

## HIGH-SPEED DIFFERENTIAL LINE TRANSCEIVER

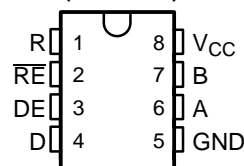
### FEATURES

- Low-Voltage Differential Driver and Receiver for Half-Duplex Operation
- Designed for Signaling Rates of 400 Mbit/s
- ESD Protection Exceeds 15 kV on Bus Pins
- Operates From a Single 3.3-V Supply
- Low-Voltage Differential Signaling With Typical Output Voltages of 350 mV and a 50-Ω Load
- Valid Output With as Little as 50 mV Input Voltage Difference
- Propagation Delay Times
  - Driver: 1.7 ns Typ
  - Receiver: 3.7 ns Typ
- Power Dissipation at 200 MHz
  - Driver: 50 mW Typical
  - Receiver: 60 mW Typical
- LVTTTL Levels Are 5-V Tolerant
- Bus Pins Are High Impedance When Disabled or With  $V_{CC}$  Less Than 1.5 V
- Open-Circuit Fail-Safe Receiver
- Surface-Mount Packaging
  - D Package (SOIC)
  - DGK Package (MSOP)

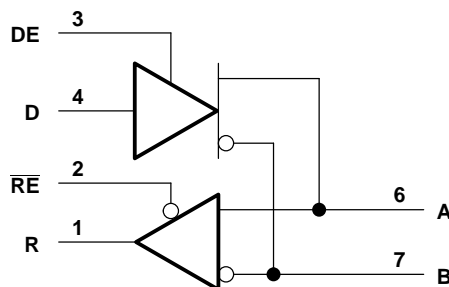
SN65LVDM176D (Marked as DM176 or LVM176)

SN65LVDM176DGK (Marked as M76)

(TOP VIEW)



logic diagram (positive logic)



### DESCRIPTION

The SN65LVDM176 is a differential line driver and receiver configured as a transceiver that uses low-voltage differential signaling (LVDS) to achieve signaling rates as high as 400 Mbit/s. These circuits are similar to TIA/EIA-644 standard compliant devices (SN65LVDS) counterparts except that the output current of the drivers is doubled. This modification provides a minimum differential output voltage magnitude of 247 mV into a 50-Ω load and allows double-terminated lines and half-duplex operation. The receivers detect a voltage difference of less than 50 mV with up to 1 V of ground potential difference between a transmitter and receiver.

The intended application of this device and signaling technique is for half-duplex or multiplex baseband data transmission over controlled impedance media of approximately 100-Ω characteristic impedance. The transmission media may be printed-circuit board traces, backplanes, or cables. (Note: The ultimate rate and distance of data transfer is dependent upon the attenuation characteristics of the media, the noise coupling to the environment, and other application specific characteristics).

The SN65LVDM176 is characterized for operation from  $-40^{\circ}\text{C}$  to  $85^{\circ}\text{C}$ .



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.



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.

**AVAILABLE OPTIONS**

| T <sub>A</sub> | PACKAGE                          |                           |
|----------------|----------------------------------|---------------------------|
|                | SMALL OUTLINE (D) <sup>(1)</sup> | MSOP (DGK) <sup>(1)</sup> |
| -40°C to 85°C  | SN65LVDM176D                     | SN65LVDM176DGK            |

(1) The D package is available taped and reeled. Add the suffix R to the device type(e.g., SN65LVDM176DR).

**FUNCTION TABLES**

**DRIVER<sup>(1)</sup>**

| INPUT D | ENABLE DE | OUTPUTS |   |
|---------|-----------|---------|---|
|         |           | A       | B |
| L       | H         | L       | H |
| H       | H         | H       | L |
| Open    | H         | L       | H |
| X       | L         | Z       | Z |

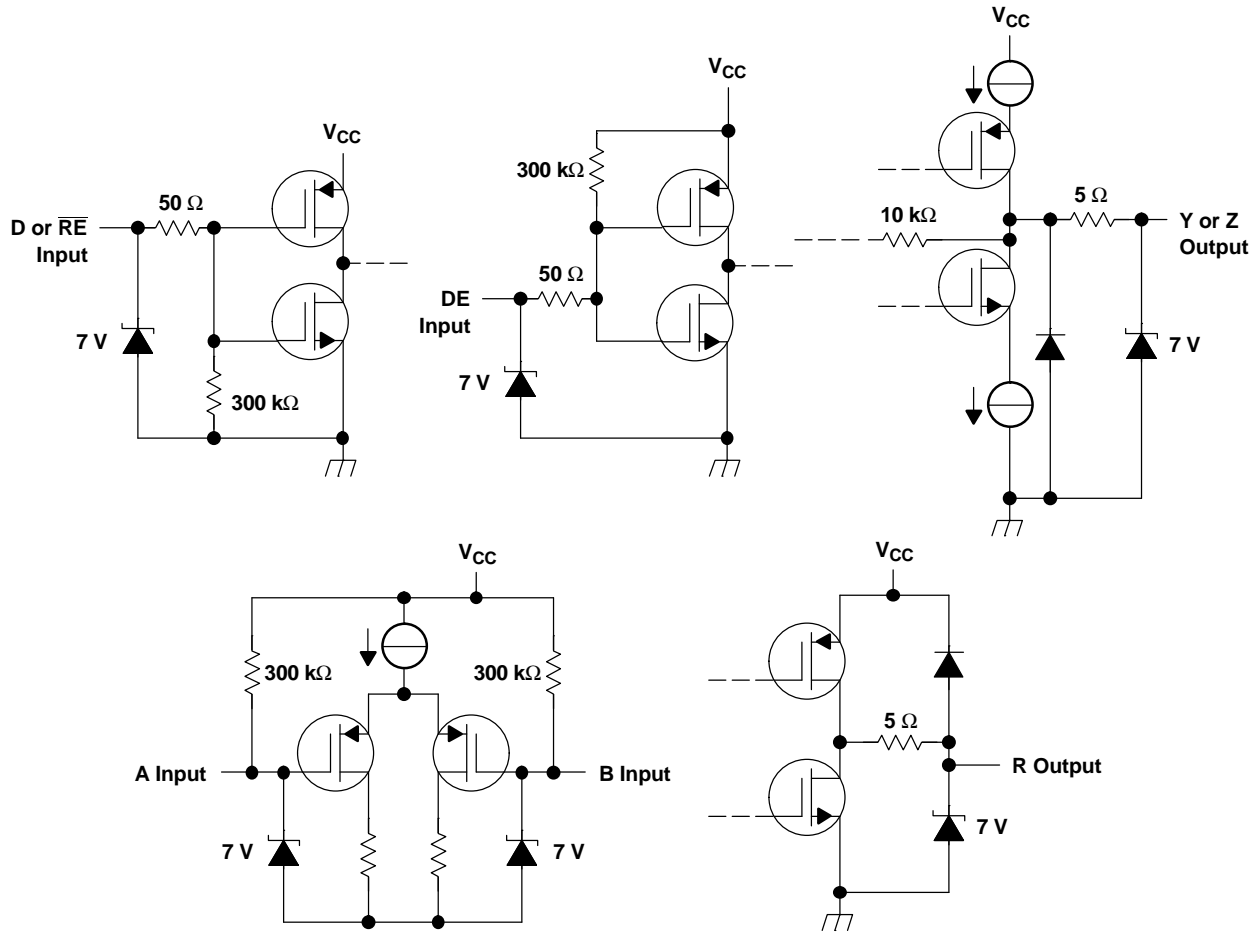
(1) H = high level, L = low level, X = irrelevant, Z = high impedance

**RECEIVER<sup>(1)</sup>**

| DIFFERENTIAL INPUTS<br>V <sub>ID</sub> = V <sub>A</sub> - V <sub>B</sub> | ENABLE RE | OUTPUT R |
|--|-----------|----------|
| V <sub>ID</sub> ≥ 50 mV  | L         | H        |
| 50 mV < V <sub>ID</sub> < 50 mV  | L         | ?        |
| V <sub>ID</sub> ≤ -50 mV   | L         | L        |
| Open   | L         | H        |
| X  | H         | Z        |

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

**EQUIVALENT INPUT AND OUTPUT SCHEMATIC DIAGRAMS**



**ABSOLUTE MAXIMUM RATINGS**

over operating free-air temperature range (unless otherwise noted)<sup>(1)</sup>

|  |                                      | UNIT                         |
|--|--------------------------------------|------------------------------|
| $V_{CC}$   | Supply voltage <sup>(2)</sup>        | -0.5 V to 4 V                |
| Input voltage range  | D, R, DE, $\overline{RE}$            | -0.5 V to 6 V                |
|  | A or B                               | -0.5 V to 4 V                |
| Electrostatic discharge                                      | A, B, and GND <sup>(3)</sup>         | Class 3, A:15 kV, B:600 V    |
|  | All terminals                        | Class 3, A:7 kV, B:500 V     |
| Continuous total power dissipation                           |                                      | See Dissipation Rating Table |
| $T_A$  | Operating free-air temperature range | -40°C to 85°C                |
| $T_{stg}$  | Storage temperature range            | -65°C to 150°C               |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds |                                      | 260°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 voltage, are with respect to network ground terminal.
- (3) Tested in accordance with MIL-STD-883C Method 3015.7.

## DISSIPATION RATING TABLE

| PACKAGE | $T_A \leq 25^\circ\text{C}$<br>POWER RATING | DERATING FACTOR<br>ABOVE $T_A = 25^\circ\text{C}$ | $T_A = 85^\circ\text{C}$<br>POWER RATING |
|---------|---|---|--|
| D       | 725 mW                                      | 5.8 mW/°C   | 377 mW                                   |
| DGK     | 424 mW                                      | 3.4 mW/°C   | 220 mW                                   |

## RECOMMENDED OPERATING CONDITIONS

|            |  | MIN                  | NOM                        | MAX | UNIT |
|------------|--|----------------------|----------------------------|-----|------|
| $V_{CC}$   | Supply voltage                           | 3                    | 3.3                        | 3.6 | V    |
| $V_{IH}$   | High-level input voltage                 | 2                    |                            |     | V    |
| $V_{IL}$   | Low-level input voltage                  |                      |                            | 0.8 | V    |
| $ V_{ID} $ | Magnitude of differential input voltage  | 0.1                  |                            | 0.6 | V    |
| $V_{IC}$   | Common-mode input voltage (see Figure 1) | $\frac{ V_{ID} }{2}$ | $2.4 - \frac{ V_{ID} }{2}$ |     | V    |
|            |  |                      | $V_{CC} - 0.8$             |     |      |
| $T_A$      | Operating free-air temperature           | -40                  |                            | 85  | °C   |

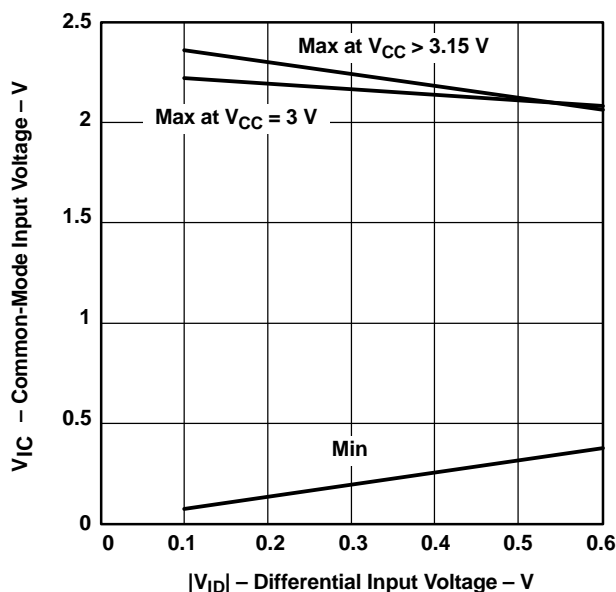
COMMON-MODE INPUT VOLTAGE  
vs  
DIFFERENTIAL INPUT VOLTAGE

Figure 1.

## DEVICE ELECTRICAL CHARACTERISTICS

over recommended operating conditions (unless otherwise noted)

| PARAMETER               | TEST CONDITIONS  | MIN | TYP <sup>(1)</sup> | MAX | UNIT |
|-------------------------|--|-----|--------------------|-----|------|
| $I_{CC}$ Supply current | Driver and receiver enabled, no receiver load, driver $R_L = 50\ \Omega$ |     | 10                 | 15  | mA   |
|                         | Driver enabled, receiver disabled, $R_L = 50\ \Omega$                    |     | 9                  | 15  |      |
|                         | Driver disabled, receiver enabled, no load                               |     | 1.8                | 5   |      |
|                         | Disabled   |     | 0.5                | 2   |      |

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

## DRIVER ELECTRICAL CHARACTERISTICS

over recommended operating conditions (unless otherwise noted)

| PARAMETER           |  | TEST CONDITIONS   | MIN                      | TYP   | MAX | UNIT          |
|---------------------|--|---|--------------------------|-------|-----|---------------|
| $ V_{OD} $          | Differential output voltage magnitude                                  | $R_L = 50 \Omega$ , See <a href="#">Figure 2</a> and <a href="#">Figure 3</a> | 247                      | 340   | 454 | mV            |
| $\Delta V_{OD} $    | Change in differential output voltage magnitude between logic states   |   | -50                      |       | 50  |               |
| $V_{OC(SS)}$        | Steady-state common-mode output voltage                                | See <a href="#">Figure 4</a>  | 1.125                    | 1.375 |     | V             |
| $\Delta V_{OC(SS)}$ | Change in steady-state common-mode output voltage between logic states |   | -50                      |       | 50  | mV            |
| $V_{OC(PP)}$        | Peak-to-peak common-mode output voltage                                |   |                          | 50    | 150 | mV            |
| $I_{IH}$            | High-level input current <sup>(1)</sup>                                | DE  | $V_{IH} = 5 \text{ V}$   | 0.5   | 10  | $\mu\text{A}$ |
|                     |  | D   |                          | 2     | 20  |               |
| $I_{IL}$            | Low-level input current <sup>(1)</sup>                                 | DE  | $V_{IL} = 0.8 \text{ V}$ | -0.5  | -10 | $\mu\text{A}$ |
|                     |  | D   |                          | 2     | 10  |               |
| $I_{OS}$            | Short-circuit output current <sup>(1)</sup>                            | $V_{OA}$ or $V_{OB} = 0 \text{ V}$  |                          |       | -10 | mA            |
|                     |  | $V_{OD} = 0 \text{ V}$  |                          |       | -10 |               |
| $C_I$               | Input capacitance  |   |                          | 3     |     | pF            |

(1) The non-algebraic convention, where the more positive (least negative) limit is designated maximum, is used in this data sheet for this parameter.

## RECEIVER ELECTRICAL CHARACTERISTICS

over recommended operating conditions (unless otherwise noted)

| PARAMETER    |   | TEST CONDITIONS                           | MIN  | TYP <sup>(1)</sup> | MAX     | UNIT          |
|--------------|---|---|------|--------------------|---------|---------------|
| $V_{IT+}$    | Positive-going differential input voltage threshold | See <a href="#">Figure 6</a>              |      |                    | 50      | mV            |
| $V_{IT-}$    | Negative-going differential input voltage threshold |   | -50  |                    |         |               |
| $V_{OH}$     | High-level output voltage                           | $I_{OH} = -8 \text{ mA}$                  | 2.4  |                    |         | V             |
| $V_{OL}$     | Low-level output voltage                            | $I_{OL} = 8 \text{ mA}$                   |      |                    | 0.4     | V             |
| $I_I$        | Input current (A or B inputs) <sup>(2)</sup>        | $V_I = 0 \text{ V}$                       | -2   |                    | -20     | $\mu\text{A}$ |
|              |   | $V_I = 2.4 \text{ V}$                     | -1.2 |                    |         |               |
| $I_{I(OFF)}$ | Power-off input current (A or B inputs)             | $V_{CC} = 0 \text{ V}$ or $1.8 \text{ V}$ |      |                    | 20      | $\mu\text{A}$ |
| $I_{IH}$     | High-level input current (enables)                  | $V_{IH} = 5 \text{ V}$                    |      |                    | 10      | $\mu\text{A}$ |
| $I_{IL}$     | Low-level input current (enables)                   | $V_{IL} = 0.8 \text{ V}$                  |      |                    | 10      | $\mu\text{A}$ |
| $I_{OZ}$     | High-impedance output current <sup>(2)</sup>        | $V_O = 0 \text{ V}$ or $5 \text{ V}$      |      |                    | $\pm 1$ | $\mu\text{A}$ |

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

(2) The non-algebraic convention, where the more positive (least negative) limit is designated maximum, is used in this data sheet for this parameter.

## DRIVER SWITCHING CHARACTERISTICS

over recommended operating conditions (unless otherwise noted)

| PARAMETER                   |   | TEST CONDITIONS   | MIN | TYP <sup>(1)</sup> | MAX | UNIT |
|-----------------------------|---|---|-----|--------------------|-----|------|
| $t_{PLH}$                   | Propagation delay time, low-to-high-level output            | $R_L = 50 \Omega$ , $C_L = 10 \text{ pF}$ ,<br>See Figure 3 | 0.5 | 1.7                | 2.7 | ns   |
| $t_{PHL}$                   | Propagation delay time, high-to-low-level output            |   | 0.5 | 1.7                | 2.7 |      |
| $t_{sk(p)}$                 | Pulse skew ( $ t_{pHL} - t_{pLH} $ )                        |   |     | 0.2                |     | ns   |
| $t_r$                       | Differential output signal rise time                        |   |     | 0.6                | 1   | ns   |
| $t_f$                       | Differential output signal fall time                        |   |     | 0.6                | 1   |      |
| $t_{sk(pp)}$ <sup>(2)</sup> | Part-to-part skew   |   |     | 1                  | ns  |      |
| $t_{PZH}$                   | Propagation delay time, high-impedance-to-high-level output | See Figure 5  |     | 8                  | 12  | ns   |
| $t_{PZL}$                   | Propagation delay time, high-impedance-to-low-level output  |   |     | 7                  | 10  |      |
| $t_{PHZ}$                   | Propagation delay time, high-level-to-high-impedance output |   |     | 3                  | 10  |      |
| $t_{PLZ}$                   | Propagation delay time, low-level-to-high-impedance output  |   |     | 4                  | 10  |      |

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

(2)  $t_{sk(pp)}$  is the magnitude of the difference in propagation delay times between any specified terminals of two devices when both devices operate with the same supply voltages, at the same temperature, and have identical packages and test circuits.

## RECEIVER SWITCHING CHARACTERISTICS

over recommended operating conditions (unless otherwise noted)

| PARAMETER                   |   | TEST CONDITIONS                      | MIN | TYP <sup>(1)</sup> | MAX | UNIT |
|-----------------------------|---|--------------------------------------|-----|--------------------|-----|------|
| $t_{PLH}$                   | Propagation delay time, low-to-high-level output            | $C_L = 10 \text{ pF}$ , See Figure 7 | 2.3 | 3.7                | 4.5 | ns   |
| $t_{PHL}$                   | Propagation delay time, high-to-low-level output            |                                      | 2.3 | 3.7                | 4.5 |      |
| $t_{sk(p)}$                 | Pulse skew ( $ t_{pHL} - t_{pLH} $ )                        |                                      |     | 0.4                |     | ns   |
| $t_r$                       | Output signal rise time                                     |                                      |     | 0.8                | 1.5 |      |
| $t_f$                       | Output signal fall time                                     |                                      |     | 0.8                | 1.5 |      |
| $t_{sk(pp)}$ <sup>(2)</sup> | Part-to-part skew   |                                      |     | 1                  | ns  |      |
| $t_{PZH}$                   | Propagation delay time, high-level-to-high-impedance output | See Figure 8                         |     | 3                  | 10  | ns   |
| $t_{PZL}$                   | Propagation delay time, low-level-to-low-impedance output   |                                      |     | 3                  | 10  |      |
| $t_{PHZ}$                   | Propagation delay time, high-impedance-to-high-level output |                                      |     | 4                  | 10  |      |
| $t_{PLZ}$                   | Propagation delay time, low-impedance-to-high-level output  |                                      |     | 6                  | 10  |      |

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

(2)  $t_{sk(pp)}$  is the magnitude of the difference in propagation delay times between any specified terminals of two devices when both devices operate with the same supply voltages, at the same temperature, and have identical packages and test circuits.

## PARAMETER MEASUREMENT INFORMATION

### DRIVER

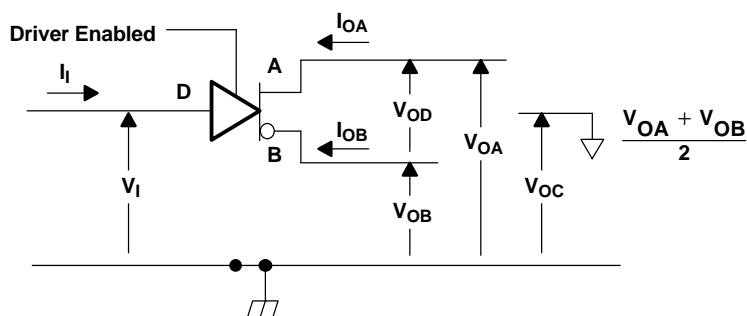
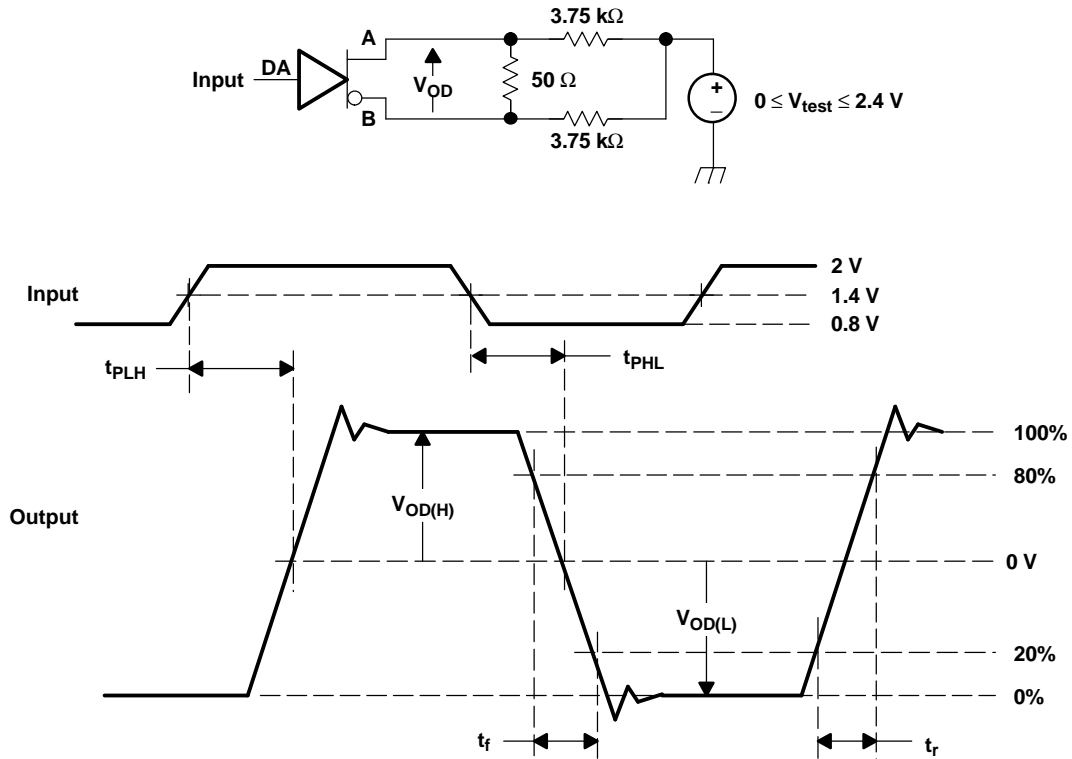


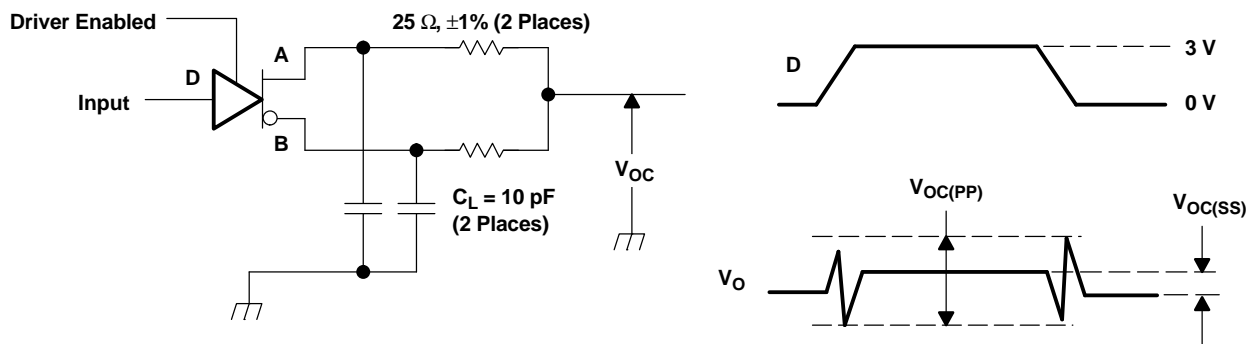
Figure 2. Driver Voltage and Current Definitions

PARAMETER MEASUREMENT INFORMATION (continued)



- A. All input pulses are supplied by a generator having the following characteristics:  $t_{\text{r}}$  or  $t_{\text{f}} \leq 1 \text{ ns}$ , pulse repetition rate (PRR) = 50 Mpps, pulse width =  $10 \pm 0.2 \text{ ns}$ .  $C_{\text{L}}$  includes instrumentation and fixture capacitance within 0,06 mm of the D.U.T.

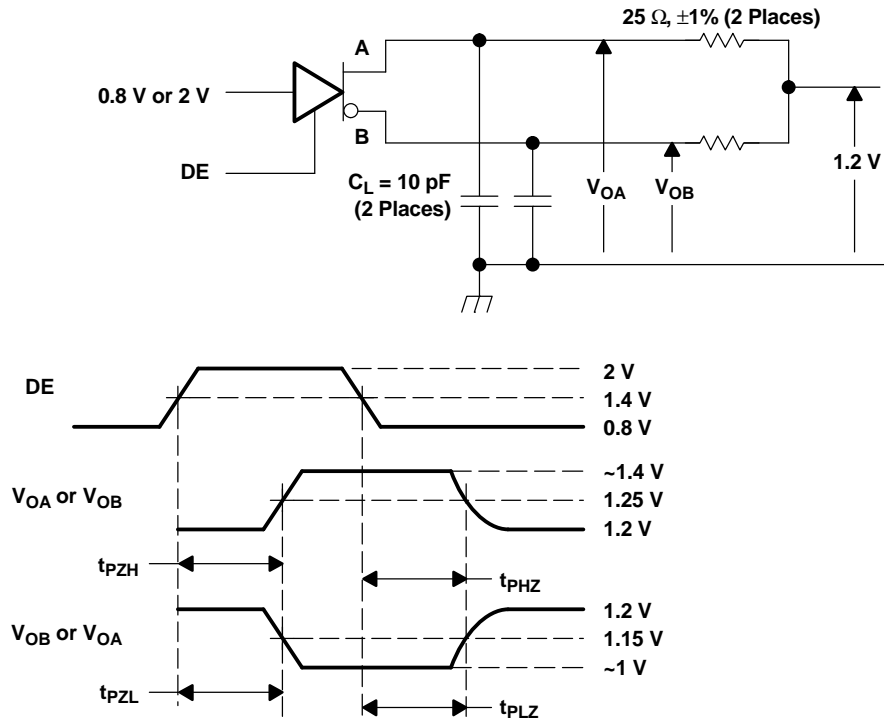
Figure 3. Test Circuit, Timing, and Voltage Definitions for the Differential Output Signal



- A. All input pulses are supplied by a generator having the following characteristics:  $t_{\text{r}}$  or  $t_{\text{f}} \leq 1 \text{ ns}$ , pulse repetition rate (PRR) = 0.5 Mpps, pulse width =  $500 \pm 10 \text{ ns}$ .  $C_{\text{L}}$  includes instrumentation and fixture capacitance within 0,06 mm of the D.U.T. The measurement of  $V_{\text{OC(PP)}}$  is made on test equipment with a -3 dB bandwidth of at least 300 MHz.

Figure 4. Test Circuit and Definitions for the Driver Common-Mode Output Voltage

PARAMETER MEASUREMENT INFORMATION (continued)



- A. All input pulses are supplied by a generator having the following characteristics:  $t_r$  or  $t_f \leq 1$  ns, pulse repetition rate (PRR) = 0.5 Mpps, pulse width =  $500 \pm 10$  ns.  $C_L$  includes instrumentation and fixture capacitance within 0,06 mm of the D.U.T.

Figure 5. Enable and Disable Time Circuit and Definitions

RECEIVER

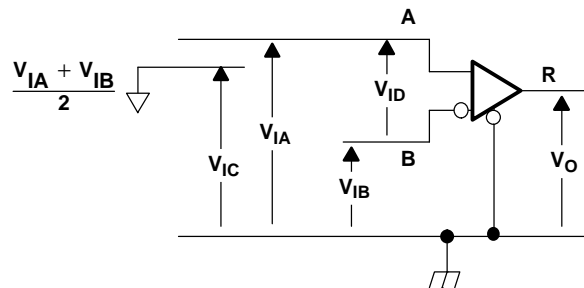
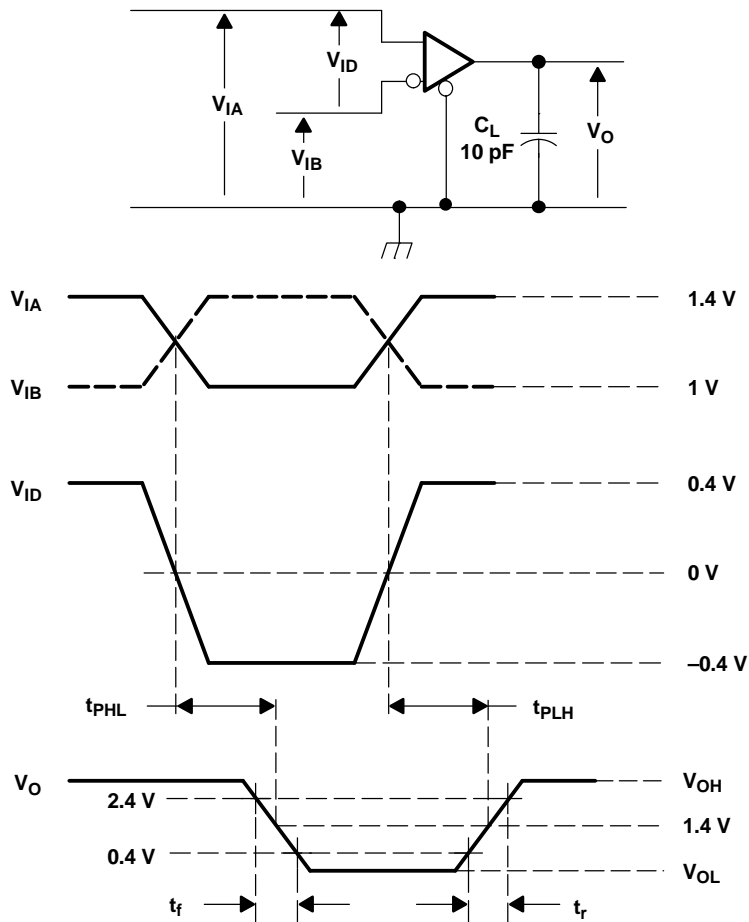


Figure 6. Receiver Voltage Definitions



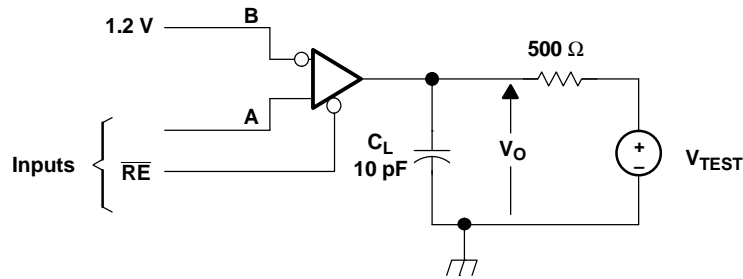
Table 1. Receiver Minimum and Maximum Input Threshold Test Voltages

| APPLIED VOLTAGES (V) |          | RESULTING DIFFERENTIAL INPUT VOLTAGE (mV) | RESULTING COMMON-MODE INPUT VOLTAGE (V) |
|----------------------|----------|---|---|
| $V_{IA}$             | $V_{IB}$ | $V_{ID}$                                  | $V_{IC}$                                |
| 1.225                | 1.175    | 50  | 1.2                                     |
| 1.175                | 1.225    | -50                                       | 1.2                                     |
| 2.41                 | 2.36     | 50  | 2.385                                   |
| 2.36                 | 2.41     | -50                                       | 2.385                                   |
| 0.05                 | 0        | 50  | 0.025                                   |
| 0                    | 0.05     | -50                                       | 0.025                                   |
| 1.5                  | 0.9      | 600                                       | 1.2                                     |
| 0.9                  | 1.5      | -600                                      | 1.2                                     |
| 2.4                  | 1.8      | 600                                       | 2.1                                     |
| 1.8                  | 2.4      | -600                                      | 2.1                                     |
| 0.6                  | 0        | 600                                       | 0.3                                     |
| 0                    | 0.6      | -600                                      | 0.3                                     |



- A. All input pulses are supplied by a generator having the following characteristics:  $t_f$  or  $t_r \leq 1$  ns, pulse repetition rate (PRR) = 50 Mpps, pulse width =  $10 \pm 0.2$  ns.  $C_L$  includes instrumentation and fixture capacitance within 0,06 mm of the D.U.T.

Figure 7. Timing Test Circuit and Waveforms



- A. All input pulses are supplied by a generator having the following characteristics:  $t_r$  or  $t_f \leq 1$  ns, pulse repetition rate (PRR) = 0.5 Mpps, pulse width =  $5000 \pm 10$  ns.  $C_L$  includes instrumentation and fixture capacitance within 0,06 mm of the D.U.T.

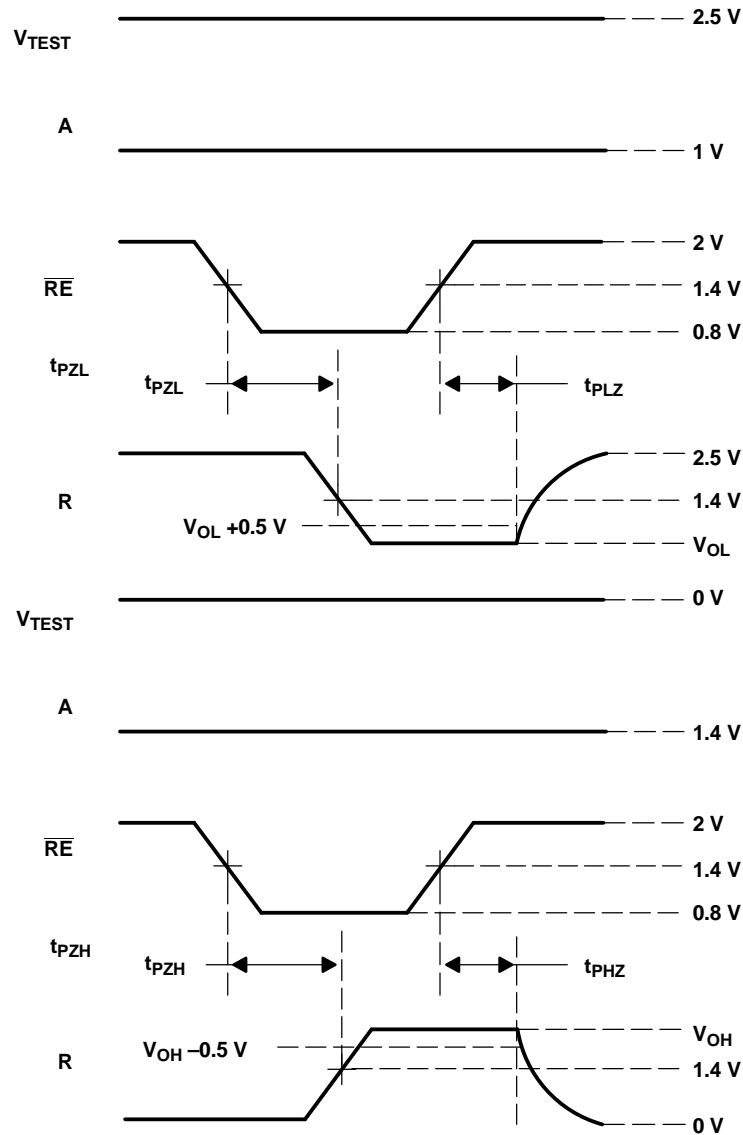


Figure 8. Enable/Disable Time Test Circuit and Waveforms

**TYPICAL CHARACTERISTICS**

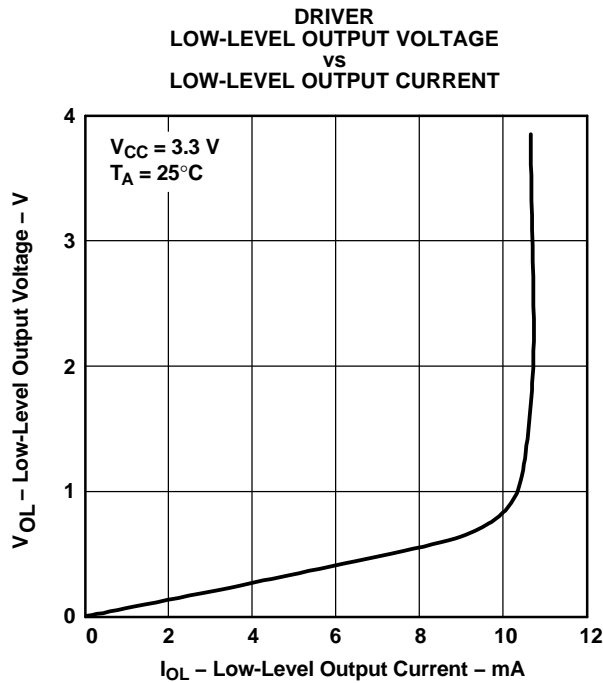


Figure 9.

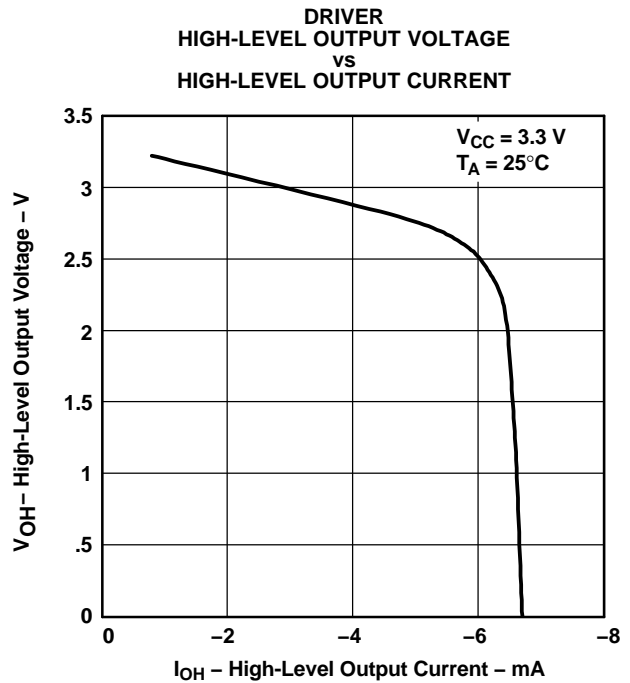


Figure 10.

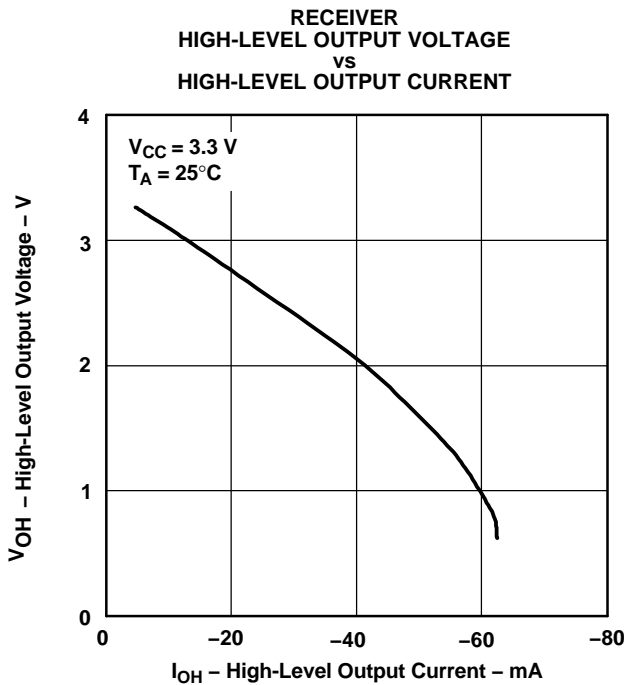


Figure 11.

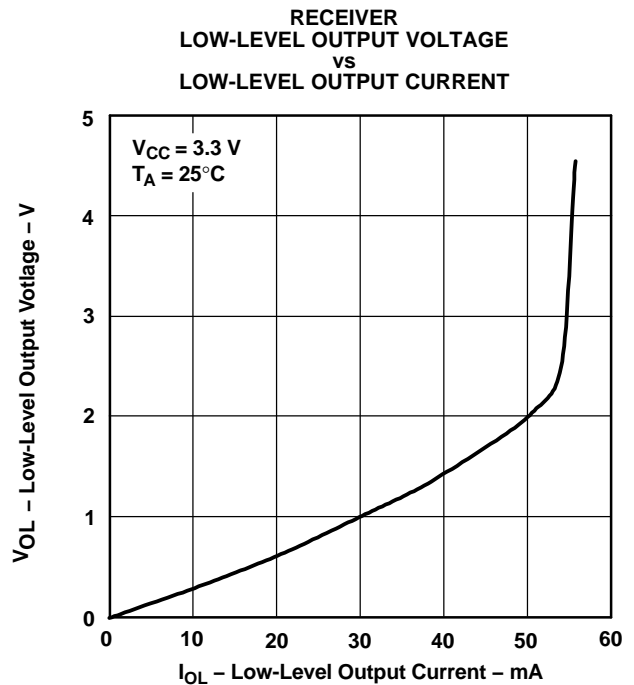
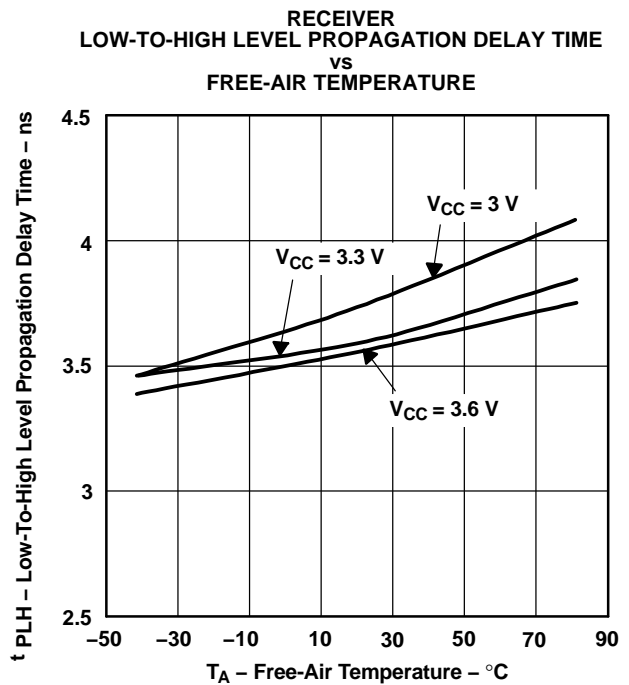
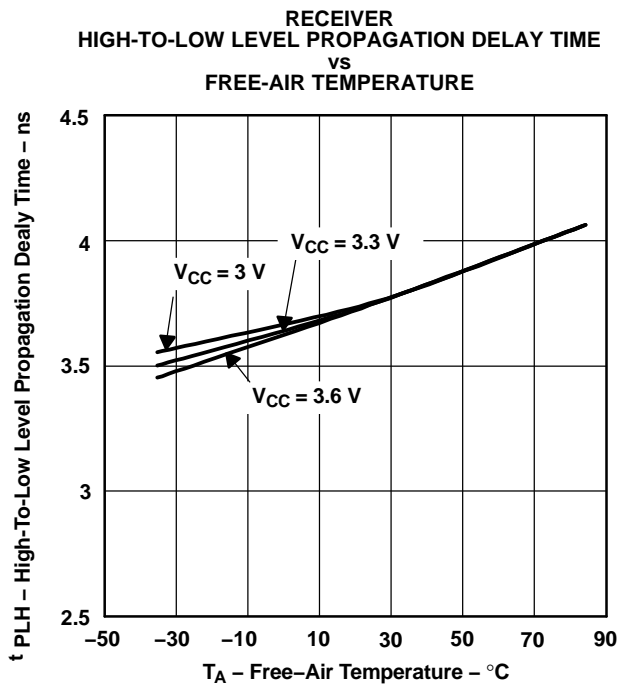
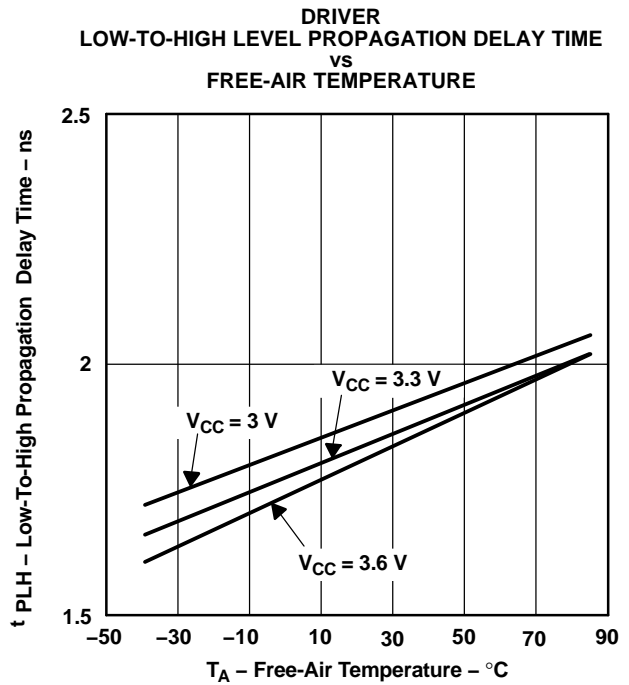
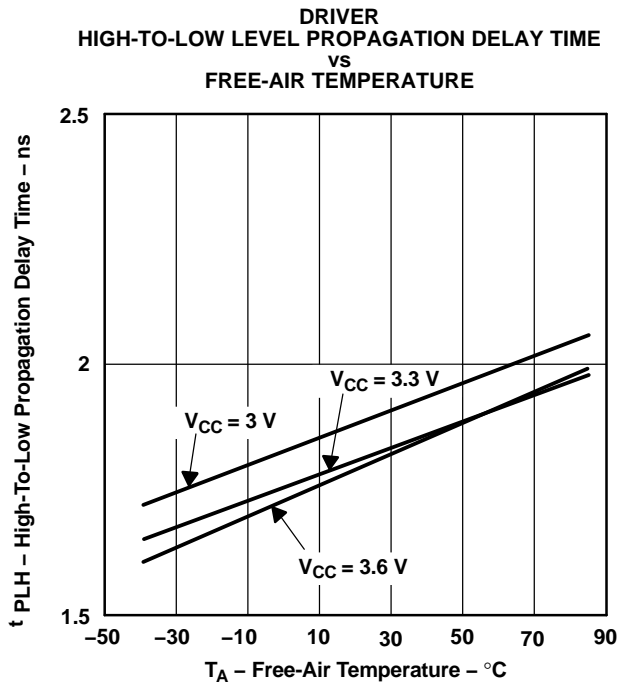


Figure 12.

TYPICAL CHARACTERISTICS (continued)



## APPLICATION INFORMATION

The devices are generally used as building blocks for high-speed point-to-point data transmission. Ground differences are less than 1 V with a low common-mode output and balanced interface for very low noise emissions. Devices can interoperate with RS-422, PECL, and IEEE-P1596. Drivers/receivers maintain ECL speeds without the power and dual supply requirements.

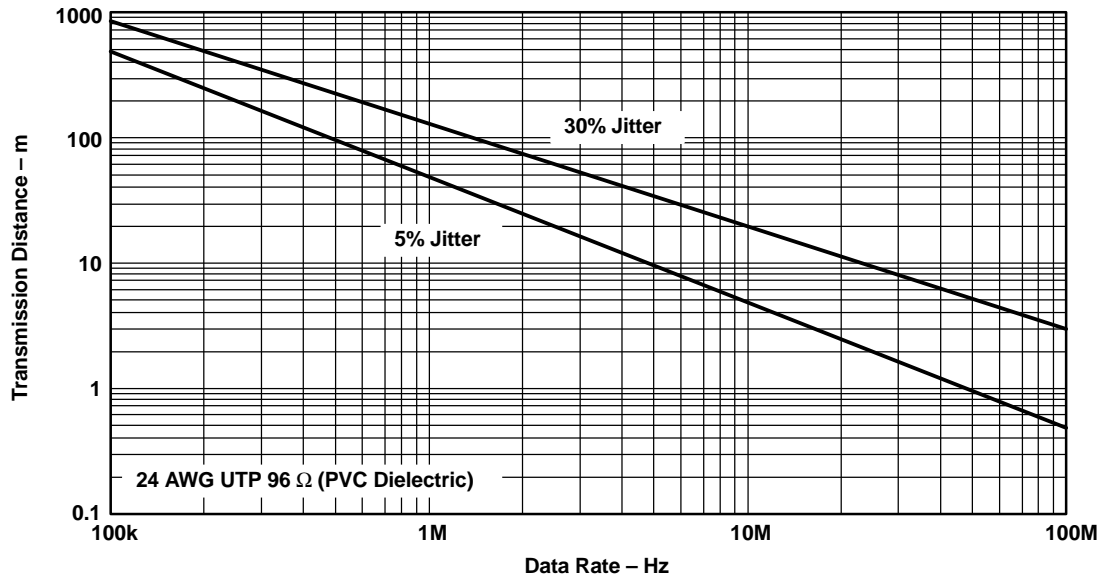


Figure 17. Data Transmission Distance Versus Rate

## FAIL SAFE

One of the most common problems with differential signaling applications is how the system responds when no differential voltage is present on the signal pair. The LVDS receiver is like most differential line receivers, in that its output logic state can be indeterminate when the differential input voltage is between  $-50$  mV and  $50$  mV and within its recommended input common-mode voltage range. TI's LVDS receiver is different in how it handles the open-input circuit situation, however.

Open-circuit means that there is little or no input current to the receiver from the data line itself. This could be when the driver is in a high-impedance state or the cable is disconnected. When this occurs, the LVDS receiver will pull each line of the signal pair to near  $V_{CC}$  through  $300$ -k $\Omega$  resistors as shown in Figure 18. The fail-safe feature uses an AND gate with input voltage thresholds at about  $2.3$  V to detect this condition and force the output to a high-level regardless of the differential input voltage.

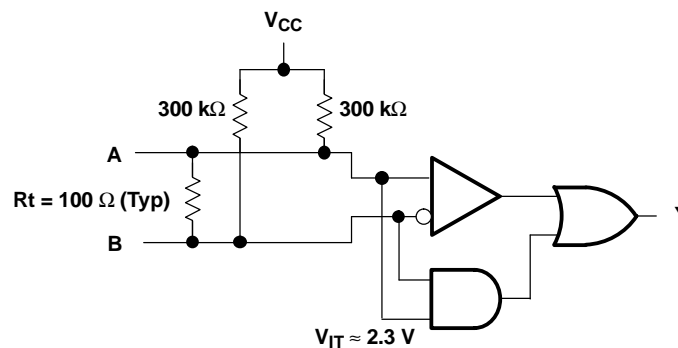
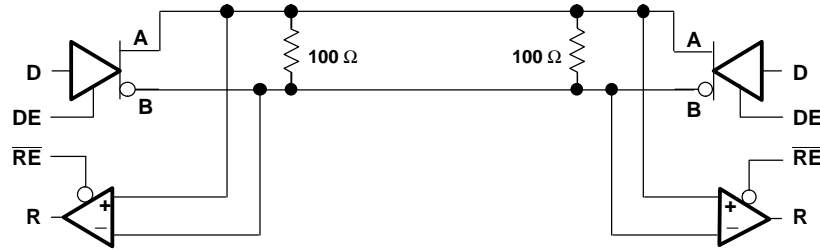


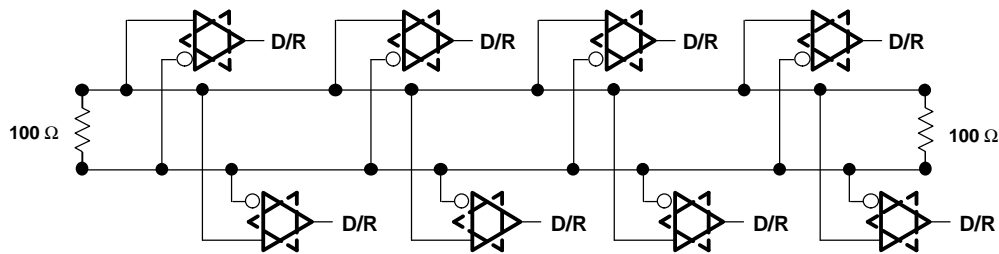
Figure 18. Open-Circuit Fail Safe of the LVDS Receiver

### APPLICATION INFORMATION (continued)

It is only under these conditions that the output of the receiver will be valid with less than a 50-mV differential input voltage magnitude. The presence of the termination resistor,  $R_t$ , does not affect the fail-safe function as long as it is connected as shown in the figure. Other termination circuits may allow a dc current to ground that could defeat the pullup currents from the receiver and the fail-safe feature.



Bidirectional Half-Duplex Applications



Multipoint Bus Applications

Note A: Keep drivers and receivers as close to the LVDS bus side connector as possible.

Figure 19. Bidirectional Half-Duplex and Multipoint Bus Applications

**PACKAGING INFORMATION**

| Orderable Device  | Status <sup>(1)</sup> | Package Type | Package Drawing | Pins | Package Qty | Eco Plan <sup>(2)</sup> | Lead/Ball Finish | MSL Peak Temp <sup>(3)</sup> |
|-------------------|-----------------------|--------------|-----------------|------|-------------|-------------------------|------------------|------------------------------|
| SN65LVDM176D      | ACTIVE                | SOIC         | D               | 8    | 75          | Green (RoHS & no Sb/Br) | CU NIPDAU        | Level-1-260C-UNLIM           |
| SN65LVDM176DG4    | ACTIVE                | SOIC         | D               | 8    | 75          | Green (RoHS & no Sb/Br) | CU NIPDAU        | Level-1-260C-UNLIM           |
| SN65LVDM176DGK    | ACTIVE                | MSOP         | DGK             | 8    | 80          | Green (RoHS & no Sb/Br) | CU NIPDAU        | Level-1-260C-UNLIM           |
| SN65LVDM176DGKG4  | ACTIVE                | MSOP         | DGK             | 8    | 80          | Green (RoHS & no Sb/Br) | CU NIPDAU        | Level-1-260C-UNLIM           |
| SN65LVDM176DGKR   | ACTIVE                | MSOP         | DGK             | 8    | 2500        | Green (RoHS & no Sb/Br) | CU NIPDAU        | Level-1-260C-UNLIM           |
| SN65LVDM176DGKRG4 | ACTIVE                | MSOP         | DGK             | 8    | 2500        | Green (RoHS & no Sb/Br) | CU NIPDAU        | Level-1-260C-UNLIM           |
| SN65LVDM176DR     | ACTIVE                | SOIC         | D               | 8    | 2500        | Green (RoHS & no Sb/Br) | CU NIPDAU        | Level-1-260C-UNLIM           |
| SN65LVDM176DRG4   | ACTIVE                | SOIC         | D               | 8    | 2500        | Green (RoHS & no Sb/Br) | CU NIPDAU        | Level-1-260C-UNLIM           |

<sup>(1)</sup> 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.

<sup>(2)</sup> 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)

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

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