3.3-V CAN TRANSCEIVER

Check for Samples: SN65HVD233-HT

FEATURES

- **Bus-Pin Fault Protection Exceeds ±36 V**
- **Bus-Pin ESD Protection Exceeds 16-kV Human Body Model (HBM)**
- **Compatible With ISO 11898**
- **Signaling Rates(1) up to 1 Mbps**
- **Extended –7-V to 12-V Common-Mode Range**
- **High-Input Impedance Allows for 120 Nodes**
- **LVTTL I/Os Are 5-V Tolerant**
- **Adjustable Driver Transition Times for Improved Signal Quality**
- **Unpowered Node Does Not Disturb the Bus**
- **Low-Current Standby Mode . . . 200 µA Typical**
- **Power-Up/Down Glitch-Free Bus Inputs and Outputs**
  - **High Input Impedance With Low V_{CC}**
  - **Monolithic Output During Power Cycling**
- **Loopback for Diagnostic Functions Available**
- **DeviceNet™ Vendor ID #806**

(1) 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).

APPLICATIONS

- **Down-Hole Drilling**
- **High Temperature Environments**
- **Industrial Automation**
  - **DeviceNet™ Data Buses**
  - **Smart Distributed Systems (SDS™)**
- **SAE J1939 Data Bus Interface**
- **NMEA 2000 Data Bus Interface**
- **ISO 11783 Data Bus Interface**
- **CAN Data Bus Interface**

SUPPORTS EXTREME TEMPERATURE APPLICATIONS

- **Controlled Baseline**
- **One Assembly/Test Site**
- **One Fabrication Site**
- **Available in Extreme (–55°C/210°C) Temperature Range** (1)
- **Extended Product Life Cycle**
- **Extended Product-Change Notification**
- **Product Traceability**
- **Texas Instruments high temperature products utilize highly optimized silicon (die) solutions with design and process enhancements to maximize performance over extended temperatures.**

DESCRIPTION/ORDERING INFORMATION

The SN65HVD233 is used in applications employing the controller area network (CAN) serial communication physical layer in accordance with the ISO 11898 standard, with the exception that the thermal shutdown is removed. As a CAN transceiver, the device provides transmit and receive capability between the differential CAN bus and a CAN controller, with signaling rates up to 1 Mbps.

Designed for operation in especially harsh environments, the device features cross wire, overvoltage, and loss-of-ground protection to ±36 V, with common-mode transient protection of ±100 V. This device operates over a –7-V to 12-V common-mode range with a maximum of 60 nodes on a bus.

If the common-mode range is restricted to the ISO 11898 standard range of –2 V to 7 V, up to 120 nodes may be connected on a bus. This transceiver interfaces the single-ended CAN controller with the differential CAN bus found in industrial, building automation, and automotive applications.

(1) Custom temperature ranges available

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.

DESCRIPTION/ORDERING INFORMATION (CONTINUED)

R_S (pin 8) provides for three modes of operation: high-speed, slope control, or low-power standby mode. The high-speed mode of operation is selected by connecting R_S directly to ground, allowing the driver output transistors to switch on and off as fast as possible with no limitation on the rise and fall slope. The rise and fall slope can be adjusted by connecting a resistor to ground at R_S, since the slope is proportional to the pin's output current. Slope control is implemented with a resistor value of 10 kΩ to achieve a slew rate of ≠ 15 V/µs, and a value of 100 kΩ to achieve ≠ 2.0 V/µs slew rate. For more information about slope control, refer to the application information section.

The SN65HVD233 enters a low-current standby mode, during which the driver is switched off and the receiver remains active if a high logic level is applied to R_S. The local protocol controller reverses this low-current standby mode when it needs to transmit to the bus.

A logic high on the loopback (LBK, pin 5) of the SN65HVD233 places the bus output and bus input in a high-impedance state. The remaining circuit remains active and available for the driver to receiver loopback, self-diagnostic node functions without disturbing the bus.

AVAILABLE OPTIONS

PART NUMBER	LOW-POWER MODE	SLOPE CONTROL	DIAGNOSTIC LOOPBACK	AUTOBAUD LOOPBACK
SN65HVD233HD	200-µA standby mode	Adjustable	Yes	No
SN65HVD233SJD	200-µA standby mode	Adjustable	Yes	No
SN65HVD233SKGDA	200-µA standby mode	Adjustable	Yes	No
SN65HVD233SHKJ	200-µA standby mode	Adjustable	Yes	No
SN65HVD233SHKQ	200-µA standby mode	Adjustable	Yes	No

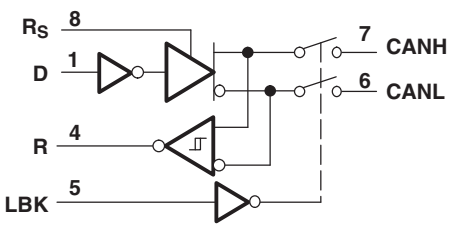
ORDERING INFORMATION(1)

T_A	PACKAGE(2)	ORDERABLE PART NUMBER	TOP-SIDE MARKING
–55°C to 175°C	D	SN65HVD233HD	233S
–55°C to 210°C	KGD	SN65HVD233SKGDA	N/A
	HKJ	SN65HVD233SHKJ	SN65HVD233SHKJ
	HKQ	SN65HVD233SHKQ	HVD233SHKQ
	JD	SN65HVD233SJD	SN65HVD233SJD

(1) For the most current packaging and ordering information, see the Package Option Addendum at the end of this document, or see the TI web site at www.ti.com.

(2) Package drawings, thermal data, and symbolization are available at www.ti.com/packaging.

FUNCTIONAL BLOCK DIAGRAM



BARE DIE INFORMATION

DIE THICKNESS	BACKSIDE FINISH	BACKSIDE POTENTIAL	BOND PAD METALLIZATION COMPOSITION
15 mils.	Silicon with backgrind	GND	Al-Si-Cu (0.5%)

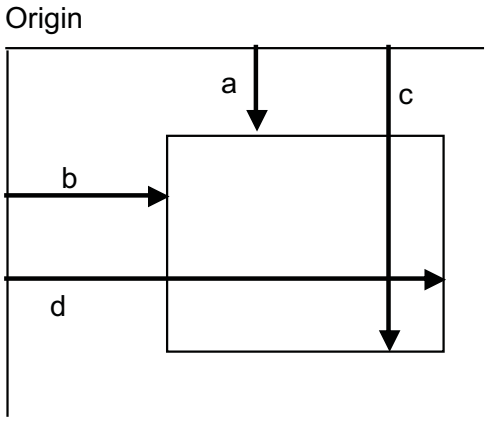
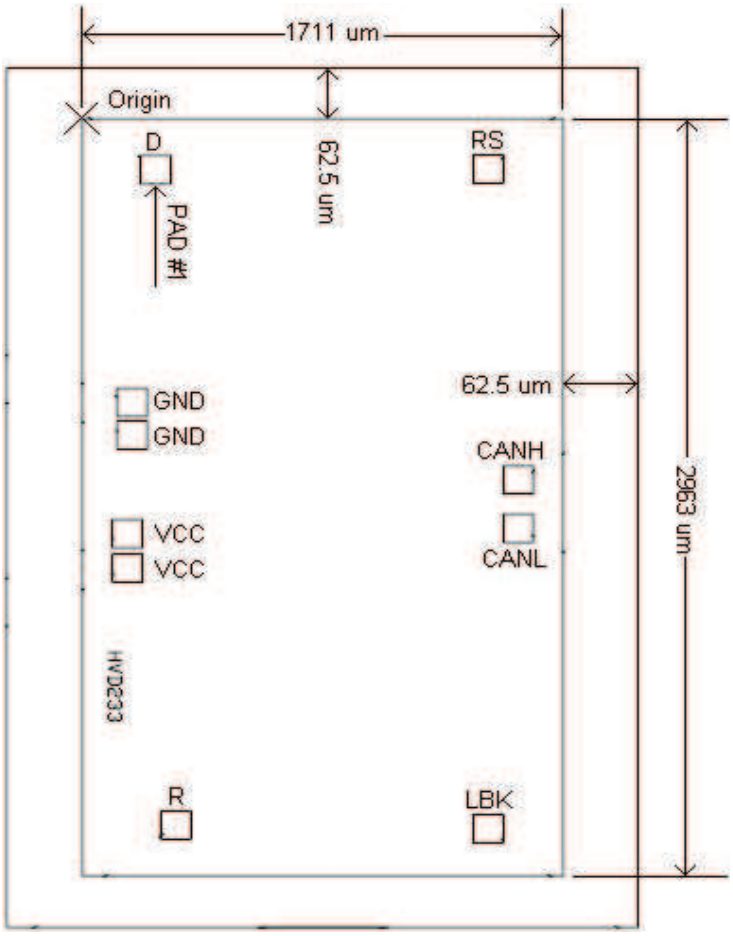


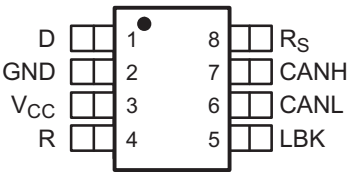
Table 1. Bond Pad Coordinates in Microns - Rev A

DISCRIPTION	PAD NUMBER	a	b	c	d
D	1	86.40	157.85	203.40	274.85
GND	2	1035.05	69.75	1150.05	184.75
GND	3	1168.15	69.75	1283.15	184.75
VCC	4	1572.05	51.85	1687.05	166.85
VCC	5	1711.95	51.85	1826.95	166.85
R	6	2758.85	237.65	2873.85	352.65
LBK	7	2774.25	1429.985	2889.25	1544.95
CANL	8	1549.90	1544.95	1664.90	1659.95
CANH	9	1351.45	1544.95	1466.45	1659.95
RS	10	83.50	1429.95	198.50	1544.95

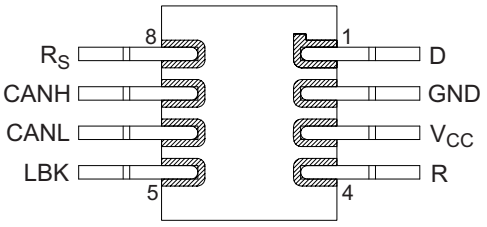


DEVICE INFORMATION

D, JD OR HKJ PACKAGE
(TOP VIEW)

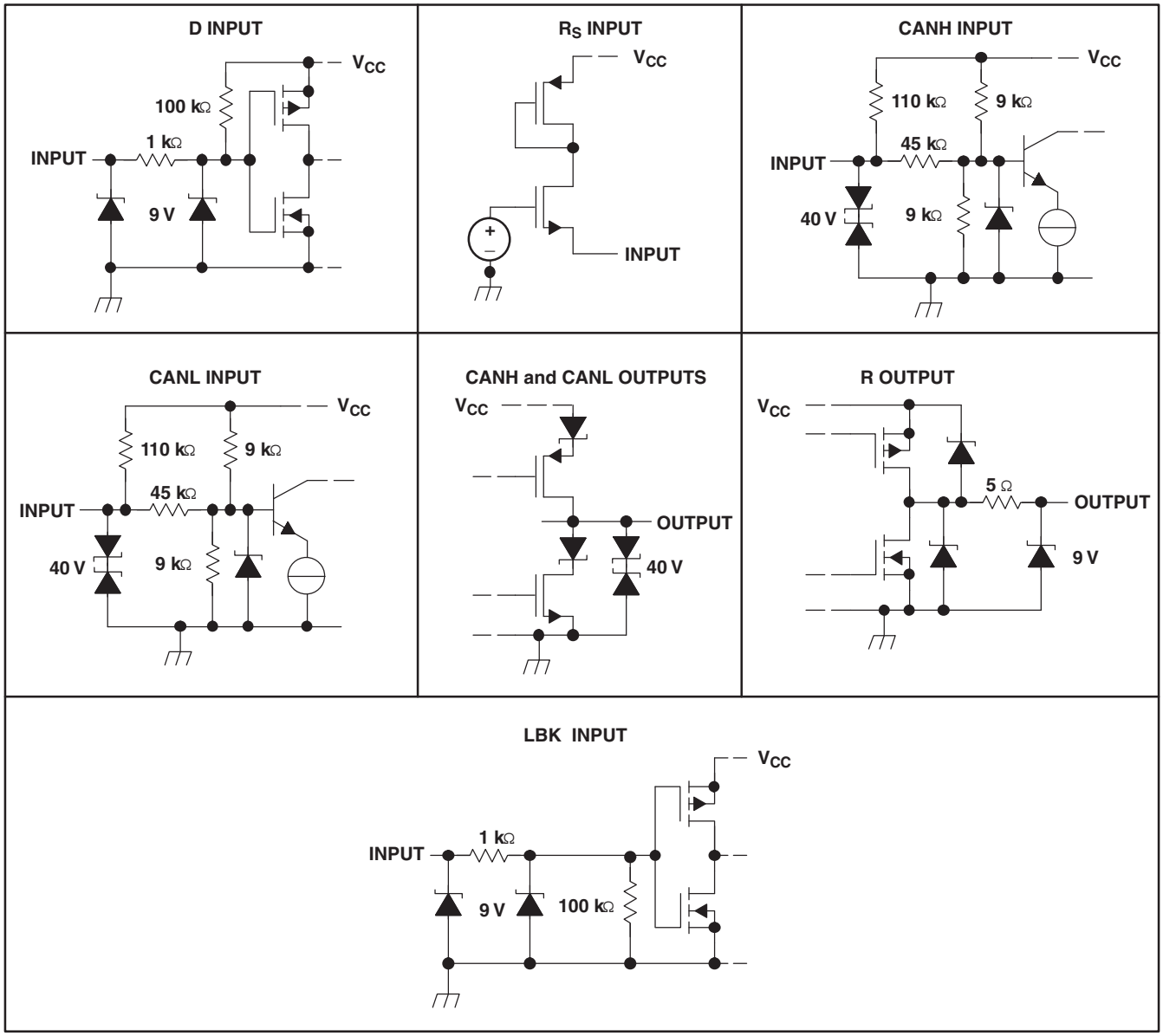


HKQ PACKAGE
(TOP VIEW)



HKQ as formed or HKJ mounted dead bug

EQUIVALENT INPUT AND OUTPUT SCHEMATIC DIAGRAMS



FUNCTION TABLES(1)

(1) H = high level, L = low level, Z = high impedance, X = irrelevant, ? = indeterminate

DRIVER					
INPUTS			OUTPUTS		
D	LBK	R_S	CANH	CANL	BUS STATE
X	X	>0.75 V_{CC}	Z	Z	Recessive
L	L or open	≤0.33 V_{CC}	H	L	Dominant
H or open	X		Z	Z	Recessive
X	H	≤0.33 V_{CC}	Z	Z	Recessive

RECEIVER				
INPUTS				OUTPUT
BUS STATE	$V_{ID} = V_{(CANH)} - V_{(CANL)}$	LBK	D	R
Dominant	V_{ID} ≥ 0.9 V	L or open	X	L
Recessive	V_{ID} ≤ 0.5 V or open	L or open	H or open	H
?	0.5 V < V_{ID} < 0.9 V	L or open	H or open	?
X	X	H	L	L
X	X		H	H

ABSOLUTE MAXIMUM RATINGS(1) (2)

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

				VALUE	UNIT
V_{CC}	Supply voltage range			–0.3 to 7	V
	Voltage range at any bus terminal (CANH or CANL)			–36 to 36	V
	Voltage input range, transient pulse (CANH and CANL) through 100 Ω (see Figure 8)			–100 to 100	V
V_I	Input voltage range (D, R, R_S, LBK)			–0.5 to 7	V
I_O	Receiver output current			–10 to 10	mA
	Electrostatic discharge	Human-Body Model (HBM)(3)	CANH, CANL, and GND	16	kV
			All pins	3	
		Charged-Device Mode (CDM)(4)	All pins	1	

(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.

THERMAL CHARACTERISTICS FOR D PACKAGE

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

PARAMETER		MIN	TYP	MAX	UNIT
θ_{JC}	Junction-to-case thermal resistance (to bottom of case)		49		°C/W

THERMAL CHARACTERISTICS FOR JD PACKAGE

over operating free-air temperature range unless otherwise noted

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
θ_{JA}	Junction-to-ambient thermal resistance(1)	Low-K(2) board, no air flow			83.4	°C/W
		High-K(3) board, no air flow			64.9	
θ_{JB}	Junction-to-board thermal resistance	High-K(3) board, no air flow			27.9	°C/W
θ_{JC}	Junction-to-case thermal resistance				6.49	°C/W
$P_{(AVG)}$	Average power dissipation	R_L = 60 Ω, R_S = 0 V, input to D a 1-MHz 50% duty cycle square wave, V_{CC} = 3.3 V, T_A = 25°C			114	mW

(1) See TI literature number SZZA003 for an explanation of this parameter.
(2) JESD51-3 low effective thermal conductivity test board for leaded surface-mount packages.
(3) JESD51-7 high effective thermal conductivity test board for leaded surface-mount packages.

THERMAL CHARACTERISTICS FOR HKJ OR HKQ PACKAGE

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

PARAMETER			MIN	TYP	MAX	UNIT
θ_{JC}	Junction-to-case thermal resistance	to ceramic side of case			5.7	°C/W
		to top of case lid (metal side of case)			13.7	

RECOMMENDED OPERATING CONDITIONS

			T_A = –55°C to 210°C		UNIT
			MIN	MAX	
V_{CC}	Supply voltage		3	3.6	V
	Voltage at any bus terminal (separately or common mode)		–7	12	V
V_{IH}	High-level input voltage	D, LBK	2	5.5	V
V_{IL}	Low-level input voltage	D, LBK	0	0.8	V
V_{ID}	Differential input voltage		–6	6	V
	Resistance from R_S to ground		0	100	kΩ
$V_{I(Rs)}$	Input voltage at R_S for standby		0.75 V_{CC}	5.5	V
I_{OH}	High-level output current	Driver	–50		mA
		Receiver	–10		
I_{OL}	Low-level output current	Driver		50	mA
		Receiver		10	
T_J	Operating junction temperature			212	°C
T_A	Operating free-air temperature(1)		-55	210	°C

(1) Maximum free-air temperature operation is allowed as long as the device maximum junction temperature is not exceeded.

DRIVER ELECTRICAL CHARACTERISTICS

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

PARAMETER			TEST CONDITIONS	T_A = –55°C to 125°C			T_A = 175°C(1)			T_A = 210°C(2)			UNIT
				MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
$V_{O(D)}$	Bus output voltage (dominant)	CANH	D = 0 V, R_S = 0 V, See Figure 2 and Figure 3	2.45		V_{CC}	2.45		V_{CC}	2.45		V_{CC}	V
		CANL		0.5		1.25	0.5		1.25	0.5		1.25	
V_O	Bus output voltage (recessive)	CANH	D = 3 V, R_S = 0 V, See Figure 2 and Figure 3		2.3			2.3			2.3		V
		CANL			2.3			2.3			2.3		
$V_{OD(D)}$	Differential output voltage (Dominant)		D = 0 V, R_S = 0 V, See Figure 2 and Figure 3	1.5	2	3	1.4	1.75	3	1.4	1.75	3	V
			D = 0 V, R_S = 0 V, See Figure 3 and Figure 4	1.1	2	3	1.1	1.47	3	1.1	1.47	3	
V_{OD}	Differential output voltage (Recessive)		D = 3 V, R_S = 0 V, See Figure 2 and Figure 3	–120		12	–120		12	–120		12	mV
			D = 3 V, R_S = 0 V, No load	–0.5		0.05	–0.5		0.8	–0.5		1.2	V
$V_{OC(pp)}$	Peak-to-peak common-mode output voltage		See Figure 10		1			1			1		V
I_{IH}	High-level input current	D, LBK	D = 2 V	–30		30	–30		30	–30		30	µA
I_{IL}	Low-level input current	D, LBK	D = 0.8 V	–30		30	–30		30	–30		30	µA
I_{OS}	Short-circuit output current		V_{CANH} = –7 V, CANL open, See Figure 13	–250			–250			–250			mA
			V_{CANH} = 12 V, CANL open, See Figure 13			1			1			1	
			V_{CANL} = –7 V, CANH open, See Figure 13	–1			–1			–1			
			V_{CANL} = 12 V, CANH open, See Figure 13			250			250			250	
C_O	Output capacitance		See receiver input capacitance										
$I_{IRs(s)}$	R_S input current for standby		R_S = 0.75 V_{CC}	–10			–10			–10			µA
I_{CC}	Supply current	Standby	R_S = V_{CC}, D = V_{CC}, LBK = 0 V		200	600		400	600		400	600	µA
		Dominant	D = 0 V, No load, LBK = 0 V, R_S = 0 V			6			6			6	mA
		Recessive	D =t V_{CC}, No load, LBK = 0 V, R_S = 0 V			6			6			6	

(1) Minimum and maximum parameters are characterized for operation at T_A = 175°C and production tested at T_A = 125°C.
(2) Minimum and maximum parameters are characterized for operation at T_A = 210°C but may not be production tested at that temperature. Production test limits with statistical guardbands are used to ensure high temperature performance.

DRIVER SWITCHING CHARACTERISTICS

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

PARAMETER		TEST CONDITIONS	T_A = –55°C to 125°C			T_A = 175°C(1)			T_A = 210°C(2)			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
t_{PLH}	Propagation delay time, low-to-high-level output	R_S = 0 V, See Figure 5		35	85		50			50		ns
		R_S with 10 kΩ to ground, See Figure 5		70	125		75			75		
		R_S with 100 kΩ to ground, See Figure 5		500	870		500			500		
t_{PHL}	Propagation delay time, high-to-low-level output	R_S = 0 V, See Figure 5		70	120		70			70		ns
		R_S with 10 kΩ to ground, See Figure 5		130	180		130			130		
		R_S with 100 kΩ to ground, See Figure 5		870	1200		870			870		
$t_{sk(p)}$	Pulse skew ($\lvert t_{PHL} - t_{PLH} \rvert$)	R_S = 0 V, See Figure 5		35			9			9		ns
		R_S with 10 kΩ to ground, See Figure 5		60			35			35		
		R_S with 100 kΩ to ground, See Figure 5		370			475			475		
t_r	Differential output signal rise time	R_S = 0 V, See Figure 5	20		70	20		75	20		75	ns
t_f	Differential output signal fall time		18		70	20		75	20		75	
t_r	Differential output signal rise time	R_S with 10 kΩ to ground, See Figure 5	30		135	30		140	30		140	ns
t_f	Differential output signal fall time		30		135	30		140	30		140	
t_r	Differential output signal rise time	R_S with 100 kΩ to ground, See Figure 5	250		1400	250		1400	250		1400	ns
t_f	Differential output signal fall time		350		1400	350		1400	350		1400	
$t_{en(s)}$	Enable time from standby to dominant	See Figure 9		0.6	1.5		0.6	1.5		0.6	1.5	µs

(1) Minimum and maximum parameters are characterized for operation at T_A = 210°C but not production tested at T_A = 175°C or 210°C.
(2) Minimum and maximum parameters are characterized for operation at T_A = 210°C but may not be production tested at that temperature. Production test limits with statistical guardbands are used to ensure high temperature performance.

RECEIVER ELECTRICAL CHARACTERISTICS

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

PARAMETER		TEST CONDITIONS	T_A = –55°C to 125°C			T_A = 175°C(1)			T_A = 210°C(2)			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
V_{IT+}	Positive-going input threshold voltage	LBK = 0 V, See Table 2		620	900		600	900		600	900	mV
$V_{IT–}$	Negative-going input threshold voltage		500	715		500	725		500	725		mV
V_{hys}	Hysteresis voltage ($V_{IT+} - V_{IT–}$)			100			140			140		mV
V_{OH}	High-level output voltage	I_O = –4 mA, See Figure 7	2.4			2.4			2.4			V

(1) Minimum and maximum parameters are characterized for operation at T_A = 210°C and are not chacterized or production tested at T_A = 175°C.
(2) Minimum and maximum parameters are characterized for operation at T_A = 210°C but may not be production tested at that temperature. Production test limits with statistical guardbands are used to ensure high temperature performance.

RECEIVER ELECTRICAL CHARACTERISTICS (continued)

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

PARAMETER			TEST CONDITIONS		T_A = –55°C to 125°C			T_A = 175°C(1)			T_A = 210°C(2)			UNIT
					MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
V_{OL}	Low-level output voltage		I_O = 4 mA, See Figure 7				0.4			0.4			0.4	V
I_I	Bus input current		CANH or CANL = 12 V	Other bus pin = 0 V, D = 3 V, LBK = 0 V, R_S = 0 V,	140		500	140		500	140		500	μA
			CANH or CANL = 12 V, V_{CC} = 0 V		200		600	200		700	200		800	
			CANH or CANL = –7 V		–610		–150	–610		–150	–610		–150	
			CANH or CANL = –7 V, V_{CC} = 0 V		–450		–130	–450		–130	–450		–130	
C_I	Input capacitance (CANH or CANL)		Pin to ground, V_I = 0.4 sin (4E6πt) + 0.5 V, D = 3 V, LBK = 0 V			45			55			55		pF
C_{ID}	Differential input capacitance		Pin to pin, V_I = 0.4 sin (4E6πt) + 0.5 V, D = 3 V, LBK = 0 V			15			15			15		pF
R_{ID}	Differential input resistance		D = 3 V, LBK = 0 V		40		110	40		110	40		110	kΩ
R_{IN}	Input resistance (CANH or CANL)				20		51	19		51	18		51	kΩ
I_{CC}	Supply current	Standby	R_S = V_{CC}, D = V_{CC}, LBK = 0 V			200	600		400	600		400	600	μA
		Dominant	D = 0 V, No load, R_S = 0 V, LBK = 0 V				6			6			6	mA
		Recessive	D = V_{CC}, No load, R_S = 0 V, LBK = 0 V				6			6			6	

RECEIVER SWITCHING CHARACTERISTICS

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

PARAMETER		TEST CONDITIONS	T_A = –55°C to 125°C			T_A = 175°C(1)			T_A = 210°C(2)			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
t_{PLH}	Propagation delay time, low-to-high-level output	See Figure 7		35	60		50	60		50	60	ns
t_{PHL}	Propagation delay time, high-to-low-level output			35	60		45	60		45	60	ns
$t_{sk(p)}$	Pulse skew ($\lvert t_{PHL} - t_{PLH} \rvert$)			7			5			5		ns
t_r	Output signal rise time			2	6.5		6.5	8		6.5	8	ns
t_f	Output signal fall time			2	6.5		6.5	9		6.5	9	ns

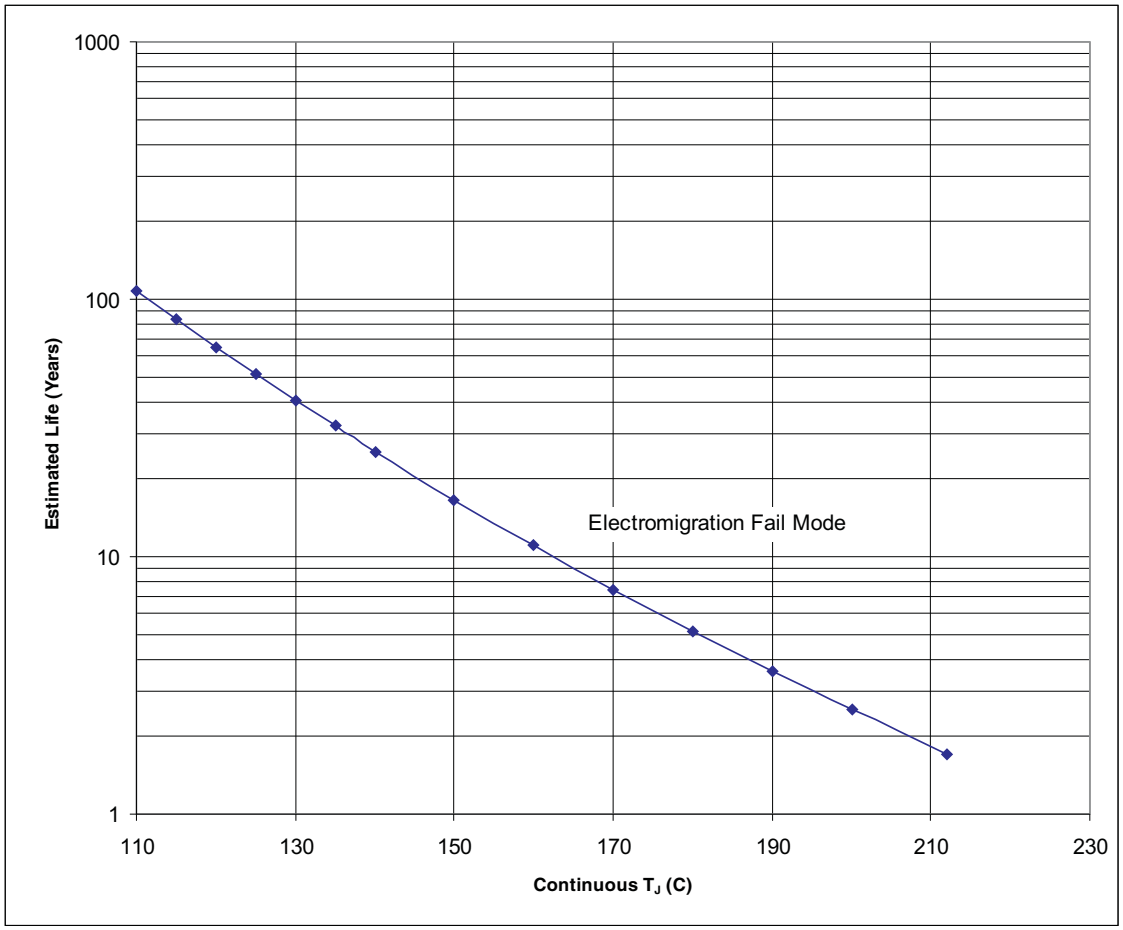
(1) Minimum and maximum parameters are characterized for operation at T_A = 210°C but not production tested at T_A = 175°C or 210°C.
(2) Minimum and maximum parameters are characterized for operation at T_A = 210°C but may not be production tested at that temperature. Production test limits with statistical guardbands are used to ensure high temperature performance.

DEVICE SWITCHING CHARACTERISTICS

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

PARAMETER		TEST CONDITIONS	T_A = –55°C to 125°C			T_A = 175°C(1)			T_A = 210°C(2)			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
$t_{(LBK)}$	Loopback delay, driver input to receiver output	See Figure 12		7.5	15		12	15		12	15	ns
$t_{(loop1)}$	Total loop delay, driver input to receiver output, recessive to dominant	R_S = 0 V, See Figure 11		70	135		90	135		90	135	ns
		R_S with 10 kΩ to ground, See Figure 11		105	190		115	190		115	190	
		R_S with 100 kΩ to ground, See Figure 11		535	1000		430	1000		430	1000	
$t_{(loop2)}$	Total loop delay, driver input to receiver output, dominant to recessive	R_S = 0 V, See Figure 11		70	135		98	135		98	135	ns
		R_S with 10 kΩ to ground, See Figure 11		105	190		150	190		150	190	
		R_S with 100 kΩ to ground, See Figure 11		535	1100		880	1200		880	1200	

(1) Minimum and maximum parameters are characterized for operation at T_A = 210°C but not production tested at T_A = 175°C or 210°C.
(2) Minimum and maximum parameters are characterized for operation at T_A = 210°C but may not be production tested at that temperature. Production test limits with statistical guardbands are used to ensure high temperature performance.



A. See data sheet for absolute maximum and minimum recommended operating conditions.

B. Silicon operating life design goal is 10 years at 105°C junction temperature (does not include package interconnect life).

Figure 1. SN65HVD233HD/SN65HVD233SJD/SN65HVD233SKGDA/SN65HVD233SHKJ/SN65HVD233SHKQ Operating Life Derating Chart

PARAMETER MEASUREMENT INFORMATION

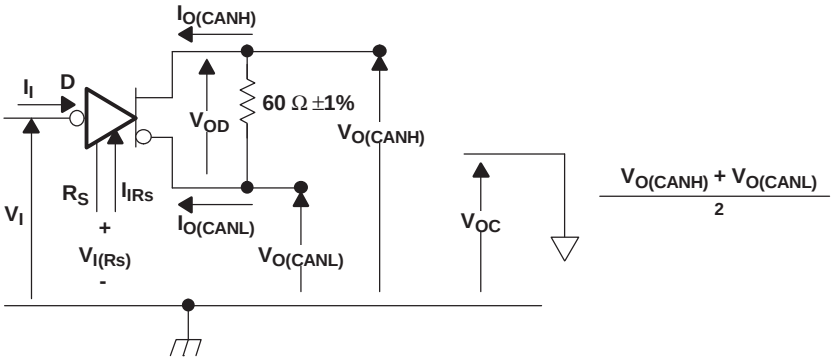


Figure 2. Driver Voltage, Current, and Test Definition

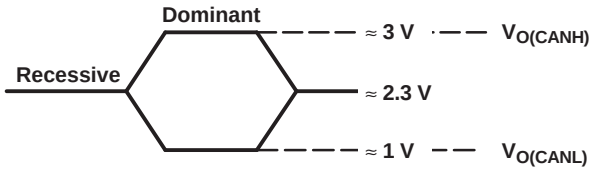


Figure 3. Bus Logic State Voltage Definitions

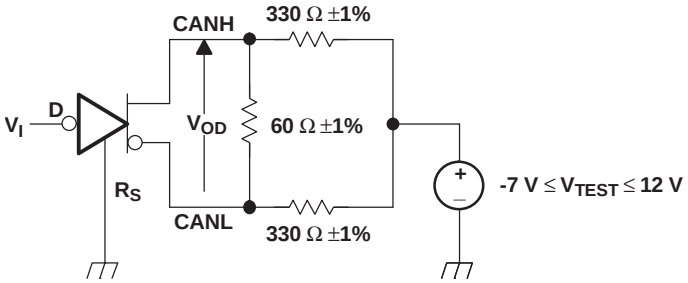
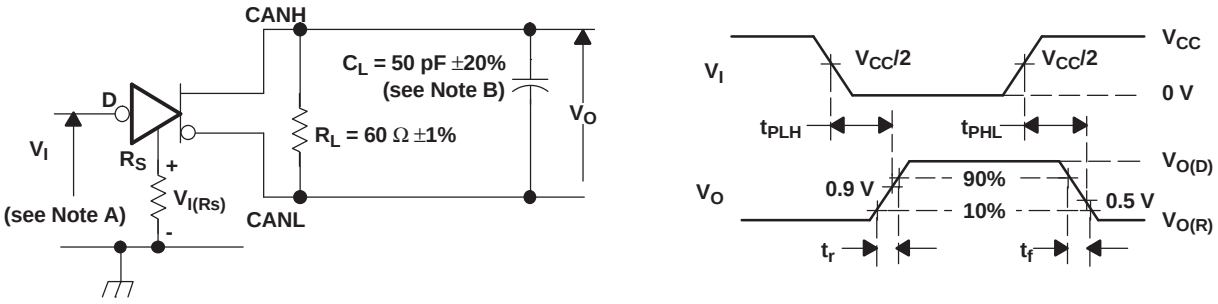


Figure 4. Driver V_{OD}



A. The input pulse is supplied by a generator having the following characteristics: Pulse repetition rate (PRR) ≤ 125 kHz, 50% duty cycle, t_r ≤ 6 ns, t_f ≤ 6 ns, Z_O = 50 Ω.

B. C_L includes fixture and instrumentation capacitance.

Figure 5. Driver Test Circuit and Voltage Waveforms

PARAMETER MEASUREMENT INFORMATION (continued)

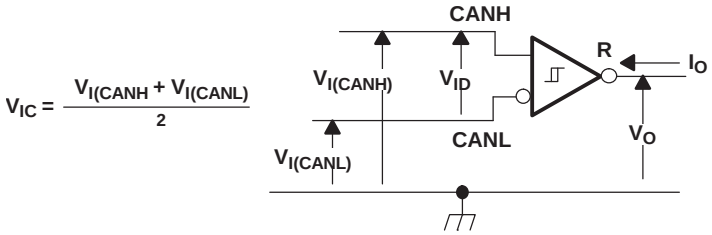
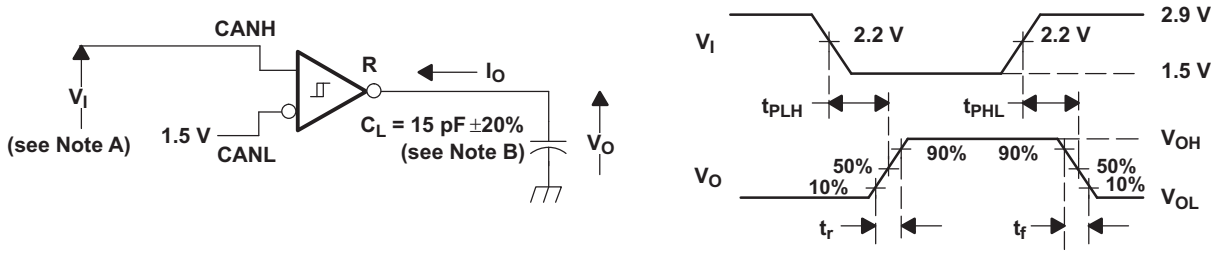


Figure 6. Receiver Voltage and Current Definitions



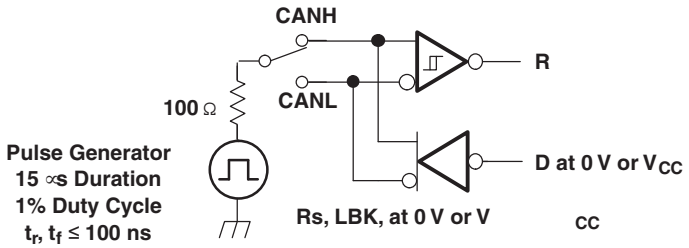
A. The input pulse is supplied by a generator having the following characteristics: Pulse repetition rate (PRR) ≤ 125 kHz, 50% duty cycle, t_r ≤ 6 ns, t_f ≤ 6 ns, Z_O = 50 Ω.

B. C_L includes fixture and instrumentation capacitance.

Figure 7. Receiver Test Circuit and Voltage Waveforms

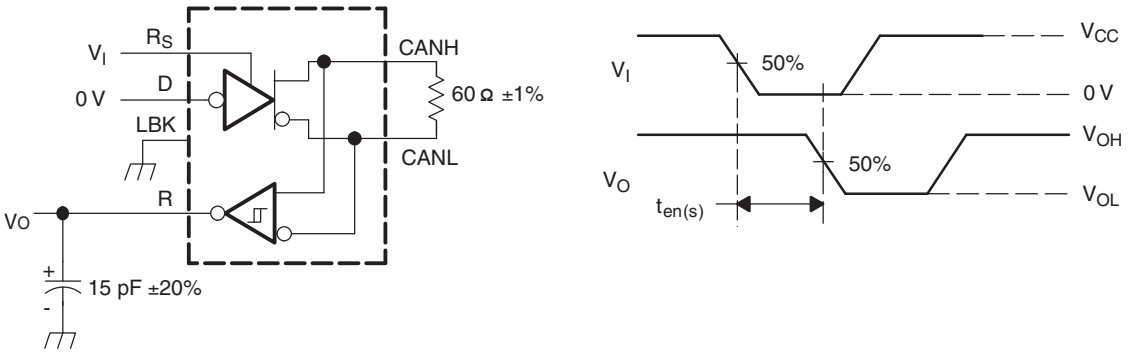
Table 2. Differential Input Voltage Threshold Test

INPUT		OUTPUT		MEASURED
V_{CANH}	V_{CANL}	R		$\lvert V_{ID}\rvert$
–6.1 V	–7 V	L	V_{OL}	900 mV
12 V	11.1 V	L		900 mV
–1 V	–7 V	L		6 V
12 V	6 V	L		6 V
–6.5 V	–7 V	H	V_{OH}	500 mV
12 V	11.5 V	H		500 mV
–7 V	–1 V	H		6 V
6 V	12 V	H		6 V
Open	Open	H		X



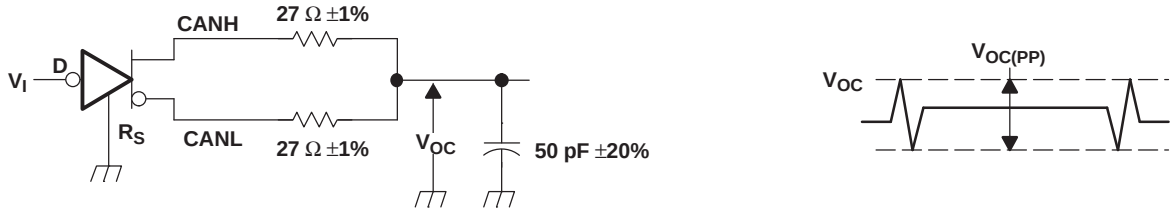
NOTE: This test is conducted to test survivability only. Data stability at the R output is not specified.

Figure 8. Test Circuit, Transient Over Voltage Test



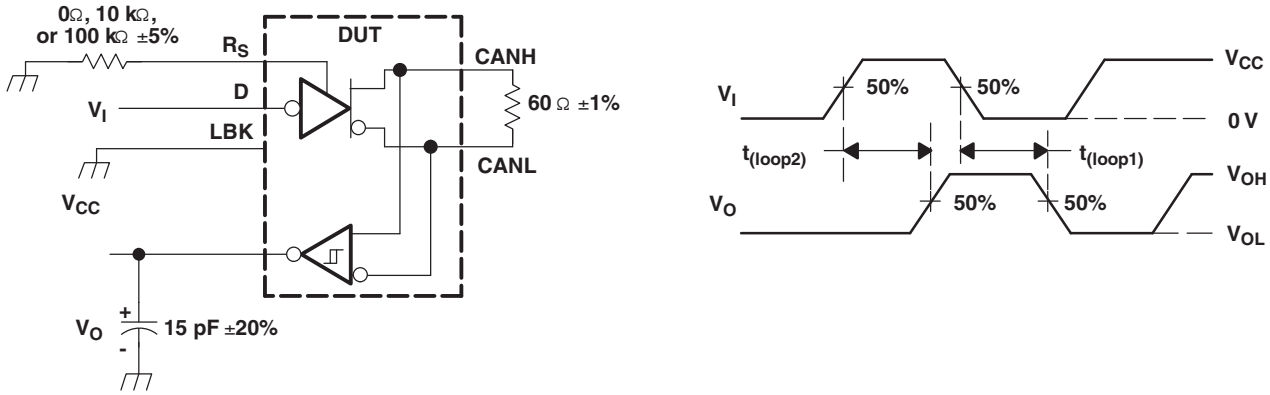
NOTE: All V_I input pulses are supplied by a generator having the following characteristics: t_r or t_f ≤ 6 ns, pulse repetition rate (PRR) = 125 kHz, 50% duty cycle.

Figure 9. $t_{en(s)}$ Test Circuit and Voltage Waveforms



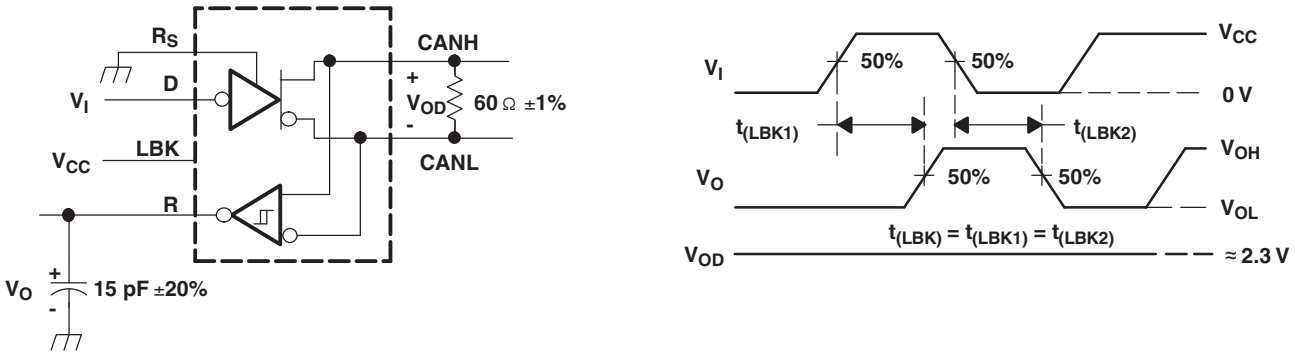
NOTE: All V_I input pulses are supplied by a generator having the following characteristics: t_r or t_f ≤ 6 ns, pulse repetition rate (PRR) = 125 kHz, 50% duty cycle.

Figure 10. $V_{OC(pp)}$ Test Circuit and Voltage Waveforms



NOTE: All V_I input pulses are supplied by a generator having the following characteristics: t_r or t_f ≤ 6 ns, pulse repetition rate (PRR) = 125 kHz, 50% duty cycle.

Figure 11. $t_{(loop)}$ Test Circuit and Voltage Waveforms



NOTE: All V_I input pulses are supplied by a generator having the following characteristics: t_r or t_f ≤ 6 ns, pulse repetition rate (PRR) = 125 kHz, 50% duty cycle.

Figure 12. $t_{(LBK)}$ Test Circuit and Voltage Waveforms

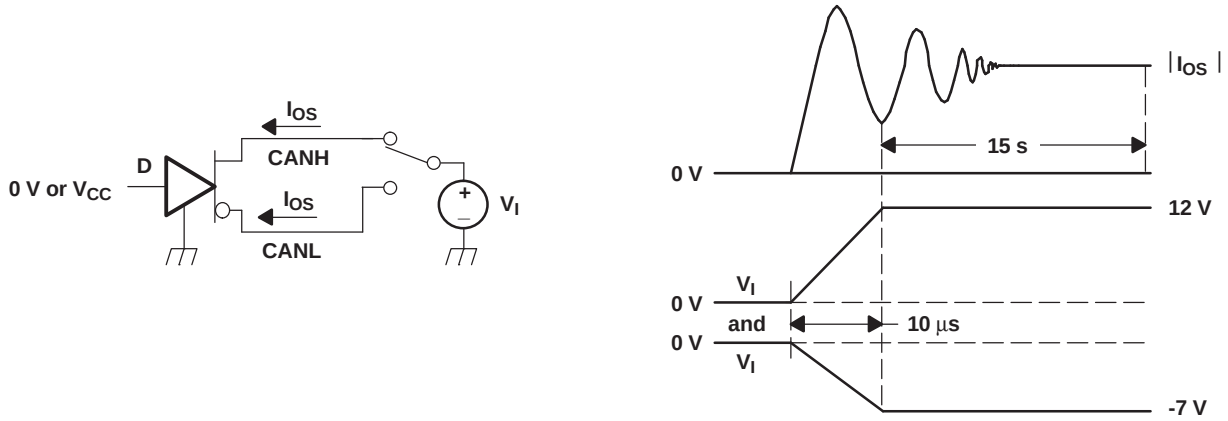
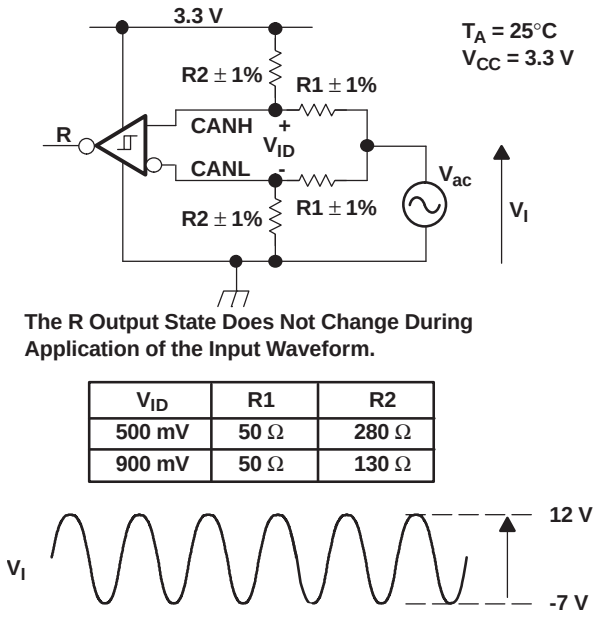


Figure 13. I_{OS} Test Circuit and Waveforms



V_{ID}	R1	R2
500 mV	50 Ω	280 Ω
900 mV	50 Ω	130 Ω

NOTE: All input pulses are supplied by a generator with f ≤ 1.5 MHz.

Figure 14. Common-Mode Voltage Rejection

TYPICAL CHARACTERISTICS

RECESSIVE-TO-DOMINANT LOOP TIME vs FREE-AIR TEMPERATURE

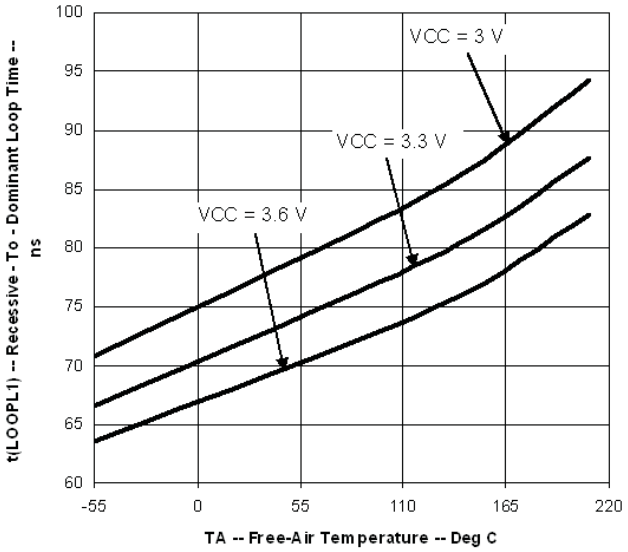


Figure 15.

DOMINANT-TO-RECESSIVE LOOP TIME vs FREE-AIR TEMPERATURE

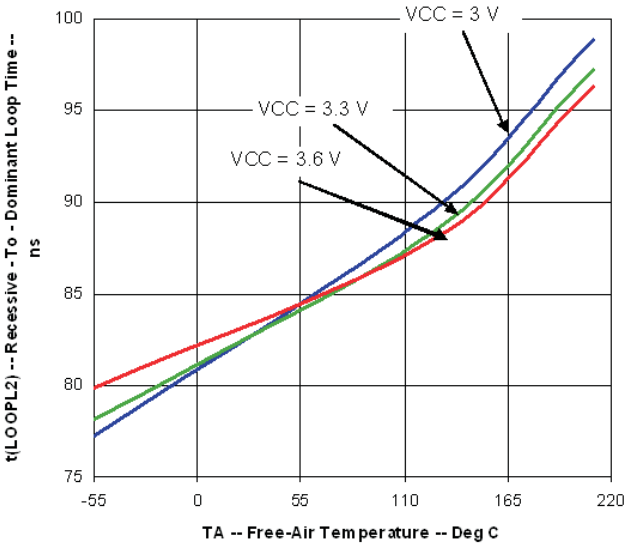


Figure 16.

SUPPLY CURRENT vs FREQUENCY

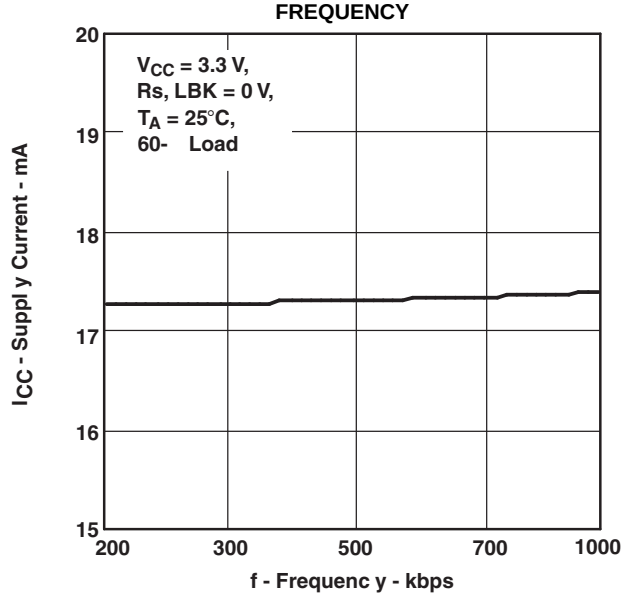


Figure 17.

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

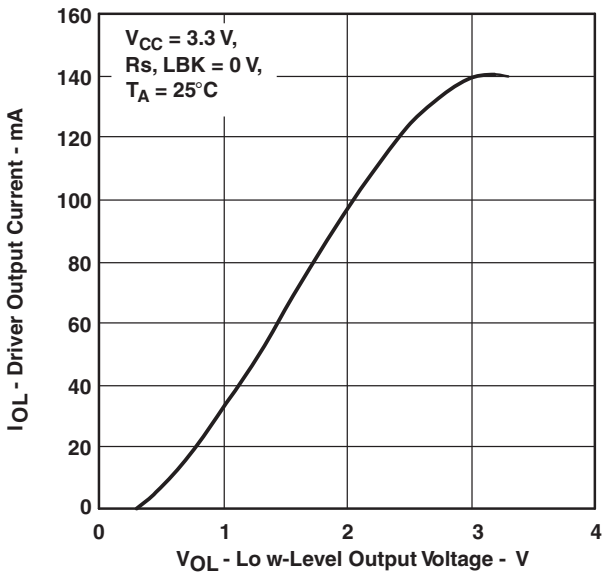


Figure 18.

TYPICAL CHARACTERISTICS (continued)

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

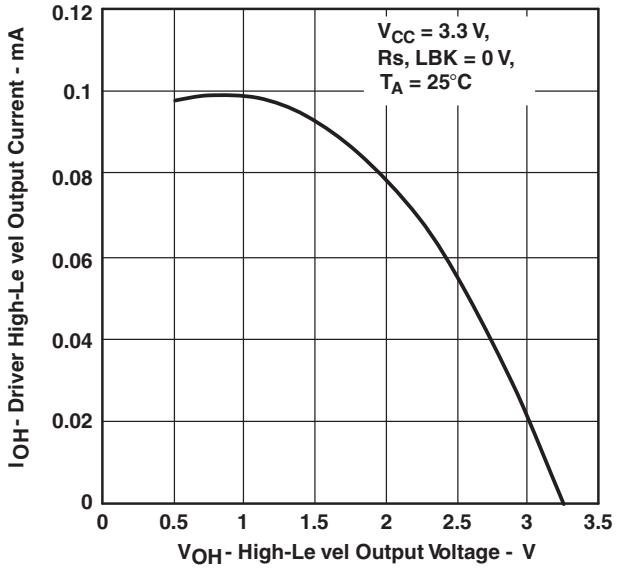


Figure 19.

DIFFERENTIAL OUTPUT VOLTAGE vs FREE-AIR TEMPERATURE

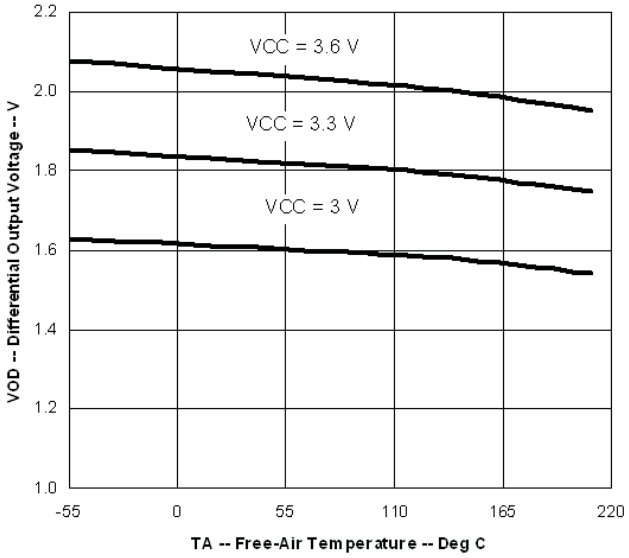


Figure 20.

RECEIVER LOW-TO-HIGH PROPAGATION DELAY vs FREE-AIR TEMPERATURE

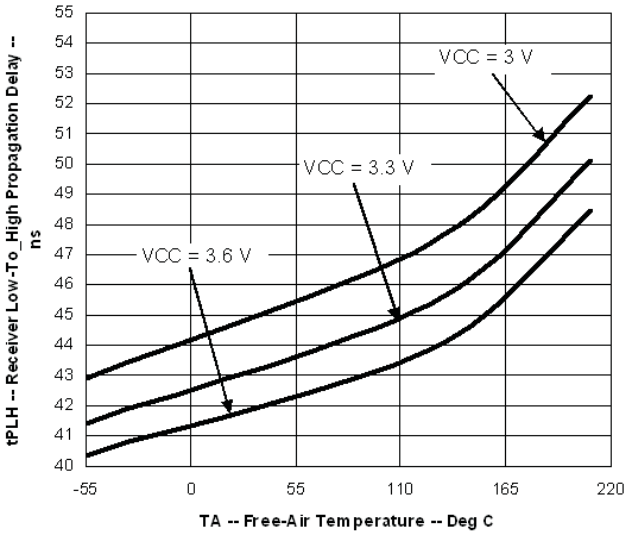


Figure 21.

RECEIVER HIGH-TO-LOW PROPAGATION DELAY vs FREE-AIR TEMPERATURE

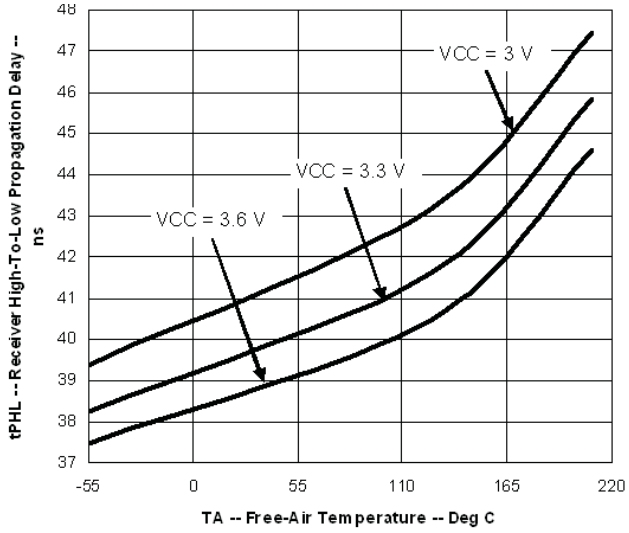


Figure 22.

TYPICAL CHARACTERISTICS (continued)

DRIVER LOW-TO-HIGH PROPAGATION DELAY vs FREE-AIR TEMPERATURE

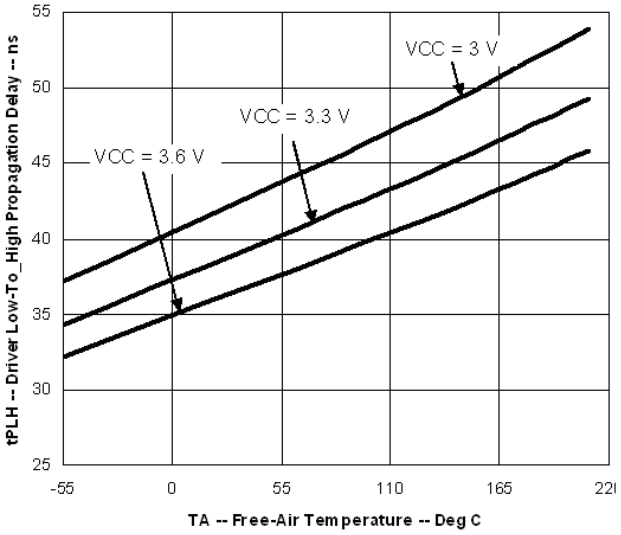


Figure 23.

DRIVER HIGH-TO-LOW PROPAGATION DELAY vs FREE-AIR TEMPERATURE

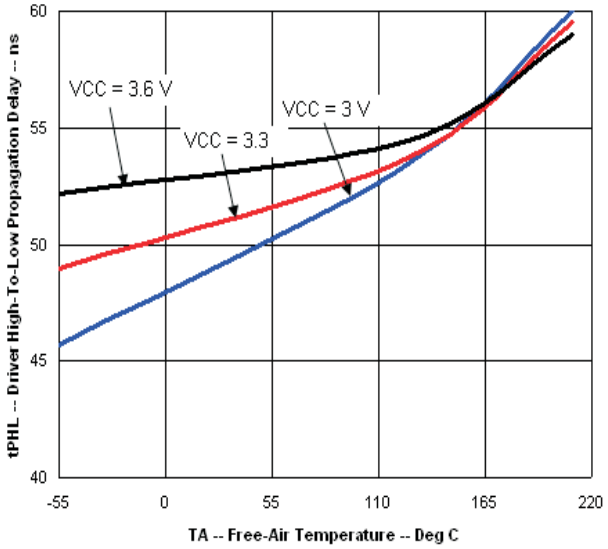


Figure 24.

DRIVER OUTPUT CURRENT vs SUPPLY VOLTAGE

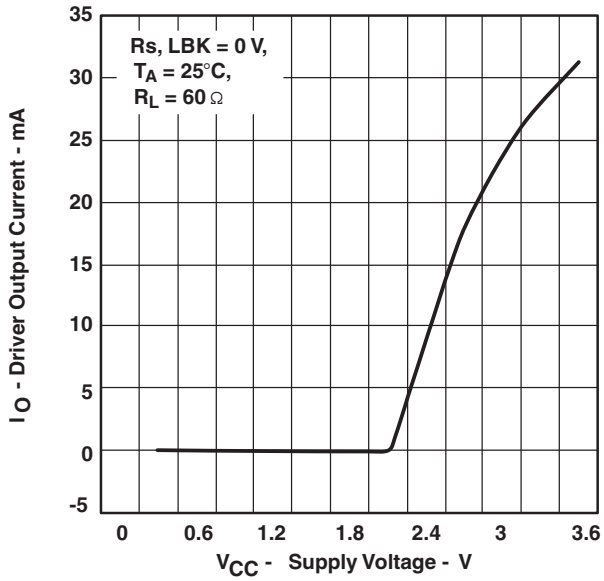


Figure 25.

APPLICATION INFORMATION

Diagnostic Loopback

The loopback (LBK) function of the SN65HVD233 is enabled with a high-level input to pin 5. This forces the driver into a recessive state and redirects the data (D) input at pin 1 to the received-data (R) output at pin 4. This allows the host controller to input and read back a bit sequence to perform diagnostic routines without disturbing the CAN bus. A typical CAN bus application is displayed in Figure 26.

If the LBK pin is not used, it may be tied to ground (GND). However, it is pulled low internally (defaults to a low-level input) and may be left open if not in use.

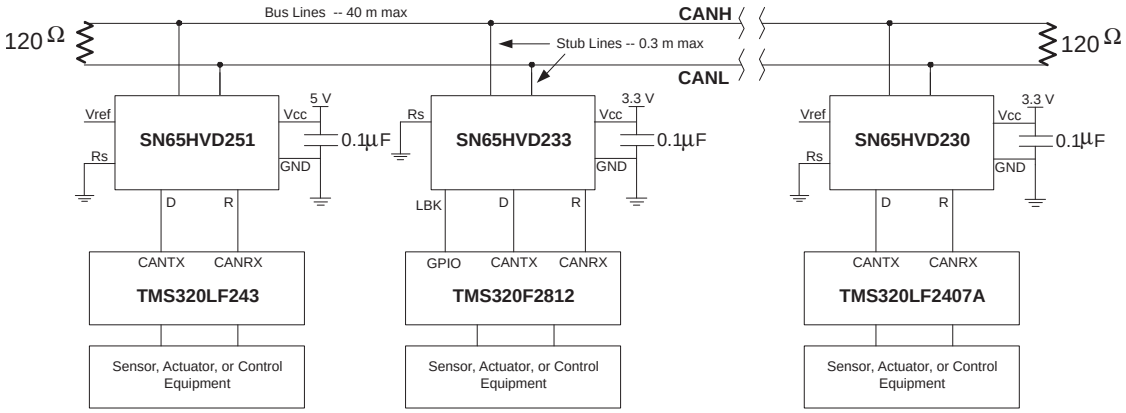


Figure 26. Typical SN65HVD233 Application

ISO 11898 Compliance of SN65HVD230 Family of 3.3-V CAN Transceivers

Introduction

Many users value the low power consumption of operating CAN transceivers from a 3.3-V supply. However, some are concerned about the interoperability with 5-V supplied transceivers on the same bus. This section analyzes this situation to address those concerns.

Differential Signal

CAN is a differential bus where complementary signals are sent over two wires, and the voltage difference between the two wires defines the logical state of the bus. The differential CAN receiver monitors this voltage difference and outputs the bus state with a single-ended output signal.

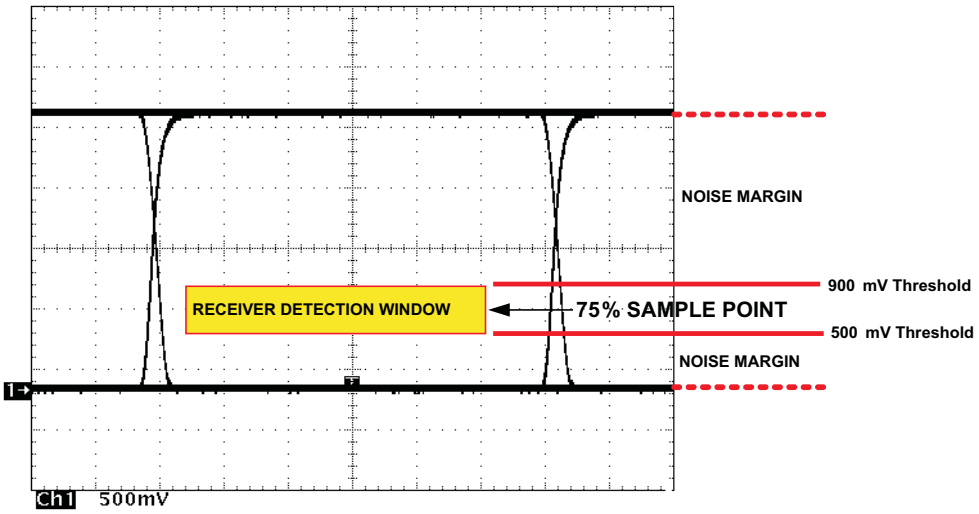


Figure 27. Typical SN65HVD230 Differential Output Voltage Waveform

The CAN driver creates the difference voltage between CANH and CANL in the dominant state. The dominant differential output of the SN65HVD230 is greater than 1.5 V and less than 3 V across a 60-Ω load. The minimum required by ISO 11898 is 1.5 V and the maximum is 3 V. These are the same limiting values for 5-V supplied CAN transceivers. The bus termination resistors drive the recessive bus state and not the CAN driver.

A CAN receiver is required to output a recessive state with less than 500 mV and a dominant state with more than 900-mV difference voltage on its bus inputs. The CAN receiver must do this with common-mode input voltages from –2 V to 7 V. The SN65HVD230 family receivers meet these same input specifications as 5-V supplied receivers.

Common-Mode Signal

A common-mode signal is an average voltage of the two signal wires that the differential receiver rejects. The common-mode signal comes from the CAN driver, ground noise, and coupled bus noise. Obviously, the supply voltage of the CAN transceiver has nothing to do with noise. The SN65HVD230 family driver lowers the common-mode output in a dominant bit by a couple hundred millivolts from that of most 5-V drivers. While this does not fully comply with ISO 11898, this small variation in the driver common-mode output is rejected by differential receivers and does not affect data, signal noise margins, or error rates.

Interoperability of 3.3-V CAN in 5-V CAN Systems

The 3.3-V–supplied SN65HVD23x family of CAN transceivers are electrically interchangeable with 5-V CAN transceivers. The differential output is the same. The recessive common-mode output is the same. The dominant common-mode output voltage is a couple hundred millivolts lower than 5-V–supplied drivers, while the receivers exhibit identical specifications as 5-V devices.

Electrical interoperability does not assure interchangeability however. Most implementers of CAN buses recognize that ISO 11898 does not sufficiently specify the electrical layer and that strict standard compliance alone does not ensure interchangeability. This comes only with thorough equipment testing.

Bus Cable

ISO 11898 specifies a maximum bus length of 40 m and maximum stub length of 0.3 m with a maximum of 30 nodes. However, with careful design, users can have longer cables, longer stub lengths, and many more nodes to a bus. A large number of nodes requires a transceiver with high input impedance, such as the SN65HVD233.

The standard specifies the interconnect to be a single twisted-pair cable (shielded or unshielded) with 120-Ω characteristic impedance (Z_O). Resistors equal to the characteristic impedance of the line terminate both ends of the cable to prevent signal reflections. Unterminated drop lines (stubs) connecting nodes to the bus should be kept as short as possible to minimize signal reflections.

Slope Control

The rise and fall slope of the SN65HVD233 driver output can be adjusted by connecting a resistor from R_s (pin 8) to ground (GND), or to a low-level input voltage (see Figure 28).

The slope of the driver output signal is proportional to the pin's output current. This slope control is implemented with an external resistor value of 10 kΩ to achieve a ≠15-V/µs slew rate, and up to 100 kΩ to achieve a ≠2.0-V/µs slew rate (see Figure 29). Typical driver output waveforms with slope control are displayed in Figure 30.

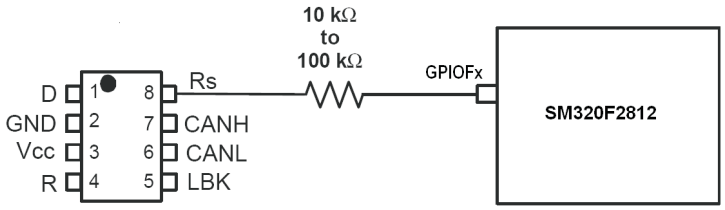


Figure 28. Slope Control/Standby Connection to DSP

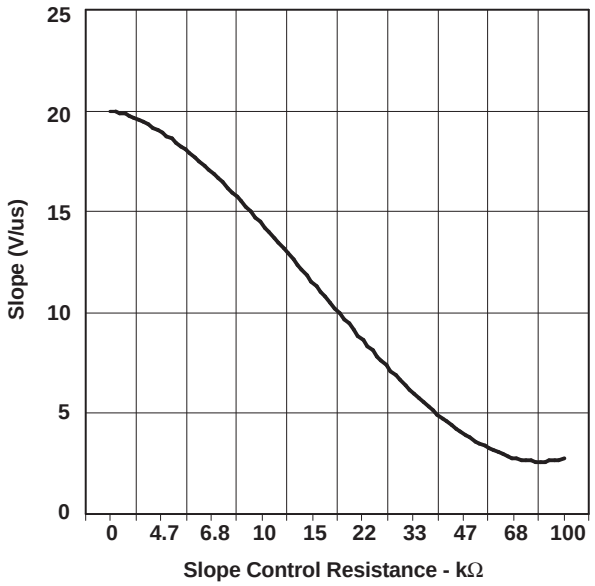


Figure 29. SN65HVD233 Driver Output Signal Slope vs Slope Control Resistance Value

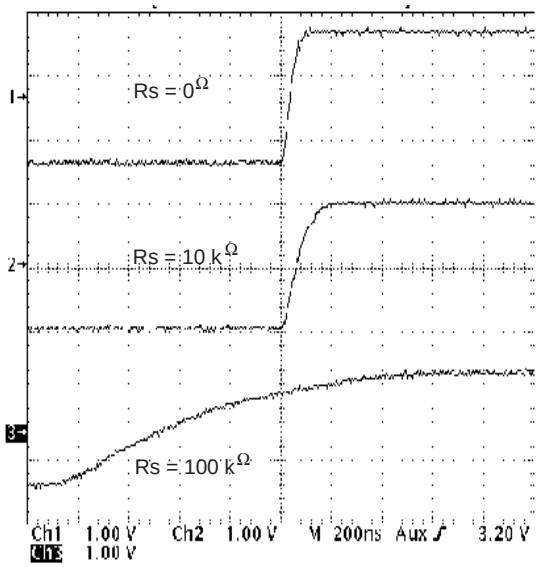


Figure 30. Typical SN65HVD233 250-kbps Output Pulse Waveforms With Slope Control

STANDBY

If a high-level input (>0.75 V_{CC}) is applied to R_s, the circuit enters a low-current, *listen-only* standby mode, during which the driver is switched off and the receiver remains active. The local controller can reverse this low-power standby mode when the rising edge of a dominant state (bus differential voltage >900 mV typical) occurs on the bus.

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish	MSL Peak Temp (3)	Op Temp (°C)	Top-Side Markings (4)	Samples
SN65HVD233HD	ACTIVE	SOIC	D	8	75	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-55 to 175	233S	Samples
SN65HVD233SHKJ	ACTIVE	CFP	HKJ	8	1	TBD	Call TI	N / A for Pkg Type	-55 to 210	SN65HVD233S HKJ	Samples
SN65HVD233SHKQ	ACTIVE	CFP	HKQ	8	25	TBD	AU	N / A for Pkg Type	-55 to 210	HVD233S HKQ	Samples
SN65HVD233SJD	ACTIVE	CDIP SB	JDJ	8	1	TBD	POST-PLATE	N / A for Pkg Type	-55 to 210	SN65HVD233SJD	Samples
SN65HVD233SKGDA	ACTIVE	XCEPT	KGD	0	130	TBD	Call TI	N / A for Pkg Type	-55 to 210		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) Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check http://www.ti.com/productcontent for the latest availability information and additional product content details.
TBD: The Pb-Free/Green conversion plan has not been defined.
Pb-Free (RoHS): TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.
Pb-Free (RoHS Exempt): This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.
Green (RoHS & no Sb/Br): TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

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

(4) Only one of markings shown within the brackets will appear on the physical device.

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.

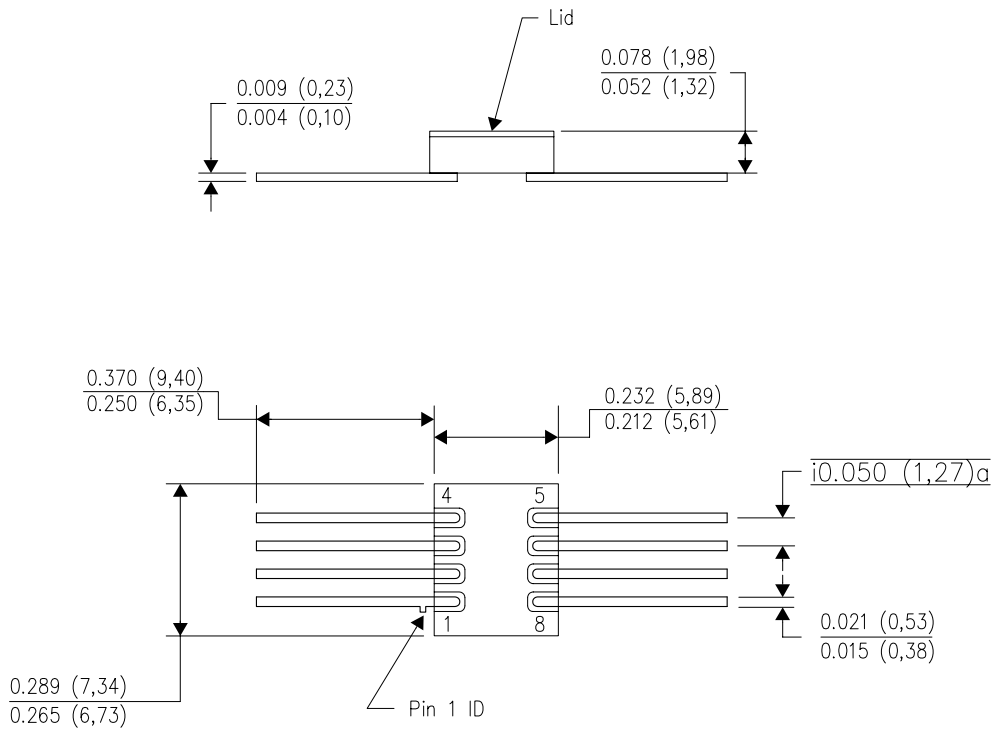
OTHER QUALIFIED VERSIONS OF SN65HVD233-HT :

- Catalog: SN65HVD233
- Enhanced Product: SN65HVD233-EP

NOTE: Qualified Version Definitions:

- Catalog - TI's standard catalog product
- Enhanced Product - Supports Defense, Aerospace and Medical Applications

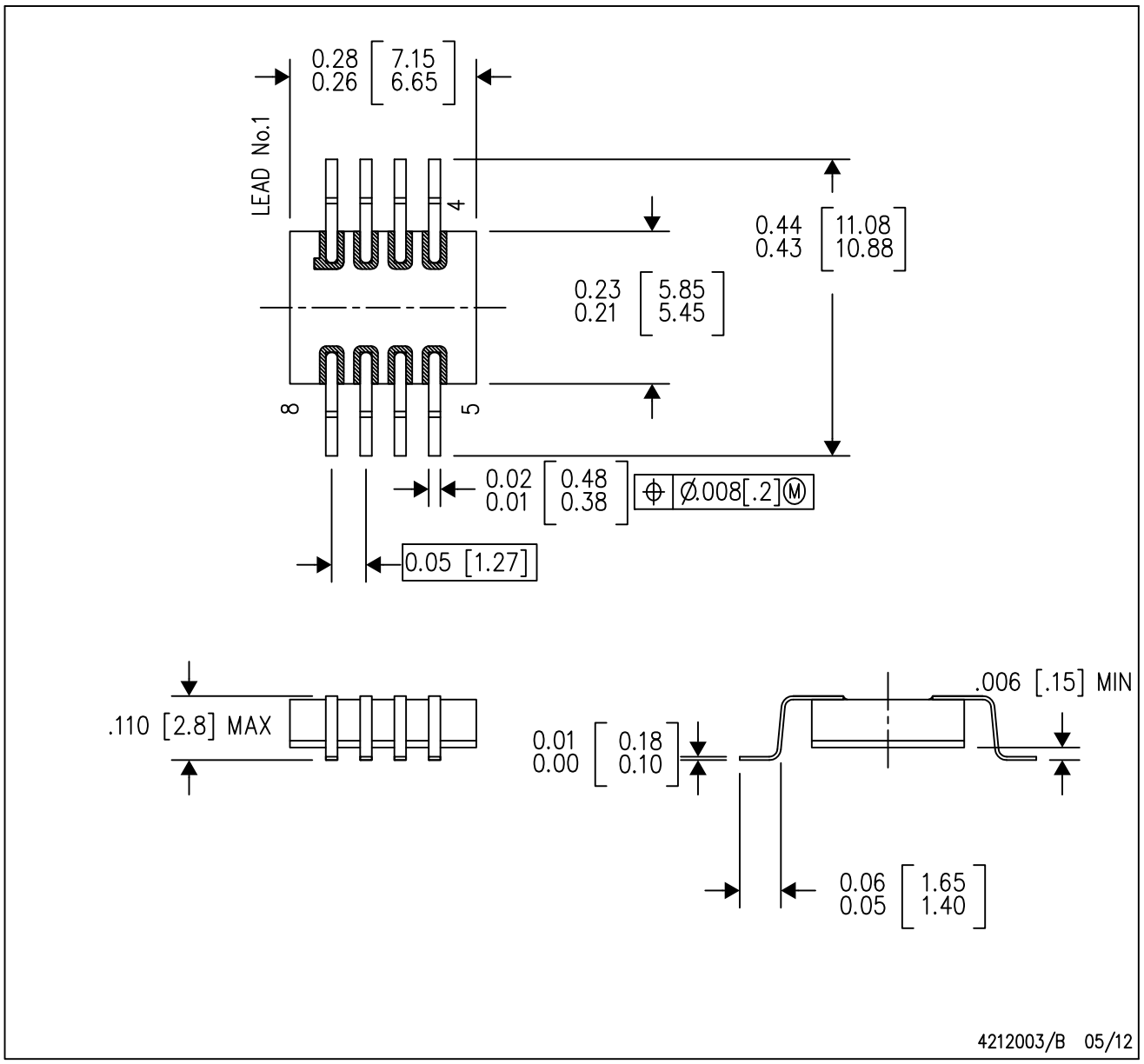
HKJ (R–CDFP–F8) CERAMIC DUAL FLATPACK



4209892/A 10/08

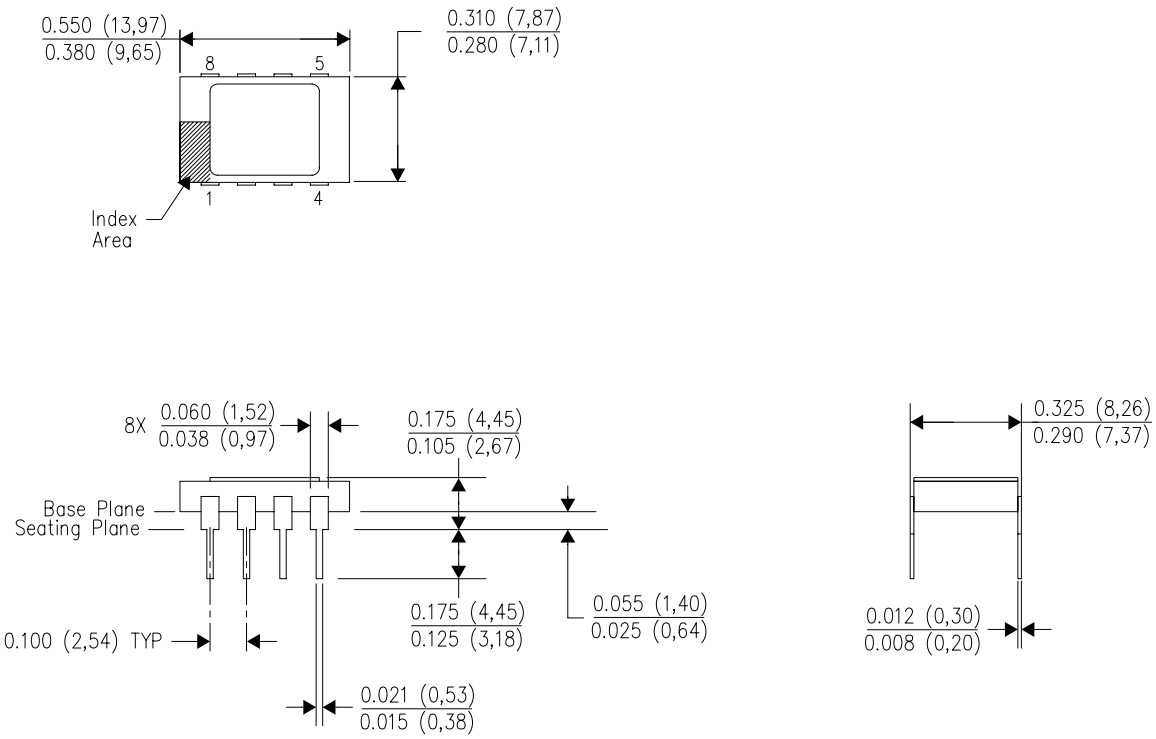
NOTES:
A. All linear dimensions are in inches (millimeters).
B. This drawing is subject to change without notice.
C. This package can be hermetically sealed with a metal lid.
D. The terminals will be gold plated.

HKQ (R–CDFP–G8) CERAMIC GULL WING



NOTES:
A. All linear dimensions are in inches (millimeters).
B. This drawing is subject to change without notice.
C. This package can be hermetically sealed with a metal lid.
D. The terminals will be gold plated.
E. Lid is not connected to any lead.

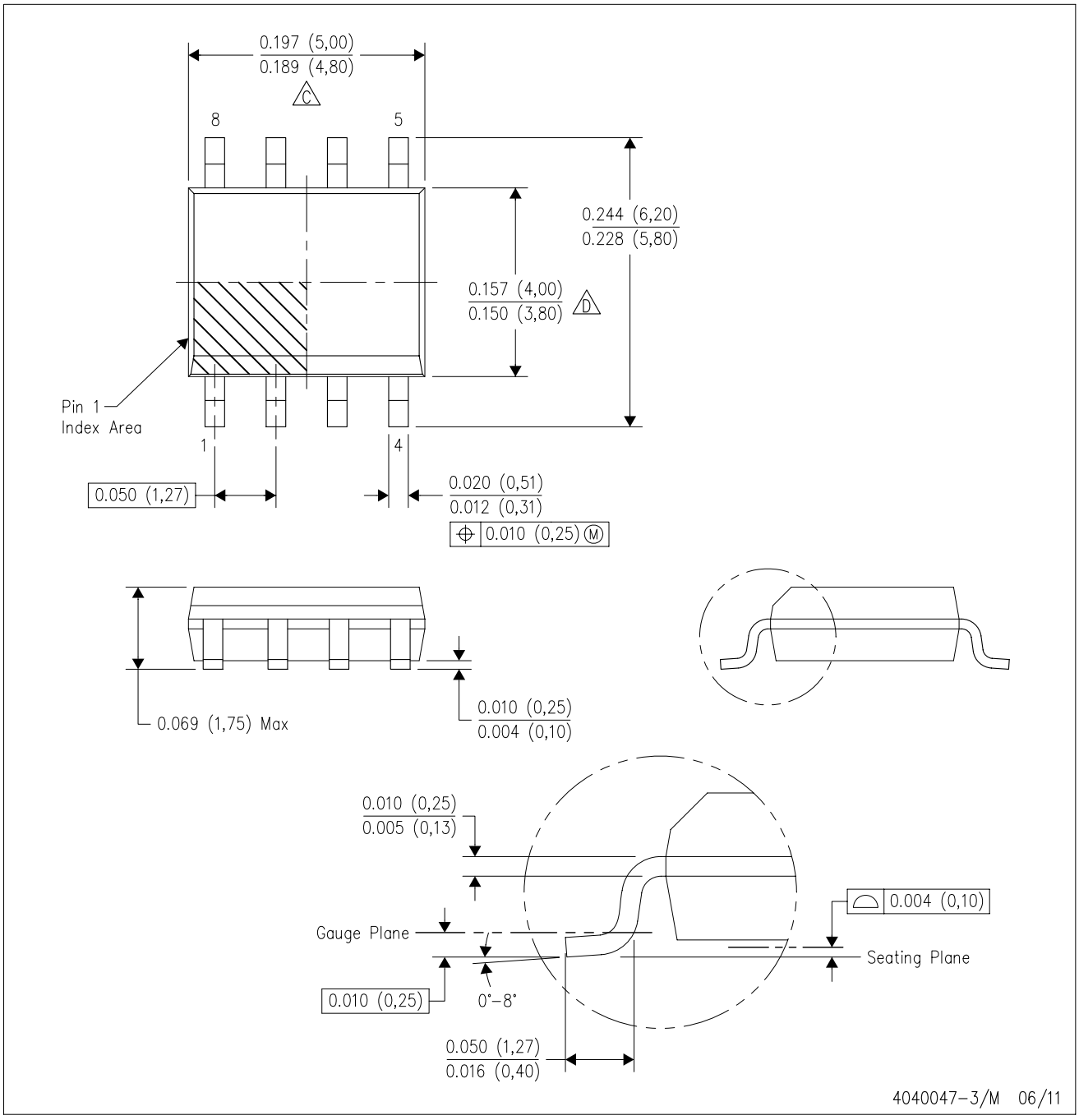
JDJ (R–CDIP–T8) CERAMIC DUAL IN–LINE PACKAGE



4202646–2/B 07/10

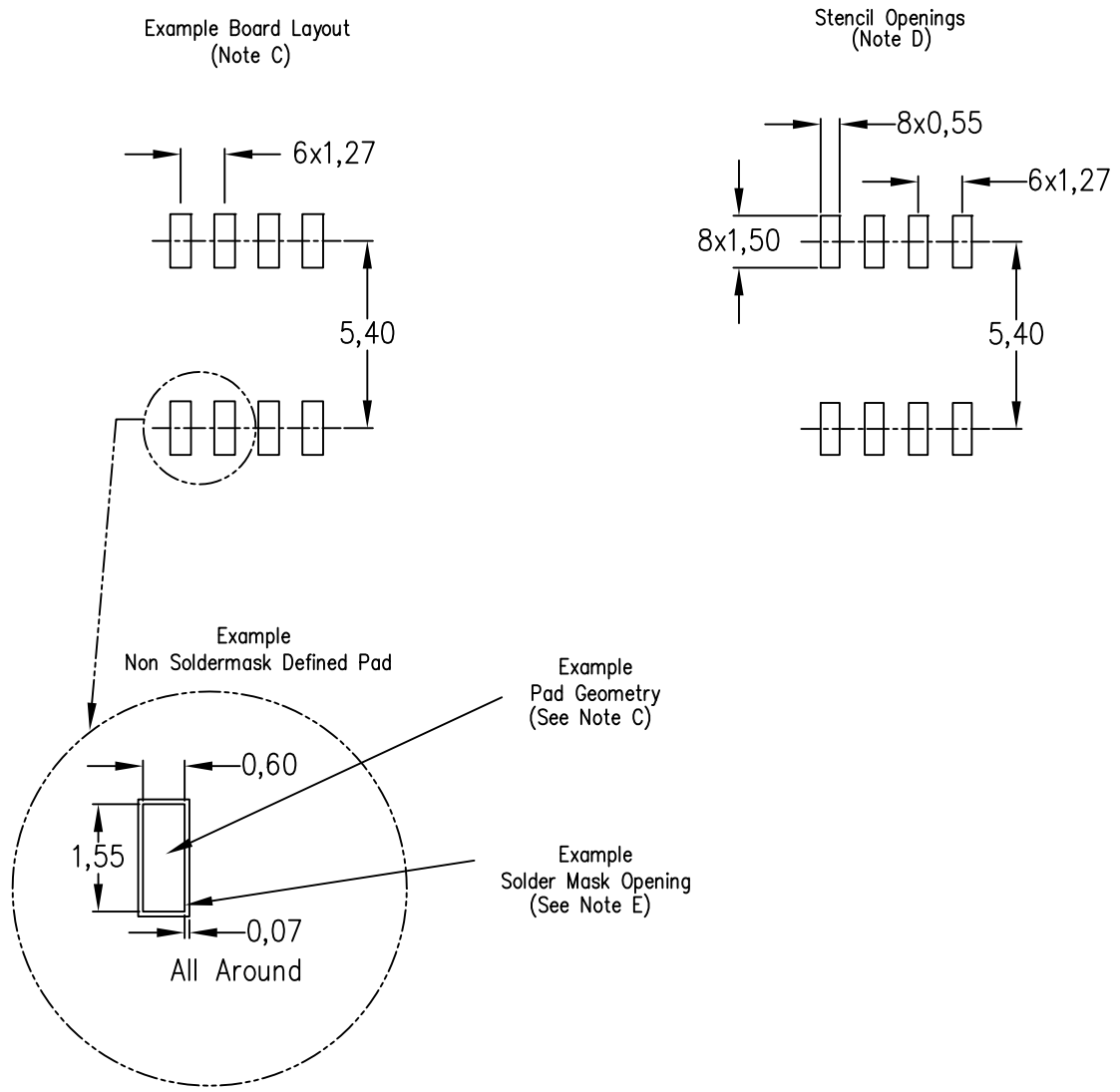
NOTES:
A. All linear dimensions are in inches (millimeters).
B. This drawing is subject to change without notice.
C. Ceramic quad flatpack with flat leads brazed to non–conductive tie bar carrier.
D. This package is hermetically sealed with a metal lid.
E. The leads are gold plated and can be solderdipped.
F. Leads not shown for clarity purposes.
G. Lid and heat sink are connected to GND leads.

D (R–PDSO–G8) PLASTIC SMALL OUTLINE



NOTES:
A. All linear dimensions are in inches (millimeters).
B. This drawing is subject to change without notice.
C. Body length does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.006 (0,15) each side.
D. Body width does not include interlead flash. Interlead flash shall not exceed 0.017 (0,43) each side.
E. Reference JEDEC MS–012 variation AA.

D (R–PDSO–G8) PLASTIC SMALL OUTLINE



NOTES:
A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Publication IPC–7351 is recommended for alternate designs.
D. Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Refer to IPC–7525 for other stencil recommendations.
E. Customers should contact their board fabrication site for solder mask tolerances between and around signal pads.

IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, enhancements, improvements and other changes to its semiconductor products and services per JESD46, latest issue, and to discontinue any product or service per JESD48, latest issue. Buyers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All semiconductor products (also referred to herein as “components”) are sold subject to TI’s terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its components to the specifications applicable at the time of sale, in accordance with the warranty in TI’s terms and conditions of sale of semiconductor products. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by applicable law, testing of all parameters of each component is not necessarily performed.

TI assumes no liability for applications assistance or the design of Buyers’ products. Buyers are responsible for their products and applications using TI components. To minimize the risks associated with Buyers’ products and applications, Buyers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any patent right, copyright, mask work right, or other intellectual property right relating to any combination, machine, or process in which TI components or services are used. Information published by TI regarding third-party products or services does not constitute a license to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of significant portions of TI information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. TI is not responsible or liable for such altered documentation. Information of third parties may be subject to additional restrictions.

Resale of TI components or services with statements different from or beyond the parameters stated by TI for that component or service voids all express and any implied warranties for the associated TI component or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

Buyer acknowledges and agrees that it is solely responsible for compliance with all legal, regulatory and safety-related requirements concerning its products, and any use of TI components in its applications, notwithstanding any applications-related information or support that may be provided by TI. Buyer represents and agrees that it has all the necessary expertise to create and implement safeguards which anticipate dangerous consequences of failures, monitor failures and their consequences, lessen the likelihood of failures that might cause harm and take appropriate remedial actions. Buyer will fully indemnify TI and its representatives against any damages arising out of the use of any TI components in safety-critical applications.

In some cases, TI components may be promoted specifically to facilitate safety-related applications. With such components, TI’s goal is to help enable customers to design and create their own end-product solutions that meet applicable functional safety standards and requirements. Nonetheless, such components are subject to these terms.

No TI components are authorized for use in FDA Class III (or similar life-critical medical equipment) unless authorized officers of the parties have executed a special agreement specifically governing such use.

Only those TI components which TI has specifically designated as military grade or “enhanced plastic” are designed and intended for use in military/aerospace applications or environments. Buyer acknowledges and agrees that any military or aerospace use of TI components which have ***not*** been so designated is solely at the Buyer's risk, and that Buyer is solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI has specifically designated certain components as meeting ISO/TS16949 requirements, mainly for automotive use. In any case of use of non-designated products, TI will not be responsible for any failure to meet ISO/TS16949.

Products		**Applications**	
Audio	www.ti.com/audio	Automotive and Transportation	www.ti.com/automotive
Amplifiers	amplifier.ti.com	Communications and Telecom	www.ti.com/communications
Data Converters	dataconverter.ti.com	Computers and Peripherals	www.ti.com/computers
DLP® Products	www.dlp.com	Consumer Electronics	www.ti.com/consumer-apps
DSP	dsp.ti.com	Energy and Lighting	www.ti.com/energy
Clocks and Timers	www.ti.com/clocks	Industrial	www.ti.com/industrial
Interface	interface.ti.com	Medical	www.ti.com/medical
Logic	logic.ti.com	Security	www.ti.com/security
Power Mgmt	power.ti.com	Space, Avionics and Defense	www.ti.com/space-avionics-defense
Microcontrollers	microcontroller.ti.com	Video and Imaging	www.ti.com/video
RFID	www.ti-rfid.com		
OMAP Applications Processors	www.ti.com/omap	**TI E2E Community**	e2e.ti.com
Wireless Connectivity	www.ti.com/wirelessconnectivity		

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