



# Half-Duplex RS-485-/RS-422-Compatible Transceiver with AutoDirection Control

## General Description

The MAX13487E/MAX13488E +5V, half-duplex,  $\pm 15\text{kV}$  ESD-protected RS-485/RS-422-compatible transceivers feature one driver and one receiver. The MAX13487E/MAX13488E include a hot-swap capability to eliminate false transitions on the bus during power-up or live insertion.

The MAX13487E/MAX13488E feature Maxim's proprietary AutoDirection control. This architecture makes the devices ideal for applications, such as isolated RS-485 ports, where the driver input is used in conjunction with the driver-enable signal to drive the differential bus.

The MAX13487E features reduced slew-rate drivers that minimize EMI and reduce reflections caused by improperly terminated cables, allowing error-free transmission up to 500kbps. The MAX13488E driver slew rate is not limited, allowing transmit speeds up to 16Mbps.

The MAX13487E/MAX13488E feature a 1/4-unit load receiver input impedance, allowing up to 128 transceivers on the bus. These devices are intended for half-duplex communications. All driver outputs are protected to  $\pm 15\text{kV}$  ESD using the Human Body Model. The MAX13487E/MAX13488E are available in an 8-pin SO package. The devices operate over the extended  $-40^{\circ}\text{C}$  to  $+85^{\circ}\text{C}$  temperature range.

## Applications

Isolated RS-485 Interfaces  
Utility Meters  
Industrial Controls  
Industrial Motor Drives  
Automated HVAC Systems

Pin Configuration/Typical Application Circuit appear at end of data sheet.

## Features

- ◆ +5V Operation
- ◆ AutoDirection Enables Driver Automatically on Transmission
- ◆ Hot-Swappable for Telecom Applications
- ◆ Enhanced Slew-Rate Limiting Facilitates Error-Free Data Transmission (MAX13487E)
- ◆ High-Speed Version (MAX13488E) Allows for Transmission Speeds Up to 16Mbps
- ◆ Extended ESD Protection for RS-485 I/O Pins  $\pm 15\text{kV}$  Human Body Model
- ◆ 1/4-Unit Load, Allowing Up to 128 Transceivers on the Bus
- ◆ 8-Pin SO Package

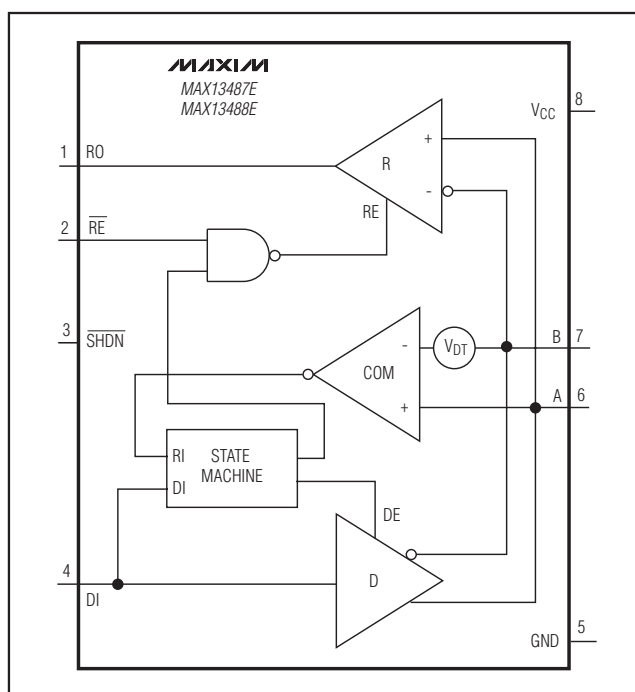
## Ordering Information/ Selector Guide

| PART                 | PIN-PACKAGE | SLEW-RATE LIMITED | PKG CODE |
|----------------------|-------------|-------------------|----------|
| <b>MAX13487EESA+</b> | 8 SO        | Yes               | S8-2     |
| <b>MAX13488EESA+</b> | 8 SO        | No                | S8-2     |

+ Denotes a lead-free package

**Note:** All devices operate over the  $-40^{\circ}\text{C}$  to  $+85^{\circ}\text{C}$  temperature range.

## Functional Diagram



# Half-Duplex RS-485-/RS-422-Compatible Transceiver with AutoDirection Control

## ABSOLUTE MAXIMUM RATINGS

(All voltages referenced to GND.)

|                                                                            |              |
|----------------------------------------------------------------------------|--------------|
| Supply Voltage $V_{CC}$ .....                                              | +6V          |
| SHDN, $\overline{RE}$ , DI .....                                           | -0.3V to +6V |
| A, B .....                                                                 | -8V to +13V  |
| Short-Circuit Duration ( $R_O$ , A, B) to GND .....                        | Continuous   |
| Continuous Power Dissipation ( $T_A = +70^\circ\text{C}$ ) .....           |              |
| 8-Pin SO (derate 5.9mW/ $^\circ\text{C}$ above $+70^\circ\text{C}$ ) ..... | 471mW        |

|                                        |                                               |
|----------------------------------------|-----------------------------------------------|
| Operating Temperature Range .....      | -40 $^\circ\text{C}$ to +85 $^\circ\text{C}$  |
| Junction Temperature .....             | +150 $^\circ\text{C}$                         |
| Storage Temperature Range .....        | -65 $^\circ\text{C}$ to +150 $^\circ\text{C}$ |
| Lead Temperature (soldering 10s) ..... | +300 $^\circ\text{C}$                         |

Stresses beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

## ELECTRICAL CHARACTERISTICS

( $V_{CC} = +5V \pm 5\%$ ,  $T_A = T_{MIN}$  to  $T_{MAX}$ , unless otherwise noted. Typical values are at  $V_{CC} = +5V$  and  $T_A = +25^\circ\text{C}$ .) (Note 1)

| PARAMETER                                             | SYMBOL            | CONDITIONS                                                                 |                        | MIN                   | TYP  | MAX             | UNITS |
|-------------------------------------------------------|-------------------|----------------------------------------------------------------------------|------------------------|-----------------------|------|-----------------|-------|
| DRIVER                                                |                   |                                                                            |                        |                       |      |                 |       |
| Differential Driver Output                            | V <sub>OD</sub>   | R <sub>DIFF</sub> = 100Ω, Figure 1                                         |                        | 2.0                   |      | V <sub>CC</sub> | V     |
|                                                       |                   | R <sub>DIFF</sub> = 54Ω, Figure 1                                          |                        | 1.5                   |      |                 |       |
|                                                       |                   | No load                                                                    |                        |                       |      | V <sub>CC</sub> |       |
| Driver Common-Mode Output Voltage                     | V <sub>OC</sub>   | R <sub>L</sub> = 100Ω or 54Ω, Figure 1                                     |                        | V <sub>CC</sub> / 2   |      | 3               | V     |
| Driver Disable Threshold                              | V <sub>DT</sub>   | Figure 2 (Note 2)                                                          |                        | +0.6                  |      | +1              | V     |
| Input-High Voltage                                    | V <sub>IH</sub>   | DI, $\overline{\text{SHDN}}$ , $\overline{\text{RE}}$                      |                        | 2.0                   |      |                 | V     |
| Input-Low Voltage                                     | V <sub>IL</sub>   | DI, $\overline{\text{SHDN}}$ , $\overline{\text{RE}}$                      |                        |                       |      | 0.8             | V     |
| Input Current                                         | I <sub>IN</sub>   | DI, $\overline{\text{SHDN}}$ , $\overline{\text{RE}}$                      |                        |                       |      | ±1              | μA    |
| Driver Short-Circuit Output Current (Note 3)          | I <sub>OSD</sub>  | 0V ≤ V <sub>OUT</sub> ≤ +12V                                               |                        | +50                   |      | +250            | mA    |
|                                                       |                   | -7V ≤ V <sub>OUT</sub> ≤ 0V                                                |                        | -250                  |      | -50             |       |
| Driver Short-Circuit Foldback Output Current (Note 3) | I <sub>OSDF</sub> | (V <sub>CC</sub> - 1V) ≤ V <sub>OUT</sub> ≤ +12V                           |                        | 20                    |      |                 | mA    |
|                                                       |                   | -7V ≤ V <sub>OUT</sub> ≤ 0V                                                |                        |                       |      | -20             |       |
| RECEIVER                                              |                   |                                                                            |                        |                       |      |                 |       |
| Input Current (A and B)                               | I <sub>A, B</sub> | DI = V <sub>CC</sub> , V <sub>CC</sub> = GND or +5V                        | V <sub>IN</sub> = +12V |                       |      | 250             | μA    |
|                                                       |                   |                                                                            | V <sub>IN</sub> = -7V  |                       | -200 |                 |       |
| Receiver Differential Threshold Voltage               | V <sub>TH</sub>   | -7V ≤ V <sub>CM</sub> ≤ +12V                                               |                        | -200                  |      | +200            | mV    |
| Receiver Input Hysteresis                             | ΔV <sub>TH</sub>  | V <sub>A</sub> + V <sub>B</sub> = 0V                                       |                        | 25                    |      |                 | mV    |
| Output-High Voltage                                   | V <sub>OH</sub>   | I <sub>O</sub> = -1.6mA, V <sub>A</sub> - V <sub>B</sub> > V <sub>TH</sub> |                        | V <sub>CC</sub> - 1.5 |      |                 | V     |
| Output-Low Voltage                                    | V <sub>OL</sub>   | I <sub>O</sub> = 1mA, V <sub>A</sub> - V <sub>B</sub> < -V <sub>TH</sub>   |                        |                       |      | 0.4             | V     |
| Tri-State Output Current at Receiver                  | I <sub>OZR</sub>  | 0V ≤ V <sub>O</sub> ≤ V <sub>CC</sub>                                      |                        |                       |      | ±1              | μA    |
| Receiver Input Resistance                             | R <sub>IN</sub>   | -7V ≤ V <sub>CM</sub> ≤ +12V                                               |                        | 48                    |      |                 | kΩ    |
| Receiver Output Short-Circuit Current                 | I <sub>OSR</sub>  | 0V ≤ V <sub>RO</sub> ≤ V <sub>CC</sub>                                     |                        | ±7                    |      | ±95             | mA    |

# Half-Duplex RS-485-/RS-422-Compatible Transceiver with AutoDirection Control

MAX13487E/MAX13488E

## ELECTRICAL CHARACTERISTICS (continued)

( $V_{CC} = +5V \pm 5\%$ ,  $T_A = T_{MIN}$  to  $T_{MAX}$ , unless otherwise noted. Typical values are at  $V_{CC} = +5V$  and  $T_A = +25^\circ C$ .) (Note 1)

| PARAMETER                       | SYMBOL            | CONDITIONS                                  | MIN  | TYP | MAX  | UNITS |
|---------------------------------|-------------------|---------------------------------------------|------|-----|------|-------|
| POWER SUPPLY                    |                   |                                             |      |     |      |       |
| Supply Voltage                  | V <sub>CC</sub>   |                                             | 4.75 |     | 5.25 | V     |
| Supply Current                  | I <sub>CC</sub>   | SHDN = 1, RE = 0, no load                   |      |     | 4.5  | mA    |
| Shutdown Supply Current         | I <sub>SHDN</sub> | SHDN = 0                                    |      |     | 10   | μA    |
| ESD PROTECTION                  |                   |                                             |      |     |      |       |
| ESD Protection (A, B)           |                   | Air Gap Discharge IEC 61000-4-2 (MAX13487E) | ±15  |     |      | kV    |
|                                 |                   | Human Body Model                            | ±15  |     |      |       |
| ESD Protection (All Other Pins) |                   | Human Body Model                            | ±2   |     |      | kV    |

## SWITCHING CHARACTERISTICS—MAX13487E

( $V_{CC} = +5V \pm 5\%$ ,  $T_A = T_{MIN}$  to  $T_{MAX}$ , unless otherwise noted. Typical values are at  $V_{CC} = +5V$  and  $T_A = +25^\circ C$ .)

| PARAMETER                                    | SYMBOL                     | CONDITIONS                                         | MIN | TYP | MAX  | UNITS   |
|----------------------------------------------|----------------------------|----------------------------------------------------|-----|-----|------|---------|
| <b>DRIVER</b>                                |                            |                                                    |     |     |      |         |
| Driver Propagation Delay                     | $t_{DPLH}$                 | $R_L = 110\Omega$ , $C_L = 50pF$ , Figures 2 and 3 | 200 |     | 1000 | ns      |
|                                              | $t_{DPLH}$                 |                                                    | 200 |     | 1000 |         |
| Driver Differential Output Rise or Fall Time | $t_{HL}$                   | $R_L = 110\Omega$ , $C_L = 50pF$ , Figures 2 and 3 | 200 |     | 900  | ns      |
|                                              | $t_{LH}$                   |                                                    | 200 |     | 900  |         |
| Maximum Data Rate                            |                            |                                                    | 500 |     |      | kbps    |
| Driver Disable Delay                         | $t_{DDD}$                  | Figure 3                                           |     |     | 2500 | ns      |
| Driver Enable from Shutdown to Output High   | $t_{DZH}(\overline{SHDN})$ | Figure 4                                           |     |     | 5.5  | $\mu s$ |
| Driver Enable from Shutdown to Output Low    | $t_{DZL}(\overline{SHDN})$ | Figure 4                                           |     |     | 5.5  | $\mu s$ |
| Time to Shutdown                             | $t_{SHDN}$                 |                                                    | 50  | 340 | 700  | ns      |
| <b>RECEIVER</b>                              |                            |                                                    |     |     |      |         |
| Receiver Propagation Delay                   | $t_{RPLH}$                 | $C_L = 15pF$ , Figures 5 and 6                     |     |     | 80   | ns      |
|                                              | $t_{RPHL}$                 |                                                    |     |     | 80   |         |
| Receiver Output Skew                         | $t_{RSKEW}$                | $C_L = 15pF$ , Figure 6                            |     |     | 13   | ns      |
| Maximum Data Rate                            |                            |                                                    | 500 |     |      | kbps    |
| Receiver Enable to Output High               | $t_{RZH}$                  | Figure 7                                           |     |     | 50   | ns      |
| Receiver Enable to Output Low                | $t_{RZL}$                  | Figure 7                                           |     |     | 50   | ns      |
| Receiver Disable Time from High              | $t_{RHZ}$                  | Figure 7                                           |     |     | 50   | ns      |
| Receiver Disable Time from Low               | $t_{RLZ}$                  | Figure 7                                           |     |     | 50   | ns      |
| Receiver Enable from Shutdown to Output High | $t_{RZH}(\overline{SHDN})$ | Figure 8                                           |     |     | 2200 | ns      |

# Half-Duplex RS-485-/RS-422-Compatible Transceiver with AutoDirection Control

## SWITCHING CHARACTERISTICS—MAX13487E (continued)

( $V_{CC} = +5V \pm 5\%$ ,  $T_A = T_{MIN}$  to  $T_{MAX}$ , unless otherwise noted. Typical values are at  $V_{CC} = +5V$  and  $T_A = +25^\circ C$ .)

| PARAMETER                                   | SYMBOL              | CONDITIONS | MIN | TYP | MAX  | UNITS |
|---------------------------------------------|---------------------|------------|-----|-----|------|-------|
| Receiver Enable from Shutdown to Output Low | $t_{RZL}$<br>(SHDN) | Figure 8   |     |     | 2200 | ns    |
| Receiver Enable Delay                       | $t_{RED}$           | Figure 3   |     |     | 70   | ns    |
| Time to Shutdown                            | $t_{SHDN}$          |            | 50  | 340 | 700  | ns    |

## SWITCHING CHARACTERISTICS—MAX13488E

( $V_{CC} = +5V \pm 5\%$ ,  $T_A = T_{MIN}$  to  $T_{MAX}$ , unless otherwise noted. Typical values are at  $V_{CC} = +5V$  and  $T_A = +25^\circ C$ .)

| PARAMETER                                    | SYMBOL                 | CONDITIONS                                         | MIN | TYP | MAX  | UNITS   |
|----------------------------------------------|------------------------|----------------------------------------------------|-----|-----|------|---------|
| <b>DRIVER</b>                                |                        |                                                    |     |     |      |         |
| Driver Propagation Delay                     | $t_{DPLH}$             | $R_L = 110\Omega$ , $C_L = 50pF$ , Figures 2 and 3 |     |     | 50   | ns      |
|                                              | $t_{DPHL}$             |                                                    |     |     | 50   |         |
| Driver Differential Output Rise or Fall Time | $t_{HL}$               | $R_L = 110\Omega$ , $C_L = 50pF$ , Figures 2 and 3 |     |     | 15   | ns      |
|                                              | $t_{LH}$               |                                                    |     |     | 15   |         |
| Maximum Data Rate                            |                        |                                                    | 16  |     |      | Mbps    |
| Driver Disable Delay                         | $t_{DDD}$              | Figure 3                                           |     |     | 70   | ns      |
| Driver Enable from Shutdown to Output High   | $t_{DZH}(\text{SHDN})$ | Figure 4                                           |     |     | 2.2  | $\mu s$ |
| Driver Enable from Shutdown to Output Low    | $t_{DZL}(\text{SHDN})$ | Figure 4                                           |     |     | 2.2  | $\mu s$ |
| Time to Shutdown                             | $t_{SHDN}$             |                                                    | 50  | 340 | 700  | ns      |
| <b>RECEIVER</b>                              |                        |                                                    |     |     |      |         |
| Receiver Propagation Delay                   | $t_{RPLH}$             | $C_L = 15pF$ , Figures 5 and 6                     |     |     | 80   | ns      |
|                                              | $t_{RPHL}$             |                                                    |     |     | 80   |         |
| Receiver Output Skew                         | $t_{RSKEW}$            | $C_L = 15pF$ , Figure 6                            |     |     | 13   | ns      |
| Maximum Data Rate                            |                        |                                                    | 16  |     |      | Mbps    |
| Receiver Enable to Output High               | $t_{RZH}$              | Figure 7                                           |     |     | 50   | ns      |
| Receiver Enable to Output Low                | $t_{RZL}$              | Figure 7                                           |     |     | 50   | ns      |
| Receiver Disable Time from High              | $t_{RHZ}$              | Figure 7                                           |     |     | 50   | ns      |
| Receiver Disable Time from Low               | $t_{RLZ}$              | Figure 7                                           |     |     | 50   | ns      |
| Receiver Enable from Shutdown to Output High | $t_{RZH}$<br>(SHDN)    | Figure 8                                           |     |     | 2200 | ns      |

# Half-Duplex RS-485-/RS-422-Compatible Transceiver with AutoDirection Control

## SWITCHING CHARACTERISTICS—MAX13488E (continued)

( $V_{CC} = +5V \pm 5\%$ ,  $T_A = T_{MIN}$  to  $T_{MAX}$ , unless otherwise noted. Typical values are at  $V_{CC} = +5V$  and  $T_A = +25^\circ C$ .)

| PARAMETER                                   | SYMBOL           | CONDITIONS | MIN | TYP | MAX  | UNITS |
|---------------------------------------------|------------------|------------|-----|-----|------|-------|
| Receiver Enable from Shutdown to Output Low | $t_{RZL}$ (SHDN) | Figure 8   |     |     | 2200 | ns    |
| Receiver Enable Delay                       | $t_{RED}$        | Figure 3   |     |     | 70   | ns    |
| Time to Shutdown                            | $t_{SHDN}$       |            | 50  | 340 | 700  | ns    |

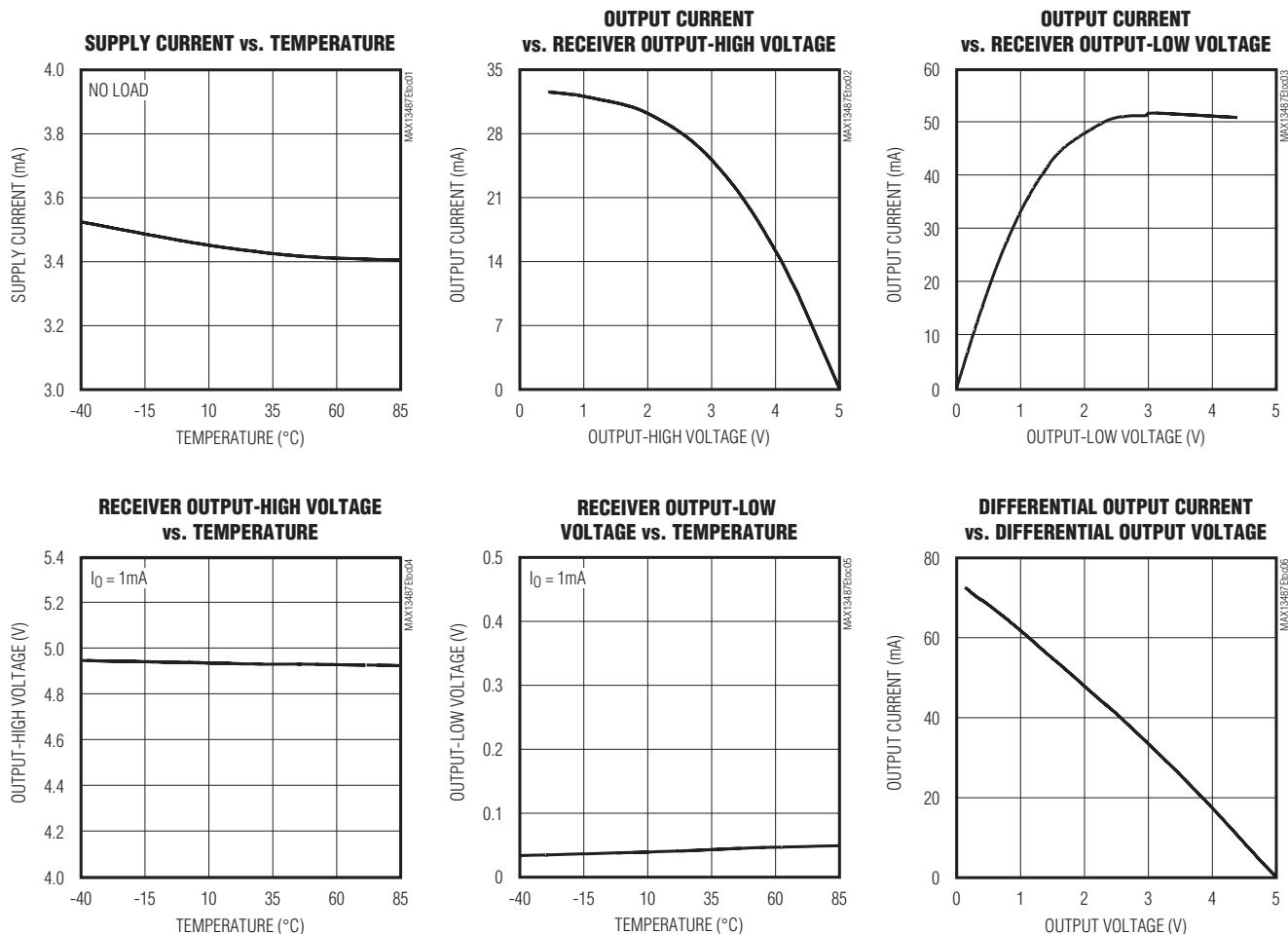
**Note 1:** All currents into the device are positive. All currents out of the device are negative. All voltages referred to device ground, unless otherwise noted.

**Note 2:** This is a differential voltage from A to B that the driving device must see on the bus to disable its driver.

**Note 3:** The short-circuit output current applied to peak current just prior to foldback current limiting. The short-circuit foldback output current applies during current limiting to allow a recovery from bus contention.

## Typical Operating Characteristics

( $V_{CC} = +5.0V$ ,  $T_A = +25^\circ C$ , unless otherwise noted.)

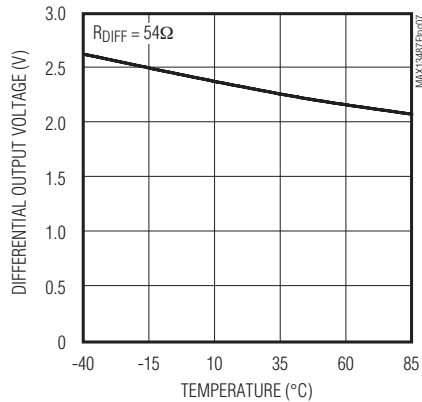


# Half-Duplex RS-485-/RS-422-Compatible Transceiver with AutoDirection Control

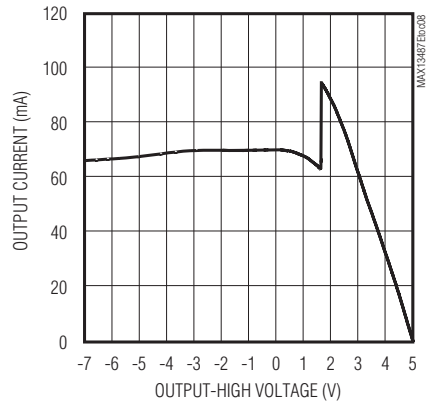
## Typical Operating Characteristics (continued)

( $V_{CC} = +5.0V$ ,  $T_A = +25^\circ C$ , unless otherwise noted.)

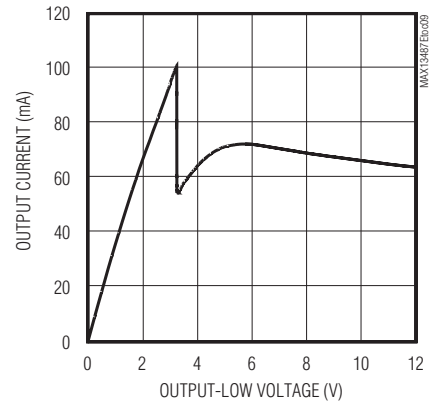
**DRIVER DIFFERENTIAL OUTPUT VOLTAGE vs. TEMPERATURE**



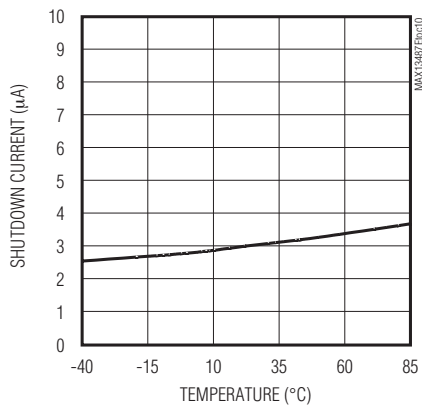
**OUTPUT CURRENT vs. TRANSMITTER OUTPUT-HIGH VOLTAGE**



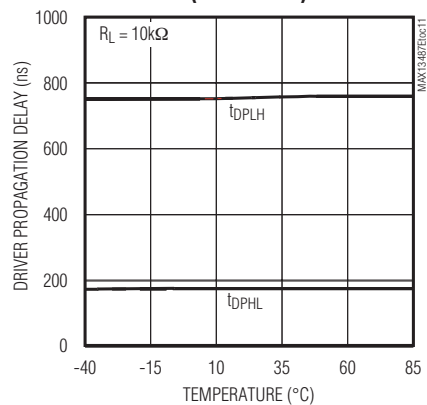
**OUTPUT CURRENT vs. TRANSMITTER OUTPUT-LOW VOLTAGE**



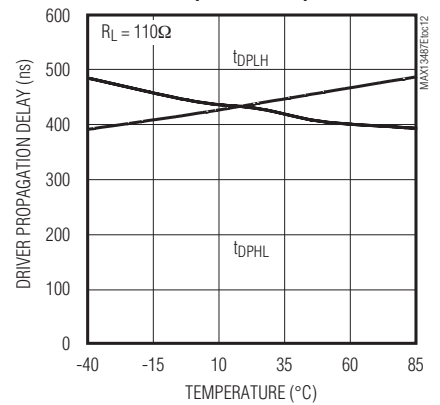
**SHUTDOWN CURRENT vs. TEMPERATURE**



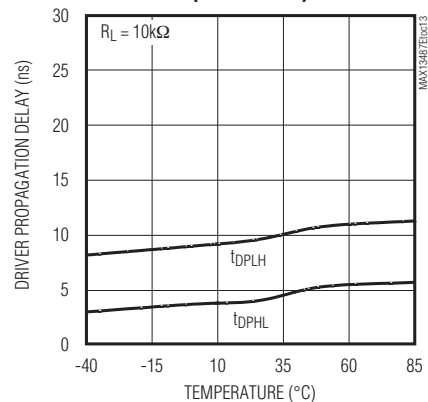
**DRIVER PROPAGATION vs. TEMPERATURE (MAX13487E)**



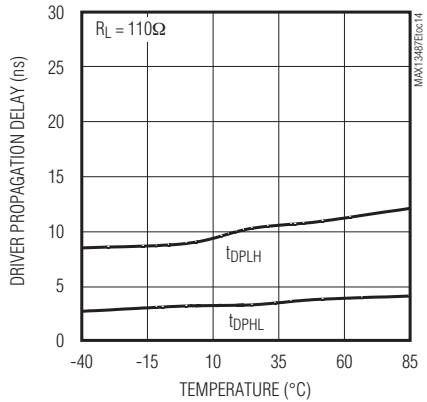
**DRIVER PROPAGATION vs. TEMPERATURE (MAX13487E)**



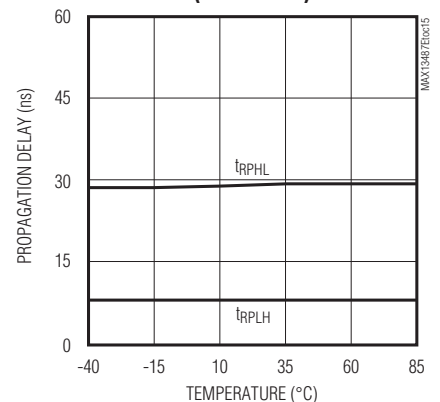
**DRIVER PROPAGATION vs. TEMPERATURE (MAX13488E)**



**DRIVER PROPAGATION vs. TEMPERATURE (MAX13488E)**



**RECEIVER PROPAGATION vs. TEMPERATURE (MAX13487E)**

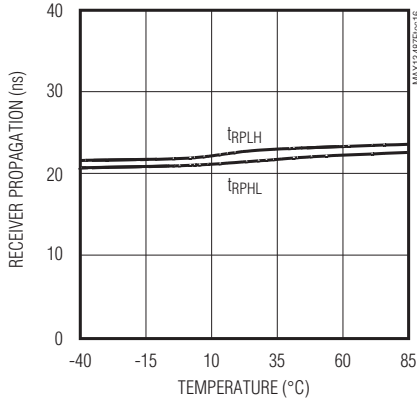


# Half-Duplex RS-485-/RS-422-Compatible Transceiver with AutoDirection Control

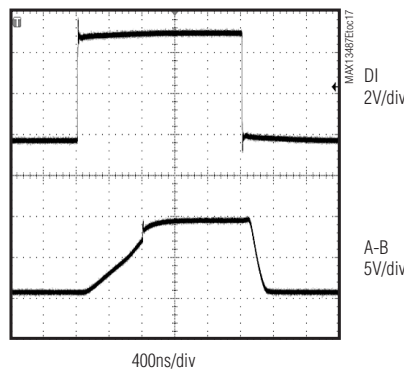
## Typical Operating Characteristics (continued)

( $V_{CC} = +5.0V$ ,  $T_A = +25^\circ C$ , unless otherwise noted.)

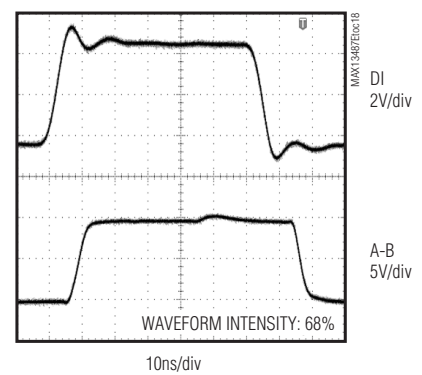
**RECEIVER PROPAGATION vs. TEMPERATURE  
(MAX13488E)**



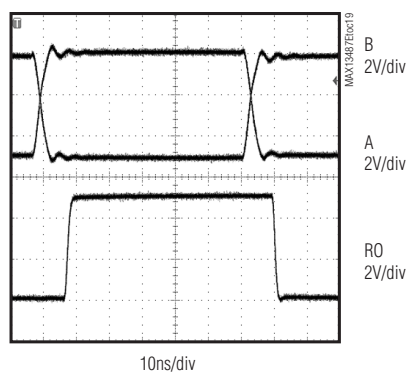
**DRIVER PROPAGATION (500kbps)  
(MAX13487E)**



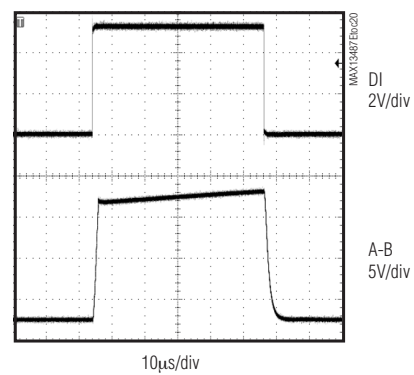
**DRIVER PROPAGATION (16Mbps)  
(MAX13488E)**



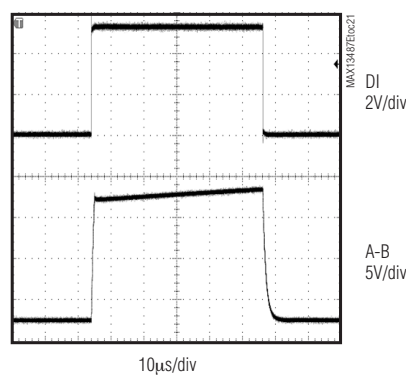
**RECEIVER PROPAGATION (16Mbps)  
(MAX13488E)**



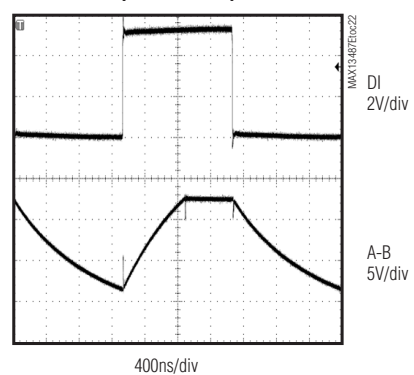
**DRIVING 16nF (19.2kbps)  
(MAX13487E)**



**DRIVING 16nF (19.2kbps)  
(MAX13488E)**



**DRIVING 16nF (750kbps)  
(MAX13488E)**



MAX13487E/MAX13488E

# Half-Duplex RS-485-/RS-422-Compatible Transceiver with AutoDirection Control

## Test Circuits and Waveforms

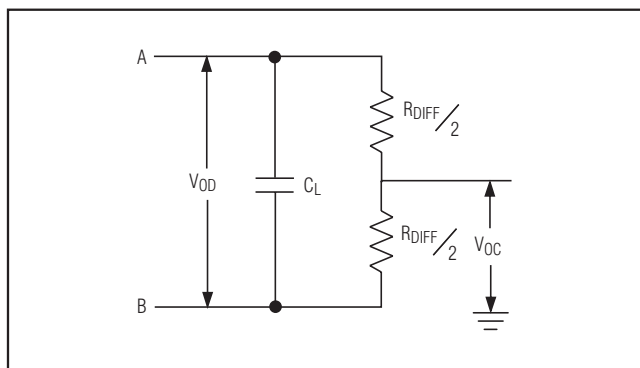


Figure 1. Driver DC Test Load

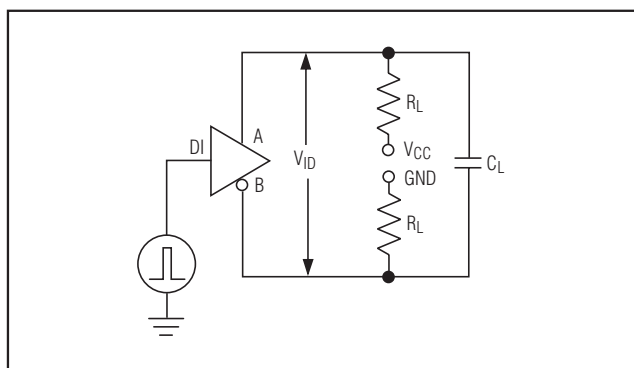


Figure 2. Driver-Timing Test Circuit

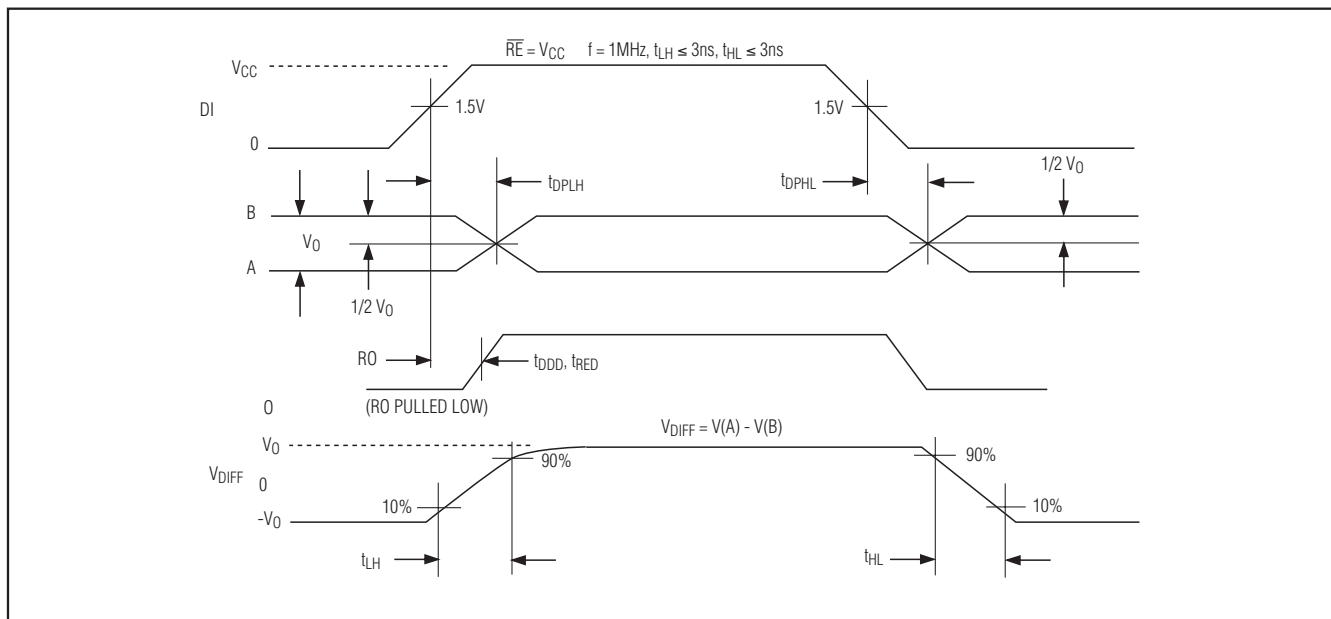


Figure 3. Driver Propagation Delays

# Half-Duplex RS-485-/RS-422-Compatible Transceiver with AutoDirection Control

## Test Circuits and Waveforms (continued)

MAX13487E/MAX13488E

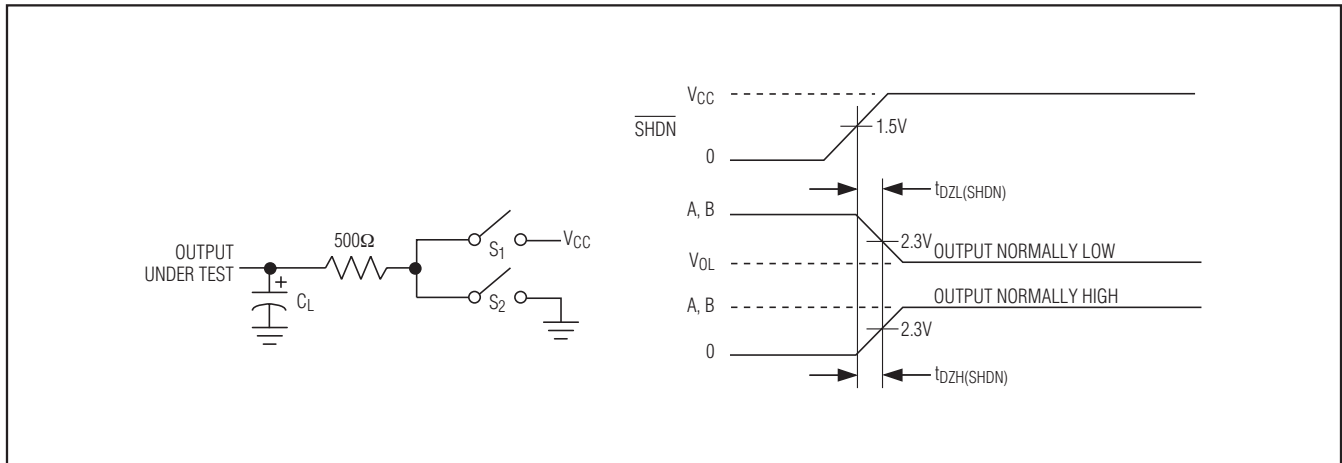


Figure 4. Driver Enable and Disable Times

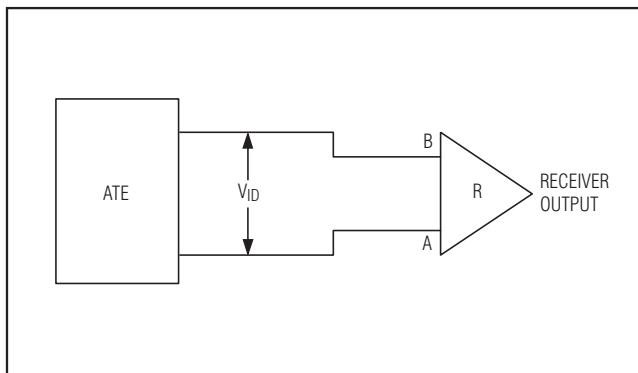


Figure 5. Receiver-Propagation-Delay Test Circuit

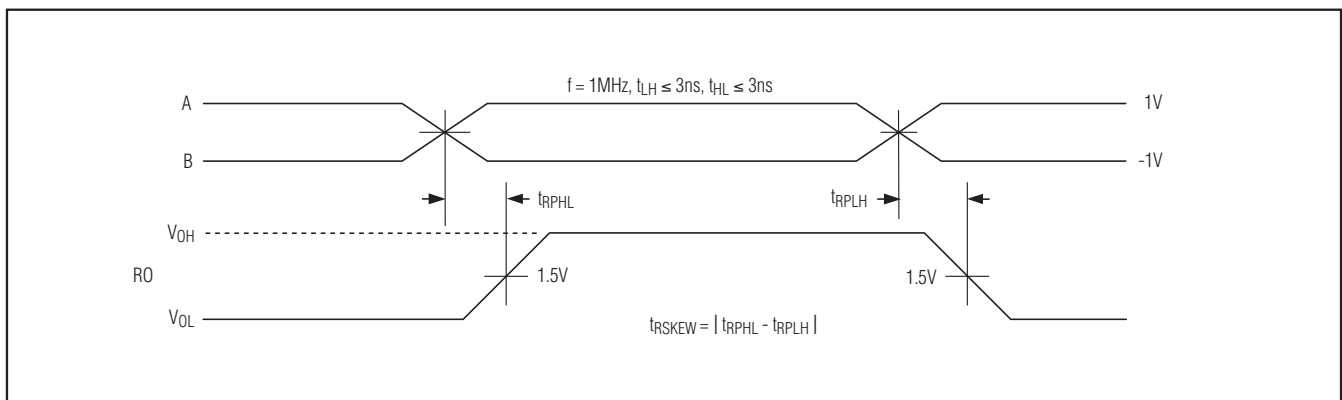


Figure 6. Receiver Propagation Delays

# Half-Duplex RS-485-/RS-422-Compatible Transceiver with AutoDirection Control

## Test Circuits and Waveforms (continued)

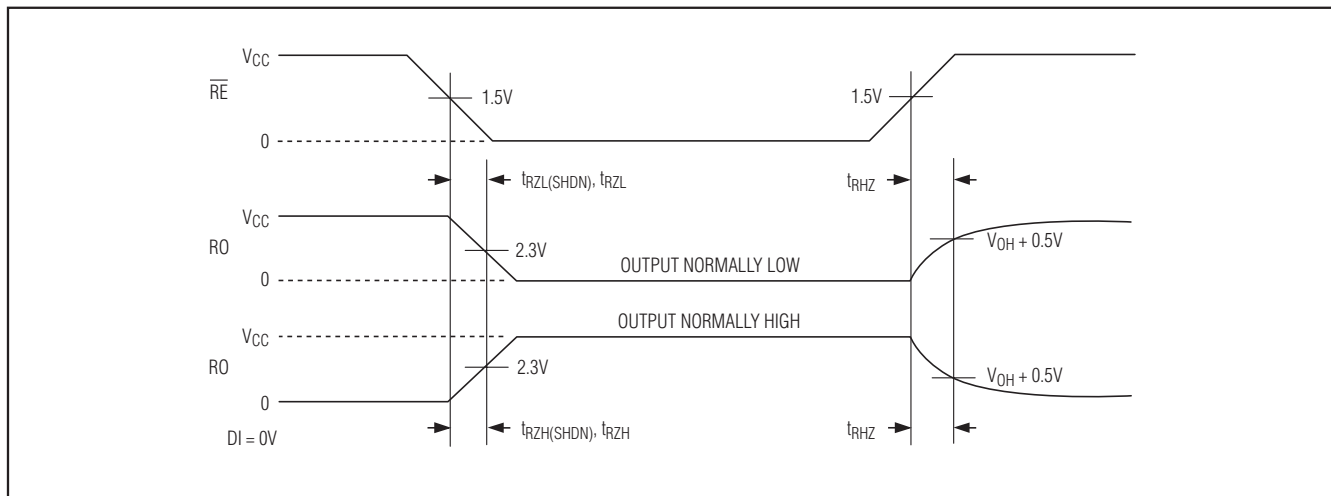


Figure 7. Receiver Enable and Disable Times

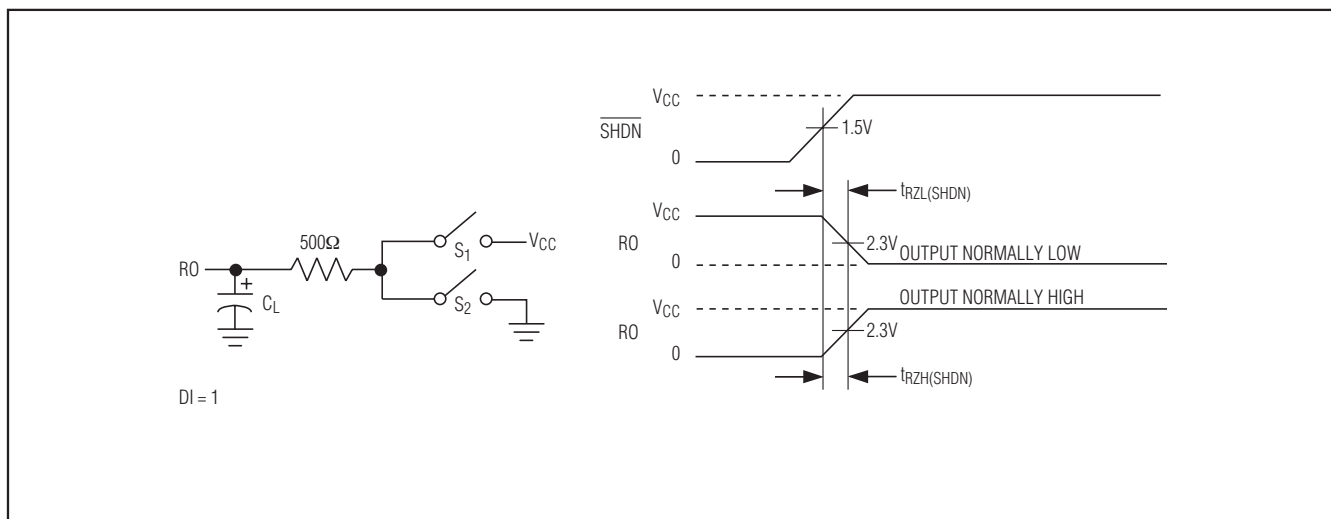


Figure 8. Receiver Enable Time from Shutdown

# Half-Duplex RS-485-/RS-422-Compatible Transceiver with AutoDirection Control

## Pin Description

| PIN | NAME                     | FUNCTION                                                                                                                                                                                                                                                                                                                                                                                                                                    |
|-----|--------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1   | RO                       | Receiver Output. When receiver is enabled and $V(A) - V(B) > +200\text{mV}$ , RO is high. If $V(A) - V(B) < -200\text{mV}$ , RO is low.                                                                                                                                                                                                                                                                                                     |
| 2   | $\overline{\text{RE}}$   | Receiver Output Enable. Drive $\overline{\text{RE}}$ low to enable the RO. Drive $\overline{\text{RE}}$ high to let the AutoDirection circuit control the receiver. $\overline{\text{RE}}$ is a hot-swap input (see the <i>Hot-Swap Capability</i> section for more details).                                                                                                                                                               |
| 3   | $\overline{\text{SHDN}}$ | Shutdown. Drive $\overline{\text{SHDN}}$ high to let the device operate in normal operation. Drive $\overline{\text{SHDN}}$ low to put the part in shutdown.                                                                                                                                                                                                                                                                                |
| 4   | DI                       | Driver Input. Drive DI low to force noninverting output low and inverting output high. Drive DI high to force noninverting output high and inverting output low. DI is an input to the internal state machine that automatically enables and disables the driver. See the <i>Function Tables</i> and <i>General Description</i> for more information. DI is a hot-swap input (see the <i>Hot-Swap Capability</i> section for more details). |
| 5   | GND                      | Ground                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| 6   | A                        | Noninverting Receiver Input and Noninverting Driver Output                                                                                                                                                                                                                                                                                                                                                                                  |
| 7   | B                        | Inverting Receiver Input and Inverting Driver Output                                                                                                                                                                                                                                                                                                                                                                                        |
| 8   | VCC                      | Positive Supply, $V_{\text{CC}} = +5\text{V} \pm 5\%$ . Bypass $V_{\text{CC}}$ to GND with a $0.1\mu\text{F}$ capacitor.                                                                                                                                                                                                                                                                                                                    |

## Function Tables

| TRANSMITTING             |    |                       |                                |                |                |
|--------------------------|----|-----------------------|--------------------------------|----------------|----------------|
| INPUTS                   |    |                       |                                | OUTPUTS        |                |
| $\overline{\text{SHDN}}$ | DI | $A-B > V_{\text{DT}}$ | ACTION                         | A              | B              |
| 1                        | 0  | X                     | Turn driver ON                 | 0              | 1              |
| 1                        | 1  | False                 | If driver was OFF, keep it OFF | HIGH IMPEDANCE | HIGH IMPEDANCE |
| 1                        | 1  | False                 | If driver was ON, keep it ON   | 1              | 0              |
| 1                        | 1  | True                  | Turn driver OFF                | HIGH IMPEDANCE | HIGH IMPEDANCE |
| 0                        | X  | X                     | X                              | SHUTDOWN       |                |

| RECEIVING                |                        |                      |              |                |                |
|--------------------------|------------------------|----------------------|--------------|----------------|----------------|
| INPUTS                   |                        |                      |              |                | OUTPUT         |
| $\overline{\text{SHDN}}$ | $\overline{\text{RE}}$ | A-B                  | DRIVER STATE | RECEIVER STATE | RO             |
| 1                        | 0                      | $\geq +200\text{mV}$ | X            | ON             | 1              |
| 1                        | 0                      | $\leq -200\text{mV}$ | X            | ON             | 0              |
| 1                        | 1                      | X                    | ON           | OFF            | HIGH IMPEDANCE |
| 1                        | 1                      | $\geq +200\text{mV}$ | OFF          | ON             | 1              |
| 1                        | 1                      | $\leq -200\text{mV}$ | OFF          | ON             | 0              |
| 0                        | X                      | X                    | X            | X              | SHUTDOWN       |

X = Don't care, shutdown mode, driver, and receiver outputs are in high impedance.

MAX13487E/MAX13488E

# Half-Duplex RS-485-/RS-422-Compatible Transceiver with AutoDirection Control

## Detailed Description

The MAX13487E/MAX13488E half-duplex, high-speed transceivers for RS-485/RS-422 communication contain one driver and one receiver. The MAX13487E/MAX13488E feature a hot-swap capability allowing line insertion without erroneous data transfer (see the *Hot-Swap Capability* section). The MAX13487E features reduced slew-rate drivers that minimize EMI and reduce reflections caused by improperly terminated cables, allowing error-free transmission up to 500kbps. The MAX13488E driver slew rate is not limited, making data throughput of up to 16Mbps possible.

## AutoDirection Circuitry

Internal circuitry in the MAX13487E/MAX13488E, in conjunction with an external pullup resistor on A and pulldown resistor on B (see *Typical Application Circuit*), act to automatically disable or enable the driver and receiver to keep the bus in the correct state. This AutoDirection circuitry consists of a state machine and an additional receive comparator that determines whether this device is trying to drive the bus, or another node on the network is driving the bus.

The internal state machine has two inputs:

- DI
- The current state of A-B (determined by a dedicated differential comparator)

The state machine also has two outputs:

- DRIVER\_ENABLE—Internal signal that enables and disables the driver
- RECEIVER\_ENABLE—Internal signal that is the inverse of the DRIVER\_ENABLE signal, but it can be overridden by an external pin

When DI is low, the device always drives the bus low. When DI is high, the device drives the bus for a short time, then disables the driver and allows the external pullup/pulldown resistors to hold the bus in the high state ( $A-B > 200\text{mV}$ ). During each low-to-high transition of DI, the driver stays enabled until  $(A-B) > V_{DT}$ , and then disables the driver, letting the pullup/pulldown resistors hold the A and B lines in the correct state.

## Pullup and Pulldown Resistors

The pullup and pulldown resistors on the A and B lines are required for proper operation of the device although their exact value is not critical. They function to hold the bus in the high state ( $A-B > 200\text{mV}$ ) following a low-to-high transition. Sizing of these resistors is determined in the same way as when using any other RS-485 driver and depends on how the line is terminated and how many nodes are on the bus. The most

important factor when sizing these resistors is to guarantee that the idle voltage on the bus (A-B) is greater than 200mV in order to remain compatible with standard RS-485 receiver thresholds.

## Idle State

When not transmitting data, the MAX13487E/MAX13488E require the DI input be driven high to remain in the idle state. A conventional RS-485 transceiver has DE and  $\overline{\text{RE}}$  inputs that are used to enable and disable the driver and receiver. However, the MAX13487E/MAX13488E does not have a DE input, and instead uses an internal state machine to enable and disable the drivers. DI must be driven high in order to go to the idle state.

## Hot-Swap Capability

### Hot-Swap Inputs

When circuit boards are inserted into a hot or powered back plane, differential disturbances to the data bus can lead to data errors. Upon initial circuit-board insertion, the data communication processor undergoes its own power-up sequence. During this period, the processor's logic-output drivers are high impedance and are unable to drive the DI and  $\overline{\text{RE}}$  inputs of these devices to a defined logic level. Leakage currents up to  $\pm 10\mu\text{A}$  from the high-impedance state of the processor's logic drivers could cause standard CMOS enable inputs of a transceiver to drift to an incorrect logic level. Additionally, parasitic circuit-board capacitance could cause coupling of  $V_{CC}$  or GND to the enable inputs. Without the hot-swap capability, these factors could improperly enable the transceiver's driver.

To overcome both these problems, two different pullup switches (strong and weak) are turned on during the power-up. When  $V_{CC}$  rises, an internal power-up signal enables a strong pullup circuit. It holds DI and  $\overline{\text{RE}}$  high with 1mA for 15 $\mu\text{s}$ . Once the timeout is expired, this strong pullup is switched off. A weak pullup (100 $\mu\text{A}$ ) remains active to overcome leakage on the pin. This second weak pullup disappears as soon as the microcontroller forces a low state on these pins. Therefore, in normal operation (after the first activation), these pins can be considered as high-impedance pins (CMOS inputs) without any pullup circuitry.

The AutoDirection state machine is initialized, forcing the driver disabled. The receiver is enabled in AutoDirection mode.

## Hot-Swap Input Circuitry

The enable inputs feature hot-swap capability. At the input there are two pMOS devices, M1 and M2 (Figure 9). When  $V_{CC}$  ramps from zero, an internal 15 $\mu\text{s}$  timer turns

# Half-Duplex RS-485-/RS-422-Compatible Transceiver with AutoDirection Control

on M2 and sets the SR latch, which also turns on M1. Transistors M2, a 1.5mA current source, and M1, a 500 $\mu$ A current source, pull  $\overline{RE}$  to  $V_{CC}$  through a 5k $\Omega$  resistor. M2 is designed to pull  $\overline{RE}$  to the disabled state against an external parasitic capacitance up to 100pF that can drive  $\overline{RE}$  high. After 15 $\mu$ s, the timer deactivates M2 while M1 remains on, holding DI high against three-state leakages that can drive  $\overline{RE}$  low. M1 remains on until an external source overcomes the required input current. At this time, the SR latch resets and M1 turns off. When M1 turns off,  $\overline{RE}$  reverts to a standard, high-impedance CMOS input. Whenever  $V_{CC}$  drops below 1V, the hot-swap input is reset. DI has similar hot-swap circuitry.

## $\pm 15kV$ ESD Protection

As with all Maxim devices, ESD-protection structures are incorporated on all pins to protect against electrostatic discharges encountered during handling and assembly. The driver outputs and receiver inputs of the MAX13487E/MAX13488E have extra protection against static electricity. Maxim's engineers have developed state-of-the-art structures to protect these pins against ESD of  $\pm 15kV$  without damage. The ESD structures withstand high ESD in all states: normal operation, shut-down, and powered down. After an ESD event, the MAX13487E/MAX13488E keep working without latchup or damage.

ESD protection can be tested in various ways. The transmitter outputs and receiver inputs of the MAX13487E/MAX13488E are characterized for protection to the following limits:

- $\pm 15kV$  using the Human Body Model
- $\pm 15kV$  using the Air Gap Discharge Method specified in IEC 61000-4-2 (MAX13487E only)

## ESD Test Conditions

ESD performance depends on a variety of conditions. Contact Maxim for a reliability report that documents test setup, test methodology, and test results.

## Human Body Model

Figure 10a shows the Human Body Model, and Figure 10b shows the current waveform it generates when discharged into a low impedance. This model consists of a 100pF capacitor charged to the ESD voltage of interest, which is then discharged into the test device through a 1.5k $\Omega$  resistor.

## IEC 61000-4-2

The IEC 61000-4-2 standard covers ESD testing and performance of finished equipment. However, it does not specifically refer to integrated circuits. The MAX13487E/MAX13488E help you design equipment to

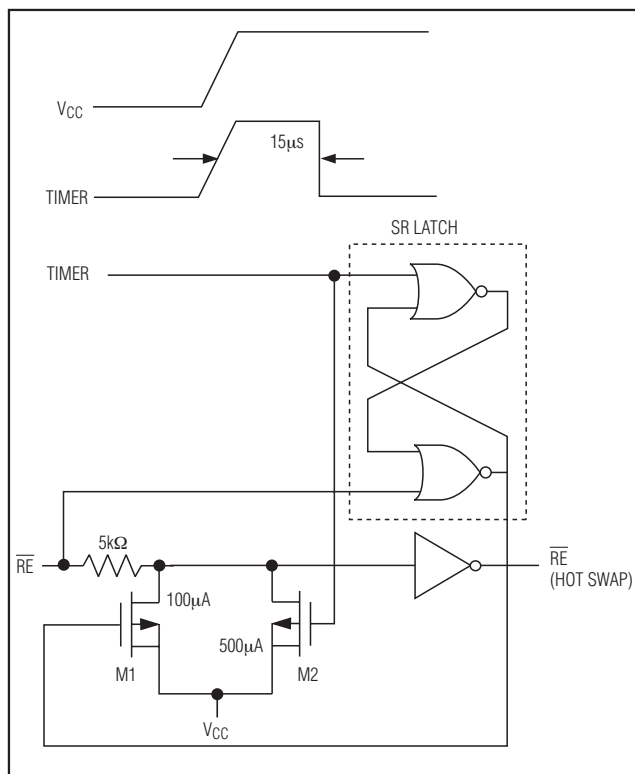


Figure 9. Simplified Structure of the Receiver Enable Pin ( $\overline{RE}$ )

meet IEC 61000-4-2 without the need for additional ESD-protection components.

The major difference between tests done using the Human Body Model and IEC 61000-4-2 is higher peak current in IEC 61000-4-2 because series resistance is lower in the IEC 61000-4-2 model. Hence, the ESD withstand voltage measured to IEC 61000-4-2 is generally lower than that measured using the Human Body Model. Figure 10c shows the IEC 61000-4-2 model, and Figure 10d shows the current waveform for IEC 61000-4-2 ESD Contact Discharge test.

## Machine Model

The machine model for ESD tests all pins using a 200pF storage capacitor and zero discharge resistance.

The objective is to emulate the stress caused when I/O pins are contacted by handling equipment during test and assembly. Of course, all pins require this protection, not just RS-485 inputs and outputs.

The Air-Gap test involves approaching the device with a charged probe. The Contact-Discharge method connects the probe to the device before the probe is energized.

MAX13487E/MAX13488E

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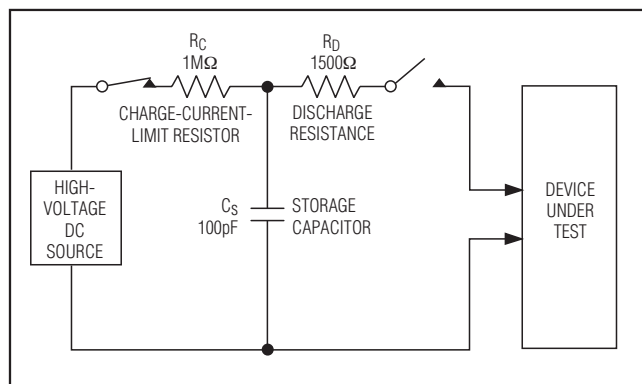


Figure 10a. Human Body ESD Test Model

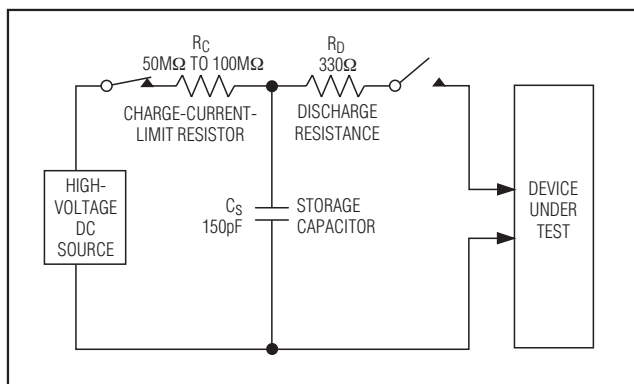


Figure 10c. IEC 61000-4-2 ESD Test Model

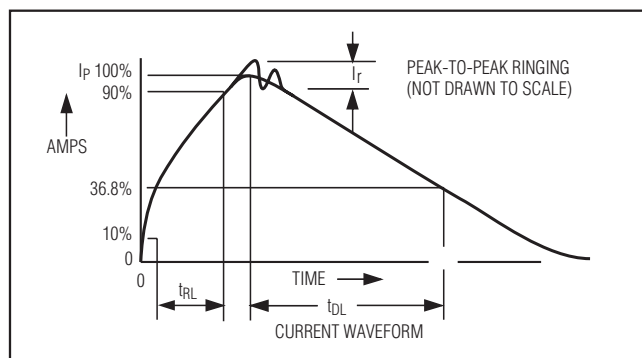


Figure 10b. Human Body Current Waveform

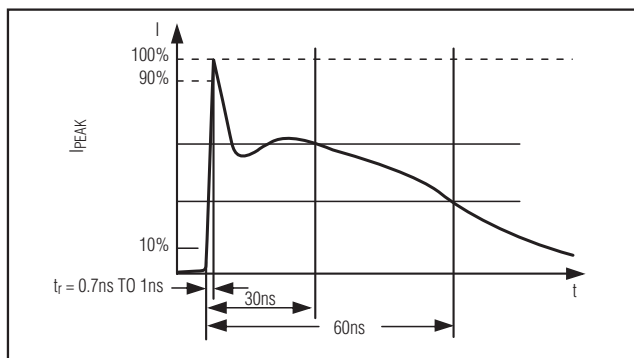


Figure 10d. IEC 61000-4-2 ESD Generator Current Waveform

## Applications Information

### 128 Transceivers on the Bus

The standard RS-485 receiver input impedance is 12k $\Omega$  (1-unit load), and the standard driver can drive up to 32-unit loads. The MAX13487E/MAX13488E have a 1/4-unit load receiver input impedance (48k $\Omega$ ), allowing up to 128 transceivers to be connected in parallel on one communication line. Any combination of these devices, as well as other RS-485 transceivers with a total of 32-unit loads or fewer, can be connected to the line.

### Reduced EMI and Reflections

The MAX13487E features reduced slew-rate drivers that minimize EMI and reduce reflections caused by improperly terminated cables, allowing error-free data transmission up to 500kbps.

### Low-Power Shutdown Mode

Low-power shutdown mode is initiated by bringing  $\overline{\text{SHDN}}$  low. In shutdown, the devices draw a maximum of 10 $\mu\text{A}$  of supply current.

The devices are guaranteed not to enter shutdown if  $\overline{\text{SHDN}}$  is low for less than 50ns. If the inputs are in this state for at least 700ns, the devices are guaranteed to enter shutdown.

Enable times  $t_{ZH}$  and  $t_{ZL}$  (see the *Switching Characteristics* section) assume the devices were not in a low-power shutdown state. Enable times  $t_{ZH}(\text{SHDN})$  and  $t_{ZL}(\text{SHDN})$  assume the devices were in shutdown state. It takes drivers and receivers longer to become enabled from low-power shutdown mode ( $t_{ZH}(\text{SHDN})$ ,  $t_{ZL}(\text{SHDN})$ ) than from driver/receiver-disable mode ( $t_{ZH}$ ,  $t_{ZL}$ ).

### Line Length

The RS-485/RS-422 standard covers line lengths up to 4000ft.

## Half-Duplex RS-485-/RS-422-Compatible Transceiver with AutoDirection Control

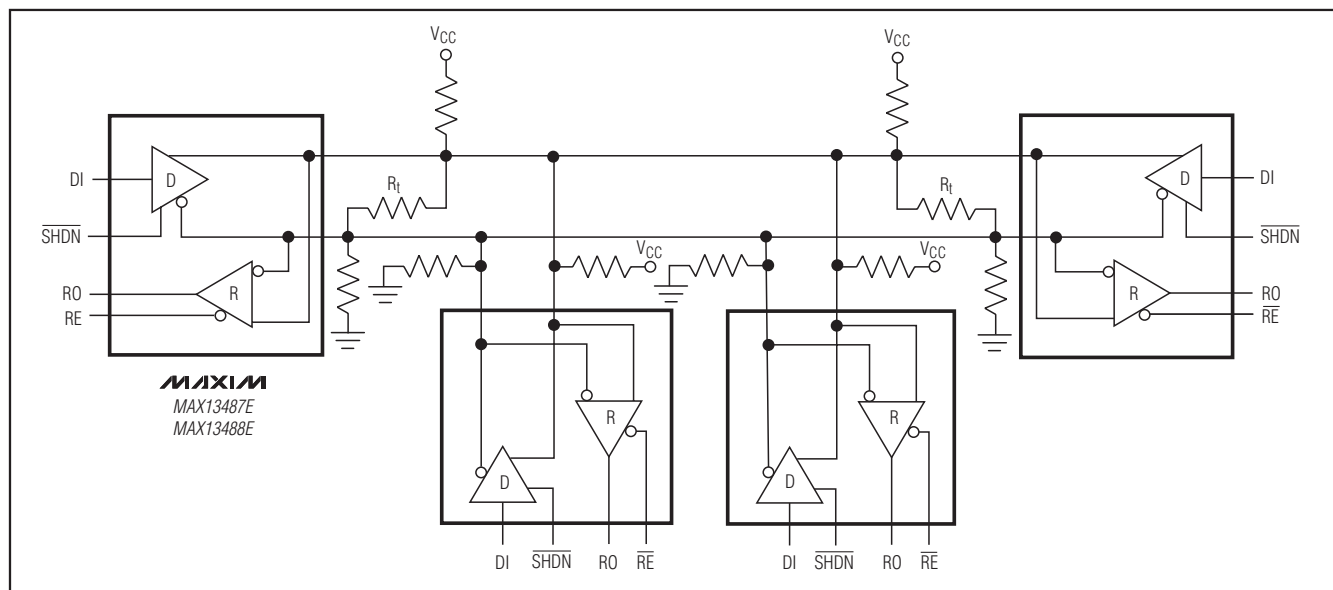


Figure 11. Typical Half-Duplex RS-485 Network

### Typical Applications

The MAX13487E/MAX13488E transceivers are designed for half-duplex, bidirectional data communications on multipoint bus transmission lines. Figure 11 shows a typical network application. To minimize reflections, terminate the line at both ends in its characteristic impedance, and keep stub lengths off the main line as short as possible. The slew-rate-limited MAX13487E is more tolerant of imperfect termination.

### Isolated RS-485 Interface

An isolated RS-485 interface electrically isolates different nodes on the bus to protect the bus from problems due to high common-mode voltages that exceed the RS-485 common-mode voltage range, conductive noise, and ground loops. The *Typical Application*

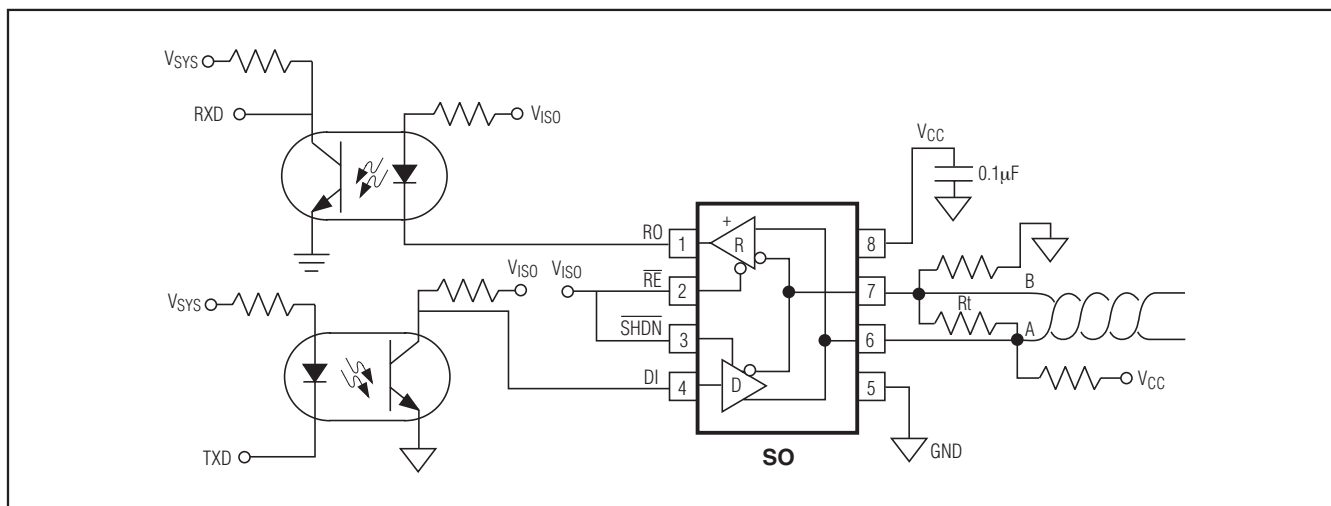
*Circuit* shows an isolated RS-485 interface using the MAX13487E/MAX13488E. The transceiver is powered separately from the controlling circuitry. The AutoDirection feature of the MAX13487E/MAX13488E (see the *AutoDirection Circuitry* section), replaces an external relay allowing faster switching speeds, no contact bounce, better reliability, and better electrical isolation. The MAX13487E/MAX13488E only require two optocouplers to electrically isolate the transceiver.

### Chip Information

PROCESS: BiCMOS

# Half-Duplex RS-485-/RS-422-Compatible Transceiver with AutoDirection Control

## Pin Configuration/Typical Application Circuit

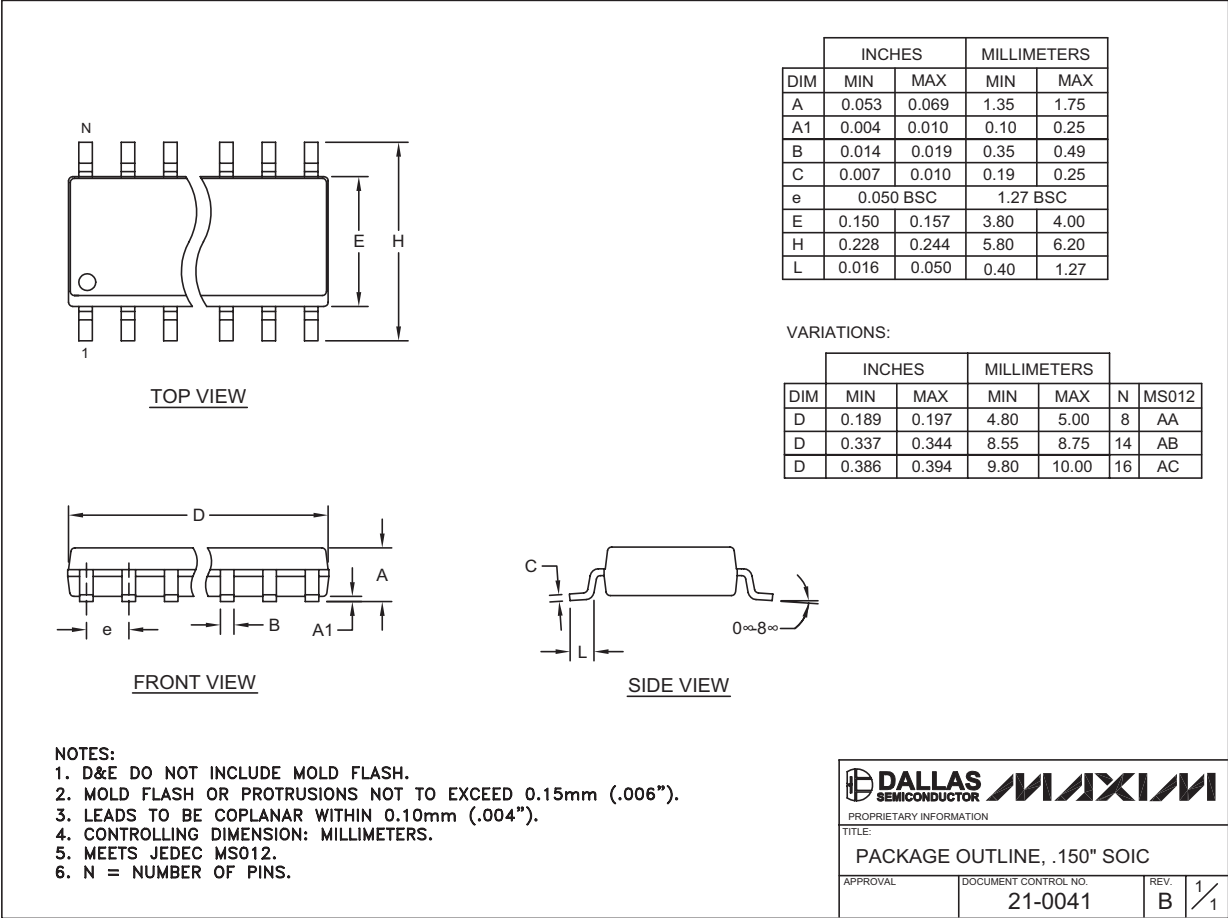


# Half-Duplex RS-485-/RS-422-Compatible Transceiver with AutoDirection Control

## Package Information

(The package drawing(s) in this data sheet may not reflect the most current specifications. For the latest package outline information, go to [www.maxim-ic.com/packages](http://www.maxim-ic.com/packages).)

MAX13487E/MAX13488E



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