



SN65HVD1050 EMC Optimized CAN Bus Transceiver

1 Features

- Improved Replacement for the TJA1050
- High Electromagnetic Immunity (EMI)
- Very Low Electromagnetic Emissions (EME)
- Meets or Exceeds the Requirements of ISO 11898-2
- CAN Bus-Fault Protection of -27 V to 40 V
- Dominant Time-Out Function
- Power-Up and Power-Down Glitch-Free CAN Bus Inputs and Outputs
 - High Input Impedance With Low V_{CC}
 - Monotonic Outputs During Power Cycling

2 Applications

- Industrial Automation
 - DeviceNet™ Data Buses (Vendor ID #806)
- SAE J2284 High-Speed CAN Bus for Automotive Applications
- SAE J1939 Standard Data Bus Interface
- ISO 11783 Standard Data Bus Interface
- NMEA 2000 Standard Data Bus Interface

3 Description

The SN65HVD1050 meets or exceeds the specifications of the ISO 11898 standard for use in applications employing a Controller Area Network (CAN).

As a CAN transceiver, this device provides differential transmit capability to the bus and differential receive capability to a CAN controller at signaling rates up to 1 megabit per second (Mbps) ⁽¹⁾.

The SN65HVD1050 is designed for operation in especially harsh environments. As a result, the device features cross-wire, overvoltage and loss of ground protection from -27 V to 40 V , overtemperature shutdown, a -12 V to 12 V common-mode range, and will withstand voltage transients from -200 V to 200 V according to ISO 7637.

Device Information⁽¹⁾

| PART NUMBER | PACKAGE | BODY SIZE (NOM) |
|-------------|----------|-------------------|
| SN65HVD1050 | SOIC (8) | 4.90 mm x 3.91 mm |

(1) For all available packages, see the orderable addendum at the end of the data sheet.

(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)

Functional Block Diagram

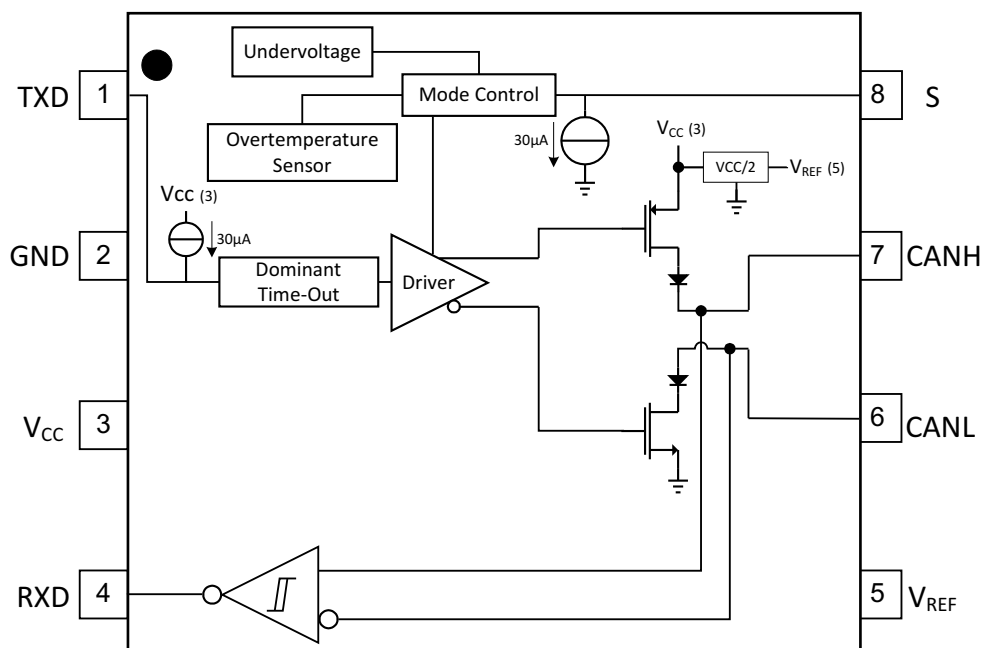


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4 Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

| Changes from Revision B (March 2010) to Revision C | Page |
|---|------|
| <ul style="list-style-type: none"> Added <i>Pin Configuration and Functions</i> section, <i>ESD Ratings</i> table, <i>Feature Description</i> section, <i>Device Functional Modes</i>, <i>Application and Implementation</i> section, <i>Power Supply Recommendations</i> section, <i>Layout</i> section, <i>Device and Documentation Support</i> section, and <i>Mechanical, Packaging, and Orderable Information</i> section | 1 |

| Changes from Revision A (May 2007) to Revision B | Page |
|--|---------------------------------|
| <ul style="list-style-type: none"> Deleted The device is also qualified for use in ISO 11898-2 automotive applications in accordance with AEC-Q100." and footnote, "The device is available with Q100 qualification as the SN65HVD1050Q." Changed V_{CC} min/max range from 4.75-5.25V to 4.5-5.5V Changed V_{IH} max from 5.25V to 5.5V Added rows for various parameters showing parameters with $V_{CC} \pm 5\%$ and $\pm 10\%$ Added Signaling Rate spec, min 20kbps Changed V_{IH} min from 2 to 2.1V Changed Bus output voltage (Dominant) CANH $4.5V < V_{CC} < 5.5V$ from 4.75 to 5.2 | 1 4 4 4 4 4 5 |

5 Description (Continued)

Pin 8 provides for two different modes of operation: high-speed or silent mode. The high-speed mode of operation is selected by connecting S (pin 8) to ground.

If a high logic level is applied to the S pin of the SN65HVD1050, the device enters a listen-only silent mode during which the driver is switched off while the receiver remains fully functional.

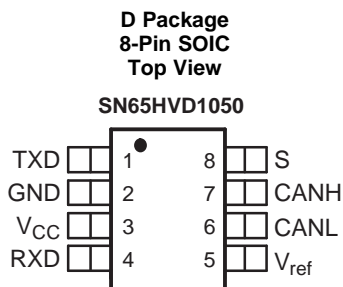
In silent mode, all bus activity is passed by the receiver output to the local protocol controller. When data transmission is required, the local protocol controller reverses this low-current silent mode by placing a logic-low on the S pin to resume full operation.

A dominant time-out circuit in the SN65HVD1050 prevents the driver from blocking network communication with a hardware or software failure. The time-out circuit is triggered by a falling edge on TXD (pin 1). If no rising edge is seen before the time-out constant of the circuit expires, the driver is disabled. The circuit is then reset by the next rising edge on TXD.

V_{ref} (pin 5) is available as a $V_{CC}/2$ voltage reference to stabilize the output common mode voltage point.

The SN65HVD1050 is characterized for operation from -40°C to 125°C .

6 Pin Configuration and Functions



Pin Functions

| PIN | | TYPE | DESCRIPTION |
|-----------|-----|--------|--|
| NAME | NO. | | |
| TXD | 1 | I | CAN transmit data input (LOW for dominant and HIGH for recessive bus states) |
| GND | 2 | GND | Device ground |
| V_{CC} | 3 | Supply | Transceiver 5-V supply |
| RXD | 4 | O | CAN receive data output (LOW for dominant and HIGH for recessive bus states) |
| V_{REF} | 5 | O | Reference output voltage |
| CANL | 6 | I/O | Low level CAN bus line |
| CANH | 7 | I/O | High level CAN bus line |
| S | 8 | I | Mode select pin (Logic LOW places the device in high-speed mode and logic HIGH places the device in a listen-only silent mode) |

7 Specifications

7.1 Absolute Maximum Ratings⁽¹⁾

| | MIN | MAX | UNIT |
|---|------|-----|------|
| V _{CC} Supply voltage ⁽²⁾ | −0.3 | 7 | V |
| Voltage range at any bus terminal (CANH, CANL, V _{ref}) | −27 | 40 | V |
| I _O Receiver output current | | 20 | mA |
| V _I Voltage input, transient pulse ⁽³⁾ (CANH, CANL) | −200 | 200 | V |
| V _I Voltage input range (TXD, S) | −0.5 | 6 | V |
| T _J Junction temperature | −55 | 170 | °C |
| T _{stg} Storage temperature | −40 | 125 | °C |

- (1) Stresses beyond those listed under *Absolute Maximum Ratings* may cause permanent damage to the device. These are stress ratings only and functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Conditions* is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.
- (2) All voltage values, except differential I/O bus voltages, are with respect to network ground terminal.
- (3) Tested in accordance with ISO 7637, test pulses 1, 2, 3a, 3b, 5, 6, and 7.

7.2 ESD Ratings

| | | | VALUE | UNIT |
|--|--|-----------------|-------|------|
| V _(ESD) Electrostatic discharge | Human body model (HBM), per ANSI/ESDA/JEDEC JS-001 ⁽¹⁾ | All pins | ±8000 | V |
| | | Bus pins vs GND | ±4000 | |
| | Charged-device model (CDM), per JEDEC specification JESD22-C101 ⁽²⁾ | | ±1500 | |
| | Machine Model, ANSI/ESDS5.2-1996 | | ±200 | |

- (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.

7.3 Recommended Operating Conditions

| | | | MIN | NOM | MAX | UNIT |
|-----------------------------------|---|---|-----|-----|-----------------|------|
| V _{CC} | Supply voltage | | 4.5 | | 5.5 | V |
| V _I or V _{IC} | Voltage at any bus terminal (separately or common mode) | | −12 | | 12 | V |
| V _{IH} | High-level input voltage | TXD, S | 2.1 | | V _{CC} | V |
| V _{IL} | Low-level input voltage | | 0 | | 0.8 | V |
| V _{ID} | Differential input voltage | | −7 | | 7 | V |
| I _{OH} | High-level output current | Driver | −70 | | | mA |
| | | Receiver | −2 | | | |
| I _{OL} | Low-level output current | Driver | | | 70 | mA |
| | | Receiver | | | 2 | |
| T _J | Junction temperature | See <i>Absolute Maximum Ratings</i> ⁽¹⁾ , 1-Mbps minimum signaling rate with R _L = 54 Ω | −40 | | 150 | °C |
| | Signaling Rate | | 20 | | | kbps |

- (1) Stresses beyond those listed under *Absolute Maximum Ratings* may cause permanent damage to the device. These are stress ratings only and functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Conditions* is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

7.4 Thermal Information

| THERMAL METRIC ⁽¹⁾ | | SN65HVD1050 | UNIT |
|-------------------------------|--|-------------|------|
| | | D (SOIC) | |
| | | 8 PINS | |
| R _{θJA} | Junction-to-air, Low-K thermal resistance ⁽²⁾ | 211 | °C/W |
| | Junction-to-air, High-K thermal resistance | 131 | |
| R _{θJC(top)} | Junction-to-case (top) thermal resistance | 79 | |
| R _{θJB} | Junction-to-board thermal resistance | 53 | |
| ψ _{JT} | Junction-to-top characterization parameter | 10.3 | |
| ψ _{JB} | Junction-to-board characterization parameter | 56.6 | |
| R _{θJC(bot)} | Junction-to-case (bottom) thermal resistance | 112 | mW |
| P _D | Average power dissipation, V _{CC} = 5.0V, T _J = 27°C, R _L = 60 Ω, S at 0V, Input to TXD a 500 kHz, 50% duty cycle square wave. CL at RXD = 15 pF | 170 | |
| | Average power dissipation, V _{CC} = 5.5V, T _J = 130°C, R _L = 45 Ω, S at 0V, Input to TXD a 500 kHz, 50% duty cycle square wave. CL at RXD = 15 pF | 170 | |
| T _{J_shutdown} | Junction temperature, thermal shutdown ⁽³⁾ | 190 | °C |

(1) For more information about traditional and new thermal metrics, see the *IC Package Thermal Metrics* application report, [SPRA953](#).

(2) Tested in accordance with the Low-K or High-K thermal metric definitions of EIA/JESD51-3 for leaded surface-mount packages.

(3) Extended operation in thermal shutdown may affect device reliability, see APPLICATIONS INFORMATION.

7.5 Driver Electrical Characteristics

over recommended operating conditions (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | | MIN | TYP ⁽¹⁾ | MAX | UNIT | | |
|----------------------|---|-----------------|--|--|---------------------------------|------|-------|----|-----|
| V _{O(D)} | Bus output voltage (Dominant) | CANH | V _I = 0V, S at 0V, R _L = 60 Ω, See Figure 11 and Figure 12 | 4.75V < V _{CC} < 5.25V | 2.9 | 3.4 | 4.5 | V | |
| | | | | 4.5V < V _{CC} < 5.5V | 2.75 | | 5.2 | | |
| | | | | CANL | 4.75V < V _{CC} < 5.25V | 0.8 | | | 1.5 |
| | | | | | 4.5V < V _{CC} < 5.5V | | | | 1.6 |
| V _{O(R)} | Bus output voltage (Recessive) | | V _I = 3V, S at 0V, R _L = 60 Ω, See Figure 11 and Figure 12 | 4.75V < V _{CC} < 5.25V | 2 | 2.3 | 3 | V | |
| | | | | 4.5V < V _{CC} < 5.5V | 1.8 | | 3 | | |
| V _{OD(D)} | Differential output voltage (Dominant) | | V _I = 0V, R _L = 60 Ω, S at 0V, See Figure 11 , Figure 12 , and Figure 13 | 4.75V < V _{CC} < 5.25V | 1.5 | | 3 | V | |
| | | | | 4.5V < V _{CC} < 5.5V | 1.4 | | 3 | | |
| | | | | V _I = 0V, R _L = 45 Ω, S at 0V, See Figure 11 , Figure 12 , and Figure 13 | 4.75V < V _{CC} < 5.25V | 1.4 | | | 3 |
| | | | | | 4.5V < V _{CC} < 5.5V | 1.3 | | | 3 |
| V _{OD(R)} | Differential output voltage (Recessive) | | V _I = 3V, S at 0V, See Figure 11 and Figure 12 | | –0.012 | | 0.012 | V | |
| | | | | V _I = 3V, S at 0V, No Load | –0.5 | | 0.05 | | |
| V _{OC(ss)} | Steady state common-mode output voltage | | S at 0V, Figure 18 | 4.75V < V _{CC} < 5.25V | 2 | 2.3 | 3 | V | |
| | | | | 4.5V < V _{CC} < 5.5V | 1.9 | | 3 | | |
| ΔV _{OC(ss)} | Change in steady-state common-mode output voltage | | | | | 30 | | mV | |
| I _{IH} | High-level input current, TXD input | | V _I at V _{CC} | | –2 | | 2 | μA | |
| I _{IL} | Low-level input current, TXD input | | V _I at 0V | | –50 | | –10 | | |
| I _{O(off)} | Power-off TXD output current | | V _{CC} at 0V, TXD at 5V | | | | 1 | | |
| I _{OS(ss)} | Short-circuit steady-state output current | | V _{CANH} = –12V, CANL Open, See Figure 21 | | –105 | –72 | | mA | |
| | | | V _{CANH} = 12V, CANL Open, See Figure 21 | | | 0.36 | 1 | | |
| | | | V _{CANL} = –12V, CANH Open, See Figure 21 | | –1 | –0.5 | | | |
| | | | V _{CANL} = 12V, CANH Open, See Figure 21 | | | 71 | 105 | | |
| C _O | Output capacitance | | See receiver input capacitance | | | | | | |

(1) All typical values are at 25°C with a 5-V supply.

7.6 Receiver Electrical Characteristics

over recommended operating conditions (unless otherwise noted)

| PARAMETER | TEST CONDITIONS | MIN | TYP ⁽¹⁾ | MAX | UNIT |
|--|--|---------------------------------|--------------------|-----|------|
| V _{IT+} Positive-going input threshold voltage | S at 0V, See Table 1 | | 800 | 900 | mV |
| V _{IT-} Negative-going input threshold voltage | | 500 | 650 | | |
| V _{hys} Hysteresis voltage (V _{IT+} – V _{IT-}) | | 100 | 125 | | |
| V _{OH} High-level output voltage | I _O = –2 mA, See Figure 16 | 4.75V < V _{CC} < 5.25V | 4 | 4.6 | V |
| V _{OL} Low-level output voltage | | 4.5V < V _{CC} < 5.5V | 3.8 | | |
| I _{I(off)} Power-off bus input current | I _O = 2 mA, See Figure 16 | | 0.2 | 0.4 | V |
| I _{O(off)} Power-off RXD leakage current | CANH or CANL = 5V, Other pin at 0V, V _{CC} at 0V, TXD at 0V | | 165 | 250 | μA |
| C _I Input capacitance to ground, (CANH or CANL) | V _{CC} at 0V, RXD at 5V | | | 20 | μA |
| C _{ID} Differential input capacitance | TXD at 3V, V _I = 0.4 sin (4E6πt) | | 13 | | pF |
| R _{ID} Differential input resistance | TXD at 3V, S at 0V | | 5 | | |
| R _{IN} Input resistance, (CANH or CANL) | | 30 | | 80 | kΩ |
| R _{I(m)} Input resistance matching [1 – (R _{IN (CANH)} / R _{IN (CANL)})] x 100% | | 15 | 30 | 40 | |
| | V _(CANH) = V _(CANL) | –3% | 0% | 3% | |

(1) All typical values are at 25°C with a 5-V supply.

7.7 Device Switching Characteristics

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

| PARAMETER | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|--|-------------------------------------|---------------------------------|-----|-----|------|
| t _{d(LOOP1)} Total loop delay, driver input to receiver output, recessive to dominant | Figure 19 , S at 0V | 4.75V < V _{CC} < 5.25V | 90 | 190 | ns |
| | | 4.5V < V _{CC} < 5.5V | 85 | 195 | |
| t _{d(LOOP2)} Total loop delay, driver input to receiver output, dominant to recessive | | 4.75V < V _{CC} < 5.25V | 90 | 190 | |
| | | 4.5V < V _{CC} < 5.5V | 85 | 195 | |

7.8 Driver Switching Characteristics

over recommended operating conditions (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | | MIN | TYP | MAX | UNIT |
|--------------------|--|---|---------------------------------|-----|-----|-----|------|
| t _{PLH} | Propagation delay time, low-to-high-level output | S at 0V, See Figure 14 | | 25 | 65 | 120 | ns |
| t _{PHL} | Propagation delay time, high-to-low-level output | | | 25 | 45 | 90 | |
| t _r | Differential output signal rise time | | | 25 | | | |
| t _f | Differential output signal fall time | | | 50 | | | |
| t _{en} | Enable time from silent mode to dominant | See Figure 17 | | 1 | | | μs |
| t _(dom) | Dominant time-out | ↓V _I , See Figure 20 | 4.75V < V _{CC} < 5.25V | 300 | 450 | 700 | μs |
| | | | 4.5V < V _{CC} < 5.5V | 280 | 700 | | |

7.9 Receiver Switching Characteristics

over recommended operating conditions (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | | MIN | TYP | MAX | UNIT |
|-----------|--|---|--------------------------|-----|-----|-----|------|
| t_{PLH} | Propagation delay time, low-to-high-level output | S at 0V or V_{CC} . See Figure 16 | $4.75V < V_{CC} < 5.25V$ | 60 | 100 | 130 | ns |
| | | | $4.5V < V_{CC} < 5.5V$ | 60 | | 135 | |
| t_{PHL} | Propagation delay time, high-to-low-level output | | $4.75V < V_{CC} < 5.25V$ | 45 | 70 | 90 | |
| | | | $4.5V < V_{CC} < 5.5V$ | 45 | | 95 | |
| t_r | Output signal rise time | | | | 8 | | |
| t_f | Output signal fall time | | | | 8 | | |

7.10 Supply Current

over recommended operating conditions (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | | MIN | TYP | MAX | UNIT |
|-----------|--------------------|-----------------|--|-----|-----|-----|------|
| I_{CC} | 5-V Supply current | Silent mode | S at V_{CC} , $V_I = V_{CC}$ | | 6 | 10 | mA |
| | | Dominant | $V_I = 0V$, 60 Ω Load, S at 0V | | 50 | 70 | |
| | | | $4.75V < V_{CC} < 5.25V$ | | | 75 | |
| | | Recessive | $V_I = V_{CC}$, No Load, S at 0V | | 6 | 10 | |

7.11 S-Pin Characteristics

over recommended operating conditions (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | | MIN | TYP | MAX | UNIT |
|-----------|--------------------------|-----------------|--|-----|-----|-----|---------|
| I_{IH} | High level input current | S at 2V | | 20 | 40 | 70 | μA |
| I_{IL} | Low level input current | S at 0.8V | | 5 | 20 | 30 | |

7.12 VREF-Pin Characteristics

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

| PARAMETER | | TEST CONDITIONS | | MIN | TYP | MAX | UNIT |
|-----------|--------------------------|------------------------------|--|-------------|-------------|-------------|------|
| V_{REF} | Reference output voltage | $-50 \mu A < I_O < 50 \mu A$ | | $0.4V_{CC}$ | $0.5V_{CC}$ | $0.6V_{CC}$ | V |

7.13 Typical Characteristics

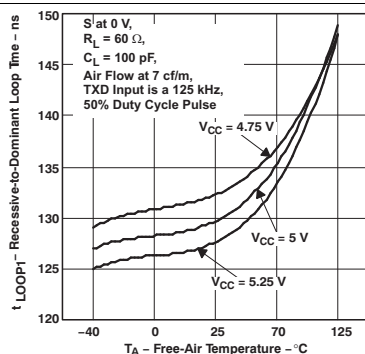


Figure 1. Recessive-to-Dominant Loop Time vs Free-Air Temperature (Across V_{CC})

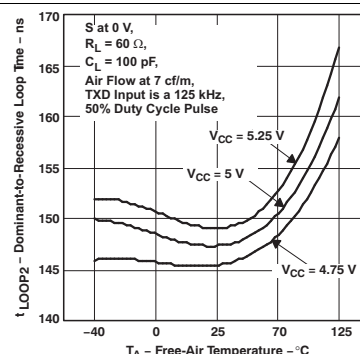


Figure 2. Dominant-to-Recessive Loop Time vs Free-Air Temperature (Across V_{CC})

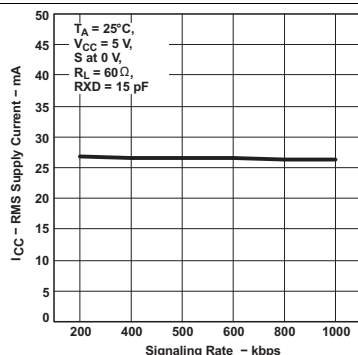


Figure 3. Supply Current (RMS) vs Signaling Rate

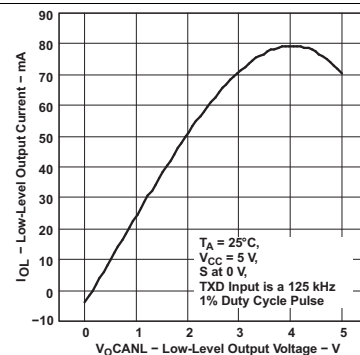


Figure 4. Driver Low-Level Output Voltage vs Low-Level Output Current

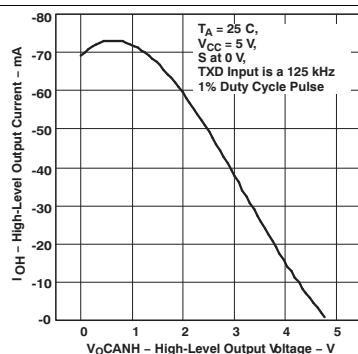


Figure 5. Driver High-Level Output Voltage vs High-Level Output Current

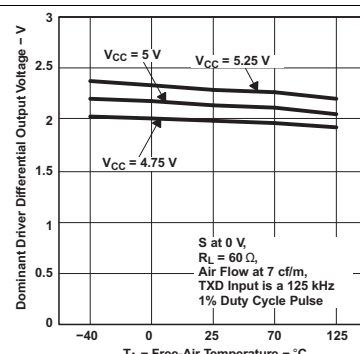


Figure 6. Driver Differential Output Voltage vs Free-Air Temperature (Across V_{CC})

Typical Characteristics (continued)

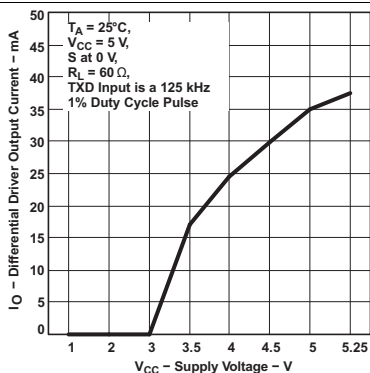


Figure 7. Driver Output Current vs Supply Voltage

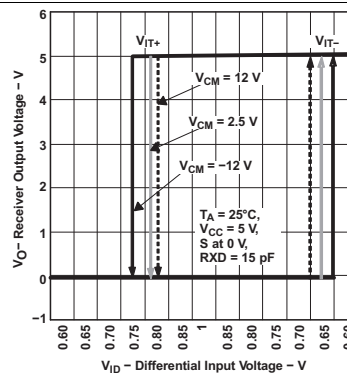


Figure 8. Receiver Output Voltage vs Differential Input Voltage

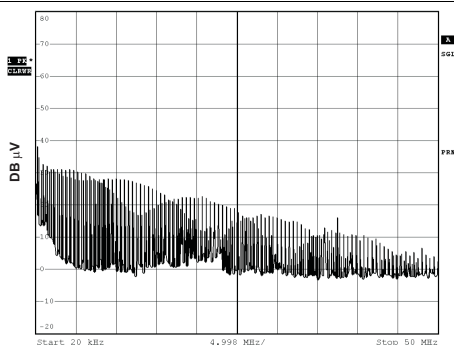


Figure 9. Frequency Spectrum of Common-Mode Emissions

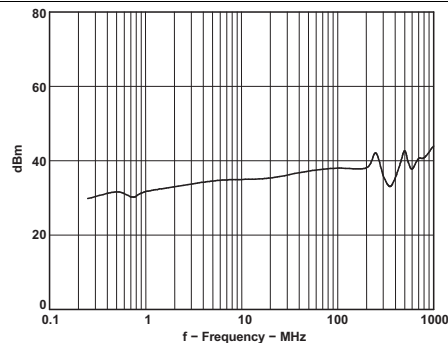


Figure 10. Direct Power Injection (DPI) Response vs Frequency

8 Parameter Measurement Information

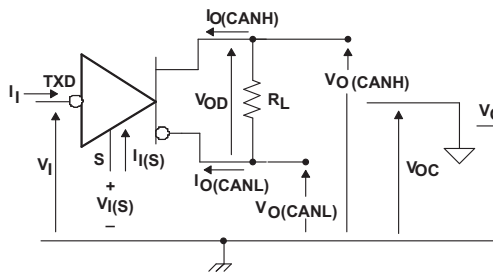


Figure 11. Driver Voltage, Current, and Test Definition

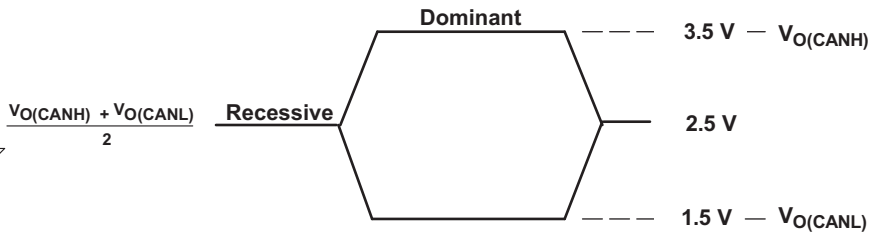


Figure 12. Bus Logic State Voltage Definitions

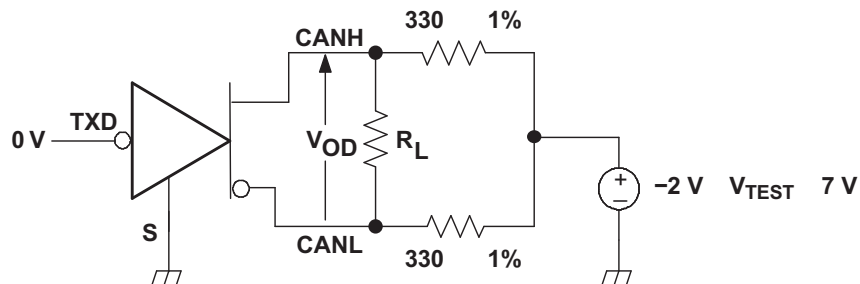


Figure 13. Driver V_{OD} Test Circuit

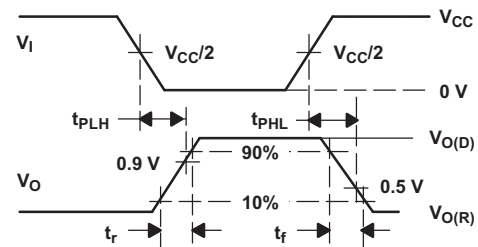
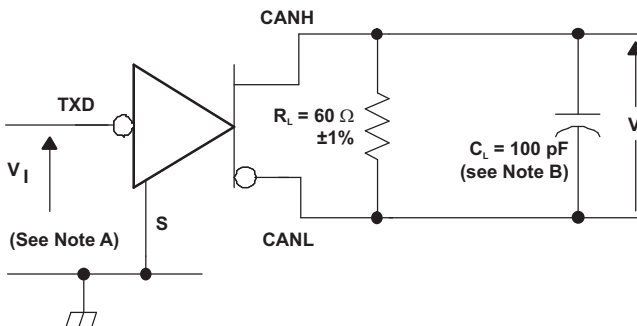


Figure 14. Driver Test Circuit and Voltage Waveforms

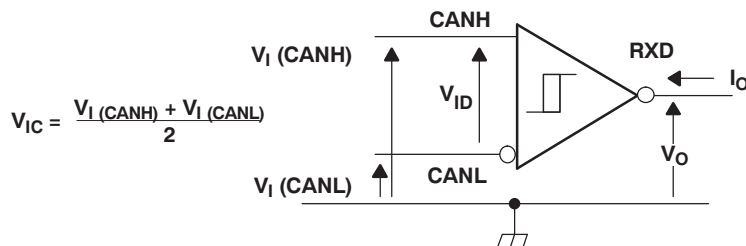
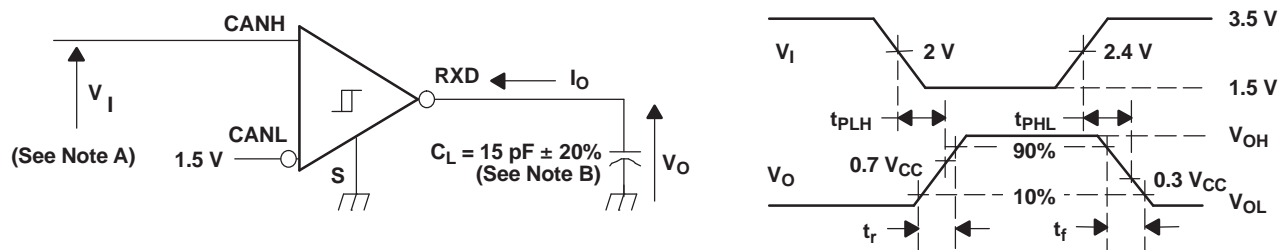


Figure 15. Receiver Voltage and Current Definitions

Parameter Measurement Information (continued)



- A. The input pulse is supplied by a generator having the following characteristics: PRR \leq 125 kHz, 50% duty cycle, $t_r \leq$ 6 ns, $t_f \leq$ 6 ns, $Z_0 = 50 \Omega$.
- B. C_L includes instrumentation and fixture capacitance within $\pm 20\%$.

Figure 16. Receiver Test Circuit and Voltage Waveforms

Table 1. Differential Input Voltage Threshold Test

| INPUT | | | OUTPUT | |
|------------|------------|------------|--------|----------|
| V_{CANH} | V_{CANL} | $ V_{ID} $ | R | |
| -11.1V | -12V | 900 mV | L | V_{OL} |
| 12V | 11.1V | 900 mV | L | |
| -6V | -12V | 6V | L | |
| 12V | 6V | 6V | L | |
| -11.5V | -12V | 500 mV | H | V_{OH} |
| 12V | 11.5V | 500 mV | H | |
| -12V | -6V | 6V | H | |
| 6V | 12V | 6V | H | |
| Open | Open | X | H | |

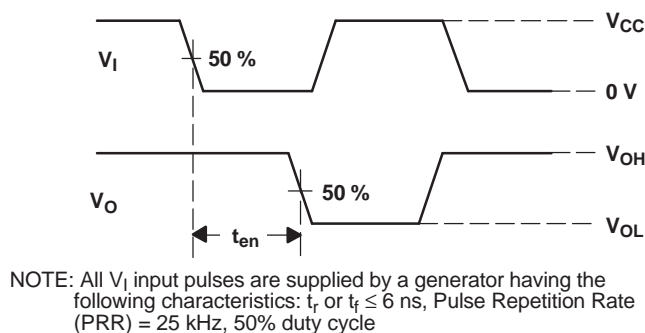
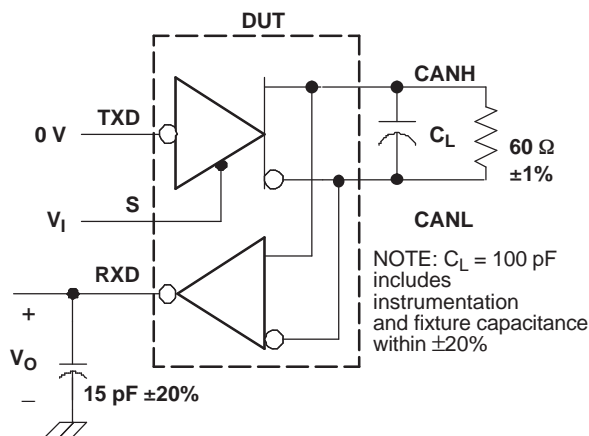
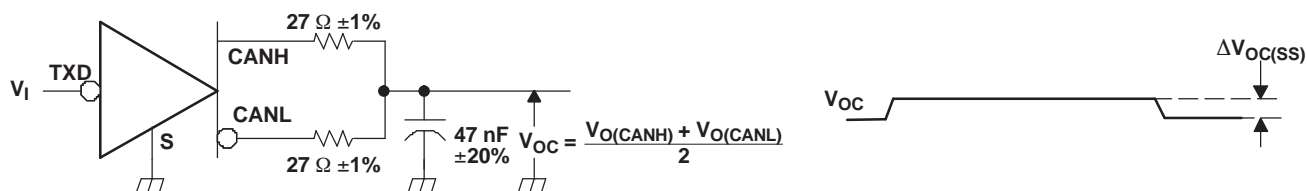


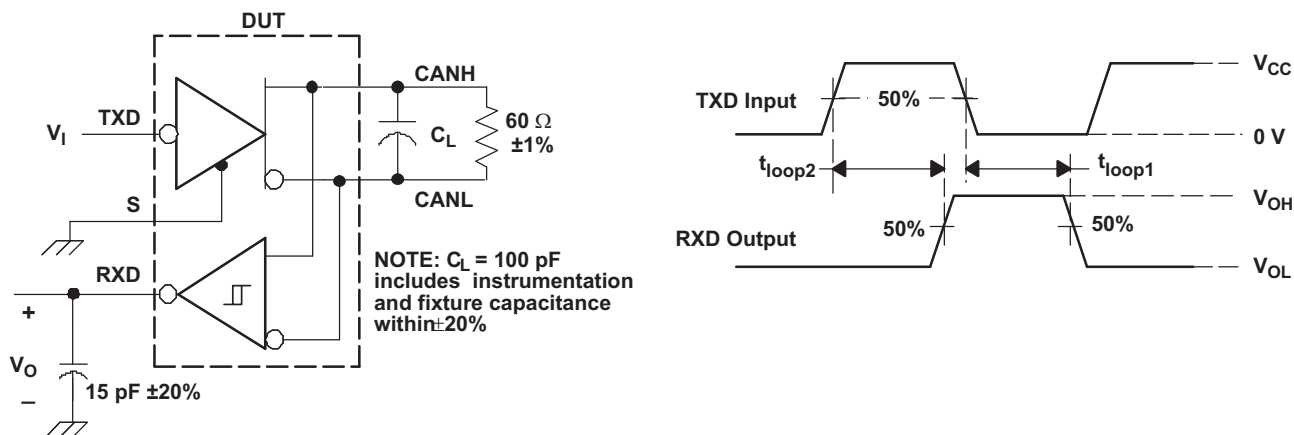
Figure 17. T_{EN} Test Circuit and Waveform

SN65HVD1050

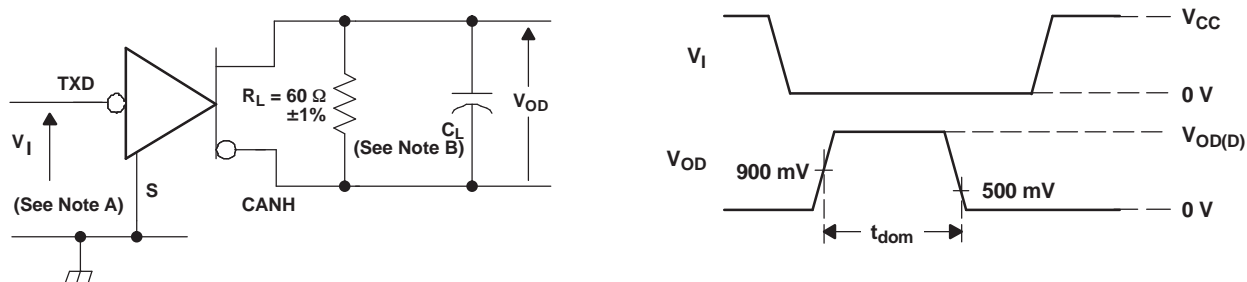
SLLS632C – DECEMBER 2005 – REVISED FEBRUARY 2015

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NOTE: All V_I input pulses are from 0V to V_{CC} and supplied by a generator having the following characteristics: t_r or $t_f \leq 6$ ns. Pulse Repetition Rate (PRR) = 125 kHz, 50% duty cycle.

Figure 18. Common Mode Output Voltage Test and Waveforms


A. All V_I input pulses are from 0V to V_{CC} and supplied by a generator having the following characteristics: t_r or $t_f \leq 6$ ns. Pulse Repetition Rate (PRR) = 125 kHz, 50% duty cycle.

Figure 19. $T_{(LOOP)}$ Test Circuit and Waveform


A. All V_I input pulses are from 0 V to V_{CC} and supplied by a generator having the following characteristics: t_r or $t_f \leq 6$ ns. Pulse Repetition Rate (PRR) = 500 Hz, 50% duty cycle.

B. $C_L = 100$ pF includes instrumentation and fixture capacitance within $\pm 20\%$.

Figure 20. Dominant Time-Out Test Circuit and Waveforms

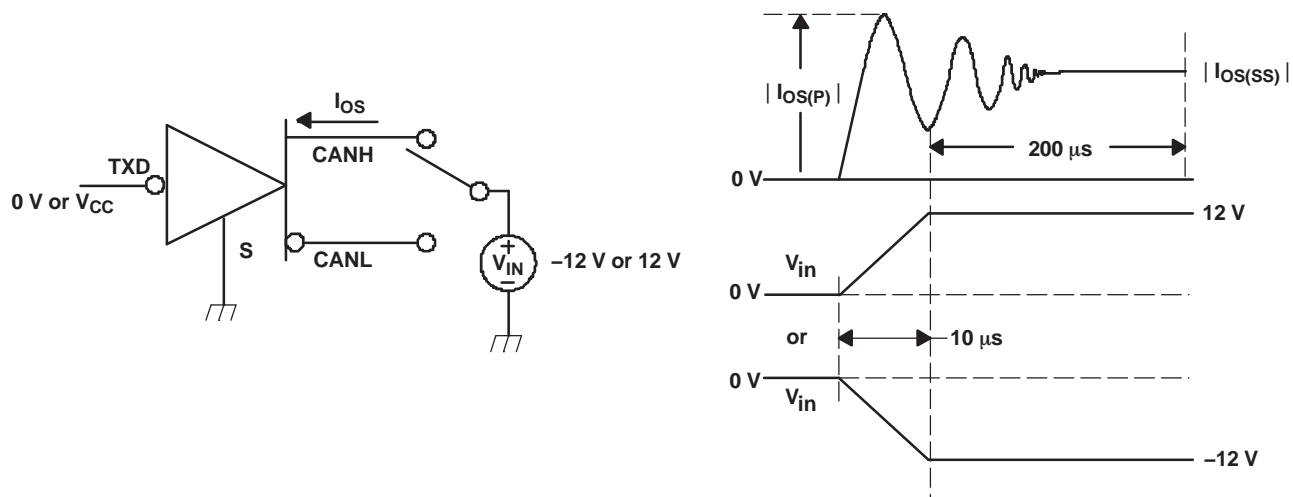


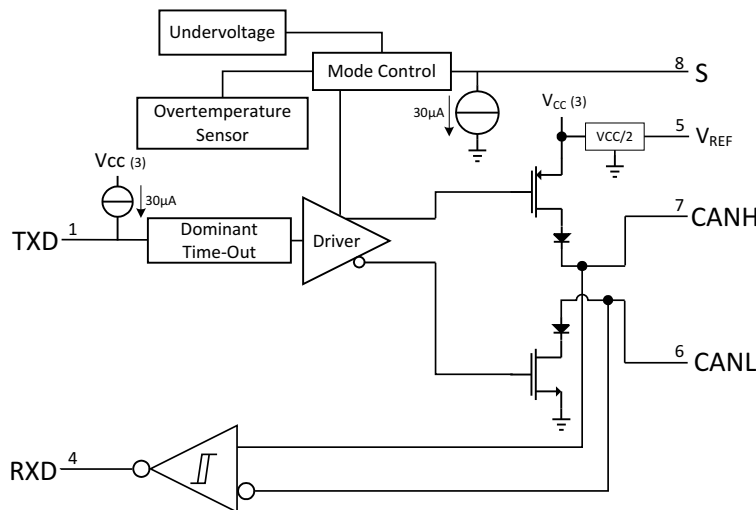
Figure 21. Driver Short-Circuit Current Test and Waveform

9 Detailed Description

9.1 Overview

The SN65HVD1050 CAN transceivers is compatible with the ISO1189-2 High Speed CAN (Controller Area Network) physical layer standard. It is designed to interface between the differential bus lines in controller area network and the CAN protocol controller at data rates up to 1 Mbps.

9.2 Functional Block Diagram



9.3 Feature Description

9.3.1 Mode Control

9.3.1.1 Normal Mode

Select the normal mode of the device operation by setting the S pin low. The CAN bus driver and receiver are fully operational and the CAN communication is bidirectional. The driver is translating a digital input on TXD to a differential output on CANH and CANL. The receiver is translating the differential signal from CANH and CANL to a digital output on RXD.

9.3.1.2 Silent Mode

Activate silent mode (receive only) by setting the S pin high. The CAN driver is turned off while the receiver remains active and RXD outputs the received bus data.

NOTE

Silent mode may be used to implement babbling idiot protection, to ensure that the driver does not disrupt the network during a local fault. Silent mode may also be used in redundant systems to select or deselect the redundant transceiver (driver) when needed.

9.3.2 TXD Dominant Timeout (DTO)

During normal mode, the mode where the CAN driver is active, the TXD DTO circuit prevents the transceiver from blocking network communication in the event of a hardware or software failure where TXD is held dominant longer than the timeout period t_{TXD_DTO} . The DTO circuit is triggered on a falling edge on the driver input, TXD. The DTO circuit disables the CAN bus driver if no rising edge is seen on TXD before the timeout period expires. This frees the CAN bus for communication between other nodes on the network. The CAN driver is re-enabled when a rising edge is seen on the driver input, TXD, thus clearing the TXD DTO condition. The receiver and RXD pin still reflect the CAN bus, and the bus pins are biased to recessive level during a TXD DTO.

Feature Description (continued)

NOTE

The minimum dominant TXD time allowed by the TXD DTO circuit limits the minimum possible transmitted data rate on the device. The CAN protocol allows a maximum of eleven successive dominant bits (on TXD) for the worst case, where five successive dominant bits are followed immediately by an error frame. This, along with the t_{TXD_DTO} minimum, limits the minimum data rate. Calculate the minimum transmitted data rate using: Minimum Data Rate = $11 / t_{TXD_DTO}$

9.3.3 Thermal Shutdown

The SN65HVD1050 has a thermal shutdown feature that turns off the driver outputs when the junction temperature nears 190°C. This shutdown prevents catastrophic failure from bus shorts, but does not protect the circuit from possible damage. The user should strive to maintain recommended operating conditions and not exceed absolute-maximum ratings at all times. If an SN65HVD1050 is subjected to many, or long-duration faults that can put the device into thermal shutdown, it should be replaced.

9.3.4 V_{REF}

A reference voltage of $V_{CC}/2$ is available through the V_{REF} output pin. The V_{REF} voltage should be tied to the common mode point in a split termination network to help stabilize the output common mode voltage. See [Figure 27](#) for more application specific information on properly terminating the CAN bus.

If the V_{REF} output pin is not used it can be left floating.

9.3.5 Operating Temperature Range

The SN65HVD1050 is characterized for operation from –40°C to 125°C.

9.4 Device Functional Modes

Table 2. Driver

| INPUTS | | OUTPUTS | | BUS STATE |
|--------------------|------------------|---------------------|---------------------|-----------|
| TXD ⁽¹⁾ | S ⁽¹⁾ | CANH ⁽¹⁾ | CANL ⁽¹⁾ | |
| L | L or Open | H | L | DOMINANT |
| H | X | Z | Z | RECESSIVE |
| Open | X | Z | Z | RECESSIVE |
| X | H | Z | Z | RECESSIVE |

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

Table 3. Receiver

| DIFFERENTIAL INPUTS $V_{ID} = V(CANH) - V(CANL)$ | OUTPUT RXD ⁽¹⁾ | BUS STATE |
|---|---------------------------|-----------|
| $V_{ID} \geq 0.9V$ | L | DOMINANT |
| $0.5V < V_{ID} < 0.9V$ | ? | ? |
| $V_{ID} \leq 0.5V$ | H | RECESSIVE |
| Open | H | RECESSIVE |

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

Table 4. Parametric Cross Reference With the TJA1050

| TJA1050 ⁽¹⁾ | PARAMETER | HVD1050 |
|----------------------------|---|--|
| TRANSMITTER SECTION | | |
| V _{IH} | High-level input voltage | Recommended V _{IH} |
| V _{IL} | Low-level input voltage | Recommended V _{IL} |
| I _{IH} | High-level input current | Driver I _{IH} |
| I _{IL} | Low-level input current | Driver I _{IL} |
| BUS SECTION | | |
| I _{LI} | Power-off bus input current | Receiver I _{I(off)} |
| I _{O(SC)} | Short-circuit output current | Driver I _{OS(SS)} |
| V _{O(dom)} | Dominant output voltage | Driver V _{O(D)} |
| V _{i(dif)(th)} | Differential input voltage | Receiver V _{IT} and recommended V _{ID} |
| V _{i(dif)(hys)} | Differential input hysteresis | Receiver V _{hys} |
| V _{O(reces)} | Recessive output voltage | Driver V _{O(R)} |
| V _{O(dif)(bus)} | Differential bus voltage | Driver V _{OD(D)} and V _{OD(R)} |
| R _{i(cm)} | CANH, CANL input resistance | Receiver R _{IN} |
| R _{i(dif)} | Differential input resistance | Receiver R _{ID} |
| R _{i(cm)(m)} | Input resistance matching | Receiver R _{I(m)} |
| C _i | Input capacitance to ground | Receiver C _I |
| C _{i(dif)} | Differential input capacitance | Receiver C _{ID} |
| RECEIVER SECTION | | |
| I _{OH} | High-level output current | Recommended I _{OH} |
| I _{OL} | Low-level output current | Recommended I _{OL} |
| Vref PIN SECTION | | |
| V _{ref} | Reference output voltage | V _O |
| TIMING SECTION | | |
| t _{d(TXD-BUSon)} | Delay TXD to bus active | Driver t _{PLH} |
| t _{d(TXD-BUSoff)} | Delay TXD to bus inactive | Driver t _{PHL} |
| t _{d(BUSon-RXD)} | Delay bus active to RXD | Receiver t _{PHL} |
| t _{d(BUSoff-RXD)} | Delay bus inactive to RXD | Receiver t _{PLH} |
| | t _{d(TXD-BUSon)} + t _{d(BUSon-RXD)} | Device t _{LOOP1} |
| | t _{d(TXD-BUSoff)} + t _{d(BUSoff-RXD)} | Device t _{LOOP2} |
| t _{dom(TXD)} | Dominant time out | Driver t _(dom) |
| S PIN SECTION | | |
| V _{IH} | High-level input voltage | Recommended V _{IH} |
| V _{IL} | Low-level input voltage | Recommended V _{IL} |
| I _{IH} | High-level input current | I _{IH} |
| I _{IL} | Low-level input current | I _{IL} |

(1) From TJA1050 Product Specification, Philips Semiconductors, 2002 May 16.

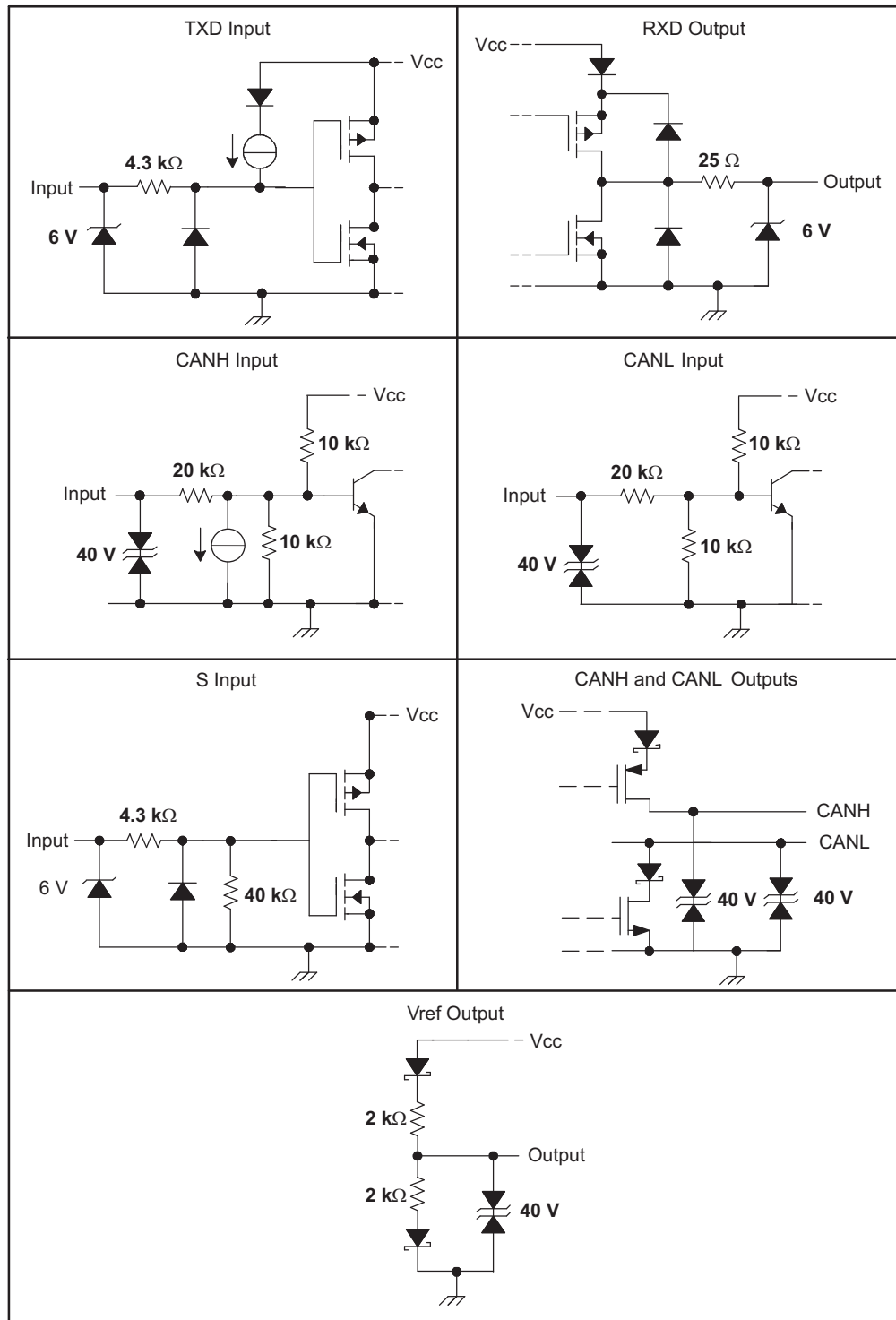


Figure 22. Equivalent Input and Output Schematic Diagrams

10 Application and Implementation

NOTE

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

10.1 Application Information

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_{IN} and R_{ID} of the receiver, corresponding to a logic high on the D and R pins. See Figure 23 and Figure 24.

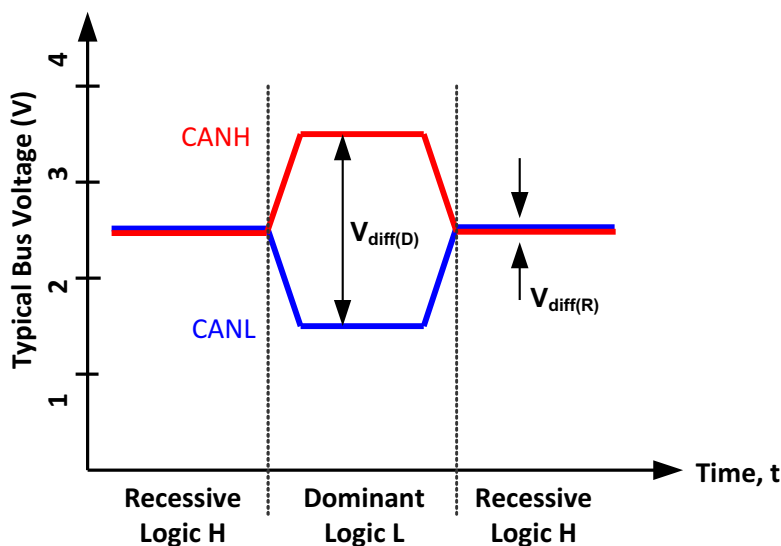


Figure 23. Bus States

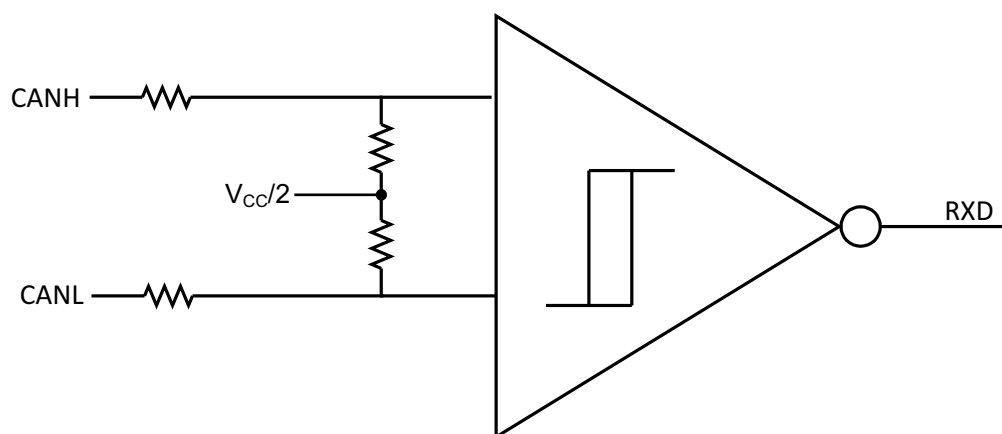


Figure 24. Simplified Recessive Common Mode Bias and Receiver

These CAN transceivers are typically used in applications with a host microprocessor or FPGA that includes the link layer portion of the CAN protocol. The different nodes on the network are typically connected through the use of a 120-Ω characteristic impedance twisted-pair cable with termination on both ends of the bus.

10.2 Typical Application

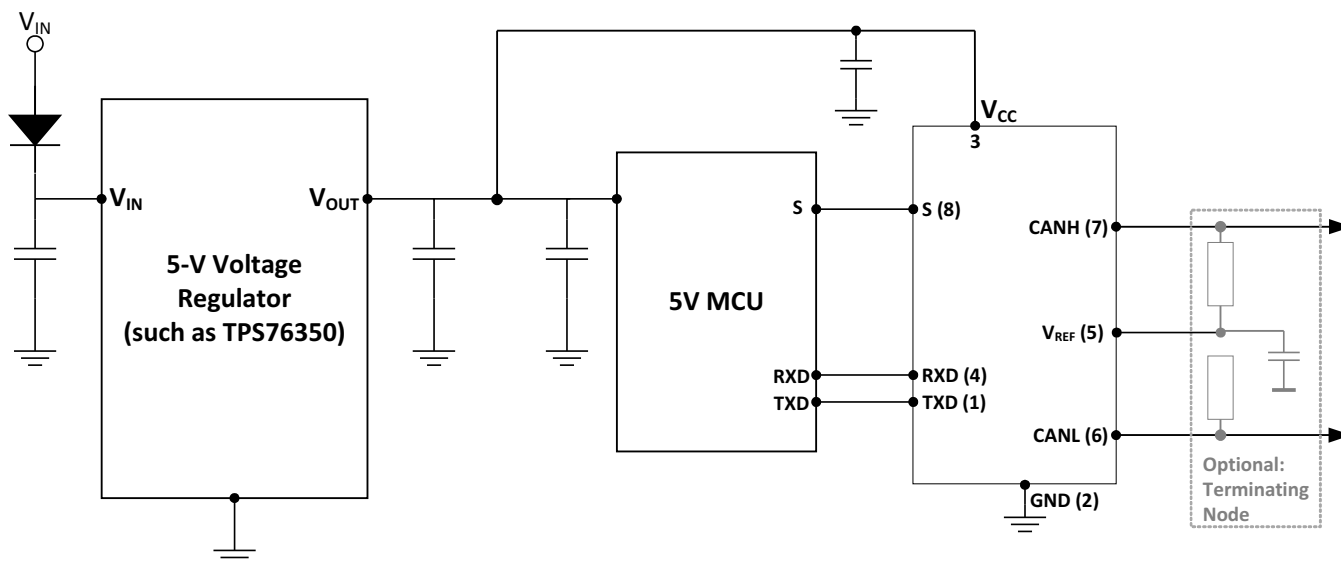


Figure 25. Typical Application Schematic

10.2.1 Design Requirements

10.2.1.1 Bus Loading, Length, and Number of Nodes

The ISO 11898 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 to a bus. Many CAN organizations and standards have scaled the use of CAN for applications outside the original ISO 11898 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.

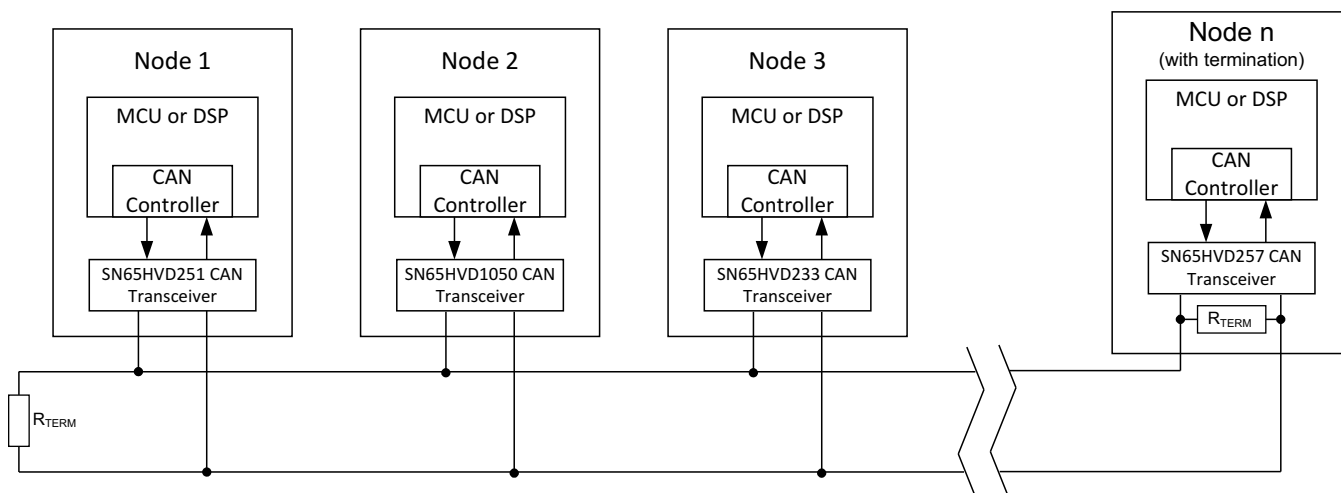


Figure 26. Typical CAN Bus

Typical Application (continued)

A high number of nodes requires a transceiver with high input impedance and wide common mode range such as the SN65HVD1050 CAN transceiver. ISO 11898-2 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 SN65HVD1050 device is 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 330- Ω coupling network. This network represents the bus loading of 90 SN65HVD1050 transceivers based on their minimum differential input resistance of 30 k Ω . Therefore, the SN65HVD1050 supports up to 90 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 ISO 11898 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 ISO 11898 CAN standard.

10.2.1.2 CAN Termination

The ISO 11898 standard specifies the interconnect to be a twisted pair cable (shielded or unshielded) with 120- Ω characteristic impedance (Z_0). 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.

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 27). Split termination uses two 60- Ω 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 when determining the power ratings of the termination resistors. A typical worst case fault condition is if the system power supply and ground were shorted across the termination resistance which would result in much higher current through the termination resistance than the CAN transceiver's current limit.

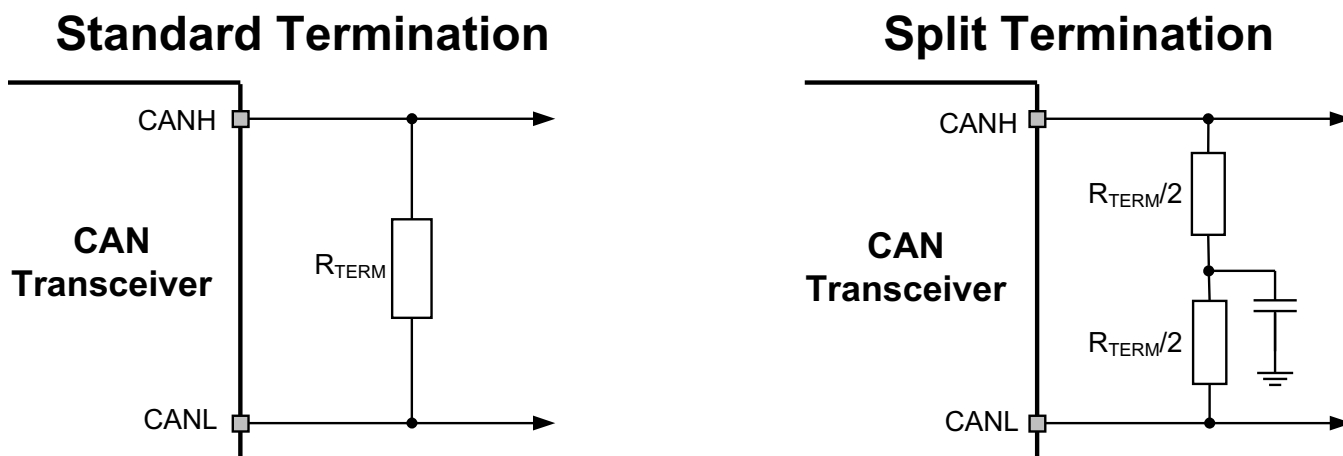


Figure 27. CAN Termination

10.2.1.2.1 Loop Propagation Delay

Transceiver loop delay is a measure of the overall device propagation delay, consisting of the delay from the driver input (TXD pin) to the differential outputs (CANH and CANL pins), plus the delay from the receiver inputs (CANH and CANL) to its output (RXD pin). A typical loop delay for the SN65HVD1050 transceiver is displayed in Figure 29.

Typical Application (continued)

10.2.2 Detailed Design Procedure

10.2.2.1 ESD Protection

A typical application that employs a CAN bus network may require some form of ESD, burst, and surge protection to shield the CAN transceiver against unwanted transients that can potentially damage the transceiver. To help shield the SN65HVD1050 transceiver against these high energy transients, transient voltage suppressors can be implemented on the CAN differential bus terminals. These devices will help absorb the impact of a ESD, burst, and/or surge strike.

10.2.2.2 Transient Voltage Suppressor (TVS) Diodes

Transient voltage suppressors are the preferred protection components for a CAN bus due to their low capacitance, which allows them to be designed into every node of a multi-node network without requiring a reduction in data rate. With response times of a few picoseconds and power ratings of up to several kilowatts, TVS diodes present the most effective protection against ESD, burst, and surge transients.

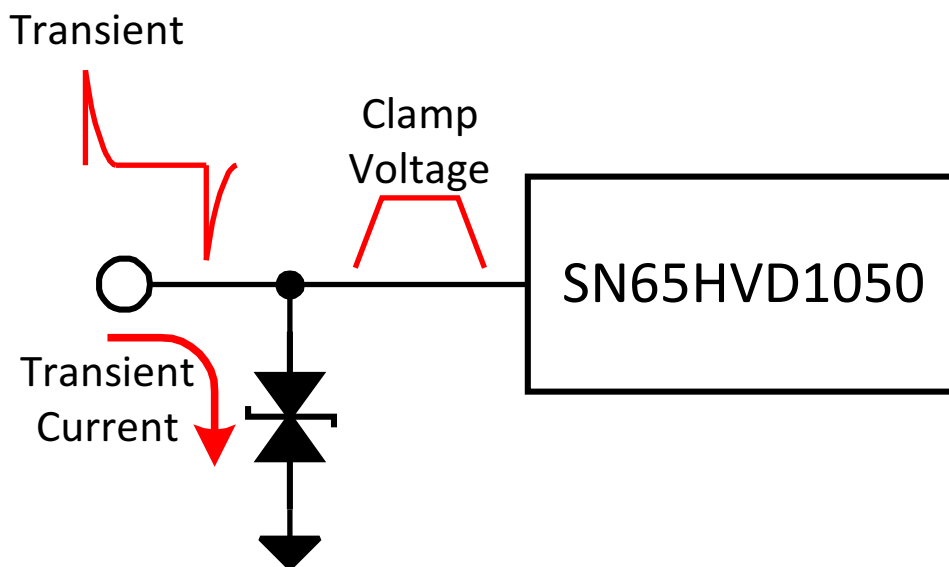


Figure 28. Effect of Transient Voltage Suppressor

Typical Application (continued)

10.2.3 Application Curve

Figure 29 shows the typical loop delay for the SN65HVD1050.

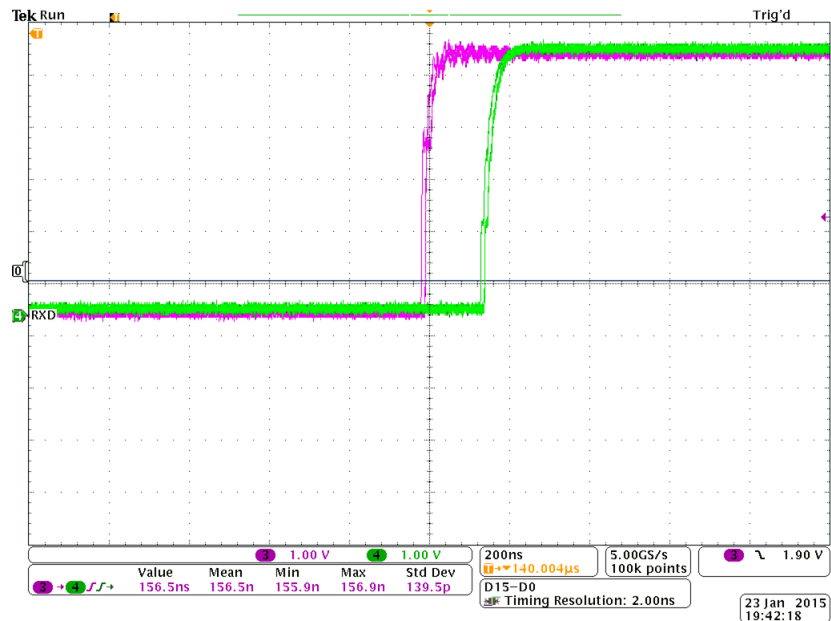


Figure 29. tLOOP Delay Waveform

10.3 System Example

10.3.1 ISO 11898 Compliance of SN65HVD1050 5-V CAN Transceiver

10.3.1.1 Introduction

The SN65HVD1050 CAN transceiver is a 5-V CAN transceiver that meets or exceeds the specification of the ISO 11898 standard for applications employing a controller area network.

10.3.1.2 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 logic level output signal.

System Example (continued)

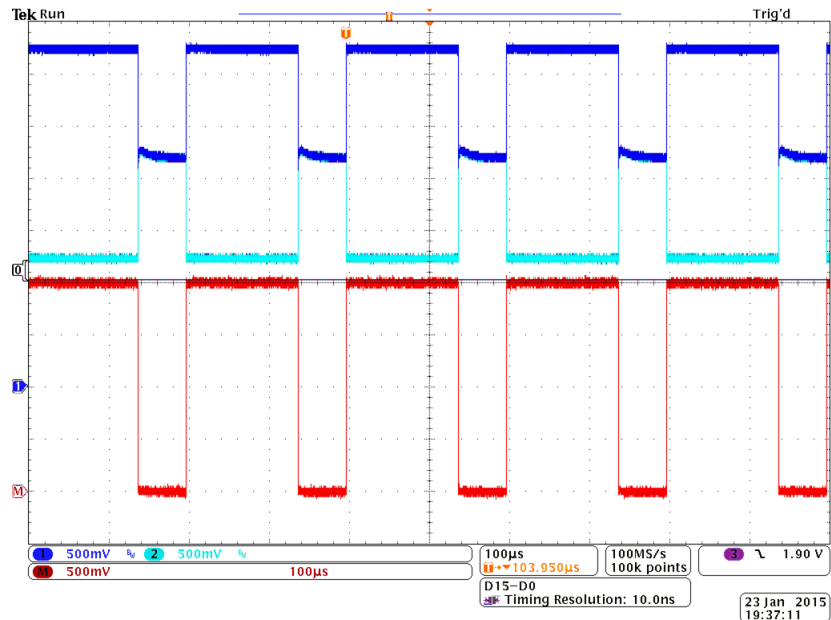


Figure 30. Differential Output Waveform

The CAN driver creates the differential voltage between CANH and CANL in the dominant state. The dominant differential output of the SN65HVD1050 is greater than 1.5 V and less than 3 V across a 60-Ω load as defined by the ISO 11898 standard. Figure 30 shows CANH, CANL, and the differential dominant state level for the SN65HVD1050.

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 V.

10.3.1.3 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. Because the bias voltage of the recessive state of the device is dependent on V_{CC} , any noise present or variation of V_{CC} will have an effect on this bias voltage seen by the bus. The SN65HVD1050 CAN transceiver has the recessive bias voltage set to $0.5 \times V_{CC}$ to comply with the ISO 11898-2 CAN standard.

11 Power Supply Recommendations

To ensure reliable operation at all data rates and supply voltages, each supply should be decoupled with a 100-nF ceramic capacitor located as close as possible to the V_{CC} supply pins as possible. The SN65HVD1050 is a linear voltage regulator suitable for the 5-V supply rail.

12 Layout

12.1 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 bidirectional diode or varistor solution) and bus filter capacitors C5 and C7 are shown in [Figure 25](#).

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 27](#) shows split termination. This is where the termination is split into two resistors, R5 and R6, with the center or split tap of the termination connected to ground via capacitor C6. 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.

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.

Because the internal pullup and pulldown biasing of the device is weak for floating pins, an external 1-k Ω to 10-k Ω pullup or pulldown 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 TXD pin of the device an external pullup resistor between 1 k Ω and 10 k Ω should be used to drive the recessive input state of the device.

Pin 5: V_{REF} should be connected to the center point of a split termination scheme to help stabilize the common mode voltage to $V_{CC}/2$. If V_{REF} is unused it should be left floating.

Pin 8: Is shown assuming the mode pin, S, will be used. If the device will only be used in normal mode, R3 is not needed and the pads of C4 could be used for the pulldown resistor to GND.

12.2 Layout Example

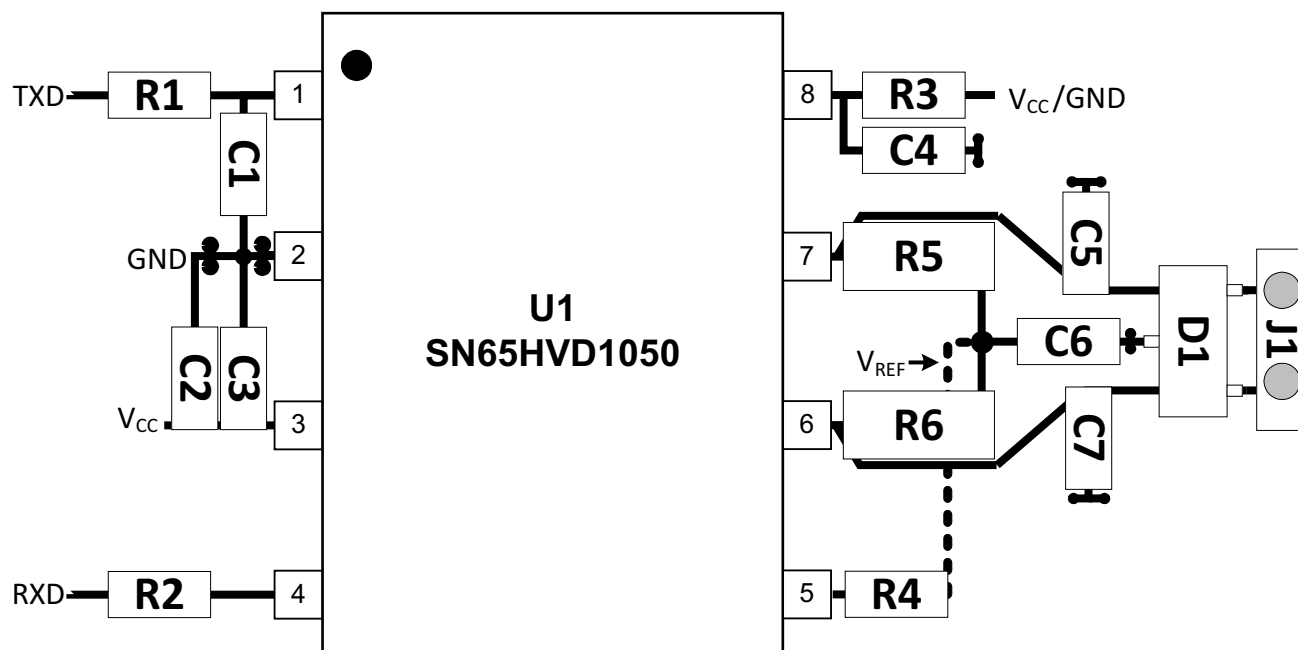


Figure 31. Layout Example

13 Device and Documentation Support

13.1 Trademarks

DeviceNet is a trademark of Open DeviceNet Vendors Association, Inc. All other trademarks are the property of their respective owners.

13.2 Electrostatic Discharge Caution



These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

13.3 Glossary

[SLYZ022](#) — *TI Glossary*.

This glossary lists and explains terms, acronyms, and definitions.

14 Mechanical, Packaging, and Orderable Information

The following pages include mechanical, packaging, and orderable information. This information is the most current data available for the designated devices. This data is subject to change without notice and revision of this document. For browser-based versions of this data sheet, refer to the left-hand navigation.

PACKAGING INFORMATION

| Orderable Device | Status (1) | Package Type | Package Drawing | Pins | Package Qty | Eco Plan (2) | Lead/Ball Finish (6) | MSL Peak Temp (3) | Op Temp (°C) | Device Marking (4/5) | Samples |
|------------------|---------------|--------------|--------------------|------|----------------|----------------------------|-------------------------|----------------------|--------------|-------------------------|-------------------------|
| SN65HVD1050D | ACTIVE | SOIC | D | 8 | 75 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | -40 to 125 | VP1050 | Samples |
| SN65HVD1050DG4 | ACTIVE | SOIC | D | 8 | 75 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | -40 to 125 | VP1050 | Samples |
| SN65HVD1050DR | ACTIVE | SOIC | D | 8 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | -40 to 125 | VP1050 | Samples |
| SN65HVD1050DRG4 | ACTIVE | SOIC | D | 8 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | -40 to 125 | VP1050 | Samples |

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

ACTIVE: Product device recommended for new designs.

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

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

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

OBSOLETE: TI has discontinued the production of the device.

(2) Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check <http://www.ti.com/productcontent> for the latest availability information and additional product content details.

TBD: The Pb-Free/Green conversion plan has not been defined.

Pb-Free (RoHS): TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.

Pb-Free (RoHS Exempt): This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.

Green (RoHS & no Sb/Br): TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

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

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

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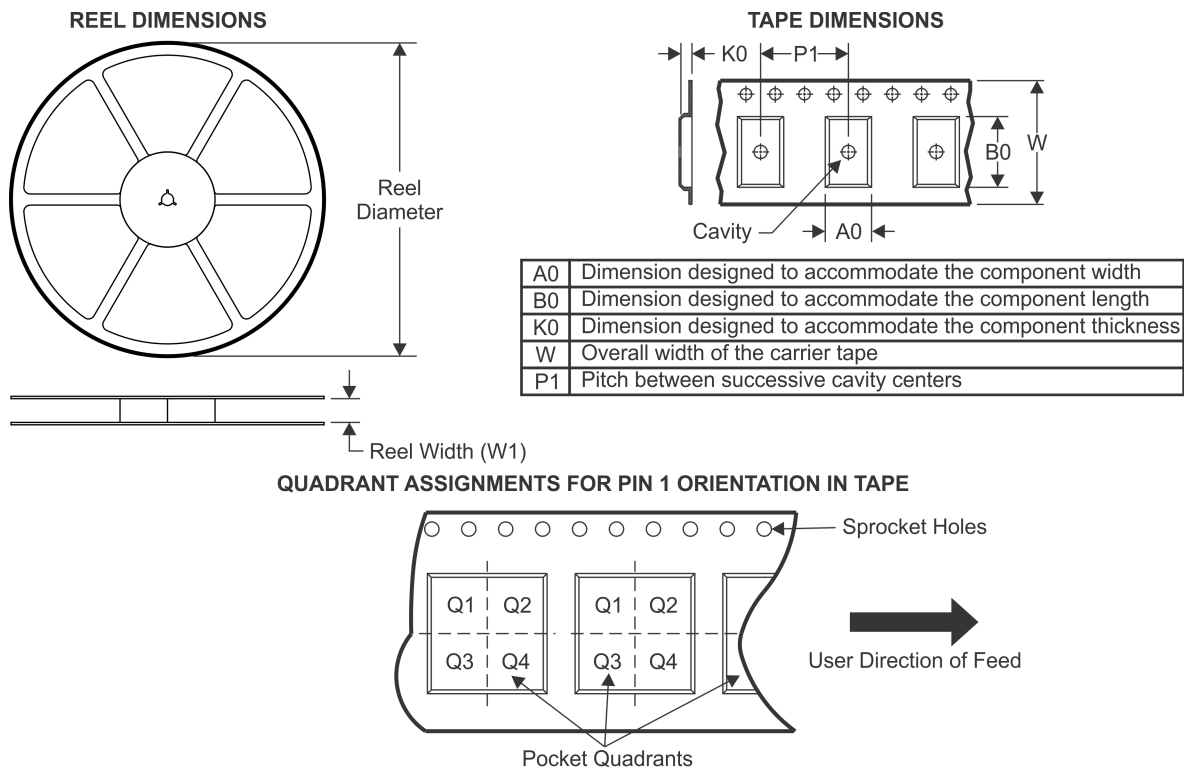
In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

OTHER QUALIFIED VERSIONS OF SN65HVD1050 :

- Automotive: [SN65HVD1050-Q1](#)
- Enhanced Product: [SN65HVD1050-EP](#)

NOTE: Qualified Version Definitions:

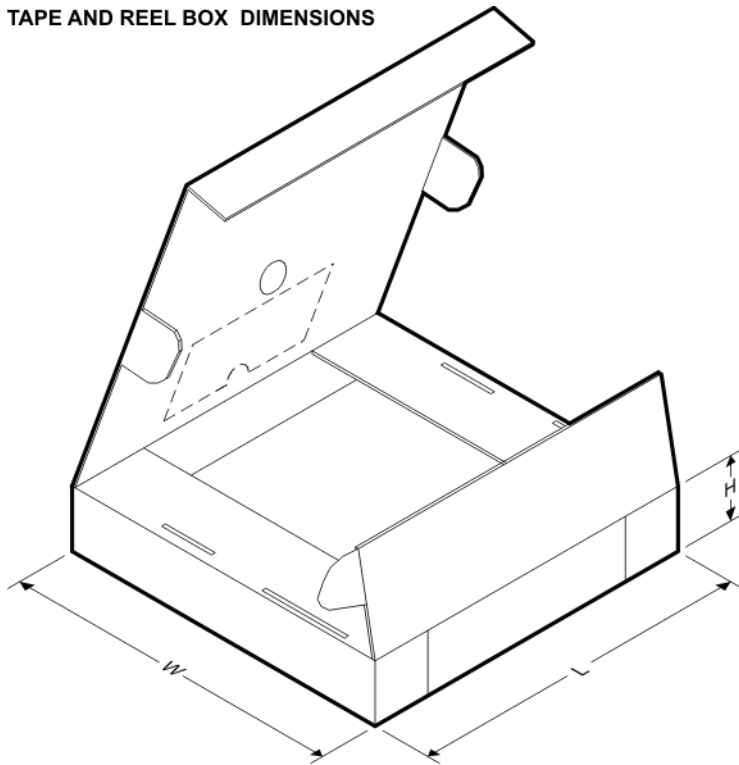
- Automotive - Q100 devices qualified for high-reliability automotive applications targeting zero defects
- Enhanced Product - Supports Defense, Aerospace and Medical Applications

TAPE AND REEL INFORMATION


*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 |
|---------------|--------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| SN65HVD1050DR | SOIC | D | 8 | 2500 | 330.0 | 12.4 | 6.4 | 5.2 | 2.1 | 8.0 | 12.0 | Q1 |

TAPE AND REEL BOX DIMENSIONS

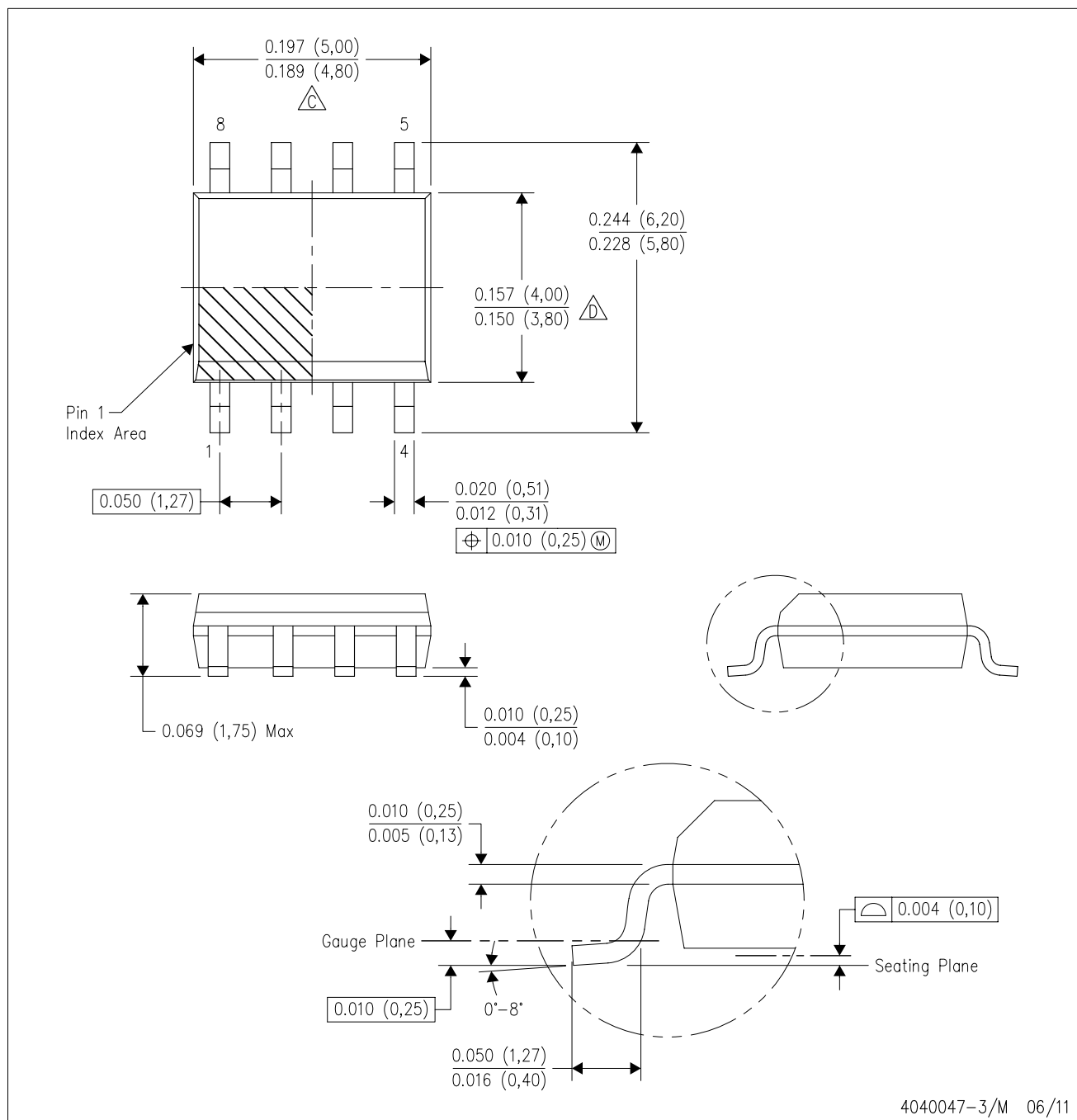


*All dimensions are nominal

| Device | Package Type | Package Drawing | Pins | SPQ | Length (mm) | Width (mm) | Height (mm) |
|---------------|--------------|-----------------|------|------|-------------|------------|-------------|
| SN65HVD1050DR | SOIC | D | 8 | 2500 | 367.0 | 367.0 | 35.0 |

D (R-PDSO-G8)

PLASTIC SMALL OUTLINE

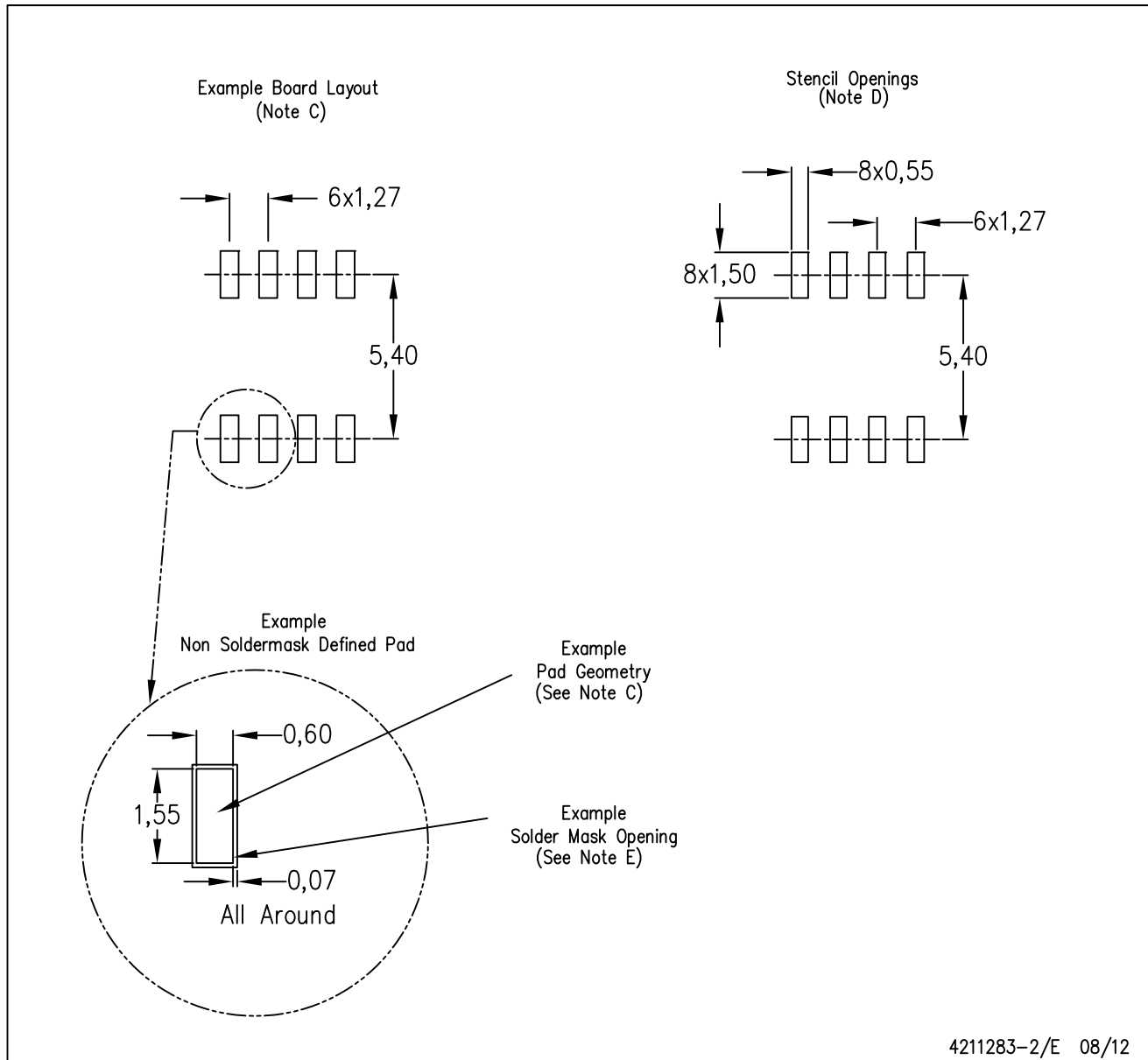


NOTES:

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

D (R-PDSO-G8)

PLASTIC SMALL OUTLINE



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

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