

# TS3USB221E High-Speed USB 2.0 (480-Mbps) 1:2 Multiplexer – Demultiplexer Switch With Single Enable and IEC Level 3 ESD Protection

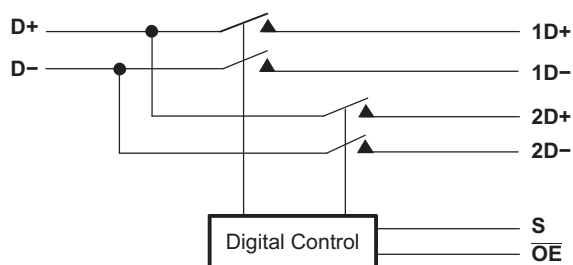
## 1 Features

- $V_{CC}$  operation of 2.3 V to 3.6 V
- Switch I/Os accept signals up to 5.5 V
- 1.8-V compatible control-pin inputs
- Low-power mode when  $\overline{OE}$  is disabled (1  $\mu$ A)
- $r_{ON} = 6 \Omega$  maximum
- $\Delta t_{ON} = 0.2 \Omega$  typical
- $C_{io(on)} = 7$  pF maximum
- Low power consumption (30  $\mu$ A maximum)
- ESD performance tested per JESD 22
  - 7000-V human body model (A114-B, Class II)
  - 1000-V charged-device model (C101)
- ESD performance I/O port to GND
  - 12-kV human body model (A114-B, Class II)
  - $\pm 7$ -kV contact discharge (IEC 61000-4-2)
- High bandwidth (1 GHz typical)

## 2 Applications

- Routes signals for USB 1.0, 1.1, and 2.0
- Mobile phones
- Digital cameras
- Notebooks
- USB I/O expansion
- MHL 1.0

**Block Diagram**



## 3 Description

The TS3USB221E is a high-bandwidth switch specially designed for the switching of high-speed USB 2.0 signals in handset and consumer applications, such as cell phones, digital cameras, and notebooks with hubs or controllers with limited USB I/Os. The wide bandwidth (1 GHz) of this switch allows signals to pass with minimum edge and phase distortion. The device multiplexes differential outputs from a USB host device to one of two corresponding outputs. The switch is bidirectional and offers little or no attenuation of the high-speed signals at the outputs. The TS3USB221E is designed for low bit-to-bit skew and high channel-to-channel noise isolation, and is compatible with various standards, such as high-speed USB 2.0 (480 Mbps).

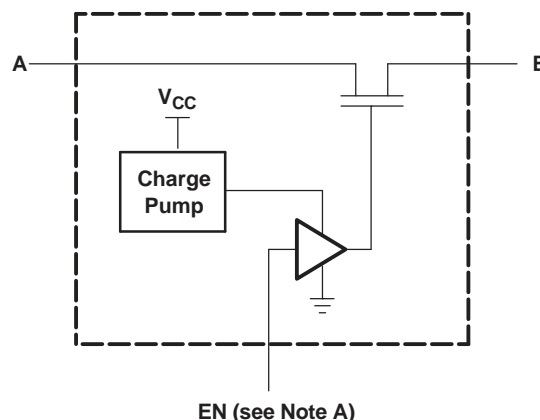
The TS3USB221E integrates ESD protection cells on all pins, is available in a SON package (3 mm  $\times$  3 mm) as well as in a tiny  $\mu$ QFN package (2 mm  $\times$  1.5 mm) and is characterized over the free-air temperature range from  $-40^{\circ}\text{C}$  to  $85^{\circ}\text{C}$ .

**Device Information<sup>(1)</sup>**

| PART NUMBER | PACKAGE   | BODY SIZE (NOM)          |
|-------------|-----------|--------------------------|
| TS3USB221E  | VSON (10) | 3.00 mm $\times$ 3.00 mm |
|             | UQFN (10) | 1.50 mm $\times$ 2.00 mm |

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

**Simplified Schematic, Each FET Switch (SW)**



A. EN is the internal enable signal applied to the switch.



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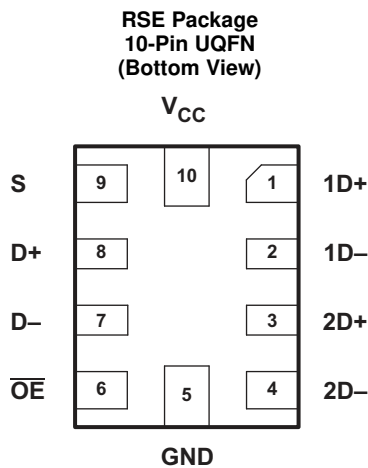
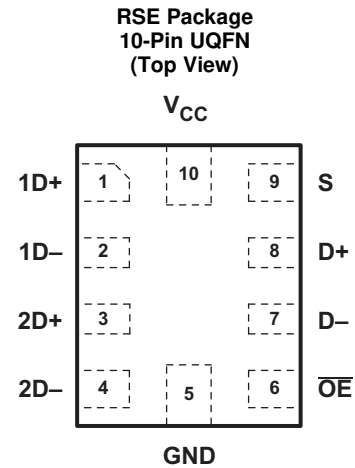
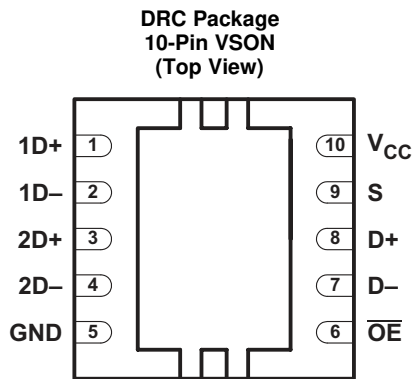
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## 4 Revision History

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

| <b>Changes from Revision C (April 2015) to Revision D</b>  | <b>Page</b> |
|--|-------------|
| • Changed $V_{CC}$ Operation FROM 2.5 V to 3.3 V TO 2.3 V to 3.6 V .....   | <b>1</b>    |
| <hr/>  |             |
| <b>Changes from Revision B (July 2012) to Revision C</b>   | <b>Page</b> |
| • Added <i>Pin Configuration and Functions</i> section, <i>ESD Ratings</i> table, <i>Thermal Information</i> table, <i>Feature Description</i> section, <i>Device Functional Modes</i> , <i>Application and Implementation</i> section, <i>Power Supply Recommendations</i> section, <i>Layout</i> section, <i>Device and Documentation Support</i> section, and <i>Mechanical, Packaging, and Orderable Information</i> section ..... | <b>1</b>    |
| • Removed <i>Ordering Information</i> table .....  | <b>1</b>    |
| <hr/>  |             |
| <b>Changes from Revision A (February 2010) to Revision B</b>   | <b>Page</b> |
| • Updated TOP-SIDE MARKING for RSE package in <i>Ordering Information</i> table .....  | <b>1</b>    |

## 5 Pin Configuration and Functions



### Pin Functions

| PIN                    |     | I/O | DESCRIPTION       |
|------------------------|-----|-----|-------------------|
| NAME                   | NO. |     |                   |
| 1D+                    | 1   | I/O | USB port 1        |
| 1D-                    | 2   | I/O |                   |
| 2D+                    | 3   | I/O |                   |
| 2D-                    | 4   | I/O |                   |
| GND                    | 5   | —   | Ground            |
| $\overline{\text{OE}}$ | 6   | I   | Bus-switch enable |
| D-                     | 7   | I/O | Common USB port   |
| D+                     | 8   | I/O |                   |
| S                      | 9   | I   | Select input      |
| V <sub>CC</sub>        | 10  | —   | Supply voltage    |

## 6 Specifications

### 6.1 Absolute Maximum Ratings

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

|                   |   | MIN                  | MAX  | UNIT |
|-------------------|---|----------------------|------|------|
| V <sub>CC</sub>   | Supply voltage                                    | -0.5                 | 4.6  | V    |
| V <sub>IN</sub>   | Control input voltage <sup>(2)(3)</sup>           | -0.5                 | 7    | V    |
| V <sub>I/O</sub>  | Switch I/O voltage <sup>(2)(3)(4)</sup>           | -0.5                 | 7    | V    |
| I <sub>IK</sub>   | Control input clamp current                       | V <sub>IN</sub> < 0  | -50  | mA   |
| I <sub>I/OK</sub> | I/O port clamp current                            | V <sub>I/O</sub> < 0 | -50  | mA   |
| I <sub>I/O</sub>  | ON-state switch current <sup>(5)</sup>            |                      | ±120 | mA   |
|                   | Continuous current through V <sub>CC</sub> or GND |                      | ±100 | mA   |
| θ <sub>JA</sub>   | Package thermal impedance <sup>(6)</sup>          | DRC package          | 48.7 | °C/W |
|                   |   | RSE package          | 243  |      |
| T <sub>stg</sub>  | Storage temperature                               | -65                  | 150  | °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 voltages are with respect to ground, unless otherwise specified.
- (3) The input and output voltage ratings may be exceeded if the input and output clamp-current ratings are observed.
- (4) V<sub>I</sub> and V<sub>O</sub> are used to denote specific conditions for V<sub>I/O</sub>.
- (5) I<sub>I</sub> and I<sub>O</sub> are used to denote specific conditions for I<sub>I/O</sub>.
- (6) The package thermal impedance is calculated in accordance with JESD 51-7.

### 6.2 ESD Ratings

|                    |                         |  | VALUE  | UNIT   |   |
|--------------------|-------------------------|--|--|--------|---|
| V <sub>(ESD)</sub> | Electrostatic discharge | Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001 <sup>(1)</sup>              | All pins except GND, $\overline{OE}$ , S and V <sub>CC</sub> | ±12000 | V |
|                    |                         |  | Pins GND, $\overline{OE}$ , S and V <sub>CC</sub>            | ±7000  |   |
|                    |                         | Charged-device model (CDM), per JEDEC specification JESD22-C101 <sup>(2)</sup> | All pins except GND, $\overline{OE}$ , S and V <sub>CC</sub> | ±7000  |   |
|                    |                         |  | Pins GND, $\overline{OE}$ , S and V <sub>CC</sub>            | ±1000  |   |

- (1) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process.
- (2) JEDEC document JEP157 states that 250-V CDM allows safe manufacturing with a standard ESD control process.

### 6.3 Recommended Operating Conditions

 See <sup>(1)</sup>.

|                  |                                  | MIN                              | MAX                    | UNIT |
|------------------|----------------------------------|----------------------------------|------------------------|------|
| V <sub>CC</sub>  | Supply voltage                   | 2.3                              | 3.6                    | V    |
| V <sub>IH</sub>  | High-level control input voltage | V <sub>CC</sub> = 2.3 V to 2.7 V | 0.46 × V <sub>CC</sub> | V    |
|                  |                                  | V <sub>CC</sub> = 2.7 V to 3.6 V | 0.46 × V <sub>CC</sub> |      |
| V <sub>IL</sub>  | Low-level control input voltage  | V <sub>CC</sub> = 2.3 V to 2.7 V | 0.25 × V <sub>CC</sub> | V    |
|                  |                                  | V <sub>CC</sub> = 2.7 V to 3.6 V | 0.25 × V <sub>CC</sub> |      |
| V <sub>I/O</sub> | Data input/output voltage        | 0                                | 5.5                    | V    |
| T <sub>A</sub>   | Operating free-air temperature   | -40                              | 85                     | °C   |

- (1) All unused control inputs of the device must be held at V<sub>CC</sub> or GND to ensure proper device operation. Refer to the TI application report, *Implications of Slow or Floating CMOS Inputs*, SCBA004.

## 6.4 Thermal Information

| THERMAL METRIC <sup>(1)</sup> |  | TS3USB221E |            | UNIT |
|-------------------------------|--|------------|------------|------|
|                               |  | DRC (VSON) | RSE (UQFN) |      |
|                               |  | 10 PINS    | 10 PINS    |      |
| R <sub>θJA</sub>              | Junction-to-ambient thermal resistance       | 57.7       | 169.8      | °C/W |
| R <sub>θJC(top)</sub>         | Junction-to-case (top) thermal resistance    | 87.7       | 84.7       |      |
| R <sub>θJB</sub>              | Junction-to-board thermal resistance         | 32.6       | 94.9       |      |
| ψ <sub>JT</sub>               | Junction-to-top characterization parameter   | 8.2        | 5.7        |      |
| ψ <sub>JB</sub>               | Junction-to-board characterization parameter | 32.8       | 94.9       |      |
| R <sub>θJC(bot)</sub>         | Junction-to-case (bottom) thermal resistance | 18.5       | N/A        |      |

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

## 6.5 Electrical Characteristics

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

| PARAMETER                        | TEST CONDITIONS   |   | MIN                     | TYP <sup>(2)</sup> | MAX  | UNIT |
|----------------------------------|---|---|-------------------------|--------------------|------|------|
| V <sub>IK</sub>                  | V <sub>CC</sub> = 3.6 V, 2.7 V,   | I <sub>I</sub> = -18 mA   |                         |                    | -1.8 | V    |
| I <sub>IN</sub>                  | Control inputs  | V <sub>CC</sub> = 3.6 V, 2.7 V, 0 V, V <sub>IN</sub> = 0 V to 3.6 V         |                         |                    | ±1   | μA   |
| I <sub>OZ</sub> <sup>(3)</sup>   | V <sub>CC</sub> = 3.6 V, 2.7 V, V <sub>O</sub> = 0 V to 5.25 V, V <sub>I</sub> = 0 V, | V <sub>IN</sub> = V <sub>CC</sub> or GND, Switch OFF                        |                         |                    | ±1   | μA   |
| I <sub>OFF</sub>                 | V <sub>CC</sub> = 0 V   | V <sub>I/O</sub> = 0 V to 5.25 V  |                         |                    | ±2   | μA   |
|                                  |   | V <sub>I/O</sub> = 0 V to 3.6 V   |                         |                    | ±2   |      |
|                                  |   | V <sub>I/O</sub> = 0 V to 2.7 V   |                         |                    | ±1   |      |
| I <sub>CC</sub>                  | V <sub>CC</sub> = 3.6 V, 2.7 V, V <sub>IN</sub> = V <sub>CC</sub> or GND,             | I <sub>I/O</sub> = 0 V, Switch ON or OFF                                    |                         |                    | 30   | μA   |
| I <sub>CC</sub> (low power mode) | V <sub>CC</sub> = 3.6 V, 2.7 V, V <sub>IN</sub> = V <sub>CC</sub> or GND              | Switch disabled (OE in high state)  |                         |                    | 1    | μA   |
| I <sub>CC</sub> <sup>(4)</sup>   | Control inputs  | One input at 1.8 V, Other inputs at V <sub>CC</sub> or GND                  | V <sub>CC</sub> = 3.6 V |                    | 20   | μA   |
|                                  |   |   | V <sub>CC</sub> = 2.7 V |                    | 0.5  |      |
| C <sub>in</sub>                  | Control inputs  | V <sub>CC</sub> = 3.3 V, 2.5 V, V <sub>IN</sub> = 3.3 V or 0 V              |                         | 1.5                | 2.5  | pF   |
| C <sub>IO(OFF)</sub>             |   | V <sub>CC</sub> = 3.3 V, 2.5 V, V <sub>I/O</sub> = 3.3 V or 0 V, Switch OFF |                         | 3.5                | 5    | pF   |
| C <sub>IO(ON)</sub>              |   | V <sub>CC</sub> = 3.3 V, 2.5 V, V <sub>I/O</sub> = 3.3 V or 0 V, Switch ON  |                         | 6                  | 7.5  | pF   |
| r <sub>ON</sub> <sup>(5)</sup>   | V <sub>CC</sub> = 3 V, 2.3 V  | V <sub>I</sub> = 0 V, I <sub>O</sub> = 30 mA                                |                         | 3                  | 6    | Ω    |
|                                  |   | V <sub>I</sub> = 2.4 V, I <sub>O</sub> = -15 mA                             |                         | 3.4                | 6    |      |
| Δr <sub>ON</sub>                 | V <sub>CC</sub> = 3 V, 2.3 V  | V <sub>I</sub> = 0 V, I <sub>O</sub> = 30 mA                                |                         | 0.2                |      | Ω    |
|                                  |   | V <sub>I</sub> = 1.7, I <sub>O</sub> = -15 mA                               |                         | 0.2                |      |      |
| r <sub>ON(flat)</sub>            | V <sub>CC</sub> = 3 V, 2.3 V  | V <sub>I</sub> = 0 V, I <sub>O</sub> = 30 mA                                |                         | 1                  |      | Ω    |
|                                  |   | V <sub>I</sub> = 1.7, I <sub>O</sub> = -15 mA                               |                         | 1                  |      |      |

(1) V<sub>IN</sub> and I<sub>IN</sub> refer to control inputs. V<sub>I</sub>, V<sub>O</sub>, I<sub>I</sub>, and I<sub>O</sub> refer to data pins.

(2) All typical values are at V<sub>CC</sub> = 3.3 V (unless otherwise noted), T<sub>A</sub> = 25°C.

(3) For I/O ports, the parameter I<sub>OZ</sub> includes the input leakage current.

(4) This is the increase in supply current for each input that is at the specified TTL voltage level, rather than V<sub>CC</sub> or GND.

(5) Measured by the voltage drop between the A and B terminals at the indicated current through the switch. ON-state resistance is determined by the lower of the voltages of the two (A or B) terminals.

## 6.6 Dynamic Electrical Characteristics, $V_{CC} = 3.3\text{ V} \pm 10\%$

 over operating range,  $T_A = -40^\circ\text{C}$  to  $85^\circ\text{C}$ ,  $V_{CC} = 3.3\text{ V} \pm 10\%$ ,  $GND = 0\text{ V}$ 

| PARAMETER         |                   | TEST CONDITIONS                   | TYP <sup>(1)</sup> | UNIT |
|-------------------|-------------------|-----------------------------------|--------------------|------|
| X <sub>TALK</sub> | Crosstalk         | $R_L = 50$ , $f = 250\text{ MHz}$ | -40                | dB   |
| O <sub>IRR</sub>  | OFF isolation     | $R_L = 50$ , $f = 250\text{ MHz}$ | -40                | dB   |
| BW                | Bandwidth (-3 dB) | $R_L = 50$                        | 1                  | GHz  |

 (1) For Maximum or Minimum conditions, use the appropriate value specified under [Electrical Characteristics](#) for the applicable device type.

## 6.7 Dynamic Electrical Characteristics, $V_{CC} = 2.5\text{ V} \pm 10\%$

 over operating range,  $T_A = -40^\circ\text{C}$  to  $85^\circ\text{C}$ ,  $V_{CC} = 2.5\text{ V} \pm 10\%$ ,  $GND = 0\text{ V}$ 

| PARAMETER         |                  | TEST CONDITIONS                   | TYP <sup>(1)</sup> | UNIT |
|-------------------|------------------|-----------------------------------|--------------------|------|
| X <sub>TALK</sub> | Crosstalk        | $R_L = 50$ , $f = 250\text{ MHz}$ | -39                | dB   |
| O <sub>IRR</sub>  | OFF isolation    | $R_L = 50$ , $f = 250\text{ MHz}$ | -40                | dB   |
| BW                | Bandwidth (3 dB) | $R_L = 50$                        | 1                  | GHz  |

 (1) For Maximum or Minimum conditions, use the appropriate value specified under [Electrical Characteristics](#) for the applicable device type.

## 6.8 Switching Characteristics, $V_{CC} = 3.3\text{ V} \pm 10\%$

 over operating range,  $T_A = -40^\circ\text{C}$  to  $85^\circ\text{C}$ ,  $V_{CC} = 3.3\text{ V} \pm 10\%$ ,  $GND = 0\text{ V}$ 

| PARAMETER          |  | MIN                             | TYP <sup>(1)</sup> | MAX | UNIT |
|--------------------|--|---------------------------------|--------------------|-----|------|
| t <sub>pd</sub>    | Propagation delay <sup>(2) (3)</sup>   |                                 | 0.25               |     | ns   |
| t <sub>ON</sub>    | Line enable time   | S to D, nD                      |                    | 30  | ns   |
|                    |  | $\overline{\text{OE}}$ to D, nD |                    | 17  |      |
| t <sub>OFF</sub>   | Line disable time  | S to D, nD                      |                    | 12  | ns   |
|                    |  | $\overline{\text{OE}}$ to D, nD |                    | 10  |      |
| t <sub>SK(O)</sub> | Output skew between center port to any other port <sup>(2)</sup>   |                                 | 0.1                | 0.2 | ns   |
| t <sub>SK(P)</sub> | Skew between opposite transitions of the same output (t <sub>PHL</sub> - t <sub>PLH</sub> ) <sup>(2)</sup> |                                 | 0.1                | 0.2 | ns   |

 (1) For Maximum or Minimum conditions, use the appropriate value specified under [Electrical Characteristics](#) for the applicable device type.

(2) Specified by design

(3) The bus switch contributes no propagational delay other than the RC delay of the on resistance of the switch and the load capacitance. The time constant for the switch alone is of the order of 0.25 ns for 10-pF load. Because this time constant is much smaller than the rise/fall times of typical driving signals, it adds very little propagational delay to the system. Propagational delay of the bus switch, when used in a system, is determined by the driving circuit on the driving side of the switch and its interactions with the load on the driven side.

## 6.9 Switching Characteristics, $V_{CC} = 2.5\text{ V} \pm 10\%$

 over operating range,  $T_A = -40^\circ\text{C}$  to  $85^\circ\text{C}$ ,  $V_{CC} = 2.5\text{ V} \pm 10\%$ ,  $GND = 0\text{ V}$ 

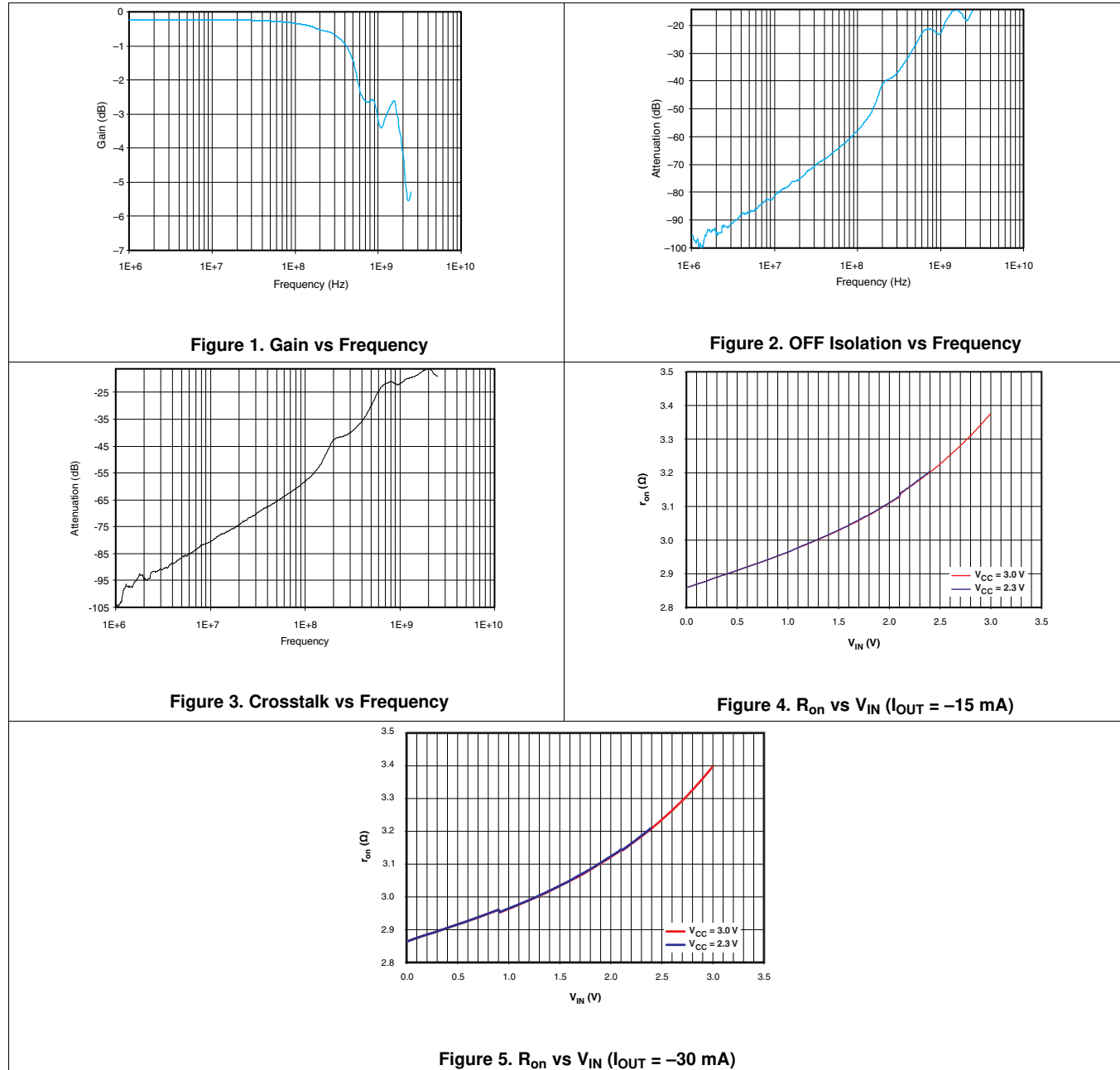
| PARAMETER          |  | MIN                             | TYP <sup>(1)</sup> | MAX | UNIT |
|--------------------|--|---------------------------------|--------------------|-----|------|
| t <sub>pd</sub>    | Propagation delay <sup>(2) (3)</sup>   |                                 | 0.25               |     | ns   |
| t <sub>ON</sub>    | Line enable time   | S to D, nD                      |                    | 50  | ns   |
|                    |  | $\overline{\text{OE}}$ to D, nD |                    | 32  |      |
| t <sub>OFF</sub>   | Line disable time  | S to D, nD                      |                    | 23  | ns   |
|                    |  | $\overline{\text{OE}}$ to D, nD |                    | 12  |      |
| t <sub>SK(O)</sub> | Output skew between center port to any other port <sup>(2)</sup>   |                                 | 0.1                | 0.2 | ns   |
| t <sub>SK(P)</sub> | Skew between opposite transitions of the same output (t <sub>PHL</sub> - t <sub>PLH</sub> ) <sup>(2)</sup> |                                 | 0.1                | 0.2 | ns   |

 (1) For Maximum or Minimum conditions, use the appropriate value specified under [Electrical Characteristics](#) for the applicable device type.

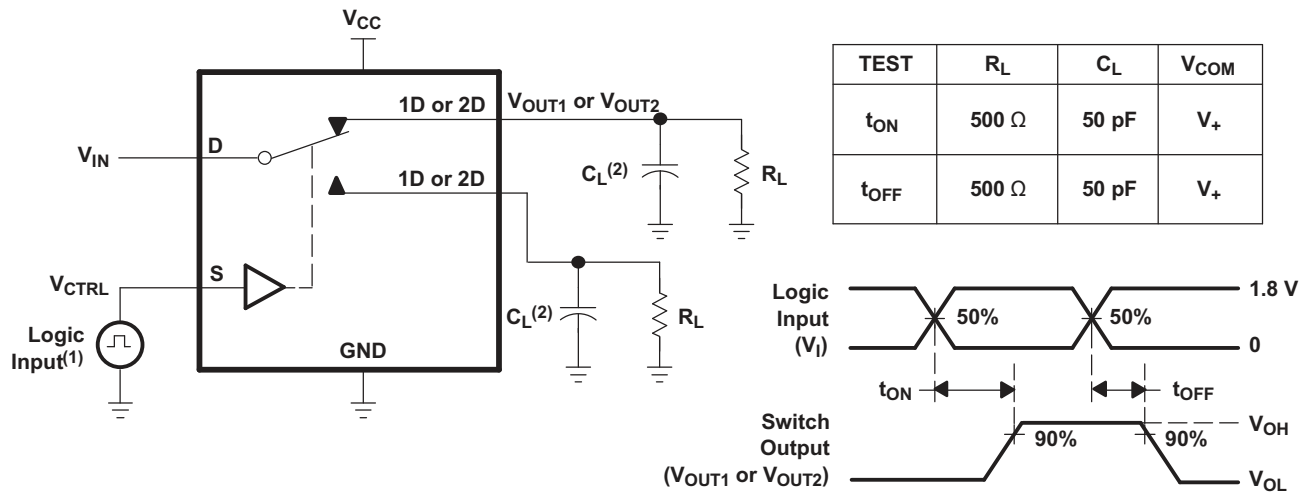
(2) Specified by design

(3) The bus switch contributes no propagational delay other than the RC delay of the on resistance of the switch and the load capacitance. The time constant for the switch alone is of the order of 0.25 ns for 10-pF load. Because this time constant is much smaller than the rise/fall times of typical driving signals, it adds very little propagational delay to the system. Propagational delay of the bus switch, when used in a system, is determined by the driving circuit on the driving side of the switch and its interactions with the load on the driven side.

## 6.10 Typical Characteristics



## 7 Parameter Measurement Information



- (1) All input pulses are supplied by generators having the following characteristics: PRR ≤ 10 MHz, Z<sub>O</sub> = 50 Ω, t<sub>r</sub> < 5 ns, t<sub>f</sub> < 5 ns.
- (2) C<sub>L</sub> includes probe and jig capacitance.

Figure 6. Turnon (T<sub>ON</sub>) and Turnoff Time (T<sub>OFF</sub>)

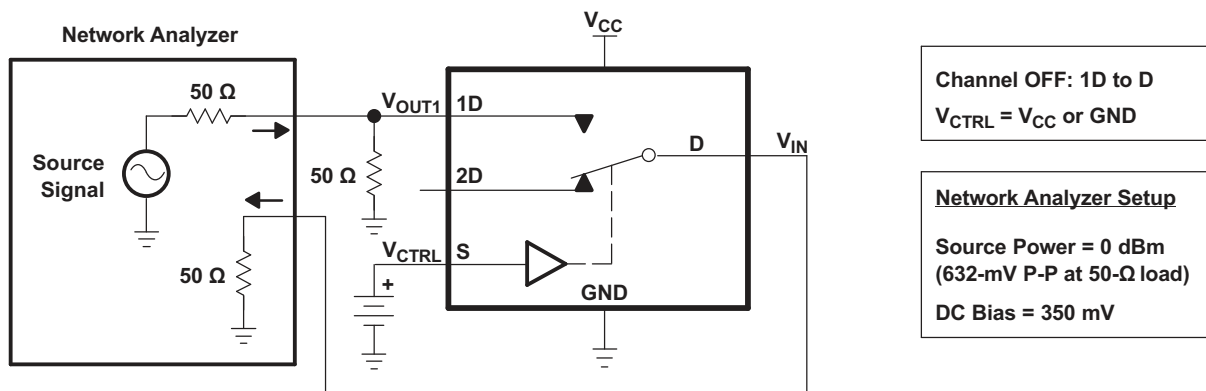


Figure 7. OFF Isolation (O<sub>ISO</sub>)

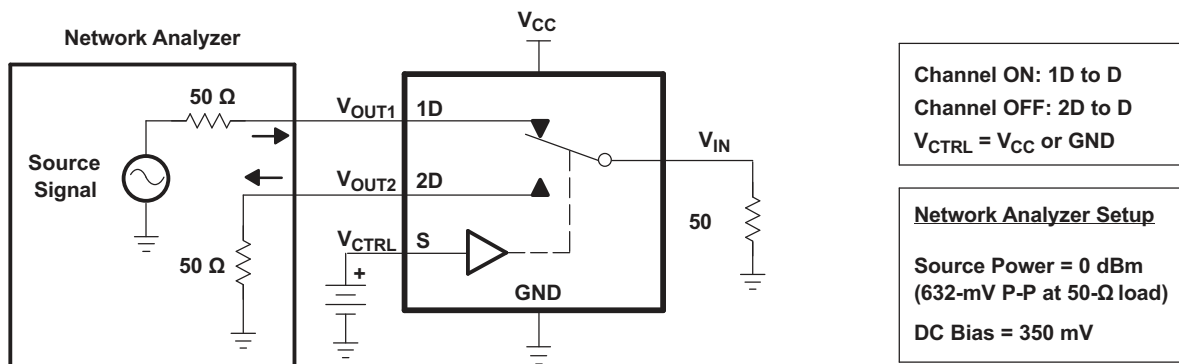


Figure 8. Crosstalk (X<sub>TALK</sub>)



Parameter Measurement Information (continued)

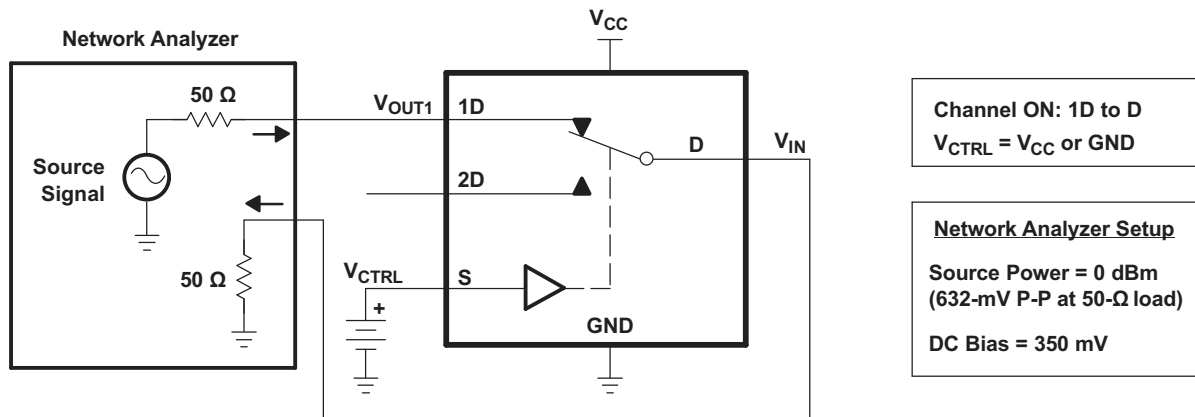


Figure 9. Bandwidth (BW)

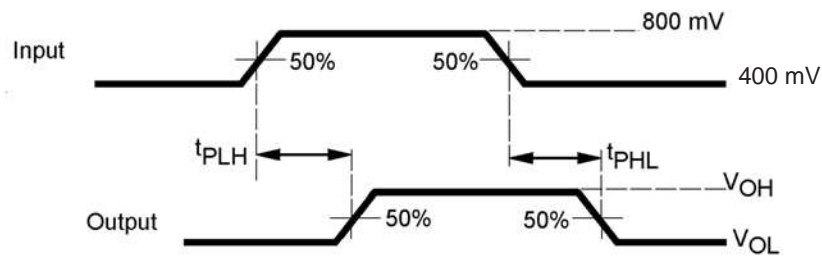


Figure 10. Propagation Delay

Parameter Measurement Information (continued)

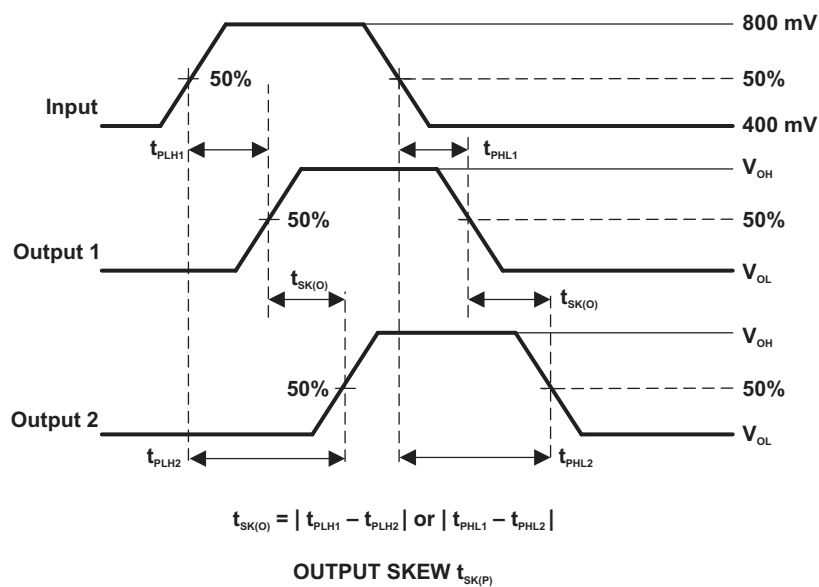
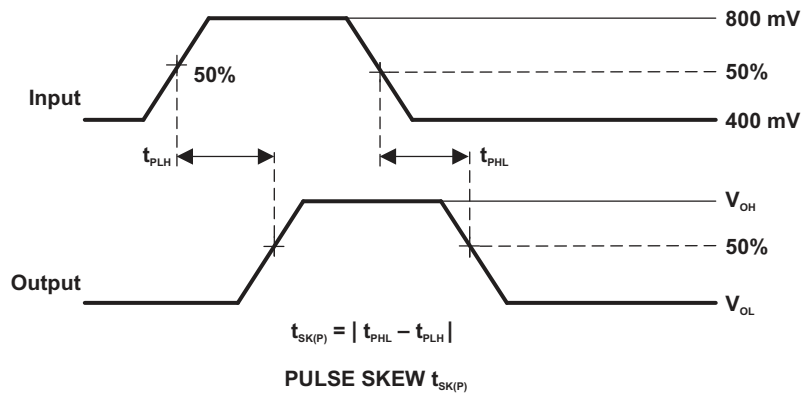


Figure 11. Skew Test

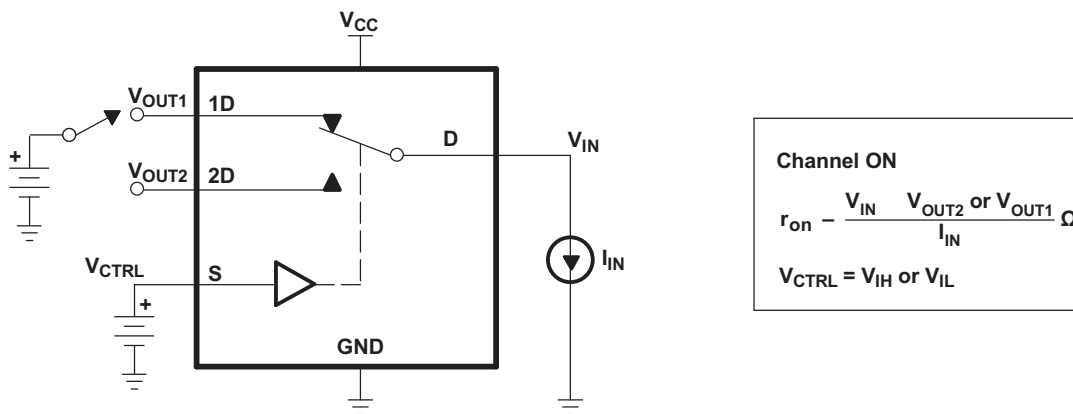


Figure 12. ON-State Resistance ( $R_{on}$ )

Parameter Measurement Information (continued)

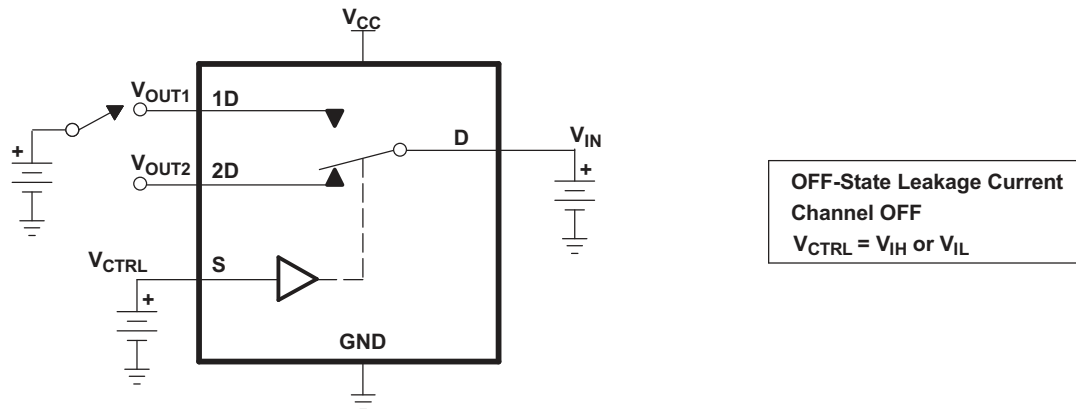


Figure 13. OFF-State Leakage Current

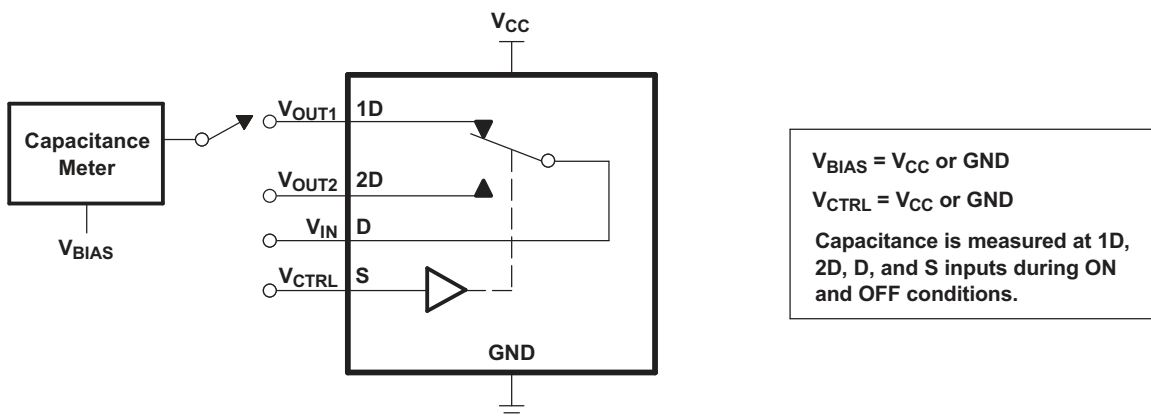


Figure 14. Capacitance

## 8 Detailed Description

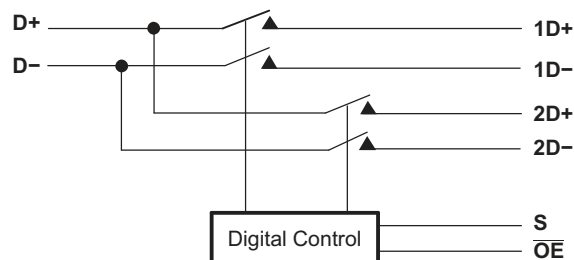
### 8.1 Overview

The TS3USB221E device is a 2-channel SPDT switch specially designed for the switching of high-speed USB 2.0 signals in handset and consumer applications, such as cell phones, digital cameras, and notebooks with hubs or controllers with limited USB I/Os. The wide bandwidth (1 GHz) of this switch allows signals to pass with minimum edge and phase distortion. The device multiplexes differential outputs from a USB host device to one of two corresponding outputs. The switch is bidirectional and offers little or no attenuation of the high-speed signals at the outputs. The device also has a low power mode that reduces the power consumption to 1  $\mu\text{A}$  for portable applications with a battery or limited power budget.

The device is designed for low bit-to-bit skew and high channel-to-channel noise isolation, and is compatible with various standards, such as high-speed USB 2.0 (480 Mbps).

The TS3USB221E device integrates ESD protection cells on all pins, is available in a tiny  $\mu\text{QFN}$  package (2 mm  $\times$  1.5 mm) and is characterized over the free-air temperature range from  $-40^{\circ}\text{C}$  to  $85^{\circ}\text{C}$ .

### 8.2 Functional Block Diagram



### 8.3 Feature Description

#### 8.3.1 Low Power Mode

The TS3USB221E has a low power mode that reduces the power consumption to 1  $\mu\text{A}$  when the device is not in use. To put the device in low power mode and disable the switch, the bus-switch enable pin  $\overline{\text{OE}}$  must be supplied with a logic high signal.

### 8.4 Device Functional Modes

**Table 1. Truth Table**

| S | $\overline{\text{OE}}$ | FUNCTION   |
|---|------------------------|------------|
| X | H                      | Disconnect |
| L | L                      | D = 1D     |
| H | L                      | D = 2D     |

## 9 Application and Implementation

### NOTE

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

### 9.1 Application Information

There are many USB applications in which the USB hubs or controllers have a limited number of USB I/Os. The TS3USB221E solution can effectively expand the limited USB I/Os by switching between multiple USB buses in order to interface them to a single USB hub or controller. TS3USB221E can also be used to connect a single controller to two USB connectors.

### 9.2 Typical Application

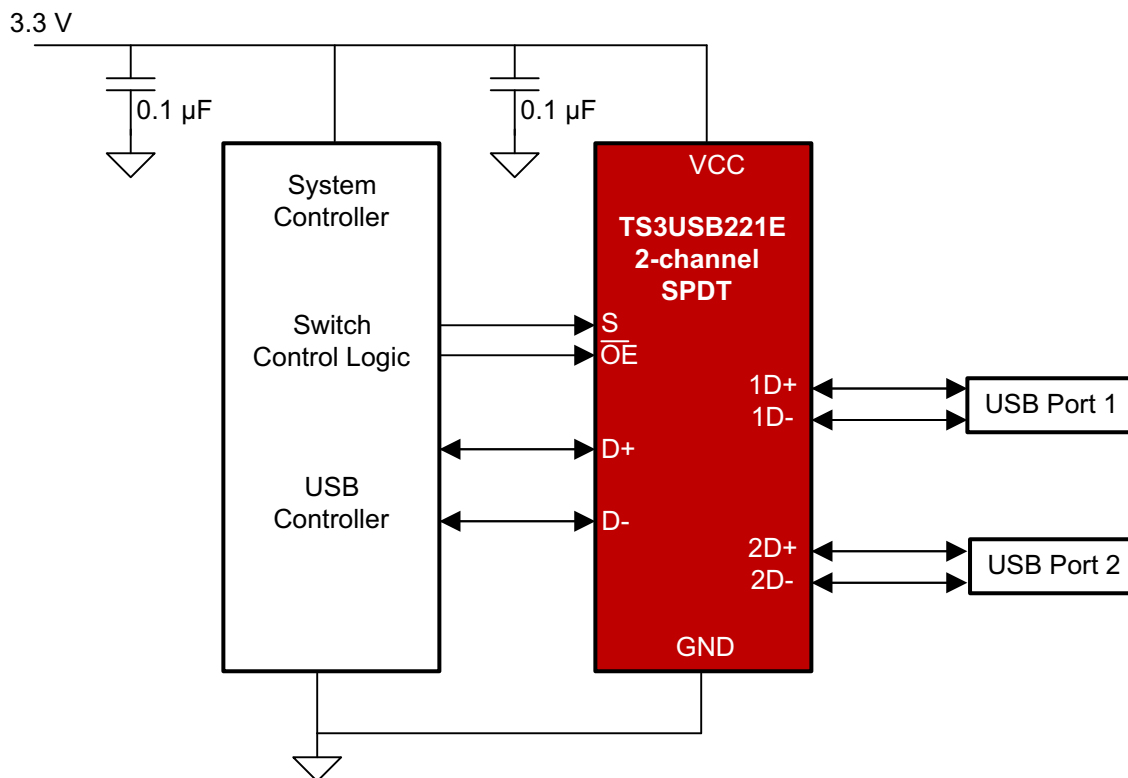


Figure 15. Simplified Schematic

#### 9.2.1 Design Requirements

Design requirements of the USB 1.0, 1.1, and 2.0 standards should be followed.

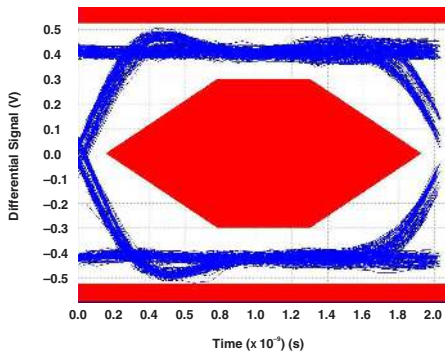
TI recommends that the digital control pins S and  $\overline{OE}$  be pulled up to  $V_{CC}$  or down to GND to avoid undesired switch positions that could result from the floating pin.

#### 9.2.2 Detailed Design Procedure

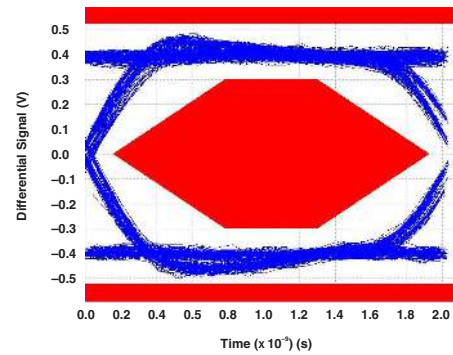
The TS3USB221E can be properly operated without any external components. However, it is recommended that unused pins should be connected to ground through a 50-Ω resistor to prevent signal reflections back into the device.

**Typical Application (continued)**

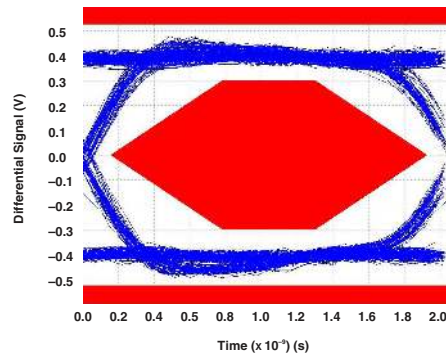
**9.2.3 Application Curves**



**Figure 16. Eye Pattern: 480-Mbps USB Signal With No Switch (Through Path)**



**Figure 17. Eye Pattern: 480-Mbps USB Signal With Switch 1D Path**



**Figure 18. Eye Pattern: 480-Mbps USB Signal With Switch 2D Path**

## 10 Power Supply Recommendations

Power to the device is supplied through the  $V_{CC}$  pin and should follow the USB 1.0, 1.1, and 2.0 standards. TI recommends placing a bypass capacitor as close as possible to the supply pin  $V_{CC}$  to help smooth out lower frequency noise to provide better load regulation across the frequency spectrum.

## 11 Layout

### 11.1 Layout Guidelines

Place supply bypass capacitors as close to  $V_{CC}$  pin as possible and avoid placing the bypass caps near the D+/D– traces.

The high speed D+/D– traces should always be matched lengths and must be no more than 4 inches; otherwise, the eye diagram performance may be degraded. A high-speed USB connection is made through a shielded, twisted pair cable with a differential characteristic impedance. In layout, the impedance of D+ and D– traces should match the cable characteristic differential impedance for optimal performance.

Route the high-speed USB signals using a minimum of vias and corners which will reduce signal reflections and impedance changes. When a via must be used, increase the clearance size around it to minimize its capacitance. Each via introduces discontinuities in the signal's transmission line and increases the chance of picking up interference from the other layers of the board. Be careful when designing test points on twisted pair lines; through-hole pins are not recommended.

When it becomes necessary to turn 90°, use two 45° turns or an arc instead of making a single 90° turn. This reduces reflections on the signal traces by minimizing impedance discontinuities.

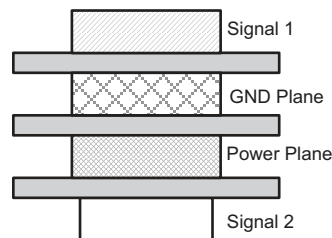
Do not route USB traces under or near crystals, oscillators, clock signal generators, switching regulators, mounting holes, magnetic devices or IC's that use or duplicate clock signals.

Avoid stubs on the high-speed USB signals because they cause signal reflections. If a stub is unavoidable, then the stub should be less than 200 mm.

Route all high-speed USB signal traces over continuous planes ( $V_{CC}$  or GND), with no interruptions.

Avoid crossing over anti-etch, commonly found with plane splits.

Due to high frequencies associated with the USB, a printed circuit board with at least four layers is recommended; two signal layers separated by a ground and power layer as shown in [Figure 19](#).



**Figure 19. Four-Layer Board Stack-Up**

The majority of signal traces should run on a single layer, preferably Signal 1. Immediately next to this layer should be the GND plane, which is solid with no cuts. Avoid running signal traces across a split in the ground or power plane. When running across split planes is unavoidable, sufficient decoupling must be used. Minimizing the number of signal vias reduces EMI by reducing inductance at high frequencies. For more information on layout guidelines, see *High Speed Layout Guidelines (SCAA082)* and *USB 2.0 Board Design and Layout Guidelines (SPRAAR7)*.

## 11.2 Layout Example

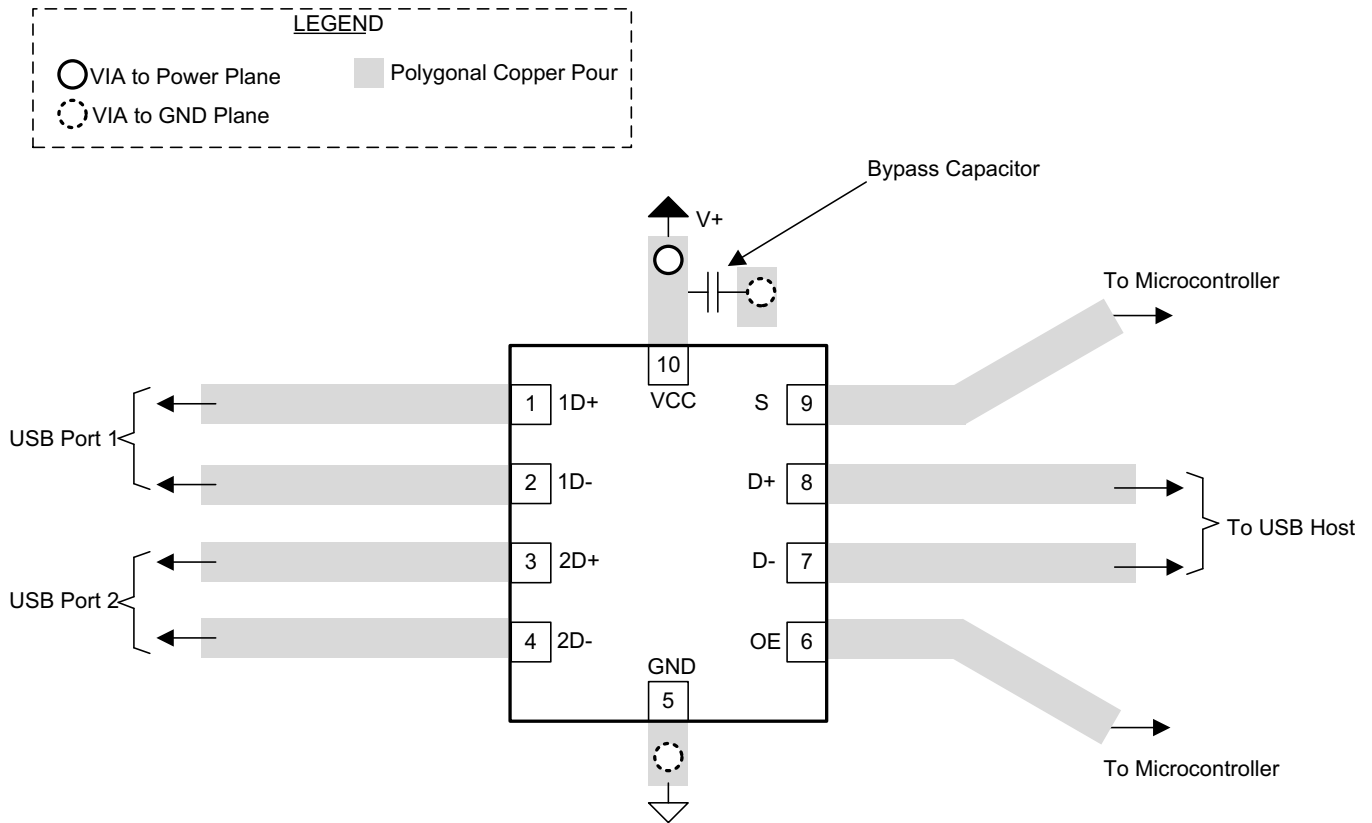


Figure 20. Package Layout Diagram



## 12 Device and Documentation Support

### 12.1 Documentation Support

#### 12.1.1 Related Documentation

For related documentation, see the following:

- *Implications of Slow or Floating CMOS Inputs*, [SCBA004](#)
- *High Speed Layout Guidelines*, [SCAA082](#)
- *USB 2.0 Board Design and Layout Guidelines*, [SPRAAR7](#)

### 12.2 Receiving Notification of Documentation Updates

To receive notification of documentation updates, navigate to the device product folder on ti.com. In the upper right corner, click on *Alert me* to register and receive a weekly digest of any product information that has changed. For change details, review the revision history included in any revised document.

### 12.3 Support Resources

[TI E2E™ support forums](#) are an engineer's go-to source for fast, verified answers and design help — straight from the experts. Search existing answers or ask your own question to get the quick design help you need.

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### 12.4 Trademarks

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All other trademarks are the property of their respective owners.

### 12.5 Electrostatic Discharge Caution



This integrated circuit can be damaged by ESD. Texas Instruments recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

### 12.6 Glossary

[SLYZ022](#) — *TI Glossary*.

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

## 13 Mechanical, Packaging, and Orderable Information

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

**PACKAGING INFORMATION**

| Orderable Device | Status<br>(1) | Package Type | Package Drawing | Pins | Package Qty | Eco Plan<br>(2) | Lead finish/<br>Ball material<br>(6) | MSL Peak Temp<br>(3) | Op Temp (°C) | Device Marking<br>(4/5) | Samples                 |
|------------------|---------------|--------------|-----------------|------|-------------|-----------------|--------------------------------------|----------------------|--------------|-------------------------|-------------------------|
| TS3USB221EDRCR   | ACTIVE        | VSON         | DRC             | 10   | 3000        | RoHS & Green    | NIPDAU                               | Level-2-260C-1 YEAR  | -40 to 85    | ZVM                     | <a href="#">Samples</a> |
| TS3USB221ERSER   | ACTIVE        | UQFN         | RSE             | 10   | 3000        | RoHS & Green    | NIPDAU   NIPDAUAG                    | Level-1-260C-UNLIM   | -40 to 85    | (LGO, LGR, LGV)         | <a href="#">Samples</a> |

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

**ACTIVE:** Product device recommended for new designs.

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

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

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

**OBSOLETE:** TI has discontinued the production of the device.

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

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

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

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

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

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

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

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**TAPE AND REEL INFORMATION**

**QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE**


\*All dimensions are nominal

| Device         | Package Type | Package Drawing | Pins | SPQ  | Reel Diameter (mm) | Reel Width W1 (mm) | A0 (mm) | B0 (mm) | K0 (mm) | P1 (mm) | W (mm) | Pin1 Quadrant |
|----------------|--------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| TS3USB221EDRCR | VSON         | DRC             | 10   | 3000 | 330.0              | 12.4               | 3.3     | 3.3     | 1.1     | 8.0     | 12.0   | Q2            |
| TS3USB221ERSER | UQFN         | RSE             | 10   | 3000 | 180.0              | 9.5                | 1.7     | 2.2     | 0.75    | 4.0     | 8.0    | Q1            |
| TS3USB221ERSER | UQFN         | RSE             | 10   | 3000 | 180.0              | 8.4                | 1.68    | 2.13    | 0.76    | 4.0     | 8.0    | Q1            |

**TAPE AND REEL BOX DIMENSIONS**


\*All dimensions are nominal

| Device         | Package Type | Package Drawing | Pins | SPQ  | Length (mm) | Width (mm) | Height (mm) |
|----------------|--------------|-----------------|------|------|-------------|------------|-------------|
| TS3USB221EDRCR | VSON         | DRC             | 10   | 3000 | 356.0       | 356.0      | 35.0        |
| TS3USB221ERSER | UQFN         | RSE             | 10   | 3000 | 189.0       | 185.0      | 36.0        |
| TS3USB221ERSER | UQFN         | RSE             | 10   | 3000 | 202.0       | 201.0      | 28.0        |

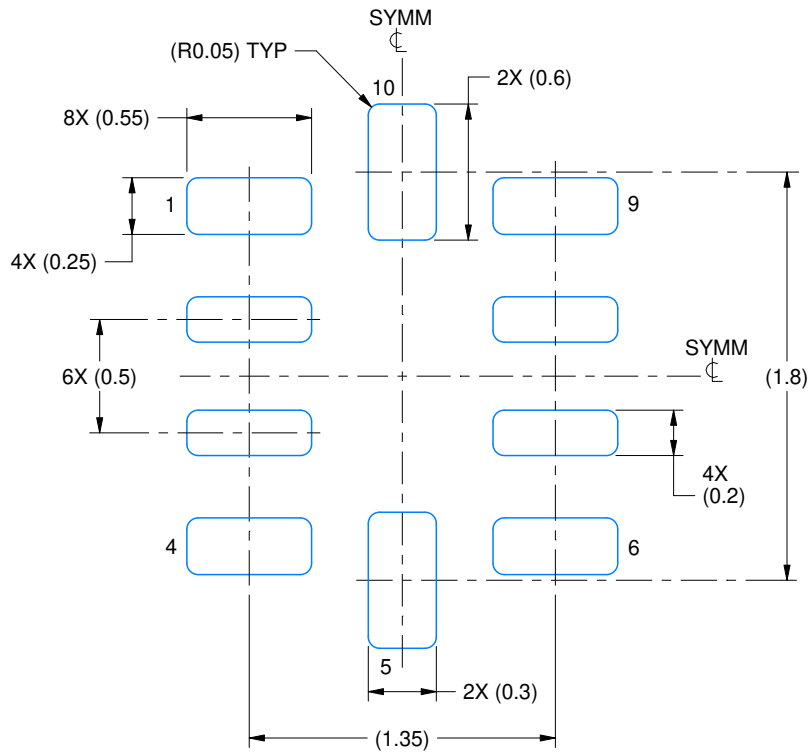


# EXAMPLE BOARD LAYOUT

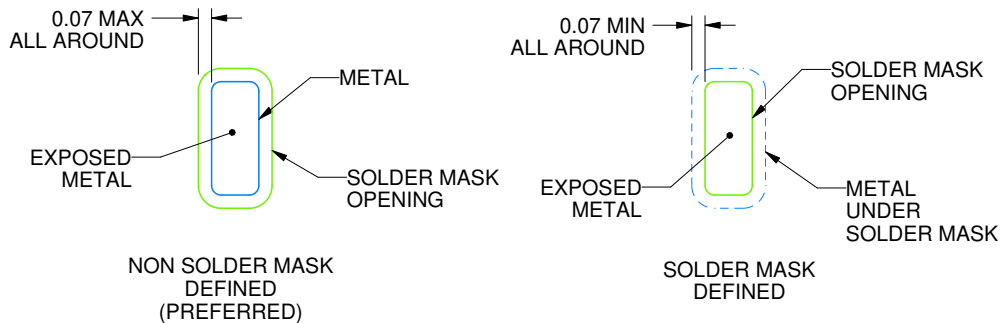
RSE0010A

UQFN - 0.6 mm max height

PLASTIC QUAD FLATPACK - NO LEAD



LAND PATTERN EXAMPLE  
EXPOSED METAL SHOWN  
SCALE:30X



SOLDER MASK DETAILS  
NOT TO SCALE

4220307/A 03/2020

NOTES: (continued)

3. For more information, see Texas Instruments literature number SLUA271 ([www.ti.com/lit/slua271](http://www.ti.com/lit/slua271)).





## GENERIC PACKAGE VIEW

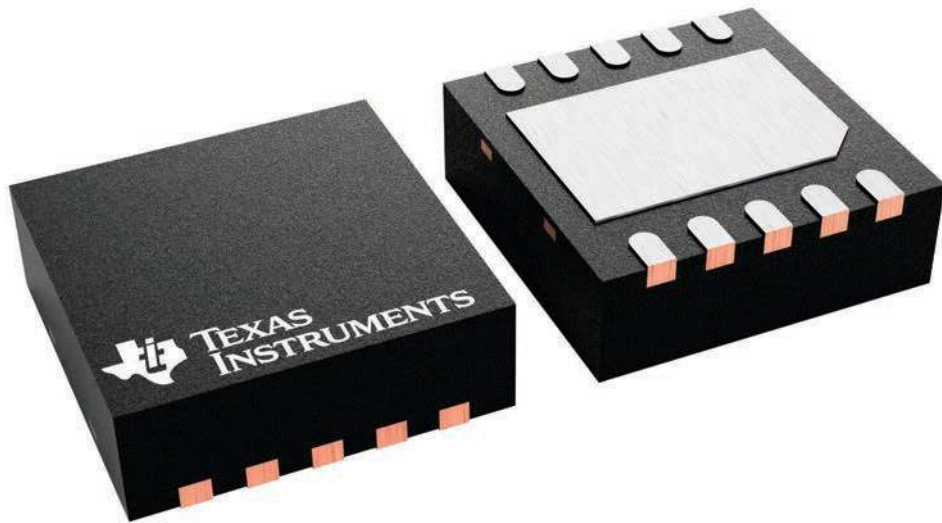
**DRC 10**

**VSON - 1 mm max height**

3 x 3, 0.5 mm pitch

PLASTIC SMALL OUTLINE - NO LEAD

This image is a representation of the package family, actual package may vary.  
Refer to the product data sheet for package details.



4226193/A

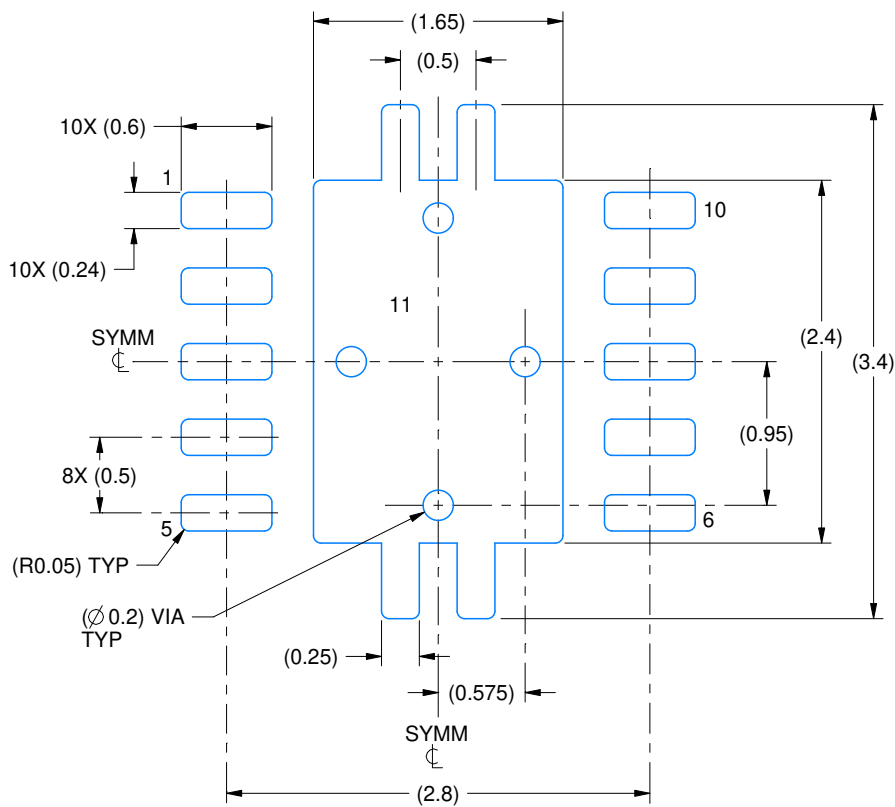


# EXAMPLE BOARD LAYOUT

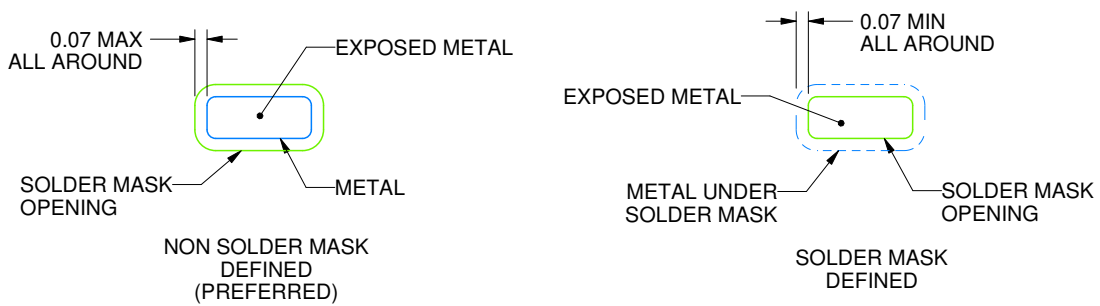
DRC0010J

VSON - 1 mm max height

PLASTIC SMALL OUTLINE - NO LEAD



LAND PATTERN EXAMPLE  
EXPOSED METAL SHOWN  
SCALE:20X



SOLDER MASK DETAILS

4218878/B 07/2018

NOTES: (continued)

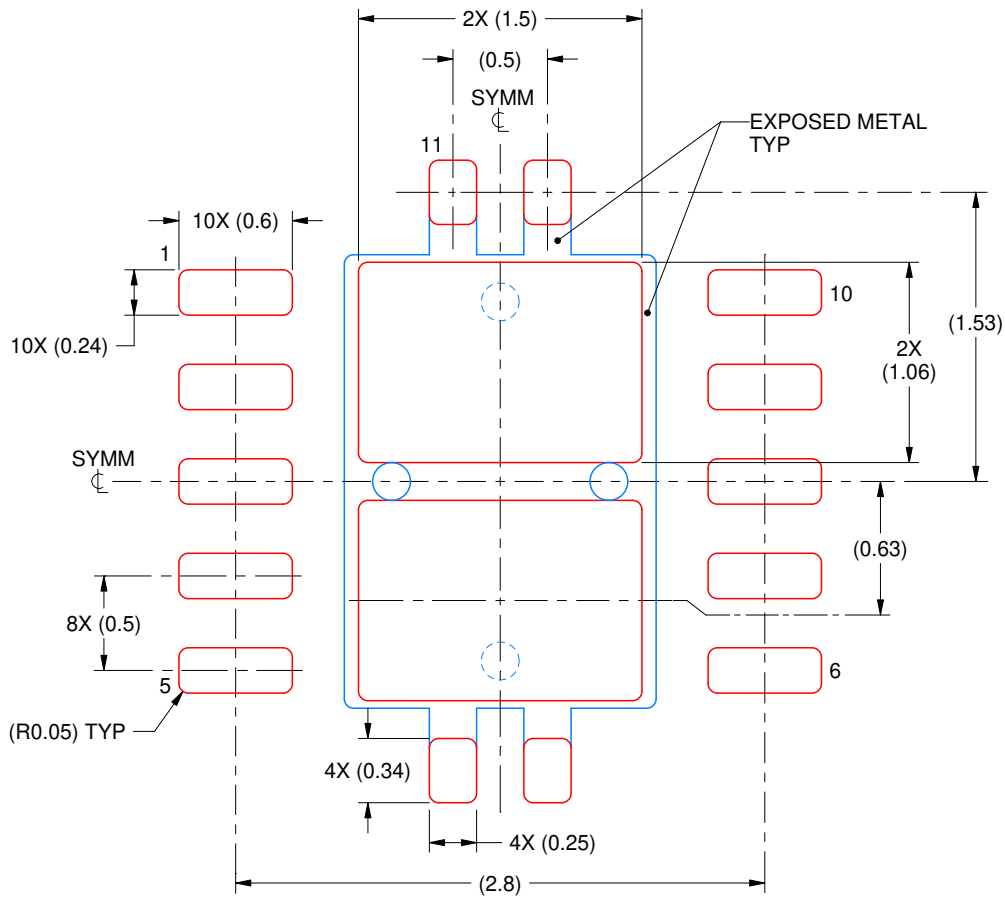
4. This package is designed to be soldered to a thermal pad on the board. For more information, see Texas Instruments literature number SLUA271 ([www.ti.com/lit/sluea271](http://www.ti.com/lit/sluea271)).
5. Vias are optional depending on application, refer to device data sheet. If any vias are implemented, refer to their locations shown on this view. It is recommended that vias under paste be filled, plugged or tented.

# EXAMPLE STENCIL DESIGN

DRC0010J

VSON - 1 mm max height

PLASTIC SMALL OUTLINE - NO LEAD



SOLDER PASTE EXAMPLE  
BASED ON 0.125 mm THICK STENCIL

EXPOSED PAD 11:  
80% PRINTED SOLDER COVERAGE BY AREA  
SCALE:25X

4218878/B 07/2018

NOTES: (continued)

6. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.

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