

## 3.3-V RS-485 TRANSCEIVERS

### FEATURES

- Operates With a 3.3-V Supply
- Bus-Pin ESD Protection Exceeds 16 kV HBM
- 1/8 Unit-Load Option Available (Up to 256 Nodes on the Bus)
- Optional Driver Output Transition Times for Signaling Rates† of 1 Mbps, 10 Mbps and 25 Mbps
- Meets or Exceeds the Requirements of ANSI TIA/EIA-485-A
- Bus-Pin Short Circuit Protection From –7 V to 12 V
- Low-Current Standby Mode . . . 1  $\mu$ A Typical
- Open-Circuit, Idle-Bus, and Shorted-Bus Failsafe Receiver
- Thermal Shutdown Protection
- Glitch-Free Power-Up and Power-Down Protection for Hot-Plugging Applications
- SN75176 Footprint

### APPLICATIONS

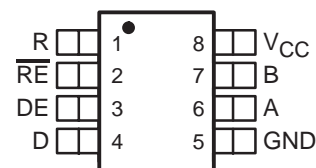
- Digital Motor Control
- Utility Meters
- Chassis-to-Chassis Interconnects
- Electronic Security Stations
- Industrial Process Control
- Building Automation
- Point-of-Sale (POS) Terminals and Networks

### DESCRIPTION

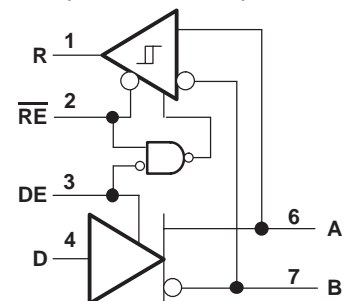
The SN65HVD10, SN75HVD10, SN65HVD11, SN75HVD11, SN65HVD12, and SN75HVD12 combine a 3-state differential line driver and differential input line receiver that operate with a single 3.3-V power supply. They are designed for balanced transmission lines and meet or exceed ANSI standard TIA/EIA-485-A and ISO 8482:1993. These differential bus transceivers are monolithic integrated circuits designed for bidirectional data communication on multipoint bus-transmission lines. The drivers and receivers have active-high and active-low enables respectively, that can be externally connected together to function as direction control. Very low device standby supply current can be achieved by disabling the driver and the receiver.

The driver differential outputs and receiver differential inputs connect internally to form a differential input/ output (I/O) bus port that is designed to offer minimum loading to the bus whenever the driver is disabled or  $V_{CC} = 0$ . These parts feature wide positive and negative common-mode voltage ranges, making them suitable for party-line applications.

D OR P PACKAGE  
(TOP VIEW)



LOGIC DIAGRAM  
(POSITIVE LOGIC)



Please be aware that an important notice concerning availability, standard warranty, and use in critical applications of Texas Instruments semiconductor products and disclaimers thereto appears at the end of this data sheet.

†The signaling rate of a line is the number of voltage transitions that are made per second expressed in the units bps (bits per second).



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.

## ORDERING INFORMATION

SIGNALING RATE	UNIT LOADS	T <sub>A</sub>	PACKAGE		SOIC MARKING
			SOIC(1)	PDIP	
25 Mbps	1/2	-40°C to 85°C	SN65HVD10D	SN65HVD10P	VP10
10 Mbps	1/8		SN65HVD11D	SN65HVD11P	VP11
1 Mbps	1/8		SN65HVD12D	SN65HVD12P	VP12
25 Mbps	1/2	-0°C to 70°C	SN75HVD10D	SN75HVD10P	VN10
10 Mbps	1/8		SN75HVD11D	SN75HVD11P	VN11
1 Mbps	1/8		SN75HVD12D	SN75HVD12P	VN12
25 Mbps	1/2	-40°C to 125°C	SN65HVD10QD	SN65HVD10QP	VP10Q
10 Mbps	1/8		SN65HVD11QD	SN65HVD11QP	VP11Q

(1) The D package is available taped and reeled. Add an R suffix to the part number (i.e., SN75HVD11DR).

## ABSOLUTE MAXIMUM RATINGS

over operating free-air temperature range unless otherwise noted<sup>(1)</sup> (2)

			SN65HVD10, SN75HVD10 SN65HVD11, SN75HVD11 SN65HVD12, SN75HVD12
Supply voltage range, V <sub>CC</sub>			-0.3 V to 6 V
Voltage range at A or B			-9 V to 14 V
Input voltage range at D, DE, R or $\overline{RE}$			-0.5 V to V <sub>CC</sub> + 0.5 V
Voltage input range, transient pulse, A and B, through 100 Ω (see Figure 11)			-50 V to 50 V
Electrostatic discharge	Human body model <sup>(3)</sup>	A, B and GND	16 kV
		All pins	4 kV
	Charged-device model <sup>(4)</sup>	All pins Charge	1 kV
Continuous total power dissipation			See Dissipation Rating Table
Junction temperature, T <sub>J</sub>			170°C
Storage temperature range, T <sub>stg</sub>			-65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds			260°C

(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.

(2) All voltage values, except differential I/O bus voltages, are with respect to network ground terminal.

(3) Tested in accordance with JEDEC Standard 22, Test Method A114-A.

(4) Tested in accordance with JEDEC Standard 22, Test Method C101.

## PACKAGE DISSIPATION RATINGS

PACKAGE	T <sub>A</sub> ≤ 25°C	DERATING FACTOR <sup>(1)</sup>	T <sub>A</sub> = 70°C	T <sub>A</sub> = 85°C	T <sub>A</sub> = 125°C
	POWER RATING	ABOVE T <sub>A</sub> = 25°C	POWER RATING	POWER RATING	POWER RATING
D <sup>(2)</sup>	597 mW	4.97 mW/°C	373 mW	298 mW	100 mW
D <sup>(3)</sup>	990 mW	8.26 mW/°C	620 mW	496 mW	165 mW
P	1290 mW	10.75 mW/°C	806 mW	645 mW	215 mW

(1) This is the inverse of the junction-to-ambient thermal resistance when board-mounted and with no air flow.

(2) Tested in accordance with the Low-K thermal metric definitions of EIA/JESD51-3.

(3) Tested in accordance with the High-K thermal metric definitions of EIA/JESD51-7.

**RECOMMENDED OPERATING CONDITIONS**

		MIN	NOM	MAX	UNIT
Supply voltage, $V_{CC}$		3		3.6	V
Voltage at any bus terminal (separately or common mode) $V_I$ or $V_{IC}$		-7 <sup>(1)</sup>		12	V
High-level input voltage, $V_{IH}$	D, DE, $\overline{RE}$	2		$V_{CC}$	V
Low-level input voltage, $V_{IL}$	D, DE, $\overline{RE}$	0		0.8	V
Differential input voltage, $V_{ID}$ (see Figure 7)		-12		12	V
High-level output current, $I_{OH}$	Driver	-60			mA
	Receiver	-8			
Low-level output current, $I_{OL}$	Driver			60	mA
	Receiver			8	
Differential load resistance, $R_L$		54	60		$\Omega$
Differential load capacitance, $C_L$			50		pF
Signaling rate	HVD10			25	Mbps
	HVD11			10	
	HVD12			1	
Junction temperature, $T_J$ <sup>(2)</sup>				145	$^{\circ}\text{C}$

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

(2) See thermal characteristics table for information regarding this specification.

**DRIVER ELECTRICAL CHARACTERISTICS**

over recommended operating conditions unless otherwise noted

PARAMETER		TEST CONDITIONS		MIN	TYP <sup>(1)</sup>	MAX	UNIT
$V_{IK}$	Input clamp voltage	$I_I = -18 \text{ mA}$		-1.5			V
$ V_{OD} $	Differential output voltage <sup>(2)</sup>	$I_O = 0$		2		$V_{CC}$	V
		$R_L = 54 \Omega$ , See Figure 1		1.5			
		$V_{\text{test}} = -7 \text{ V to } 12 \text{ V}$ , See Figure 2		1.5			
$\Delta V_{OD} $	Change in magnitude of differential output voltage	See Figure 1 and Figure 2		-0.2		0.2	V
$V_{OC(PP)}$	Peak-to-peak common-mode output voltage	See Figure 3			400		mV
$V_{OC(SS)}$	Steady-state common-mode output voltage			1.4		2.5	V
$\Delta V_{OC(SS)}$	Change in steady-state common-mode output voltage			-0.05		0.05	V
$I_{OZ}$	High-impedance output current	See receiver input currents					
$I_I$	Input current	D		-100		0	$\mu\text{A}$
		DE		0		100	
$I_{OS}$	Short-circuit output current	$-7 \text{ V} \leq V_O \leq 12 \text{ V}$		-250		250	mA
$C_{(OD)}$	Differential output capacitance	$V_{OD} = 0.4 \sin(4E6\pi t) + 0.5 \text{ V}$ , DE at 0 V			16		pF
$I_{CC}$	Supply current	$\overline{RE}$ at $V_{CC}$ , D & DE at $V_{CC}$ , No load	Receiver disabled and driver enabled		9	15.5	mA
		$\overline{RE}$ at $V_{CC}$ , D at $V_{CC}$ , DE at 0 V, No load	Receiver disabled and driver disabled (standby)		1	5	$\mu\text{A}$
		$\overline{RE}$ at 0 V, D & DE at $V_{CC}$ , No load	Receiver enabled and driver enabled		9	15.5	mA

(1) All typical values are at 25 $^{\circ}\text{C}$  and with a 3.3-V supply.

(2) For  $T_A > 85^{\circ}\text{C}$ ,  $V_{CC}$  is  $\pm 5\%$ .

**DRIVER SWITCHING CHARACTERISTICS**

over recommended operating conditions unless otherwise noted

PARAMETER		TEST CONDITIONS	MIN	TYP(1)	MAX	UNIT
t <sub>PLH</sub>	Propagation delay time, low-to-high-level output	HVD10	5	8.5	16	ns
		HVD11	18	25	40	
		HVD12	135	200	300	
t <sub>PHL</sub>	Propagation delay time, high-to-low-level output	HVD10	5	8.5	16	ns
		HVD11	18	25	40	
		HVD12	135	200	300	
t <sub>r</sub>	Differential output signal rise time	HVD10	3	4.5	10	ns
		HVD11	10	20	30	
		HVD12	100	170	300	
t <sub>f</sub>	Differential output signal fall time	HVD10	3	4.5	10	ns
		HVD11	10	20	30	
		HVD12	100	170	300	
t <sub>sk(pp)</sub>	Pulse skew ((t <sub>PHL</sub> – t <sub>PLH</sub> ))	HVD10			1.5	ns
		HVD11			2.5	
		HVD12			7	
t <sub>sk(pp)</sub> <sup>(2)</sup>	Part-to-part skew	HVD10			6	ns
		HVD11			11	
		HVD12			100	
t <sub>PZH</sub>	Propagation delay time, high-impedance-to-high-level output	HVD10			31	ns
		HVD11			55	
		HVD12			300	
t <sub>PHZ</sub>	Propagation delay time, high-level-to-high-impedance output	HVD10			25	ns
		HVD11			55	
		HVD12			300	
t <sub>PZL</sub>	Propagation delay time, high-impedance-to-low-level output	HVD10			26	ns
		HVD11			55	
		HVD12			300	
t <sub>PLZ</sub>	Propagation delay time, low-level-to-high-impedance output	HVD10			26	ns
		HVD11			75	
		HVD12			400	
t <sub>PZH</sub>	Propagation delay time, standby-to-high-level output	R <sub>L</sub> = 110 Ω, $\overline{RE}$ at 3 V, See Figure 5			6	μs
t <sub>PZL</sub>	Propagation delay time, standby-to-low-level output	R <sub>L</sub> = 110 Ω, $\overline{RE}$ at 3 V, See Figure 6			6	μs

(1) All typical values are at 25°C and with a 3.3-V supply.

(2) t<sub>sk(pp)</sub> is the magnitude of the difference in propagation delay times between any specified terminals of two devices when both devices operate with the same supply voltages, at the same temperature, and have identical packages and test circuits.

## RECEIVER ELECTRICAL CHARACTERISTICS

over recommended operating conditions unless otherwise noted

PARAMETER		TEST CONDITIONS		MIN	TYP <sup>(1)</sup>	MAX	UNIT	
$V_{IT+}$	Positive-going input threshold voltage	$I_O = -8 \text{ mA}$				-0.01	V	
$V_{IT-}$	Negative-going input threshold voltage	$I_O = 8 \text{ mA}$		-0.2				
$V_{hys}$	Hysteresis voltage ( $V_{IT+} - V_{IT-}$ )				35		mV	
$V_{IK}$	Enable-input clamp voltage	$I_I = -18 \text{ mA}$		-1.5			V	
$V_{OH}$	High-level output voltage	$V_{ID} = 200 \text{ mV}$ ,	$I_{OH} = -8 \text{ mA}$ ,	See Figure 7		2.4	V	
$V_{OL}$	Low-level output voltage	$V_{ID} = -200 \text{ mV}$ ,	$I_{OL} = 8 \text{ mA}$ ,	See Figure 7		0.4	V	
$I_{OZ}$	High-impedance-state output current	$V_O = 0 \text{ or } V_{CC}$ , $\overline{RE}$ at $V_{CC}$		-1		1	$\mu\text{A}$	
$I_I$	Bus input current	$V_A \text{ or } V_B = 12 \text{ V}$		HVD11, HVD12, Other input at 0 V	0.05	0.11	mA	
		$V_A \text{ or } V_B = 12 \text{ V}$ , $V_{CC} = 0 \text{ V}$			0.06	0.13		
		$V_A \text{ or } V_B = -7 \text{ V}$			-0.1	-0.05		
		$V_A \text{ or } V_B = -7 \text{ V}$ , $V_{CC} = 0 \text{ V}$			-0.05	-0.04		
		$V_A \text{ or } V_B = 12 \text{ V}$		HVD10, Other input at 0 V	0.2	0.5	mA	
		$V_A \text{ or } V_B = 12 \text{ V}$ , $V_{CC} = 0 \text{ V}$			0.25	0.5		
		$V_A \text{ or } V_B = -7 \text{ V}$			-0.4	-0.2		
		$V_A \text{ or } V_B = -7 \text{ V}$ , $V_{CC} = 0 \text{ V}$			-0.4	-0.15		
$I_{IH}$	High-level input current, $\overline{RE}$	$V_{IH} = 2 \text{ V}$		-30		0	$\mu\text{A}$	
$I_{IL}$	Low-level input current, $\overline{RE}$	$V_{IL} = 0.8 \text{ V}$		-30		0	$\mu\text{A}$	
$C_{ID}$	Differential input capacitance	$V_{ID} = 0.4 \sin(4E6\pi t) + 0.5 \text{ V}$ , DE at 0 V			15		pF	
$I_{CC}$	Supply current	$\overline{RE}$ at 0 V, D & DE at 0 V, No load		Receiver enabled and driver disabled		4	8	mA
		$\overline{RE}$ at $V_{CC}$ , D at $V_{CC}$ , DE at 0 V, No load		Receiver disabled and driver disabled (standby)		1	5	$\mu\text{A}$
		$\overline{RE}$ at 0 V, D & DE at $V_{CC}$ , No load		Receiver enabled and driver enabled		9	15.5	mA

(1) All typical values are at 25°C and with a 3.3-V supply.

## RECEIVER SWITCHING CHARACTERISTICS

over recommended operating conditions unless otherwise noted

PARAMETER			TEST CONDITIONS	MIN	TYP(1)	MAX	UNIT	
t <sub>PLH</sub>	Propagation delay time, low-to-high-level output	HVD10	V <sub>ID</sub> = -1.5 V to 1.5 V, C <sub>L</sub> = 15 pF, See Figure 8	12.5	20	25	ns	
t <sub>PHL</sub>	Propagation delay time, high-to-low-level output	HVD10		12.5	20	25		
t <sub>PLH</sub>	Propagation delay time, low-to-high-level output	HVD11 HVD12		30	55	70	ns	
t <sub>PHL</sub>	Propagation delay time, high-to-low-level output	HVD11 HVD12		30	55	70		
t <sub>sk(p)</sub>	Pulse skew ( t <sub>PHL</sub> - t <sub>PLH</sub>  )	HVD10					1.5	ns
		HVD11					4	
		HVD12				4		
t <sub>sk(pp)</sub> (2)	Part-to-part skew	HVD10				8	ns	
		HVD11				15		
		HVD12				15		
t <sub>r</sub>	Output signal rise time	C <sub>L</sub> = 15 pF, See Figure 8		1	2	5	ns	
t <sub>f</sub>	Output signal fall time			1	2	5		
t <sub>PZH</sub> (1)	Output enable time to high level	C <sub>L</sub> = 15 pF, DE at 3 V, See Figure 9				15	ns	
t <sub>PZL</sub> (1)	Output enable time to low level					15		
t <sub>PHZ</sub>	Output disable time from high level					20		
t <sub>PLZ</sub>	Output disable time from low level					15		
t <sub>PZH</sub> (2)	Propagation delay time, standby-to-high-level output	C <sub>L</sub> = 15 pF, DE at 0, See Figure 10				6	μs	
t <sub>PZL</sub> (2)	Propagation delay time, standby-to-low-level output					6		

(1) All typical values are at 25°C and with a 3.3-V supply.

(2) t<sub>sk(pp)</sub> is the magnitude of the difference in propagation delay times between any specified terminals of two devices when both devices operate with the same supply voltages, at the same temperature, and have identical packages and test circuits.

## THERMAL CHARACTERISTICS

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

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNITS
θ <sub>JA</sub>	Junction-to-ambient thermal resistance(2)	High-K board(3), No airflow	D pkg		121		°C/W
		No airflow(4)	P pkg		93		
θ <sub>JB</sub>	Junction-to-board thermal resistance	High-K board	D pkg		67		°C/W
		See Note (4)	P pkg		57		
θ <sub>JC</sub>	Junction-to-case thermal resistance		D pkg		41		°C/W
			P pkg		55		
P <sub>D</sub>	Device power dissipation	R <sub>L</sub> = 60Ω, C <sub>L</sub> = 50 pF, DE at V <sub>CC</sub> RE at 0 V, Input to D a 50% duty cycle square wave at indicated signaling rate	HVD10 (25 Mbps)		198	233	mW
			HVD11 (10 Mbps)		141	176	mW
			HVD12 (500 kbps)		133	161	mW
T <sub>A</sub>	Ambient air temperature	High-K board, No airflow	D pkg	-40		116	°C
		No airflow(4)	P pkg	-40		123	
T <sub>JSD</sub>	Thermal shutdown junction temperature				165		°C

(1) See *Application Information* section for an explanation of these parameters.

(2) The intent of θ<sub>JA</sub> specification is solely for a thermal performance comparison of one package to another in a standardized environment. This methodology is not meant to and will not predict the performance of a package in an application-specific environment.

(3) JSD51-7, High Effective Thermal Conductivity Test Board for Leaded Surface Mount Packages.

(4) JESD51-10, Test Boards for Through-Hole Perimeter Leaded Package Thermal Measurements.

PARAMETER MEASUREMENT INFORMATION

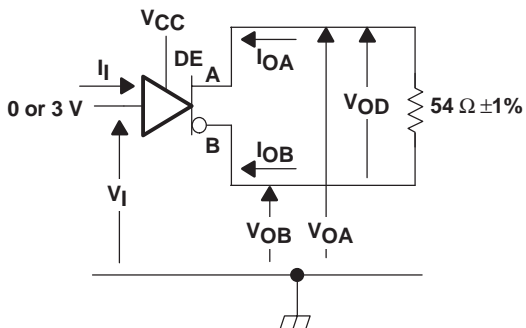


Figure 1. Driver  $V_{OD}$  Test Circuit and Voltage and Current Definitions

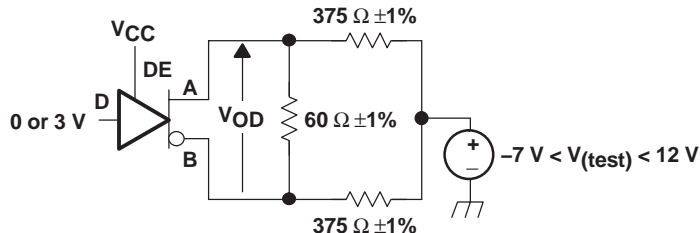
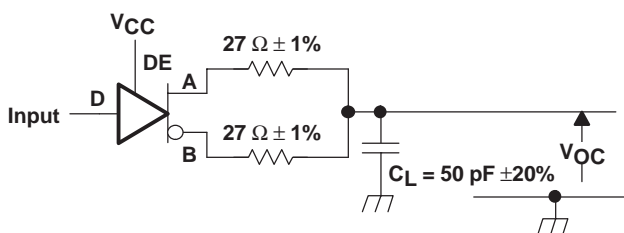


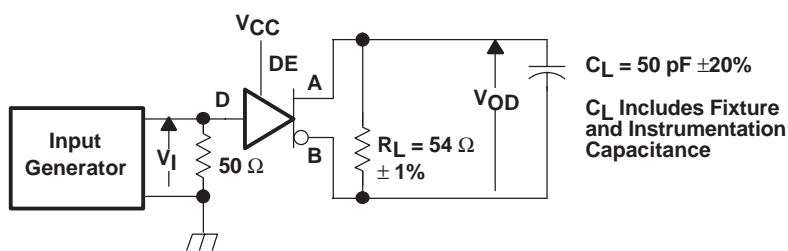
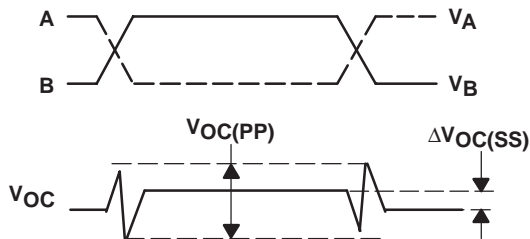
Figure 2. Driver  $V_{OD}$  With Common-Mode Loading Test Circuit



$C_L$  Includes Fixture and Instrumentation Capacitance

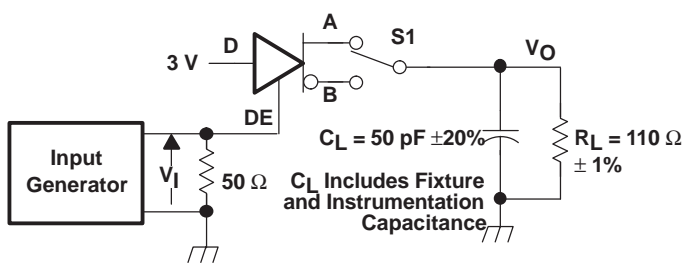
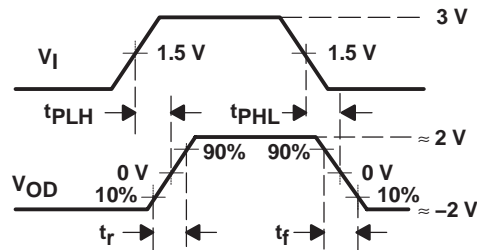
Input: PRR = 500 kHz, 50% Duty Cycle,  $t_r < 6$  ns,  $t_f < 6$  ns,  $Z_O = 50 \Omega$

Figure 3. Test Circuit and Definitions for the Driver Common-Mode Output Voltage



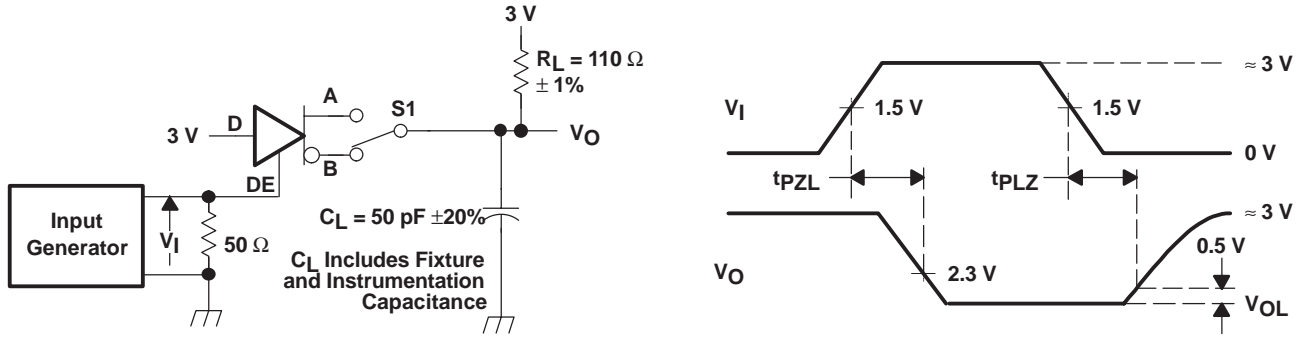
Generator: PRR = 500 kHz, 50% Duty Cycle,  $t_r < 6$  ns,  $t_f < 6$  ns,  $Z_O = 50 \Omega$

Figure 4. Driver Switching Test Circuit and Voltage Waveforms



Generator: PRR = 500 kHz, 50% Duty Cycle,  $t_r < 6$  ns,  $t_f < 6$  ns,  $Z_O = 50 \Omega$

Figure 5. Driver High-Level Enable and Disable Time Test Circuit and Voltage Waveforms



Generator: PRR = 500 kHz, 50% Duty Cycle,  $t_r < 6$  ns,  $t_f < 6$  ns,  $Z_O = 50 \Omega$

Figure 6. Driver Low-Level Output Enable and Disable Time Test Circuit and Voltage Waveforms

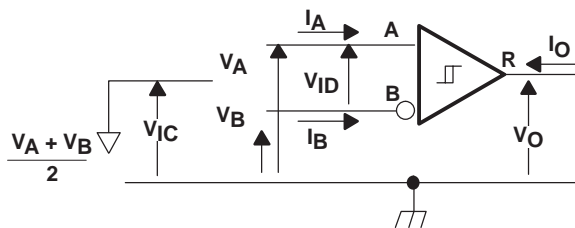
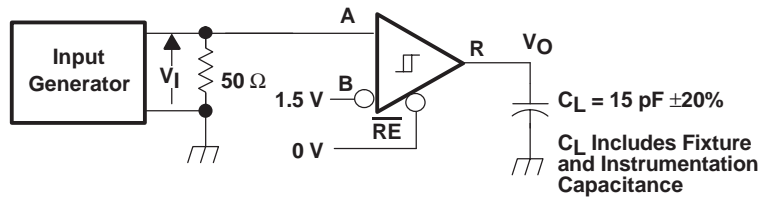


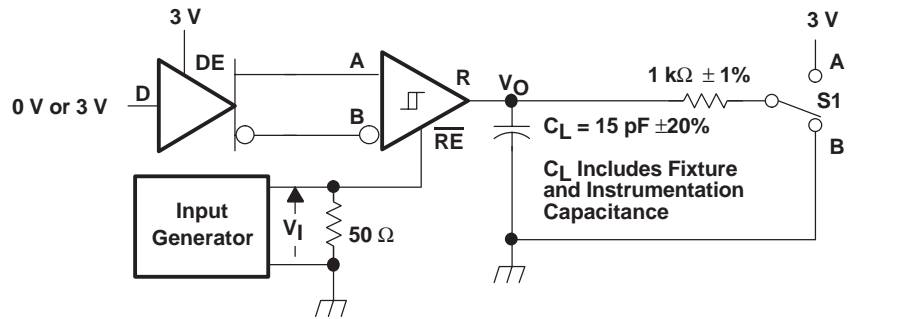
Figure 7. Receiver Voltage and Current Definitions



Generator: PRR = 500 kHz, 50% Duty Cycle,  $t_r < 6$  ns,  $t_f < 6$  ns,  $Z_O = 50 \Omega$

Figure 8. Receiver Switching Test Circuit and Voltage Waveforms





Generator: PRR = 500 kHz, 50% Duty Cycle,  $t_r < 6$  ns,  $t_f < 6$  ns,  $Z_0 = 50 \Omega$

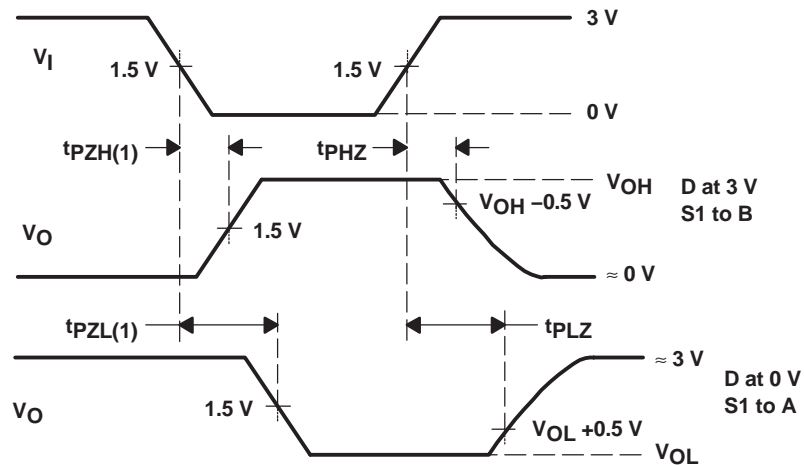


Figure 9. Receiver Enable and Disable Time Test Circuit and Voltage Waveforms With Drivers Enabled

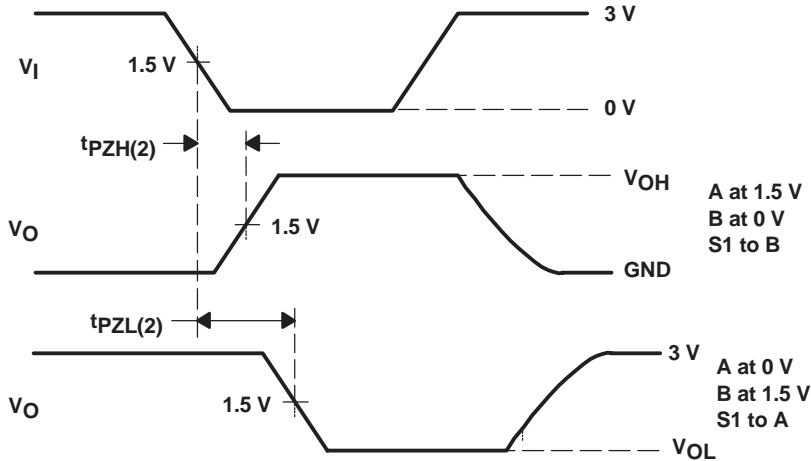
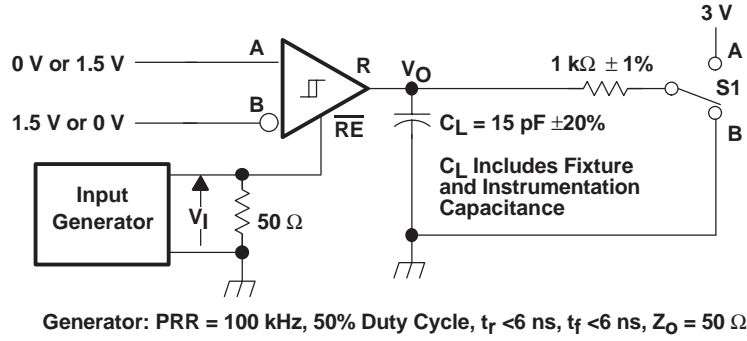
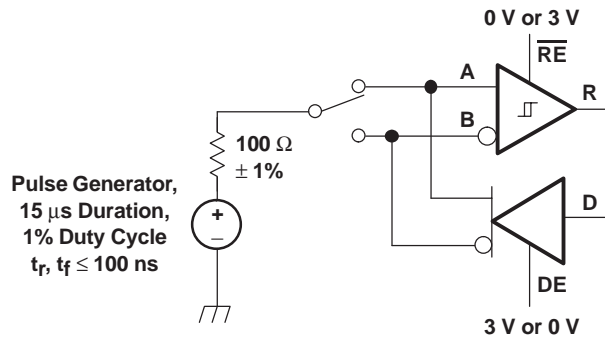


Figure 10. Receiver Enable Time From Standby (Driver Disabled)



NOTE: This test is conducted to test survivability only. Data stability at the R output is not specified.

Figure 11. Test Circuit, Transient Over Voltage Test

**Function Tables**

**DRIVER**

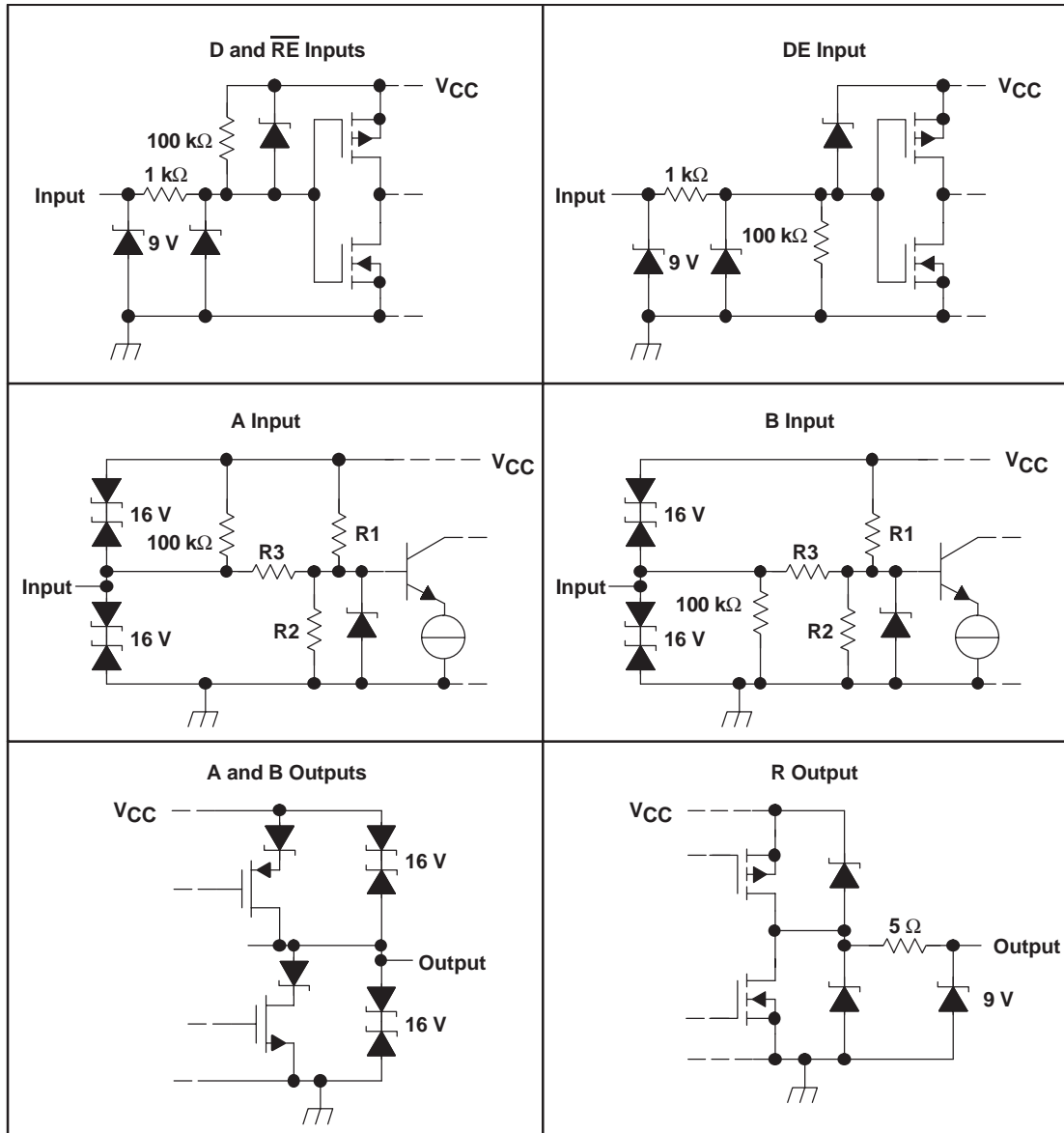
INPUT	ENABLE	OUTPUTS	
	DE	A	B
H	H	H	L
L	H	L	H
X	L	Z	Z
Open	H	H	L

**RECEIVER**

DIFFERENTIAL INPUTS	ENABLE	OUTPUT
$V_{ID} = V_A - V_B$	$\overline{RE}$	R
$V_{ID} \leq -0.2\text{ V}$	L	L
$-0.2\text{ V} < V_{ID} < -0.01\text{ V}$	L	?
$-0.01\text{ V} \leq V_{ID}$	L	H
X	H	Z
Open Circuit	L	H
Short Circuit	L	H

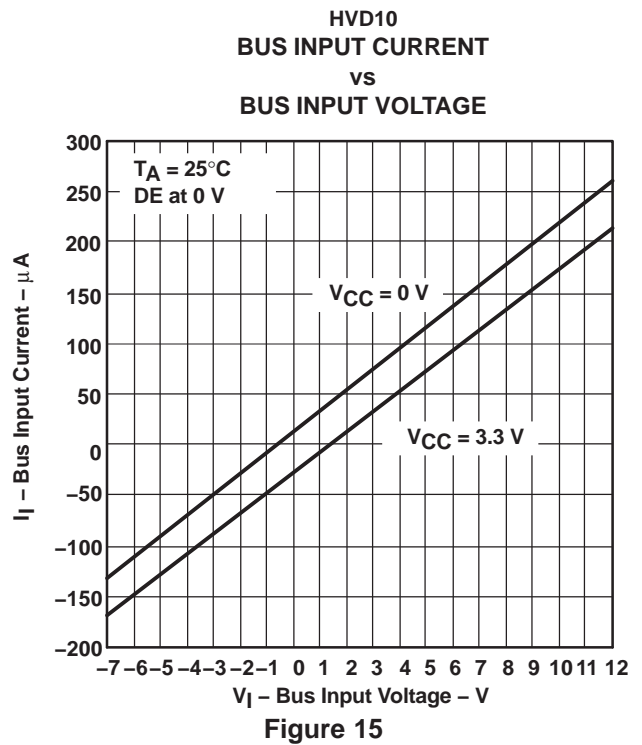
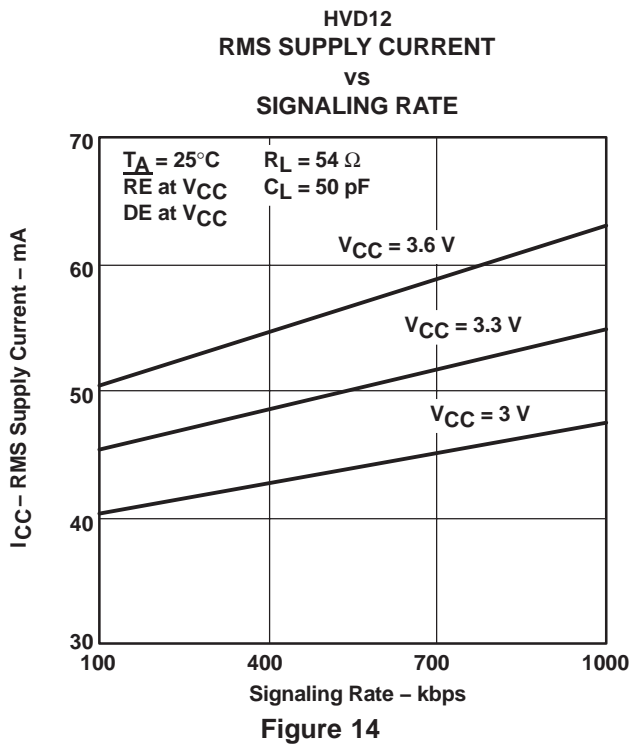
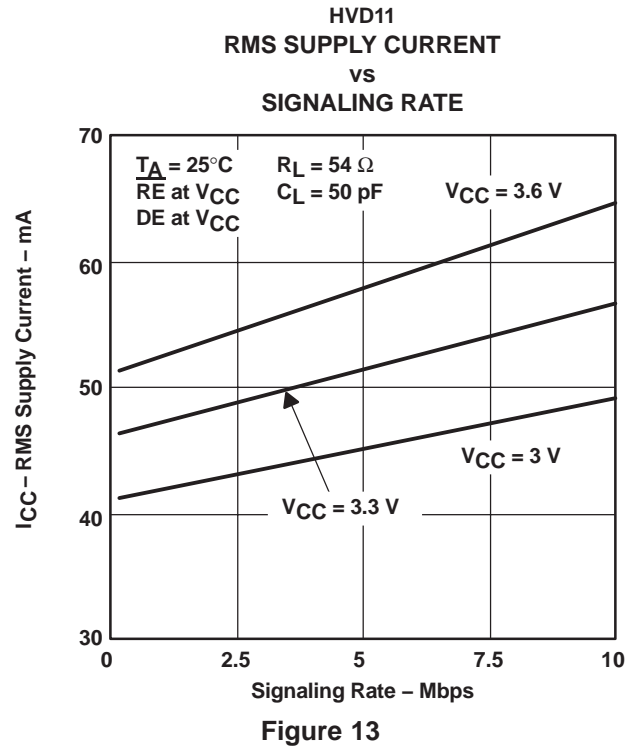
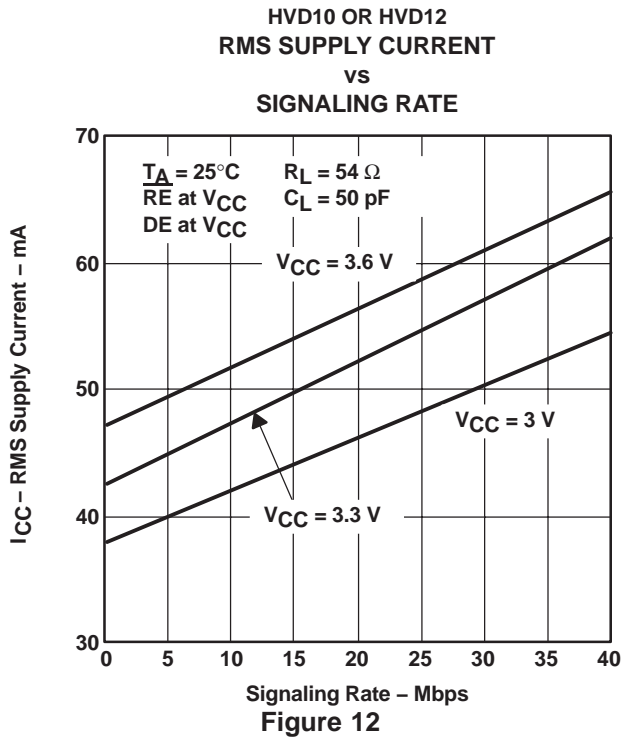
H = high level; L = low level; Z = high impedance; X = irrelevant; ? = indeterminate

EQUIVALENT INPUT AND OUTPUT SCHEMATIC DIAGRAMS



	R1/R2	R3
SN65HVD10	9 kΩ	45 kΩ
SN65HVD11	36 kΩ	180 kΩ
SN65HVD12	36 kΩ	180 kΩ

TYPICAL CHARACTERISTICS



HVD11 OR HVD12  
 BUS INPUT CURRENT  
 vs  
 BUS INPUT VOLTAGE

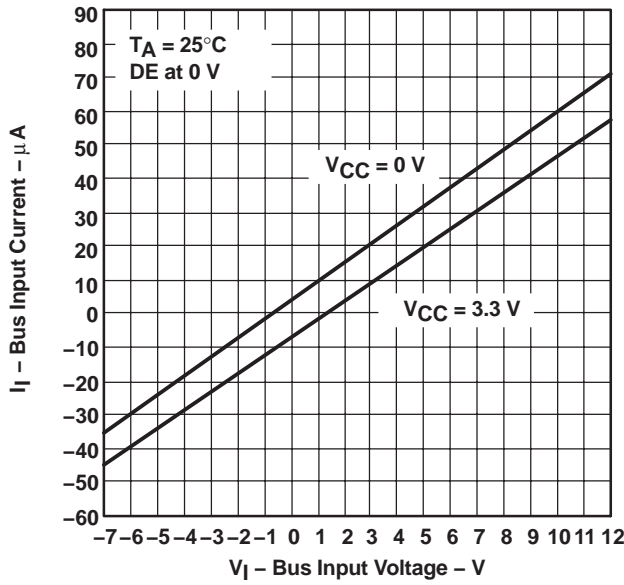


Figure 16

HIGH-LEVEL OUTPUT CURRENT  
 vs  
 DRIVER HIGH-LEVEL OUTPUT VOLTAGE

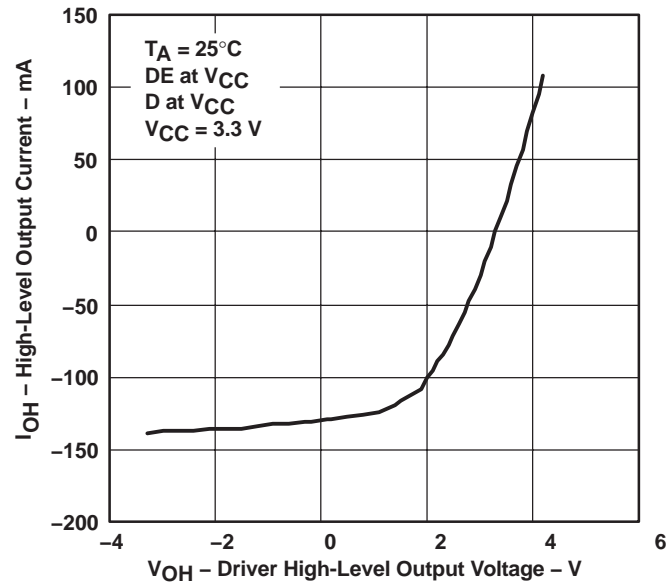


Figure 17

LOW-LEVEL OUTPUT CURRENT  
 vs  
 DRIVER LOW-LEVEL OUTPUT VOLTAGE

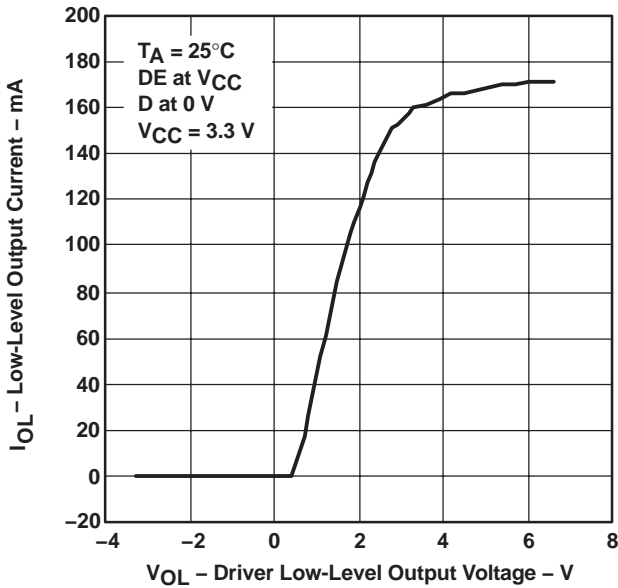


Figure 18

DRIVER DIFFERENTIAL OUTPUT  
 vs  
 FREE-AIR TEMPERATURE

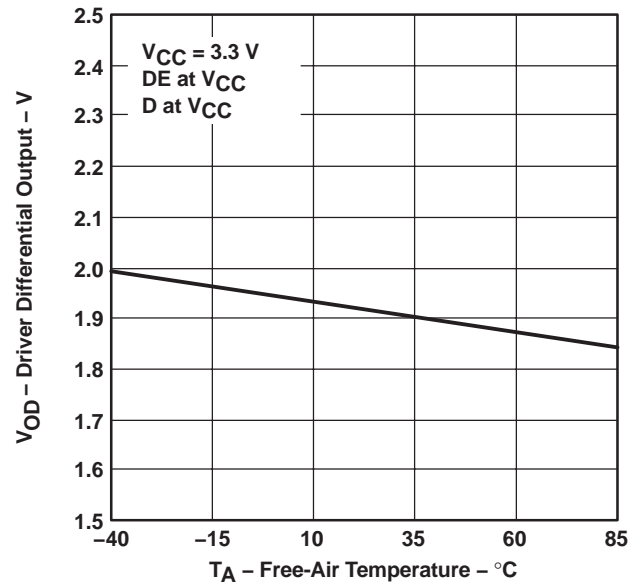


Figure 19

### TYPICAL CHARACTERISTICS

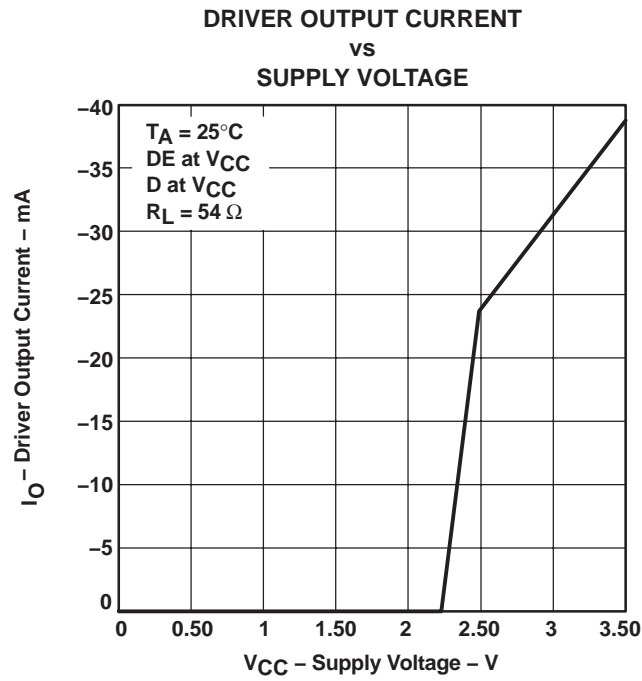
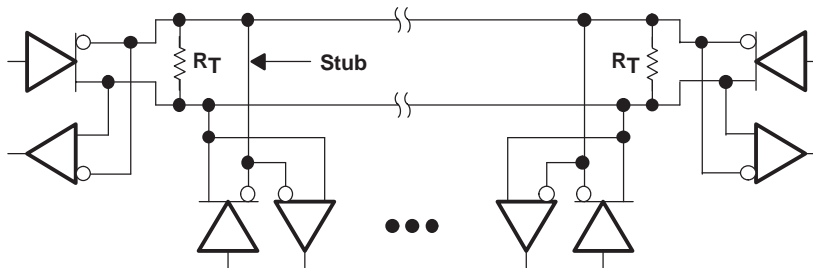


Figure 20

APPLICATION INFORMATION



Device	Number of Devices on Bus
HVD10	64
HVD11	256
HVD12	256

NOTE: The line should be terminated at both ends with its characteristic impedance ( $R_T = Z_0$ ). Stub lengths off the main line should be kept as short as possible.

Figure 21. Typical Application Circuit

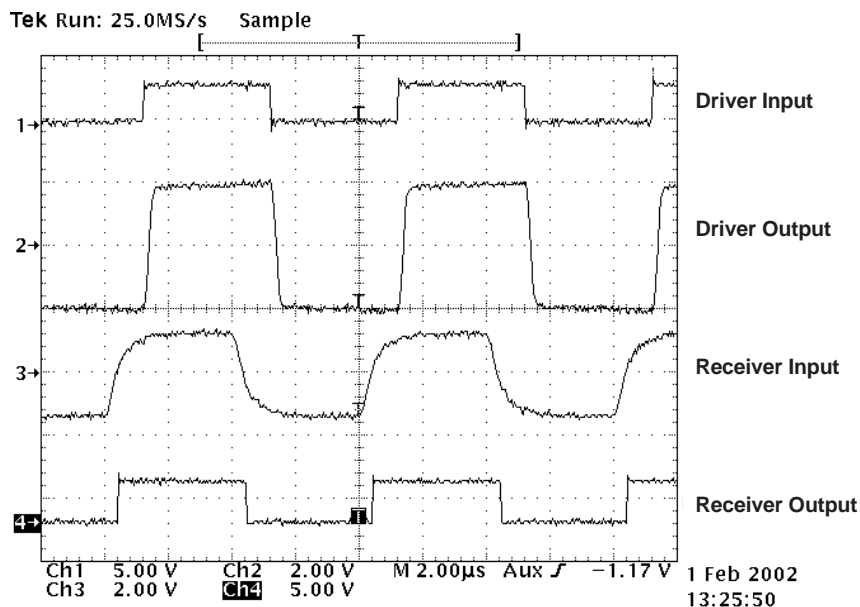


Figure 22. HVD12 Input and Output Through 2000 Feet of Cable

An example application for the HVD12 is illustrated in Figure 21. Two HVD12 transceivers are used to communicate data through a 2000 foot (600 m) length of Commscope 5524 category 5e+ twisted pair cable. The

bus is terminated at each end by a 100-Ω resistor, matching the cable characteristic impedance. Figure 22 illustrates operation at a signaling rate of 250 kbps.



## THERMAL CHARACTERISTICS OF IC PACKAGES

$\theta_{JA}$  (**Junction-to-Ambient Thermal Resistance**) is defined as the difference in junction temperature to ambient temperature divided by the operating power.

$\theta_{JA}$  is *not* a constant and is a strong function of:

- the PCB design (50% variation)
- altitude (20% variation)
- device power (5% variation)

$\theta_{JA}$  can be used to compare the thermal performance of packages if the specific test conditions are defined and used. Standardized testing includes specification of PCB construction, test chamber volume, sensor locations, and the thermal characteristics of holding fixtures.  $\theta_{JA}$  is often misused when it is used to calculate junction temperatures for other installations.

TI uses two test PCBs as defined by JEDEC specifications. The low-k board gives *average* in-use condition thermal performance, and it consists of a single copper trace layer 25 mm long and 2-oz thick. The high-k board gives *best case* in-use condition, and it consists of two 1-oz buried power planes with a single copper trace layer 25 mm long and 2-oz thick. A 4% to 50% difference in  $\theta_{JA}$  can be measured between these two test cards

$\theta_{JC}$  (**Junction-to-Case Thermal Resistance**) is defined as difference in junction temperature to case divided by the operating power. It is measured by putting the mounted package up against a copper block cold plate to force heat to flow from die, through the mold compound into the copper block.

$\theta_{JC}$  is a useful thermal characteristic when a heatsink is applied to package. It is *not* a useful characteristic to predict junction temperature because it provides pessimistic numbers if the case temperature is measured in a nonstandard system and junction temperatures are backed out. It can be used with  $\theta_{JB}$  in 1-dimensional thermal simulation of a package system.

$\theta_{JB}$  (**Junction-to-Board Thermal Resistance**) is defined as the difference in the junction temperature and the PCB temperature at the center of the package (closest to the die) when the PCB is clamped in a cold-plate structure.  $\theta_{JB}$  is only defined for the high-k test card.

$\theta_{JB}$  provides an overall thermal resistance between the die and the PCB. It includes a bit of the PCB thermal resistance (especially for BGA's with thermal balls) and can be used for simple 1-dimensional network analysis of package system (see Figure 23).

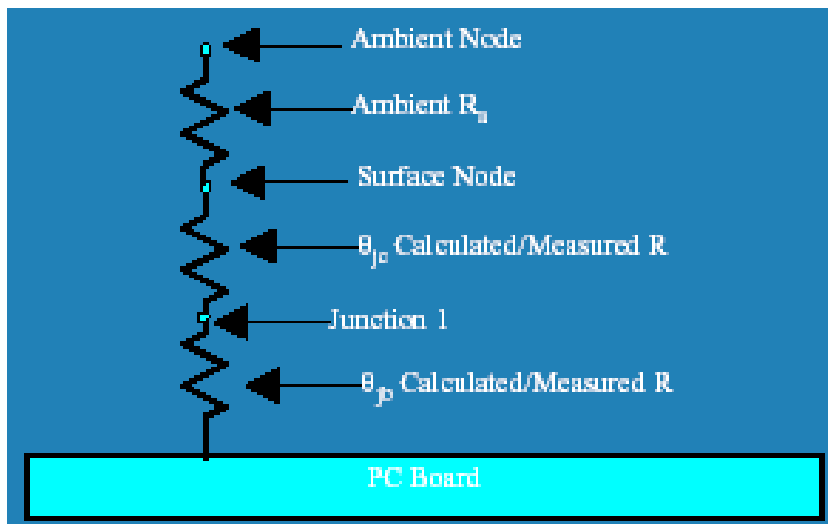
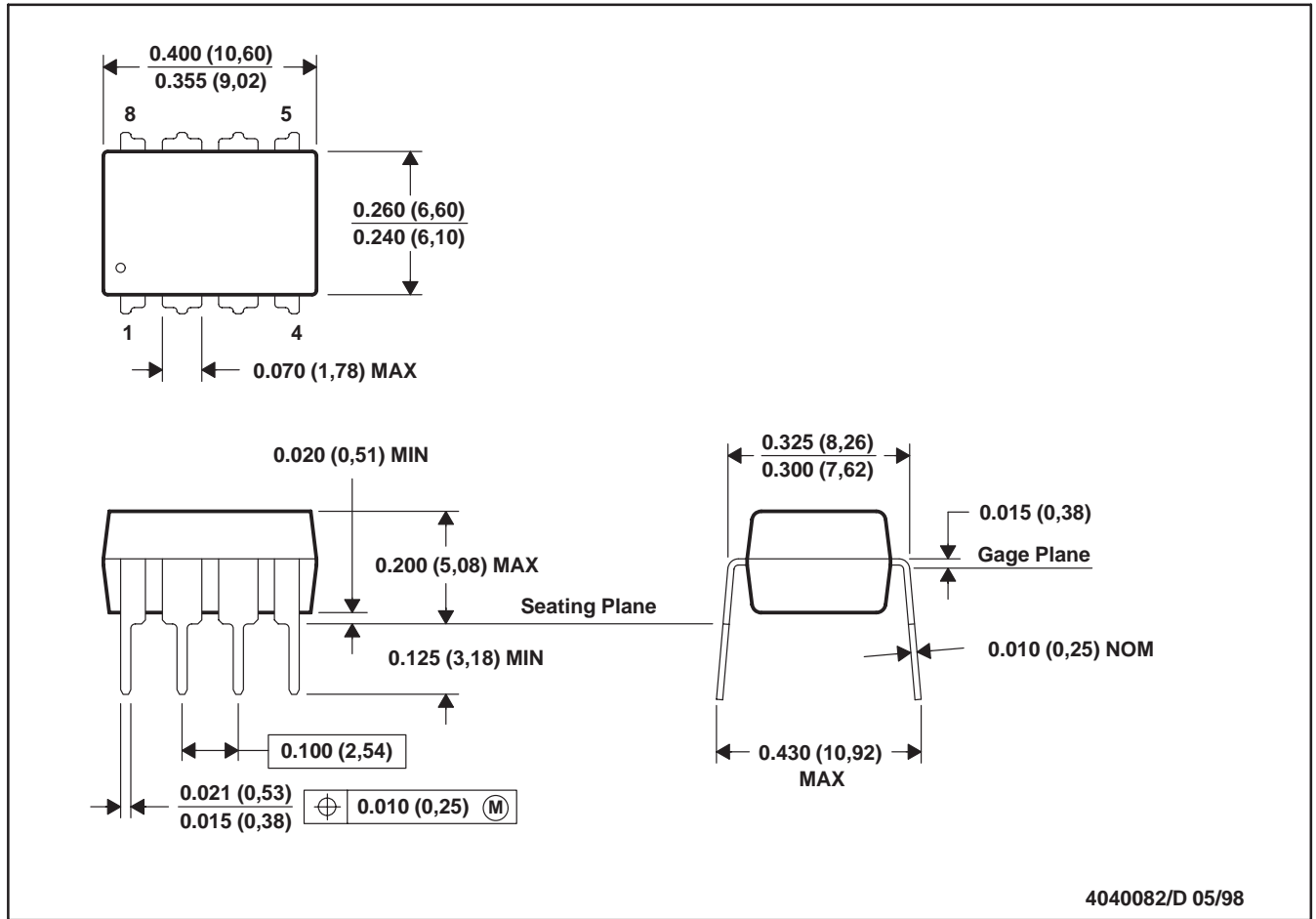


Figure 23. Thermal Resistance

P (R-PDIP-T8)

PLASTIC DUAL-IN-LINE

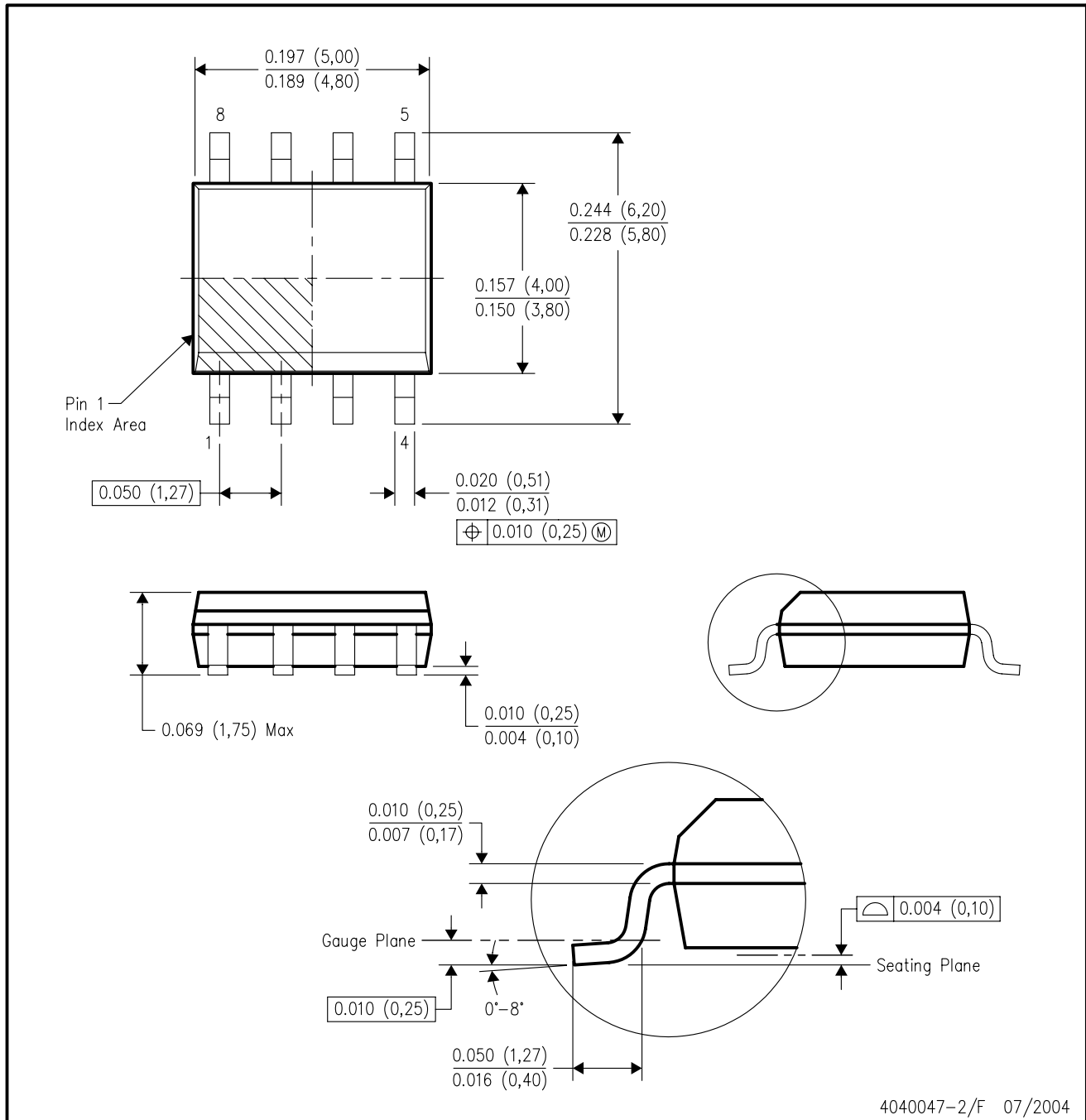


- NOTES: A. All linear dimensions are in inches (millimeters).  
 B. This drawing is subject to change without notice.  
 C. Falls within JEDEC MS-001

For the latest package information, go to [http://www.ti.com/sc/docs/package/pkg\\_info.htm](http://www.ti.com/sc/docs/package/pkg_info.htm)

D (R-PDSO-G8)

PLASTIC SMALL-OUTLINE PACKAGE



- NOTES:
- A. All linear dimensions are in inches (millimeters).
  - B. This drawing is subject to change without notice.
  - C. Body dimensions do not include mold flash or protrusion not to exceed 0.006 (0,15).
  - D. Falls within JEDEC MS-012 variation AA.

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Mailing Address: Texas Instruments  
Post Office Box 655303 Dallas, Texas 75265