



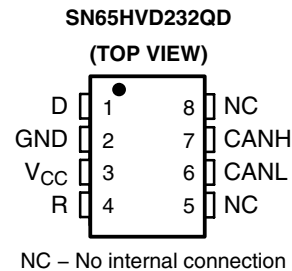
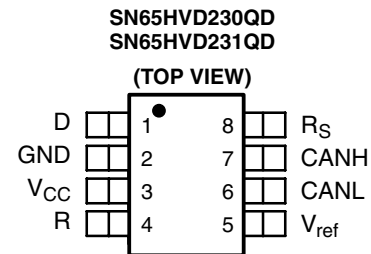
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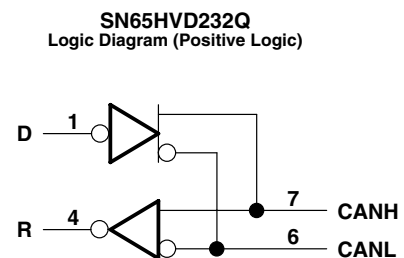
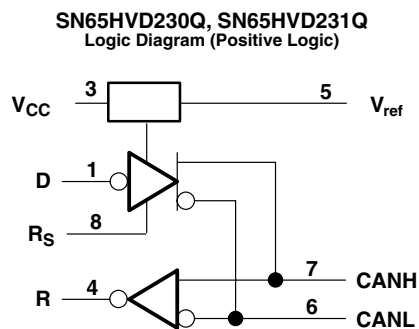
3.3-V CAN TRANSCEIVERS

FEATURES

- Qualified for Automotive Applications
- ESD Protection Exceeds 2000 V Per MIL-STD-883, Method 3015; Exceeds 200 V Using Machine Model (C = 200 pF, R = 0)
- Operates With a 3.3-V Supply
- Low Power Replacement for the PCA82C250 Footprint
- Bus/Pin ESD Protection Exceeds 15-kV HBM
- Controlled Driver Output Transition Times for Improved Signal Quality on the SN65HVD230Q and SN65HVD231Q
- Unpowered Node Does Not Disturb the Bus
- Compatible With the Requirements of the ISO 11898 Standard
- Low-Current SN65HVD230Q Standby Mode 370 μ A Typical
- Low-Current SN65HVD231Q Sleep Mode 0.1 μ A Typical
- Designed for Signaling Rates[‡] Up To 1 Megabit/Second (Mbps)
- Thermal Shutdown Protection
- Open-Circuit Fail-Safe Design



logic diagram (positive logic)



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

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

SN65HVD230Q-Q1
SN65HVD231Q-Q1
SN65HVD232Q-Q1

SGLS398A – APRIL 2002 – REVISED APRIL 2008

DESCRIPTION

The SN65HVD230Q, SN65HVD231Q, and SN65HVD232Q 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 SN65HVD230Q and SN65HVD231Q, R_S (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.

The circuit of the SN65HVD230Q enters a low-current standby mode during which the driver is switched off and the receiver remains active if a high logic level is applied to R_S (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 SN65HVD230Q and the SN65HVD231Q is that both the driver and the receiver are switched off in the SN65HVD231Q when a high logic level is applied to R_S (pin 8) and remain in this sleep mode until the circuit is reactivated by a low logic level on R_S.

The V_{ref} (pin 5 on the SN65HVD230Q and SN65HVD231Q) is available as a V_{CC}/2 voltage reference.

The SN65HVD232Q is a basic CAN transceiver with no added options; pins 5 and 8 are NC, no connection.

AVAILABLE OPTIONS†‡

| FUNCTION NUMBER | LOW POWER MODE | INTEGRATED SLOPE CONTROL | Vref PIN |
|-----------------|--------------------------|--------------------------|----------|
| '230 | 370-μA standby mode | Yes | Yes |
| '231 | 10-μA sleep mode | Yes | Yes |
| '232 | No standby or sleep mode | No | No |

| PART NUMBER | Q100 | T _A | MARKED AS: |
|----------------|------|----------------|------------|
| SN65HVD230QD | No | –40°C to 125°C | HV230Q |
| SN65HVD231QD | No | | HV231Q |
| SN65HVD232QD | No | | HV232Q |
| SN65HVD230QDQ1 | Yes | –40°C to 125°C | 230Q1 |
| SN65HVD231QDQ1 | Yes | | 231Q1 |
| SN65HVD232QDQ1 | Yes | | 232Q1 |

† For the most current package and ordering information, see the Package Option Addendum at the end of this document, or see the TI web site at <http://www.ti.com>.

‡ Package drawings, thermal data, and symbolization are available at <http://www.ti.com/packaging>.

The D package is available taped and reeled. Add the suffix R to device type (e.g., SN65HVD230QDRQ1).

Function Tables

DRIVER (SN65HVD230Q, SN65HVD231Q)

| INPUT D | R _S | OUTPUTS | | BUS STATE |
|---------|--|---------|------|-----------|
| | | CANH | CANL | |
| L | V _(RS) < 1.2 V | H | L | Dominant |
| H | | Z | Z | Recessive |
| Open | X | Z | Z | Recessive |
| X | V _(RS) > 0.75 V _{CC} | Z | Z | Recessive |

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

DRIVER (SN65HVD232Q)

| 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

RECEIVER (SN65HVD230Q)

| DIFFERENTIAL INPUTS | R _S | 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 |

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

RECEIVER (SN65HVD231Q)

| DIFFERENTIAL INPUTS | R _S | OUTPUT R |
|---------------------------------|--|----------|
| V _{ID} ≥ 0.9 V | V _(RS) < 1.2 V | L |
| 0.5 V < V _{ID} < 0.9 V | | ? |
| V _{ID} ≤ 0.5 V | | H |
| X | V _(RS) > 0.75 V _{CC} | H |
| X | 1.2 V < V _(RS) < 0.75 V _{CC} | ? |
| Open | X | H |

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

RECEIVER (SN65HVD232Q)

| DIFFERENTIAL INPUTS | OUTPUT R |
|---------------------------------|----------|
| V _{ID} ≥ 0.9 V | L |
| 0.5 V < V _{ID} < 0.9 V | ? |
| V _{ID} ≤ 0.5 V | H |
| Open | H |

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

Function Tables (Continued)

TRANSCEIVER MODES (SN65HVD230Q, SN65HVD231Q)

| $V_{(RS)}$ | OPERATING MODE |
|---|-------------------------------|
| $V_{(RS)} > 0.75 V_{CC}$ | Standby |
| 10 k Ω to 100 k Ω to ground | Slope control |
| $V_{(RS)} < 1 V$ | High speed (no slope control) |

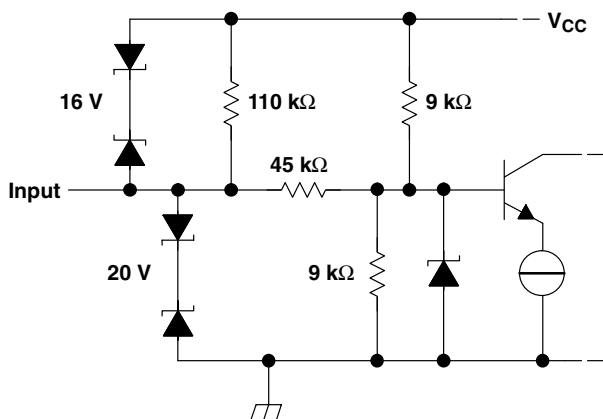
Terminal Functions

| SN65HVD230Q, SN65HVD231Q | | |
|--------------------------|-----|-----------------------|
| 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 _S | 8 | Standby/slope control |
| V _{CC} | 3 | Supply voltage |
| V _{ref} | 5 | Reference output |

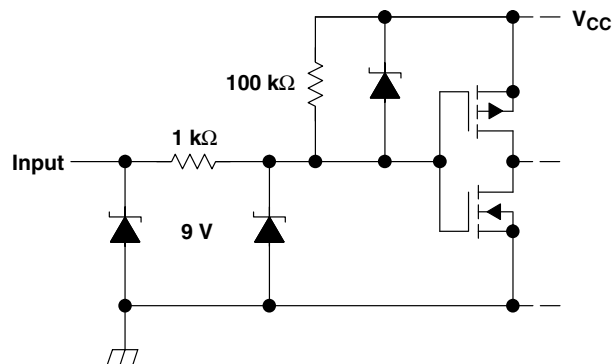
| SN65HVD232Q | | |
|-----------------|------|-----------------|
| TERMINAL NAME | NO. | DESCRIPTION |
| CANL | 6 | Low bus output |
| CANH | 7 | High bus output |
| D | 1 | Driver input |
| GND | 2 | Ground |
| NC | 5, 8 | No connection |
| R | 4 | Receiver output |
| V _{CC} | 3 | Supply voltage |

equivalent input and output schematic diagrams

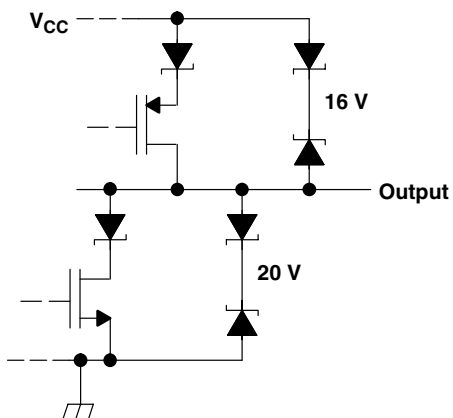
CANH and CANL Inputs



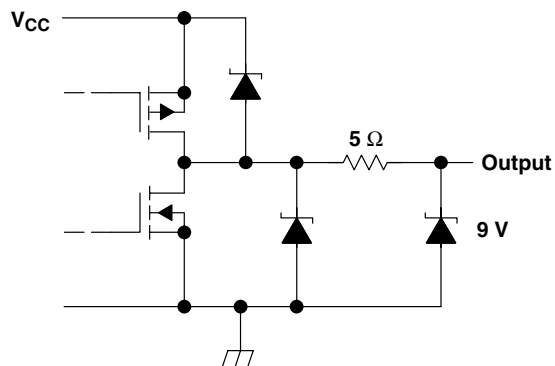
D Input



CANH and CANL Outputs



R Output



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

| PARAMETER | | | TEST CONDITIONS | | MIN | TYP† | MAX | UNIT | | |
|------------------------------------|------------------------------|-------------|--|--|-----------|------|-----------------|------|----|----|
| V _{OH} | Bus output voltage | Dominant | V _I = 0 V, See Figure 1 and Figure 3 | CANH | 2.45 | | V _{CC} | V | | |
| | | | | CANL | 0.5 | 1.25 | | | | |
| V _{OL} | | Recessive | V _I = 3 V, See Figure 1 and Figure 3 | CANH | | 2.3 | | | | |
| | | | | CANL | | 2.3 | | | | |
| V _{OD(D)} | Differential output voltage | Dominant | V _I = 0 V, See Figure 1 | | 1.5 | 2 | 3 | V | | |
| V _I = 0 V, See Figure 2 | | | | 1.2 | 2 | 3 | | | | |
| V _{OD(R)} | | Recessive | V _I = 3 V, See Figure 1 | | -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 current | | 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} | Supply current | Standby | SN65HVD230Q | V _(RS) = V _{CC} | 370 | | | 600 | μA | |
| | | Sleep | SN65HVD231Q | | 0.1 | | | | | |
| | | All devices | Dominant | V _I = 0 V, No load | Dominant | 10 | | | 17 | mA |
| | | | Recessive | V _I = V _{CC} , No load | Recessive | 10 | | | 17 | |

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

driver switching characteristics at T_A = 25°C (unless otherwise noted)

SN65HVD230Q and SN65HVD231Q

| 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 4 | 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 _{P(HL)} - t _{P(LH)}) | | 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 | | V _(RS) = 0 V | 40 | | | 55 | 80 | ns |
| t _r | Differential output signal rise time | | R _S with 10 kΩ to ground | 80 | | | 120 | 160 | ns |
| t _f | Differential output signal fall time | | R _S with 10 kΩ to ground | 80 | | | 125 | 150 | ns |
| t _r | Differential output signal rise time | | R _S with 100 kΩ to ground | 600 | | | 800 | 1200 | ns |
| t _f | Differential output signal fall time | | R _S with 100 kΩ to ground | 600 | | | 825 | 1000 | ns |

SN65HVD230Q-Q1
SN65HVD231Q-Q1
SN65HVD232Q-Q1

SGLS398A – APRIL 2002 – REVISED APRIL 2008

driver switching characteristics at $T_A = 25^\circ\text{C}$ (unless otherwise noted)

SN65HVD232Q

| PARAMETER | | TEST CONDITIONS | MIN | TYP | MAX | UNIT | |
|-------------|--|-------------------------------------|-----|-----|-----|------|----|
| t_{PLH} | Propagation delay time, low-to-high-level output | $C_L = 50\text{ pF}$, See Figure 4 | | 35 | 85 | ns | |
| t_{PHL} | Propagation delay time, high-to-low-level output | | | 70 | 120 | ns | |
| $t_{sk(p)}$ | Pulse skew ($ t_{P(HL)} - t_{P(LH)} $) | | | 35 | | ns | |
| t_r | Differential output signal rise time | | | 25 | 50 | 100 | ns |
| t_f | 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_{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 | $-6\text{ V} \leq V_{ID} \leq 500\text{ mV}$, $I_O = -8\text{ mA}$, See Figure 5 | 2.4 | | | V | |
| V_{OL} | Low-level output voltage | $900\text{ mV} \leq V_{ID} \leq 6\text{ V}$, $I_O = 8\text{ mA}$, See Figure 5 | | | 0.4 | | |
| I_I | Bus input current | $V_{IH} = 7\text{ V}$ | Other input at 0 V, $D = 3\text{ V}$ | 100 | 250 | μA | |
| | | $V_{IH} = 7\text{ V}$, $V_{CC} = 0\text{ V}$ | | 100 | 350 | | |
| | | $V_{IH} = -2\text{ V}$ | | -200 | -30 | μA | |
| | | $V_{IH} = -2\text{ V}$, $V_{CC} = 0\text{ V}$ | | -100 | -20 | | |
| C_i | CANH, CANL input capacitance | Pin-to-ground, $V_I = 0.4 \sin(4E6\pi t) + 0.5\text{ V}$ | $V_{(D)} = 3\text{ V}$, | 32 | | pF | |
| C_{diff} | Differential input capacitance | Pin-to-pin, $V_I = 0.4 \sin(4E6\pi t) + 0.5\text{ V}$ | $V_{(D)} = 3\text{ V}$, | 16 | | pF | |
| R_{diff} | Differential input resistance | Pin-to-pin, $V_{(D)} = 3\text{ V}$ | | 40 | 70 | 100 | $k\Omega$ |
| R_T | CANH, CANL input resistance | | | 20 | 35 | 50 | $k\Omega$ |
| I_{CC} | Supply current | See driver | | | | | |

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

receiver switching characteristics at $T_A = 25^\circ\text{C}$ (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|--------------|---|---|-----|-----|-----|------|
| t_{PLH} | Propagation delay time, low-to-high-level output | See Figure 6 | | 35 | 50 | ns |
| t_{PHL} | Propagation delay time, high-to-low-level output | | | 35 | 50 | ns |
| $t_{sk(p)}$ | Pulse skew ($ t_{P(HL)} - t_{P(LH)} $) | | | | 10 | ns |
| t_r | Output signal rise time | See Figure 6 | | 1.5 | | ns |
| t_f | Output signal fall time | | | 1.5 | | ns |
| $t_{(loop)}$ | Total loop delay, driver input to receiver output | $V_{(RS)} = 0\text{ V}$ | | 70 | 135 | ns |
| $t_{(loop)}$ | Total loop delay, driver input to receiver output | R_S with $10\text{ k}\Omega$ to ground | | 105 | 175 | |
| $t_{(loop)}$ | Total loop delay, driver input to receiver output | R_S with $100\text{ k}\Omega$ to ground | | 535 | 920 | |

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

| PARAMETER | | TEST CONDITIONS | MIN | TYP† | MAX | UNIT |
|--------------|---|---|---------------|------|---------------|---------------|
| $t_{(WAKE)}$ | SN65HVD230Q wake-up time from standby mode with R_S | See Figure 8 | | 0.55 | 1.5 | μS |
| | SN65HVD231Q wake-up time from sleep mode with R_S | | | | 3 | μS |
| V_{ref} | Reference output voltage | $-5 \mu\text{A} < I_{(Vref)} < 5 \mu\text{A}$ | $0.45 V_{CC}$ | | $0.55 V_{CC}$ | V |
| | | $-50 \mu\text{A} < I_{(Vref)} < 50 \mu\text{A}$ | $0.4 V_{CC}$ | | $0.6 V_{CC}$ | |
| $I_{(RS)}$ | Input current for high-speed | $V_{(RS)} < 1 \text{ V}$ | -450 | | 0 | μA |

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

PARAMETER MEASUREMENT INFORMATION

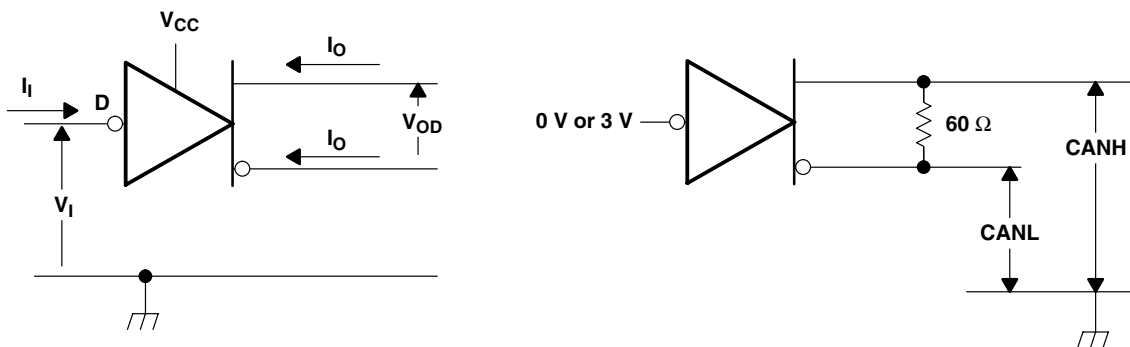


Figure 1. Driver Voltage and Current Definitions

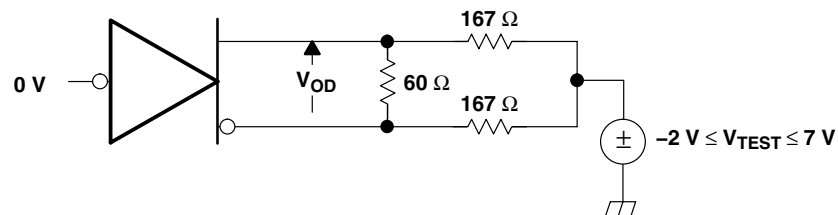


Figure 2. Driver V_{OD}

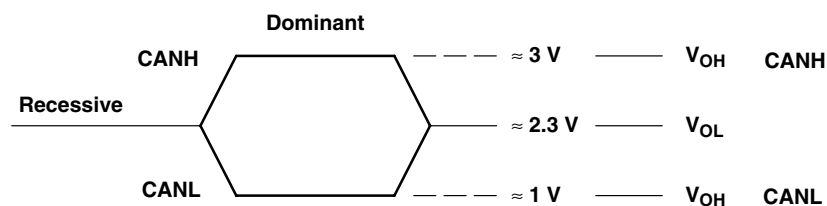
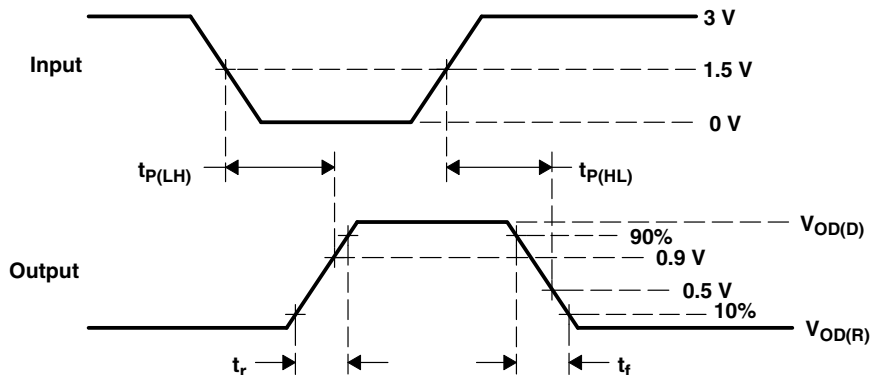
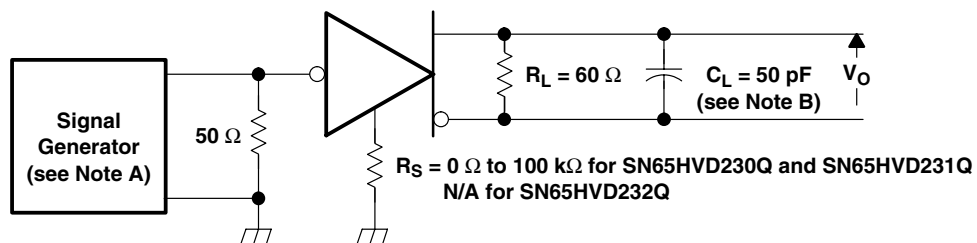


Figure 3. Driver Output Voltage Definitions

PARAMETER MEASUREMENT INFORMATION



- 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, $Z_o = 50 \Omega$.
 B. C_L includes probe and jig capacitance.

Figure 4. Driver Test Circuit and Voltage Waveforms

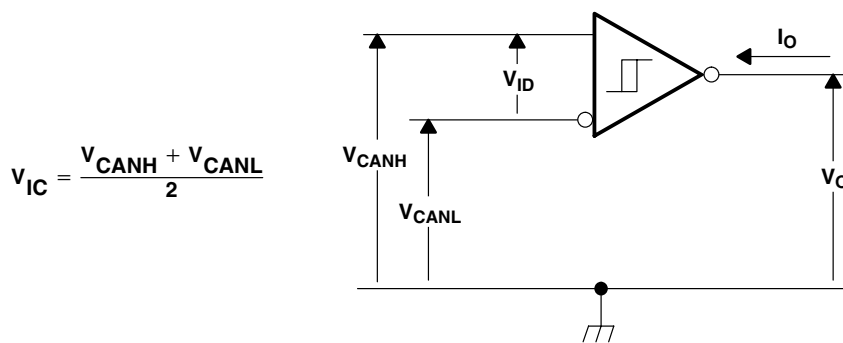
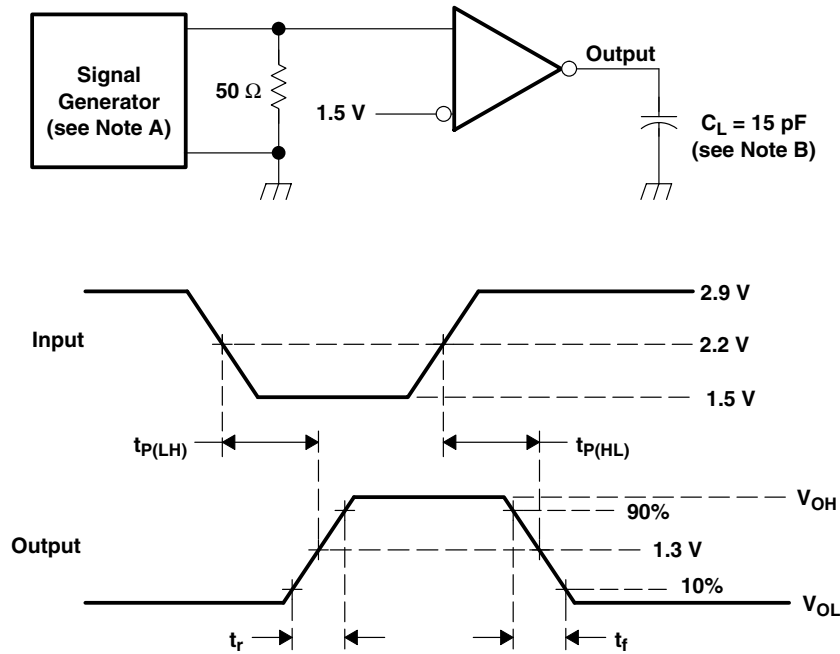


Figure 5. Receiver Voltage and Current Definitions

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, $Z_o = 50 \Omega$.
 B. C_L includes probe and jig capacitance.

Figure 6. Receiver Test Circuit and Voltage Waveforms

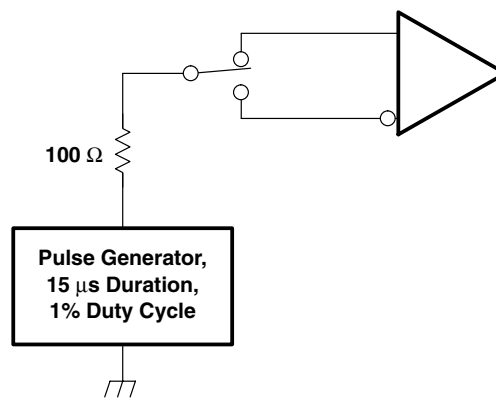


Figure 7. Overvoltage Protection

PARAMETER MEASUREMENT INFORMATION

Table 1. Receiver Characteristics Over Common Mode With V(RS) at 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 | |

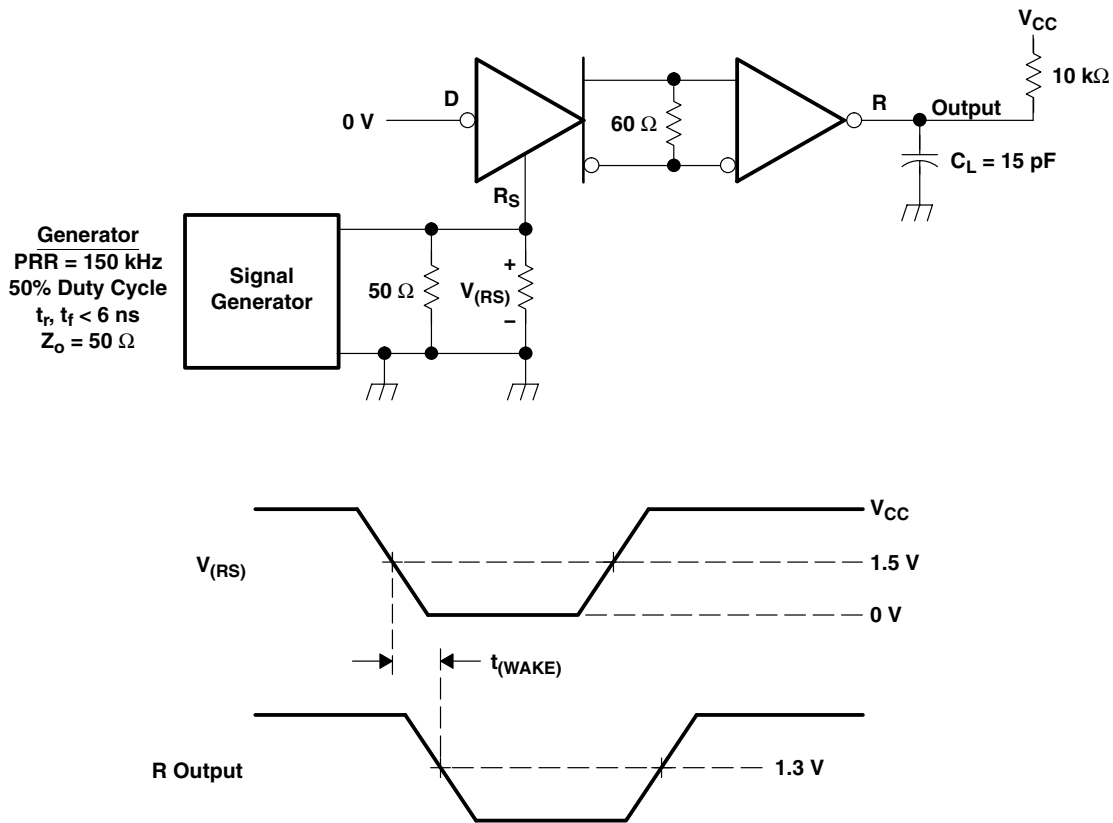


Figure 8. $t_{(WAKE)}$ Test Circuit and Voltage Waveforms

TYPICAL CHARACTERISTICS

SUPPLY CURRENT (RMS)
 vs
 FREQUENCY

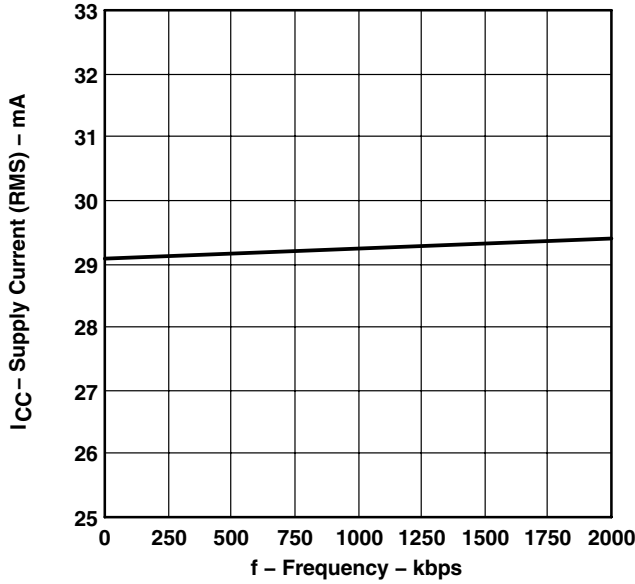


Figure 9

LOGIC INPUT CURRENT (D PIN)
 vs
 INPUT VOLTAGE

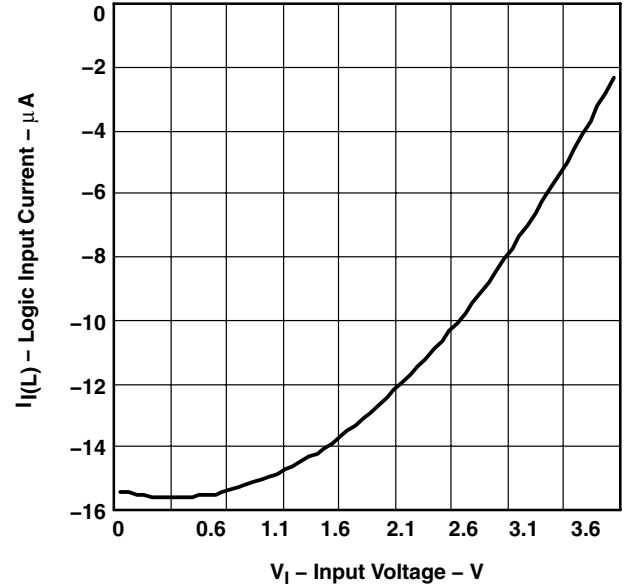


Figure 10

BUS INPUT CURRENT
 vs
 BUS INPUT VOLTAGE

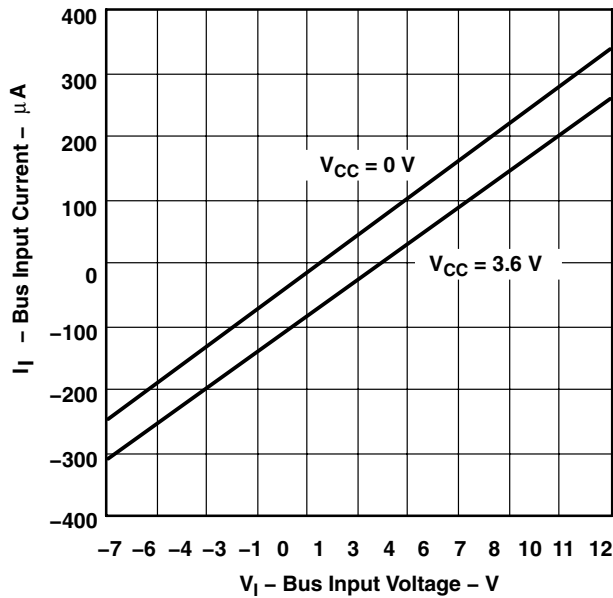


Figure 11

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

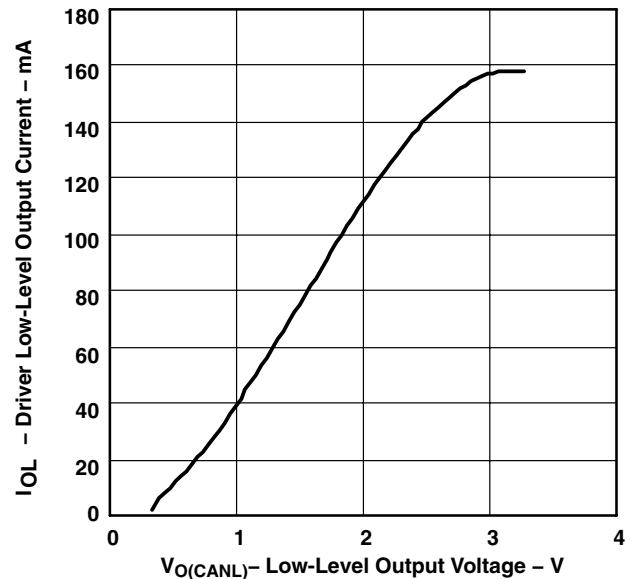


Figure 12

TYPICAL CHARACTERISTICS

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

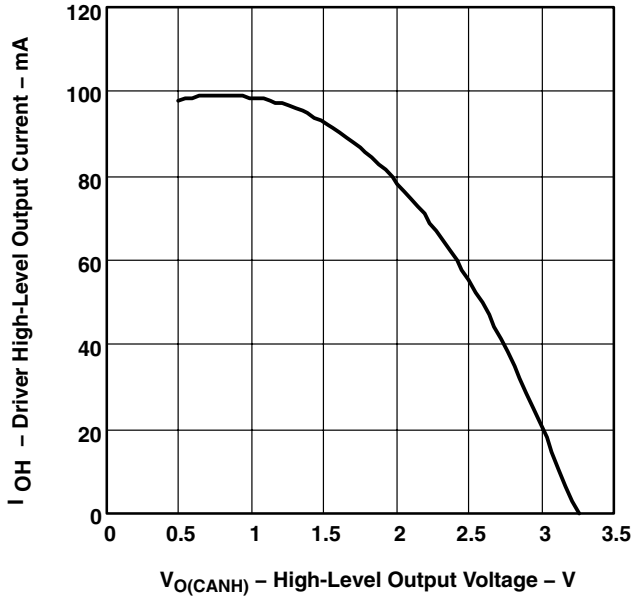


Figure 13

DOMINANT VOLTAGE (VOD)
 vs
 FREE-AIR TEMPERATURE

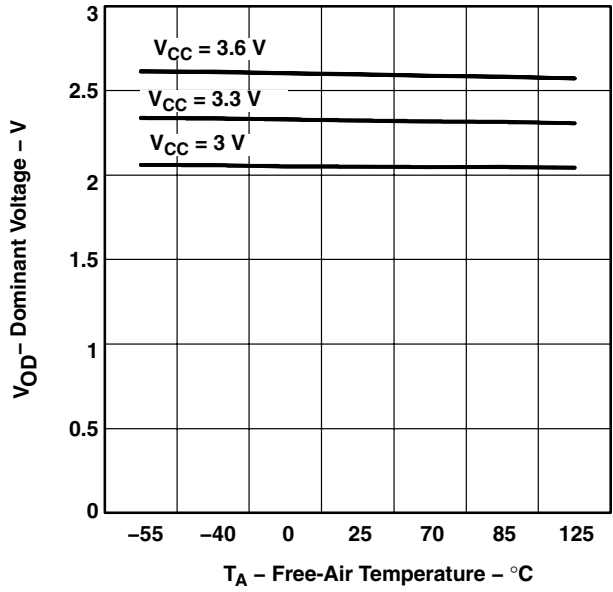


Figure 14

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

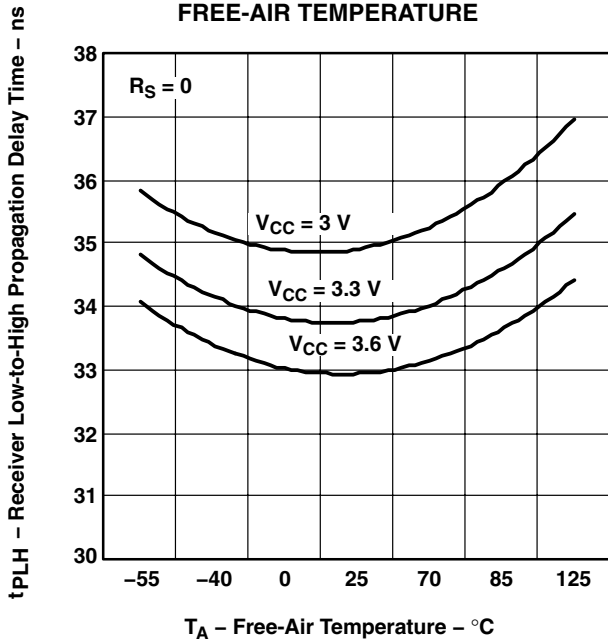


Figure 15

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

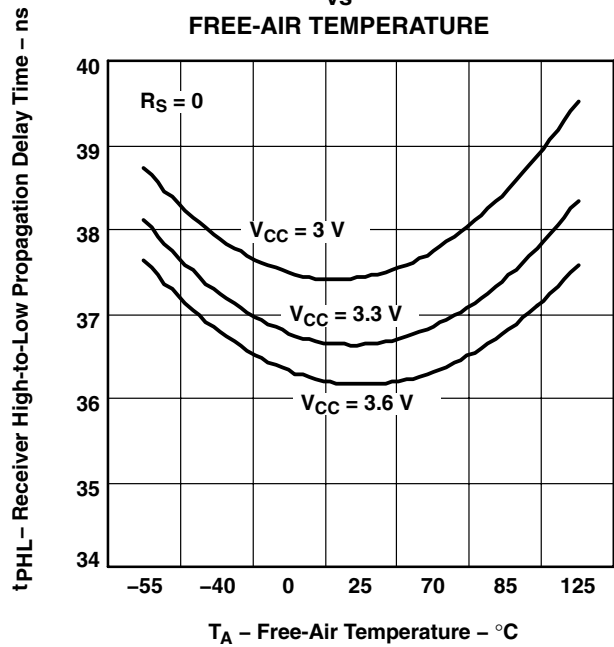


Figure 16

TYPICAL CHARACTERISTICS

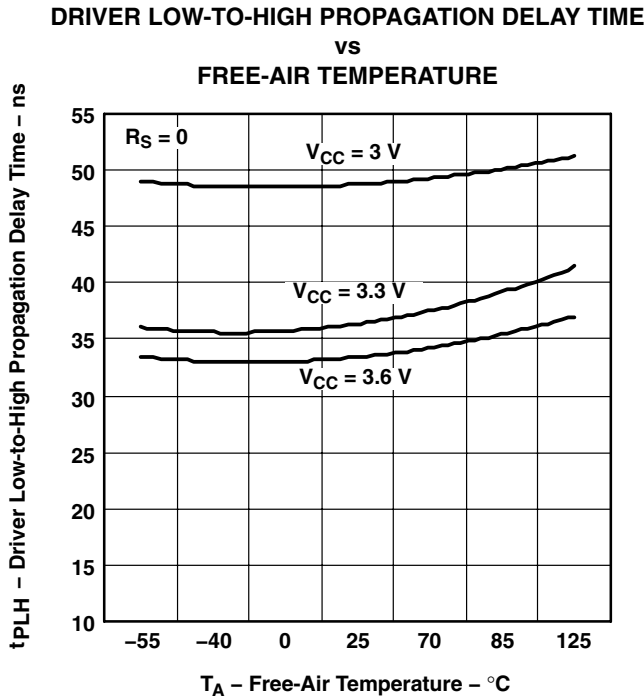


Figure 17

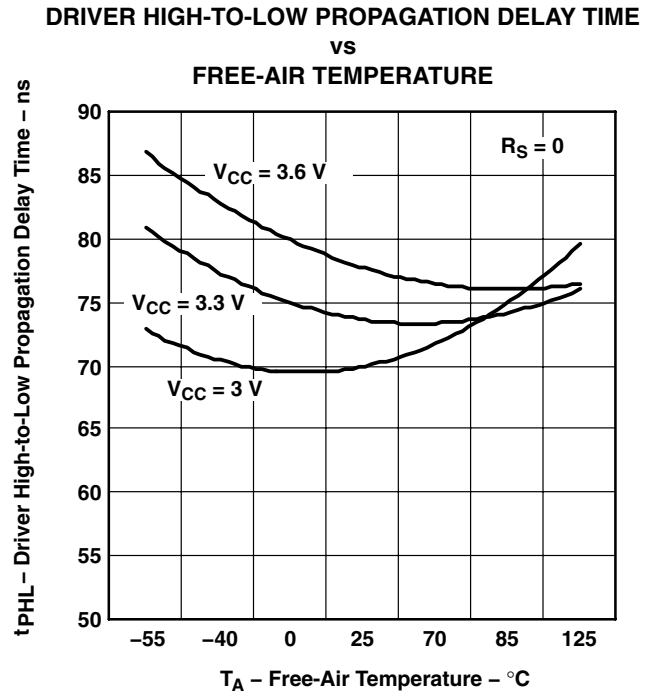


Figure 18

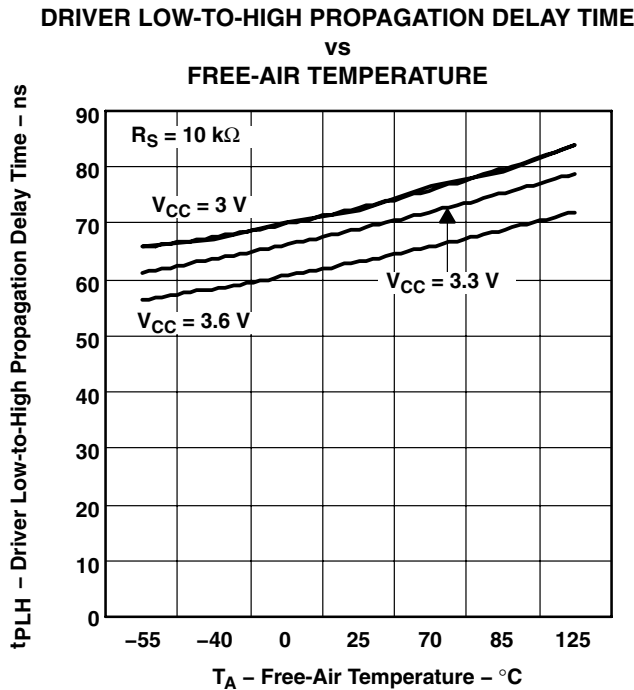


Figure 19

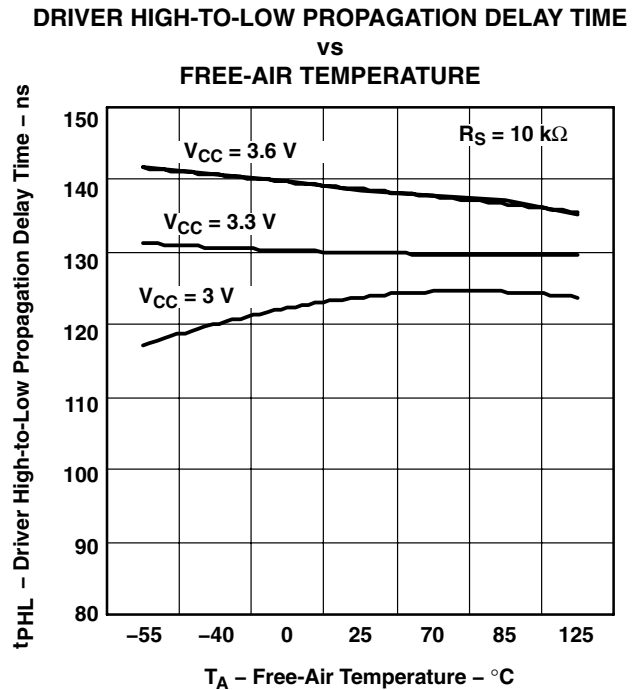


Figure 20

TYPICAL CHARACTERISTICS

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

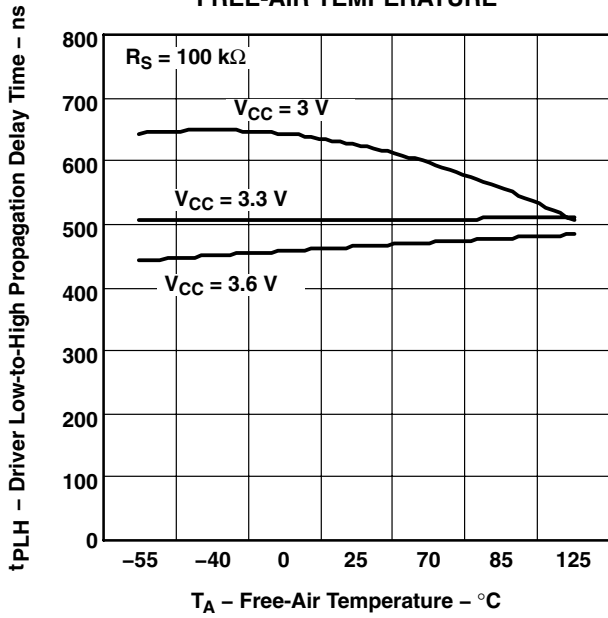


Figure 21

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

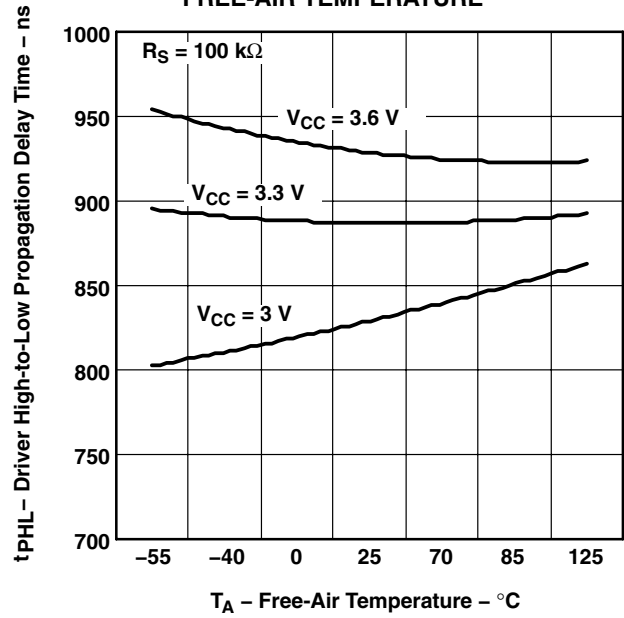


Figure 22

DRIVER OUTPUT CURRENT
 vs
 SUPPLY VOLTAGE

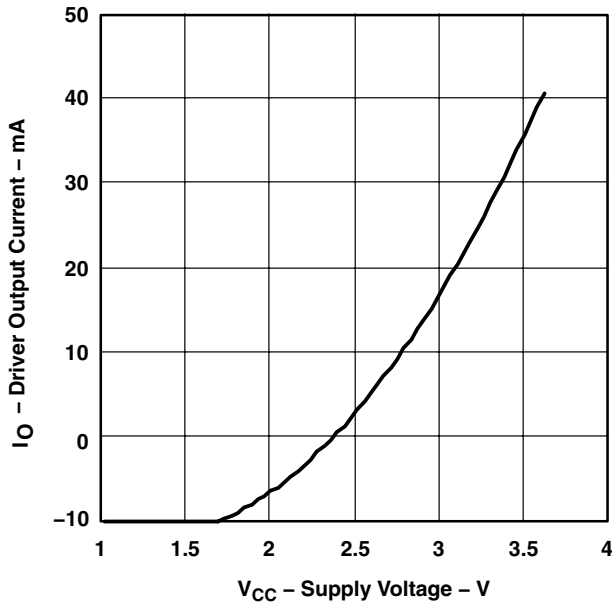


Figure 23

DIFFERENTIAL DRIVER OUTPUT FALL TIME
 vs Source Resistance (RS)

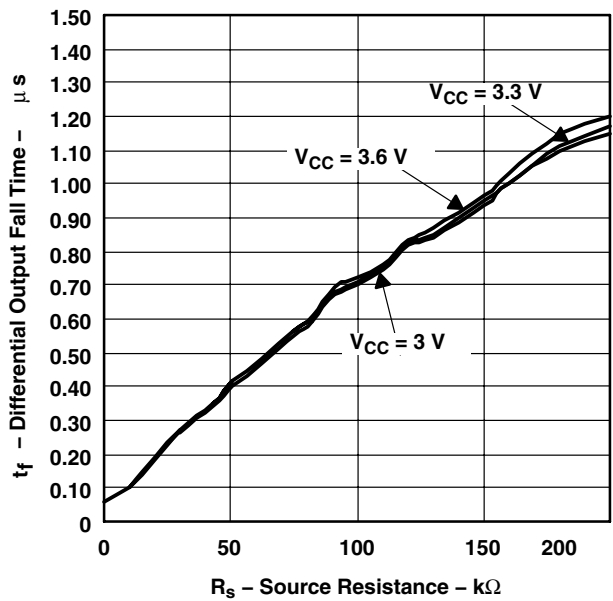


Figure 24

TYPICAL CHARACTERISTICS

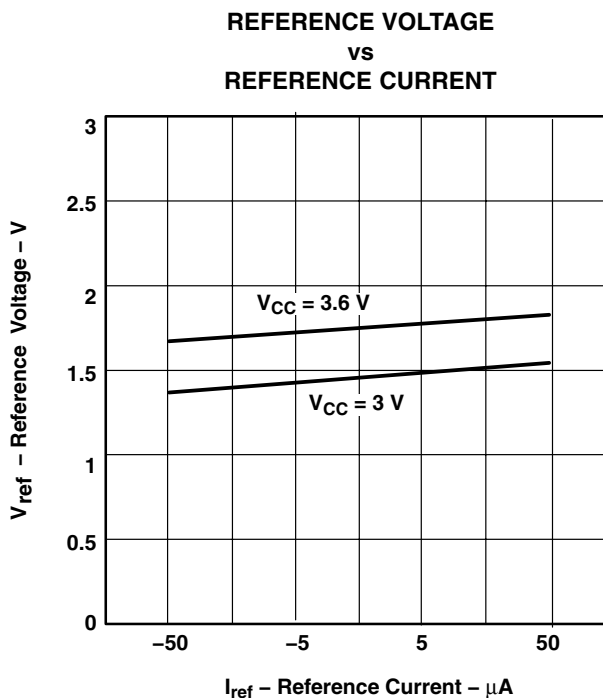


Figure 25

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 SN65HVD230Q 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 26.

APPLICATION INFORMATION

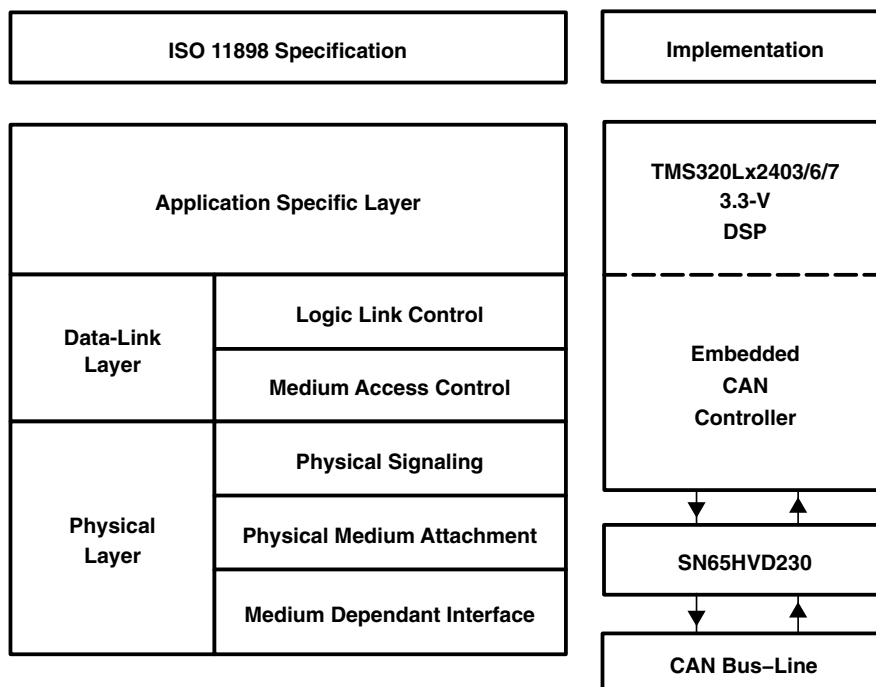


Figure 26. The Layered ISO 11898 Standard Architecture

The SN65HVD230Q family of CAN transceivers are compatible with the ISO 11898 standard; this ensures interoperability with other standard-compliant products.

application of the SN65HVD230Q

Figure 27 illustrates a typical application of the SN65HVD230Q 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 28. 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

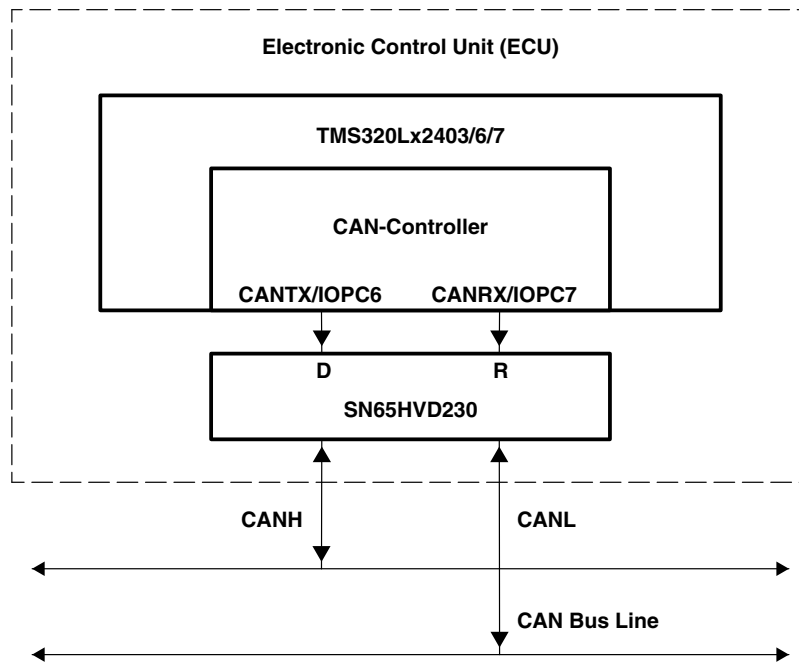


Figure 27. Details of a Typical CAN Node

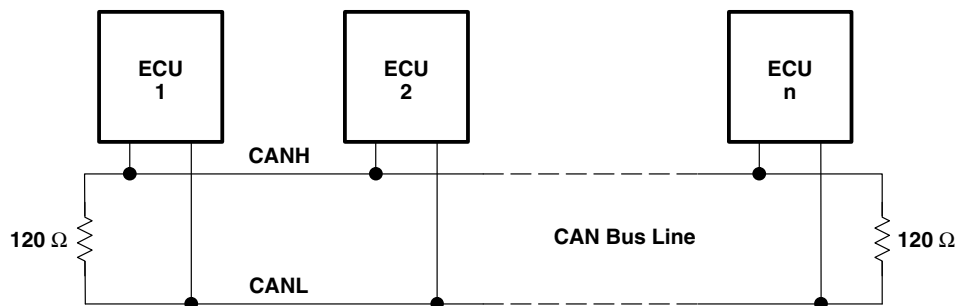


Figure 28. Typical CAN Network

The SN65HVD230Q/231Q/232Q 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 SN65HVD230Q, SN65HVD231Q, and SN65HVD232Q

The SN65HVD230Q/231Q/232Q 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 failsafe 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 SN65HVD230Q, SN65HVD231Q, and SN65HVD232Q (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 will 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 SN65HVD230Q and SN65HVD231Q provides for three different modes of operation: high-speed mode, slope-control mode, and low-power standby mode.

high-speed mode

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 mode operation, and the logic-high level ($> 0.75\text{ V}_{CC}$) for standby mode operation. Figure 29 shows a typical DSP connection, and Figure 30 shows the SN65HVD230Q driver output signal in high-speed mode on the CAN bus.

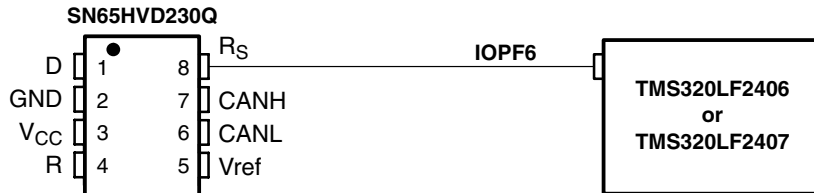


Figure 29. R_S (Pin 8) Connection to a TMS320LF2406/07 for High-Speed or Standby Mode Operation

APPLICATION INFORMATION

high-speed mode (continued)

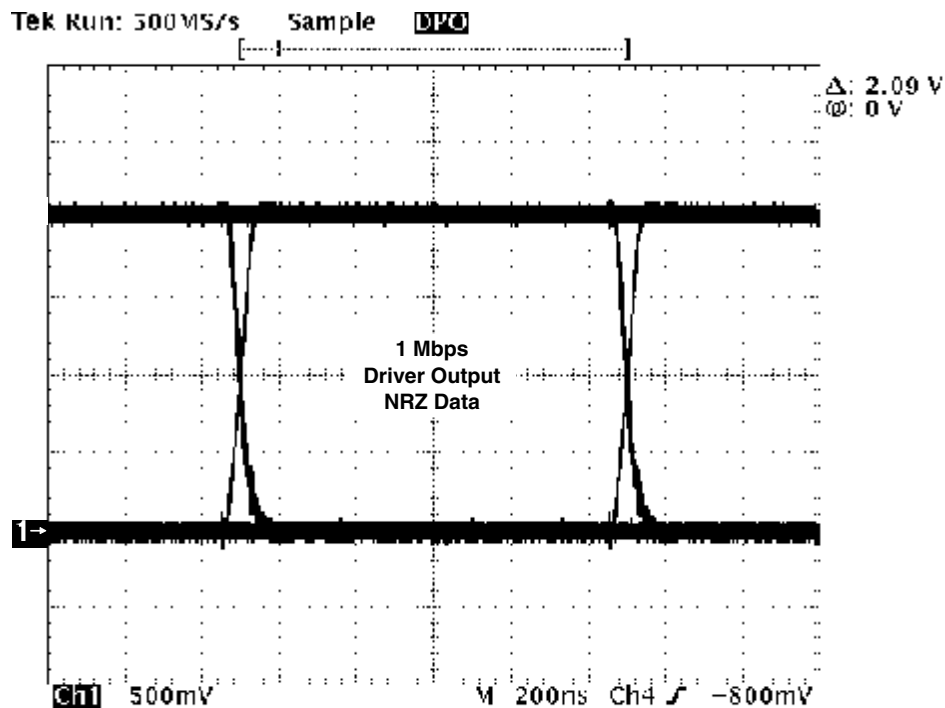


Figure 30. Typical SN65HVD230Q High-Speed Mode Output Waveform Into a 60-Ω Load

slope-control mode

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 SN65HVD230Q and SN65HVD231Q 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 31. 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 32. Typical driver output waveforms from a pulse input signal with and without slope control are displayed in Figure 33. A pulse input is used rather than NRZ data to clearly display the actual slew rate.

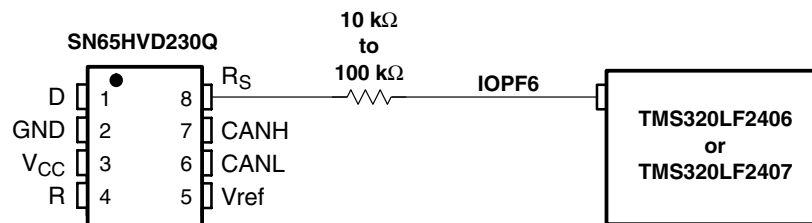


Figure 31. Slope-Control or Standby Mode Connection to a DSP

APPLICATION INFORMATION

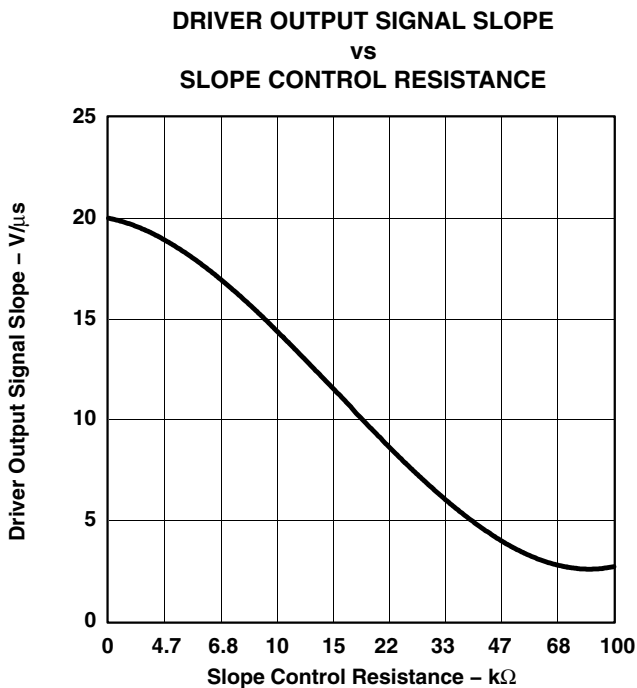


Figure 32. SN65HVD230Q Driver Output Signal Slope vs Slope Control Resistance Value

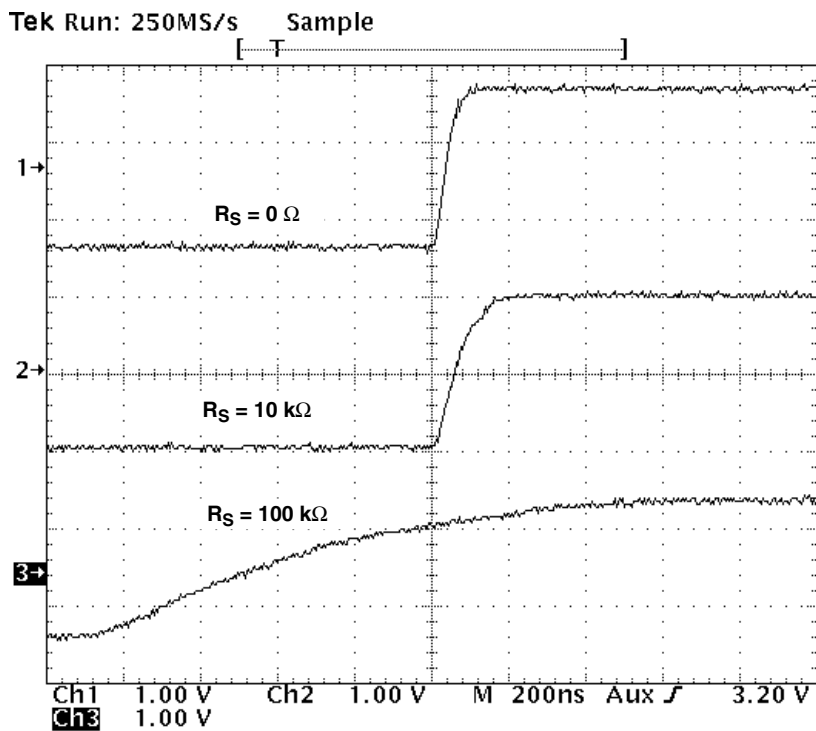


Figure 33. Typical SN65HVD230Q 250-kbps Output Pulse Waveforms With Slope Control

APPLICATION INFORMATION

standby mode (listen only mode) of the SN65HVD230Q

If a logic high ($> 0.75 V_{CC}$) is applied to R_S (pin 8) in Figures 29 and 31, the circuit of the SN65HVD230Q 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 31. 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 SN65HVD231Q

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 SN65HVD231Q

The unique difference between the SN65HVD230Q and the SN65HVD231Q is that both driver and receiver are switched off in the SN65HVD231Q 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 34 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 ≈ 100 ns when employing slope control with a 10-k Ω resistor, and ≈ 500 ns with a 100-k Ω resistor. Therefore, considering that the rule-of-thumb propagation delay of typical bus cable is 5 ns/m, slope control with the 100-k Ω 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 $(500 - 70.7) / 5$ 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 high-quality shielded bus cable.

APPLICATION INFORMATION

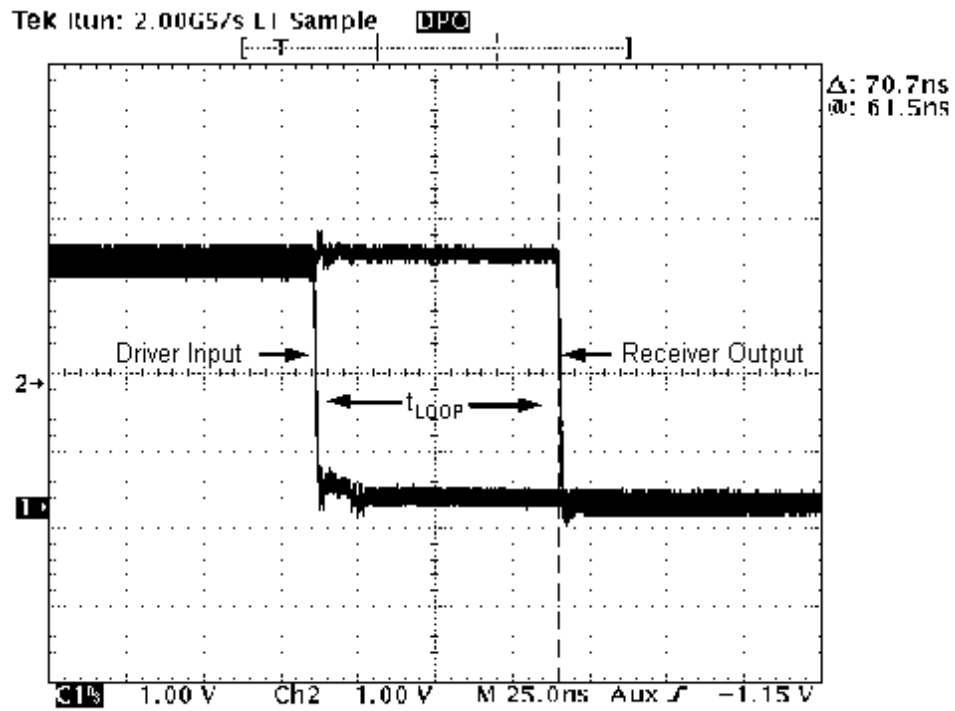


Figure 34. 70.7-ns Loop Delay Through the SN65HVD230Q With $R_S = 0$

APPLICATION INFORMATION

interoperability with 5-V CAN systems

It is essential that the 3.3-V SN65HVD230Q family performs seamlessly with 5-V transceivers because of the large number of 5-V devices installed. Figure 35 displays a test bus of a 3.3-V node with the SN65HVD230Q, and three 5-V nodes: one for each of TI's SN65LBC031 and UC5350 transceivers, and one using a competitor X250 transceiver.

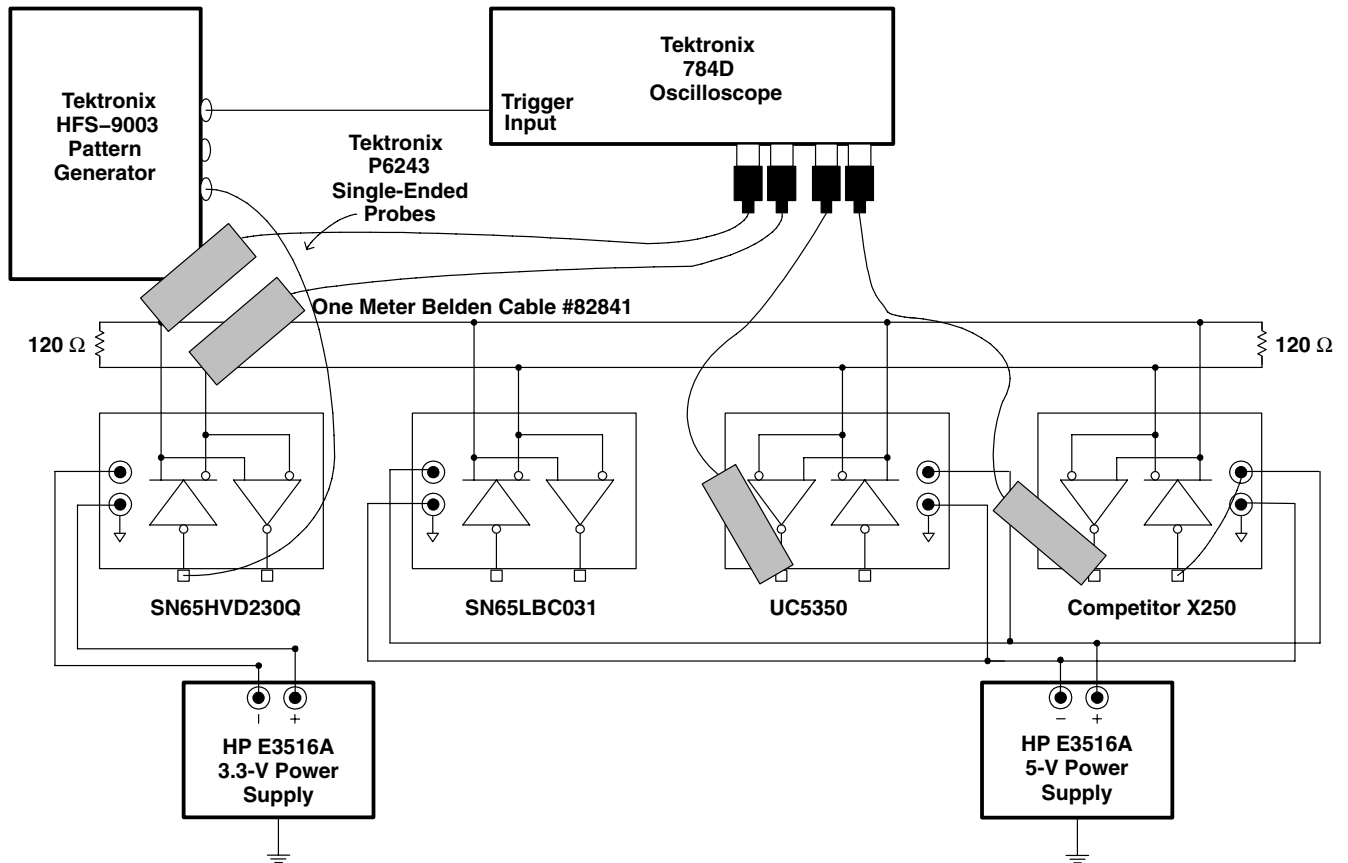


Figure 35. 3.3-V/5-V CAN Transceiver Test Bed

APPLICATION INFORMATION

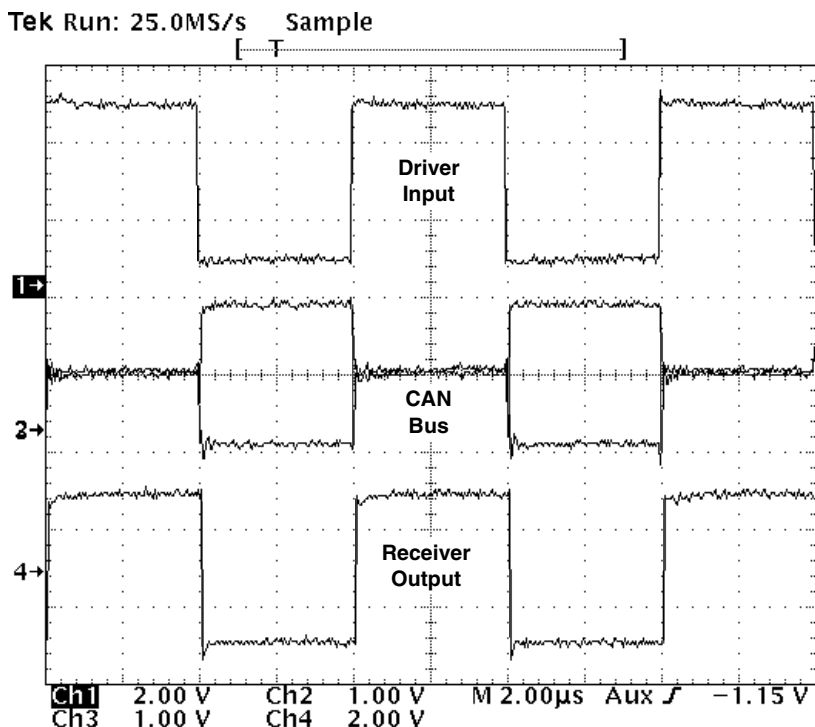


Figure 36. SN65HVD230Q's Input, CAN Bus, and X250's RXD Output Waveforms

Figure 36 displays the SN65HVD230Q'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 35 to the SN65HVD230Q 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 36 displays the 250-kbps pulse input waveform to the SN65HVD230Q 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.

PACKAGING INFORMATION

| Orderable Device | Status (1) | Package Type | Package Drawing | Pins | Package Qty | Eco Plan (2) | Lead finish/ Ball material (6) | MSL Peak Temp (3) | Op Temp (°C) | Device Marking (4/5) | Samples |
|-------------------|---------------|--------------|-----------------|------|-------------|-----------------|--------------------------------------|----------------------|--------------|-------------------------|-------------------------|
| SN65HVD230QDG4Q1 | ACTIVE | SOIC | D | 8 | 75 | RoHS & Green | NIPDAU | Level-1-260C-UNLIM | -40 to 125 | 230Q1 | Samples |
| SN65HVD230QDR | ACTIVE | SOIC | D | 8 | 2500 | RoHS & Green | NIPDAU | Level-1-260C-UNLIM | -40 to 125 | HV230Q | Samples |
| SN65HVD230QDRG4Q1 | ACTIVE | SOIC | D | 8 | 2500 | RoHS & Green | NIPDAU | Level-1-260C-UNLIM | -40 to 125 | 230Q1 | Samples |
| SN65HVD231QD | ACTIVE | SOIC | D | 8 | 75 | RoHS & Green | NIPDAU | Level-1-260C-UNLIM | -40 to 125 | HV231Q | Samples |
| SN65HVD231QDG4 | ACTIVE | SOIC | D | 8 | 75 | RoHS & Green | NIPDAU | Level-1-260C-UNLIM | -40 to 125 | HV231Q | Samples |
| SN65HVD231QDR | ACTIVE | SOIC | D | 8 | 2500 | RoHS & Green | NIPDAU | Level-1-260C-UNLIM | -40 to 125 | HV231Q | Samples |
| SN65HVD231QDRG4Q1 | ACTIVE | SOIC | D | 8 | 2500 | RoHS & Green | NIPDAU | Level-1-260C-UNLIM | -40 to 125 | 231Q1 | Samples |
| SN65HVD231QDRQ1 | ACTIVE | SOIC | D | 8 | 2500 | RoHS & Green | NIPDAU | Level-1-260C-UNLIM | -40 to 125 | 231Q1 | Samples |
| SN65HVD232QD | ACTIVE | SOIC | D | 8 | 75 | RoHS & Green | NIPDAU | Level-1-260C-UNLIM | -40 to 125 | HV232Q | Samples |
| SN65HVD232QDG4 | ACTIVE | SOIC | D | 8 | 75 | RoHS & Green | NIPDAU | Level-1-260C-UNLIM | -40 to 125 | HV232Q | Samples |
| SN65HVD232QDR | ACTIVE | SOIC | D | 8 | 2500 | RoHS & Green | NIPDAU | Level-1-260C-UNLIM | -40 to 125 | HV232Q | Samples |
| SN65HVD232QDRG4 | ACTIVE | SOIC | D | 8 | 2500 | RoHS & Green | NIPDAU | Level-1-260C-UNLIM | -40 to 125 | HV232Q | Samples |
| SN65HVD232QDRG4Q1 | ACTIVE | SOIC | D | 8 | 2500 | RoHS & Green | NIPDAU | Level-1-260C-UNLIM | -40 to 125 | 232Q1 | Samples |
| SN65HVD232QDRQ1 | ACTIVE | SOIC | D | 8 | 2500 | RoHS & Green | NIPDAU | Level-1-260C-UNLIM | -40 to 125 | 232Q1 | Samples |

(1) The marketing status values are defined as follows:

ACTIVE: Product device recommended for new designs.

LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.

NRND: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.

PREVIEW: Device has been announced but is not in production. Samples may or may not be available.

OBSOLETE: TI has discontinued the production of the device.

(2) **RoHS:** TI defines "RoHS" to mean semiconductor products that are compliant with the current EU RoHS requirements for all 10 RoHS substances, including the requirement that RoHS substance do not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, "RoHS" products are suitable for use in specified lead-free processes. TI may reference these types of products as "Pb-Free".

RoHS Exempt: TI defines "RoHS Exempt" to mean products that contain lead but are compliant with EU RoHS pursuant to a specific EU RoHS exemption.

Green: TI defines "Green" to mean the content of Chlorine (Cl) and Bromine (Br) based flame retardants meet JS709B low halogen requirements of <=1000ppm threshold. Antimony trioxide based flame retardants must also meet the <=1000ppm threshold requirement.

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

(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

(5) Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

(6) Lead finish/Ball material - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.

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OTHER QUALIFIED VERSIONS OF SN65HVD230Q, SN65HVD230Q-Q1, SN65HVD231Q, SN65HVD231Q-Q1, SN65HVD232Q, SN65HVD232Q-Q1 :

● Catalog : [SN65HVD230Q](#), [SN65HVD231Q](#), [SN65HVD232Q](#)

● Automotive : [SN65HVD230Q-Q1](#), [SN65HVD231Q-Q1](#), [SN65HVD232Q-Q1](#)

NOTE: Qualified Version Definitions:

● Catalog - TI's standard catalog product

● Automotive - Q100 devices qualified for high-reliability automotive applications targeting zero defects

TAPE AND REEL INFORMATION

QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE


*All dimensions are nominal

| Device | Package Type | Package Drawing | Pins | SPQ | Reel Diameter (mm) | Reel Width W1 (mm) | A0 (mm) | B0 (mm) | K0 (mm) | P1 (mm) | W (mm) | Pin1 Quadrant |
|---------------|--------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| SN65HVD230QDR | SOIC | D | 8 | 2500 | 330.0 | 12.5 | 6.4 | 5.2 | 2.1 | 8.0 | 12.0 | Q1 |
| SN65HVD231QDR | SOIC | D | 8 | 2500 | 330.0 | 12.5 | 6.4 | 5.2 | 2.1 | 8.0 | 12.0 | Q1 |
| SN65HVD232QDR | SOIC | D | 8 | 2500 | 330.0 | 12.5 | 6.4 | 5.2 | 2.1 | 8.0 | 12.0 | Q1 |

TAPE AND REEL BOX DIMENSIONS


*All dimensions are nominal

| Device | Package Type | Package Drawing | Pins | SPQ | Length (mm) | Width (mm) | Height (mm) |
|---------------|--------------|-----------------|------|------|-------------|------------|-------------|
| SN65HVD230QDR | SOIC | D | 8 | 2500 | 340.5 | 338.1 | 20.6 |
| SN65HVD231QDR | SOIC | D | 8 | 2500 | 340.5 | 338.1 | 20.6 |
| SN65HVD232QDR | SOIC | D | 8 | 2500 | 340.5 | 338.1 | 20.6 |

TUBE


*All dimensions are nominal

| Device | Package Name | Package Type | Pins | SPQ | L (mm) | W (mm) | T (μm) | B (mm) |
|------------------|--------------|--------------|------|-----|--------|--------|--------|--------|
| SN65HVD230QDG4Q1 | D | SOIC | 8 | 75 | 507 | 8 | 3940 | 4.32 |
| SN65HVD231QD | D | SOIC | 8 | 75 | 507 | 8 | 3940 | 4.32 |
| SN65HVD231QDG4 | D | SOIC | 8 | 75 | 507 | 8 | 3940 | 4.32 |
| SN65HVD232QD | D | SOIC | 8 | 75 | 507 | 8 | 3940 | 4.32 |
| SN65HVD232QDG4 | D | SOIC | 8 | 75 | 507 | 8 | 3940 | 4.32 |



D0008A

PACKAGE OUTLINE

SOIC - 1.75 mm max height

SMALL OUTLINE INTEGRATED CIRCUIT



NOTES:

1. Linear dimensions are in inches [millimeters]. Dimensions in parenthesis are for reference only. Controlling dimensions are in inches. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed $.006$ [0.15] per side.
4. This dimension does not include interlead flash.
5. Reference JEDEC registration MS-012, variation AA.

EXAMPLE BOARD LAYOUT

D0008A

SOIC - 1.75 mm max height

SMALL OUTLINE INTEGRATED CIRCUIT



LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE:8X



SOLDER MASK DETAILS

4214825/C 02/2019

NOTES: (continued)

- 6. Publication IPC-7351 may have alternate designs.
- 7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.

EXAMPLE STENCIL DESIGN

D0008A

SOIC - 1.75 mm max height

SMALL OUTLINE INTEGRATED CIRCUIT



SOLDER PASTE EXAMPLE
BASED ON .005 INCH [0.125 MM] THICK STENCIL
SCALE:8X

4214825/C 02/2019

NOTES: (continued)

8. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
9. Board assembly site may have different recommendations for stencil design.

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