (driver)	20Mbps	325	mW
			50 Mbps	522	
		RS-485 load R_L = 54 Ω, C_L = 50 pF (driver)	20Mbps	355	mW
			50 Mbps	526	

5.7 Electrical Characteristics

over operating free-air temperature range (unless otherwise noted). All typical values are at 25°C and supply voltage of V_{CC} = 5 V, V_{IO} = 3.3 V , unless otherwise noted. (2)

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
Driver							
$\|V_{OD}\|$	Driver differential output voltage magnitude	R_L = 60 Ω, –12 V ≤ V_{test} ≤ 12 V. See Figure 6-1		1.5	2.8		V
		R_L = 60 Ω, –12 V ≤ V_{test} ≤ 12 V, 4.5 V ≤ V_{CC} ≤ 5.5 V. See Figure 6-1		2.1	3.3		V
		R_L = 100 Ω See Figure 6-2		2	4		V
		R_L = 54 Ω. See Figure 6-2		1.5	3.3		V
$\Delta\|V_{OD}\|$	Change in differential output voltage	R_L = 54 Ω or 100 Ω. See Figure 6-2		–200		200	mV
V_{OC}	Common-mode output voltage	R_L = 54 Ω or 100 Ω (See Figure 6-2		1	V_{CC}/2	3	V
$\Delta V_{OC(SS)}$	Change in steady-state common-mode output voltage	R_L = 54 Ω or 100 Ω. See Figure 6-2		–50		50	mV
I_{OS}	Short-circuit output current	DE = V_{IO}, -40 V ≤ (V_A or V_B) ≤ 40 V, or A shorted to B (A,B are driver terminals for half duplex, Y/Z are for full duplex)		–250		250	mA
Receiver							
I_I	Bus input current	DE = 0 V, V_{CC} and V_{IO} = 0 V or 5.5 V	V_I = 12 V		75	125	µA
			V_I = –7 V	–100	–60		µA
V_{TH+}	Positive-going input threshold voltage(1)	Over common-mode range of ± 12 V		40	125	200	mV
V_{TH-}	Negative-going input threshold voltage(1)			–200	–125	-40	mV
V_{HYS}	Input hysteresis				250		mV
V_{TH_FSH}	Input fail-safe threshold			–40		40	mV
$C_{A,B}$	Input differential capacitance	Measured between A and B, f = 1 MHz			50		pF
V_{OH}	Output high voltage	I_{OH} = –8 mA, V_{IO} = 3 to 3.6 V or 4.5 V to 5.5 V		V_{IO} – 0.4	V_{IO} – 0.2		V
V_{OL}	Output low voltage	I_{OL} = 8 mA, V_{IO} = 3 to 3.6 V or 4.5 V to 5.5 V			0.2	0.4	V
V_{OH}	Output high voltage	I_{OH} = –4 mA, V_{IO} = 1.65 to 1.95 V or 2.25 V to 2.75 V		V_{IO} – 0.4	V_{IO} – 0.2		V
V_{OL}	Output low voltage	I_{OL} = 4 mA, V_{IO} = 1.65 to 1.95 V or 2.25 V to 2.75 V			0.2	0.4	V
I_{OZ}	Output high-impedance current, R pin	V_O = 0 V or V_{IO}, $\overline{RE}$ = V_{IO}		–1		1	µA
Logic							
I_{IN}	Input current (DE , SLR)	1.65 V ≤ V_{IO} ≤ 5.5 V, 0 V ≤ V_{IN} ≤ V_{IO}				5	µA
I_{IN}	Input current (D, $\overline{RE}$)	1.65 V ≤ V_{IO} ≤ 5.5 V, 0 V ≤ V_{IN} ≤ V_{IO}		–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	1.35		V
$UV_{VIO(hys)}$	Hysteresis on under-voltage of V_{IO}				40		mV

5.7 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} = 5 V, V_{IO} = 3.3 V , unless otherwise noted. (2)

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
I_{CC}	Supply current (quiescent), V_{CC} = 4.5 V to 5.5 V	Driver and receiver enabled	$\overline{RE}$ = 0 V, DE = V_{IO}, No load		4	7.2	mA
		Driver enabled, receiver disabled	$\overline{RE}$ = V_{IO}, DE = V_{IO}, No load		3	4.2	mA
		Driver disabled, receiver enabled	$\overline{RE}$ = 0 V, DE = 0 V, No load		2.5	3	mA
		Driver and receiver disabled	$\overline{RE}$ = V_{IO}, DE = 0 V, D = open, No load		30	100	µA
I_{CC}	Supply current (quiescent), V_{CC} = 3 V to 3.6 V	Driver and receiver enabled	$\overline{RE}$ = 0 V, DE = V_{IO}, No load		3.5	5	mA
		Driver enabled, receiver disabled	$\overline{RE}$ = V_{IO}, DE = V_{IO}, No load		2.5	3	mA
		Driver disabled, receiver enabled	$\overline{RE}$ = 0 V, DE = 0 V, No load		2	3	mA
		Driver and receiver disabled	$\overline{RE}$ = V_{IO}, DE = 0 V, D = open, No load		30	100	µA
I_{IO}	Logic supply current (quiescent), V_{IO} = 3 to 3.6 V	Driver disabled, Receiver enabled, SLR = GND	DE = 0 V, $\overline{RE}$ = 0 V, No load		4.5	10	µA
		Driver disabled, Receiver enabled, SLR = V_{IO}			3.3	10	µA
		Driver disabled, Receiver disabled, SLR = GND	DE = 0 V, $\overline{RE}$ = V_{IO}, No load		4.5	8.4	µA
		Driver disabled, Receiver disabled, SLR = V_{IO}			3.3	8.4	µA

(1) Under any specific conditions, V_{TH+} is assured to be at least V_{HYS} higher than V_{TH-}.
(2) A and B are receiver inputs, Y and Z are driver output terminals for the device

5.8 Switching Characteristics: 20Mbps

20-Mbps (SLR = V_{IO}) 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
Driver							
t_r, t_f	Differential output rise/fall time	R_L = 54 Ω, C_L = 50 pF	See Figure 6-3	4	8	15	ns
t_{PHL}, t_{PLH}	Propagation delay			6	15	30	ns
$t_{SK(P)}$	Pulse skew, $\lvert t_{PHL} - t_{PLH} \rvert$				1	3	ns
t_{PHZ}, t_{PLZ}	Disable time	$\overline{RE}$ = X	See Figure 6-4 and Figure 6-3		17	35	ns
t_{PZH}, t_{PZL}	Enable time	$\overline{RE}$ = 0 V			14	39	ns
		$\overline{RE}$ = V_{IO}			3	4.5	µs
t_{SHDN}	Time to shutdown	$\overline{RE}$ = V_{IO}		50		500	ns
Receiver							
t_r, t_f	Output rise/fall time	C_L = 15 pF	See Figure 6-6		1.5	6	ns
t_{PHL}, t_{PLH}	Propagation delay			25	35	60	ns
$t_{SK(P)}$	Pulse skew, $\lvert t_{PHL} - t_{PLH} \rvert$				1	5	ns
t_{PHZ}, t_{PLZ}	Disable time	DE = X			12	25	ns
$t_{PZH(1)}$, $t_{PZL(1)}$	Enable time	DE = V_{IO}	See Figure 6-7		50	82	ns
$t_{PZH(2)}$, $t_{PZL(2)}$	Enable time	DE = 0 V	See Figure 6-8		2.8	5	µs
$t_{D(OFS)}$	Delay to enter fail-safe operation	C_L = 15 pF	See Figure 6-9	7	11	18	µs
$t_{D(FSO)}$	Delay to exit fail-safe operation			19	32	50	ns
t_{SHDN}	Time to shutdown	DE = 0 V	See Figure 6-8	50		500	ns

(1) A and B are receiver inputs, Y and Z are driver output terminals for the device

5.9 Switching Characteristics: 50Mbps

50-Mbps (SLR = 0) 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
Driver							
t_r, t_f	Differential output rise/fall time	R_L = 54 Ω, C_L = 50 pF	See Figure 6-3	1	5	7	ns
t_{PHL}, t_{PLH}	Propagation delay			7	12	22	ns
$t_{SK(P)}$	Pulse skew, $\lvert t_{PHL} - t_{PLH} \rvert$				1	3	ns
t_{PHZ}, t_{PLZ}	Disable time	$\overline{RE}$ = X	See Figure 6-4 and Figure 6-5		14	30	ns
t_{PZH}, t_{PZL}	Enable time	$\overline{RE}$ = 0 V			20	35	ns
t_{PZH}, t_{PZL}	Enable time	$\overline{RE}$ = V_{IO}			2.5	4.5	µs
t_{SHDN}	Time to shutdown	$\overline{RE}$ = V_{IO}		50		500	ns
Receiver							
t_r, t_f	Output rise/fall time	C_L = 15 pF	See Figure 6-6		1.5	6	ns
t_{PHL}, t_{PLH}	Propagation delay			25	35	60	ns
$t_{SK(P)}$	Pulse skew, $\lvert t_{PHL} - t_{PLH} \rvert$				1	5	ns
t_{PHZ}, t_{PLZ}	Disable time	DE = X			12	25	ns
$t_{PZH(1)}$, $t_{PZL(1)}$	Enable time	DE = V_{IO}	See Figure 6-7		50	82	ns
$t_{PZH(2)}$, $t_{PZL(2)}$	Enable time	DE = 0 V	See Figure 6-8		3	5	µs
$t_{D(OFS)}$	Delay to enter fail-safe operation	C_L = 15 pF	See Figure 6-9	7	10	18	µs
$t_{D(FSO)}$	Delay to exit fail-safe operation			19	35	50	ns
t_{SHDN}	Time to shutdown	DE = 0 V	See Figure 6-8	50		500	ns

(1) A and B are receiver inputs, Y and Z are driver output terminals for the device

5.10 Typical Characteristics

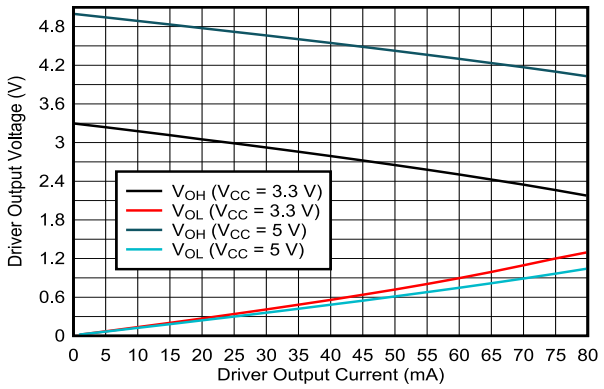


Figure 5-1. Driver Output Voltage vs. Driver Output Current

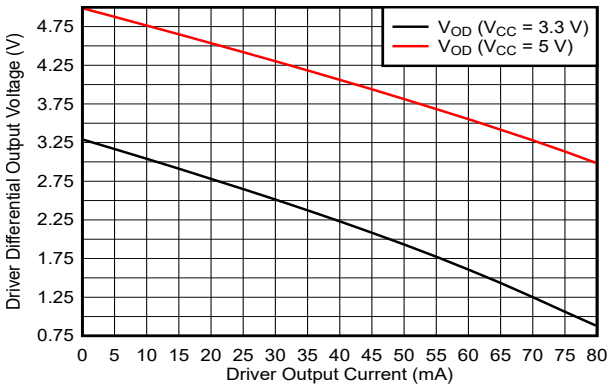


Figure 5-2. Driver Differential Output Voltage vs. Driver Output Current

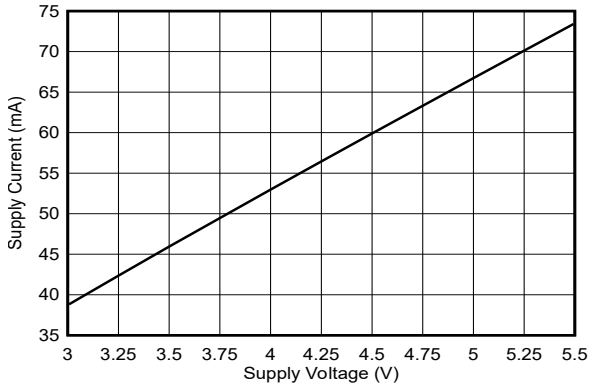


Figure 5-3. Supply Current vs. Supply Voltage

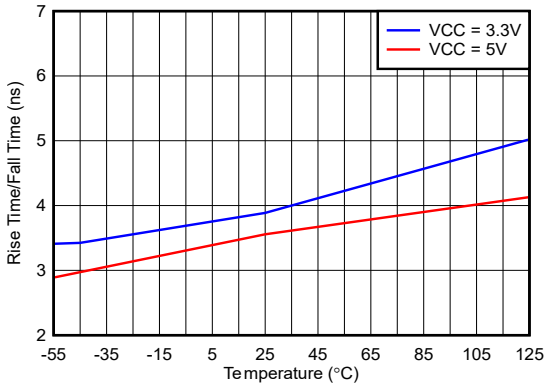


Figure 5-4. Rise and Fall Time vs. Temperature

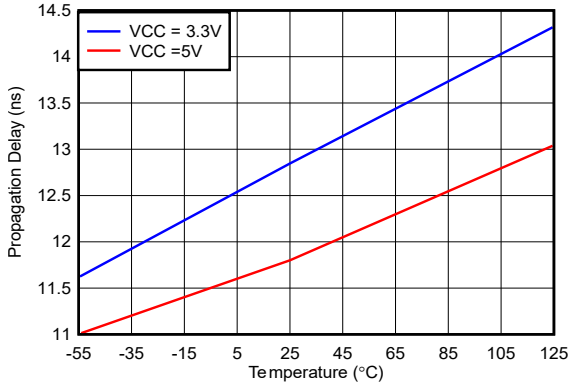


Figure 5-5. Propagation Delay vs. Temperature

6 Parameter Measurement Information

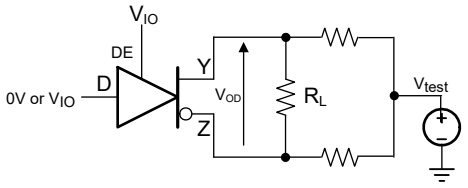


Figure 6-1. Measurement of Driver Differential Output Voltage With Common-Mode Load

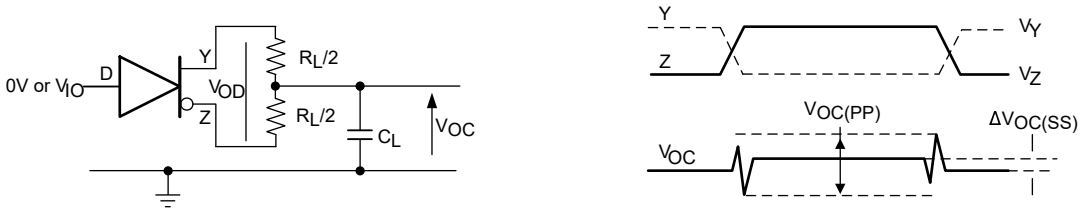


Figure 6-2. Measurement of Driver Differential and Common-Mode Output With RS-485 Load

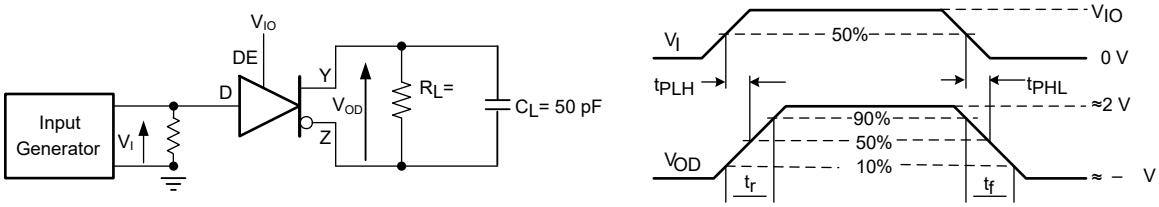


Figure 6-3. Measurement of Driver Differential Output Rise and Fall Times and Propagation Delays

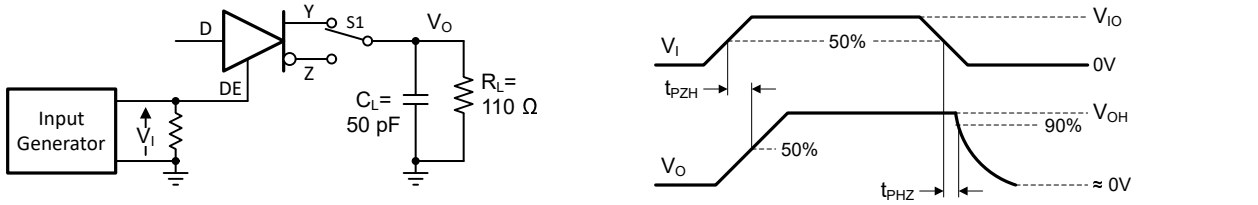


Figure 6-4. Measurement of Driver Enable and Disable Times With Active High Output and Pull-Down Load

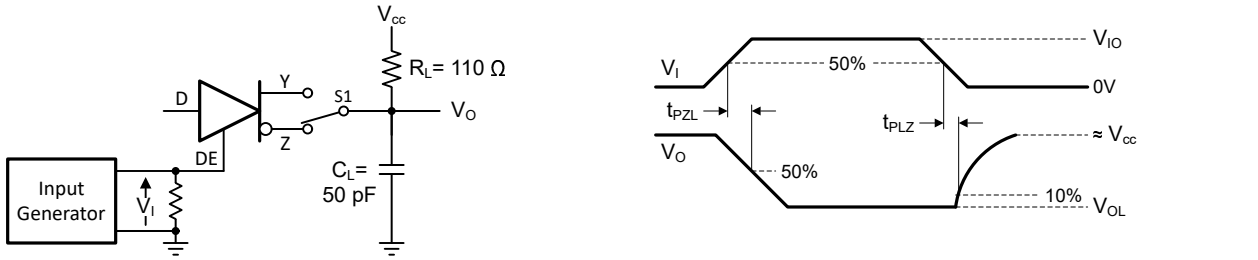


Figure 6-5. Measurement of Driver Enable and Disable Times With Active Low Output and Pull-up Load

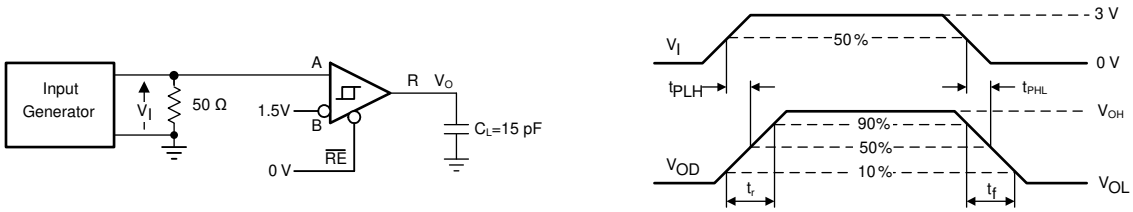


Figure 6-6. Measurement of Receiver Output Rise and Fall Times and Propagation Delays

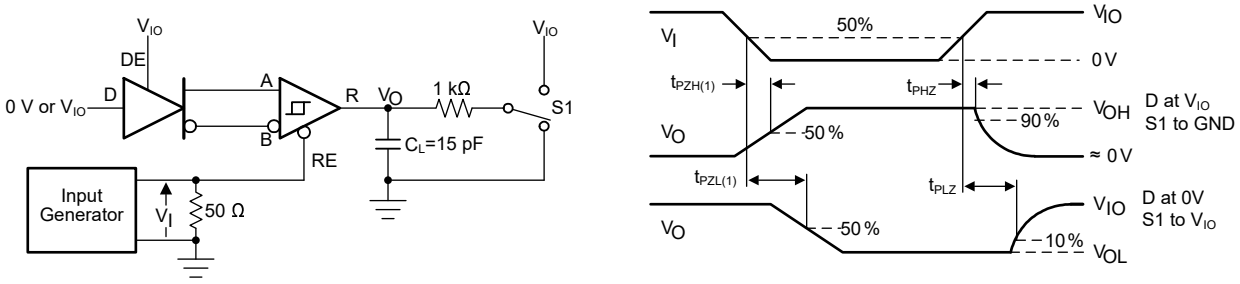


Figure 6-7. Measurement of Receiver Enable/Disable Times With Driver Enabled

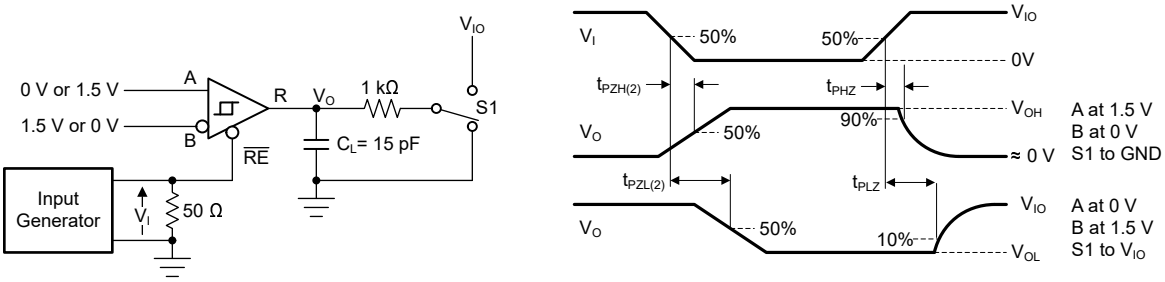


Figure 6-8. Measurement of Receiver Enable Times With Driver Disabled

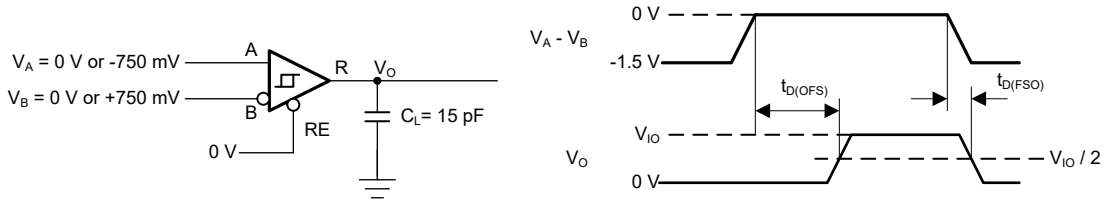


Figure 6-9. Measurement of Fail-Safe Delay

7 Detailed Description

7.1 Overview

THVD9491-SEP is a fault-protected, full duplex RS-485 transceiver that can support two speed grades suitable for data transmission up to 20Mbps and 50Mbps respectively, based on the logic level on the SLR pin. The device has active-high driver enable and active-low receiver enables.

7.2 Functional Block Diagrams

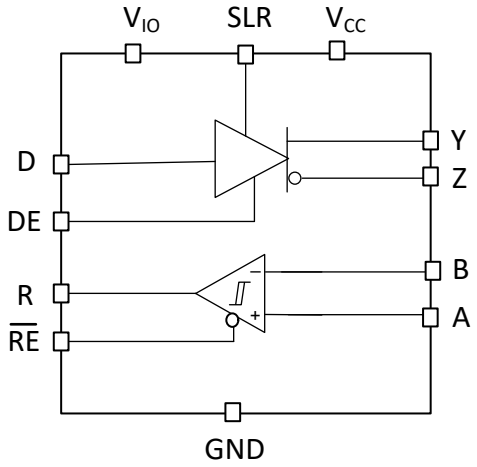


Figure 7-1. THVD9491-SEP Block Diagram

7.3 Feature Description

7.3.1 ±40-V Fault Protection

THVD9491-SEP transceivers have extended bus fault protection compared to standard RS-485 devices. Transceivers that operate in rugged industrial environments are often exposed to voltage transients greater than the -7V to +12V defined by the TIA/EIA-485A standard. To protect against such conditions, the generic RS-485 devices with lower absolute maximum ratings requires expensive external protection components. To simplify system design and reduce overall system cost, the device is protected up to ±40V without the need for any external components.

7.3.2 Integrated IEC ESD and EFT Protection

Internal ESD protection circuits protect the transceivers against electrostatic discharges (ESD) according to IEC 61000-4-2 of up to ±8kV and against electrical fast transients (EFT) according to IEC 61000-4-4 of up to ±4kV. The integrated ESD structures help to limit voltage excursions and recover from them quickly that they allow EFT Criterion A at the system level (no data loss when transient noise is present).

7.3.3 Driver Overvoltage and Overcurrent Protection

The THVD9491-SEP driver is protected against any DC supply shorts in the range of -40V to +40V. The devices internally limit the short circuit current to ±250mA to comply with the TIA/EIA-485A standard. In addition, a fold-back current limiting circuit further reduces the driver short circuit current to less than ±5mA if the output fault voltage exceeds |±25V|.

The device features thermal shutdown protection that disables the driver and the receiver if the junction temperature exceeds the T_{SHDN} threshold due to excessive power dissipation.

7.3.4 Enhanced Receiver Noise Immunity

The differential receivers of THVD9491-SEP feature fully symmetric thresholds to maintain duty cycle of the signal even with small input amplitudes. 250mV (typical) hysteresis provides excellent noise immunity.

7.3.5 Receiver Fail-Safe Operation

The receivers are fail-safe 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 $|V_{TH\_FSH}|$.

7.3.6 Low-Power Shutdown Mode

Driving DE low and $\overline{RE}$ high for longer than 500ns puts the devices into the shutdown mode. If either DE goes high or $\overline{RE}$ goes low, the counters reset. The devices does not enter the shutdown mode if the enable pins are in disable state for less than 50ns. This feature prevents the devices from accidentally going into shutdown mode due to skew between DE and $\overline{RE}$.

7.4 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. In this case 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, thus when left open the driver is disabled (high-impedance) by default. The D pin has an internal pull-up resistor to V_{IO}, thus, when left open while the driver is enabled, output A turns high and B turns low.

Table 7-1. Driver Function Table

INPUT	ENABLE	OUTPUTS		FUNCTION
D	DE	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 7-2. 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 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

Table 7-3 shows SLR (slew rate select) pin functionality. SLR has integrated pull-down, so the device remains in higher speed mode until SLR is pulled high which limits the slew rate and puts the device in slower speed mode.

Table 7-3. SLR pin control

Device	Functionality w.r.t SLR pin
THVD9491-SEP	SLR = Low or floating: Both transmitter (TX) and receiver (RX) maximum speed is 50Mbps SLR = High: Both TX and RX maximum speed is limited to 20Mbps

Table 7-4 shows the device behavior in undervoltage scenarios:

Table 7-4. Supply Function Table

V_{CC}	V_{IO}	Driver Output	Receiver Output
> $UV_{VCC(rising)}$	> $UV_{VIO(rising)}$	Determined by DE and D inputs	Determined by $\overline{RE}$ and A-B
< $UV_{VCC(falling)}$	> $UV_{VIO(rising)}$	High impedance	Failsafe H (gated by $\overline{RE}$)
> $UV_{VCC(rising)}$	< $UV_{VIO(falling)}$	High impedance	High impedance
< $UV_{VCC(falling)}$	< $UV_{VIO(falling)}$	High impedance	High impedance

8 Application and Implementation

Note

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

8.1 Application Information

The device is a fault-protected, full-duplex RS-485 transceiver commonly used for asynchronous data transmissions. For these devices, the driver and receiver enable pins allow for the configuration of different operating modes.

8.2 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, whose value matches the characteristic impedance, Z_0, of the cable. This method, known as parallel termination, generally allows for higher data rates over longer cable length.

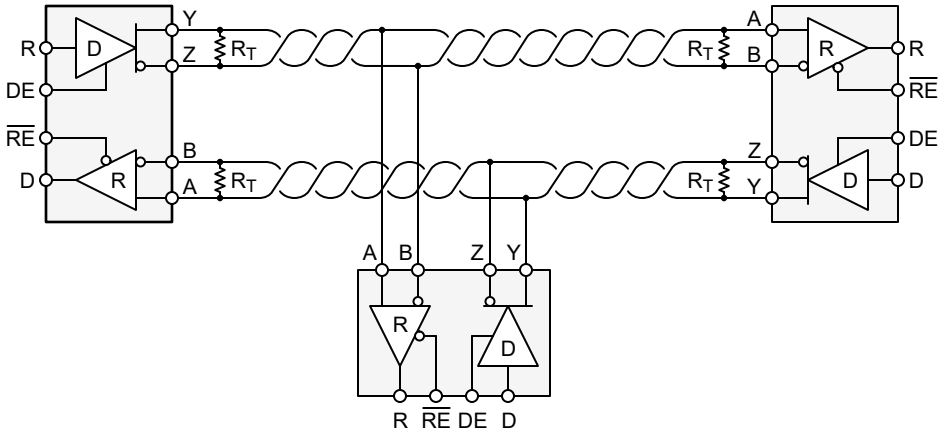


Figure 8-1. Typical RS-485 Network With Half-Duplex Transceivers

8.2.1 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.

8.2.1.1 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%.

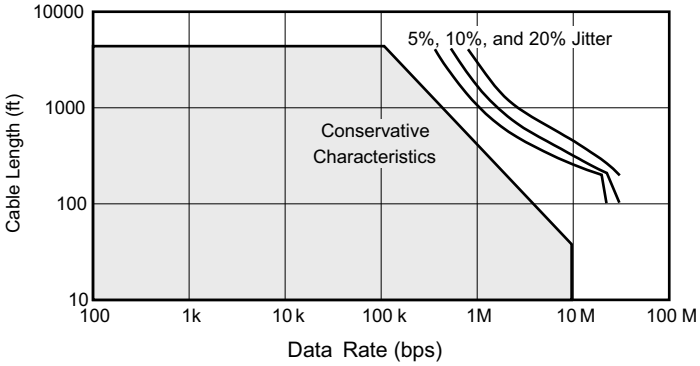


Figure 8-2. Cable Length vs Data Rate Characteristic

Even higher data rates are achievable (up to 50Mbps) in cases where the interconnect is short enough (or has suitably low attenuation at signal frequencies) to not degrade the data.

8.2.1.2 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 of varying phase 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

8.2.1.3 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 12kΩ. Because the THVD9491-SEP device consists of 1/8 UL transceivers, connecting up to 256 receivers to the bus is possible.

8.2.1.4 Transient Protection

The bus pins of the THVD9491-SEP transceivers include on-chip ESD protection against ±16kV HBM and ±8kV 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.

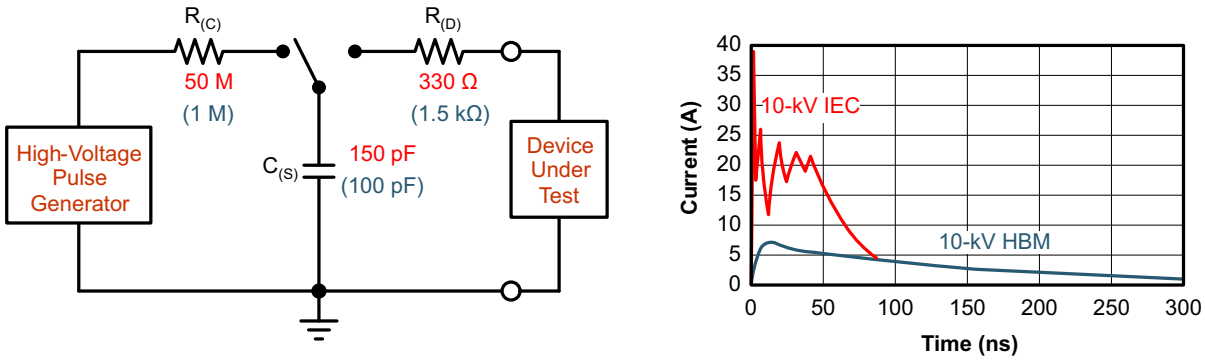


Figure 8-3. HBM and IEC ESD Models and Currents in Comparison (HBM Values in Parenthesis)

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. Designers may choose to implement protection against longer duration transients, typically referred to as surge transients.

EFTs are generally caused by relay-contact bounce or the interruption of inductive loads. 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 8-4 compares the pulse-power of the EFT and surge transients with the power caused by an IEC ESD transient. The left side diagram 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 right side diagram 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.

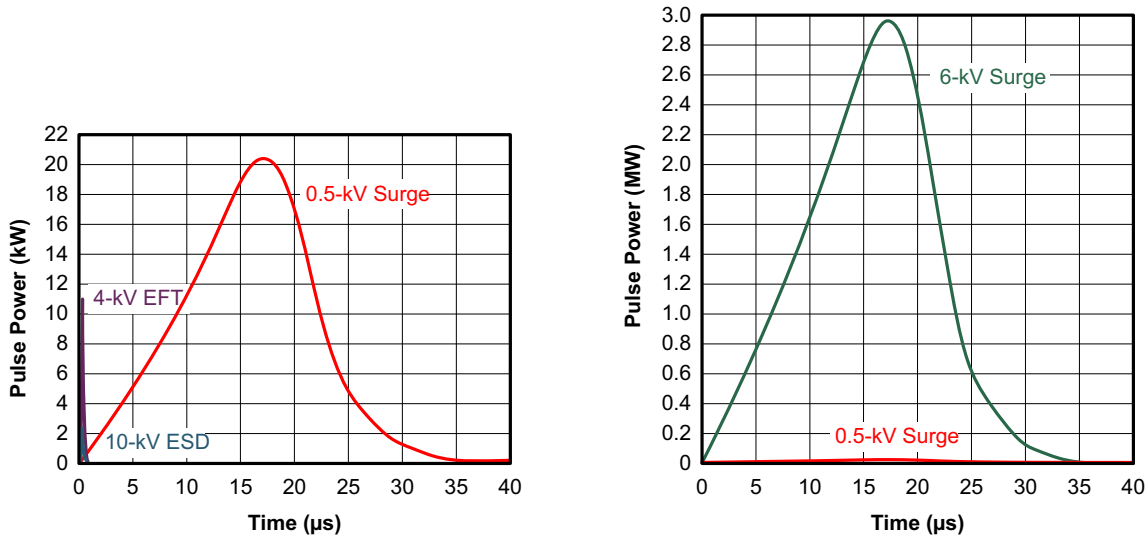


Figure 8-4. Power Comparison of ESD, EFT, and Surge Transients

For surge transients, high-energy content is characterized by long pulse duration and slow decaying pulse power. The electrical energy of a transient that is dumped into the internal protection cells of a transceiver is converted into thermal energy, which heats and destroys the protection cells, thus destroying the transceiver. Figure 8-5 shows the large differences in transient energies for single ESD, EFT, surge transients, and an EFT pulse train that is commonly applied during compliance testing.

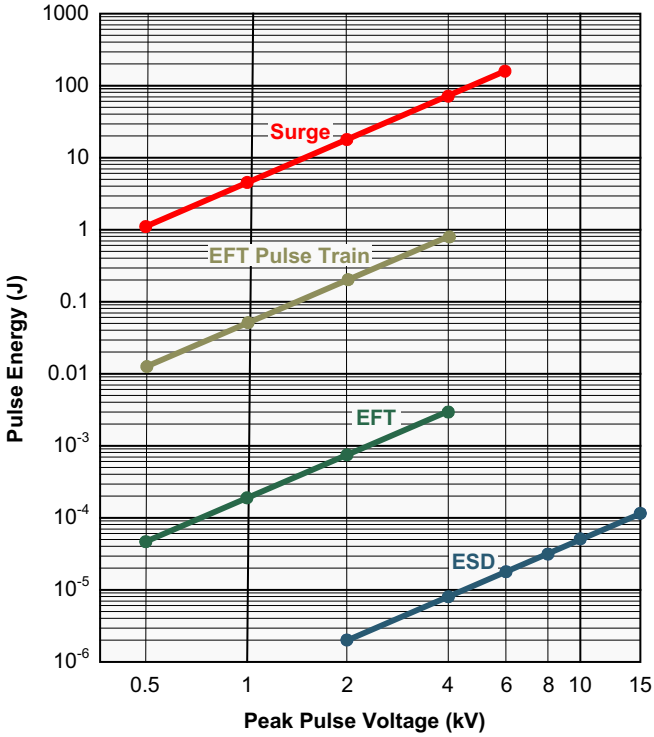


Figure 8-5. Comparison of Transient Energies

8.2.2 Detailed Design Procedure

Figure 8-6 suggests a protection circuit against 1kV surge (IEC 61000-4-5) transients. Table 8-1 shows the associated bill of materials. SMAJ30CA TVS diodes are rated to operate up to 30V. This provides the protection diodes do not conduct if a direct RS-485 bus shorts to 24V DC industrial power rail.

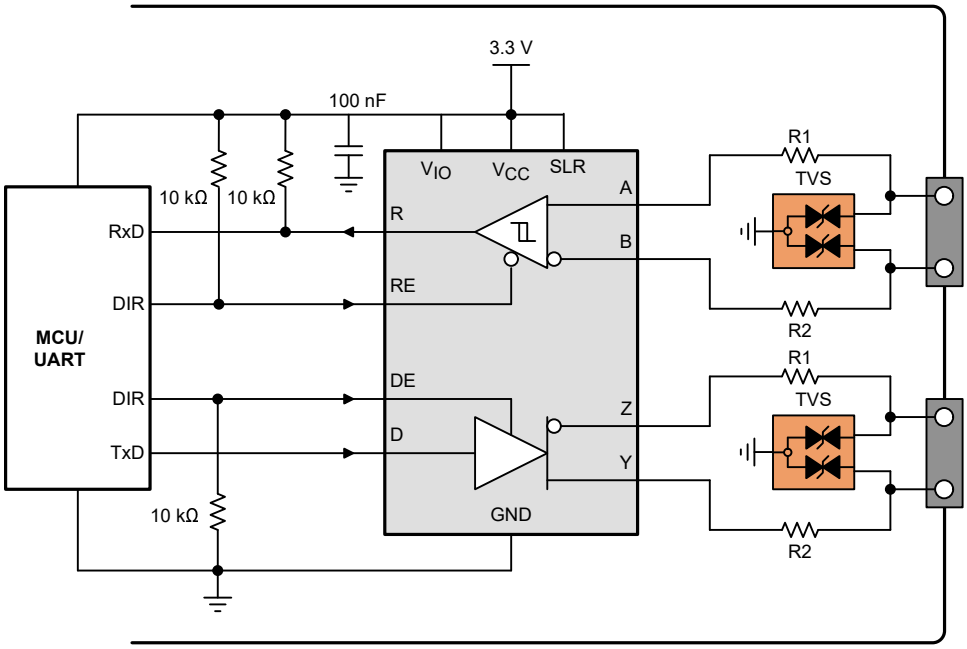


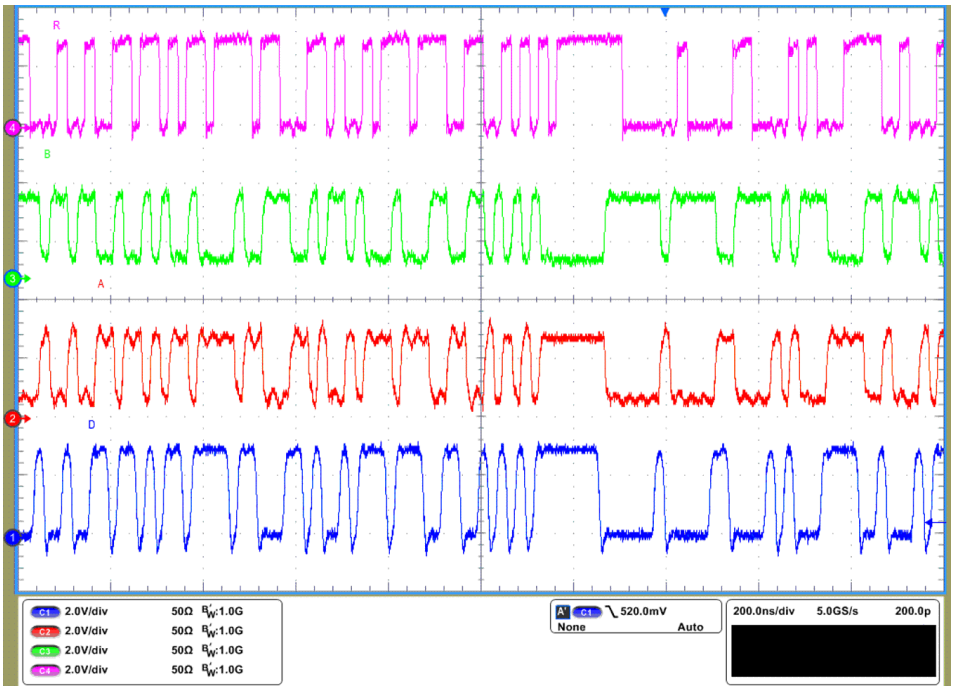
Figure 8-6. Transient Protection Against Surge Transients for Full-Duplex Devices

Table 8-1. Components List

DEVICE	FUNCTION	ORDER NUMBER	MANUFACTURER(1)
XCVR	RS-485 transceiver	THVD9491-SEP	TI
TVS	Bidirectional 400W transient suppressor	SMAJ30CA	Littelfuse

(1) See Third-Party Products Disclaimer

8.2.3 Application Curve



PRBS data at 50 Mbps | V_{CC} = V_{IO}= 3.3V | SLR = GND | R_L = 50 Ω

Figure 8-7. Driver input (D), bus (A/Y,B/Z) and receiver output (R) waveforms

8.3 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.

8.4 Layout

8.4.1 Layout Guidelines

Robust and reliable bus node design often requires the use of external transient protection devices to protect against surge transients that may occur in industrial environments. Since these transients have a wide frequency bandwidth (from approximately 3MHz to 300MHz), high-frequency layout techniques should be applied during PCB design.

1. Place the protection circuitry close to the bus connector to prevent noise transients from propagating across the board.
2. Use V_{CC} 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.
3. Design the protection components into the direction of the signal path. Do not force the transient currents to divert from the signal path to reach the protection device.
4. 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.
5. Use at least two vias for V_{CC}/V_{IO} and ground connections of decoupling capacitors and protection devices to minimize effective via inductance.
6. Use 1kΩ to 10kΩ pull-up and pull-down resistors for enable lines to limit noise currents in these lines during transient events.
7. Insert pulse-proof resistors into the A and B bus lines if the TVS clamping voltage is higher than the specified maximum voltage of the transceiver bus pins. These resistors limit the residual clamping current into the transceiver and prevent it from latching up.

8.4.2 Layout Example

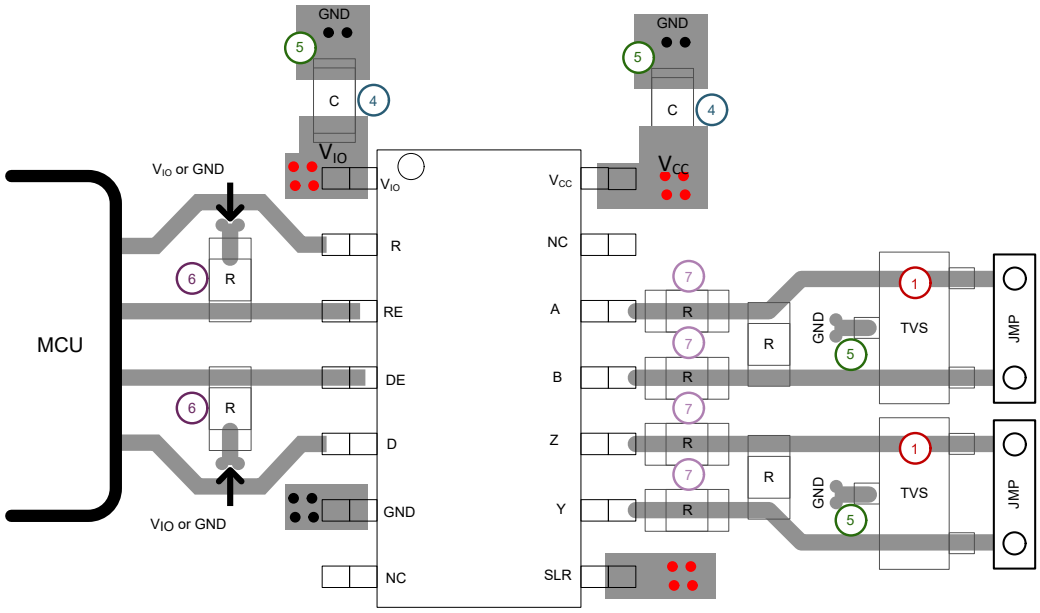


Figure 8-8. Full-Duplex Layout Example

9 Device and Documentation Support

9.1 Device Support

9.1.1 Third-Party Products Disclaimer

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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.

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This integrated circuit can be damaged by ESD. Texas Instruments recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

9.6 Glossary

TI Glossary — This glossary lists and explains terms, acronyms, and definitions.

10 Revision History

Changes from Revision A (December 2024) to Revision B (December 2024)	Page
• Updated the I_{IO} (receiver enabled) max value from 8.4µA to 10µA	6

Changes from Revision * (January 2024) to Revision A (December 2024)	Page
• Changed the document from Advanced Information to *Production* data	1

11 Mechanical, Packaging, and Orderable Information

The following pages include mechanical, packaging, and orderable information. This information is the most current data available for the designated devices. This data is subject to change without notice and revision of this document. For browser-based versions of this data sheet, refer to the left-hand navigation.

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead finish/ Ball material (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
PTHVD9491DRSEP	ACTIVE	SOIC	D	14	2500	TBD	Call TI	Call TI	-40 to 125		Samples

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

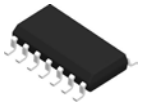
(2) **RoHS:** TI defines "RoHS" to mean semiconductor products that are compliant with the current EU RoHS requirements for all 10 RoHS substances, including the requirement that RoHS substance do not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, "RoHS" products are suitable for use in specified lead-free processes. TI may reference these types of products as "Pb-Free".
RoHS Exempt: TI defines "RoHS Exempt" to mean products that contain lead but are compliant with EU RoHS pursuant to a specific EU RoHS exemption.
Green: TI defines "Green" to mean the content of Chlorine (Cl) and Bromine (Br) based flame retardants meet JS709B low halogen requirements of <=1000ppm threshold. Antimony trioxide based flame retardants must also meet the <=1000ppm threshold requirement.

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

(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

(5) Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

(6) Lead finish/Ball material - Orderable Devices 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.

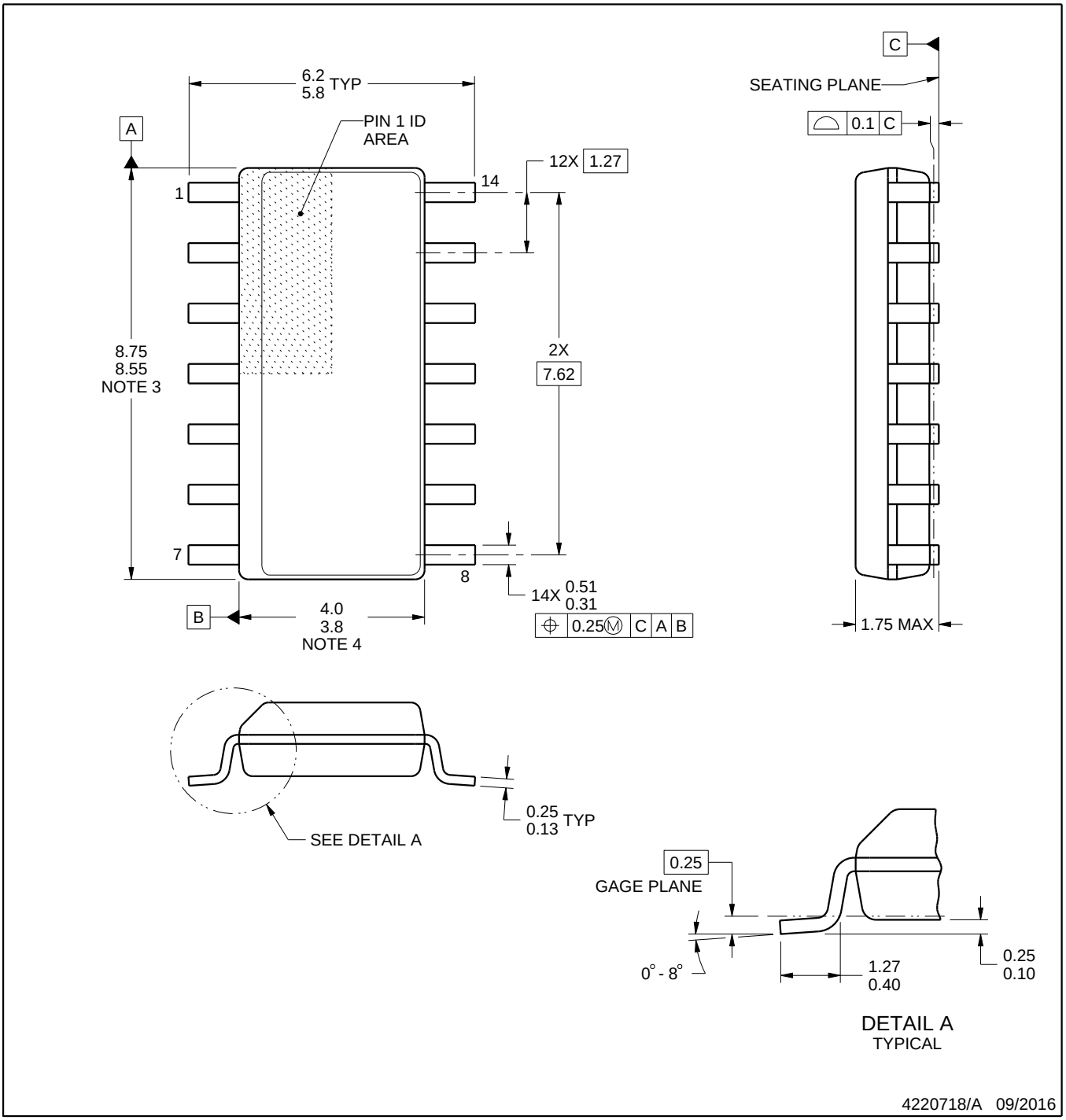


PACKAGE OUTLINE

D0014A

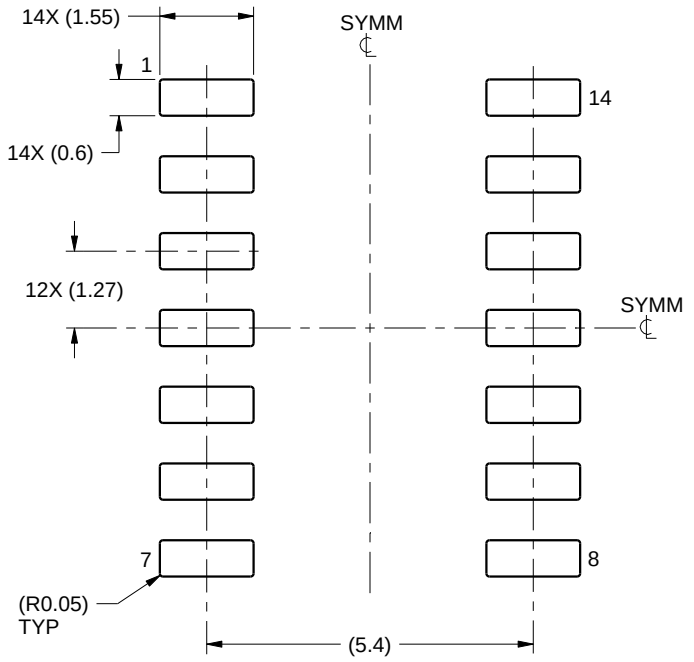
SOIC - 1.75 mm max height

SMALL OUTLINE INTEGRATED CIRCUIT

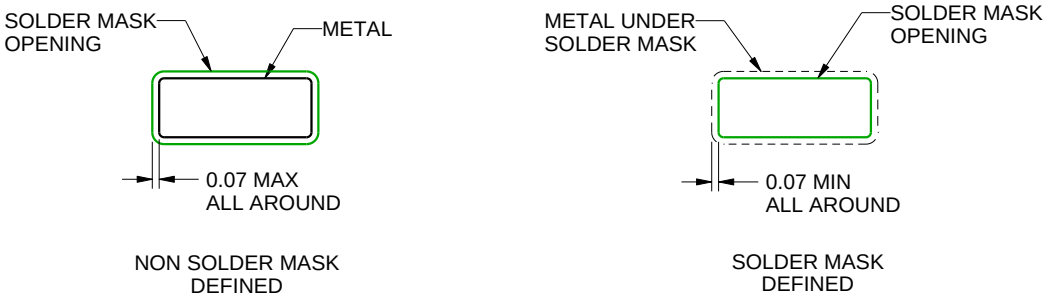


NOTES:

1. All linear dimensions are in millimeters. Dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.15 mm, per side.
4. This dimension does not include interlead flash. Interlead flash shall not exceed 0.43 mm, per side.
5. Reference JEDEC registration MS-012, variation AB.



LAND PATTERN EXAMPLE
SCALE:8X



SOLDER MASK DETAILS

4220718/A 09/2016

NOTES: (continued)

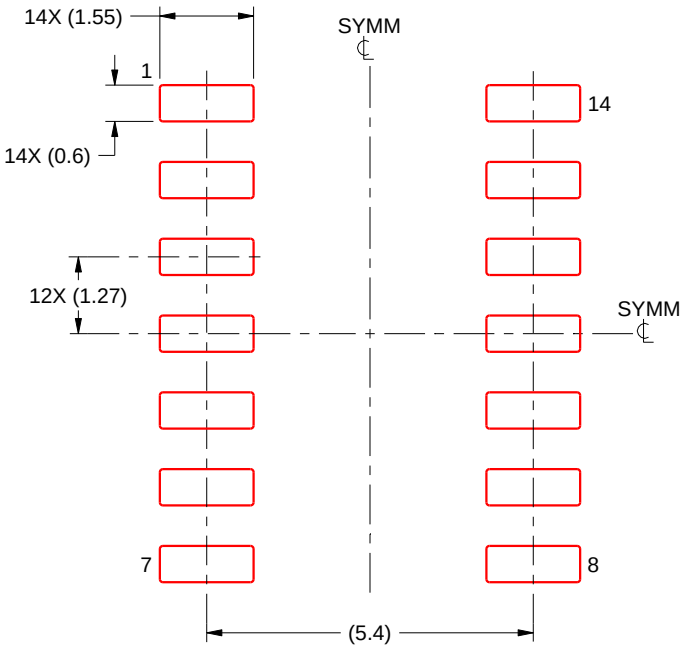
6. Publication IPC-7351 may have alternate designs.
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.

EXAMPLE STENCIL DESIGN

D0014A

SOIC - 1.75 mm max height

SMALL OUTLINE INTEGRATED CIRCUIT



SOLDER PASTE EXAMPLE
BASED ON 0.125 mm THICK STENCIL
SCALE:8X

4220718/A 09/2016

NOTES: (continued)

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

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