

## SN65HVD01 3.3V RS-485 with Flexible I/O Supply and Selectable Speed

### 1 Features

- Exceeds Requirements of TIA-485 Standard
- 1.65-V to 3.6-V Supply for Data and Enable Signals
- 3-V to 3.6-V Supply for Bus Signals
- SLR Pin Selectable Data Rates: 250 kbps or 20 Mbps
- 1/8th Unit Load to Support up to 256 Nodes on a Bus
- Small 3 mm x 3 mm SON Package
- Failsafe Receiver (Bus Open, Bus Shorted, Bus Idle)
- Operating Temperature Range:  $-40^{\circ}\text{C}$  to  $125^{\circ}\text{C}$
- Bus-Pin Protection More Than:
  - $\pm 15\text{kV}$  HBM Protection
  - $\pm 16\text{kV}$  IEC61000-4-2 Contact Discharge
  - $\pm 16\text{kV}$  IEC61000-4-2 Air Discharge
  - $4\text{kV}$  IEC61000-4-4 Fast Transient Burst

### 2 Applications

- Telecom Infrastructure
- High-Speed Data Links
- Low-Voltage  $\mu\text{C}$  Communication

### 3 Description

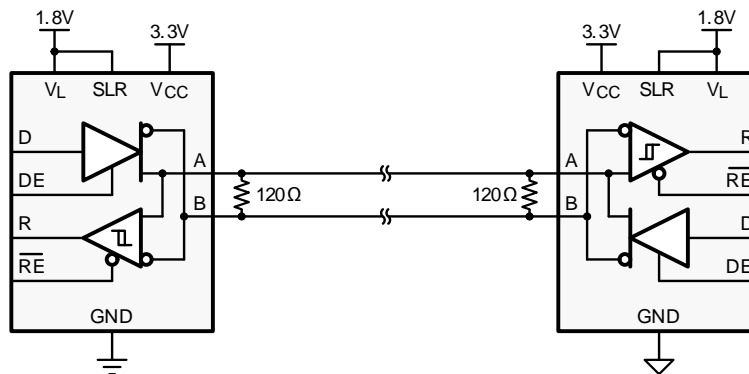
The SN65HVD01 is a low-power, 250 kbps or 20 Mbps data rate selectable RS-485 transceiver, utilizing a 1.65-V to 3.6-V supply for data and enable signals, and a  $3.3\text{ V} \pm 10\%$  supply for bus signals. The device is designed for applications requiring synchronous (parallel transceiver) signal timing. On-chip transient suppression protects the device against destructive IEC 61000 ESD and EFT transients.

The device combines a differential driver and a differential receiver, connected internally to form a bus port suitable for half-duplex (two-wire bus) communication. The device features a wide common-mode voltage range making it suitable for multi-point applications over long cable runs. The SN65HVD01 is available in a tiny, 3 mm x 3 mm, SON package with operation characterized from  $-40^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ .

#### Device Information

ORDER NUMBER	PACKAGE	BODY SIZE
SN65HVD01DRC	SON (10)	3mm x 3mm

#### Typical Application



## Table of Contents

<b>1 Features</b> .....	<b>1</b>	8.1 Overview .....	<b>15</b>
<b>2 Applications</b> .....	<b>1</b>	8.2 Functional Block Diagram .....	<b>15</b>
<b>3 Description</b> .....	<b>1</b>	8.3 Feature Description .....	<b>15</b>
<b>4 Revision History</b> .....	<b>2</b>	8.4 Device Functional Modes .....	<b>15</b>
<b>5 Pin Configuration and Functions</b> .....	<b>4</b>	<b>9 Applications and Implementation</b> .....	<b>18</b>
<b>6 Specifications</b> .....	<b>4</b>	9.1 Application Information .....	<b>18</b>
6.1 Absolute Maximum Ratings .....	<b>4</b>	9.2 Typical Application .....	<b>18</b>
6.2 Handling Ratings .....	<b>5</b>	<b>10 Power Supply Recommendations</b> .....	<b>21</b>
6.3 Recommended Operating Conditions .....	<b>5</b>	<b>11 Layout</b> .....	<b>21</b>
6.4 Thermal Information .....	<b>5</b>	11.1 Layout Guidelines .....	<b>21</b>
6.5 Dissipation Ratings .....	<b>6</b>	11.2 Layout Example .....	<b>21</b>
6.6 Electrical Characteristics .....	<b>7</b>	<b>12 Device and Documentation Support</b> .....	<b>22</b>
6.7 Switching Characteristics .....	<b>8</b>	12.1 Trademarks .....	<b>22</b>
6.8 Typical Characteristics .....	<b>9</b>	12.2 Electrostatic Discharge Caution .....	<b>22</b>
<b>7 Parameter Measurement Information</b> .....	<b>11</b>	12.3 Glossary .....	<b>22</b>
<b>8 Detailed Description</b> .....	<b>15</b>	<b>13 Mechanical, Packaging, and Orderable Information</b> .....	<b>22</b>

## 4 Revision History

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

<b>Changes from Revision E (March 2014) to Revision F</b>	<b>Page</b>
• Changed <a href="#">Figure 22</a> image and CH3 scale from: 100 V/div To 2 V/div .....	<b>20</b>
• Changed <a href="#">Figure 23</a> CH3 scale from: 100 V/div To 2 V/div .....	<b>20</b>

<b>Changes from Revision D (November 2013) to Revision E</b>	<b>Page</b>
• Changed the data sheet to the new TI standard layout .....	<b>1</b>
• Added the Device Information Table .....	<b>1</b>
• Added the Handling Ratings table .....	<b>5</b>
• Added the Detailed Description section .....	<b>15</b>
• Changed <a href="#">Figure 17</a> .....	<b>17</b>
• Added the Applications and Implementation section .....	<b>18</b>
• Deleted the Application Information section .....	<b>18</b>
• Added the Power Supply Recommendations .....	<b>21</b>
• Added the Layout section .....	<b>21</b>

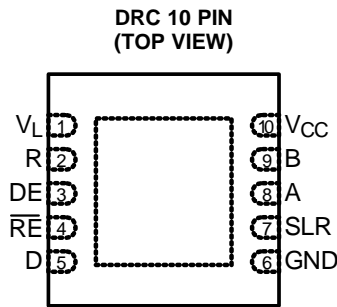
<b>Changes from Revision C (November 2013) to Revision D</b>	<b>Page</b>
• Changed Feature From: Small 3 mm x 3 mm VQFN Package To: Small 3 mm x 3 mm SON Package .....	1
• Changed Feature From: Bus-Pin Protection: To: Bus-Pin Protection More Than: .....	1
• Changed Feature From: $\leq 15\text{kV}$ To: $\pm 15\text{ kV}$ HBM Protection .....	1
• Changed Feature From: $\leq 15\text{kV}$ To: $\pm 16\text{ kV}$ Contact Discharge.....	1
• Changed Feature From: $\leq 15\text{kV}$ To: $\pm 16\text{ kV}$ Air Discharge.....	1
• Changed DESCRIPTION text From: 3 mm x 3 mm, VQFN package To: 3 mm x 3 mm, SON package .....	1
• Changed the ABSOLUTE MAXIMUM RATINGS for IEC 61000-4-2 ESD (Air-Gap Discharge) From MAX = $\pm 15$ To: MAX = $\pm 16$ .....	5
• Changed the ABSOLUTE MAXIMUM RATINGS for IEC 61000-4-2 ESD (Contact Discharge) From MAX = $\pm 15$ To: MAX = $\pm 16$ .....	5
• Changed the Thermal Information table package From VQFN (DRC) To; SON (DRC) .....	5

<b>Changes from Revision B (October 2013) to Revision C</b>	<b>Page</b>
• Changed from Product Preview to Production Data.....	1

<b>Changes from Revision A (October 2013) to Revision B</b>	<b>Page</b>
• Added 8 Typical Characteristics curves .....	9

<b>Changes from Original (July 2013) to Revision A</b>	<b>Page</b>
• Changed Feature From: 1.8-V to 3.3-V Supply for Data and Enable Signals To: 1.65-V to 3.6-V Supply for Data and Enable Signals.....	1
• Changed Feature From: 3.3 V Supply for Bus Signals To: 3-V to 3.6-V Supply for Bus Signals.....	1
• Changed Feature From: Selectable Data Rates: 250 kbps or 20 Mbps To: SLR Pin Selectable Data Rates: 250 kbps or 20 Mbps.....	1
• Changed the list of APPLICATIONS .....	1
• Changed the DESCRIPTION .....	1
• Changed From: 100 $\Omega$ resistors To: 120 $\Omega$ resistors in the Typical Application circuit.....	1
• Changed the ELECTRICAL CHARACTERISTICS table values .....	7
• Changed the SWITCHING CHARACTERISTICS table values .....	8
• Changed $V_{CC}$ and 3 V to $V_L$ in <a href="#">Figure 9</a> through <a href="#">Figure 16</a> .....	11
• Changed <a href="#">Figure 17</a> .....	17

## 5 Pin Configuration and Functions



**Pin Functions**

NAME	NO.	I/O	DESCRIPTION
$V_L$	1	Logic Supply	1.65 V to 3.6 V supply for logic I/O signals R, $\overline{RE}$ , D, DE, and SLR)
R	2	Digital Output	Receive data output
DE	3	Digital Input	Driver enable input
$\overline{RE}$	4	Digital Input	Receiver enable input
D	5	Digital Input	Transmission data input
GND	6	Reference Potential	Local device ground
SLR	7	Digital Input	Slew rate select: Low = 20 Mbps, High = 250 kbps. Defaults to 20 Mbps if SLR is left floating
A	8	Bus I/O	Digital bus I/O, A
B	9	Bus I/O	Digital bus I/O, B
$V_{CC}$	10	Bus Supply	3 V to 3.6 V supply for A and B bus lines

## 6 Specifications

### 6.1 Absolute Maximum Ratings<sup>(1)</sup>

	VALUE		UNIT
	MIN	MAX	
Control supply voltage, $V_L$	-0.5	4	V
Bus supply voltage, $V_{CC}$	-0.5	5.5	V
Voltage range at A or B Inputs	-13	16.5	V
Input voltage range at any logic terminal	-0.3	5.7	V
Voltage input range, transient pulse, A and B, through 100 $\Omega$	-100	100	V
Receiver output current	-12	12	mA
Junction temperature, $T_J$		170	$^{\circ}\text{C}$
Continuous total power dissipation	See the <a href="#">Thermal Information</a> table		

- (1) Stresses beyond those listed under "absolute maximum ratings" may cause permanent damage to the device. These are stress ratings only and functional operation of the device at these or any other conditions beyond those indicated under "recommended operating conditions" is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

## 6.2 Handling Ratings

		MIN	MAX	UNIT
$T_{STG}$	Storage temperature range	-65	150	°C
$V_{ESD}$	IEC 60749-26 ESD (Human Body Model), bus terminals and GND		±15	kV
	IEC 61000-4-2 ESD (Air-Gap Discharge), bus terminals and GND <sup>(1)</sup>		±16	kV
	IEC 61000-4-2 ESD (Contact Discharge), bus terminals and GND		±16	kV
	IEC 61000-4-4 EFT (Fast transient or burst) bus terminals and GND		±4	kV
	JEDEC Standard 22, Test Method A114 (Human Body Model), all terminals		±8	kV
	JEDEC Standard 22, Test Method C101 (Charged Device Model), all terminals		±1.5	kV

(1) As stated in the IEC 61000-4-2 standard, contact discharge is the preferred transient protection test method. Although IEC air-gap testing is less repeatable than contact testing, air discharge protection levels are inferred from the contact discharge test results.

## 6.3 Recommended Operating Conditions

		MIN	NOM	MAX	UNIT
$V_L$	Control supply voltage	1.65		3.6	V
$V_{CC}$	Bus supply voltage	3	3.3	3.6	V
$V_I$	Input voltage at any bus terminal (separately or common mode) <sup>(1)</sup>	-7		12	V
$V_{IH}$	High-level input voltage (Driver, driver enable, receiver enable inputs, and slew rate select)	$0.7 \times V_L$		$V_L$	V
$V_{IL}$	Low-level input voltage (Driver, driver enable, receiver enable inputs, and slew rate select)	0		$0.3 \times V_L$	V
$V_{ID}$	Differential input voltage	-12		12	V
$I_O$	Output current	Driver		80	mA
		Receiver		2	mA
$R_L$	Differential load resistance	54	60		Ω
$C_L$	Differential load capacitance		50		pF
$1/t_{UI}$	Signaling rate	SLR = '0'		20	Mbps
		SLR = '1'		250	kbps
$T_A$ <sup>(2)</sup>	Operating free-air temperature <a href="#">Thermal Information</a>	-40		125	°C

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

(2) Operation is specified for internal (junction) temperatures up to 150°C. Self-heating due to internal power dissipation should be considered for each application. Maximum junction temperature is internally limited by the thermal shut-down (TSD) circuit which disables the driver outputs when the junction temperature reaches 170°C.

## 6.4 Thermal Information

	PARAMETER <sup>(1)</sup>	SON (DRC)	UNIT
$\theta_{JA}$	Junction-to-Ambient Thermal Resistance	41.4	°C/W
$\theta_{JC(top)}$	Junction-to-Case(top) Thermal Resistance	48.7	
$\theta_{JB}$	Junction-to-Board Thermal Resistance	18.8	
$\Psi_{JT}$	Junction-to-Top characterization parameter	0.6	
$\Psi_{JB}$	Junction-to-Board characterization parameter	19	
$\theta_{JC(bottom)}$	Junction-to-Case(bottom) Thermal Resistance	3.7	
$T_{TSD}$	Thermal Shut-down junction temperature	170	°C

(1) For more information about traditional and new thermal metrics, see the *IC Package Thermal Metrics* application report, [SPRA953](#)

## 6.5 Dissipation Ratings

PARAMETER		TEST CONDITIONS		VALUE	UNIT	
PD	Power Dissipation driver and receiver enabled, $V_{CC} = V_L = 3.6\text{ V}$ , $T_J = 150^\circ\text{C}$ , 50% duty cycle square-wave signal at signaling rate	Unterminated	$R_L = 300\ \Omega$ , $C_L = 50\ \text{pF}$ (driver)	250 kbps	125	mW
			20 Mbps	175		
		RS-422 load	$R_L = 100\ \Omega$ , $C_L = 50\ \text{pF}$ (driver)	250 kbps	165	mW
				20 Mbps	215	
		RS-485 load	$R_L = 54\ \Omega$ , $C_L = 50\ \text{pF}$ (driver)	250 kbps	200	mW
				20 Mbps	250	

## 6.6 Electrical Characteristics

over recommended operating range (unless otherwise specified)

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT	
V <sub>OD</sub>	Driver differential output voltage magnitude	R <sub>L</sub> = 60 Ω, 375 Ω on each output to -7 V to 12 V	See Figure 9	1.5	2		V	
		R <sub>L</sub> = 54 Ω (RS-485)	See Figure 10	1.5	2		V	
		R <sub>L</sub> = 100 Ω (RS-422) T <sub>J</sub> ≥ 0°C, V <sub>CC</sub> ≥ 3.2V		2			V	
Δ V <sub>OD</sub>	Change in magnitude of driver differential output voltage	R <sub>L</sub> = 54 Ω, C <sub>L</sub> = 50 pF		-50	0	50	mV	
V <sub>OC(SS)</sub>	Steady-state common-mode output voltage	Center of two 27-Ω load resistors	See Figure 10	1	V <sub>CC</sub> /2	3	V	
ΔV <sub>OC</sub>	Change in differential driver output common-mode voltage			-50	0	50	mV	
V <sub>OC(PP)</sub>	Peak-to-peak driver common-mode output voltage				500			mV
C <sub>OD</sub>	Differential output capacitance				15		pF	
V <sub>IT+</sub>	Positive-going receiver differential input voltage threshold			See <sup>(1)</sup>	-60	-20	mV	
V <sub>IT-</sub>	Negative-going receiver differential input voltage threshold			-200	-130	See <sup>(1)</sup>	mV	
V <sub>HYS</sub>	Receiver differential input voltage threshold hysteresis (V <sub>IT+</sub> - V <sub>IT-</sub> )			40	70		mV	
V <sub>OH</sub>	Receiver high-level output voltage	V <sub>L</sub> = 1.65 V, I <sub>OH</sub> = -2 mA		1.3	1.45		V	
		V <sub>L</sub> = 3 V, I <sub>OH</sub> = -2 mA		2.8	2.9		V	
V <sub>OL</sub>	Receiver low-level output voltage	V <sub>L</sub> = 1.65 V, I <sub>OL</sub> = 2 mA			0.2	0.35	V	
		V <sub>L</sub> = 3 V, I <sub>OL</sub> = 2 mA			0.1	0.2	V	
I <sub>i</sub>	Driver input, driver enable, and receiver enable input current			-2		2	μA	
I <sub>OZ</sub>	Receiver output high-impedance current	V <sub>O</sub> = 0 V or V <sub>L</sub> , $\overline{RE}$ at V <sub>L</sub>		-1		1	μA	
I <sub>OS</sub>	Driver short-circuit output current			-150		150	mA	
I <sub>i</sub>	Bus input current (disabled driver)	V <sub>L</sub> = 1.8 V, V <sub>CC</sub> = 3.3 V, DE at 0 V	V <sub>I</sub> = 12 V		85	125	μA	
			V <sub>I</sub> = -7 V		-100	-60	μA	
I <sub>CC</sub>	Supply current (quiescent)	Driver and Receiver enabled	DE=V <sub>L</sub> , RE = GND, No load	T <sub>J</sub> ≤ 85°C		750	1100	μA
							1000	μA
		Driver enabled, receiver disabled	DE=V <sub>CC</sub> , $\overline{RE}$ = V <sub>L</sub> , No load		350	650	μA	
		Driver disabled, receiver enabled	DE=GND, $\overline{RE}$ = GND, No load		650	800	μA	
	Driver and receiver disabled	DE=GND, $\overline{RE}$ = V <sub>L</sub> , No load		0.1	5	μA		
Supply current (dynamic)		See the <a href="#">Typical Characteristics</a> section						

(1) Under any specific conditions, V<sub>IT+</sub> is specified to be at least V<sub>HYS</sub> higher than V<sub>IT-</sub>.

## 6.7 Switching Characteristics

over recommended operating conditions

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
<b>DRIVER, SLR = '1', 250 kbps, bit time <math>\geq 4 \mu\text{s}</math></b>							
$t_r, t_f$	Driver differential output rise/fall time	$R_L = 54 \Omega, C_L = 50 \text{ pF}$	See <a href="#">Figure 11</a>	0.4	0.8	1.2	$\mu\text{s}$
$t_{PHL}, t_{PLH}$	Driver propagation delay			0.4	0.8	1.2	$\mu\text{s}$
$t_{SK(P)}$	Driver pulse skew, $ t_{PHL} - t_{PLH} $					0.2	$\mu\text{s}$
$t_{PHZ}, t_{PLZ}$	Driver disable time			0.025	0.1		$\mu\text{s}$
$t_{PZH}, t_{PZL}$	Driver enable time	Receiver enabled	See <a href="#">Figure 12</a> and <a href="#">Figure 13</a>		0.6	1	$\mu\text{s}$
		Receiver disabled			3.5	8	$\mu\text{s}$
<b>DRIVER, SLR = '0', 20 Mbps, bit time <math>\geq 50 \text{ ns}</math></b>							
$t_r, t_f$	Driver differential output rise/fall time	$R_L = 54 \Omega, C_L = 50 \text{ pF}$	See <a href="#">Figure 11</a>	5	10	15	ns
$t_{PHL}, t_{PLH}$	Driver propagation delay			6	15	25	ns
$t_{SK(P)}$	Driver pulse skew, $ t_{PHL} - t_{PLH} $					4	ns
$t_{PHZ}, t_{PLZ}$	Driver disable time			20	35		ns
$t_{PZH}, t_{PZL}$	Driver enable time	Receiver enabled	See <a href="#">Figure 12</a> and <a href="#">Figure 13</a>		14	30	ns
		Receiver disabled			3	7	$\mu\text{s}$
<b>RECEIVER, SLR = 'X'</b>							
$t_r, t_f$	Receiver output rise/fall time	$C_L = 15 \text{ pF}$	See <a href="#">Figure 14</a>		5	15	ns
$t_{PHL}, t_{PLH}$	Receiver propagation delay time			30	60	90	ns
$t_{SK(P)}$	Receiver pulse skew, $ t_{PHL} - t_{PLH} $					15	ns
$t_{PLZ}, t_{PHZ}$	Receiver disable time			10	20		ns
$t_{pZL(1)}, t_{pZH(1)}$ $t_{pZL(2)}, t_{pZH(2)}$	Receiver enable time	Driver enabled	See <a href="#">Figure 15</a>		15	80	ns
		Driver disabled	See <a href="#">Figure 16</a>		3	8	$\mu\text{s}$



## 6.8 Typical Characteristics

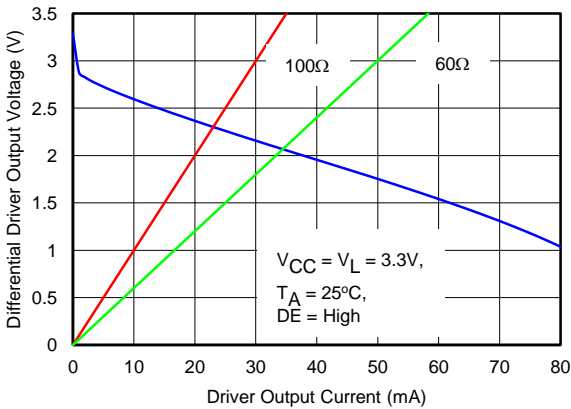


Figure 1. Differential Driver Output Voltage vs Driver Output Current

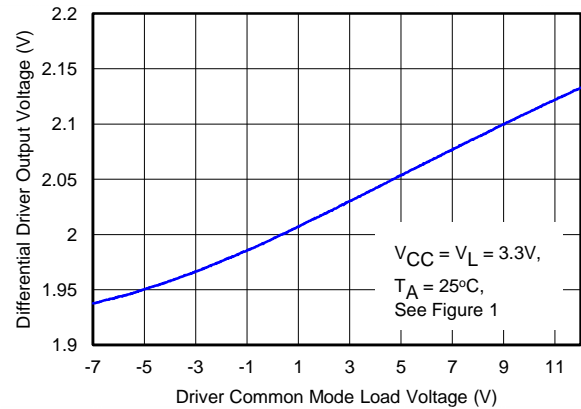


Figure 2. Differential Driver Output Voltage vs Driver Common Mode Load Voltage

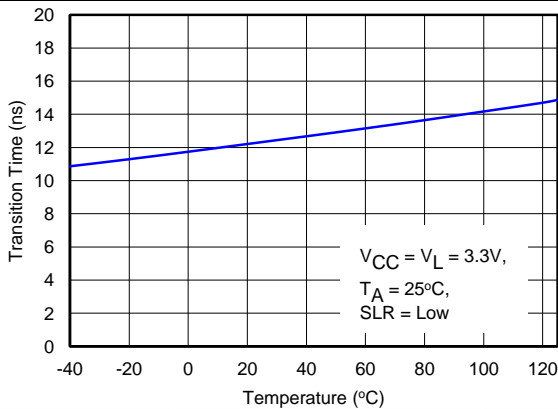


Figure 3. Transition Time vs Temperature

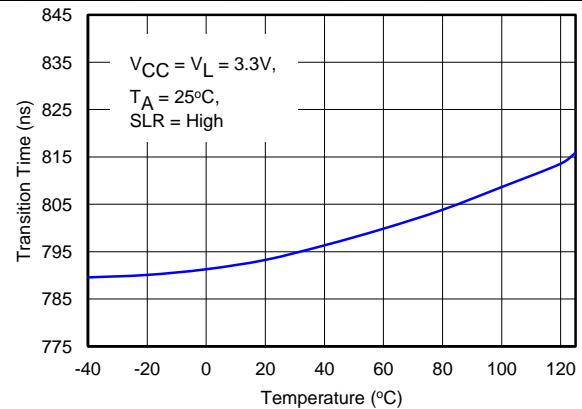


Figure 4. Transition Time vs Temperature

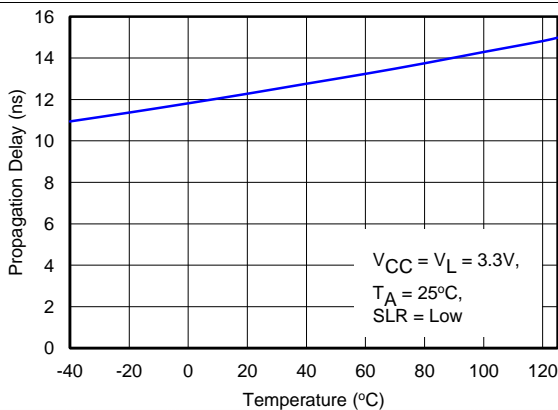


Figure 5. Propagation Delay vs Temperature

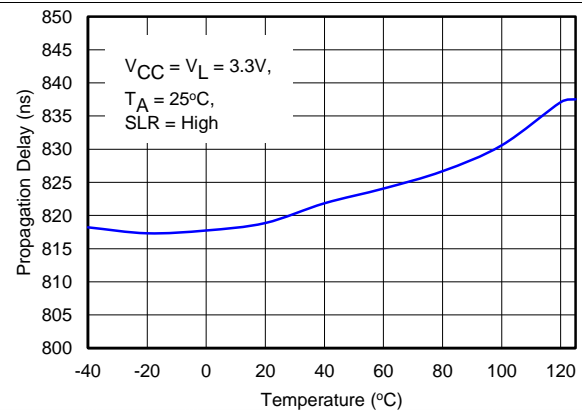
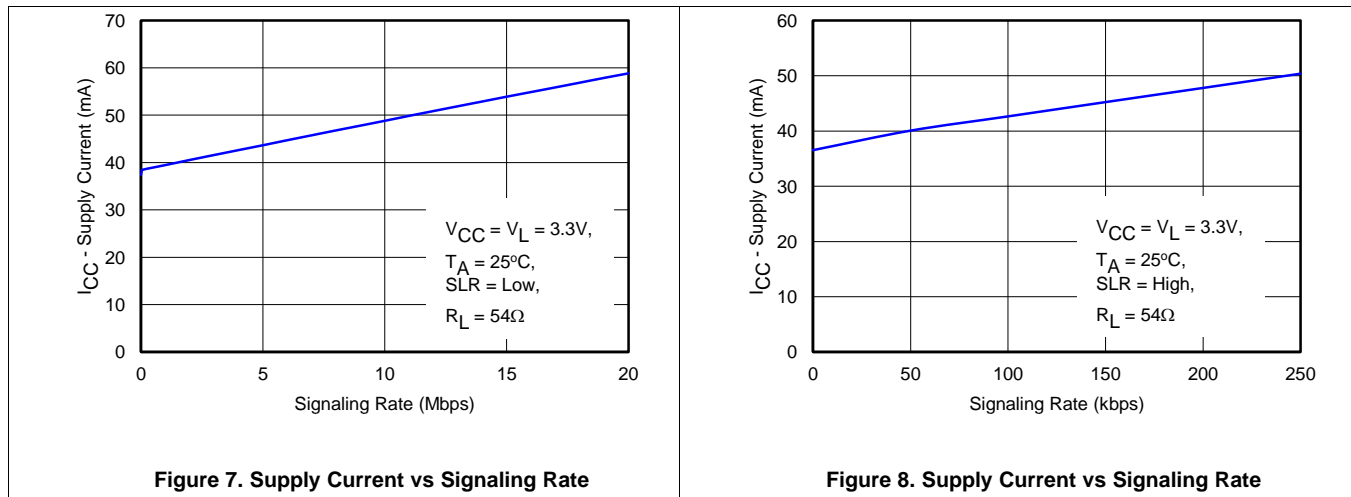


Figure 6. Propagation Delay vs Temperature

**Typical Characteristics (continued)**


## 7 Parameter Measurement Information

Input generator rate is 100 kbps, 50% duty cycle, rise and fall times less than 6 nsec.

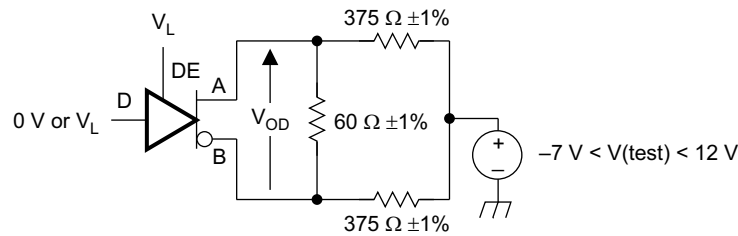


Figure 9. Measurement of Driver Differential Output Voltage with Common-Mode Load

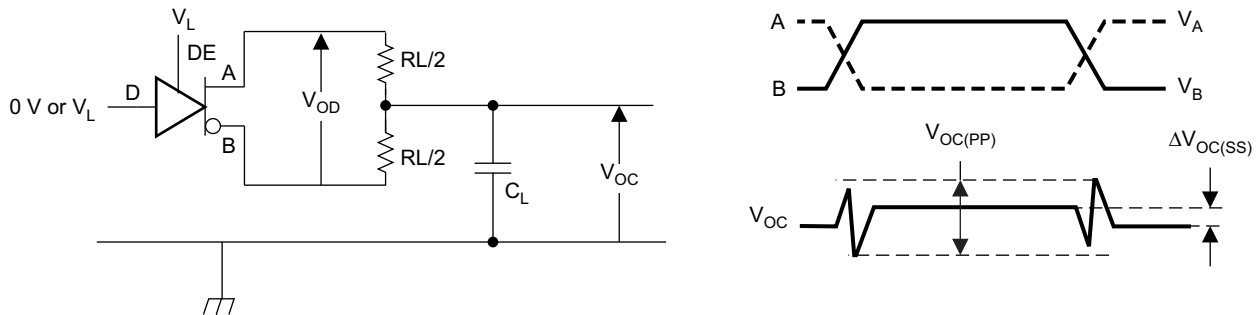


Figure 10. Measurement of Driver Differential and Common-Mode Output with RS-485 Load

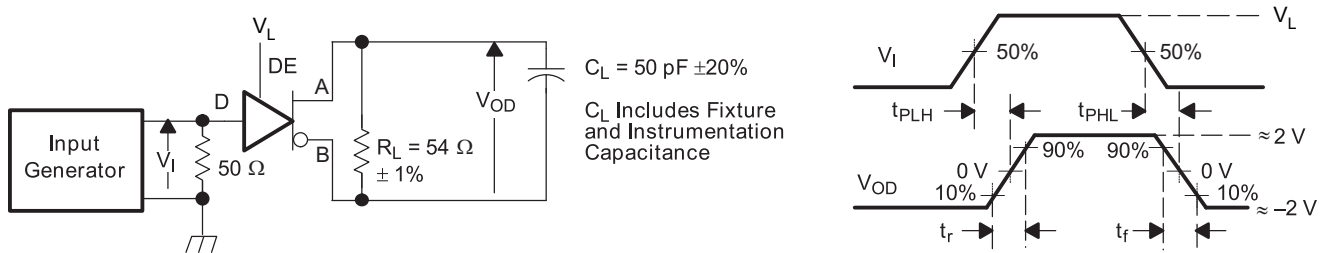
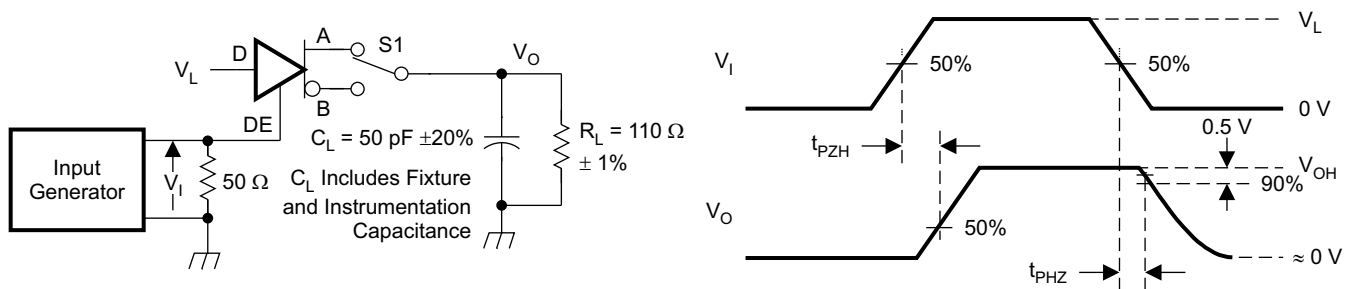


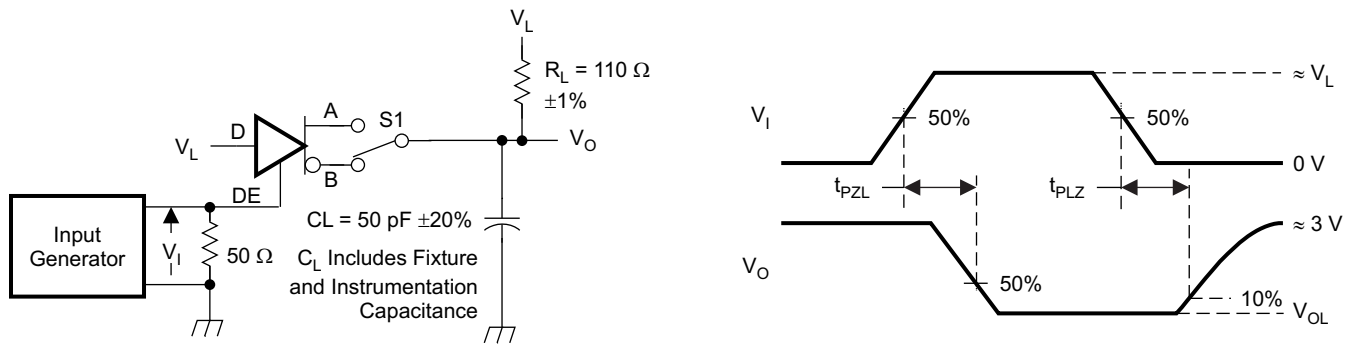
Figure 11. Measurement of Driver Differential Output Rise and Fall Times and Propagation Delays



D at  $V_L$  to test non-inverting output, D at 0 V to test inverting output.

Figure 12. Measurement of Driver Enable and Disable Times with Active High Output and Pull-Down Load

Parameter Measurement Information (continued)



D at 0V to test non-inverting output, D at  $V_L$  to test inverting output.

Figure 13. Measurement of Driver Enable and Disable Times with Active Low Output and Pull-Up Load

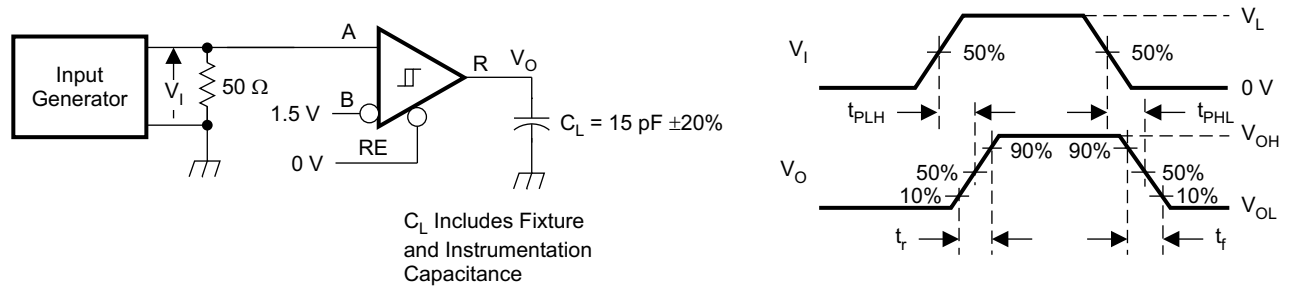


Figure 14. Measurement of Receiver Output Rise and Fall Times and Propagation Delays

Parameter Measurement Information (continued)

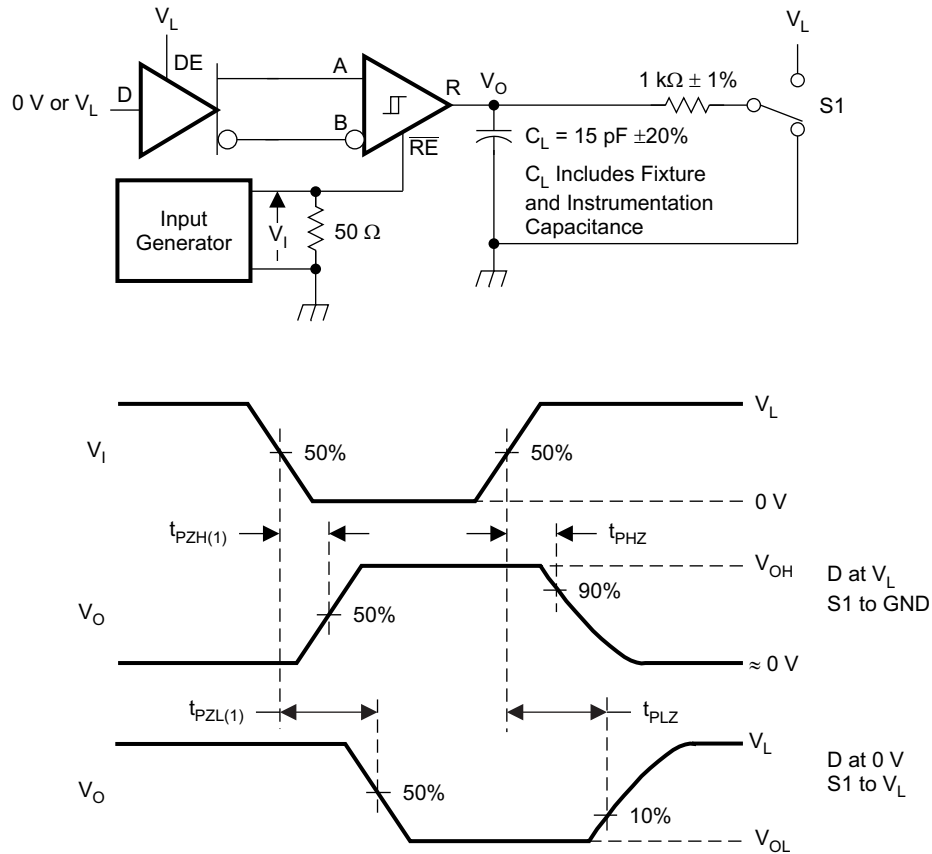


Figure 15. Measurement of Receiver Enable/Disable Times with Driver Enabled

Parameter Measurement Information (continued)

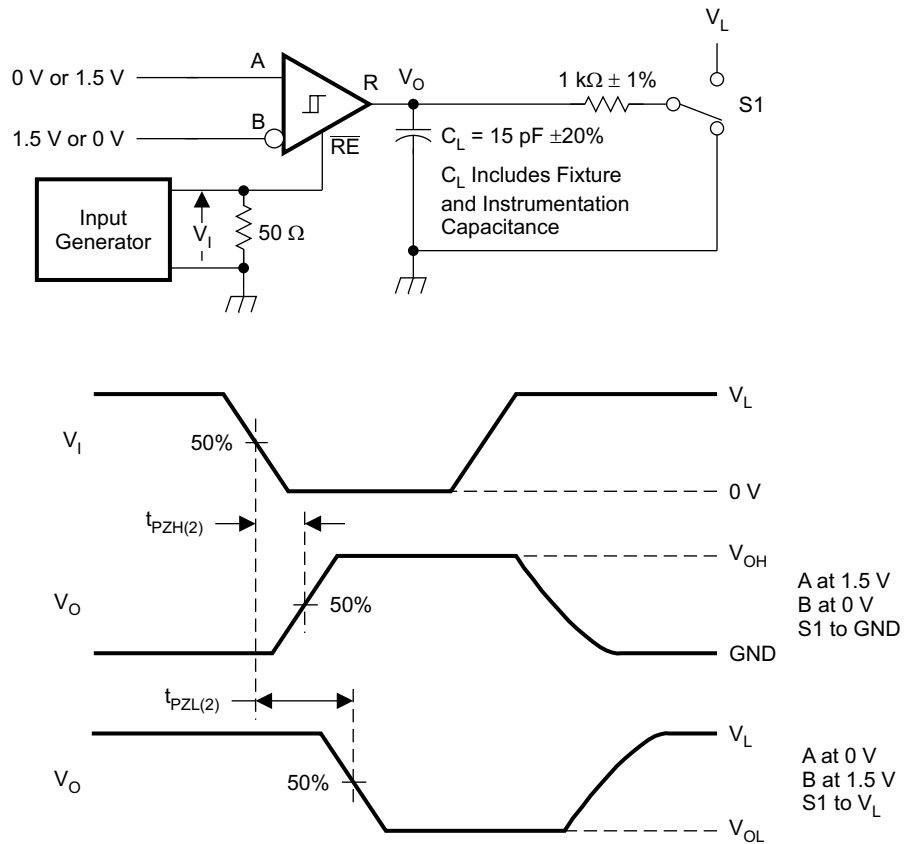


Figure 16. Measurement of Receiver Enable Times with Driver Disabled

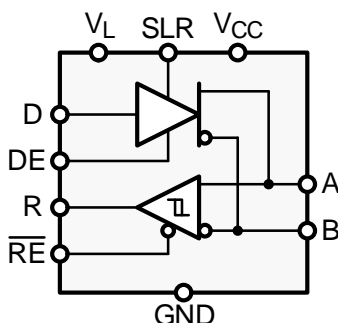
## 8 Detailed Description

### 8.1 Overview

The SN65HVD01 is a low-power, half-duplex RS-485 transceiver whose maximum data rate can be set to either 250 kbps or 20 Mbps via a selection terminal, SLR.

The device possesses two power supply inputs, one for logic control functions,  $V_L$ , and the other for the bus supply,  $V_{CC}$ .  $V_L$  can range from 1.65 V minimum up to 3.6 V maximum and allows for the direct interface to low-voltage FPGAs and micro controllers.  $V_{CC}$  requires a supply between 3 V to 3.6 V to assure sufficient output drive capability across a wide common-mode range.

### 8.2 Functional Block Diagram



### 8.3 Feature Description

Internal ESD protection circuits protect the transceiver against Electrostatic discharges (ESD) according to IEC61000-4-2 of up to  $\pm 16$  kV, and against electrical fast transients (EFT) according to IEC61000-4-4 of up to  $\pm 4$  kV.

The SN65HVD01 provides internal biasing of the receiver input thresholds in combination with large input-threshold hysteresis. At a positive input threshold of  $V_{IT+} = -60$  mV and an input hysteresis of  $V_{HYS} = 70$  mV, the receiver output remains logic high even in the presence of 130 mV<sub>PK</sub> differential noise without the need for external failsafe biasing resistors.

Device operation is specified over a wide temperature range from  $-40^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ .

### 8.4 Device Functional Modes

When driver enable terminal, 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 terminal has an internal pull-down resistor to ground, thus when left open the driver is disabled (high-impedance) by default. The D terminal has an internal pull-up resistor to  $V_L$ , thus, when left open while the driver is enabled, output A turns high and B turns low.

Table 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 terminal,  $\overline{RE}$ , is logic low, the receiver is enabled. When the differential input voltage defined as  $V_{ID} = V_A - V_B$  is positive and higher than the positive input threshold,  $V_{IT+}$ , the receiver output, R, turns high. When  $V_{ID}$  is negative and less than the negative and lower than the negative input threshold,  $V_{IT-}$ , the receiver output, R, turns low. If  $V_{ID}$  is between  $V_{IT+}$  and  $V_{IT-}$  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 (short-circuit), or the bus is not actively driven (idle bus).

**Table 2. Receiver Function Table**

DIFFERENTIAL INPUT	ENABLE	OUTPUT	FUNCTION
$V_{ID} = V_A - V_B$	$\overline{RE}$	R	
$V_{IT+} < V_{ID}$	L	H	Receive valid bus High
$V_{IT-} < V_{ID} < V_{IT+}$	L	?	Indeterminate bus state
$V_{ID} < V_{IT-}$	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

Connecting SLR to  $V_L$  limits the maximum data rate to 250 kbps and increases the driver rise and fall times to 800 ns. Connecting SLR to GND increases the upper data rate limit to 20 Mbps and reduces the driver rise and fall times to 10 ns.

**Table 3. SLR-Terminal Configuration**

SLR-INPUT	DATA RATE	TYP tr / tf
$V_L$	250 kbps	800 ns
GND or OPEN	20 Mbps	10 ns



8.4.1 Equivalent Input and Output Schematic Diagrams

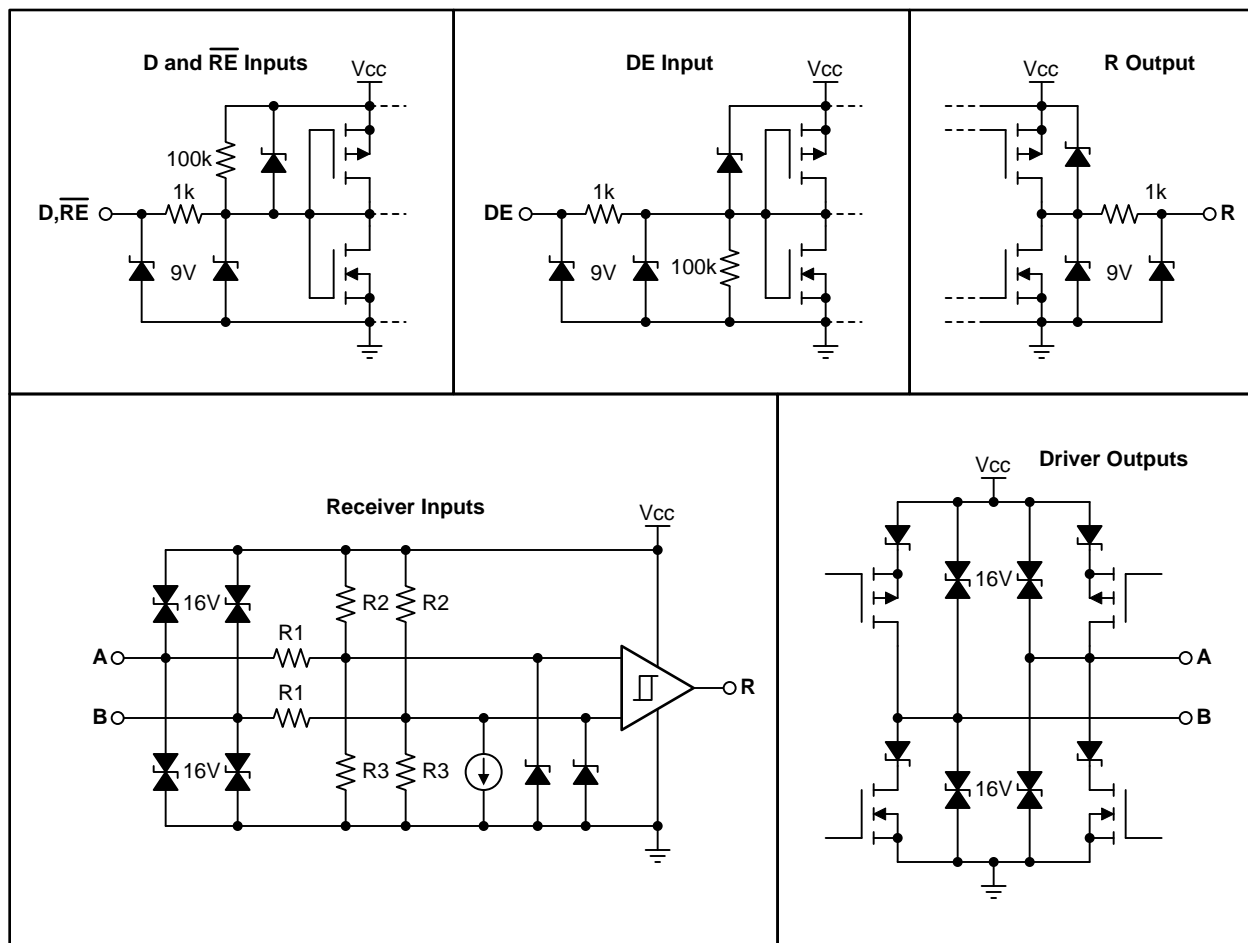
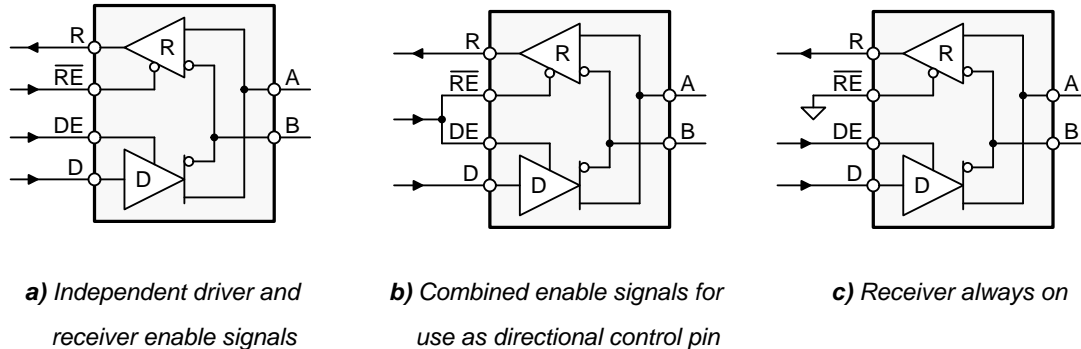


Figure 17. Equivalent Input and Output Schematic Diagrams

## 9 Applications and Implementation

### 9.1 Application Information

The SN65HVD01 is a half-duplex RS-485 transceiver commonly used for asynchronous data transmissions. The driver and receiver enable terminals allow for the configuration of different operating modes.



**Figure 18. SN65HVD01 Transceiver Configurations**

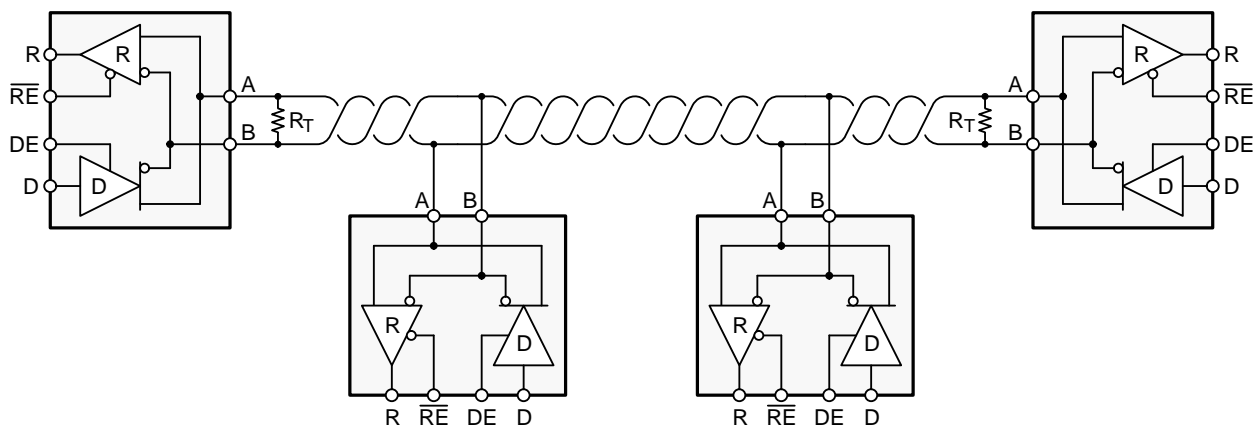
Using independent enable lines provides the most flexible control as it allows for the driver and the receiver to be turned on and off individually. While this configuration requires two control lines, it allows for selective listening into the bus traffic, whether the driver is transmitting data or not.

Combining the enable signals simplifies the interface to the controller by forming a single, direction-control signal. Thus, when the direction-control line is high, the transceiver is configured as a driver, while for a low the device operates as a receiver.

Tying the receiver-enable to ground and controlling only the driver-enable input, also uses one control line only. In this configuration, a node not only receives the data from the bus but also the data it sends and thus can verify that the correct data have been transmitted.

### 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,  $R_T$ , whose value 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 19. Typical RS-485 Network with SN65HVD01 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.

## Typical Application (continued)

### 9.2.1.1 Data Rate and Bus Length

The maximum bus length is limited by the transmission line losses and the signal jitter at a given data rate. Because data reliability sharply decreases for a jitter of 10% or more of the baud period, Figure 20 shows the cable length versus data rate characteristic of a conventional RS-485 cable for signal jitter of 10%.

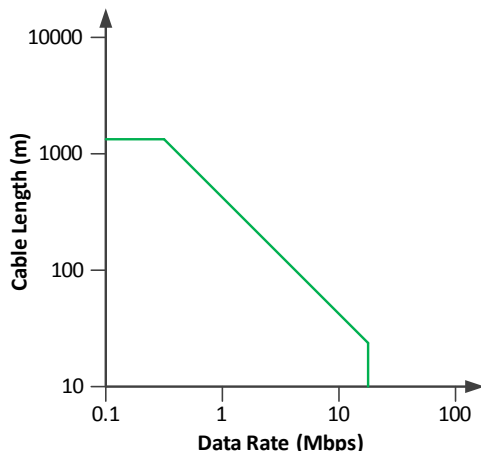


Figure 20. Cable Length vs Data Rate

### 9.2.1.2 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 SN65HVD01 is a 1/8 UL transceiver, it is possible to connect up to 256 devices to the bus.

### 9.2.2 Detailed Design Procedure

In order to protect bus nodes against high-energy transients, the implementation of external transient protection devices is therefore necessary. Figure 21 suggests a protection circuit against 10 kV ESD, 4 kV EFT, and 1 kV surge transients.

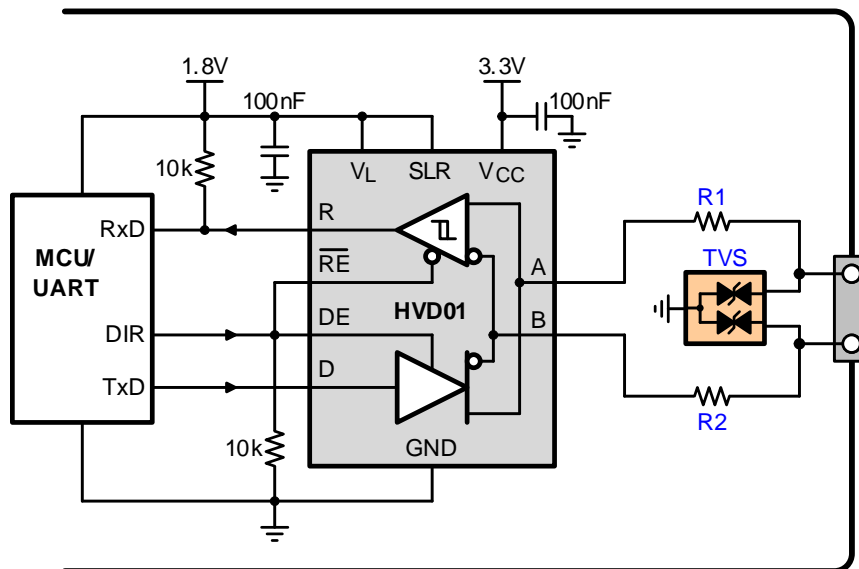


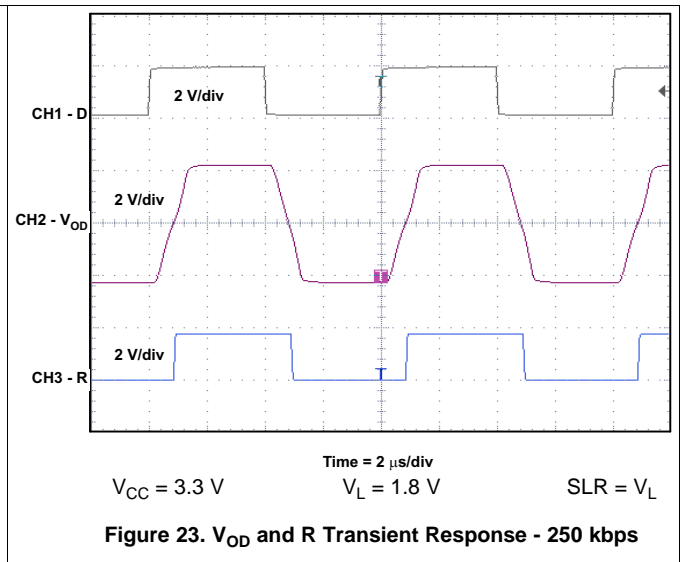
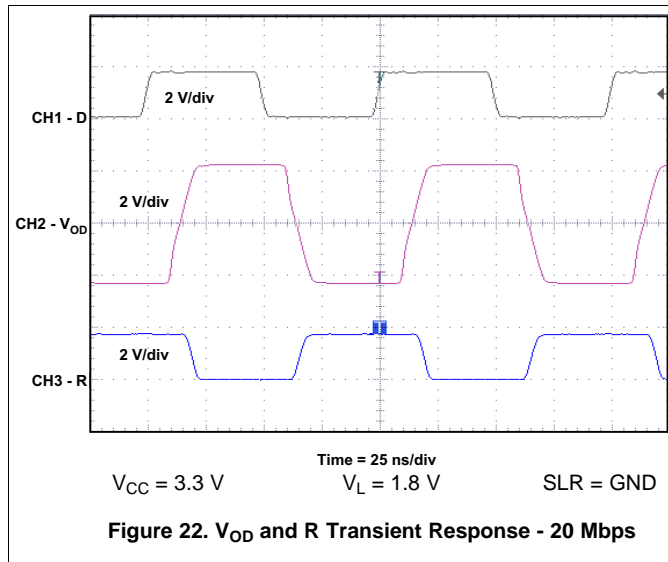
Figure 21. Transient Protection Against ESD, EFT, and Surge Transients

Typical Application (continued)

Table 4. Recommended Materials

Device	Function	Order Number
XCVR	3.3V, 250kbps RS-485 Transceiver	SN65HVD01D
R1,R2	10Ω, Pulse-Proof Thick-Film Resistor	CRCW0603010RJNEAHP
TVS	Bidirectional 400W Transient Suppressor	CDSOT23-SM712

9.2.3 Application Performance Curves



## 10 Power Supply Recommendations

To assure reliable operation at all data rates and supply voltages, each supply should be buffered with a 100 nF ceramic capacitor located as close to the supply terminals as possible. Linear voltage regulators for the 1.8 V logic and 3.3 V bus supplies are TPS76318 and TPS76333 respectively.

## 11 Layout

On-chip IEC-ESD protection is good for laboratory and portable equipment but never sufficient for EFT and surge transients occurring in industrial environments. Therefore robust and reliable bus node design requires the use of external transient protection devices.

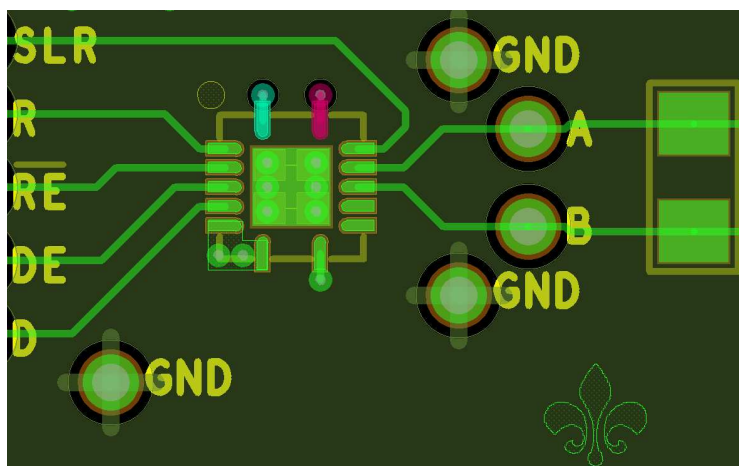
Because ESD and EFT transients have a wide frequency bandwidth from approximately 3 MHz to 3 GHz, high-frequency layout techniques must be applied during PCB design.

In order for your PCB design to be successful start with the design of the protection circuit in mind.

### 11.1 Layout Guidelines

- Place the protection circuitry close to the bus connector to prevent noise transients from penetrating your board.
- Use  $V_{CC}$  and ground planes to provide low-inductance. Note that high-frequency currents follow the path of least inductance and not the path of least impedance.
- Design the protection components into the direction of the signal path. Do not force the transients currents to divert from the signal path to reach the protection device.
- Apply 100 nF to 220 nF bypass capacitors as close as possible to the  $V_{CC}$  terminals of transceiver, UART, controller ICs on the board.
- Use at least two vias for  $V_{CC}$  and ground connections of bypass capacitors and protection devices to minimize effective via-inductance.
- Use 1k to 10k pull-up/down resistors for enable lines to limit noise currents in these lines during transient events.
- 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 terminals. These resistors limit the residual clamping current into the transceiver and prevent it from latching up.
- While pure TVS protection is sufficient for surge transients up to 1kV, higher transients require metal-oxide varistors (MOVs) which reduce the transients to a few hundred volts of clamping voltage, and transient blocking units (TBUs) that limit transient current to less than 1 mA.

### 11.2 Layout Example



## 12 Device and Documentation Support

### 12.1 Trademarks

All trademarks are the property of their respective owners.

### 12.2 Electrostatic Discharge Caution



These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

### 12.3 Glossary

[SLYZ022](#) — *TI Glossary*.

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

## 13 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
SN65HVD01DRCR	ACTIVE	VSON	DRC	10	2500	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	-40 to 125	HVD01	<a href="#">Samples</a>
SN65HVD01DRCT	ACTIVE	VSON	DRC	10	250	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	-40 to 125	HVD01	<a href="#">Samples</a>

(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.

**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**

**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
SN65HVD01DRCR	VSON	DRC	10	2500	330.0	12.4	3.3	3.3	1.1	8.0	12.0	Q2
SN65HVD01DRCT	VSON	DRC	10	250	180.0	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)
SN65HVD01DRCR	VSON	DRC	10	2500	335.0	335.0	25.0
SN65HVD01DRCT	VSON	DRC	10	250	182.0	182.0	20.0

## 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



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/sluea271](http://www.ti.com/lit/sluea271)).
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 DATA SHEETS), 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 will 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](#) or other applicable terms available either on [ti.com](https://www.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.

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

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265  
Copyright © 2023, Texas Instruments Incorporated