



# ±15kV ESD-Protected USB Transceivers

## General Description

The MAX3450E/MAX3451E/MAX3452E USB-compliant transceivers interface low-voltage ASICs with USB devices. The devices fully comply with USB 1.1 and USB 2.0 when operating at full (12Mbps) and low (1.5Mbps) speeds. The MAX3450E/MAX3451E/MAX3452E operate with  $V_L$  as low as +1.65V, ensuring compatibility with low-voltage ASICs.

The MAX3450E/MAX3451E/MAX3452E feature a logic-selectable suspend mode that reduces current consumption to less than 40 $\mu$ A. Integrated  $\pm 15$ kV ESD protection protects the USB D+ and D- bidirectional bus connections. The MAX3450E is pin compatible with Micrel's MIC2550A. The MAX3451E features an internal 1.5k $\Omega$  USB pullup resistor and an enumeration function that allows devices to logically disconnect while plugged in. The MAX3452E provides a push-pull bus-detect (BD) output that asserts high when VBUS is greater than +4.0V.

The MAX3450E/MAX3451E/MAX3452E operate over the -40°C to +85°C extended temperature range and are available in 14-pin TSSOP and 3mm x 3mm 16-pin Thin QFN packages.

## Applications

PDA's  
PC Peripherals  
Cellular Telephones  
Data Cradles  
MP3 Players

Typical Operating Circuit appears at end of data sheet.

## Features

- ◆  $\pm 15$ kV ESD Protection on D+ and D-
- ◆ Combined VP and VM Inputs/Outputs
- ◆ +1.65V to +3.6V  $V_L$  Logic Supply Input for Interfacing with Low-Voltage ASICs
- ◆ Enumerate Input Function (MAX3451E)
- ◆ Powered from Li+ Battery as Low as +3.1V (MAX3450E and MAX3451E)
- ◆ VBUS Detection (MAX3452E)
- ◆ Pin Compatible with Micrel MIC2550A (MAX3450E)
- ◆ Internal D+ or D- Pullup Resistor (MAX3451E)
- ◆ No Power-Supply Sequencing Required

## Ordering Information

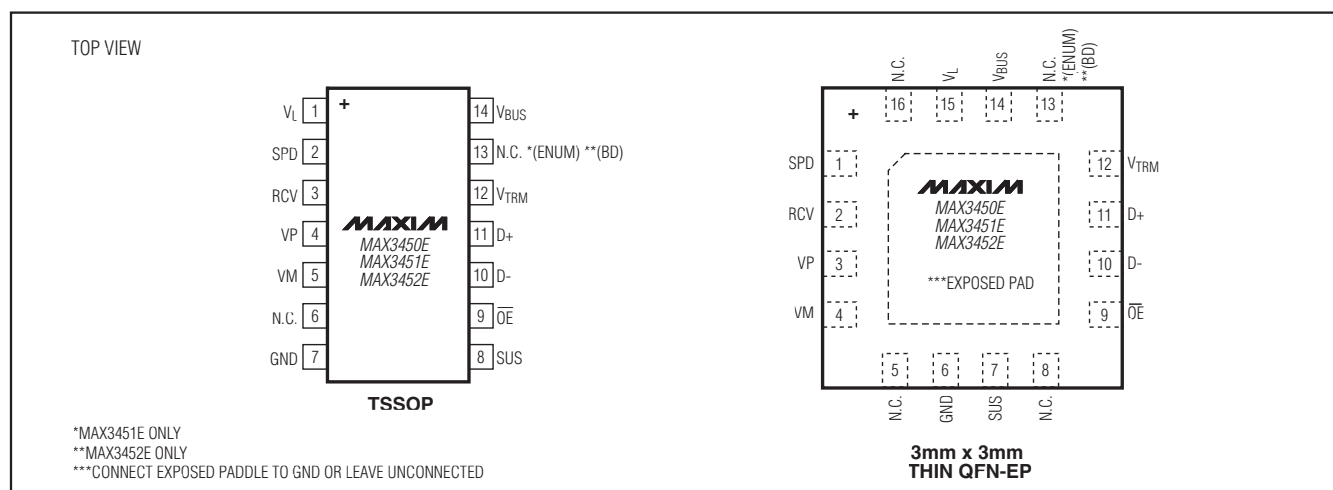
| PART         | PIN-PACKAGE     | TOP MARK |
|--------------|-----------------|----------|
| MAX3450EEUD+ | 14 TSSOP        | —        |
| MAX3450EETE+ | 16 Thin QFN-EP† | AAJ      |
| MAX3451EEUD+ | 14 TSSOP        | —        |
| MAX3451EETE+ | 16 Thin QFN-EP† | AAK      |
| MAX3452EEUD+ | 14 TSSOP        | —        |
| MAX3452EETE+ | 16 Thin QFN-EP† | AAL      |

**Note:** All devices are specified over the -40°C to +85°C operating temperature range.

+Denotes lead(Pb)-free package/RoHS-compliant package.

†EP = Exposed pad.

## Pin Configurations



# ±15kV ESD-Protected USB Transceivers

## ABSOLUTE MAXIMUM RATINGS

|   |                                    |
|---|------------------------------------|
| V <sub>BUS</sub> , V <sub>L</sub> , D+, D- to GND           | -0.3V to +6.0V                     |
| V <sub>TRM</sub> to GND                                     | -0.3V to (V <sub>BUS</sub> + 0.3V) |
| VP, VM, SUS, SPD, ENUM,<br>RCV, $\overline{OE}$ , BD to GND | -0.3V to (V <sub>L</sub> + 0.3V)   |
| Current (into any pin)                                      | ±15mA                              |
| Short-Circuit Current (D+ and D-)                           | ±150mA                             |
| Continuous Power Dissipation (T <sub>A</sub> = +70°C)       |                                    |
| 14-Pin TSSOP  |                                    |
| (derate 10mW/°C above +70°C)                                | 797mW                              |
| 16-Pin Thin QFN-EP 3mm x 3mm                                |                                    |
| (derate 20.8mW/°C above +70°C)                              | 1667mW                             |

|  |                 |
|--|-----------------|
| Package Junction-to-Ambient Thermal Resistance (θ <sub>JA</sub> ) (Note 1) |                 |
| 14-Pin TSSOP   | 100.4°C/W       |
| 16-Pin Thin QFN-EP   | 48°C/W          |
| Package Junction-to-Case Thermal Resistance (θ <sub>JC</sub> ) (Note 1)    |                 |
| 14-Pin TSSOP   | 30°C/W          |
| 16-Pin Thin QFN-EP   | 7°C/W           |
| Operating Temperature Range  | -40°C to +85°C  |
| Junction Temperature   | +150°C          |
| Storage Temperature Range  | -65°C to +150°C |
| Lead Temperature (soldering, 10s)  | +300°C          |

**Note 1:** Package thermal resistances were obtained using the method described in JEDEC specifications. For detailed information on package thermal considerations, refer to [www.maxim-ic.com/thermal-tutorial](http://www.maxim-ic.com/thermal-tutorial).

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.

## DC ELECTRICAL CHARACTERISTICS

(V<sub>BUS</sub> = +4.0V to +5.5V or V<sub>TRM</sub> = +3.0V to +3.6V, V<sub>L</sub> = +1.65V to +3.6V, T<sub>A</sub> = T<sub>MIN</sub> to T<sub>MAX</sub>, unless otherwise noted. Typical values are at V<sub>BUS</sub> = +5.0V, V<sub>L</sub> = +2.5V, and T<sub>A</sub> = +25°C.) (Note 2)

| PARAMETER  | SYMBOL                   | CONDITIONS  | MIN | TYP | MAX | UNITS |
|--|--------------------------|---|-----|-----|-----|-------|
| <b>SUPPLY INPUTS (V<sub>BUS</sub>, V<sub>TRM</sub>, V<sub>L</sub>)</b> |                          |   |     |     |     |       |
| Regulated Supply Voltage Output  | V <sub>TRM</sub>         | Internal regulator  | 3.0 | 3.3 | 3.6 | V     |
| Operating Supply Current   | I <sub>VBUS</sub>        | Full-speed transmitting/receiving at 12Mbps, C <sub>L</sub> = 50pF on D+ and D- (Note 3)              |     |     | 10  | mA    |
| Operating V <sub>L</sub> Supply Current                                | I <sub>VL</sub>          | Full-speed transmitting/receiving at 12Mbps (Note 3)  |     |     | 2.5 | mA    |
| Full-Speed Idle and SE0 Supply Current                                 | I <sub>VBUS(IDLE)</sub>  | Full-speed idle: V <sub>D+</sub> > 2.7V, V <sub>D-</sub> < 0.3V                                       |     | 250 | 350 | μA    |
|  |                          | SE0: V <sub>D+</sub> < 0.3V, V <sub>D-</sub> < 0.3V   |     | 250 | 350 |       |
| Static V <sub>L</sub> Supply Current                                   | I <sub>VL(STATIC)</sub>  | Full-speed idle, SE0, or suspend mode   |     |     | 5   | μA    |
|  |                          |   |     |     | 15  |       |
| Suspend Supply Current   | I <sub>VBUS(SUSP)</sub>  | VM = VP = open, SUS = $\overline{OE}$ = high  |     |     | 35  | μA    |
|  |                          |   |     |     | 40  |       |
| Disable-Mode Supply Current  | I <sub>VBUS(DIS)</sub>   | V <sub>L</sub> = GND or open  |     |     | 20  | μA    |
| Sharing-Mode V <sub>L</sub> Supply Current                             | I <sub>VL(SHARING)</sub> | V <sub>BUS</sub> = GND or open, $\overline{OE}$ = low, VP = low or high, VM = low or high, SUS = high |     |     | 5   | μA    |
|  |                          |   |     |     | 20  |       |
| D+/D- Sharing-Mode Load Current  | I <sub>D_(SHARING)</sub> | V <sub>BUS</sub> = GND or open, V <sub>D-</sub> = 0 or +5.5V  |     |     | 20  | μA    |
| D+/D- Disable-Mode Load Current  | I <sub>D_(DIS)</sub>     | V <sub>L</sub> = GND or open, V <sub>D-</sub> = 0 or +5.5V  |     |     | 5   | μA    |

# ±15kV ESD-Protected USB Transceivers

MAX3450E/MAX3451E/MAX3452E

## DC ELECTRICAL CHARACTERISTICS (continued)

(V<sub>BUS</sub> = +4.0V to +5.5V or V<sub>TRM</sub> = +3.0V to +3.6V, V<sub>L</sub> = +1.65V to +3.6V, T<sub>A</sub> = T<sub>MIN</sub> to T<sub>MAX</sub>, unless otherwise noted. Typical values are at V<sub>BUS</sub> = +5.0V, V<sub>L</sub> = +2.5V, and T<sub>A</sub> = +25°C.) (Note 1)

| PARAMETER   | SYMBOL                 | CONDITIONS                                    | MIN                  | TYP  | MAX                  | UNITS |
|---|------------------------|---|----------------------|------|----------------------|-------|
| USB Power-Supply Detection Threshold                                | V <sub>TH_VBUS</sub>   | MAX3450E/MAX3451E, supply lost                |                      |      | 0.8                  | V     |
|   |                        | MAX3450E/MAX3451E, supply present (Note 4)    | 3.6                  |      |                      |       |
|   |                        | MAX3452E, supply lost                         |                      |      | 3.6                  |       |
|   |                        | MAX3452E, supply present                      | 4.0                  |      |                      |       |
| USB Power-Supply Detection Hysteresis                               | V <sub>HYST_VBUS</sub> | MAX3450E/MAX3451E                             |                      | 75   |                      | mV    |
|   |                        | MAX3452E                                      |                      | 40   |                      |       |
| V <sub>L</sub> Power-Supply Detection Threshold                     | V <sub>TH_VL</sub>     |   |                      | 0.85 |                      | V     |
| <b>DIGITAL INPUTS/OUTPUTS (VP, VM, RCV, SUS, OE, SPD, BD, ENUM)</b> |                        |   |                      |      |                      |       |
| Input Voltage Low   | V <sub>IL</sub>        | VM, VP, SUS, SPD, ENUM, OE                    |                      |      | 0.3 x V <sub>L</sub> | V     |
| Input Voltage High  | V <sub>IH</sub>        | VM, VP, SUS, SPD, ENUM, OE                    | 0.7 x V <sub>L</sub> |      |                      | V     |
| Output Voltage Low  | V <sub>OL</sub>        | VM, VP, RCV, BD, I <sub>OL</sub> = +2mA       |                      |      | 0.4                  | V     |
| Output Voltage High   | V <sub>OH</sub>        | VM, VP, RCV, BD, I <sub>OH</sub> = -2mA       | V <sub>L</sub> - 0.4 |      |                      | V     |
| Input Leakage Current   | I <sub>LKG</sub>       |   | -1                   |      | +1                   | μA    |
| Input Capacitance   | C <sub>IN</sub>        | Measured from input to GND                    |                      | 10   |                      | pF    |
| <b>ANALOG INPUTS/OUTPUTS (D+, D-)</b>                               |                        |   |                      |      |                      |       |
| Differential Input Sensitivity                                      | V <sub>ID</sub>        | V <sub>D+</sub> - V <sub>D-</sub>             | 0.2                  |      |                      | V     |
| Differential Common-Mode Voltage                                    | V <sub>CM</sub>        | Includes V <sub>ID</sub> range                | 0.8                  |      | 2.5                  | V     |
| Single-Ended Input Low Voltage                                      | V <sub>ILSE</sub>      |   |                      |      | 0.8                  | V     |
| Single-Ended Input High Voltage                                     | V <sub>IHSE</sub>      |   | 2.0                  |      |                      | V     |
| Hysteresis  | V <sub>HYST</sub>      |   |                      | 250  |                      | mV    |
| Output Voltage Low  | V <sub>OLD</sub>       | R <sub>L</sub> = 1.5kΩ to +3.6V               |                      |      | 0.3                  | V     |
| Output Voltage High   | V <sub>OHD</sub>       | R <sub>L</sub> = 15kΩ to GND                  | 2.8                  |      | 3.6                  | V     |
| Off-State Leakage Current   | I <sub>LZ</sub>        |   | -1                   |      | +1                   | μA    |
| Transceiver Capacitance   | C <sub>IND</sub>       | Measured from D <sub>-</sub> to GND           |                      | 20   |                      | pF    |
| Driver Output Impedance   | Z <sub>DRV</sub>       | Steady-state drive                            | 4.0                  |      | 15.5                 | Ω     |
| Input Impedance   | Z <sub>IN</sub>        | Driver off                                    | 10                   |      |                      | MΩ    |
| Internal Pullup Resistance  | R <sub>PULLUP</sub>    | I <sub>LOAD</sub> = 500μA (MAX3451E) (Note 5) | 1.425                |      | 1.575                | kΩ    |
| <b>ESD PROTECTION (D+, D-)</b>                                      |                        |   |                      |      |                      |       |
| Human Body Model  |                        |   |                      | ±15  |                      | kV    |
| IEC 1000-4-2 Contact Discharge                                      |                        |   |                      | ±8   |                      | kV    |

# ±15kV ESD-Protected USB Transceivers

## TIMING CHARACTERISTICS

(V<sub>BUS</sub> = +4.0V to +5.5V or V<sub>TRM</sub> = +3.0V to +3.6V, V<sub>L</sub> = +1.65V to +3.6V, T<sub>A</sub> = T<sub>MIN</sub> to T<sub>MAX</sub>, unless otherwise noted. Typical values are at V<sub>BUS</sub> = +5V, V<sub>L</sub> = +2.5V, and T<sub>A</sub> = +25°C.) (Note 1)

| PARAMETER  | SYMBOL                           | CONDITIONS   | MIN | TYP | MAX | UNITS |
|--|----------------------------------|--|-----|-----|-----|-------|
| DRIVER CHARACTERISTICS (FULL-SPEED MODE, C <sub>L</sub> = 50pF)          |                                  |  |     |     |     |       |
| Rise Time  | t <sub>FR</sub>                  | 10% to 90% of I <sub>VOHD</sub> - V <sub>OLDI</sub> , Figures 1, 6 | 4   |     | 20  | ns    |
| Fall Time  | t <sub>FF</sub>                  | 90% to 10% of I <sub>VOHD</sub> - V <sub>OLDI</sub> , Figures 1, 6 | 4   |     | 20  | ns    |
| Rise-/Fall-Time Matching (Note 3)  | t <sub>FR</sub> /t <sub>FF</sub> | Excluding the first transition from idle state, (Figures 1, 6)     | 90  |     | 110 | %     |
| Output-Signal Crossover Voltage (Note 3)                                 | V <sub>CRS_F</sub>               | Excluding the first transition from idle state, (Figures 2, 6)     | 1.3 |     | 2.0 | V     |
| Driver Propagation Delay (Figures 2, 6)                                  | t <sub>PLH_DRV</sub>             | Low-to-high transition   |     |     | 18  | ns    |
|  | t <sub>PHL_DRV</sub>             | High-to-low transition   |     |     | 18  |       |
| Driver Disable Delay (Figure 3)  | t <sub>PHZ_DRV</sub>             | High-to-off transition   |     |     | 20  | ns    |
|  | t <sub>PLZ_DRV</sub>             | Low-to-off transition  |     |     | 20  |       |
| Driver Enable Delay (Figure 3)   | t <sub>PZH_DRV</sub>             | Off-to-high transition   |     |     | 20  | ns    |
|  | t <sub>PZL_DRV</sub>             | Off-to-low transition  |     |     | 20  |       |
| DRIVER CHARACTERISTICS (LOW-SPEED MODE, C <sub>L</sub> = 200pF TO 600pF) |                                  |  |     |     |     |       |
| Rise Time  | t <sub>LR</sub>                  | 10% to 90% of I <sub>VOHD</sub> - V <sub>OLDI</sub> , Figures 1, 6 | 75  |     | 300 | ns    |
| Fall Time  | t <sub>LF</sub>                  | 90% to 10% of I <sub>VOHD</sub> - V <sub>OLDI</sub> , Figures 1, 6 | 75  |     | 300 | ns    |
| Rise-/Fall-Time Matching   | t <sub>LR</sub> /t <sub>LF</sub> | Excluding the first transition from idle state, Figures 1, 6       | 80  |     | 125 | %     |
| Output-Signal Crossover Voltage  | V <sub>CRS_L</sub>               | Excluding the first transition from idle state, Figures 2, 6       | 1.3 |     | 2.0 | V     |
| RECEIVER CHARACTERISTICS (C <sub>L</sub> = 15pF)                         |                                  |  |     |     |     |       |
| Differential Receiver Propagation Delay, Figures 4, 6                    | t <sub>PLH_RCV</sub>             | Low-to-high transition   |     |     | 22  | ns    |
|  | t <sub>PHL_RCV</sub>             | High-to-low transition   |     |     | 22  |       |
| Single-Ended Receiver Propagation Delay, Figures 4, 6                    | t <sub>PLH_SE</sub>              | Low-to-high transition   |     |     | 12  | ns    |
|  | t <sub>PHL_SE</sub>              | High-to-low transition   |     |     | 12  |       |
| Single-Ended Receiver Disable Delay, Figure 5                            | t <sub>PHZ_SE</sub>              | High-to-off transition   |     |     | 15  | ns    |
|  | t <sub>PLZ_SE</sub>              | Low-to-off transition  |     |     | 15  |       |
| Single-Ended Receiver Enable Delay, Figure 5                             | t <sub>PZH_SE</sub>              | Off-to-high transition   |     |     | 15  | ns    |
|  | t <sub>PZL_SE</sub>              | Off-to-low transition  |     |     | 15  |       |

**Note 2:** Parameters are 100% production tested at +25°C, unless otherwise noted. Limits over temperature are guaranteed by design.

**Note 3:** Guaranteed by design, not production tested.

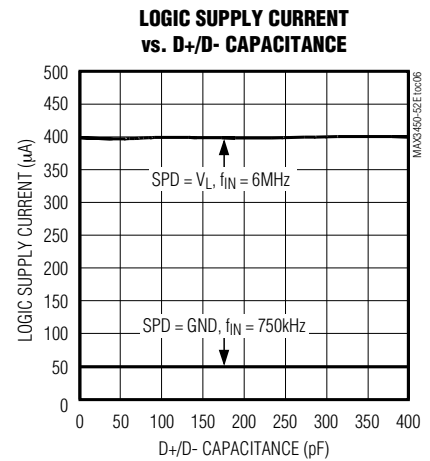
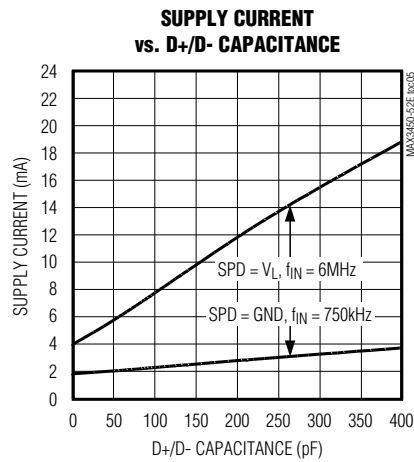
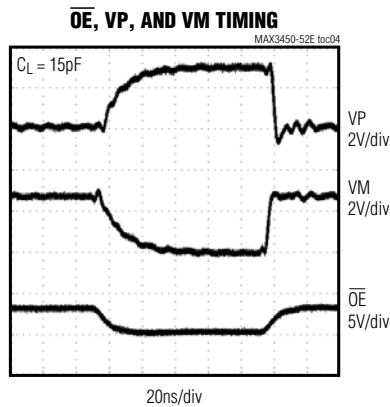
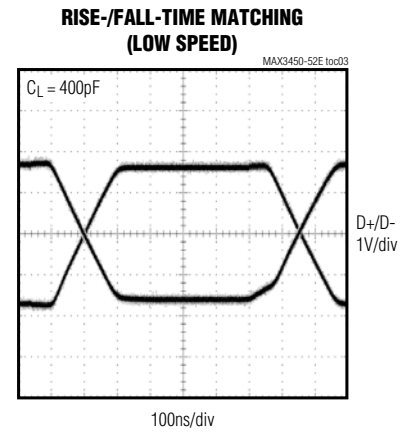
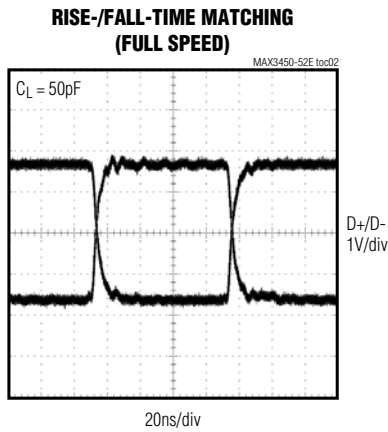
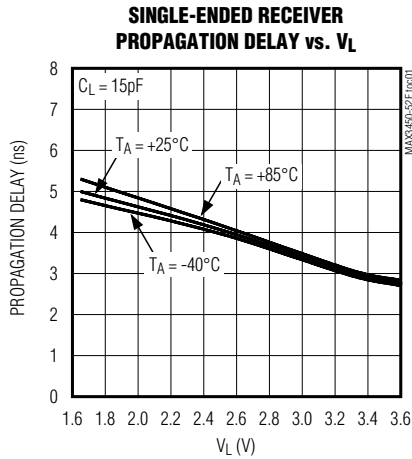
**Note 4:** Production tested to +2.7V for V<sub>L</sub> ≤ +3.0V.

**Note 5:** Including external 24.3Ω series resistor.

# ±15kV ESD-Protected USB Transceivers

## Typical Operating Characteristics

( $V_{BUS} = +5.0V$ ,  $V_L = +3.3V$ ,  $T_A = +25^\circ C$ , unless otherwise noted.)



MAX3450E/MAX3451E/MAX3452E

# ±15kV ESD-Protected USB Transceivers

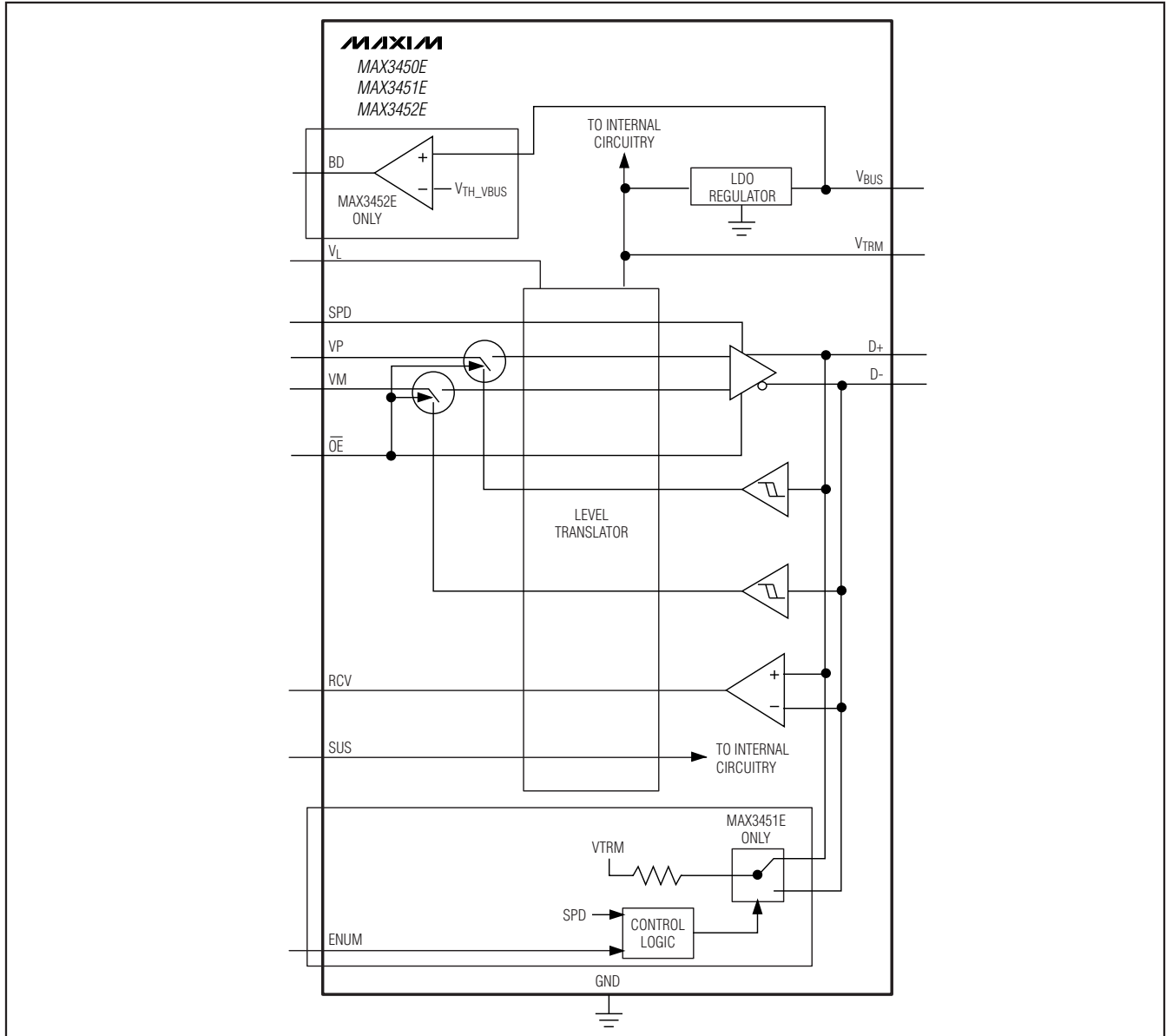
## Pin Description

| PIN   |             | NAME             | FUNCTION  |
|-------|-------------|------------------|---|
| TSSOP | THIN QFN-EP |                  |   |
| 1     | 15          | V <sub>L</sub>   | Digital I/O Connections Logic Supply. Connect a +1.65V to +3.6V supply to V <sub>L</sub> . Bypass V <sub>L</sub> to GND with a 0.1μF ceramic capacitor.   |
| 2     | 1           | SPD              | Speed-Selector Input. Connect SPD to GND to select the low-speed data rate (1.5Mbps). Connect SPD to V <sub>L</sub> to select the full-speed data rate (12Mbps).  |
| 3     | 2           | RCV              | Differential-Receiver Output. RCV responds to the differential input on D+ and D- (Tables 3 and 4). RCV asserts low if SUS = V <sub>L</sub> .   |
| 4     | 3           | VP               | Receiver Output/Driver Input. VP functions as a receiver output when $\overline{OE} = V_L$ . VP duplicates D+ when receiving. VP functions as a driver input when $\overline{OE} = GND$ .   |
| 5     | 4           | VM               | Receiver Output/Driver Input. VM functions as a receiver output when $\overline{OE} = V_L$ . VM duplicates D- when receiving. VM functions as a driver input when $\overline{OE} = GND$ .   |
| 6     | 5, 8, 16    | N.C.             | No Connection. Not internally connected.  |
| 7     | 6           | GND              | Ground  |
| 8     | 7           | SUS              | Suspend Input. Drive SUS low for normal operation. Drive SUS high to put the MAX3450E/MAX3451E/MAX3452E into suspend mode. RCV asserts low in suspend mode. VP and VM remain active in suspend mode.  |
| 9     | 9           | $\overline{OE}$  | Output Enable. Drive $\overline{OE}$ to GND to enable the transmitter outputs. Drive $\overline{OE}$ to V <sub>L</sub> to disable the transmitter outputs. $\overline{OE}$ also controls the I/O direction of VP and VM (Tables 3 and 4).   |
| 10    | 10          | D-               | USB Input/Output. For $\overline{OE} = GND$ , D- functions as a USB output, with VM providing the input signal. For $\overline{OE} = V_L$ , D- functions as a USB input, with VM functioning as a single-ended receiver output. Connect a 1.5kΩ resistor from D- to V <sub>TRM</sub> for low-speed (1.5Mbps) operation (MAX3450E and MAX3452E).   |
| 11    | 11          | D+               | USB Input/Output. For $\overline{OE} = GND$ , D+ functions as a USB output, with VP providing the input signal. For $\overline{OE} = V_L$ , D+ functions as a USB input, with VP functioning as a single-ended receiver output. Connect a 1.5kΩ resistor from D+ to V <sub>TRM</sub> for full-speed (12Mbps) operation (MAX3450E and MAX3452E).   |
| 12    | 12          | V <sub>TRM</sub> | Internal Regulator Output. V <sub>TRM</sub> provides a regulated +3.3V output. Bypass V <sub>TRM</sub> to GND with a 1μF (min) ceramic capacitor as close to the device as possible. V <sub>TRM</sub> normally derives power from V <sub>BUS</sub> . Alternatively, drive V <sub>TRM</sub> directly with a +3.3V ±10% supply (MAX3450E and MAX3451E). V <sub>TRM</sub> provides power to internal circuitry and provides the pullup voltage for an external USB pullup resistor (MAX3450E and MAX3452E). Do not use V <sub>TRM</sub> to power external circuitry. |
| 13    | 13          | N.C.             | No Connection. Not internally connected (MAX3450E).   |
|       |             | ENUM             | Enumerate Function Selection Input (MAX3451E). Drive ENUM to V <sub>L</sub> to connect the internal 1.5kΩ resistor between V <sub>TRM</sub> and D+ or D-, depending on the SPD state. Drive ENUM to GND to disconnect the internal 1.5kΩ resistor. For SPD = V <sub>L</sub> , the 1.5kΩ pullup resistor connects to D+. For SPD = GND, the 1.5kΩ pullup resistor connects to D-.  |
|       |             | BD               | Bus-Detection Output (MAX3452E). The push-pull BD output asserts low and the device enters sharing mode if V <sub>BUS</sub> < +3.6V. BD asserts high if V <sub>BUS</sub> > +4.0V.   |
| 14    | 14          | V <sub>BUS</sub> | USB Power-Supply Input. Connect a +4.0V to +5.5V power supply to V <sub>BUS</sub> . V <sub>BUS</sub> provides power to the internal linear regulator. Bypass V <sub>BUS</sub> to GND with a 0.1μF ceramic capacitor as close to the device as possible. Connect V <sub>BUS</sub> and V <sub>TRM</sub> together when powering the MAX3450E or MAX3451E with an external power supply (+3.3V ±10%).   |
| —     | —           | EP               | Exposed Pad. Connect exposed pad to ground.   |

# ±15kV ESD-Protected USB Transceivers

## Functional Diagram

MAX3450E/MAX3451E/MAX3452E



## Detailed Description

The MAX3450E/MAX3451E/MAX3452E USB-compliant transceivers convert single-ended or differential logic-level signals to USB signals and USB signals to single-ended or differential logic-level signals. The devices fully comply with USB 1.1, as well as USB 2.0 at full- (12Mbps) and low-speed (1.5Mbps) operation. The MAX3450E/MAX3451E/MAX3452E operate with  $V_L$

as low as +1.65V, ensuring compatibility with low-voltage ASICs.

The MAX3450E/MAX3451E/MAX3452E derive power from the USB host ( $V_{BUS}$ ) or from a single-cell Li+ battery (MAX3450E and MAX3451E) connected to  $V_{BUS}$  or from a +3.3V regulated supply connected to  $V_{BUS}$  and  $V_{TRM}$ . The MAX3450E/MAX3451E/MAX3452E meet the physical-layer specifications for logic-level supply volt-



# ±15kV ESD-Protected USB Transceivers

ages ( $V_L$ ) from +1.65V to +3.6V. Integrated ±15kV ESD protection protects the D+ and D- USB I/O ports.

The MAX3451E features an enumerate function providing an internal 1.5k $\Omega$  pullup resistor to  $V_{TRM}$ . The enumerate function disconnects the 1.5k $\Omega$  pullup resistor, allowing the MAX3451E to simulate a bus disconnect while powered and connected to the USB cable. The MAX3450E is pin-for-pin compatible with Micrel's MIC2550A. The MAX3452E features a BD output that asserts high if  $V_{BUS}$  is greater than +4.0V. BD asserts low if  $V_{BUS}$  is less than +3.6V. The MAX3450E and MAX3452E require external pullup resistors from either D+ or D- to  $V_{TRM}$  to set the bus speed.

## Applications Information

### Power-Supply Configurations

#### Normal Operating Mode

Connect  $V_L$  and  $V_{BUS}$  to system power supplies (Table 1). Connect  $V_L$  to a +1.65V to +3.6V supply. Connect  $V_{BUS}$  to a +4.0V to +5.5V supply. Alternatively, the MAX3450E and MAX3451E can derive power from

a single Li+ battery. Connect the battery to  $V_{BUS}$ .  $V_{TRM}$  remains above +3.0V for  $V_{BUS}$  as low as +3.1V.

Additionally, the MAX3450E and MAX3451E can derive power from a +3.3V ±10% voltage regulator. Connect  $V_{BUS}$  and  $V_{TRM}$  to an external +3.3V voltage regulator.  $V_{BUS}$  no longer consumes current to power the internal linear regulator in this configuration.

#### Disable Mode

Connect  $V_{BUS}$  to a system power supply and leave  $V_L$  unconnected or connect to GND. D+ and D- enter a tri-state mode and  $V_{BUS}$  (or  $V_{BUS}$  and  $V_{TRM}$ ) consumes less than 20 $\mu$ A of supply current. D+ and D- withstand external signals up to +5.5V in disable mode (Table 2).

#### Sharing Mode

Connect  $V_L$  to a system power supply and leave  $V_{BUS}$  (or  $V_{BUS}$  and  $V_{TRM}$ ) unconnected or connect to GND. D+ and D- enter a tri-state mode, allowing other circuitry to share the USB D+ and D- lines, and  $V_L$  consumes less than 20 $\mu$ A of supply current. D+ and D- withstand external signals up to +5.5V in sharing mode (Table 2).

Table 1. Power-Supply Configurations

| $V_{BUS}$ (V)   | $V_{TRM}$ (V)       | $V_L$ (V)       | CONFIGURATION            | NOTES              |
|-----------------|---------------------|-----------------|--------------------------|--------------------|
| +4.0 to +5.5    | +3.0 to +3.6 output | +1.65 to +3.6   | Normal mode              | —                  |
| +3.1 to +4.5    | +3.0 to +3.6 output | +1.65 to +3.6   | Battery supply           | MAX3450E, MAX3451E |
| +3.0 to +3.6    | +3.0 to +3.6 input  | +1.65 to +3.6   | Voltage regulator supply | MAX3450E, MAX3451E |
| GND or floating | Output              | +1.65 to +3.6   | Sharing mode             | Table 2            |
| +3.0 to +5.5    | $V_{BUS}$           | GND or floating | Disable mode             | Table 2            |

Table 2. Disable-Mode and Sharing-Mode Connections

| INPUTS/OUTPUTS                              | DISABLE MODE  | SHARING MODE   |
|---|---|--|
| $V_{BUS}/V_{TRM}$                           | <ul style="list-style-type: none"> <li>+5V input/+3.3V output</li> <li>+3.3V input/+3.3V input (MAX3450E and MAX3451E)</li> <li>+3.7V input/+3.3V output (MAX3450E and MAX3451E)</li> </ul> | <ul style="list-style-type: none"> <li>Floating or connected to GND (MAX3450E and MAX3451)</li> <li>&lt; +3.6V (MAX3452E)</li> </ul> |
| $V_L$                                       | Floating or connected to GND  | +1.65V to +3.6V input  |
| D+ and D-                                   | High impedance  | High impedance   |
| VP and VM                                   | Invalid*  | High impedance for $\overline{OE}$ = low   |
|   |   | High for $\overline{OE}$ = high  |
| RCV   | Invalid*  | Undefined**  |
| SPD, SUS, $\overline{OE}$ , ENUM (MAX3451E) | High impedance  | High impedance   |
| BD (MAX3452E)                               | Invalid*  | Low  |

\*High impedance or low

\*\*High or low



# ±15kV ESD-Protected USB Transceivers

## Device Control

### $\overline{OE}$

$\overline{OE}$  controls the direction of communication. Drive  $\overline{OE}$  low to transfer data from the logic side to the USB side. For  $\overline{OE}$  = low, VP and VM serve as differential driver inputs to the USB transmitter.

Drive  $\overline{OE}$  high to transfer data from the USB side to the logic side. For  $\overline{OE}$  = high, VP and VM serve as single-ended receiver outputs from the USB inputs (D+ and D-). RCV serves as a differential receiver output, regardless of the state of  $\overline{OE}$ .

### ENUM (MAX3451E)

The MAX3451E features an enumerate function that allows software control of USB enumeration. USB protocol requires a 1.5k $\Omega$  pullup resistor to D+ or D- to indicate the transmission speed to the host (see the SPD section). The MAX3451E provides an internal 1.5k $\Omega$  pullup resistor. Remove the pullup resistor from the circuit to simulate a device disconnect from the USB. Drive ENUM low to disconnect the internal pullup resistor. Drive ENUM high to connect the internal pullup resistor. The SPD state determines whether the pullup resistor connects to D+ when SPD = VL (full speed) or to D- when SPD = GND (low speed).

### SPD

SPD sets the transceiver speed. Connect SPD to GND to select the low-speed data rate (1.5Mbps). Connect SPD to VL to select the full-speed data rate (12Mbps). The MAX3451E provides an internal pullup resistor for selecting the bus speed. The MAX3450E and MAX3452E require an external pullup resistor to D+ or D- to set the bus speed. Connect the 1.5k $\Omega$  resistor between D+ and VTRM to set the full-speed (12Mbps) data rate, or connect the 1.5k $\Omega$  resistor between D- and VTRM to set the low-speed (1.5 Mbps) data rate.

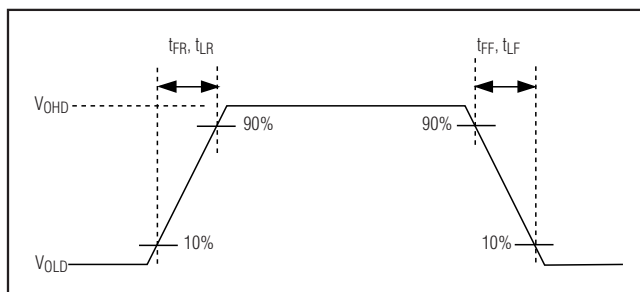


Figure 1. Rise and Fall Times

## SUS

The SUS state determines whether the MAX3450E/MAX3451E/MAX3452E operate in normal mode or in suspend mode. Connect SUS to GND to enable normal operation. Drive SUS high to enable suspend mode. RCV asserts low and VP and VM remain active in suspend mode (Tables 3 and 4). Supply current decreases in suspend mode (see the *Electrical Characteristics*).

**Table 3a. Transmit Truth Table**

( $\overline{OE}$  = 0, SUS = 0)

| INPUTS |    | OUTPUTS |    |     | OUTPUT STATE |
|--------|----|---------|----|-----|--------------|
| VP     | VM | D+      | D- | RCV |              |
| 0      | 0  | 0       | 0  | X   | SE0          |
| 0      | 1  | 0       | 1  | 0   | Logic 0      |
| 1      | 0  | 1       | 0  | 1   | Logic 1      |
| 1      | 1  | 1       | 1  | X   | Undefined    |

X = Undefined.

**Table 3b. Transmit Truth Table**

( $\overline{OE}$  = 0, SUS = 1)

| INPUTS |    | OUTPUTS |    |     | OUTPUT STATE |
|--------|----|---------|----|-----|--------------|
| VP     | VM | D+      | D- | RCV |              |
| 0      | 0  | 0       | 0  | 0   | SE0          |
| 0      | 1  | 0       | 1  | 0   | Logic 0      |
| 1      | 0  | 1       | 0  | 0   | Logic 1      |
| 1      | 1  | 1       | 1  | 0   | Undefined    |

**Table 4a. Receive Truth Table**

( $\overline{OE}$  = 1 and SUS = 0)

| INPUTS |    | OUTPUTS |    |     | OUTPUT STATE |
|--------|----|---------|----|-----|--------------|
| D+     | D- | VP      | VM | RCV |              |
| 0      | 0  | 0       | 0  | X   | SE0          |
| 0      | 1  | 0       | 1  | 0   | Logic 0      |
| 1      | 0  | 1       | 0  | 1   | Logic 1      |
| 1      | 1  | 1       | 1  | X   | Undefined    |

X = Undefined.

# ±15kV ESD-Protected USB Transceivers

**Table 4b. Receive Truth Table**  
( $\overline{OE} = 1$  and  $SUS = 1$ )

| INPUTS |    | OUTPUTS |    |     | OUTPUT STATE |
|--------|----|---------|----|-----|--------------|
| D+     | D- | VP      | VM | RCV |              |
| 0      | 0  | 0       | 0  | 0   | SE0          |
| 0      | 1  | 0       | 1  | 0   | Logic 0      |
| 1      | 0  | 1       | 0  | 0   | Logic 1      |
| 1      | 1  | 1       | 1  | 0   | Undefined    |

## BD (MAX3452E)

The push-pull bus detect (BD) output monitors  $V_{BUS}$  and asserts high if  $V_{BUS}$  is greater than +4.0V. BD asserts low if  $V_{BUS}$  is less than +3.6V and the MAX3452E enters sharing mode (Table 2).

## $V_{TRM}$

An internal linear regulator generates the  $V_{TRM}$  voltage (+3.3V typ).  $V_{TRM}$  derives power from  $V_{BUS}$  (see the *Power-Supply Configurations* section).  $V_{TRM}$  powers the internal portions of the USB circuitry and provides the pullup voltage for an external USB pullup resistor MAX3450E/MAX3452E. Bypass  $V_{TRM}$  to GND with a 1 $\mu$ F ceramic capacitor as close to the device as possible. Do not use  $V_{TRM}$  to provide power to external circuitry.

## D+ and D-

D+ and D- serve as bidirectional bus connections and are ESD protected to ±15kV (Human Body Model). For  $\overline{OE} = \text{low}$ , D+ and D- serve as transmitter outputs. For  $\overline{OE} = \text{high}$ , D+ and D- serve as receiver inputs.

## $V_{BUS}$

For most applications,  $V_{BUS}$  connects to the  $V_{BUS}$  terminal on the USB connector.  $V_{BUS}$  can also connect to an external supply as low as +3.1V (MAX3450E and MAX3451E). See the *Power-Supply Configurations* section. Drive  $V_{BUS}$  low to enable sharing mode. Bypass  $V_{BUS}$  to GND with a 0.1 $\mu$ F ceramic capacitor as close to the device as possible.

## External Components

### External Resistors

Proper USB operation requires two external resistors, each 24.3 $\Omega$  ±1%, 1/8W (or greater). Install one resistor in series between D+ of the MAX3450E/MAX3451E/MAX3452E and D+ on the USB connector. Install the other resistor in series between D- of the MAX3450E/MAX3451E/MAX3452E and D- on the USB connector (see the *Typical Operating Circuit*).

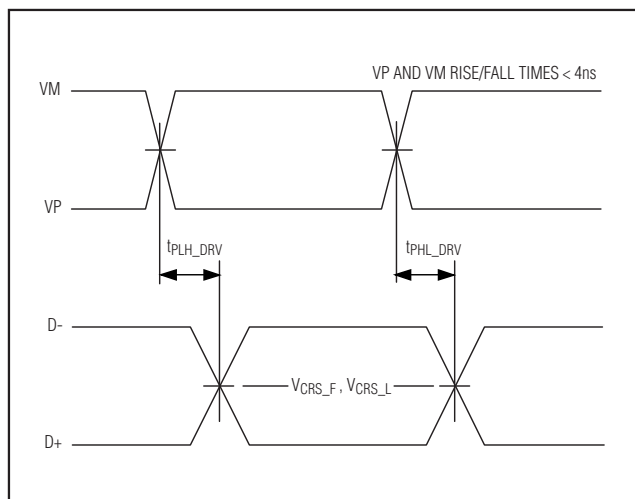


Figure 2. Timing of VP and VM to D+ and D-

The MAX3450E/MAX3452E requires an external 1.5k $\Omega$  pullup resistor between  $V_{TRM}$  and D+ or D- to set the bus speed.

## External Capacitors

The MAX3450E/MAX3451E/MAX3452E require three external capacitors for proper operation. Bypass  $V_L$  to GND with a 0.1 $\mu$ F ceramic capacitor. Bypass  $V_{BUS}$  to GND with a 0.1 $\mu$ F ceramic capacitor. Bypass  $V_{TRM}$  to GND with a 1 $\mu$ F (min) ceramic capacitor. Install all capacitors as close to the device as possible.

## Data Transfer

### Transmitting Data to the USB

The MAX3450E/MAX3451E/MAX3452E transmit data to the USB differentially on D+ and D-. VP and VM serve as differential input signals to the driver (Tables 3a and 3b).

### Receiving Data from the USB

To receive data from the USB, drive  $\overline{OE}$  high and  $SUS$  low. Differential data received by D+ and D- appears as a differential logic signal at RCV. Single-ended receivers on D+ and D- drive VP and VM, respectively (Tables 4a and 4b).

# ±15kV ESD-Protected USB Transceivers

MAX3450E/MAX3451E/MAX3452E

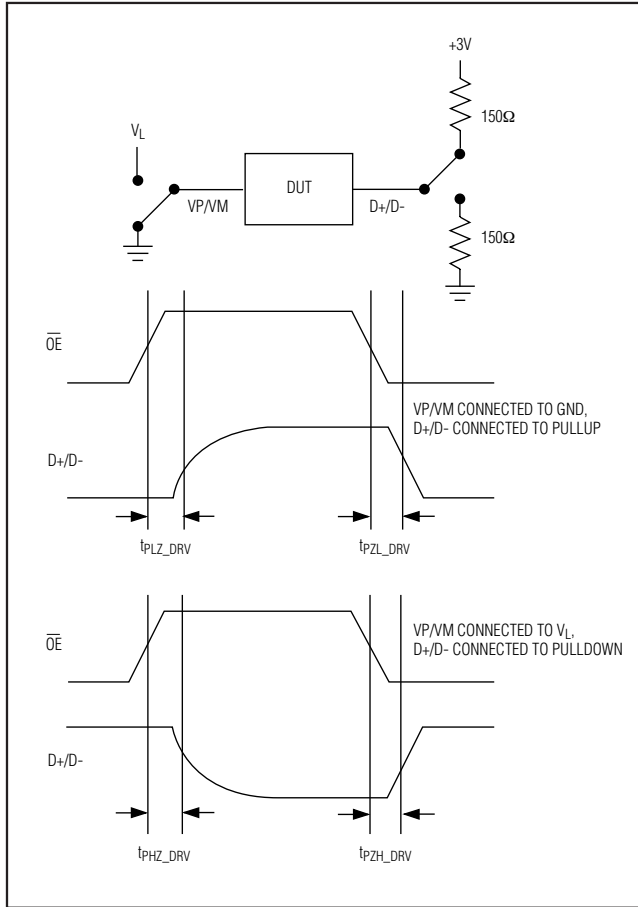


Figure 3. Enable and Disable Timing, Driver

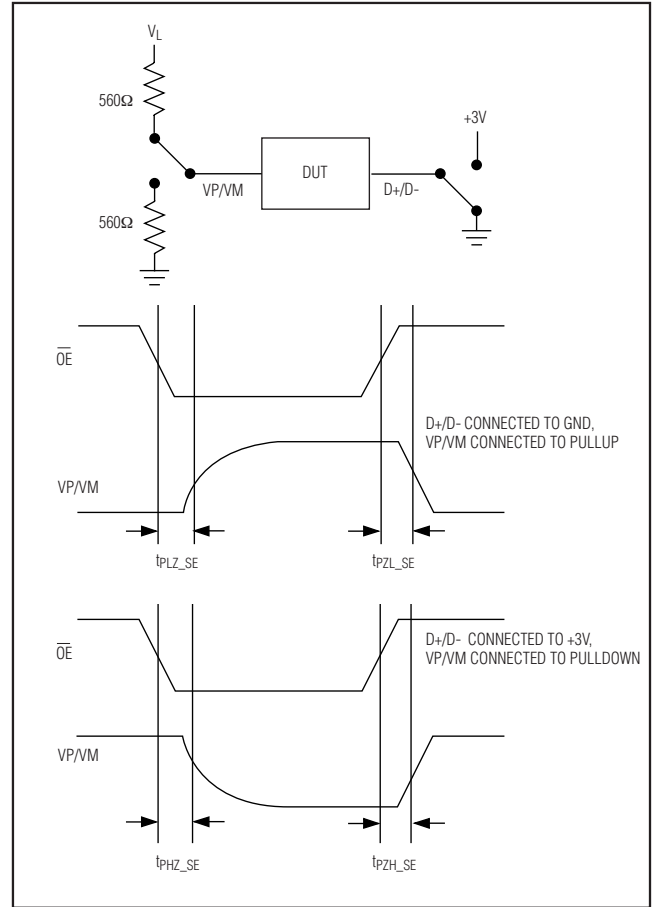


Figure 5. Enable and Disable Timing, Receiver

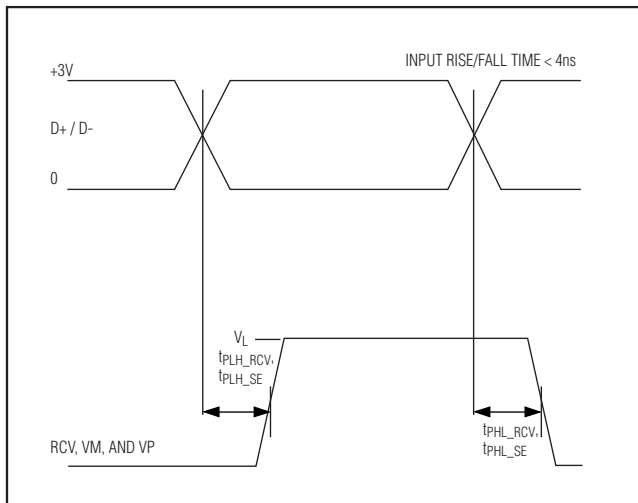


Figure 4. Timing of D+ and D- to RCV, VM, and VP

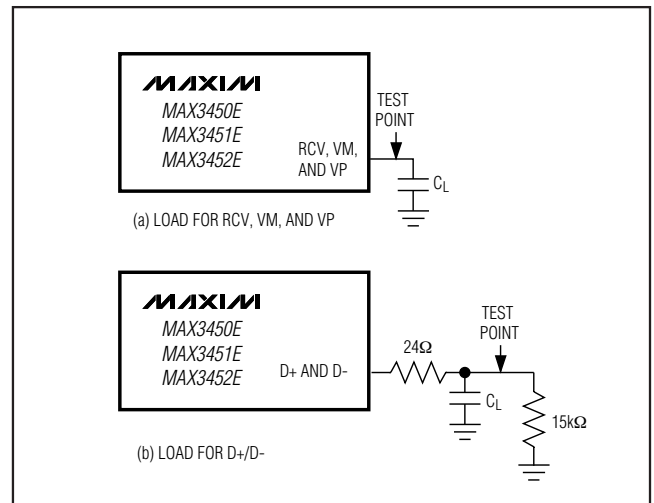


Figure 6. Test Circuits

# ±15kV ESD-Protected USB Transceivers

## ESD Protection

D+ and D- possess extra protection against static electricity to protect the devices up to ±15kV. The ESD structures withstand high ESD in all operating modes: normal operation, suspend mode, and powered down. D+ and D- provide protection to the following limits:

- ±15kV using the Human Body Model
- ±8kV using the Contact Discharge method specified in IEC 1000-4-2

## 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 7 shows the Human Body Model and Figure 8 shows the current waveform generated when discharged into a low impedance. This model consists of a 100pF capacitor charged to the ESD voltage of interest, which then discharges into the test device through a 1.5kΩ resistor.

## IEC 1000-4-2

The IEC 1000-4-2 standard covers ESD testing and performance of finished equipment. It does not specifically refer to integrated circuits. The major difference between tests done using the Human Body Model and IEC 1000-4-2 is a higher peak current in IEC 1000-4-2, due to lower series resistance. Hence, the ESD withstand voltage measured to IEC 1000-4-2 generally is lower than that measured using the Human Body Model. Figure 9 shows the IEC 1000-4-2 model. The Contact Discharge method connects the probe to the device before the probe is charged.

## Machine Model

The Machine Model for ESD tests all connections using a 200pF storage capacitor and zero discharge resistance. Its objective is to emulate the stress caused by contact that occurs with handling and assembly during manufacturing. All pins require this protection during manufacturing, not just inputs and outputs. After PC board assembly, the Machine Model is less relevant to I/O ports.

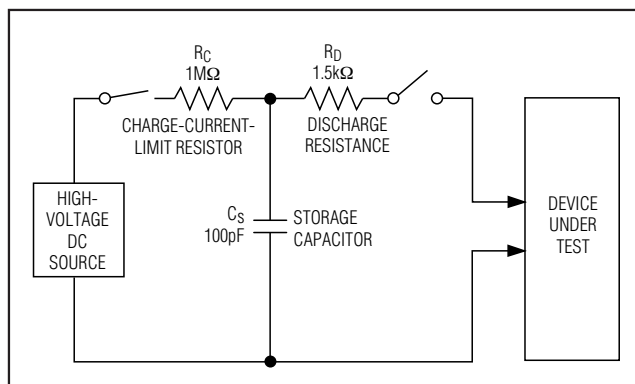


Figure 7. Human Body ESD Test Models

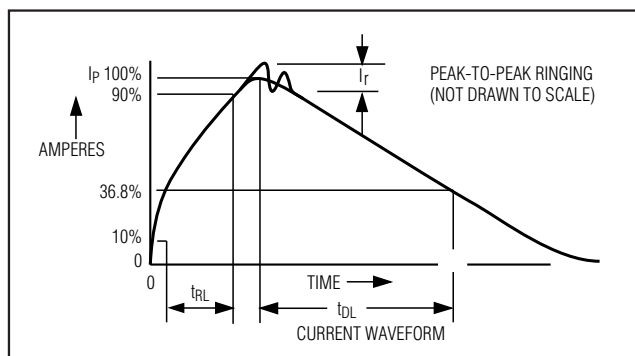


Figure 8. Human Body Model Current Waveform

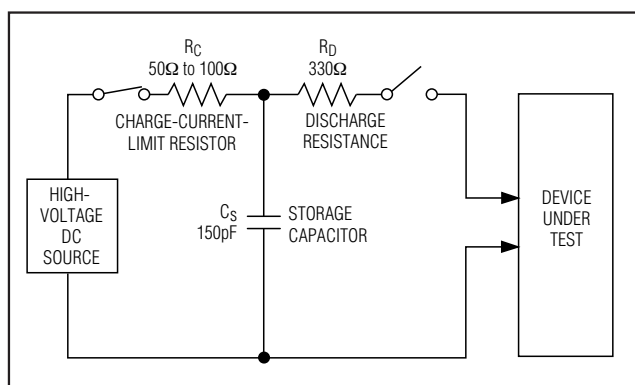
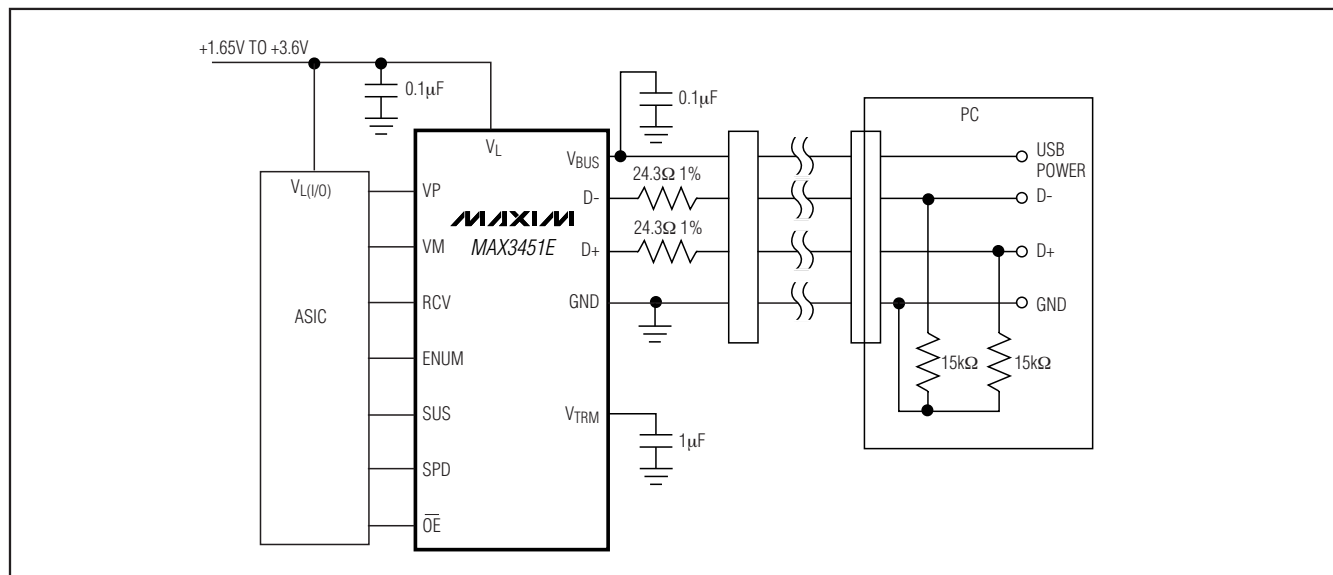


Figure 9. IEC 1000-4-2 ESD Test Model

# ±15kV ESD-Protected USB Transceivers

## Typical Operating Circuit



## Chip Information

PROCESS: BiCMOS

## Package Information

For the latest package outline information and land patterns, go to [www.maxim-ic.com/packages](http://www.maxim-ic.com/packages).

| PACKAGE TYPE   | PACKAGE CODE | DOCUMENT NO.            |
|----------------|--------------|-------------------------|
| 14 TSSOP       | U14-1        | <a href="#">21-0066</a> |
| 16 Thin QFN-EP | T1633-4      | <a href="#">21-0136</a> |

# **$\pm 15\text{kV}$ ESD-Protected USB Transceivers**

## ***Revision History***

| REVISION<br>NUMBER | REVISION<br>DATE | DESCRIPTION   | PAGES<br>CHANGED |
|--------------------|------------------|---|------------------|
| 0                  | 4/03             | Initial release   | —                |
| 1                  | 11/03            | Changed specs   | —                |
| 2                  | 10/08            | Added lead-free packaging. Updated <i>Absolute Maximum Ratings</i> information of package thermal resistances. Updated EC table notation. | 1–4, 6           |

Maxim cannot assume responsibility for use of any circuitry other than circuitry entirely embodied in a Maxim product. No circuit patent licenses are implied. Maxim reserves the right to change the circuitry and specifications without notice at any time.

14 **Maxim Integrated Products, 120 San Gabriel Drive, Sunnyvale, CA 94086 408-737-7600**

# Mouser Electronics

Authorized Distributor

Click to View Pricing, Inventory, Delivery & Lifecycle Information:

## Maxim Integrated:

[MAX3450EETE+](#) [MAX3450EETE+T](#) [MAX3450EEUD+](#) [MAX3450EEUD+T](#) [MAX3451EEUD+](#) [MAX3451EEUD+T](#)  
[MAX3452EEUD+](#) [MAX3452EEUD+T](#) [MAX3452EEUD](#) [MAX3451EEUD](#) [MAX3451EEUD-T](#) [MAX3450EETE](#)  
[MAX3452EETE-T](#) [MAX3450EEUD](#) [MAX3452EEUD-T](#) [MAX3452EETE](#) [MAX3450EETE-T](#) [MAX3450EEUD-T](#)  
[MAX3451EETE-T](#) [MAX3451EETE](#)