1. DESCRIPTION

The XL65HVD230 and XL65HVD231 controller area network (CAN) transceivers are compatible to the specifications of the ISO 11898-2 High Speed CAN Physical Layer standard (transceiver). These devices are designed for data rates up to 1 megabit per second (Mbps), and include many protection features providing device and CAN network robustness. The XL65HVD23x transceivers are designed for use with the 3.3 V µPs, MCUs and DSPs with CAN controllers, or with equivalent protocol controller devices. The devices are intended for use in applications employing the CAN serial communication physical layer in accordance with the ISO 11898 standard.

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 of operation.

The CAN transceiver is the CAN physical layer and interfaces the single ended host CAN protocol controller with the differential CAN bus found in industrial, building automation, and automotive applications. These devices operate over a -2 V to 7 V common mode range on the bus, and can withstand common mode transients of ±25 V.

The RS pin (pin 8) on the XL65HVD230 and XL65HVD231 provides three different modes of operation:high speed mode, slope control mode, and low-power mode. The high speed mode of operation is selected by connecting the RS pin 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 also be adjusted by connecting a resistor in series between the RS pin and ground. The slope will be proportional to the pin's output current. With a resistor value of 10 kΩ the device will have a slew rate of ~15 V/µs, and with a resistor value of 100 kΩ the device will have a slew rate of ~2 V/µs. See *Application Information* for more information.

The XL65HVD230 enters a low current standby mode (listen only) during which the driver is switched off and the receiver remains active if a high logic level is applied to the RS pin. This mode provides a lower power consumption mode than normal mode while still allowing the CAN controller to monitor the bus for activity indicating it should return the transceiver to normal mode or slope control mode. The host controller (MCU, DSP) returns the device to a transmitting mode (high speed or slope control)when it wants to transmit a message to the bus or if during standby mode it received bus traffic indicating the need to once again be ready to transmit.

The difference between the XL65HVD230 and the XL65HVD231 is that both the driver and the receiver are switched off in the XL65HVD231 when a high logic level is applied to the RS pin. In this sleep mode the device will not be able to transmit messages to the bus or receive messages from the bus. The device will remain in sleep mode until it is reactivated by applying a low logic level on the RS pin.

2. FEATURES

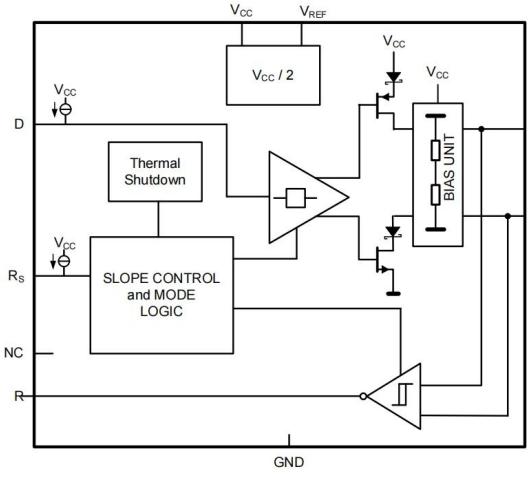
- Operates with a single 3.3 V Supply
- Compatible With ISO 11898-2 Standard
- Bus Pin ESD Protection Exceeds ±16 kV HBM
- High Input Impedance Allows for Up to 120 Nodes on a Bus
- Adjustable Driver Transition Times for Improved Emissions Performance
  – XL65HVD230 and XL65HVD231
- XL65HVD230: Low Current Standby Mode
  – 370 µA Typical
- XL65HVD231: Ultra Low Current Sleep Mode
  – 40 nA Typical
- Designed for Data Rates(1) up to 1 Mbps
- Thermal Shutdown Protection
- Open Circuit Fail-Safe Design
- Glitch Free Power Up and Power Down Protection
- for Hot Plugging Applications

(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).

3. APPLICATIONS

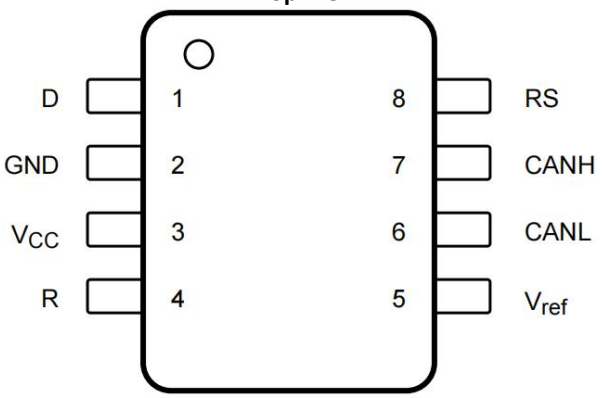
- Industrial Automation, Control, Sensors and Drive Systems
- Motor and Robotic Control
- Building and Climate Control (HVAC)
- Telecom and Basestation Control and Status
- CAN Bus Standards Such as CANopen, DeviceNet, and CAN Kingdom

Equivalent Input and Output Schematic Diagrams



4. PIN CONFIGURATION AND FUNCTIONS

XL65HVD230DR
XL65HVD231DR
Top View



Pin Functions

PIN		TYPE	DESCRIPTION
NAME	NO.		
D	1	I	CAN transmit data input (LOW for dominant and HIGH for recessive bus states), also called TXD, driver input
GND	2	GND	Ground connection
V_{CC}	3	Supply	Transceiver 3.3V supply voltage
R	4	O	CAN receive data output (LOW for dominant and HIGH for recessive bus states), also called RXD, receiver output
V_{ref}	5	O	XL65HVD230 and XL65HVD231: V_{CC} / 2 reference output pin
CANL	6	I/O	Low level CAN bus line
CANH	7	I/O	High level CAN bus line
R_S	8	I	XL65HVD230 and XL65HVD231: Mode select pin: strong pull down to GND = high speed mode, strong pull up to V_{CC} = low power mode, 10kΩ to 100kΩ pull down to GND = slope control mode

5. SPECIFICATIONS

5.1. Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted)[(1)(2)]

	MIN	MAX	UNIT
Supply voltage, V_{CC}	-0.3	6	V
Voltage at any bus terminal (CANH or CANL)	-4	16	V
Voltage input, transient pulse, CANH and CANL, through 100 Ω (see Figure 24)	-25	25	V
Digital Input and Output voltage, V_I (D or R)	-0.5	V_{CC}+0.5	V
Receiver output current, I_O	-11	11	mA
Continuous total power dissipation	See Thermal Information		
Storage temperature, T_{stg}	-40	85	℃

(1) Stresses beyond those listed under Absolute Maximum Ratings may cause permanent damage to the device. These are stress ratingsonly, and functional operation of the device at these or any other conditions beyond those indicated under Recommended OperatingConditions 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

5.2. ESD Ratings

				VALUE	UNIT
$V_{(ESD)}$	Electrostatic discharge	Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001(1)	CANH, CANL and GND	±16000	V
			All pins	±4000	
		Charged-device model (CDM), per JEDEC specification JESD22-C101(2)		±1000	

(1) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process.
(2) JEDEC document JEP157 states that 250-V CDM allows safe manufacturing with a standard ESD control process.

5.3. Recommended Operating Conditions

		MIN	NOM	MAX	NOTE
Supply voltage, V_{CC}		3		3.6	V
Voltage at any bus terminal (common mode) V_{IC}		-2(1)		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 22)		-6		6	V
Input voltage, $V_{(RS)}$		0		V_{CC}	V
Input voltage for standby or sleep,$V_{(RS)}$		0.7VCC		V_{CC}	V
Wave-shaping resistance, R_S		0		100	kΩ
High-level output current, I_{OH}	Driver	-40			mA
	Receiver	-8			
Low-level output current, I_{OL}	Driver			48	mA
	Receiver			8	
Thermal shutdown temperature			165		°C
Thermal shutdown hysteresis			10		
Operating free-air temperature, T_A		-40		85	

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

5.4. Thermal Information

THERMAL METRIC		65HVD230	65HVD231	UNIT
		D		
		8 PINS		
$R_{\theta JA}$	Junction-to-ambient thermal resistance	76.8	101.5	°CW
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	33.4	43.3	°CW
$R_{\theta JB}$	Junction-to-board thermal resistance	15.3	42.2	°CW
ψ_{JT}	Junction-to-top characterization parameter	1.4	4.8	°CW
ψ_{JB}	Junction-to-board characterization parameter	14.9	41.8	°CW

5.5. Electrical Characteristics: Driver

over recommended operating conditions (unless otherwise noted)

PARAMETER			TEST CONDITIONS		MIN	TYP(1)	MAX	UNIT
V_{OH}	Bus output voltage	Dominant	V_I = 0 V, See Figure 18 and Figure 20	CANH	2.45		V_{CC}	V
				CANL	0.5		125	
V_{OL}		Recessive	V_I = 3 V, See Figure 18 and Figure 20	CANH		2.3		
				CANL		2.3		
$V_{OD(D)}$	Differential output voltage	Dominant	V_I = 0 V, See Figure 18		1.5	2	3	V
			V_I = 0 V, See Figure 19		1.2	2	3	
$V_{OD(R)}$		Recessive	V_I = 3 V, See Figure 18		-120	0	12	mV
			V_I = 3 V, No load		-0.5	0.2	0.05	V
I_{IH}	High-level input current		V_I = 2 V		-30			µA
I_{IL}	Low-level input curren		V_I = 0.8 V		-30			µA
I_{OS}	Short-circuit output current		V_{CANH} = -2 V		-250		250	mA
			V_{CANL} = 7 V		-250		250	
C_O	Output capacitance		See receiver					
I_{CC}	Standby	XL65HVD230	$V_{(Rs)}$ = V_{CC}			370	600	µA
	Sleep	XL65HVD231	$V_{(Rs)}$ = V_{CC}, D at V_{CC}			0.04	1	
	All devices	Dominant	VI = 0 V, No load	Dominant		10	17	mA
		Recessive	V_I = V_{CC}, No load	Recessive		10	17	

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

5.6. Electrical Characteristics: Receiver

over recommended operating conditions (unless otherwise noted)

PARAMETER		TEST CONDITIONS		MIN	TYP(1)	MAX	UNIT
V_{IT+}	Positive-going input threshold voltage	See Table 1			750	900	mV
V_{IT-}	Negative-going input threshold voltage			500	650		mV
V_{HYS}	Hysteresis voltage (V_{IT+} – V_{IT-})				100		
V_{OH}	High-level output voltage	–6 V ≤ V_{ID} ≤ 500 mV, I_O = –8 mA, See Figure 22		2.4			V
V_{OL}	Low-level output voltage	900 mV ≤ V_{ID} ≤ 6 V, I_O = 8 mA, See Figure 22				0.4	
I_I	Bus input current	V_{IH} = 7 V	Other input at 0 V, D = 3 V	100		250	µA
		V_{IH} = 7 V, V_{CC} = 0 V		100		350	
		V_{IH} = -2 V		-200		-30	µA
		V_{IH} = -2 V, V_{CC} = 0 V		-100		-20	
C_I	CANH, CANL input capacitance	Pin-to-ground, $V_{(D)}$ = 3 V, V_I = 0.4 sin(4E6πt) + 0.5 V			32		pF
C_{Diff}	Differential input capacitance	Pin-to-pin, $V_{(D)}$ = 3 V, V_I = 0.4 sin(4E6πt) + 0.5 V			16		pF
R_{Diff}	Differential input resistance	Pin-to-pin, $V_{(D)}$ = 3 V		40	70	100	kΩ
R_I	CANH, CANL input resistance			20	35	50	kΩ
I_{CC}	Supply current	See driver					

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

5.7. Switching Characteristics: Driver

over recommended operating conditions (unless otherwise noted)

PARAMETER			TEST CONDITIONS	MIN	TYP	MAX	UNIT
t_{PLH}	Propagation delay time, low-to-high-level output	$V_{(Rs)}$ = 0 V	C_L = 50 pF, See Figure 21		35	85	ns
		R_S with 10 kΩ to ground			70	125	
		R_S with 100 kΩ to ground			500	870	
t_{PHL}	Propagation delay time, high-to-low-level output	$V_{(Rs)}$ = 0 V			70	120	ns
		R_S with 10 kΩ to ground			130	180	
		R_S with 100 kΩ to ground			870	1200	
$t_{sk(p)}$	Pulse skew ($\|t_{PHL} - t_{PLH}\|$)	$V_{(Rs)}$ = 0 V			35		ns
		R_S with 10 kΩ to ground			60		
		R_S with 100 kΩ to ground			370		
t_r	Differential output signal rise time	$V_{(Rs)}$ = 0 V		25	50	100	ns
t_f	Differential output signal fall time			40	55	80	ns
t_r	Differential output signal rise time	RS with 10 kΩ to ground		80	120	160	ns
t_f	Differential output signal fall time			80	125	150	ns
t_r	Differential output signal rise time	RS with 100 kΩ to ground		600	800	1200	ns
t_f	Differential output signal fall time			600	825	1000	ns

5.8. Switching Characteristics: Receiver

over recommended operating conditions (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
t_{PLH}	Propagation delay time, low-to-high-level output	See Figure 23		35	50	ns
t_{PHL}	Propagation delay time, high-to-low-level output			35	50	ns
$t_{sk(p)}$	Pulse skew ($\|t_{PHL} - t_{PLH}\|$)				10	ns
t_r	Output signal rise time	See Figure 23		1.5		ns
t_f	Output signal fall time			1.5		ns

5.9. Switching Characteristics: Device

over recommended operating conditions (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$t_{(LOOP1)}$	Total loop delay, driver input to receiver output, recessive to dominant	$V_{(Rs)}$ = 0 V, See Figure 26		70	115	ns
		R_S with 10 kΩ to ground, See Figure 26		105	175	
		R_S with 100 kΩ to ground, See Figure 26		535	920	
$t_{(LOOP2)}$	Total loop delay, driver input to receiver output, dominant to recessive	$V_{(Rs)}$ = 0 V, See Figure 26		100	135	ns
		R_S with 10 kΩ to ground, See Figure 26		155	185	
		R_S with 100 kΩ to ground, See Figure 26		830	990	

5.10. Device Control-Pin Characteristics

over recommended operating conditions (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP(1)	MAX	UNIT
$t_{(WAKE)}$	XL65HVD230 wake-up time from standby mode with R_S	See Figure 25		0.55	1.5	µs
	XL65HVD231 wake-up time from sleep mode with R_S			3	5	µs
V_{ref}	Reference output voltage	-5 µA < $I_{(Vref)}$ < 5 µA	0.45V_{CC}		0.55V_{CC}	V
		-50 µA < $I_{(Vref)}$ < 50 µA	0.4V_{CC}		0.6V_{CC}	
$I_{(Rs)}$	Input current for high-speed	$V_{(Rs)}$ < 1 V	-450		0	µA

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

5.11. Typical Characteristics

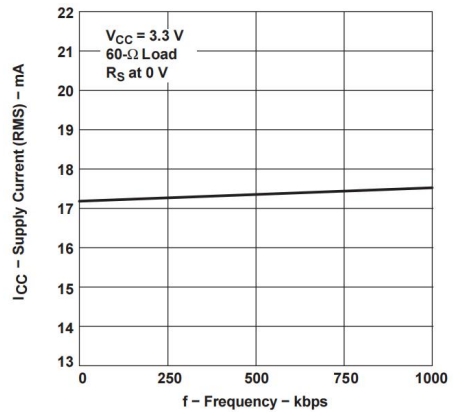


Figure 1. Supply Current (RMS) vs Frequency

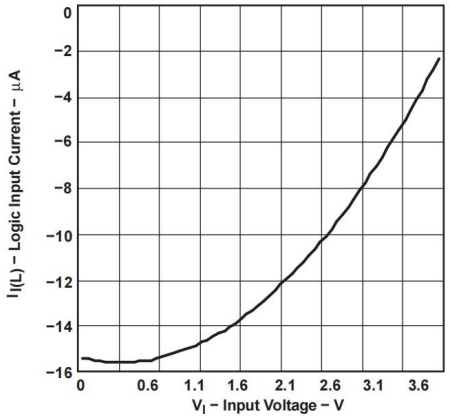


Figure 2. Logic Input Current (Pin D) vs Input Voltage

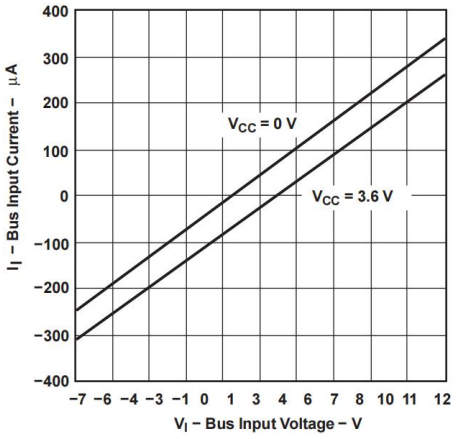


Figure 3. Bus Input Current vs Bus Input Voltage

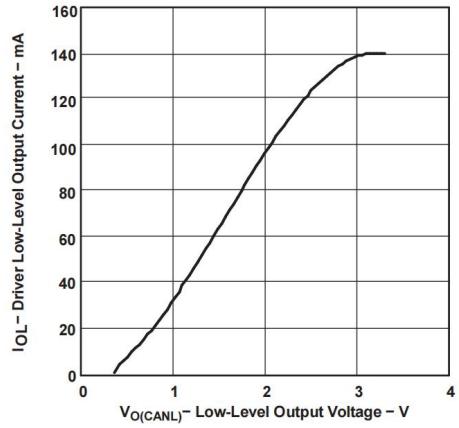


Figure 4. Driver Low-Level Output Current vs Low-Level Output Voltage

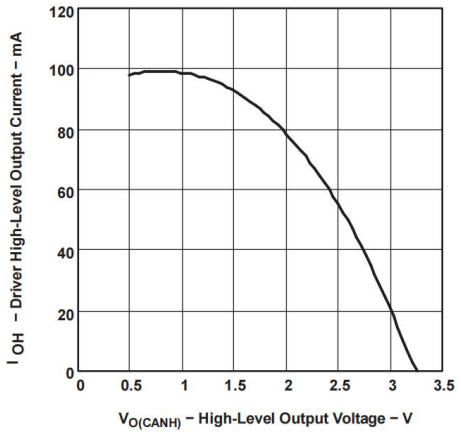


Figure 5. Driver High-Level Output Current vs High-Level Output Voltage

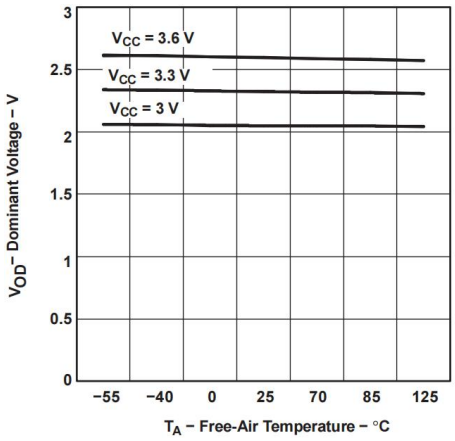


Figure 6. Dominant Voltage (VOD) vs Free-Air Temperature

Typical Characteristics (continued)

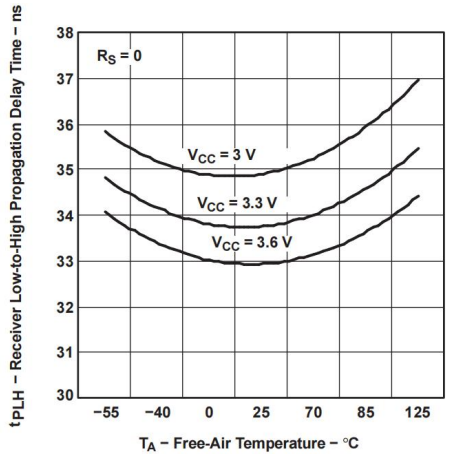


Figure 7. Receiver Low-to-High Propagation Delay Time vs Free-Air Temperature

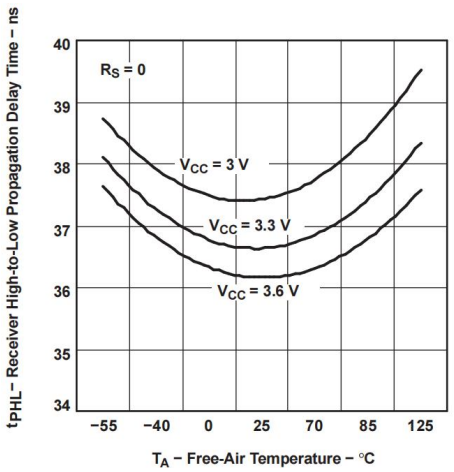


Figure 8. Receiver High-to-Low Propagation Delay Time vs Free-Air Temperature

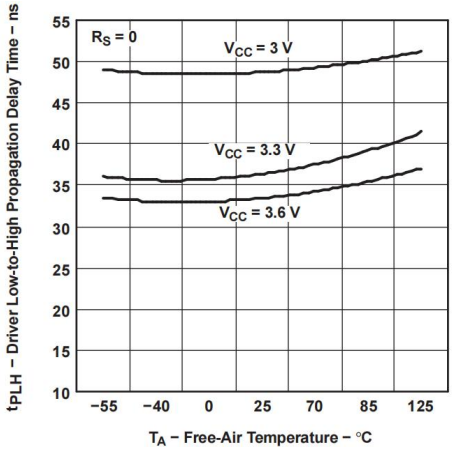


Figure 9. Driver Low-to-High Propagation Delay Time vs Free-Air Temperature

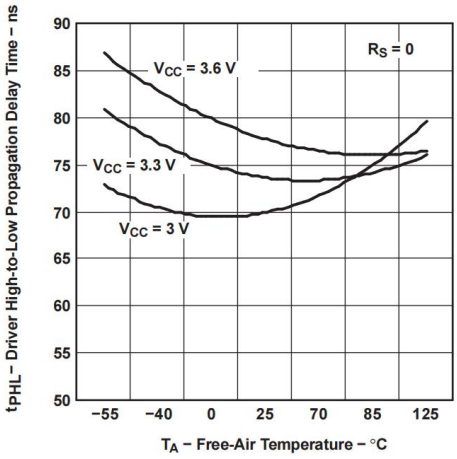


Figure 10. Driver High-to-Low Propagation Delay Time vs Free-Air Temperature

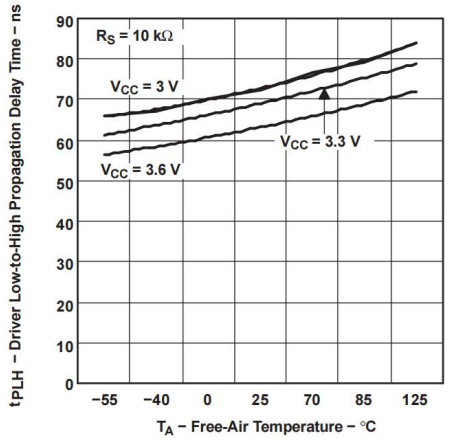


Figure 11. Driver Low-to-High Propagation Delay Time vsFree-Air Temperature

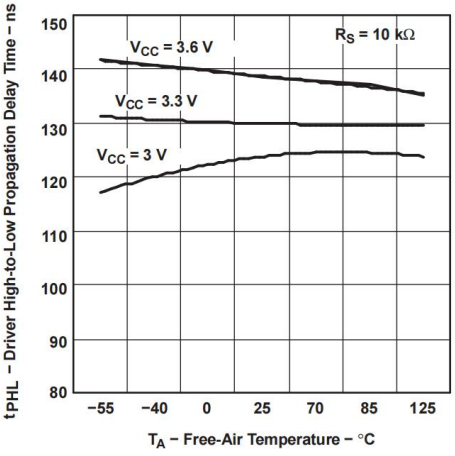


Figure 12. Driver High-to-Low Propagation Delay Time vs Free-Air Temperature

Typical Characteristics (continued)

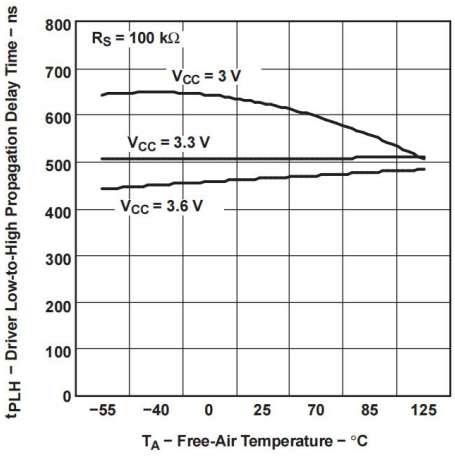


Figure 13. Driver Low-to-High Propagation Delay Time vs Free-Air Temperature

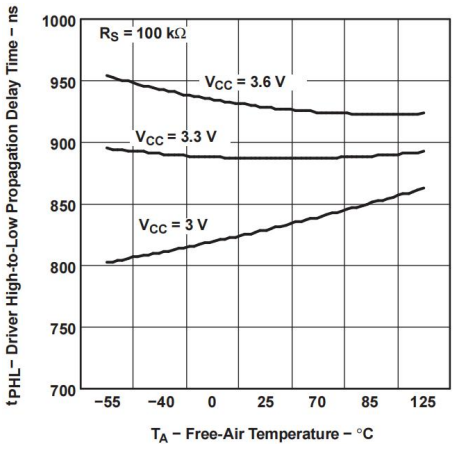


Figure 14. Driver High-to-Low Propagation Delay Time vs Free-Air Temperature

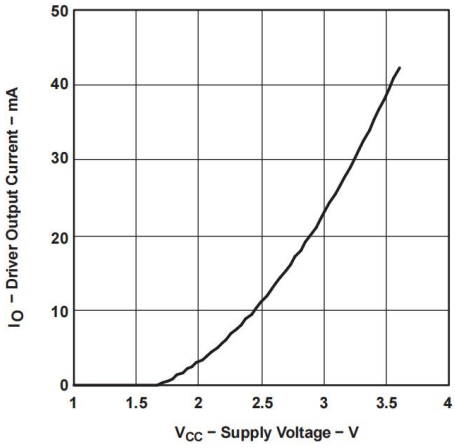


Figure 15. Driver Output Current vs Supply Voltage

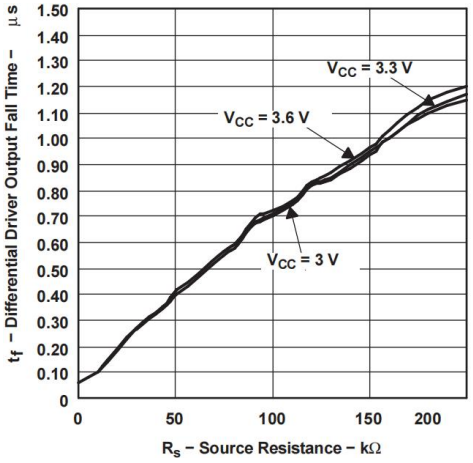


Figure 16. Differential Driver Output Fall Time vs Source Resistance (Rs)

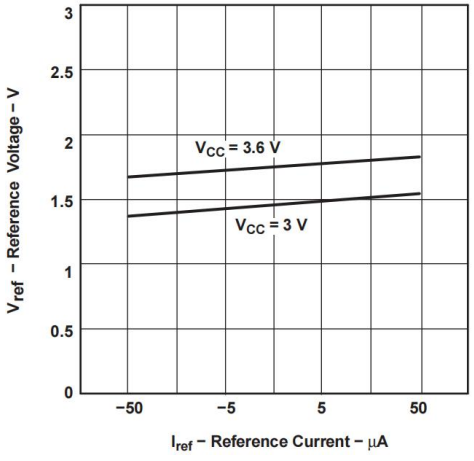


Figure 17. Reference Voltage vs Reference Current

6. PARAMETER MEASUREMENT INFORMATION

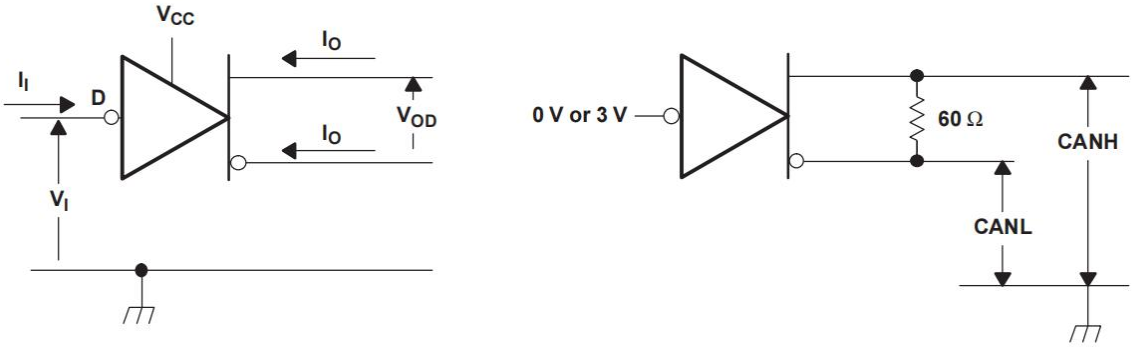


Figure 18. Driver Voltage and Current Definitions

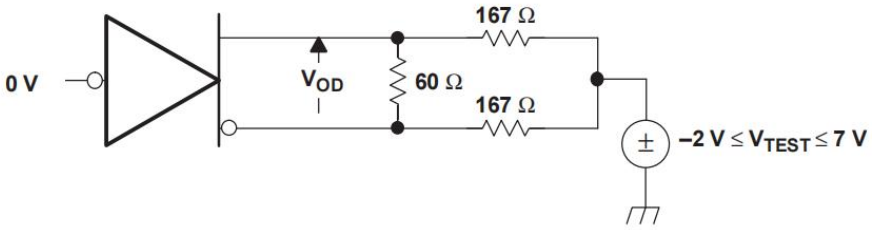


Figure 19. Driver V_{OD}

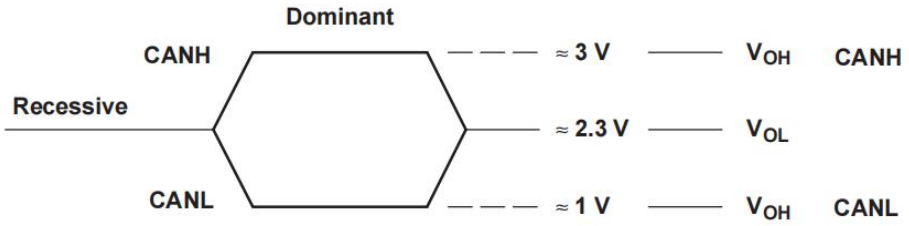
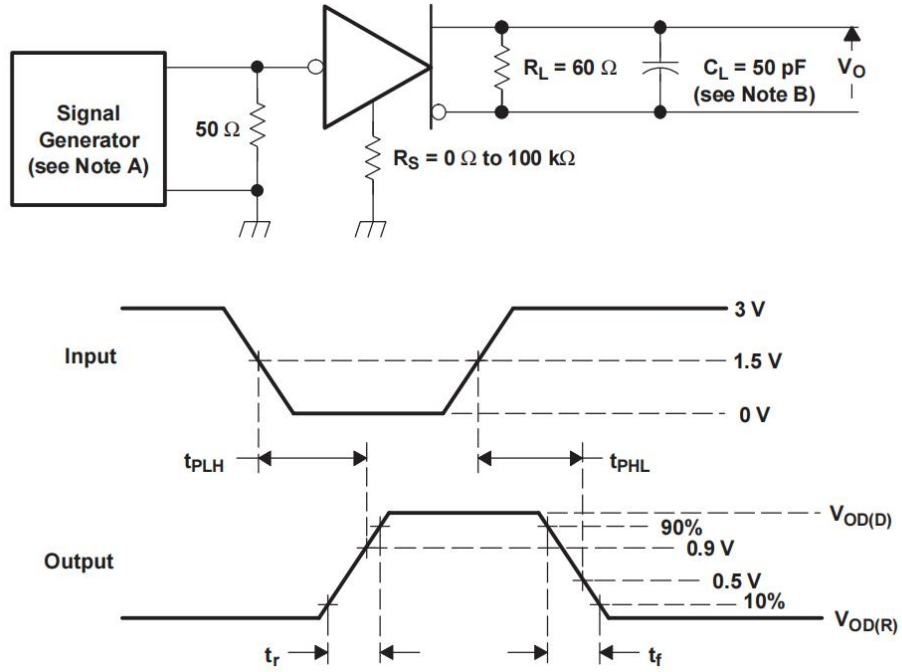


Figure 20. Driver Output Voltage Definitions



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

Figure 21. Driver Test Circuit and Voltage Waveforms

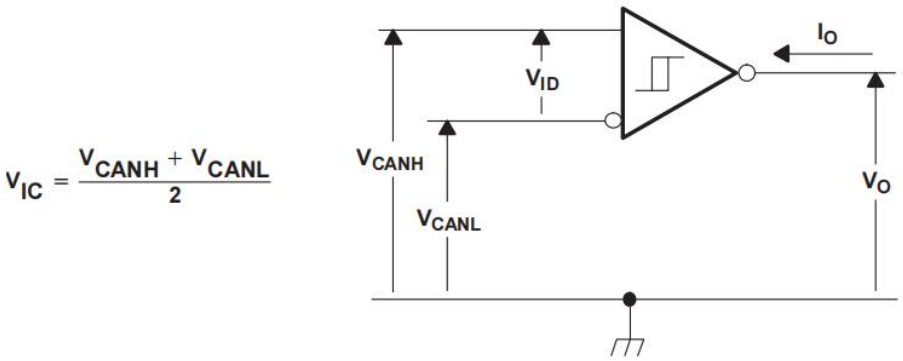
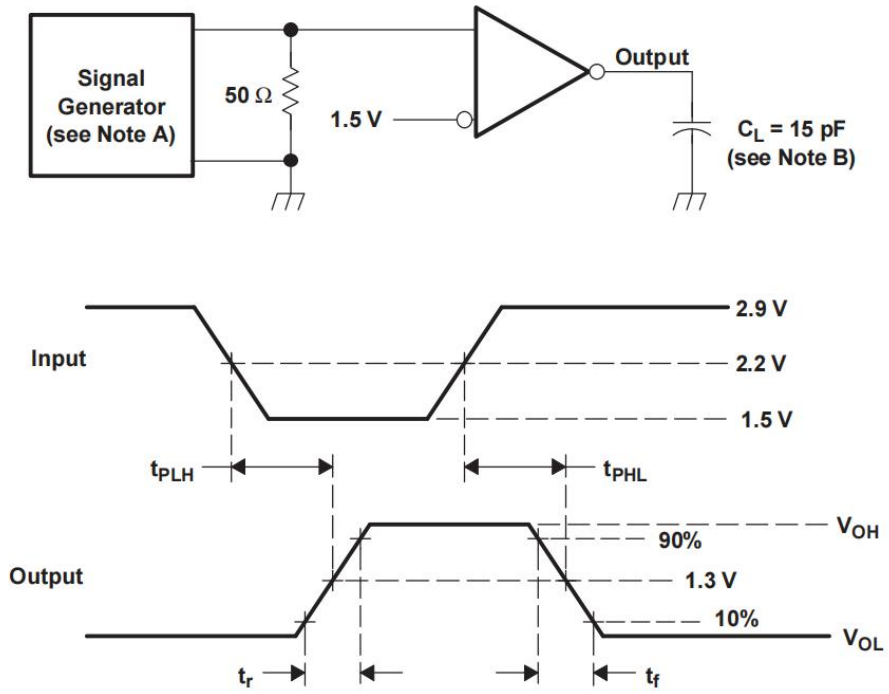


Figure 22. Receiver Voltage and Current Definitions



A. The input pulse is supplied by a generator having the following characteristics: PRR ≤ 500 kHz, 50% duty cycle, tr ≤ 6 ns, tf ≤ 6 ns, Zo = 50 Ω.
B. CL includes probe and jig capacitance.

Figure 23. Receiver Test Circuit and Voltage Waveforms

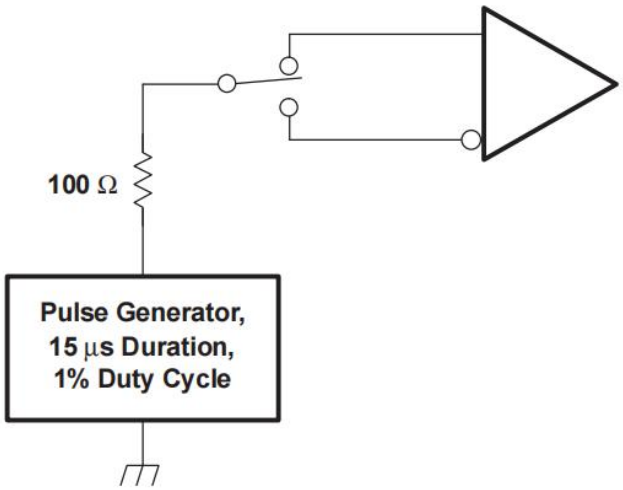


Figure 24. Overvoltage Protection

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

V_{IC}	V_{ID}	V_{CANH}	V_{CANL}	R OUTPUT	
-2 V	900 mV	-1.55 V	-2.45 V	L	V_{OL}
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_{OH}
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	

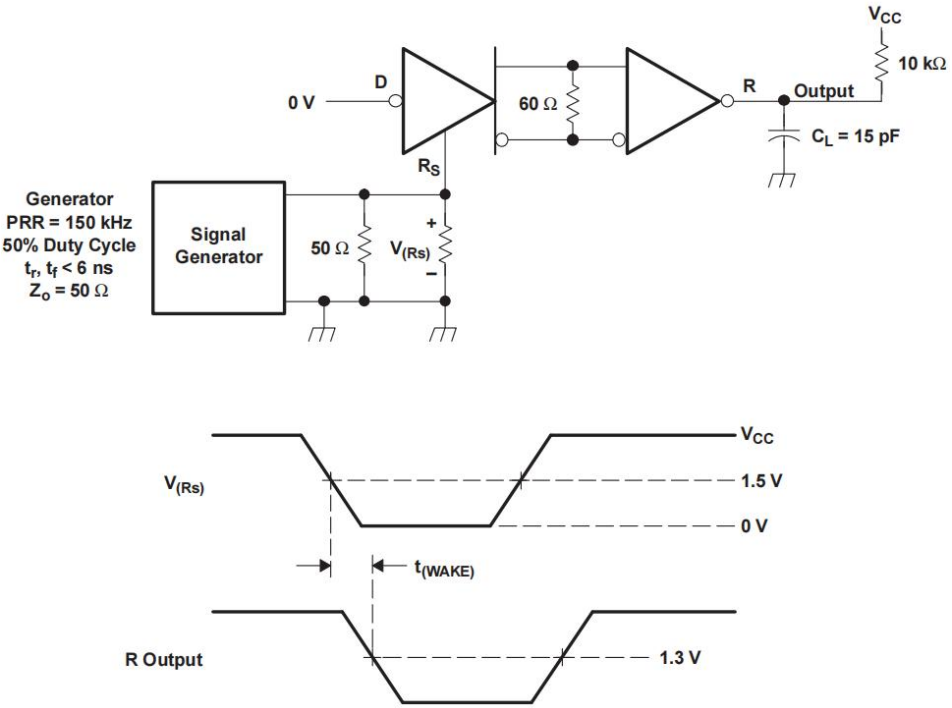
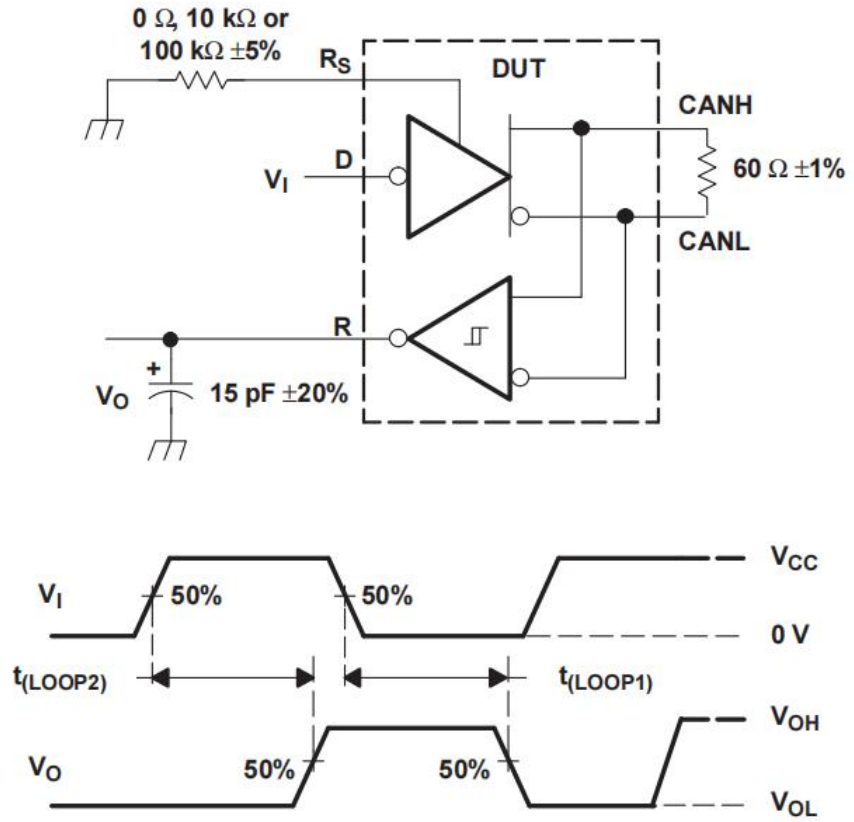


Figure 25. $t_{(WAKE)}$ Test Circuit and Voltage Waveforms



A. All VI input pulses are supplied by a generator having the following characteristics: tr or tf ≤ 6 ns, Pulse Repetition Rate (PRR) = 125 kHz, 50% duty cycle.

Figure 26. $t_{(LOOP)}$ Test Circuit and Voltage Waveforms

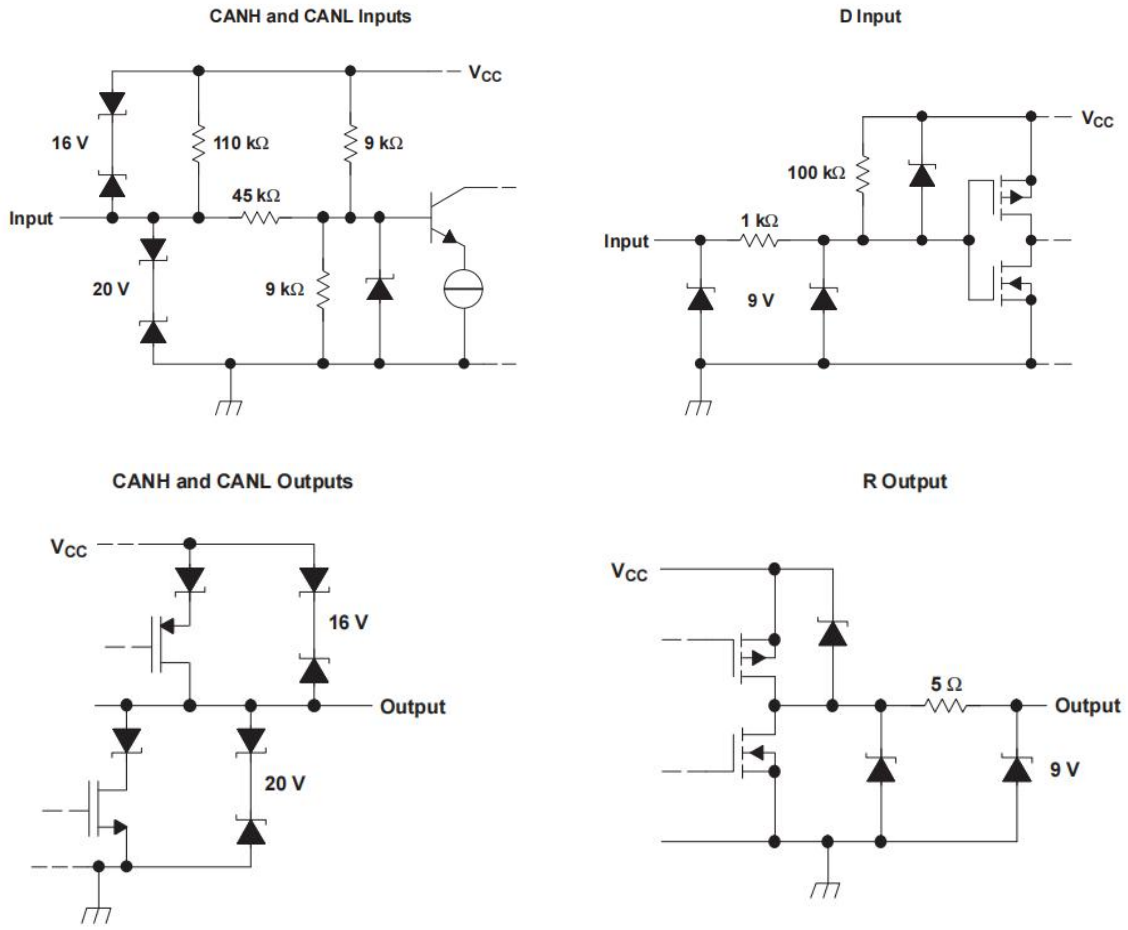


Figure 27. Equivalent Input and Output Schematic Diagrams

7. DETAILED DESCRIPTION

7.1. Overview

ISO 11898 family of standards are the international standard for high speed serial communication using the controller area network (CAN) bus protocol and physical layers (transceivers). 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 XL65HVD23x family of 3.3 V CAN transceivers implement the lowest layers of the ISO/OSI reference model, the ISO11898-2 standard. This is the interface with the physical signaling output of the CAN controller of the µPs, MCUs and DSPsas illustrated in Figure 28.

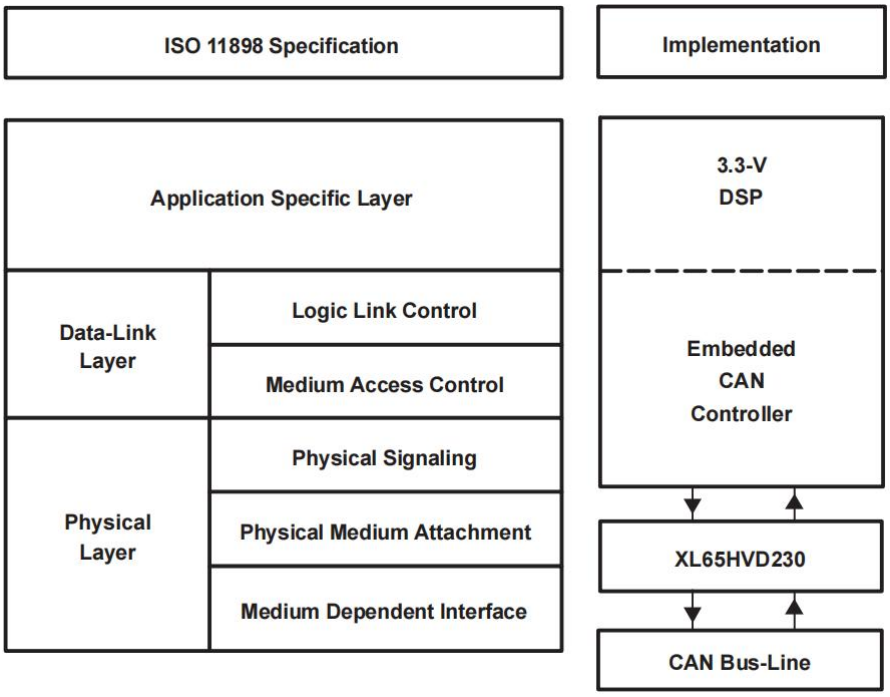


Figure 28. Layered ISO 11898 Standard Architecture

7.2. Functional Block Diagram

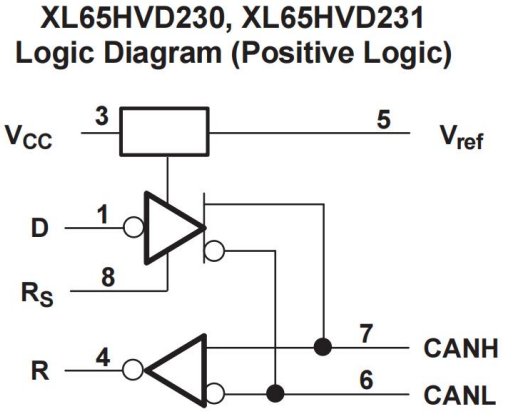


Figure 29. Logic Diagram (Positive Logic)

7.3. Feature Description

The XL65HVD230/231 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 single 3.3 V supply operation and standard compatibility with signaling rates up to 1 Mbps, ±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.

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.

7.3.1. V_{ref} Voltage Reference

The V_{ref} pin (pin 5) on the XL65HVD230 and XL65HVD231 is available as a $V_{CC}/2$ voltage reference. This pin can be connected to the common mode point of a split termination to help further stabilize the common mode voltage of the bus. If the V_{ref} pin is not used it may be left floating.

7.3.2. Thermal Shutdown

If a high ambient temperature or excessive output currents result in thermal shutdown, the driver will be disabled and the bus pins become high impedance. During thermal shutdown the D pin to bus transmission path is blocked and the CAN bus pins are high impedance and biased to a recessive level. Once the thermal shutdown condition is cleared and the junction temperature drops below the thermal shutdown temperature the driver will be reactivated and resume normal operation. During a thermal shutdown the receiver to R pin path remains operational.

7.4. Device Functional Modes

The R_S pin (Pin 8) of the XL65HVD230 and XL65HVD231 provides three different modes of operation: high speed mode, slope-control mode, and low-power mode.

7.4.1. High-Speed Mode

The high-speed mode can be selected by applying a logic low to the R_S pin (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. If the high speed transitions are a concern for emissions performance slope control mode can be used.

If both high speed mode and the low-power standby mode is to be used in the application, direct connection to a µP, MCU or DSP general purpose output pin can be used to switch between a logic-low level (< 1.2 V) for high speed operation, and the logic-high level (> 0.75 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.

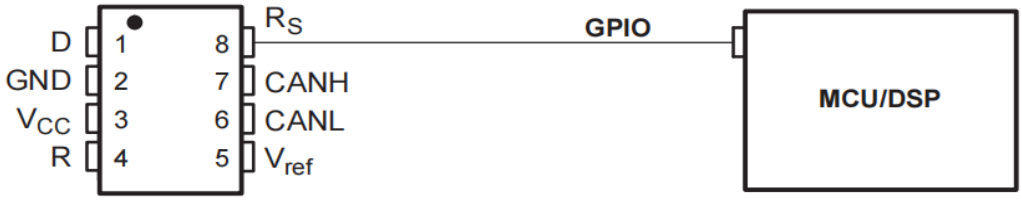


Figure 30. RS (Pin 8) Connection to a MCU/DSP for High Speed/Standby Operation

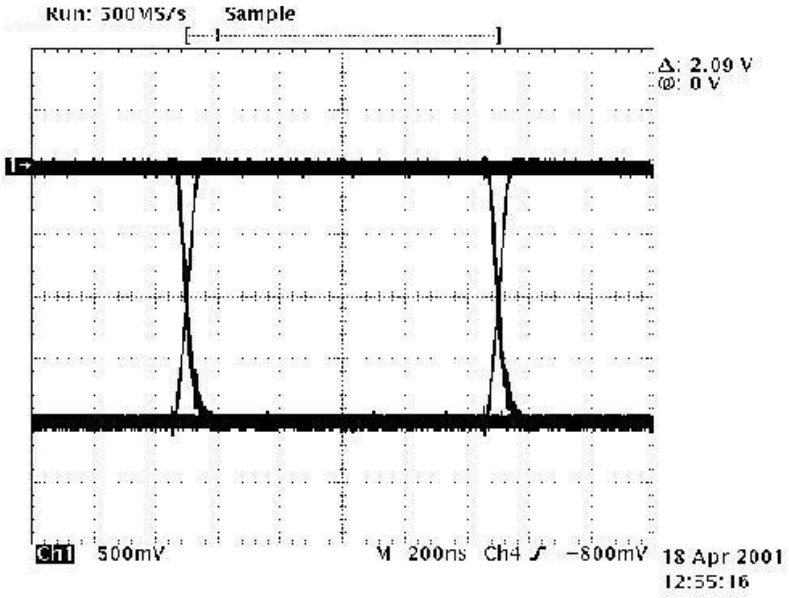


Figure 31. Typical High Speed XL65HVD230 Output Waveform into a 60-Ω Load

7.4.2. Slope Control Mode

Electromagnetic compatibility is essential in many applications while still making use of unshielded twisted pair bus cable to reduce system cost. Slope control mode was added to the XL65HVD230 and XL65HVD231 devices to reduce the electromagnetic interference produced by the rise and fall times of the driver and resulting harmonics. These rise and fall slopes of the 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 ~15 V/µs slew rate, and up to 100 kΩ to achieve a ~2.0 V/µs slew rate as displayed in Figure 33.

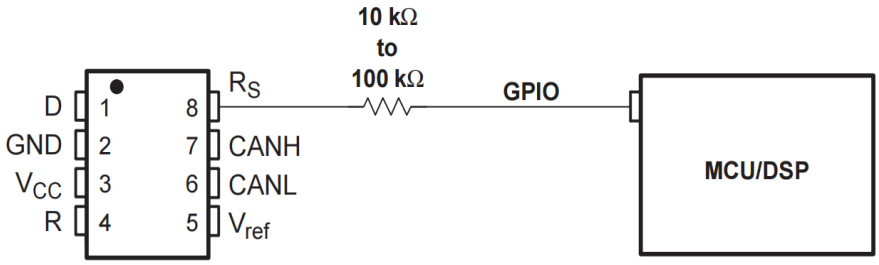


Figure 32. Slope Control/Standby Connection to a DSP

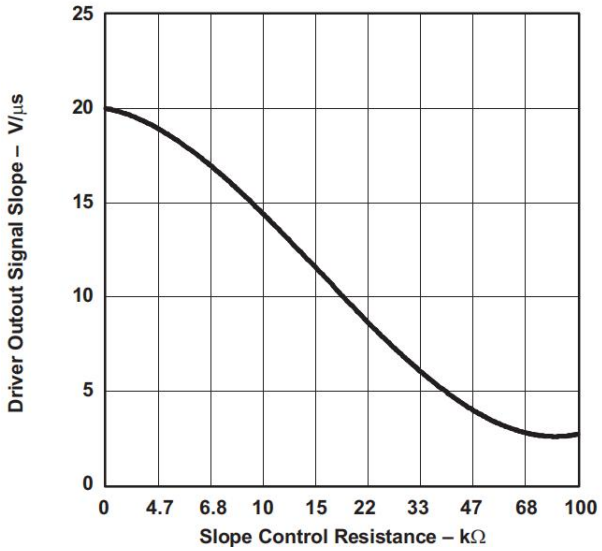


Figure 33. HVD230 Driver Output Signal Slope vs Slope Control Resistance Value

7.4.3. Standby Mode (Listen Only Mode) of the HVD230

If a logic high (> 0.75 VCC) is applied to RS (pin 8) in Figure 30 and Figure 32, the circuit of the XL65HVD230 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 µP 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 µP, sensing bus activity, reactivates the driver circuit by placing a logic low (< 1.2 V) on RS (pin 8).

7.4.4. 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 µP, MCU or DSP can engage the *listen-only* standby mode of the transceiver to disable 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 (recessive).

7.4.5. Sleep Mode of the HVD231

The unique difference between the XL65HVD230 and the XL65HVD231 is that both driver and receiver are switched off in the XL65HVD231 when a logic high is applied to RS (pin 8). The device remains in a very low power-sleep mode until the circuit is reactivated with a logic low applied to RS (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.

7.4.6. Summary of Device Operating Modes

Table 2 shows a summary of the operating modes for the XL65HVD230 and XL65HVD231.

Table 2. XL65HVD230 and XL65HVD231 Operating Modes

RS Pin	MODE		DRIVER	RECEIVER	RXD Pin
LOW, $V_{(Rs)}$ < 1.2 V, strong pull down to GND	High Speed Mode		Enabled (ON) High Speed	Enabled (ON)	Mirrors Bus State(1)
LOW, $V_{(Rs)}$ < 1.2 V, 10 kΩ to 100 kΩ pull down to GND	Slope Control Mode		Enabled (ON) with Slope Control	Enabled (ON)	Mirrors Bus State
HIGH, $V_{(Rs)}$ > 0.75 V_{CC}	Low Current Mode	XL65HVD230: Standby Mode	Disabled (OFF)	Enabled (ON)	Mirrors Bus State
		XL65HVD231: Sleep Mode		Disabled (OFF)	High

(1) Mirrors bus state: low if CAN bus is dominant, high if CAN bus is recessive.

Table 3. XL65HVD230 and XL65HVD231 Driver Functions

DRIVER (XL65HVD230, XL65HVD231)(1)				
INPUT D	RS	OUTPUTS		BUS STATE
		CANH	CANL	
L	$V_{(RS)}$< 1.2 V (including 10 kΩ to 100 kΩ pull down toGND)	H	L	Dominant
H		Z	Z	Recessive
Open	X	Z	Z	Recessive
X	$V_{(RS)}$> 0.75 V_{CC}	Z	Z	Recessive

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

Table 4. XL65HVD230 Receiver Functions

RECEIVER (XL65HVD230)(1)		
DIFFERENTIAL INPUTS	RS	OUTPUT R
V_{ID} ≥ 0.9 V	X	L
0.5 V < V_{ID} < 0.9 V	X	?
V_{ID} ≤ 0.5 V	X	H
Open	X	H

(1) H = high level; L = low level; X = irrelevant; ? = indeterminate

Table 5. XL65HVD231 Receiver Functions

RECEIVER (XL65HVD231)(1)		
DIFFERENTIAL INPUTS	RS	OUTPUT R
V_{ID} ≥ 0.9 V	$V_{(RS)}$ < 1.2 V (including 10 kΩ to 100 kΩ pull down to GND)	L
0.5 V < V_{ID} < 0.9 V		?
V_{ID} ≤ 0.5 V		H
X	$V_{(RS)}$ > 0.75 VCC	H
X	1.2 V < $V_{(RS)}$< 0.75 VCC	?
Open	X	H

(1) H = high level; L = low level; X = irrelevant; ? = indeterminate

8. APPLICATION AND IMPLEMENTATION

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

8.1. Application Information

This application section 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 CAN systems.

8.1.1. CAN Bus States

The CAN bus has two states during powered operation of the device; dominant and recessive. A dominant bus state is when the bus is driven differentially, corresponding to a logic low on the D and R pin. A recessive bus state is when the bus is biased to V_{CC} / 2 via the high-resistance internal resistors R_I and R_{Diff} of the receiver, corresponding to a logic high on the D and R pins. See Figure 34 and Figure 35.

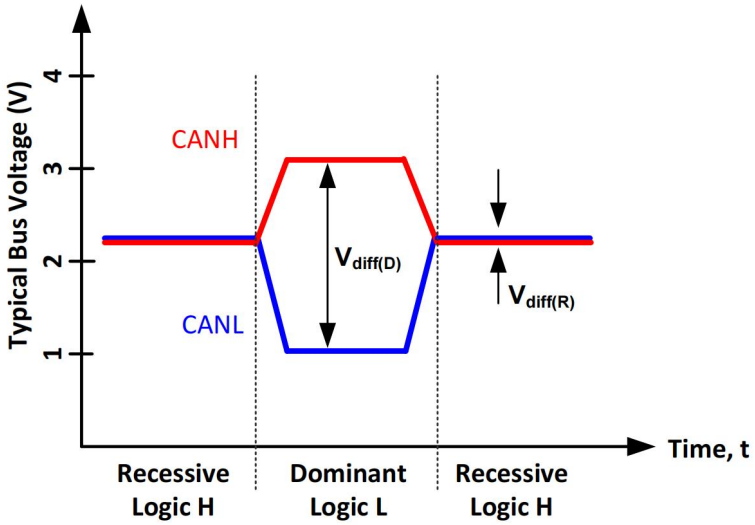


Figure 34. CAN Bus States (Physical Bit Representation)

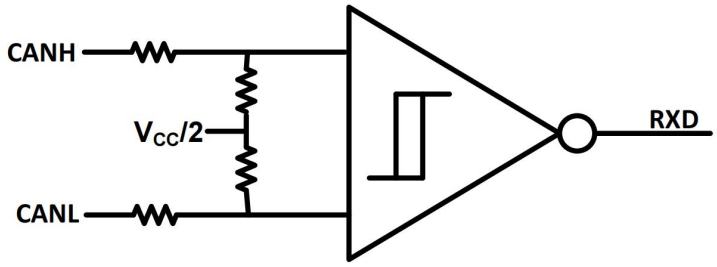


Figure 35. Simplified Recessive Common Mode Bias and Receiver

8.2. Typical Application

Figure 36 illustrates a typical application of the XL65HVD23x family. The output of the host µP's CAN controller (TXD) is connected to the transceivers driver input, pin D, and the transceivers receiver output, pin R, is connected to the input of the CAN controller (RXD). The transceiver is 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 37. Each end of the bus is terminated with 120 Ω resistors in compliance with the standard to minimize signal reflections on the bus.

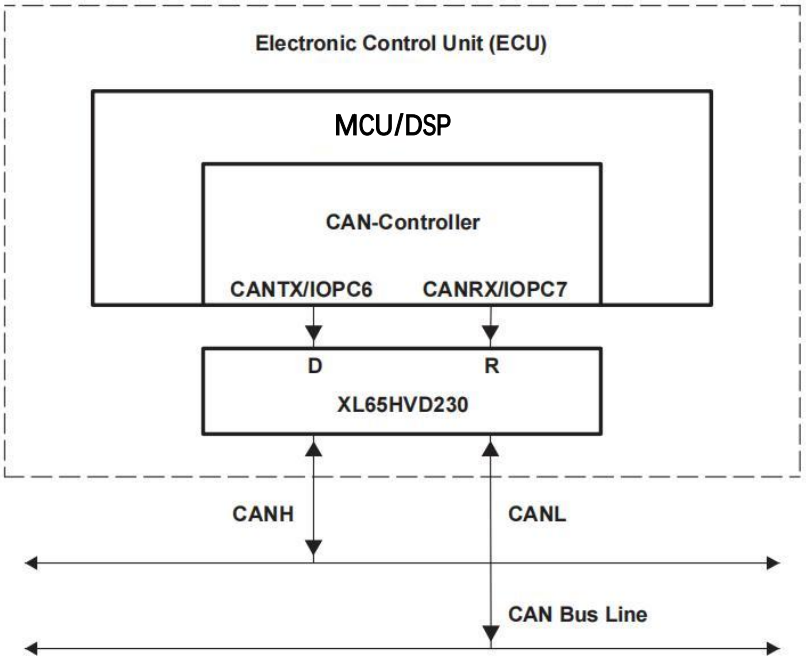


Figure 36. Details of a Typical CAN Node

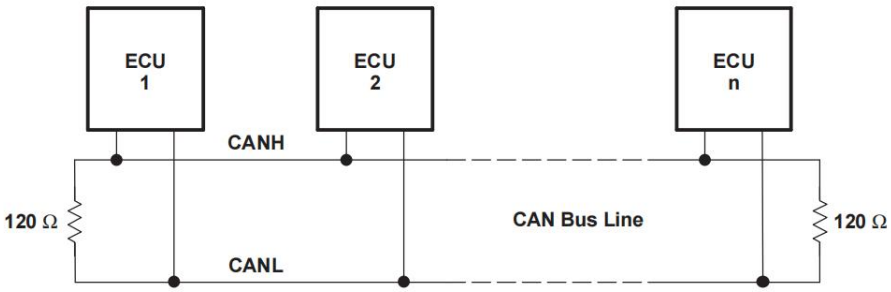


Figure 37. Typical CAN Network

8.2.1. Design Requirements

8.2.1.1. CAN Termination

The ISO11898 standard specifies the interconnect to be a single twisted pair cable (shielded or unshielded) with 120 Ω characteristic impedance (ZO). Resistors equal to the characteristic impedance of the line should be used to 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. The termination may be on the cable or in a node, but if nodes may be removed from the bus the termination must be carefully placed so that it is not removed from the bus.

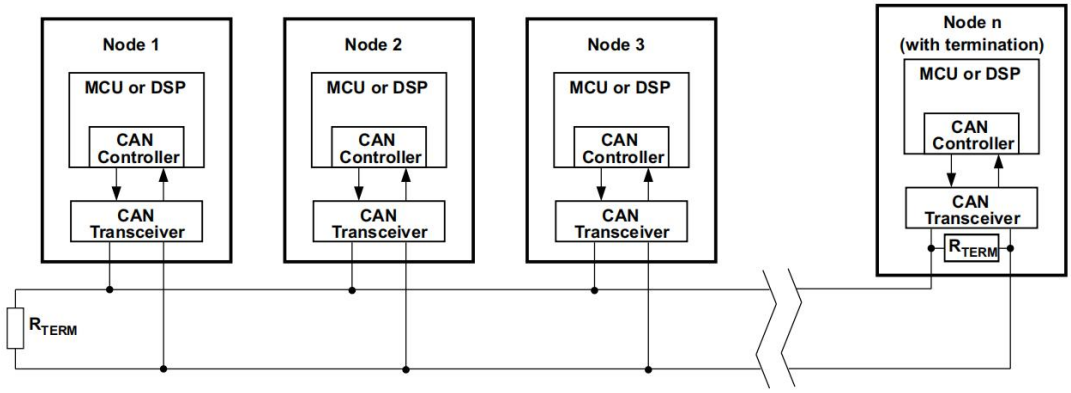


Figure 38. Typical CAN Bus

Termination is typically a 120 Ω resistor at each end of the bus. If filtering and stabilization of the common mode voltage of the bus is desired, then split termination may be used (see Figure 39). Split termination utilizes two 60Ω resistors with a capacitor in the middle of these resistors to ground. Split termination improves the electromagnetic emissions behavior of the network by eliminating fluctuations in the bus common mode voltages at the start and end of message transmissions.

Care should be taken in the power ratings of the termination resistors used. Typically the worst case condition would be if the system power supply was shorted across the termination resistance to ground. In most cases the current flow through the resistor in this condition would be much higher than the transceiver's current limit.

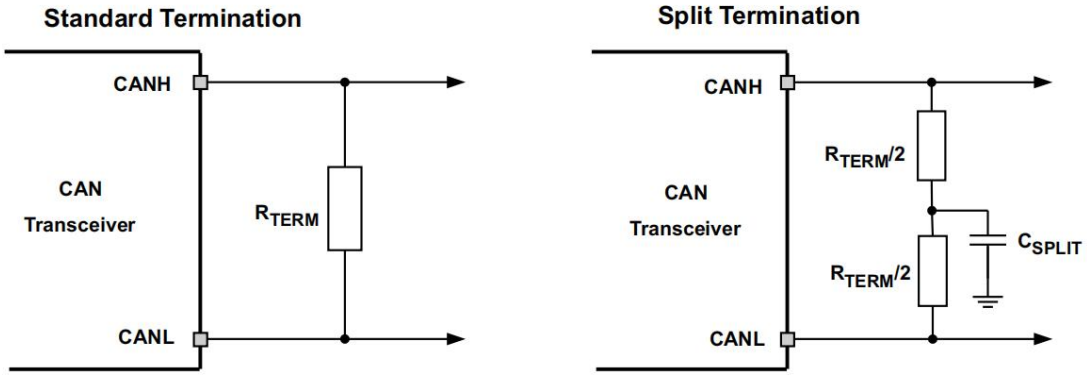


Figure 39. CAN Bus Termination Concepts

8.2.1.2. Loop Propagation Delay

Transceiver loop delay is a measure of the overall device propagation delay, consisting of the delay from the driver input (D pin) to the differential outputs (CANH and CANL pins), plus the delay from the receiver inputs (CANH and CANL) to its output (R pin).

A typical loop delay for the XL65HVD230 transceiver is displayed in Figure 40. This loop delay will increase as the slope of the driver output is slowed during slope control mode. This increased loop delay means that there is a tradeoff between the total bus length able to be used and the driver's output slope used via the slope control pin of the device. For example, the loop delay for a 10-kΩ resistor from the RS pin to ground is ~100 ns, and the loop delay for a 100-kΩ resistor is ~500 ns. Therefore, if we use the following rule-of-thumb that the propagation delay of typical twisted pair bus cable is 5 ns/m, we can calculate an approximate cable length trade-off between normal high-speed mode and slope control mode with a 100-kΩ resistor. Using typical values, the loop delay for a recessive to dominant bit with RS tied directly to ground is 70ns, and with a 100-kΩ resistor is 535 ns. At 5ns/m of propagation delay, which you have to count in both directions the difference is 46.5 meters (535-70)/(2*5).

Another option to improving the elctromagnetic emissions of the device besides slowing down the edge rates of the driver in slope control mode is using quality shielded bus cabling

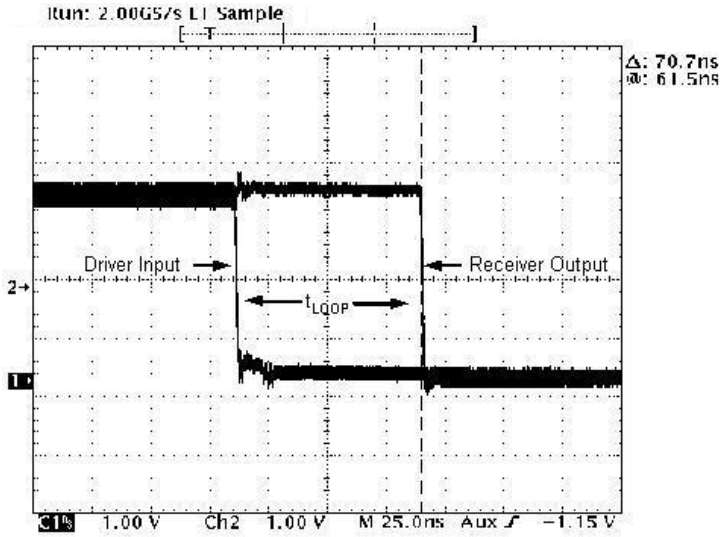


Figure 40. 70.7-ns Loop Delay Through the HVD230 With R_S = 0

8.2.1.3. Bus Loading, Length and Number of Nodes

The ISO11898 Standard specifies up to 1 Mbps data rate, maximum bus length of 40 meters, maximum drop line (stub) length of 0.3 meters and a maximum of 30 nodes. However, with careful network design, the system may have longer cables, longer stub lengths, and many more nodes. Many CAN organizations and standards have scaled the use of CAN for applications outside the original ISO11898 standard. They have made system level trade-offs for data rate, cable length, and parasitic loading of the bus. Examples of some of these specifications are ARINC825, CANopen, CAN Kingdom, DeviceNet and NMEA200.

A high number of nodes requires a transceiver with high input impedance and wide common moderange such as the XL65HVD23x CAN family. ISO11898-2 specifies the driver differential output with a 60 Ω load (two 120 Ω termination resistors in parallel) and the differential output must be greater than 1.5 V. The XL65HVD23x devices are specified to meet the 1.5 V requirement with a 60 Ω load, and additionally specified with a differential output voltage minimum of 1.2 V across a common mode range of –2 V to 7 V via a 167 Ω coupling network. This network represents the bus loading of 120 XL65HVD23x transceivers based on their minimum differential input resistance of 40 kΩ. Therefore, the XL65HVD23x supports up to 120 transceivers on a single bus segment with margin to the 1.2 V minimum differential input voltage requirement at each node. For CAN network design,margin must be given for signal loss across the system and cabling, parasitic loadings, network imbalances, ground offsets and signal integrity thus a practical maximum number of nodes may be lower. Bus length may also be extended beyond the original ISO11898 standard of 40 meters by careful system design and data rate tradeoffs. For example, CANopen network design guidelines allow the network to be up to 1 km with changes in the termination resistance, cabling, less than 64 nodes and significantly lowered data rate.

This flexibility in CAN network design is one of the key strengths of the various extensions and additional standards that have been built on the original ISO11898 CAN standard. In using this flexibility comes the responsibility of good network design.

8.2.2. Detailed Design Procedure

The following system level considerations should be looked at when designing your application. There are trade offs between the total number of nodes, the length of the bus, and the slope of the driver output that need to be evaluated when building up a system

8.2.2.1. Transient Protection

Typical applications that use CAN will sometime require some form of ESD, burst, or surge protection performance at the system level. If these requirements are higher than those of the device some form of external protection may be needed to shield the transceiver against these high power transients that can cause damage. Transient voltage suppressor (TVS) are very commonly used and can help clamp the amount of energy that reaches the transceiver.

8.2.2.2. Transient Voltage Suppressors

Transient voltage suppressors are the preferred protection components for CAN bus applications due to their low capacitance, fast response times and high peak power dissipation limits. The low bus capacitance allows these devices to be used at many, if not all, nodes on the network without having to reduce the data rate. The quick response times in the order of a few picoseconds enable these devices to clamp the energy of very fast transients like ESD and EFT. Lastly, the high peak power ratings enable these devices to handle high energy surge pulses without being damaged.

8.2.3. Application Curve

Typical driver output waveforms from a pulse input signal with different slope control resistances are displayed in Figure 41. The top waveform show the typical differential signal when transitioning from a recessive level to a dominant level on the CAN bus with RS tied to GND through a zero ohm resistor. The second waveform shows the same signal for the condition with a 10k ohm resistor tied from RS to ground. The bottom waveform shows the typical differential signal for the case where a 100k ohm resistor is tied from the RS pin to ground.

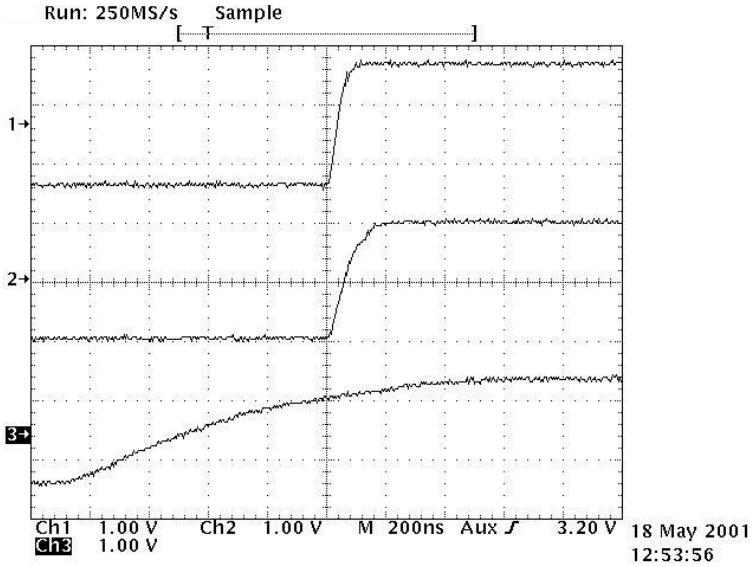


Figure 41. Typical XL65HVD230 250-kbps Output Pulse Waveforms With Slope Control

8.3. System Example

8.3.1. ISO 11898 Compliance of XL65HVD23x Family of 3.3 V CAN Transceivers

8.3.1.1. Introduction

Many users value the low power consumption of operating their 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 report analyzes this situation to address those concerns.

8.3.1.2. 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.

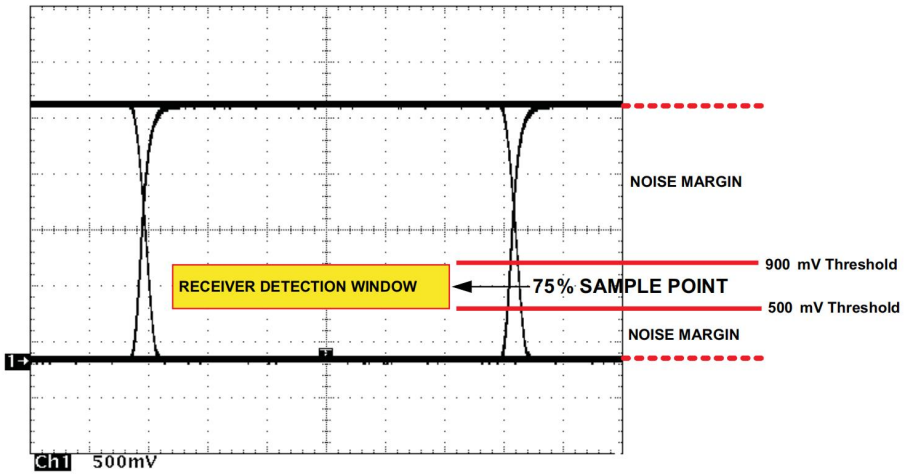


Figure 42. Typical XL65HVD230 Differential Output Voltage Waveform

The CAN driver creates the differential voltage between CANH and CANL in the dominant state. The dominant differential output of the XL65HVD23x is greater than 1.5 V and less than 3 V across a 60 ohm load as defined by the ISO 11898 standard. These are the same limiting values for 5 V supplied CAN transceivers. Typically, the bus termination resistors drive the bus back to the recessive bus state and not the CAN driver. A CAN receiver is required to output a recessive state when less than 500 mV of differential voltage exists on the bus, and a dominant state when more than 900 mV of differential voltage exists on the bus. The CAN receiver must do this with common-mode input voltages from -2 V to 7 volts per the ISO 11898-2 standard. The XL65HVD23x family receivers meet these same input specifications as 5 V supplied receivers.

8.3.1.2.1. 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. Since the bias voltage of the recessive state of the device is dependent on VCC, any noise present or variation of VCC will have an effect on this bias voltage seen by the bus. The XL65HVD23x family has the recessive bias voltage set higher than 0.5*VCC to comply with the ISO 11898-2 CAN standard which states that the recessive bias voltage must be between 2 V and 3 V. The caveat to this is that the common mode voltage will drop by a couple hundred millivolts when driving a dominant bit on the bus. This means that there is a common mode shift between the dominant bit and recessive bit states of the device. While this is not ideal, this small variation in the driver common-mode output is rejected by differential receivers and does not effect data, signal noise margins or error rates

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

The 3.3 V supplied XL65HVD23x family of CAN transceivers are fully compatible with 5 V CAN transceivers. The differential output voltage is the same, the recessive common mode output bias is the same, and the receivers have the same input specifications. The only difference is in the dominant common mode output voltage is lower in 3.3 V CAN transceivers than with 5 V supplied transceiver (by a few hundred millivolts).

To help ensure the widest interoperability possible, the XL65HVD23x family has successfully passed the internationally recognized GIFT ICT conformance and interoperability testing for CAN transceivers which is shown in . Electrical interoperability does not always 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 full interchangeability. This comes only with thorough equipment testing.

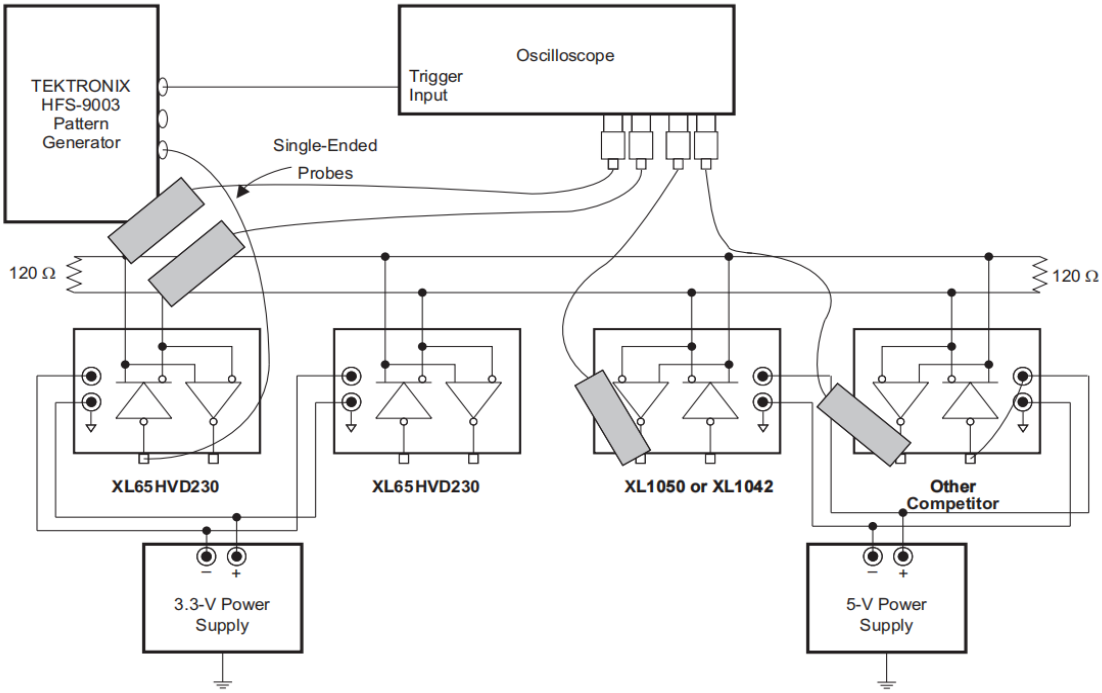


Figure 43. 3.3-V and 5-V CAN Transceiver System Testing

9. Power Supply Recommendations

The XL65HVD23x 3.3 V CAN transceivers provide the interface between the 3.3 V µPs, MCUs and DSPs and the differential bus lines, and are designed to transmit data at signaling rates up to 1 Mbps as defined by the ISO 11898 standard.

To ensure reliable operation at all data rates and supply voltages, the VCC supply pin of each CAN transceiver should be decoupled with a 100-nF ceramic capacitor located as close to the VCC and GND pins as possible. The 76333 is a linear voltage regulator suitable for supplying the 3.3-V supply

10. LAYOUT

10.1. Layout Guidelines

In order for the PCB design to be successful, start with design of the protection and filtering circuitry. Because ESD and EFT transients have a wide frequency bandwidth from approximately 3 MHz to 3 GHz, high frequency layout techniques must be applied during PCB design. On chip IEC ESD protection is good for laboratory and portable equipment but is usually not sufficient for EFT and surge transients occurring in industrial environments. Therefore robust and reliable bus node design requires the use of external transient protection devices at the bus connectors. Placement at the connector also prevents these harsh transient events from propagating further into the PCB and system.

Use V_{CC} and ground planes to provide low inductance. Note: high frequency current follows the path of least inductance and not the path of least resistance.

Design the bus protection components in the direction of the signal path. Do not force the transient current to divert from the signal path to reach the protection device.

An example placement of the Transient Voltage Suppression (TVS) device indicated as D1 (either bi-directional diode or varistor solution) and bus filter capacitors C8 and C9 are shown in .

The bus transient protection and filtering components should be placed as close to the bus connector, J1, as possible. This prevents transients, ESD and noise from penetrating onto the board and disturbing other devices.

Bus termination: Figure 44 shows split termination. This is where the termination is split into two resistors, R7 and R8, with the center or split tap of the termination connected to ground via capacitor C7. Split termination provides common mode filtering for the bus. When termination is placed on the board instead of directly on the bus, care must be taken to ensure the terminating node is not removed from the bus as this will cause signal integrity issues of the bus is not properly terminated on both ends. See the application section for information on power ratings needed for the termination resistor(s).

Bypass and bulk capacitors should be placed as close as possible to the supply pins of transceiver, examples C2, C3 (V_{CC}).

Use at least two vias for V_{CC} and ground connections of bypass capacitors and protection devices to minimize trace and via inductance.

To limit current of digital lines, serial resistors may be used. Examples are R1, R2, R3 and R4.

To filter noise on the digital IO lines, a capacitor may be used close to the input side of the IO as shown by C1 and C4.

Since the internal pull up and pull down biasing of the device is weak for floating pins, an external 1k to 10k ohm pull-up or down resistor should be used to bias the state of the pin more strongly against noise during transient events.

Pin 1: If an open drain host processor is used to drive the D pin of the device an external pull-up resistor between 1k and 10k ohms should be used to drive the recessive input state of the device (R1).

Pin 8: is shown assuming the mode pin, RS, will be used. If the device will only be used in normal mode or slope control mode, R3 is not needed and the pads of C4 could be used for the pull down resistor to GND.

Pin 5 in is shown for the XL65HVD230 and XL65HVD231 devices which have a V_{ref} output voltage reference. If used, this pin should be tied to the common mode point of the split termination. If this feature is not used, the pin can be left floating.

10.2. Layout Example

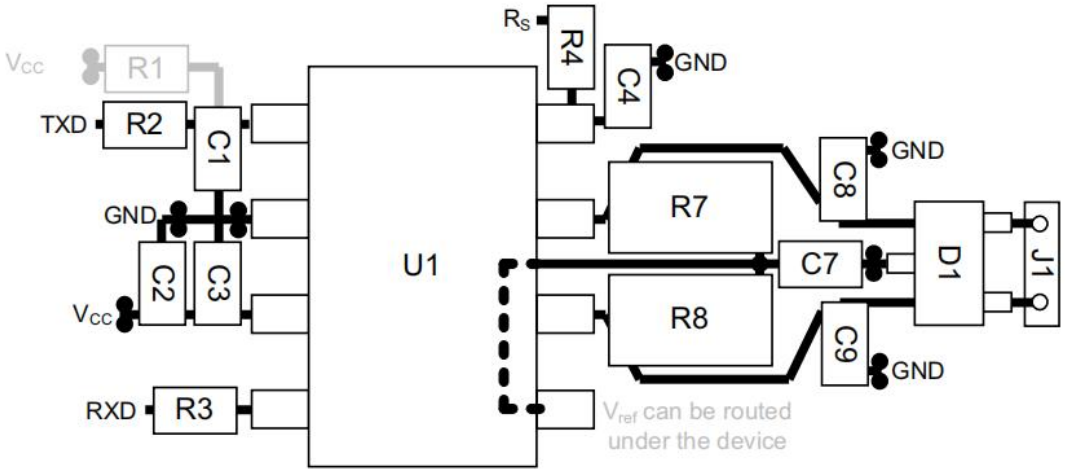


Figure 44. XL65HVD23x Board Layout

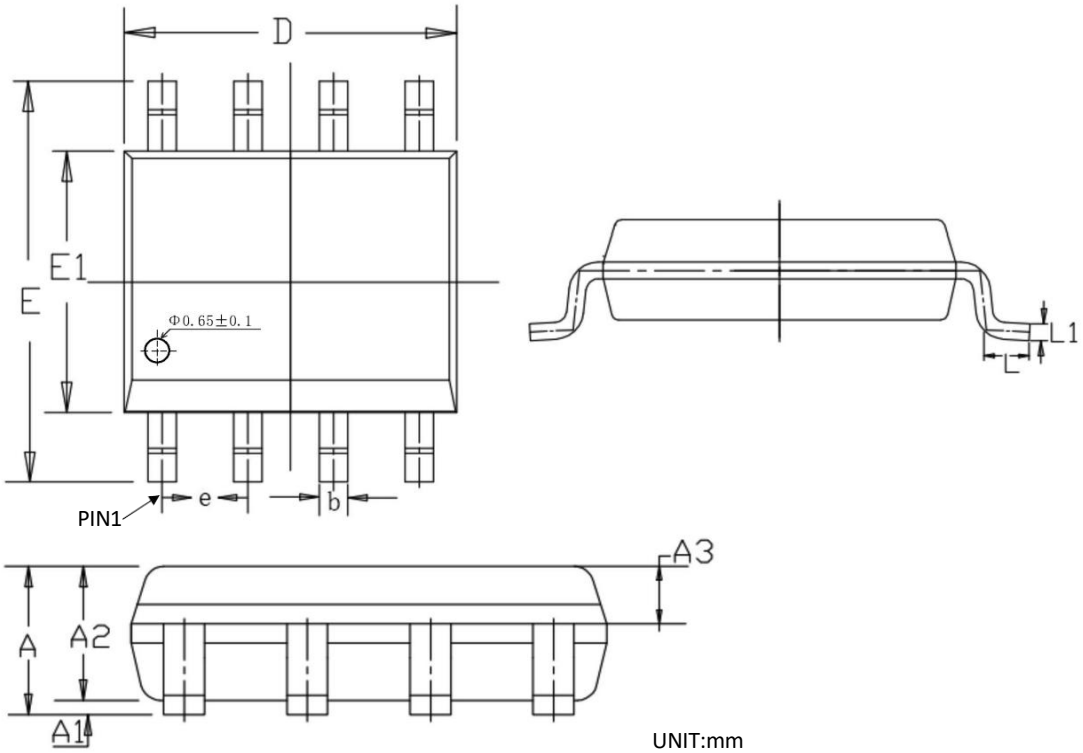
11. RDERING INFORMATION

Ordering Information

Part Number	Device Making	Package type	Body size (mm)	Temperate (℃)	MSL	Transport Media	Package Quantit
XL65HVD230DR	65HVD230	SOP-8	4.90*3.90	-40 to +85	MSL3	T&R	2500
XL65HVD231DR	65HVD231	SOP-8	4.90*3.90	-40 to +85	MSL3	T&R	2500

12. DIMENSIONAL DRAWINGS

SOP8



UNIT:mm

	MIN	NOM	MAX
A	1.450	1.550	1.650
A1	0.100	0.150	0.200
A2	1.300	1.400	1.500
A3	0.600	0.650	0.700
b	0.380	–	0.510
e	1.240	1.270	1.300
D	4.800	4.900	5.000
E	5.800	6.000	6.200
E1	3.800	3.900	4.000
L	0.450	0.600	0.750
L1	—	0.25BSC	—