

## ESD PROTECTED, HIGH-SPEED USB 2.0 (480-Mbps) 1:2 MULTIPLEXER/DEMULTIPLEXER SWITCH WITH SINGLE ENABLE

### FEATURES

- $V_{CC}$  Operation at 2.5 V to 3.3 V
- $V_{IO}$  Accepts 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
- $\Delta r_{ON} = 0.2 \Omega$  Typical
- $C_{io(on)} = 6$  pF Typical
- Low Power Consumption (30  $\mu$ A Maximum)
- High Bandwidth (900 MHz Typical)
- Latch-Up Performance Exceeds 100 mA Per JESD 78, Class II
- 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 to GND
  - 12-kV Human-Body Model

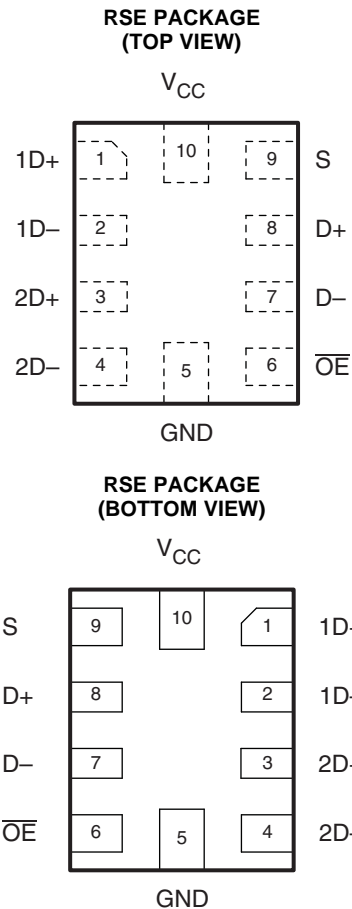
### APPLICATIONS

- Routes Signals for USB 1.0, 1.1, and 2.0

### DESCRIPTION

The TS3USB221A 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 (900 MHz) 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. It 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 TS3USB221A integrates ESD protection cells on all pins, is available in a tiny  $\mu$ QFN package (2.0 mm  $\times$  1.5 mm) and is characterized over the free air temperature range from  $-40^{\circ}\text{C}$  to  $85^{\circ}\text{C}$ .



Please be aware that an important notice concerning availability, standard warranty, and use in critical applications of Texas Instruments semiconductor products and disclaimers thereto appears at the end of this data sheet.

**ORDERING INFORMATION**

T <sub>A</sub>	PACKAGE <sup>(1)(2)</sup>		ORDERABLE PART NUMBER	TOP-SIDE MARKING
–40°C to 85°C	QFN – RSE	Reel of 3000	TS3USB221ARSER	LHR

- (1) Package drawings, thermal data, and symbolization are available at [www.ti.com/packaging](http://www.ti.com/packaging).
- (2) For the most current package and ordering information, see the Package Option Addendum at the end of this document, or see the TI website at [www.ti.com](http://www.ti.com).

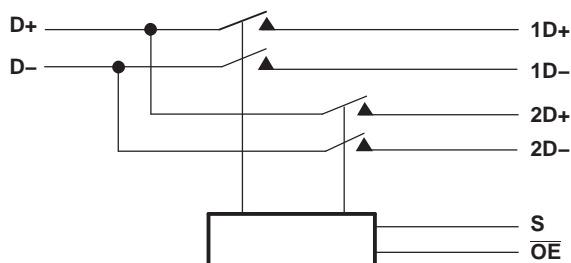
**PIN DESCRIPTION**

NAME	DESCRIPTION
$\overline{OE}$	Bus-switch enable
S	Select input
D	Bus A
nD	Bus B

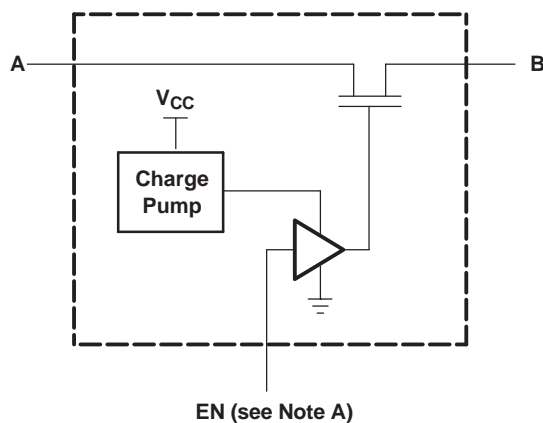
**TRUTH TABLE**

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

**BLOCK DIAGRAM**



**SIMPLIFIED SCHEMATIC, EACH FET SWITCH (SW)**



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

## ABSOLUTE MAXIMUM RATINGS<sup>(1)</sup>

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

			MIN	MAX	UNIT
$V_{CC}$	Supply voltage range		-0.5	4.6	V
$V_{IN}$	Control input voltage range <sup>(2)(3)</sup>		-0.5	7	V
$V_{I/O}$	Switch I/O voltage range <sup>(2)(3)(4)</sup>		-0.5	7	V
$I_{IK}$	Control input clamp current	$V_{IN} < 0$		-50	mA
$I_{I/OK}$	I/O port clamp current	$V_{I/O} < 0$		-50	mA
$I_{I/O}$	ON-state switch current <sup>(5)</sup>			±120	mA
	Continuous current through $V_{CC}$ or GND			±100	mA
$T_{stg}$	Storage temperature range		-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)  $V_I$  and  $V_O$  are used to denote specific conditions for  $V_{I/O}$ .

(5)  $I_I$  and  $I_O$  are used to denote specific conditions for  $I_{I/O}$ .

## PACKAGE THERMAL IMPEDANCE

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

				UNIT
$\theta_{JA}$	Package thermal impedance <sup>(1)</sup>	RSE package	243	°C/W

(1) The package thermal impedance is calculated in accordance with JESD 51-7.

## RECOMMENDED OPERATING CONDITIONS

			MIN	MAX	UNIT
$V_{CC}$	Supply voltage		2.3	3.6	V
$V_{IH}$	High-level control input voltage	$V_{CC} = 2.3 \text{ V to } 2.7 \text{ V}$	$0.46 \times V_{CC}$		V
		$V_{CC} = 2.7 \text{ V to } 3.6 \text{ V}$	$0.46 \times V_{CC}$		
$V_{IL}$	Low-level control input voltage	$V_{CC} = 2.3 \text{ V to } 2.7 \text{ V}$		$0.25 \times V_{CC}$	V
		$V_{CC} = 2.7 \text{ V to } 3.6 \text{ V}$		$0.25 \times V_{CC}$	
$V_{I/O}$	Data input/output voltage		0	5.5	V
$T_A$	Operating free-air temperature		-40	85	°C

**ELECTRICAL CHARACTERISTICS<sup>(1)</sup>**

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

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	
ΔI <sub>CC</sub> <sup>(4)</sup>		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> = V <sub>CC</sub> 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> = V <sub>CC</sub> 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> = V <sub>CC</sub> 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.

**DYNAMIC ELECTRICAL CHARACTERISTICS**over operating range, T<sub>A</sub> = -40°C to 85°C, V<sub>CC</sub> = 3.3 V ±10%, GND = 0 V

PARAMETER		TEST CONDITIONS	TYP	UNIT
X <sub>TALK</sub>	Crosstalk	R <sub>L</sub> = 50 , f = 250 MHz	-40	dB
O <sub>IRR</sub>	OFF isolation	R <sub>L</sub> = 50 , f = 250 MHz	-41	dB
BW	Bandwidth (-3 dB)	R <sub>L</sub> = 50	0.9	GHz

## DYNAMIC ELECTRICAL CHARACTERISTICS

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

PARAMETER		TEST CONDITIONS	TYP	UNIT
$X_{\text{TALK}}$	Crosstalk	$R_L = 50$ , $f = 250\text{ MHz}$	-39	dB
$O_{\text{IRR}}$	OFF isolation	$R_L = 50$ , $f = 250\text{ MHz}$	-40	dB
BW	Bandwidth (3 dB)	$R_L = 50$	0.9	GHz

## SWITCHING CHARACTERISTICS

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

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

(1) For Max or Min 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. Since 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.

## SWITCHING CHARACTERISTICS

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

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

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APPLICATION INFORMATION

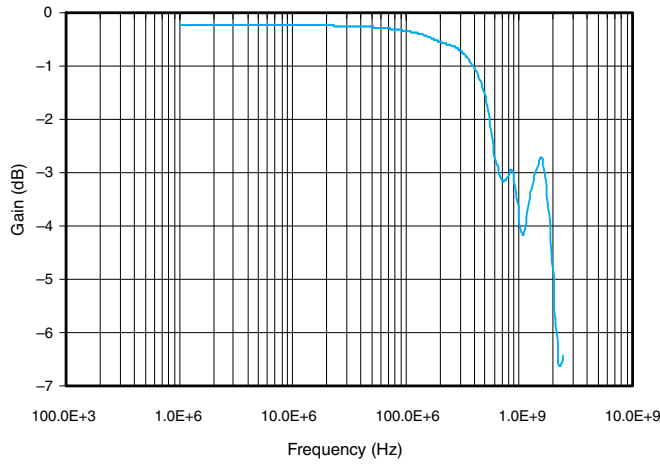


Figure 1. Gain vs Frequency

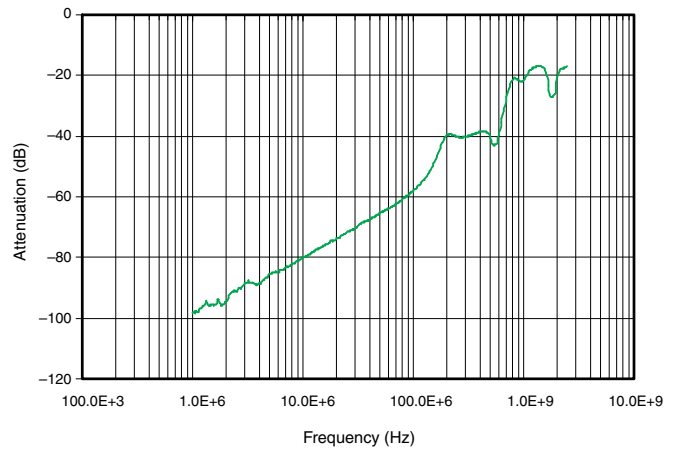


Figure 2. OFF Isolation vs Frequency

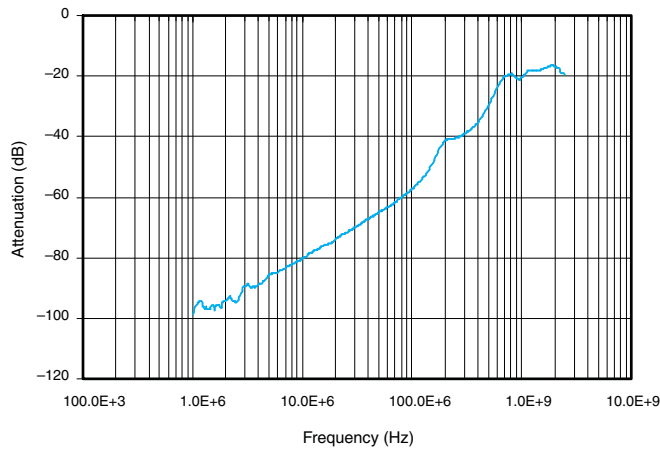


Figure 3. Crosstalk vs Frequency

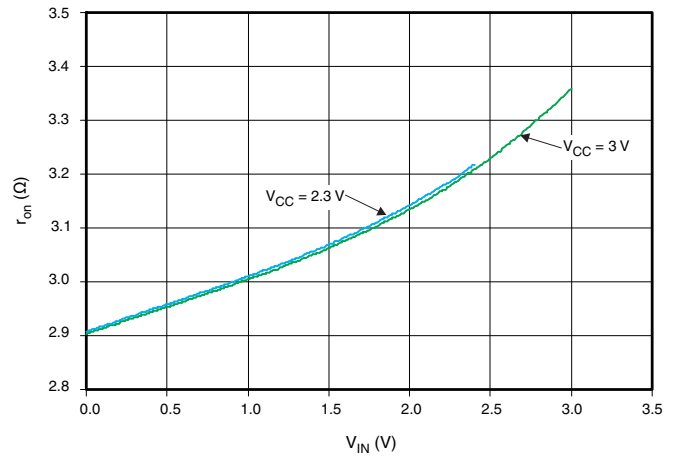


Figure 4.  $r_{on}$  vs  $V_{IN}$  ( $I_{OUT} = -15$  mA)

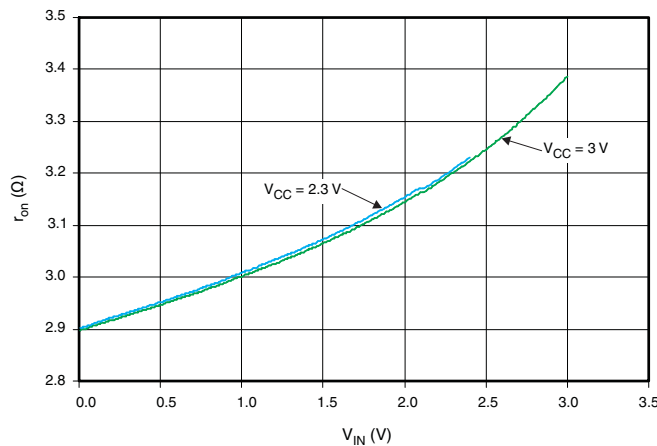


Figure 5.  $r_{on}$  vs  $V_{IN}$  ( $I_{OUT} = 30$  mA)

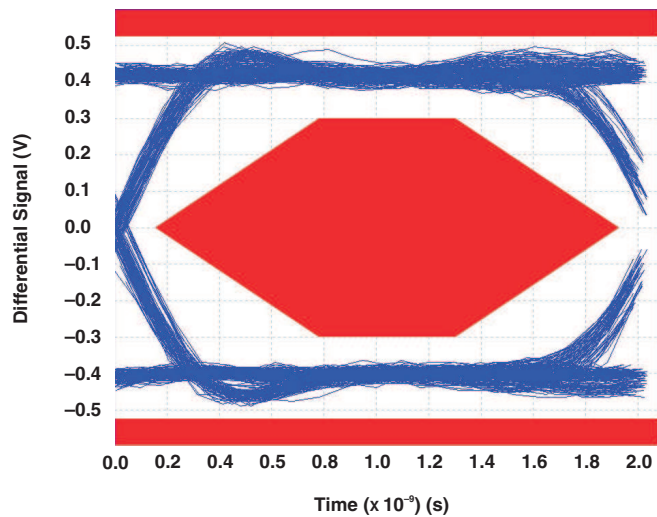


Figure 6. Eye Pattern: 480-Mbps USB Signal With No Switch (Through Path)

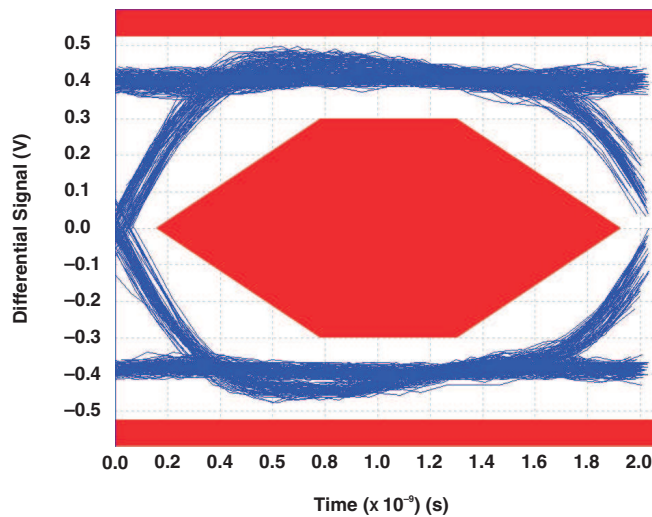


Figure 7. Eye Pattern: 480-Mbps USB Signal With Switch NC Path

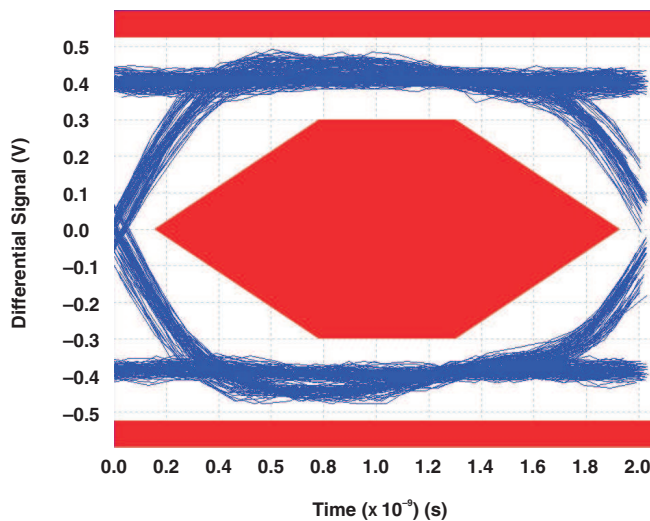
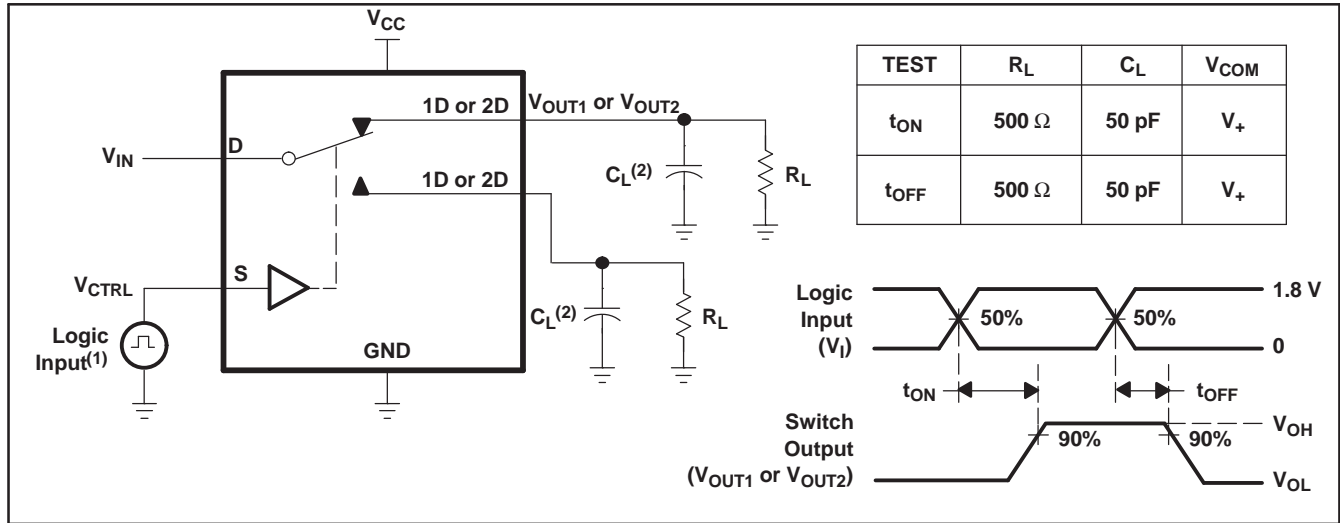


Figure 8. Eye Pattern: 480-Mbps USB Signal With Switch NO Path

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 9. Turn-On (t<sub>ON</sub>) and Turn-Off Time (t<sub>OFF</sub>)

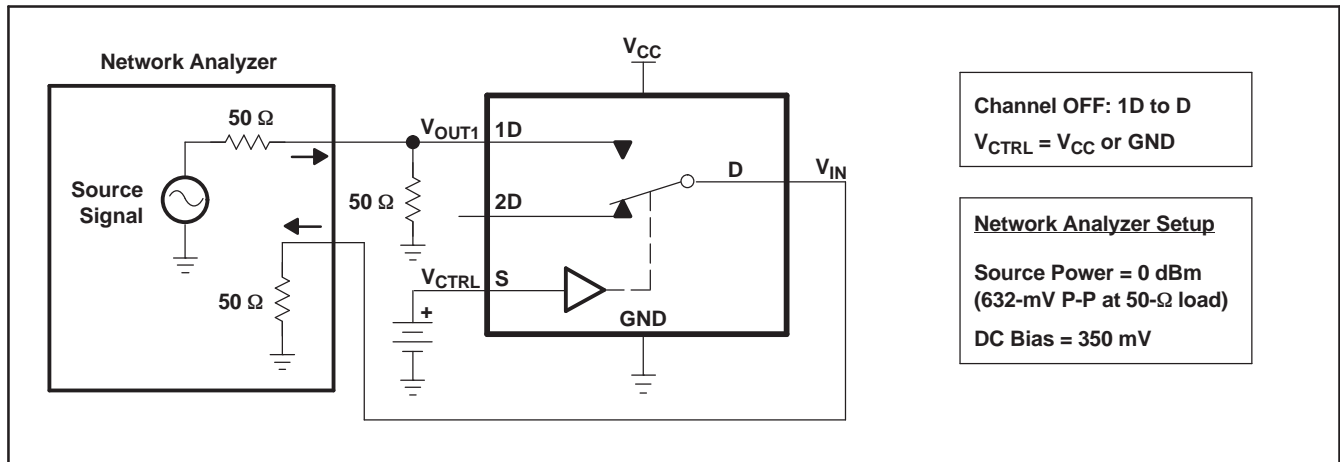


Figure 10. OFF Isolation (O<sub>ISO</sub>)



PARAMETER MEASUREMENT INFORMATION (continued)

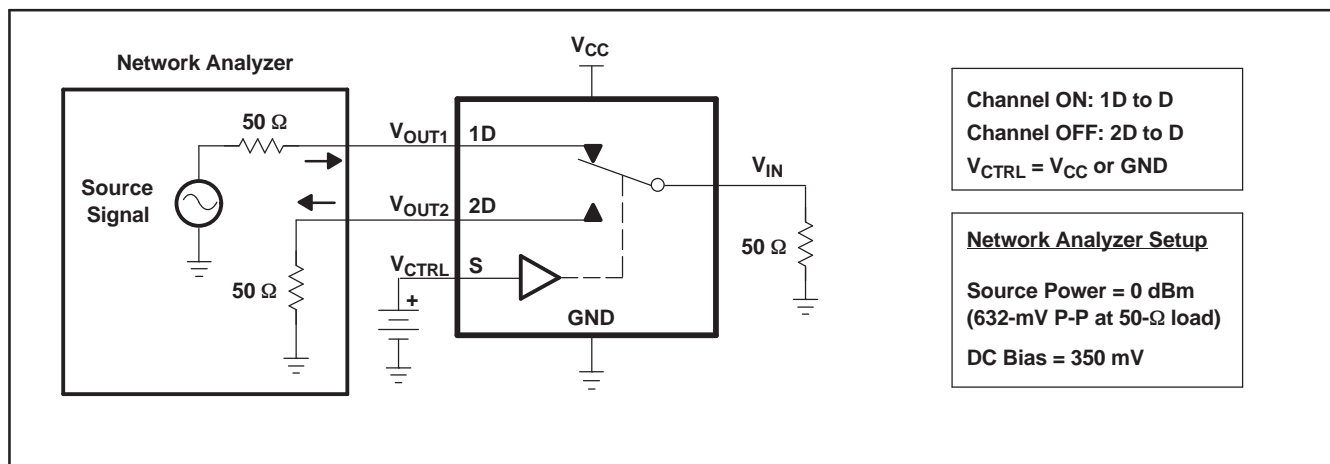


Figure 11. Crosstalk ( $X_{TALK}$ )

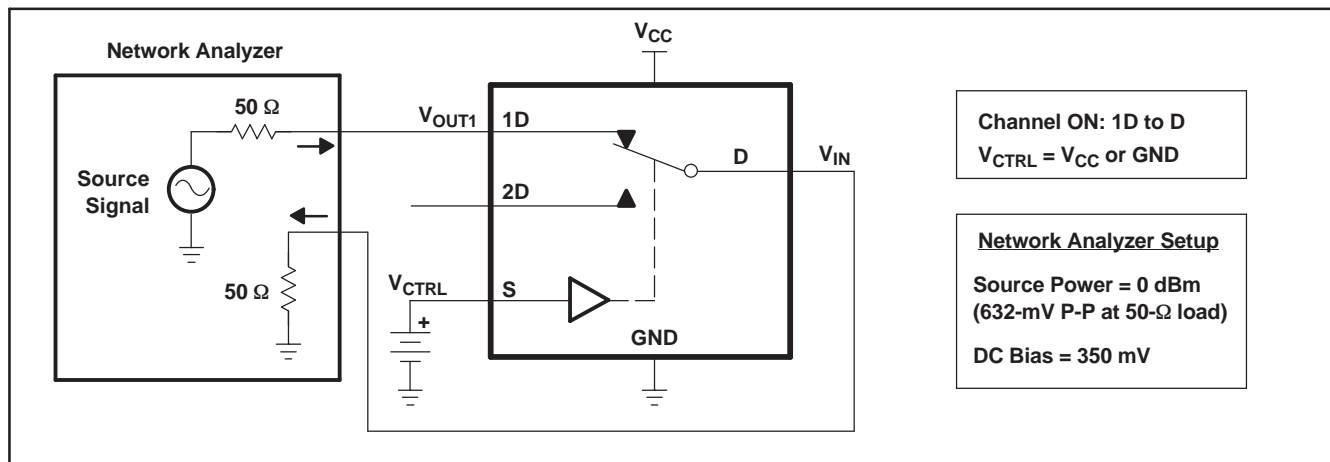


Figure 12. Bandwidth (BW)

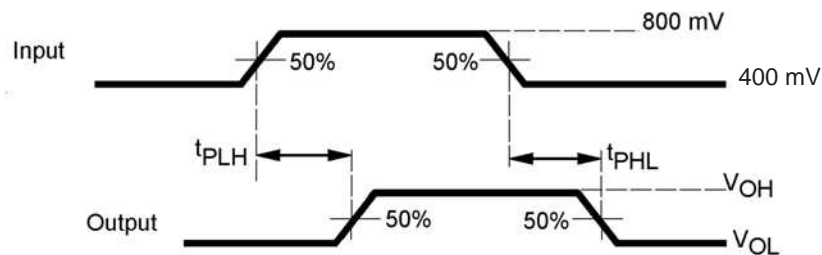


Figure 13. Propagation Delay

PARAMETER MEASUREMENT INFORMATION (continued)

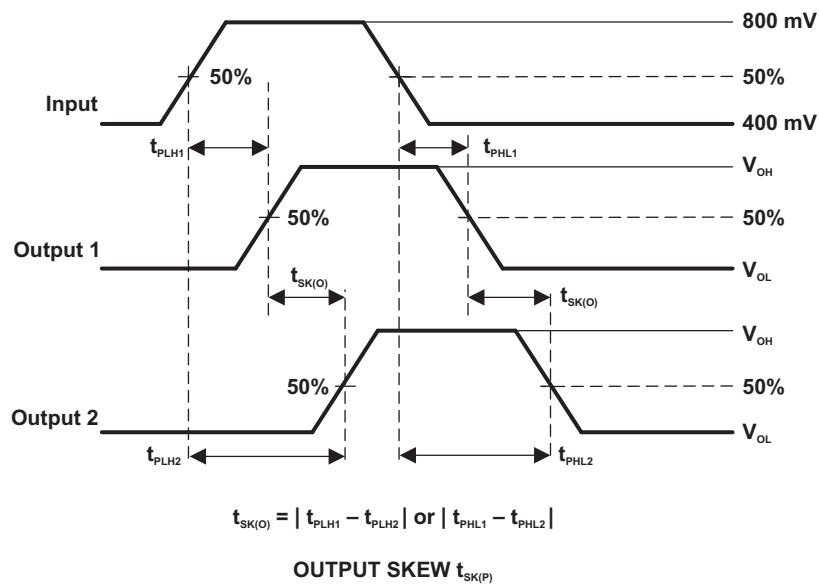
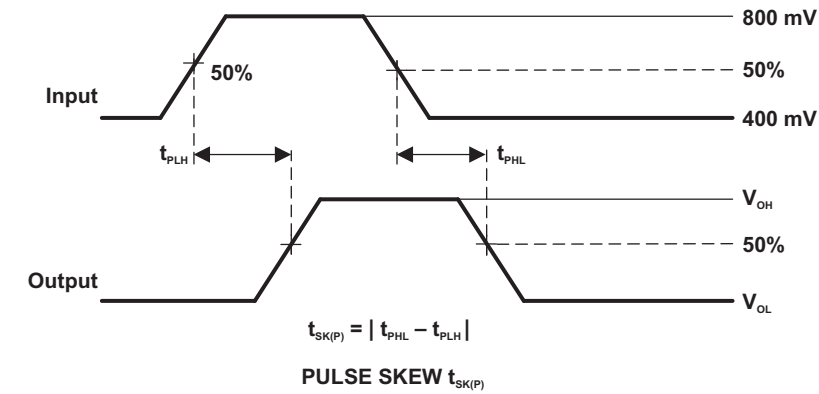


Figure 14. Skew Test

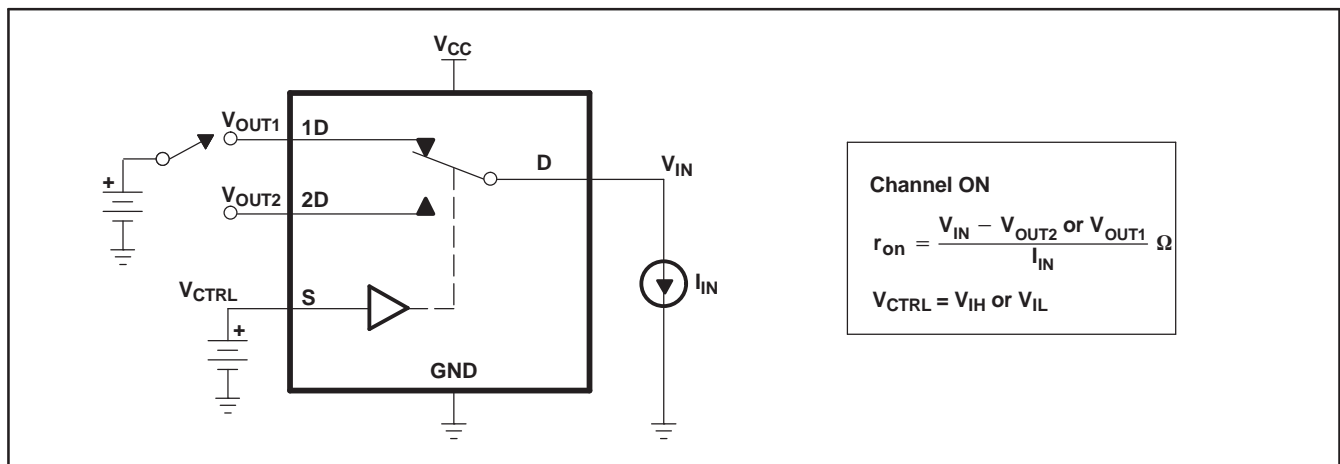


Figure 15. ON-State Resistance ( $r_{on}$ )

PARAMETER MEASUREMENT INFORMATION (continued)

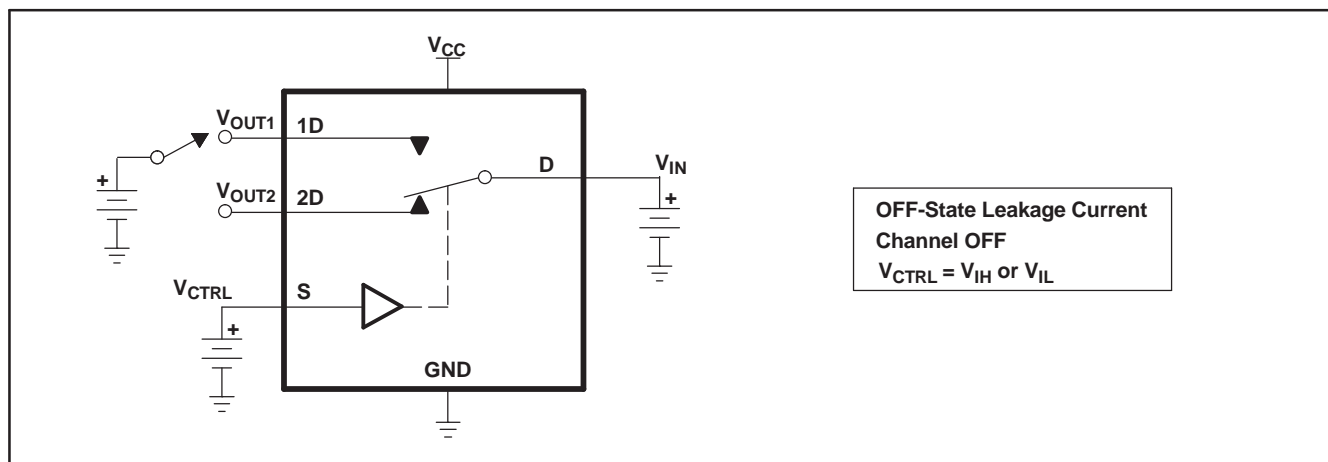


Figure 16. OFF-State Leakage Current

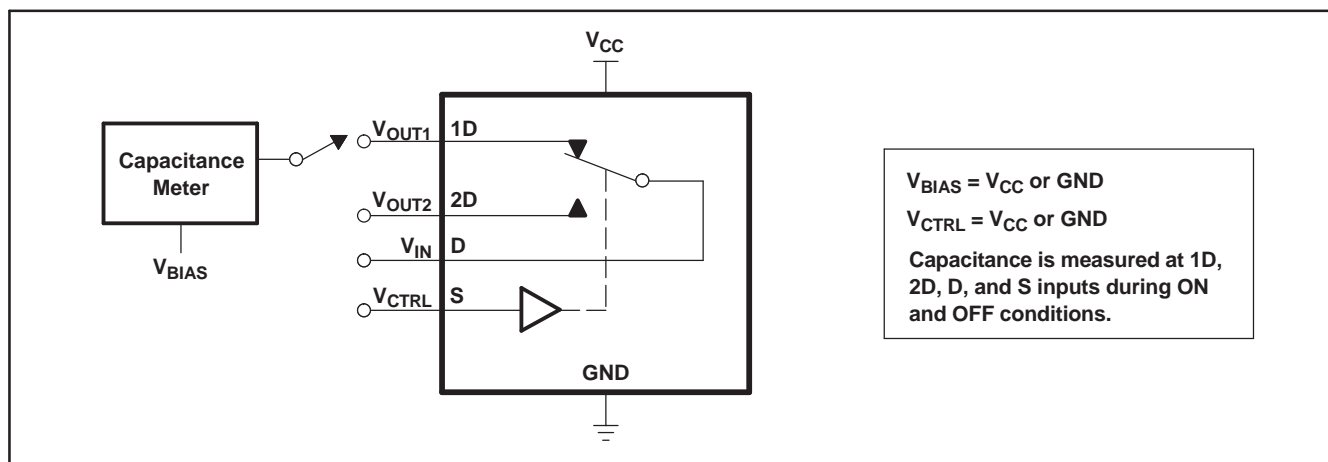


Figure 17. Capacitance

**PACKAGING INFORMATION**

Orderable Device	Status <sup>(1)</sup>	Package Type	Package Drawing	Pins	Package Qty	Eco Plan <sup>(2)</sup>	Lead/Ball Finish	MSL Peak Temp <sup>(3)</sup>
TS3USB221ARSER	ACTIVE	QFN	RSE	10	3000	Green (RoHS & no Sb/Br)	Cu NIPDAU	Level-1-260C-UNLIM
TS3USB221ARSERG4	ACTIVE	QFN	RSE	10	3000	Green (RoHS & no Sb/Br)	Cu NIPDAU	Level-1-260C-UNLIM

<sup>(1)</sup> The marketing status values are defined as follows:

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

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

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

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

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

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

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

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

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

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

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

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**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
TS3USB221ARSER	QFN	RSE	10	3000	180.0	8.4	1.68	2.13	0.76	4.0	8.0	Q1

**TAPE AND REEL BOX DIMENSIONS**

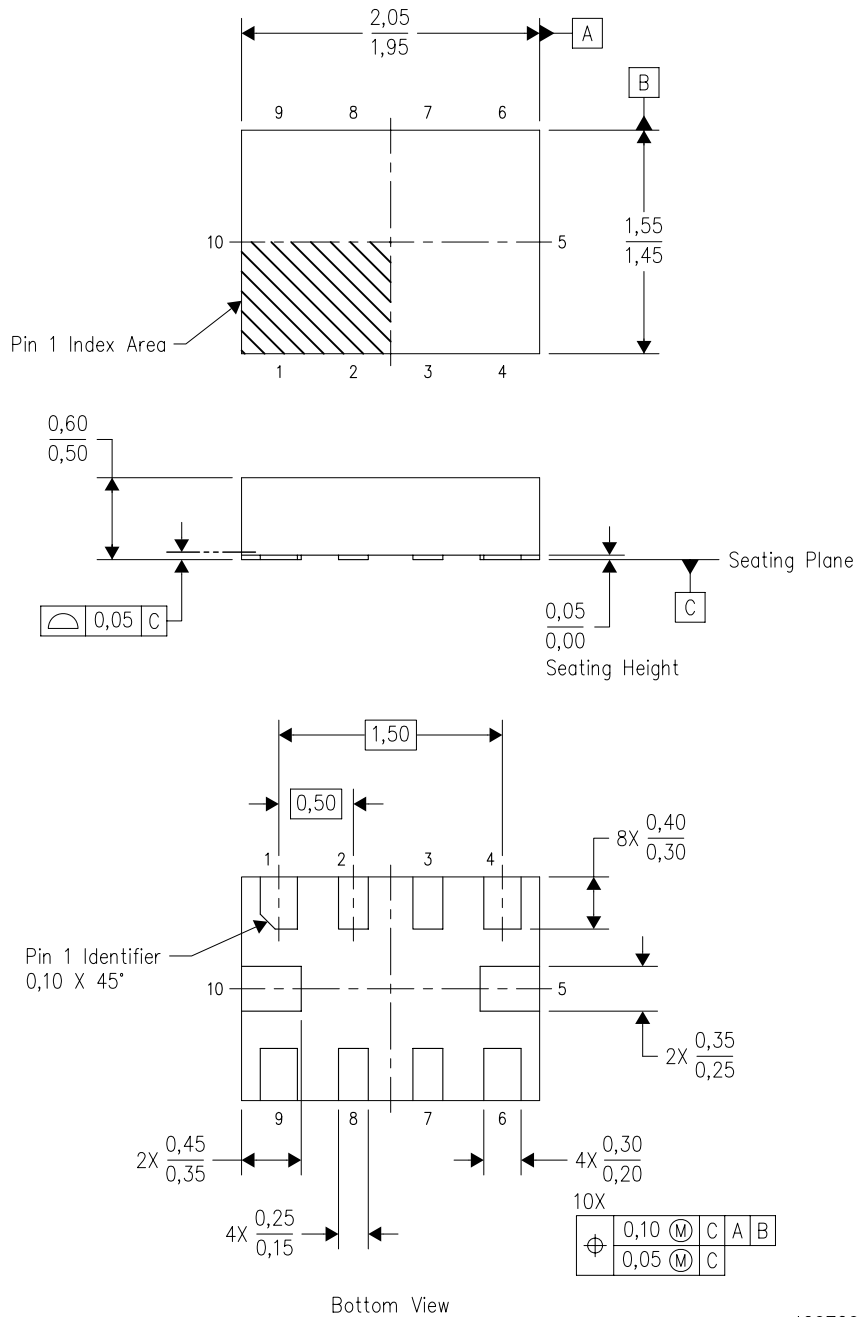


\*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
TS3USB221ARSER	QFN	RSE	10	3000	202.0	201.0	28.0

RSE (R-PQFP-N10)

PLASTIC QUAD FLATPACK



4207268-3/C 01/2008

- NOTES:
- A. All linear dimensions are in millimeters. Dimensioning and tolerancing per ASME Y14.5M-1994.
  - B. This drawing is subject to change without notice.
  - C. QFN (Quad Flatpack No-Lead) package configuration.
  - D. This package complies to JEDEC MO-288 variation UDFD.

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