

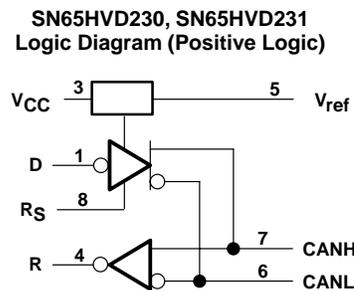


## 3.3-V CAN TRANSCEIVERS

### FEATURES

- Operates With a 3.3-V Supply
- Low Power Replacement for the PCA82C250 Footprint
- Bus/Pin ESD Protection Exceeds 16 kV HBM
- High Input Impedance Allows for 120 Nodes on a Bus
- Controlled Driver Output Transition Times for Improved Signal Quality on the SN65HVD230 and SN65HVD231
- Unpowered Node Does Not Disturb the Bus
- Compatible With the Requirements of the ISO 11898 Standard
- Low-Current SN65HVD230 Standby Mode 370  $\mu$ A Typical
- Low-Current SN65HVD231 Sleep Mode 40 nA Typical
- Designed for Signaling Rates<sup>†</sup> up to 1 Megabit/Second (Mbps)
- Thermal Shutdown Protection
- Open-Circuit Fail-Safe Design
- Glitch-Free Power-Up and Power-Down Protection for Hot-Plugging Applications

### LOGIC DIAGRAM (POSITIVE LOGIC)

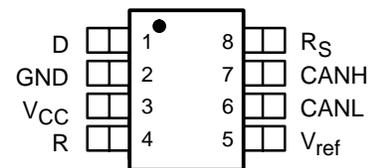


### APPLICATIONS

- Motor Control
- Industrial Automation
- Basestation Control and Status
- Robotics
- Automotive
- UPS Control

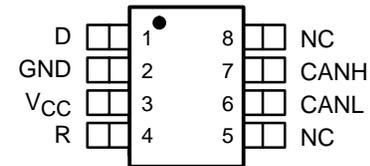
SN65HVD230D (Marked as VP230)  
SN65HVD231D (Marked as VP231)

(TOP VIEW)



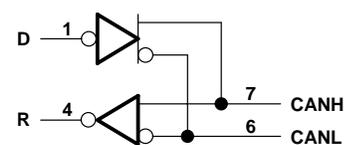
SN65HVD232D (Marked as VP232)

(TOP VIEW)



NC – No internal connection

SN65HVD232  
Logic Diagram (Positive Logic)



<sup>†</sup> 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).



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**DESCRIPTION**

The SN65HVD230, SN65HVD231, and SN65HVD232 controller area network (CAN) transceivers are designed for use with the Texas Instruments TMS320Lx240x™ 3.3-V DSPs with CAN controllers, or with equivalent devices. They are intended for use in applications employing the CAN serial communication physical layer in accordance with the ISO 11898 standard. Each CAN transceiver is designed to provide differential transmit capability to the bus and differential receive capability to a CAN controller at speeds up to 1 Mbps.

Designed for operation in especially-harsh environments, these devices feature cross-wire protection, loss-of-ground and overvoltage protection, overtemperature protection, as well as wide common-mode range.

The transceiver interfaces the single-ended CAN controller with the differential CAN bus found in industrial, building automation, and automotive applications. It operates over a –2-V to 7-V common-mode range on the bus, and it can withstand common-mode transients of ±25 V.

On the SN65HVD230 and SN65HVD231, pin 8 provides three different modes of operation: high-speed, slope control, and low-power modes. The high-speed mode of operation is selected by connecting pin 8 to ground, allowing the transmitter output transistors to switch on and off as fast as possible with no limitation on the rise and fall slopes. The rise and fall slopes can be adjusted by connecting a resistor to ground at pin 8, since the slope is proportional to the pin’s output current. This slope control is implemented with external resistor values of 10 kΩ, to achieve a 15-V/μs slew rate, to 100 kΩ, to achieve a 2-V/μs slew rate. See the *Application Information* section of this data sheet.

The circuit of the SN65HVD230 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 pin 8. The DSP controller reverses this low-current standby mode when a dominant state (bus differential voltage > 900 mV typical) occurs on the bus.

The unique difference between the SN65HVD230 and the SN65HVD231 is that both the driver and the receiver are switched off in the SN65HVD231 when a high logic level is applied to pin 8 and remain in this sleep mode until the circuit is reactivated by a low logic level on pin 8.

The V<sub>ref</sub> pin 5 on the SN65HVD230 and SN65HVD231 is available as a V<sub>CC</sub>/2 voltage reference.

The SN65HVD232 is a basic CAN transceiver with no added options; pins 5 and 8 are NC, no connection.

**AVAILABLE OPTIONS**

PART NUMBER	LOW POWER MODE	INTEGRATED SLOPE CONTROL	V <sub>ref</sub> PIN	T <sub>A</sub>	MARKED AS:
SN65HVD230	Standby mode	Yes	Yes	–40°C to 85°C	VP230
SN65HVD231	Sleep mode	Yes	Yes		VP231
SN65HVD232	No standby or sleep mode	No	No		VP232

**Function Tables**

**DRIVER (SN65HVD230, SN65HVD231)**

INPUT D	R <sub>S</sub>	OUTPUTS		BUS STATE
		CANH	CANL	
L	V <sub>(Rs)</sub> < 1.2 V	H	L	Dominant
H		Z	Z	Recessive
Open	X	Z	Z	Recessive
X	V <sub>(Rs)</sub> > 0.75 V <sub>CC</sub>	Z	Z	Recessive

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

**DRIVER (SN65HVD232)**

INPUT D	OUTPUTS		BUS STATE
	CANH	CANL	
L	H	L	Dominant
H	Z	Z	Recessive
Open	Z	Z	Recessive

H = high level; L = low level; Z = high impedance

**RECEIVER (SN65HVD230)**

DIFFERENTIAL INPUTS	R <sub>S</sub>	OUTPUT R
V <sub>ID</sub> ≥ 0.9 V	X	L
0.5 V < V <sub>ID</sub> < 0.9 V	X	?
V <sub>ID</sub> ≤ 0.5 V	X	H
Open	X	H

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

**RECEIVER (SN65HVD231)**

DIFFERENTIAL INPUTS	R <sub>S</sub>	OUTPUT R
V <sub>ID</sub> ≥ 0.9 V	V <sub>(Rs)</sub> < 1.2 V	L
0.5 V < V <sub>ID</sub> < 0.9 V		?
V <sub>ID</sub> ≤ 0.5 V		H
X	V <sub>(Rs)</sub> > 0.75 V <sub>CC</sub>	H
X	1.2 V < V <sub>(Rs)</sub> < 0.75 V <sub>CC</sub>	?
Open	X	H

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

**RECEIVER (SN65HVD232)**

DIFFERENTIAL INPUTS	OUTPUT R
V <sub>ID</sub> ≥ 0.9 V	L
0.5 V < V <sub>ID</sub> < 0.9 V	?
V <sub>ID</sub> ≤ 0.5 V	H
Open	H

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

**Function Tables (Continued)**

**TRANSCEIVER MODES (SN65HVD230, SN65HVD231)**

$V_{(Rs)}$	OPERATING MODE
$V_{(Rs)} > 0.75 V_{CC}$	Standby
10 k $\Omega$ to 100 k $\Omega$ to ground	Slope control
$V_{(Rs)} < 1 V$	High speed (no slope control)

**Terminal Functions**

**SN65HVD230, SN65HVD231**

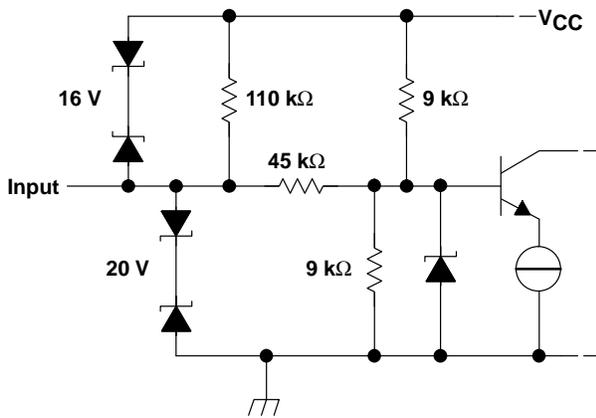
TERMINAL NAME	NO.	DESCRIPTION
CANL	6	Low bus output
CANH	7	High bus output
D	1	Driver input
GND	2	Ground
R	4	Receiver output
R <sub>S</sub>	8	Standby/slope control
V <sub>CC</sub>	3	Supply voltage
V <sub>ref</sub>	5	Reference output

**SN65HVD232**

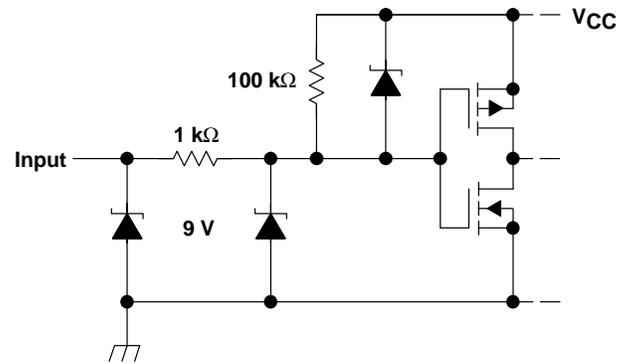
TERMINAL NAME	NO.	DESCRIPTION
CANL	6	Low bus output
CANH	7	High bus output
D	1	Driver input
GND	2	Ground
NC	5, 8	No connection
R	4	Receiver output
V <sub>CC</sub>	3	Supply voltage

equivalent input and output schematic diagrams

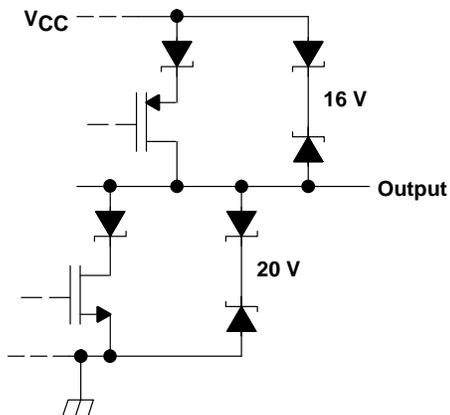
CANH and CANL Inputs



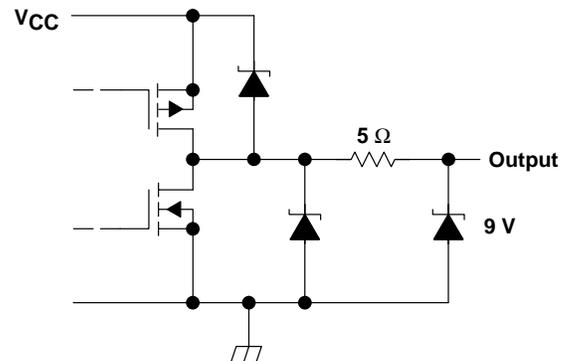
D Input



CANH and CANL Outputs



R Output



**absolute maximum ratings over operating free-air temperature (see Note 1) (unless otherwise noted)†**

Supply voltage range, $V_{CC}$ .....	-0.3 V to 6 V
Voltage range at any bus terminal (CANH or CANL) .....	-4 V to 16 V
Voltage input range, transient pulse, CANH and CANL, through 100 $\Omega$ (see Figure 7) .....	-25 V to 25 V
Input voltage range, $V_I$ (D or R) .....	-0.5 V to $V_{CC} + 0.5$ V
Electrostatic discharge: Human body model (see Note 2)	CANH, CANL and GND .....
	All Pins .....
	16 kV
	4 kV
Charged-device model (see Note 3)	All pins .....
	1 kV
Continuous total power dissipation .....	See Dissipation Rating table
Storage temperature range, $T_{stg}$ .....	-65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds .....	260°C

† 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.

- NOTES: 1. All voltage values, except differential I/O bus voltages, are with respect to network ground terminal.  
 2. Tested in accordance with JEDEC Standard 22, Test Method A114-A.  
 3. Tested in accordance with JEDEC Standard 22, Test Method C101.

**DISSIPATION RATING TABLE**

PACKAGE	$T_A \leq 25^\circ\text{C}$ POWER RATING	DERATING FACTOR‡ ABOVE $T_A = 25^\circ\text{C}$	$T_A = 70^\circ\text{C}$ POWER RATING	$T_A = 85^\circ\text{C}$ POWER RATING
D	725 mW	5.8 mW/°C	464 mW	377 mW

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

**recommended operating conditions**

PARAMETER		MIN	NOM	MAX	UNIT
Supply voltage, $V_{CC}$		3		3.6	V
Voltage at any bus terminal (common mode) $V_{IC}$		-2§		7	V
Voltage at any bus terminal (separately) $V_I$		-2.5		7.5	V
High-level input voltage, $V_{IH}$	D, R	2			V
Low-level input voltage, $V_{IL}$	D, R			0.8	V
Differential input voltage, $V_{ID}$ (see Figure 5)		-6		6	V
Input voltage, $V_{(RS)}$		0		$V_{CC}$	V
Input voltage for standby or sleep, $V_{(RS)}$		0.75 $V_{CC}$		$V_{CC}$	V
Wave-shaping resistance, $R_s$		0		100	k $\Omega$
High-level output current, $I_{OH}$	Driver	-40			mA
	Receiver	-8			
Low-level output current, $I_{OL}$	Driver			48	mA
	Receiver			8	
Operating free-air temperature, $T_A$		-40		85	°C

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

**driver electrical characteristics over recommended operating conditions (unless otherwise noted)**

PARAMETER			TEST CONDITIONS		MIN	TYP†	MAX	UNIT		
V <sub>OH</sub>	Bus output voltage	Dominant	V <sub>I</sub> = 0 V, See Figure 1 and Figure 3	CANH	2.45		V <sub>CC</sub>	V		
				CANL	0.5	1.25				
V <sub>OL</sub>		Recessive	V <sub>I</sub> = 3 V, See Figure 1 and Figure 3	CANH		2.3				
				CANL		2.3				
V <sub>OD(D)</sub>	Differential output voltage	Dominant	V <sub>I</sub> = 0 V, See Figure 1		1.5	2	3	V		
V <sub>I</sub> = 0 V, See Figure 2				1.2	2	3				
V <sub>OD(R)</sub>		Recessive	V <sub>I</sub> = 3 V, See Figure 1		-120	0	12	mV		
			V <sub>I</sub> = 3 V, No load		-0.5	-0.2	0.05	V		
I <sub>IH</sub>	High-level input current		V <sub>I</sub> = 2 V		-30			μA		
I <sub>IL</sub>	Low-level input current		V <sub>I</sub> = 0.8 V		-30			μA		
I <sub>OS</sub>	Short-circuit output current		V <sub>CANH</sub> = -2 V		-250		250	mA		
			V <sub>CANL</sub> = 7 V		-250		250			
C <sub>o</sub>	Output capacitance		See receiver							
I <sub>CC</sub>	Supply current	Standby	SN65HVD230	V(R <sub>S</sub> ) = V <sub>CC</sub>		370		600	μA	
		Sleep	SN65HVD231	V(R <sub>S</sub> ) = V <sub>CC</sub> , D at V <sub>CC</sub>		0.04		1		
		All devices	Dominant		V <sub>I</sub> = 0 V, No load	Dominant	10		17	mA
			Recessive		V <sub>I</sub> = V <sub>CC</sub> , No load	Recessive	10		17	

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

**driver switching characteristics over recommended operating conditions(unless otherwise noted)**

**SN65HVD230 and SN65HVD231**

PARAMETER			TEST CONDITIONS	MIN	TYP	MAX	UNIT
t <sub>PLH</sub>	Propagation delay time, low-to-high-level output	V(R <sub>S</sub> ) = 0 V	C <sub>L</sub> = 50 pF, See Figure 4		35	85	ns
		R <sub>S</sub> with 10 kΩ to ground			70	125	
		R <sub>S</sub> with 100 kΩ to ground			500	870	
t <sub>PHL</sub>	Propagation delay time, high-to-low-level output	V(R <sub>S</sub> ) = 0 V			70	120	ns
		R <sub>S</sub> with 10 kΩ to ground			130	180	
		R <sub>S</sub> with 100 kΩ to ground			870	1200	
t <sub>sk(p)</sub>	Pulse skew ( t <sub>PHL</sub> - t <sub>PLH</sub>  )	V(R <sub>S</sub> ) = 0 V			35		ns
		R <sub>S</sub> with 10 kΩ to ground			60		
		R <sub>S</sub> with 100 kΩ to ground			370		
t <sub>r</sub>	Differential output signal rise time	V(R <sub>S</sub> ) = 0 V			25	50	100
t <sub>f</sub>	Differential output signal fall time	V(R <sub>S</sub> ) = 0 V		40	55	80	ns
t <sub>r</sub>	Differential output signal rise time	R <sub>S</sub> with 10 kΩ to ground		80	120	160	ns
t <sub>f</sub>	Differential output signal fall time			80	125	150	ns
t <sub>r</sub>	Differential output signal rise time	R <sub>S</sub> with 100 kΩ to ground		600	800	1200	ns
t <sub>f</sub>	Differential output signal fall time			600	825	1000	ns

**driver switching characteristics over recommended operating conditions(unless otherwise noted)**

**SN65HVD232**

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT	
t <sub>PLH</sub> Propagation delay time, low-to-high-level output	C <sub>L</sub> = 50 pF, See Figure 4		35	85	ns	
t <sub>PHL</sub> Propagation delay time, high-to-low-level output			70	120	ns	
t <sub>sk(p)</sub> Pulse skew ( t <sub>p(HL)</sub> – t <sub>p(LH)</sub>  )				35	ns	
t <sub>r</sub> Differential output signal rise time			25	50	100	ns
t <sub>f</sub> Differential output signal fall time			40	55	80	ns

**receiver electrical characteristics over recommended operating conditions (unless otherwise noted)**

PARAMETER	TEST CONDITIONS	MIN	TYP†	MAX	UNIT
V <sub>IT+</sub> Positive-going input threshold voltage	See Table 1		750	900	mV
V <sub>IT-</sub> Negative-going input threshold voltage			500	650	mV
V <sub>hys</sub> Hysteresis voltage (V <sub>IT+</sub> – V <sub>IT-</sub> )				100	
V <sub>OH</sub> High-level output voltage	–6 V ≤ V <sub>ID</sub> ≤ 500 mV, I <sub>O</sub> = –8 mA, See Figure 5	2.4			V
V <sub>OL</sub> Low-level output voltage	900 mV ≤ V <sub>ID</sub> ≤ 6 V, I <sub>O</sub> = 8 mA, See Figure 5			0.4	
I <sub>I</sub> Bus input current	V <sub>IH</sub> = 7 V	Other input at 0 V, D = 3 V	100	250	μA
	V <sub>IH</sub> = 7 V, V <sub>CC</sub> = 0 V		100	350	
	V <sub>IH</sub> = –2 V		–200	–30	μA
	V <sub>IH</sub> = –2 V, V <sub>CC</sub> = 0 V		–100	–20	
C <sub>i</sub> CANH, CANL input capacitance	Pin-to-ground, V <sub>I</sub> = 0.4 sin(4E6πt) + 0.5 V		32		pF
C <sub>diff</sub> Differential input capacitance	Pin-to-pin, V <sub>I</sub> = 0.4 sin(4E6πt) + 0.5 V		16		pF
R <sub>diff</sub> Differential input resistance	Pin-to-pin, V <sub>(D)</sub> = 3 V	40	70	100	kΩ
R <sub>I</sub> CANH, CANL input resistance		20	35	50	kΩ
I <sub>CC</sub> Supply current	See driver				

† 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	MAX	UNIT
t <sub>PLH</sub> Propagation delay time, low-to-high-level output	See Figure 6		35	50	ns
t <sub>PHL</sub> Propagation delay time, high-to-low-level output			35	50	ns
t <sub>sk(p)</sub> Pulse skew ( t <sub>p(HL)</sub> – t <sub>p(LH)</sub>  )				10	ns
t <sub>r</sub> Output signal rise time	See Figure 6		1.5		ns
t <sub>f</sub> Output signal fall time			1.5		ns

**device switching characteristics over recommended operating conditions (unless otherwise noted)**

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
t <sub>(LOOP1)</sub>	Total loop delay, driver input to receiver output, recessive to dominant	V <sub>(RS)</sub> = 0 V, See Figure 9		70	115	ns
		R <sub>S</sub> with 10 kΩ to ground, See Figure 9		105	175	
		R <sub>S</sub> with 100 kΩ to ground, See Figure 9		535	920	
t <sub>(LOOP2)</sub>	Total loop delay, driver input to receiver output, dominant to recessive	V <sub>(RS)</sub> = 0 V, See Figure 9		100	135	ns
		R <sub>S</sub> with 10 kΩ to ground, See Figure 9		155	185	
		R <sub>S</sub> with 100 kΩ to ground, See Figure 9		830	990	

**device control-pin characteristics over recommended operating conditions (unless otherwise noted)**

PARAMETER		TEST CONDITIONS	MIN	TYP†	MAX	UNIT
t <sub>(WAKE)</sub>	SN65HVD230 wake-up time from standby mode with R <sub>S</sub>	See Figure 8		0.55	1.5	μS
	SN65HVD231 wake-up time from sleep mode with R <sub>S</sub>			3	5	μS
V <sub>ref</sub>	Reference output voltage	-5 μA < I <sub>(Vref)</sub> < 5 μA	0.45 V <sub>CC</sub>		0.55 V <sub>CC</sub>	V
		-50 μA < I <sub>(Vref)</sub> < 50 μA	0.4 V <sub>CC</sub>		0.6 V <sub>CC</sub>	
I <sub>(RS)</sub>	Input current for high-speed	V <sub>(RS)</sub> < 1 V	-450		0	μA

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

**PARAMETER MEASUREMENT INFORMATION**

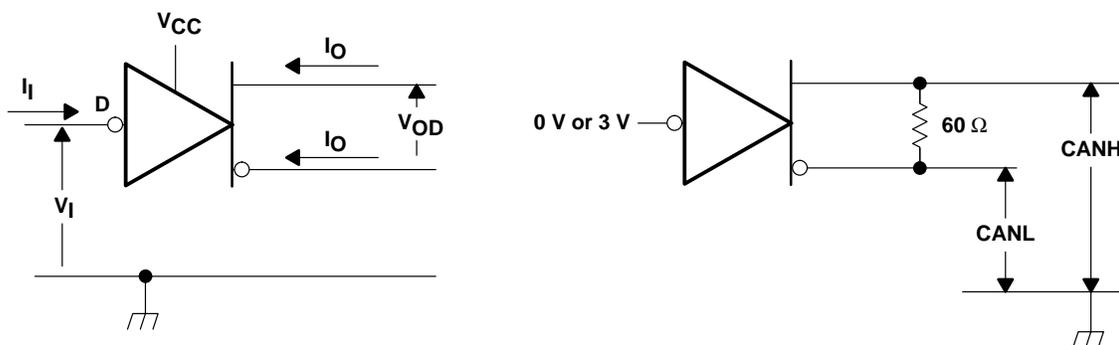


Figure 1. Driver Voltage and Current Definitions

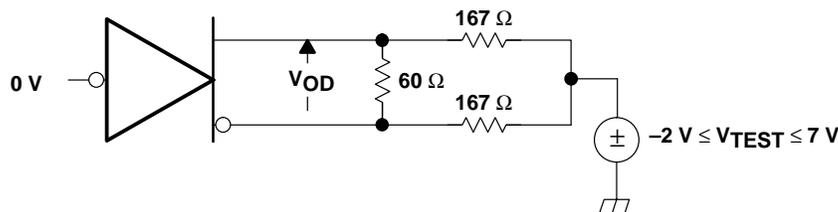


Figure 2. Driver V<sub>OD</sub>

PARAMETER MEASUREMENT INFORMATION

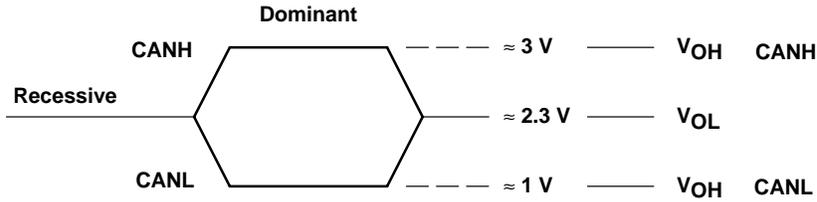
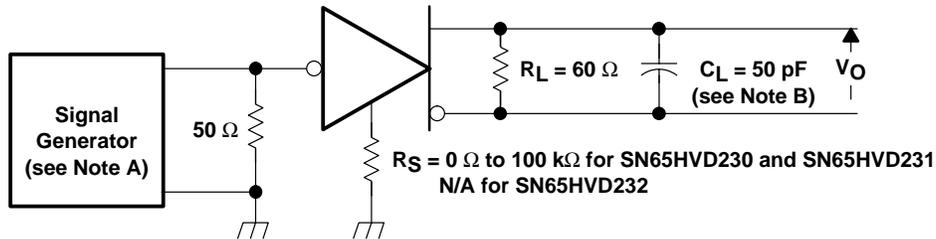


Figure 3. Driver Output Voltage Definitions



- NOTES: A. The input pulse is supplied by a generator having the following characteristics: PRR ≤ 500 kHz, 50% duty cycle,  $t_r \leq 6$  ns,  $t_f \leq 6$  ns,  $Z_0 = 50 \Omega$ .  
 B.  $C_L$  includes probe and jig capacitance.

Figure 4. Driver Test Circuit and Voltage Waveforms

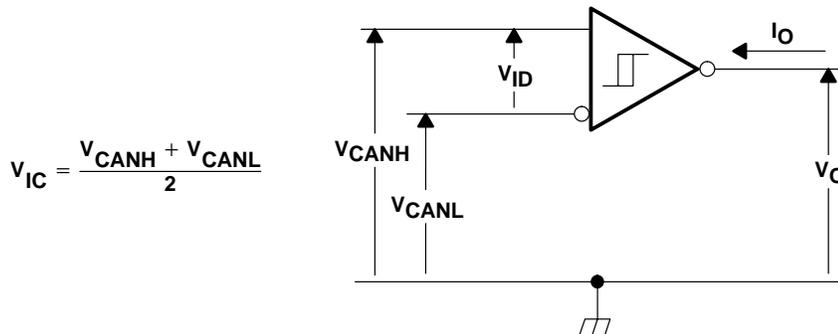
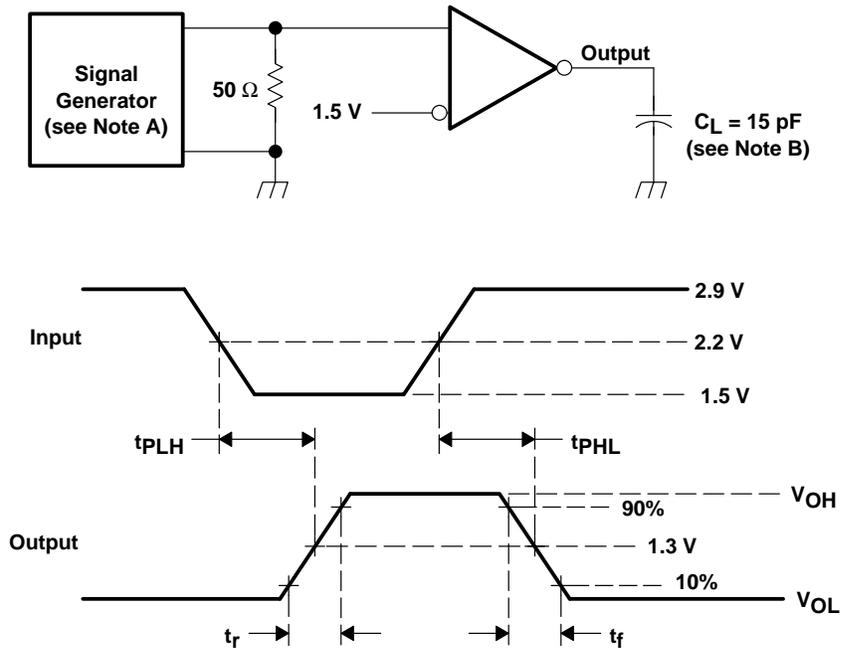


Figure 5. Receiver Voltage and Current Definitions

PARAMETER MEASUREMENT INFORMATION



- NOTES: A. The input pulse is supplied by a generator having the following characteristics:  $PRR \leq 500$  kHz, 50% duty cycle,  $t_r \leq 6$  ns,  $t_f \leq 6$  ns,  $Z_0 = 50 \Omega$ .  
 B.  $C_L$  includes probe and jig capacitance.

Figure 6. Receiver Test Circuit and Voltage Waveforms

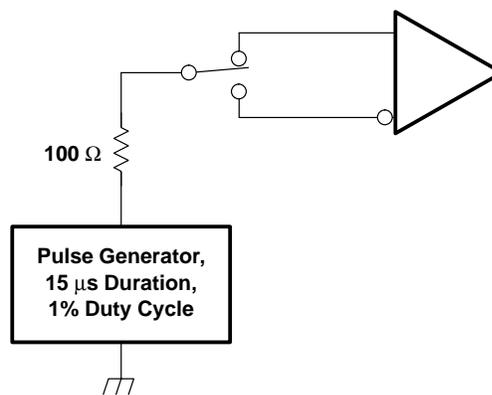


Figure 7. Overvoltage Protection

PARAMETER MEASUREMENT INFORMATION

Table 1. Receiver Characteristics Over Common Mode With  $V_{(Rs)} = 1.2\text{ V}$

$V_{IC}$	$V_{ID}$	$V_{CANH}$	$V_{CANL}$	R OUTPUT	
-2 V	900 mV	-1.55 V	-2.45 V	L	V <sub>OL</sub>
7 V	900 mV	8.45 V	6.55 V	L	
1 V	6 V	4 V	-2 V	L	
4 V	6 V	7 V	1 V	L	
-2 V	500 mV	-1.75 V	-2.25 V	H	V <sub>OH</sub>
7 V	500 mV	7.25 V	6.75 V	H	
1 V	-6 V	-2 V	4 V	H	
4 V	-6 V	1 V	7 V	H	
X	X	Open	Open	H	

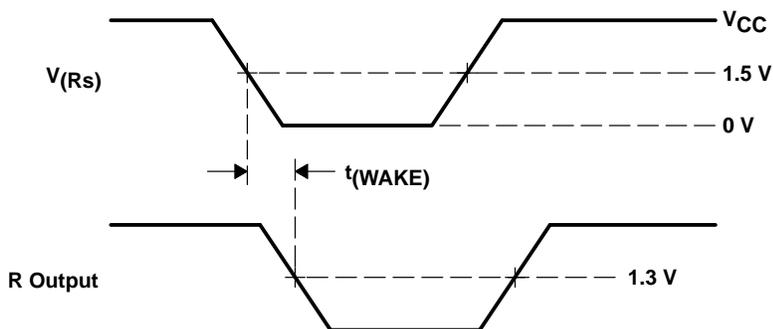
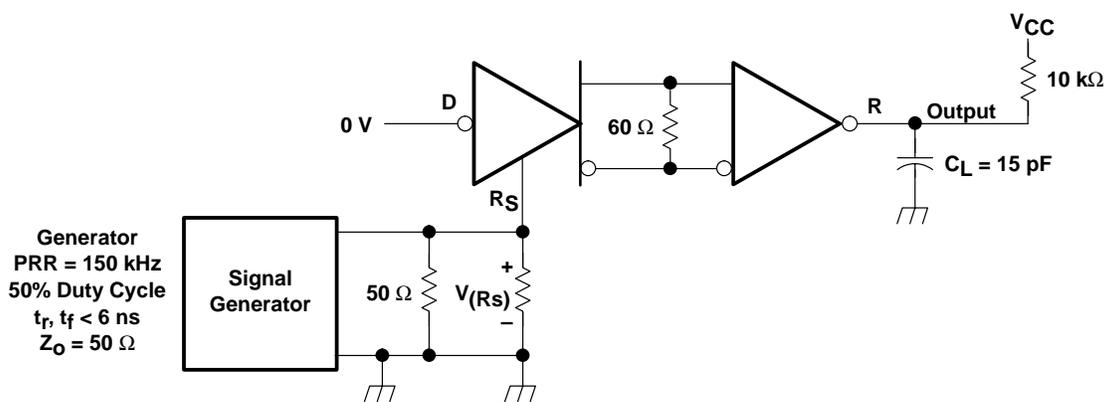


Figure 8.  $t_{(WAKE)}$  Test Circuit and Voltage Waveforms

PARAMETER MEASUREMENT INFORMATION

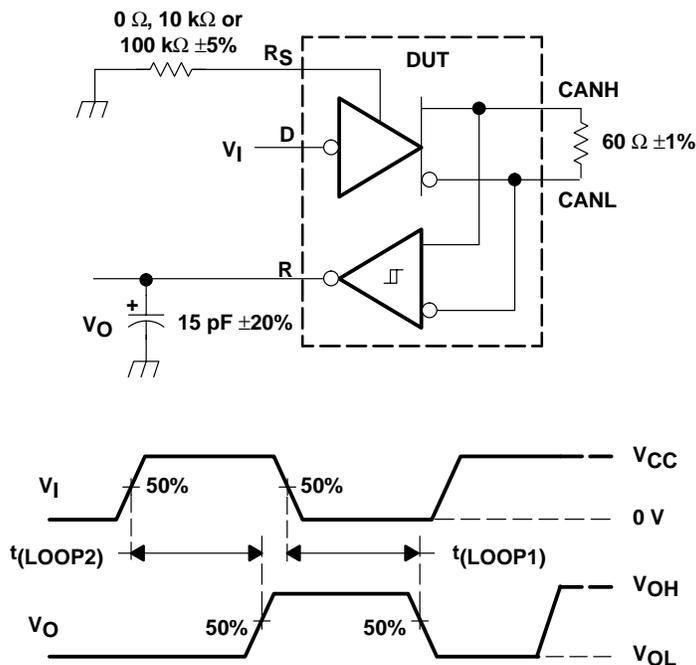


Figure 9.  $t_{(LOOP)}$  Test Circuit and Voltage Waveforms

NOTE: All  $V_I$  input pulses are supplied by a generator having the following characteristics:  $t_r$  or  $t_f \leq 6$  ns, Pulse Repetition Rate (PRR) = 125 kHz, 50% duty cycle

TYPICAL CHARACTERISTICS

SUPPLY CURRENT (RMS)  
 vs  
 FREQUENCY

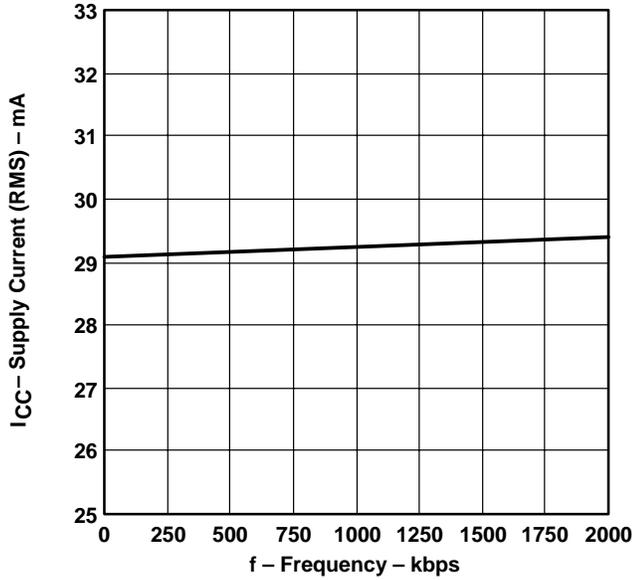


Figure 10

LOGIC INPUT CURRENT (PIN D)  
 vs  
 INPUT VOLTAGE

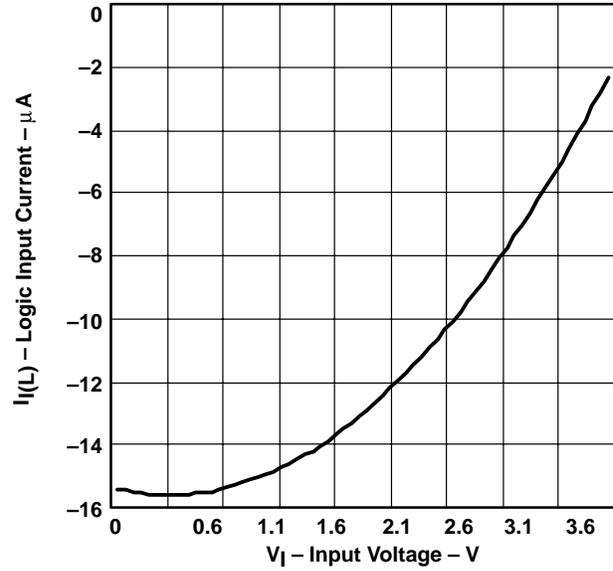


Figure 11

BUS INPUT CURRENT  
 vs  
 BUS INPUT VOLTAGE

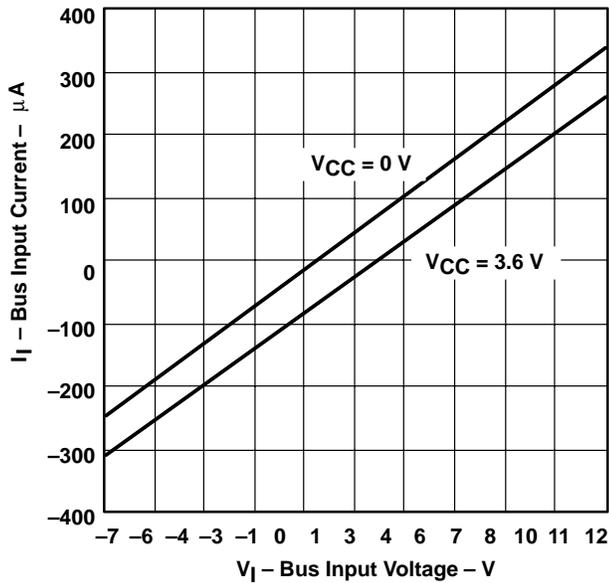


Figure 12

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

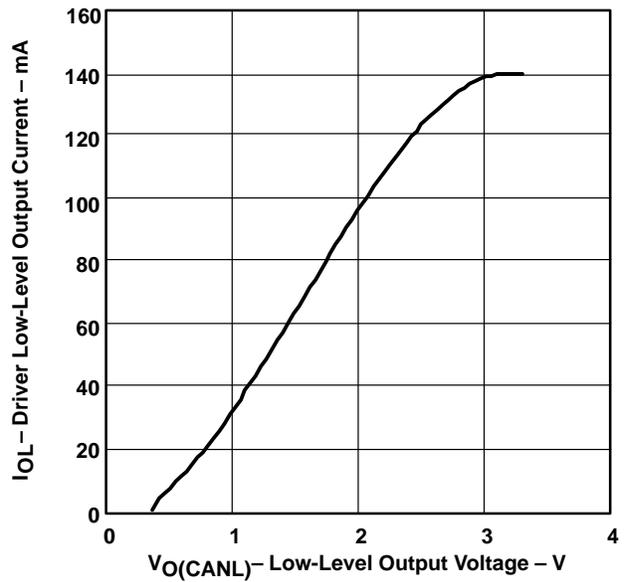


Figure 13

TYPICAL CHARACTERISTICS

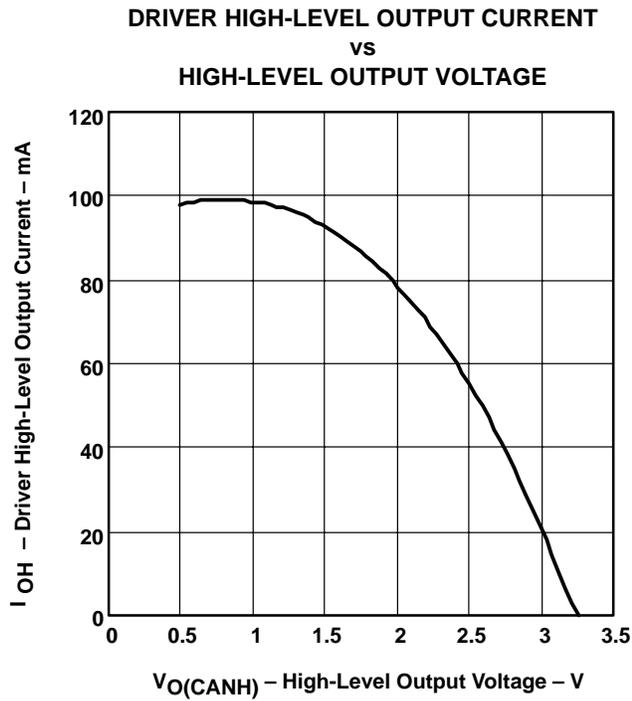


Figure 14

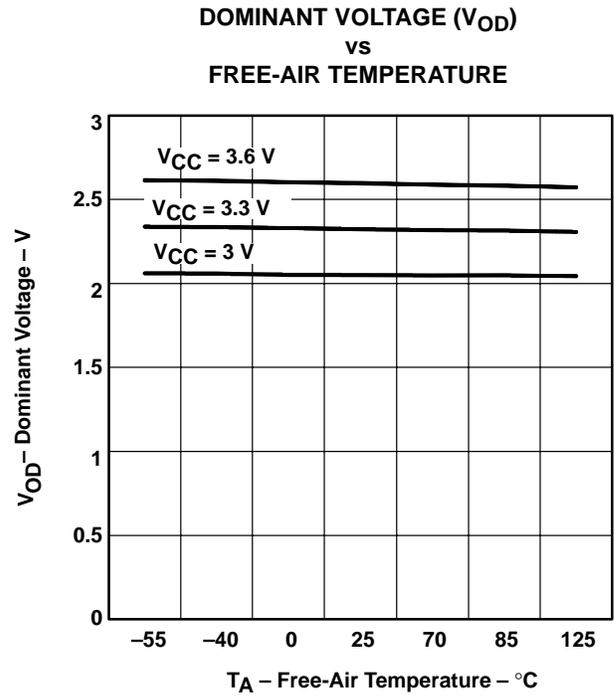


Figure 15

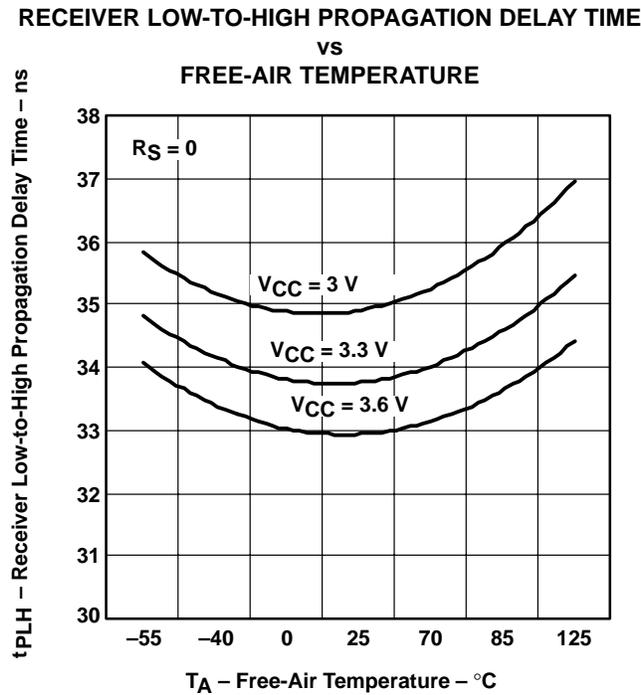


Figure 16

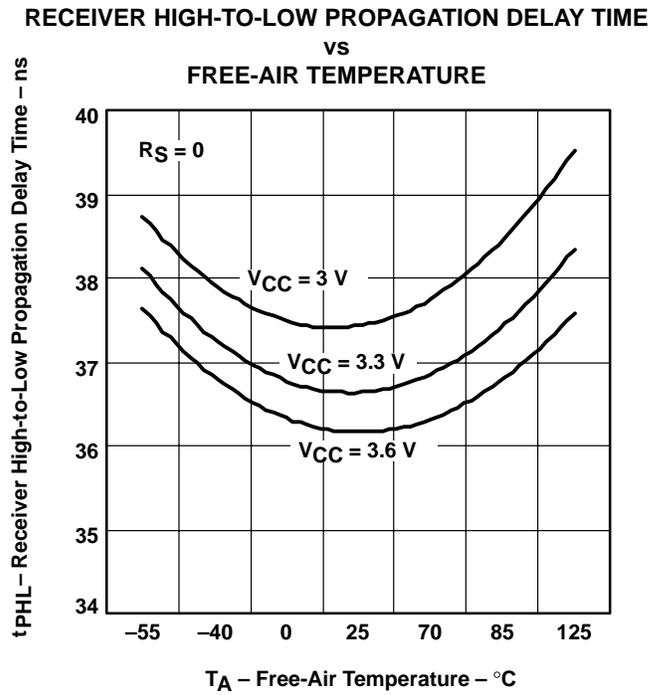


Figure 17

TYPICAL CHARACTERISTICS

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

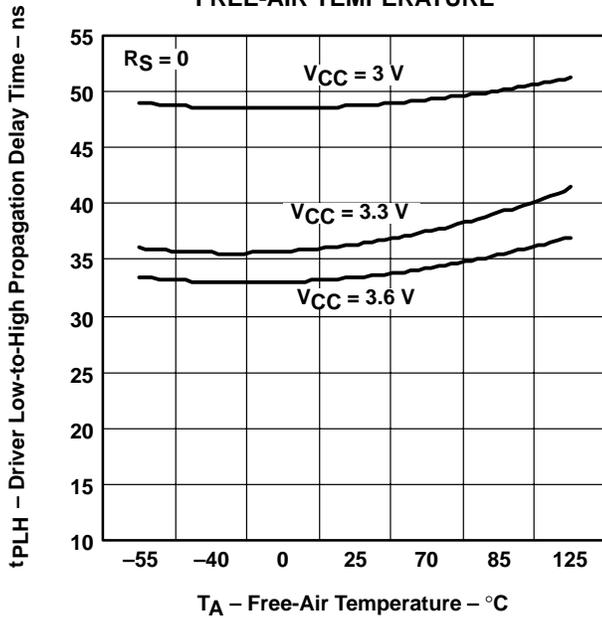


Figure 18

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

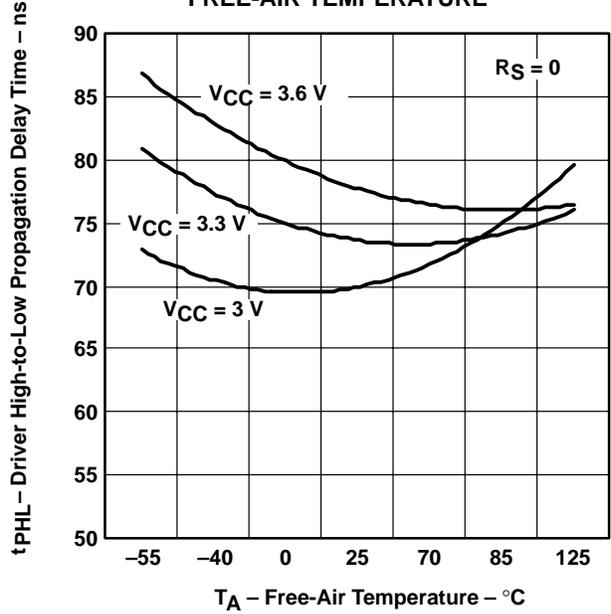


Figure 19

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

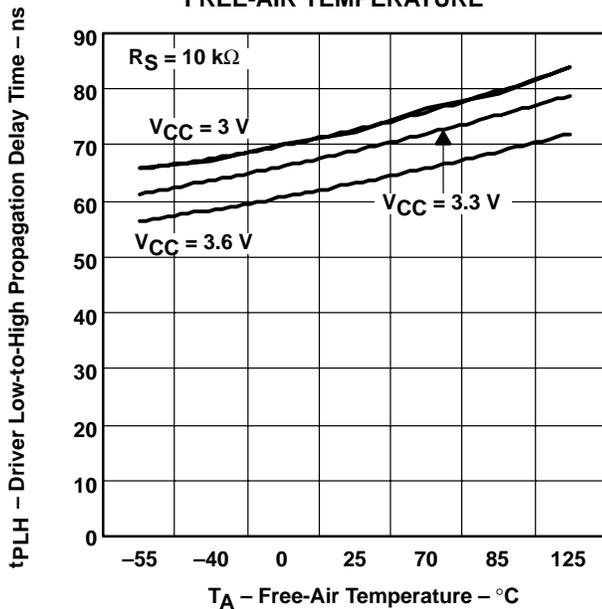


Figure 20

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

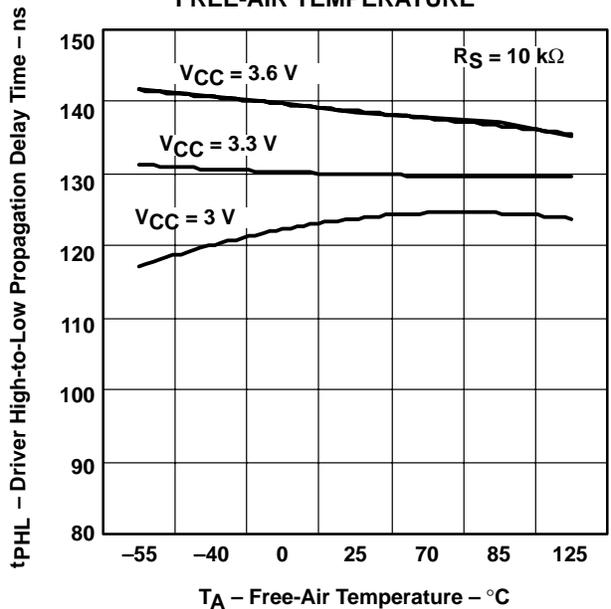


Figure 21

TYPICAL CHARACTERISTICS

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

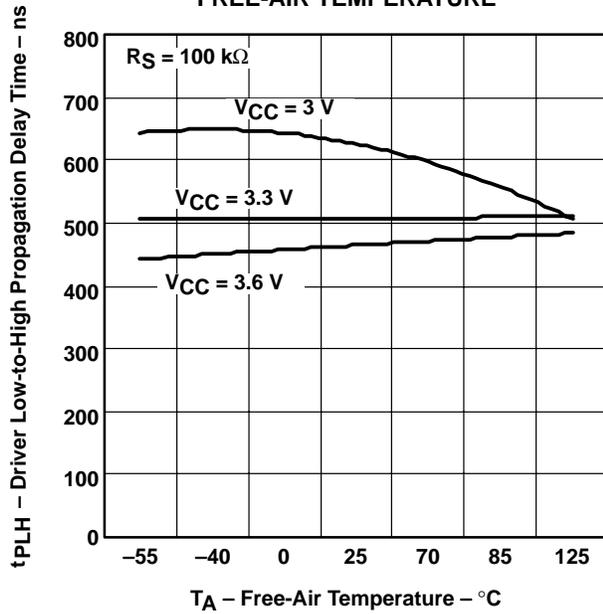


Figure 22

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

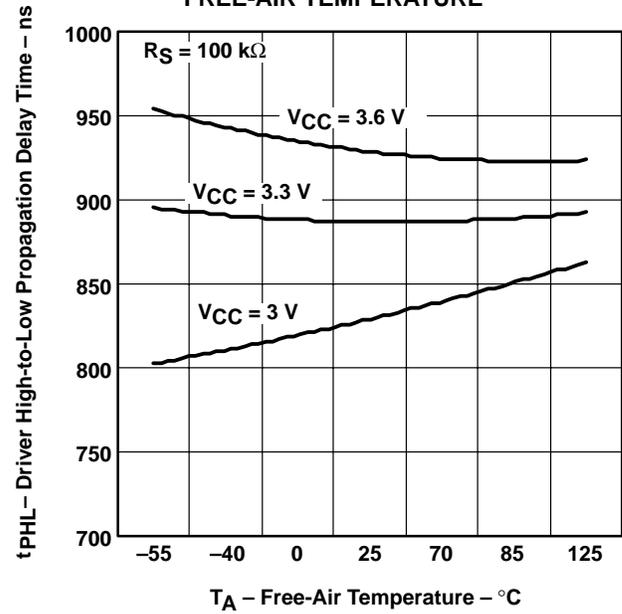


Figure 23

DRIVER OUTPUT CURRENT  
 vs  
 SUPPLY VOLTAGE

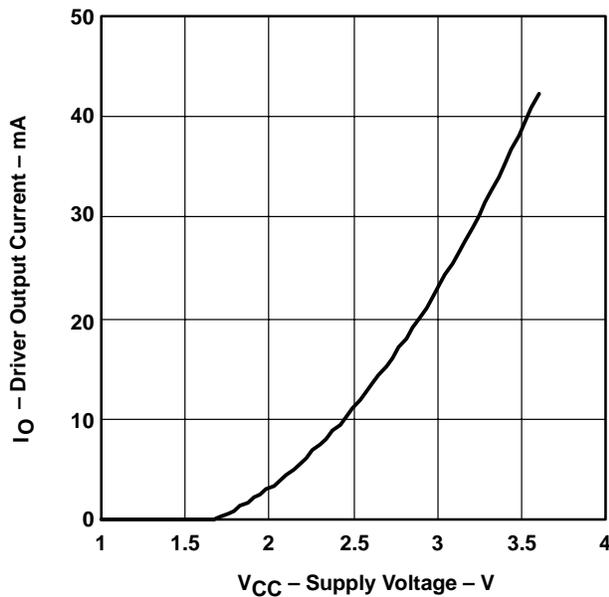


Figure 24

DIFFERENTIAL DRIVER OUTPUT FALL TIME  
 vs  
 SOURCE RESISTANCE ( $R_S$ )

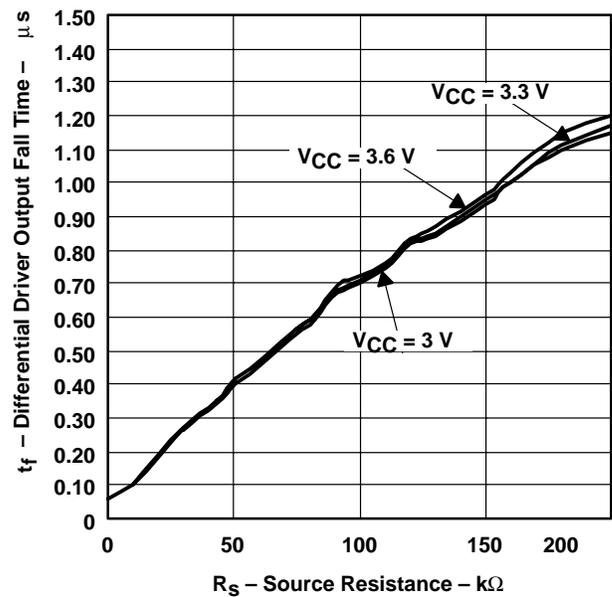


Figure 25

### TYPICAL CHARACTERISTICS

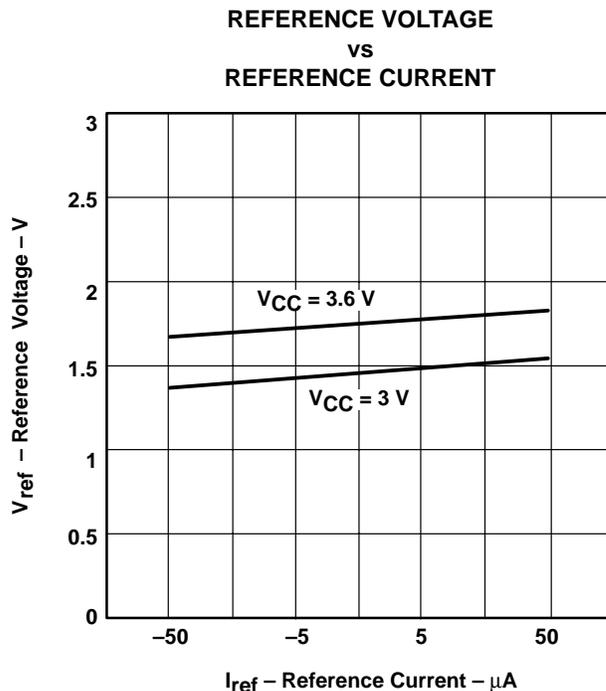


Figure 26

### APPLICATION INFORMATION

This application provides information concerning the implementation of the physical medium attachment layer in a CAN network according to the ISO 11898 standard. It presents a typical application circuit and test results, as well as discussions on slope control, total loop delay, and interoperability in 5-V systems.

#### introduction

ISO 11898 is the international standard for high-speed serial communication using the controller area network (CAN) bus protocol. It supports multimaster operation, real-time control, programmable data rates up to 1 Mbps, and powerful redundant error checking procedures that provide reliable data transmission. It is suited for networking *intelligent* devices as well as sensors and actuators within the rugged electrical environment of a machine chassis or factory floor. The SN65HVD230 family of 3.3-V CAN transceivers implement the lowest layers of the ISO/OSI reference model. This is the interface with the physical signaling output of the CAN controller of the Texas Instruments TMS320Lx240x 3.3-V DSPs, as illustrated in Figure 27.

APPLICATION INFORMATION

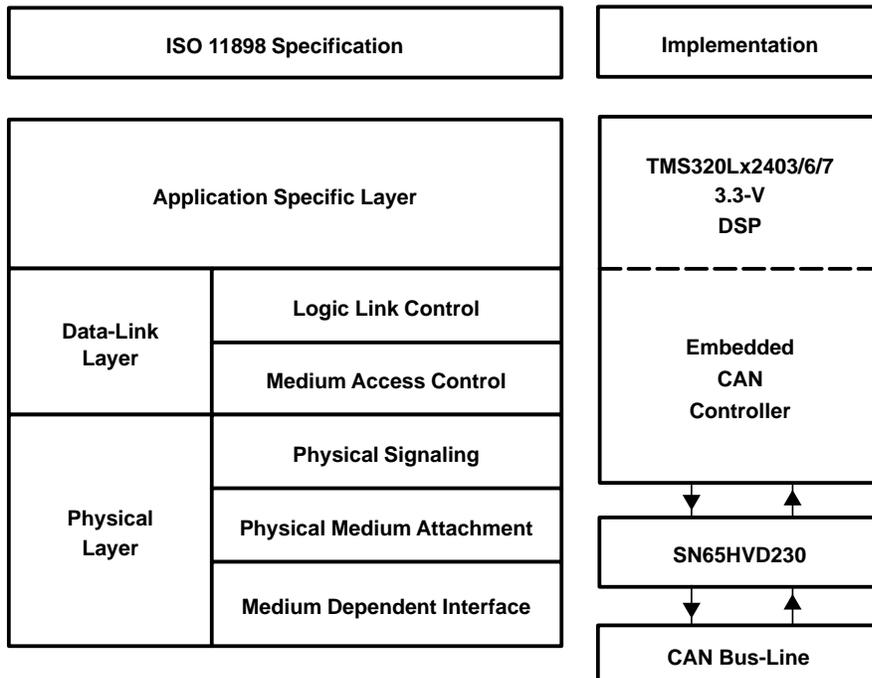


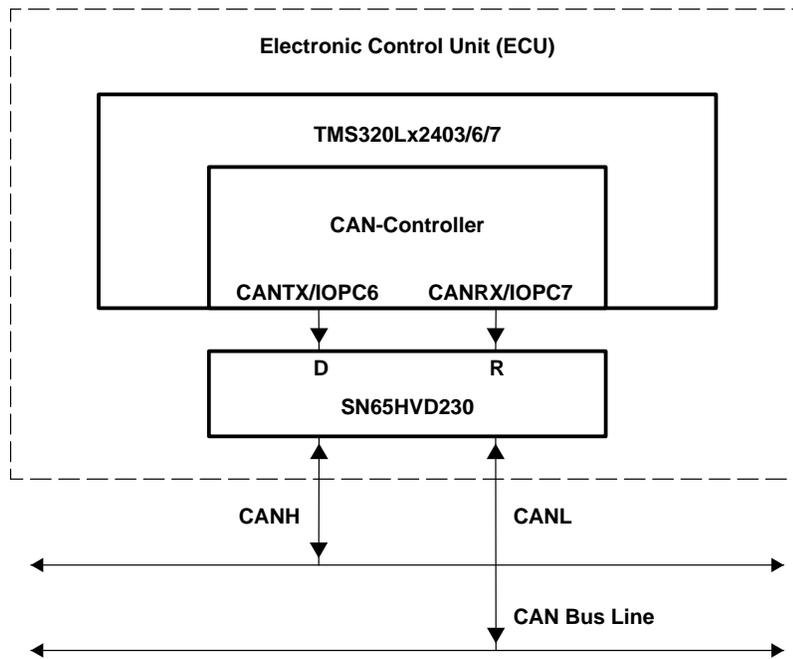
Figure 27. The Layered ISO 11898 Standard Architecture

The SN65HVD230 family of CAN transceivers are compatible with the ISO 11898 standard; this ensures interoperability with other standard-compliant products.

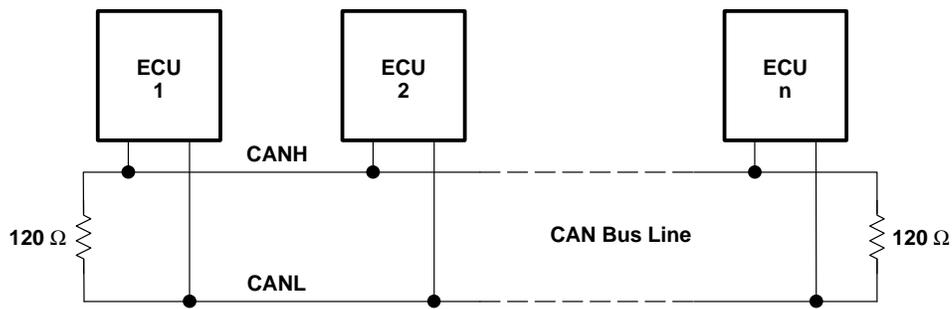
application of the SN65HVD230

Figure 28 illustrates a typical application of the SN65HVD230 family. The output of a DSP's CAN controller is connected to the serial driver input, pin D, and receiver serial output, pin R, of the transceiver. The transceiver is then attached to the differential bus lines at pins CANH and CANL. Typically, the bus is a twisted pair of wires with a characteristic impedance of 120 Ω, in the standard half-duplex multipoint topology of Figure 29. Each end of the bus is terminated with 120-Ω resistors in compliance with the standard to minimize signal reflections on the bus.

**APPLICATION INFORMATION**



**Figure 28. Details of a Typical CAN Node**



**Figure 29. Typical CAN Network**

The SN65HVD230/231/232 3.3-V CAN transceivers provide the interface between the 3.3-V TMS320Lx2403/6/7 CAN DSPs and the differential bus line, and are designed to transmit data at signaling rates up to 1 Mbps as defined by the ISO 11898 standard.

**features of the SN65HVD230, SN65HVD231, and SN65HVD232**

The SN65HVD230/231/232 are pin-compatible (but not functionally identical) with one another and, depending upon the application, may be used with identical circuit boards.

These transceivers feature 3.3-V operation and standard compatibility with signaling rates up to 1 Mbps, and also offer 16-kV HBM ESD protection on the bus pins, thermal shutdown protection, bus fault protection, and open-circuit receiver failsafe. The fail-safe design of the receiver assures a logic high at the receiver output if the bus wires become open circuited. If a high ambient operating environment temperature or excessive output current result in thermal shutdown, the bus pins become high impedance, while the D and R pins default to a logic high.

## APPLICATION INFORMATION

### features of the SN65HVD230, SN65HVD231, and SN65HVD232 (continued)

The bus pins are also maintained in a high-impedance state during low  $V_{CC}$  conditions to ensure glitch-free power-up and power-down bus protection for hot-plugging applications. This high-impedance condition also means that an unpowered node does not disturb the bus. Transceivers without this feature usually have a very low output impedance. This results in a high current demand when the transceiver is unpowered, a condition that could affect the entire bus.

### operating modes

$R_S$  (pin 8) of the SN65HVD230 and SN65HVD231 provides for three different modes of operation: high-speed mode, slope-control mode, and low-power mode.

### high-speed

The high-speed mode can be selected by applying a logic low to  $R_S$  (pin 8). The high-speed mode of operation is commonly employed in industrial applications. High-speed allows the output to switch as fast as possible with no internal limitation on the output rise and fall slopes. The only limitations of the high-speed operation are cable length and radiated emission concerns, each of which is addressed by the slope control mode of operation.

If the low-power standby mode is to be employed in the circuit, direct connection to a DSP output pin can be used to switch between a logic-low level ( $< 1\text{ V}$ ) for high speed operation, and the logic-high level ( $> 0.75\text{ V}_{CC}$ ) for standby. Figure 30 shows a typical DSP connection, and Figure 31 shows the HVD230 driver output signal in high-speed mode on the CAN bus.

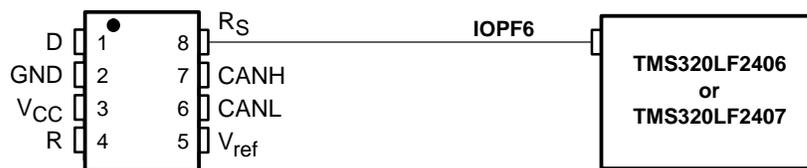


Figure 30.  $R_S$  (Pin 8) Connection to a TMS320LF2406/07 for High Speed/Standby Operation

APPLICATION INFORMATION

high-speed (continued)

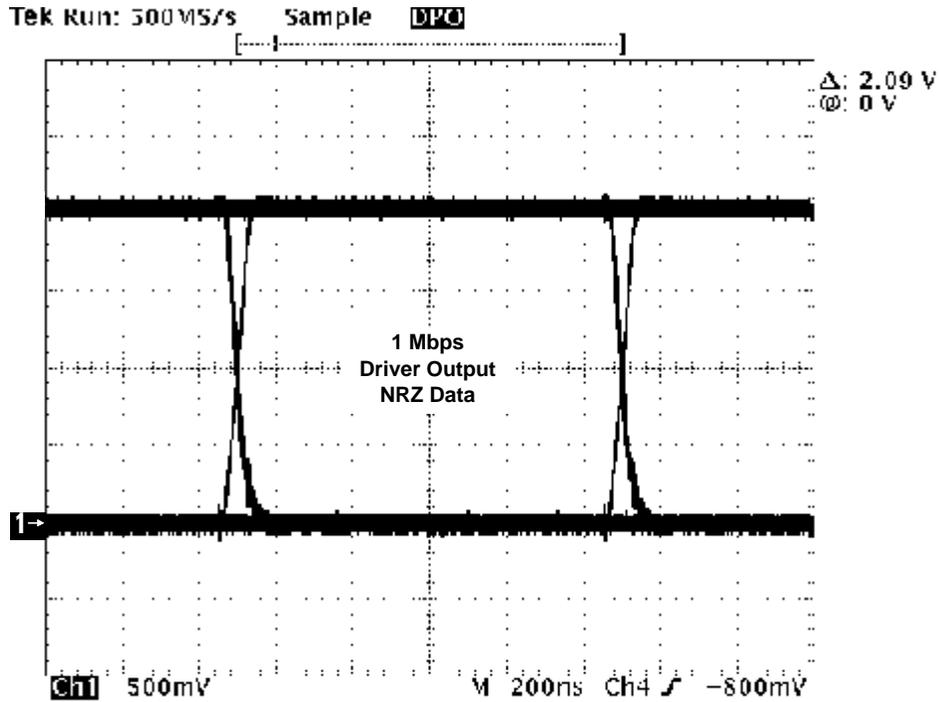


Figure 31. Typical High Speed SN65HVD230 Output Waveform Into a 60-Ω Load

slope control

Electromagnetic compatibility is essential in many applications using unshielded bus cable to reduce system cost. To reduce the electromagnetic interference generated by fast rise times and resulting harmonics, the rise and fall slopes of the SN65HVD230 and SN65HVD231 driver outputs can be adjusted by connecting a resistor from  $R_S$  (pin 8) to ground or to a logic low voltage, as shown in Figure 32. 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  $\approx 15$  V/μs slew rate, and up to 100 kΩ to achieve a  $\approx 2.0$  V/μs slew rate as displayed in Figure 33. Typical driver output waveforms from a pulse input signal with and without slope control are displayed in Figure 34. A pulse input is used rather than NRZ data to clearly display the actual slew rate.

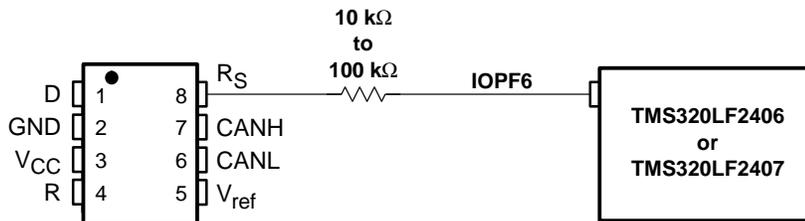


Figure 32. Slope Control/Standby Connection to a DSP

APPLICATION INFORMATION

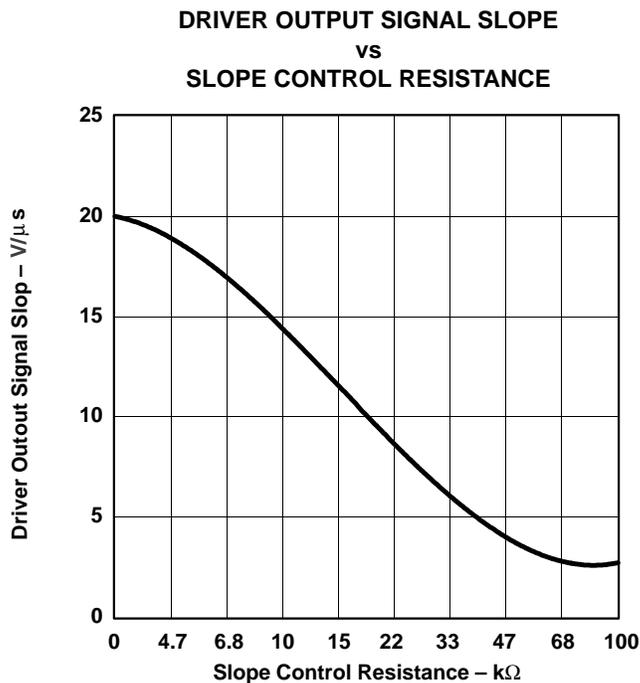


Figure 33. HVD230 Driver Output Signal Slope vs Slope Control Resistance Value

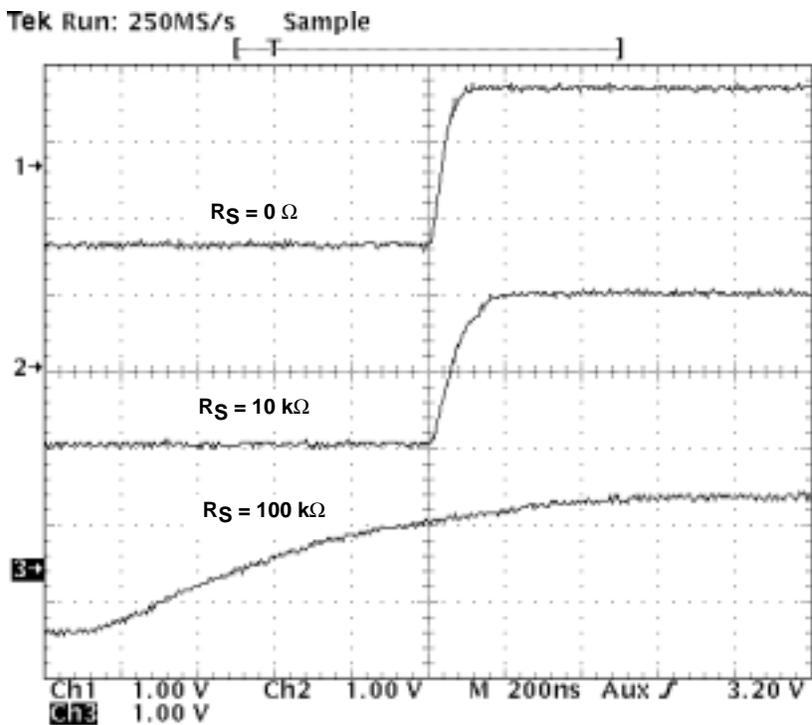


Figure 34. Typical SN65HVD230 250-kbps Output Pulse Waveforms With Slope Control

## APPLICATION INFORMATION

### standby mode (listen only mode) of the HVD230

If a logic high ( $> 0.75 V_{CC}$ ) is applied to  $R_S$  (pin 8) in Figures 30 and 32, the circuit of the SN65HVD230 enters a low-current, *listen only* standby mode, during which the driver is switched off and the receiver remains active. In this *listen only* state, the transceiver is completely passive to the bus. It makes no difference if a slope control resistor is in place as shown in Figure 32. The DSP 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. The DSP, sensing bus activity, reactivates the driver circuit by placing a logic low ( $< 1.2$  V) on  $R_S$  (pin 8).

### the babbling idiot protection of the HVD230

Occasionally, a runaway CAN controller unintentionally sends messages that completely tie up the bus (what is referred to in CAN jargon as a babbling idiot). When this occurs, the DSP can engage the *listen-only* standby mode to disengage the driver and release the bus, even when access to the CAN controller has been lost. When the driver circuit is deactivated, its outputs default to a high-impedance state.

### sleep mode of the HVD231

The unique difference between the SN65HVD230 and the SN65HVD231 is that both driver and receiver are switched off in the SN65HVD231 when a logic high is applied to  $R_S$  (pin 8). The device remains in a very low power-sleep mode until the circuit is reactivated with a logic low applied to  $R_S$  (pin 8). While in this sleep mode, the bus-pins are in a high-impedance state, while the D and R pins default to a logic high.

### loop propagation delay

Transceiver loop delay is a measure of the overall device propagation delay, consisting of the delay from the driver input to the differential outputs, plus the delay from the receiver inputs to its output.

The loop delay of the transceiver displayed in Figure 35 increases accordingly when slope control is being used. This increased loop delay means that the total bus length must be reduced to meet the CAN bit-timing requirements of the overall system. The loop delay becomes  $\approx 100$  ns when employing slope control with a 10-k $\Omega$  resistor, and  $\approx 500$  ns with a 100-k $\Omega$  resistor. Therefore, considering that the rule-of-thumb propagation delay of typical bus cable is 5 ns/m, slope control with the 100-k $\Omega$  resistor decreases the allowable bus length by the difference between the 500-ns max loop delay and the loop delay with no slope control, 70.7 ns. This equates to  $(500 - 70.7 \text{ ns}) / 5 \text{ ns}$ , or approximately 86 m less bus length. This slew-rate/bus length trade-off to reduce electromagnetic interference to adjoining circuits from the bus can also be solved with a quality shielded bus cable.

APPLICATION INFORMATION

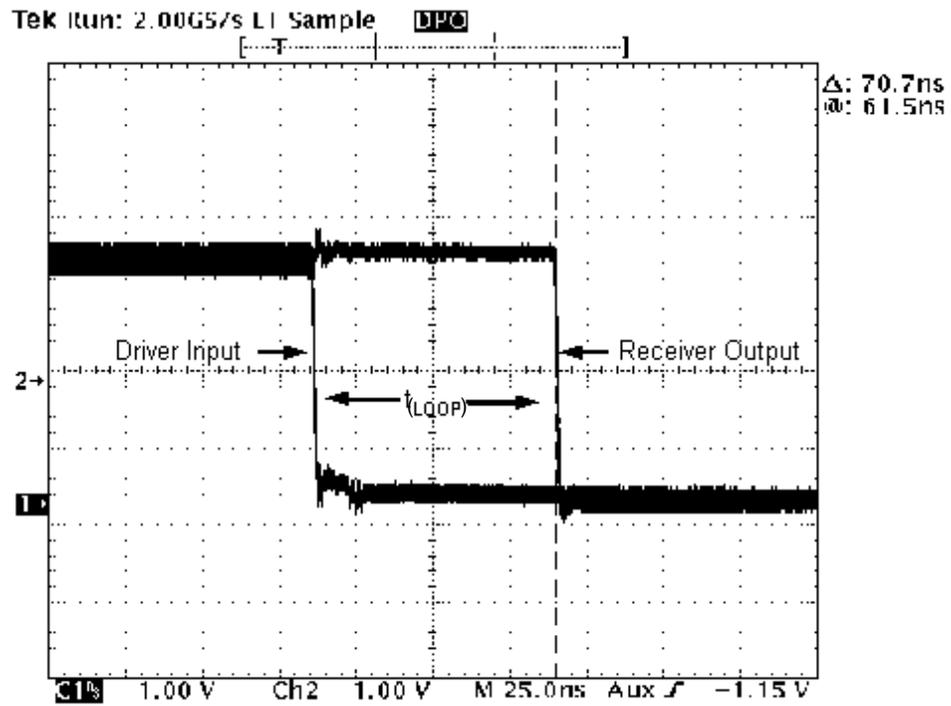


Figure 35. 70.7-ns Loop Delay Through the HVD230 With  $R_S = 0$

APPLICATION INFORMATION

interoperability with 5-V CAN systems

It is essential that the 3.3-V HVD230 family performs seamlessly with 5-V transceivers because of the large number of 5-V devices installed. Figure 36 displays a test bus of a 3.3-V node with the HVD230, and three 5-V nodes: one for each of TI's SN65LBC031 and UC5350 transceivers, and one using a competitor X250 transceiver.

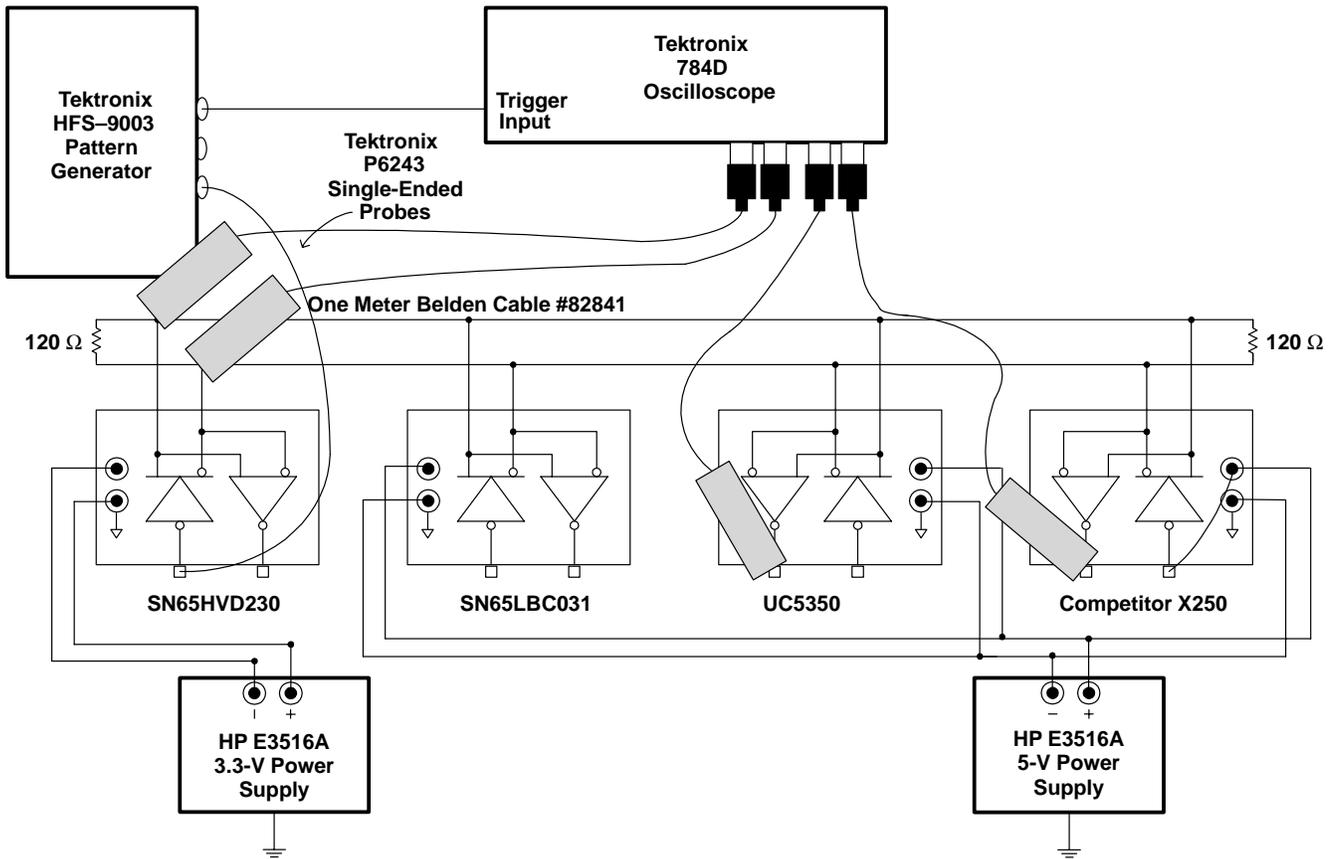


Figure 36. 3.3-V/5-V CAN Transceiver Test Bed

APPLICATION INFORMATION

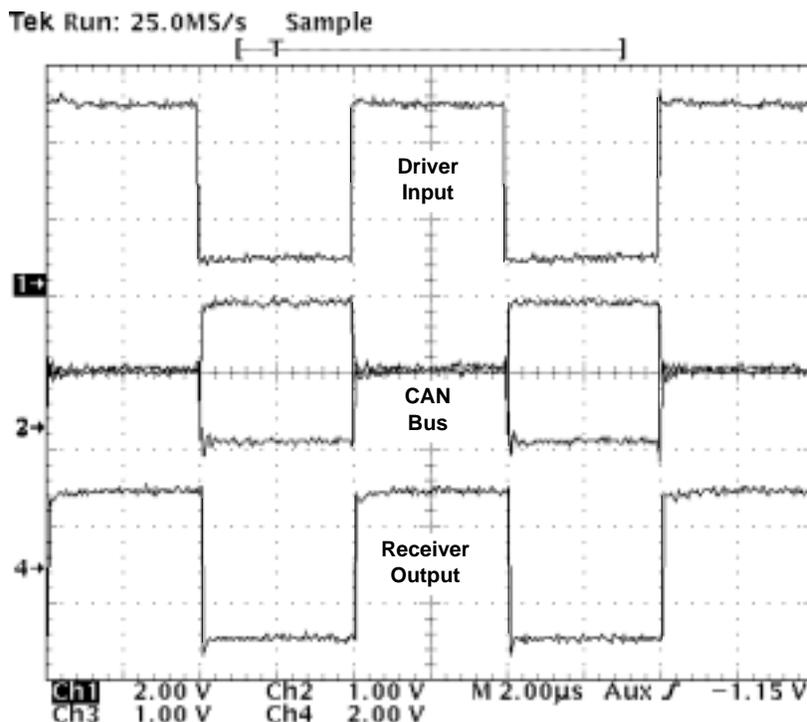


Figure 37. The HVD230's Input, CAN Bus, and X250's RXD Output Waveforms

Figure 37 displays the HVD230's input signal, the CAN bus, and the competitor X250's receiver output waveforms. The input waveform from the Tektronix HFS-9003 Pattern Generator in Figure 36 to the HVD230 is a 250-kbps pulse for this test. The circuit is monitored with Tektronix P6243, 1-GHz single-ended probes in order to display the CAN dominant and recessive bus states.

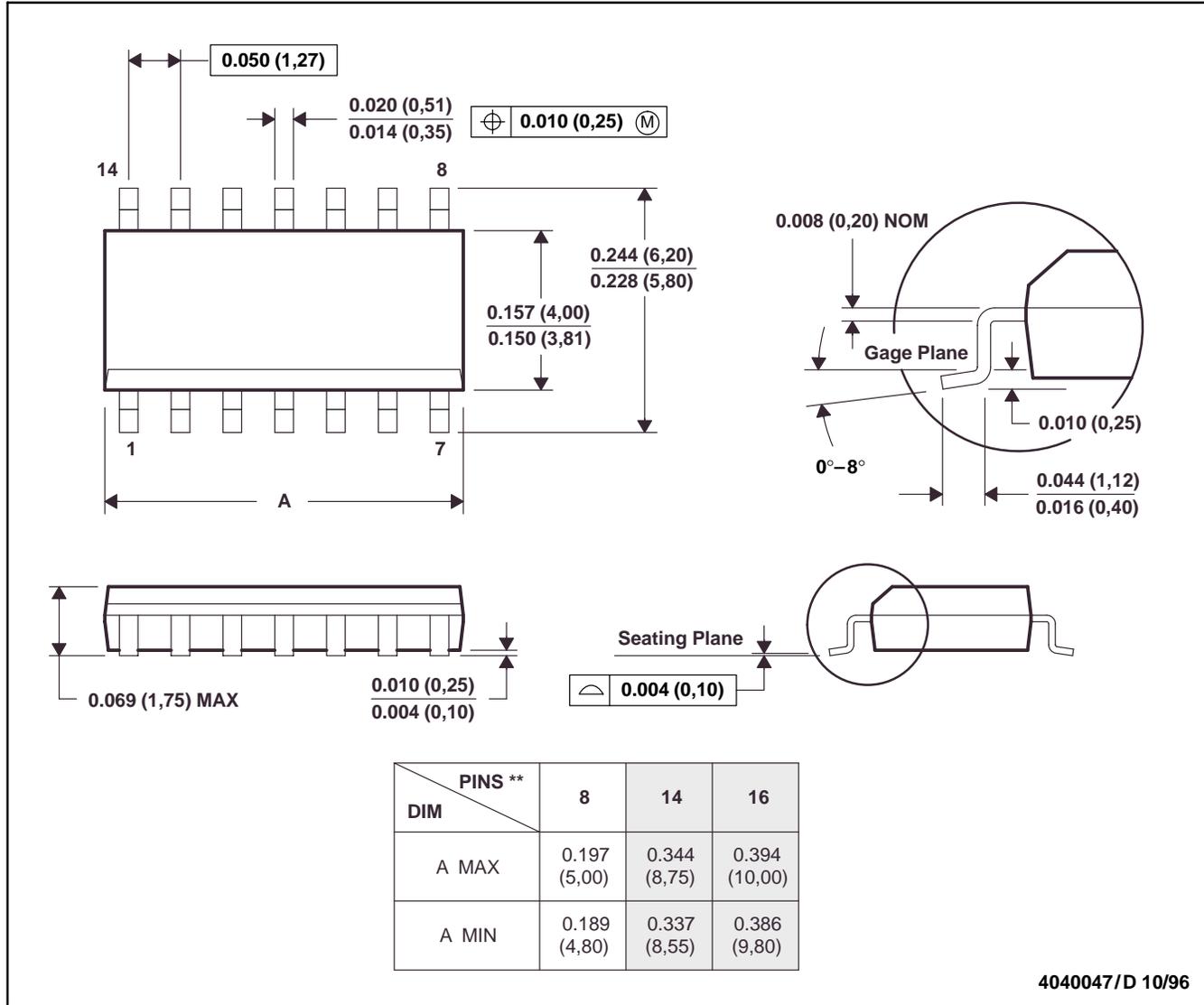
Figure 37 displays the 250-kbps pulse input waveform to the HVD230 on channel 1. Channels 2 and 3 display CANH and CANL respectively, with their recessive bus states overlaying each other to clearly display the dominant and recessive CAN bus states. Channel 4 is the receiver output waveform of the competitor X250.

MECHANICAL DATA

D (R-PDSO-G\*\*)

PLASTIC SMALL-OUTLINE PACKAGE

14 PINS SHOWN



- 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

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### Mailing Address:

Texas Instruments  
Post Office Box 655303  
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