

## 4-CHANNEL 8:16 MULTIPLEXER/DEMULTIPLEXER PCI EXPRESS SWITCH

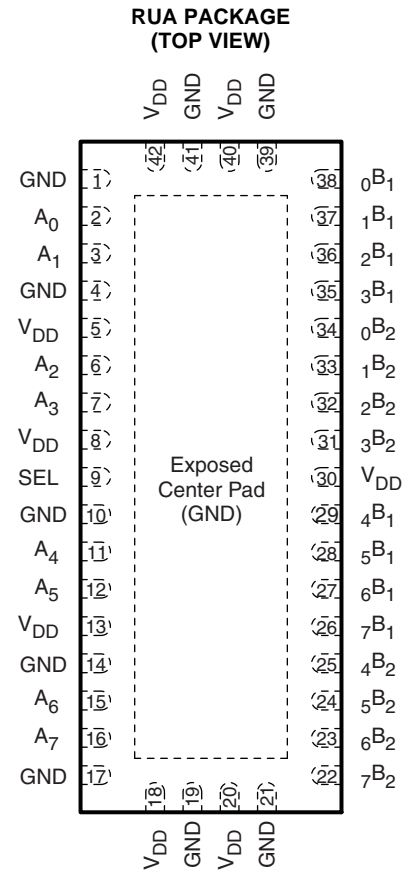
 Check for Samples: [TS2PCIE412](#)

### FEATURES

- Compatible With PCI Express (PCIe) Standard
- Wide Bandwidth of over 3 Gbps
- Low Crosstalk ( $X_{TALK} = -32$  dB Typ at 1.25 GHz)
- $O_{IRR} = -36.3$  dB Typical at 1.25 GHz
- Low Bit-to-Bit Skew ( $t_{sk(O)} = 0.06$  ns Typical)
- $V_{DD}$  Operating Range: 1.5 V to 2 V
- $I_{off}$  Supports Partial Power-Down Mode Operation
- Latch-Up Performance Exceeds 100 mA Per JESD 78, Class II
- ESD Performance Tested Per JESD 22
  - 2000-V Human-Body Model (A114-B, Class II)
  - 1000-V Charged-Device Model (C101)

### APPLICATIONS

- PCIe Bus Multiplexing and Expansion
- Routing PCI Express Data and/or Display Port Signals
- Notebook PCs
- Desktop PCs
- Servers/Storage Area Networks



If the exposed center pad is used, it must be connected to ground.

### DESCRIPTION/ ORDERING INFORMATION

The TS2PCIE412 is a 4-channel PCIe 2:1 multiplexer/demultiplexer switch that can be used to route one PCIe data lane between two possible destinations or two PCIe data lanes to one destination. Each channel consists of differential pairs of receive (RX) and transmit (TX) signals and operates at a signal-processing bandwidth speed, which supports the PCIe standard of 2.5 Gbps. The device is controlled with one select input (SEL) pin, where SEL controls the data path of the multiplexer/demultiplexer and can be connected to any GPIO in the system. The unselected channel is set in a high-impedance state.

#### ORDERING INFORMATION

$T_A$	PACKAGE <sup>(1)</sup> (2)		ORDERABLE PART NUMBER	TOP-SIDE MARKING
-40°C to 85°C	QFN – RUA	Tape and reel	TS2PCIE412RUAR	SH412

(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).



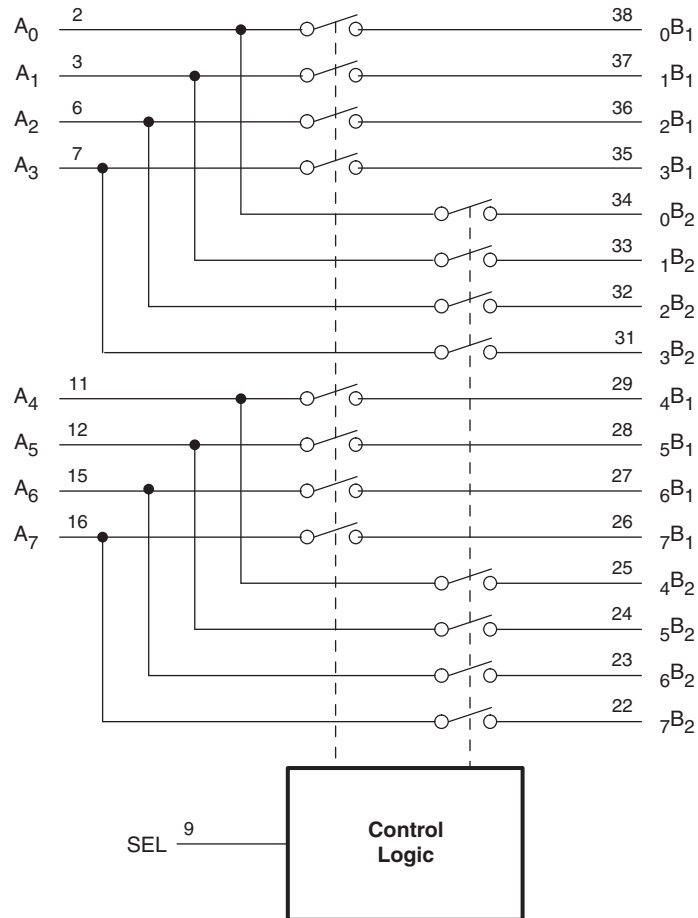
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**FUNCTION TABLE**

SEL	FUNCTION
L	$A_n$ to ${}_nB_1$
H	$A_n$ to ${}_nB_2$

**FUNCTIONAL DIAGRAM**



**TERMINAL FUNCTIONS**

TERMINAL		I/O	DESCRIPTION
NAME	NO.		
$A_n$	2, 3, 6, 7, 11, 12, 15, 16	I/O	Data I/Os
${}_nB_m$	22–29, 31–38	I/O	Data I/Os
SEL	9	I	Select input
$V_{DD}$	5, 8, 13, 18, 20, 30, 40, 42	–	Power supply
GND	1, 4, 10, 14, 17, 19, 21, 39, 41, Exposed center pad	–	Ground

## ABSOLUTE MAXIMUM RATINGS<sup>(1) (2)</sup>

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

		MIN	MAX	UNIT
$V_{DD}$	Supply voltage range	-0.5	2.5	V
$V_{IN}$	Control input voltage range <sup>(2) (3)</sup>	-0.5	2.5	V
$V_{I/O}$	Switch I/O voltage range <sup>(2) (3) (4)</sup>	-0.5	2.5	V
$I_{IK}$	Control input clamp current		$V_{IN} < GND$	-50 mA
$I_{I/OK}$	I/O port clamp current		$V_{I/O} < GND$	-50 mA
$I_{I/O}$	ON-state switch current <sup>(5)</sup>		100	mA
$I_{DD}$	Continuous current through $V_{DD}$		100	mA
$I_{GND}$	Continuous current through 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 GND unless otherwise specified.
- (3) The input voltage and output negative-voltage ratings may be exceeded if the input and output 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>	RUA package	51.2 °C/W

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

## RECOMMENDED OPERATING CONDITIONS

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

		MIN	TYP	MAX	UNIT
$V_{DD}$	Supply voltage	1.5	1.8	2	V
$V_{IH}$	High-level control input voltage (SEL)	$0.65 \times V_{DD}$			V
$V_{IL}$	Low-level control input voltage (SEL)	$0.35 \times V_{DD}$			V
$V_{IO}$	Switch input/output voltage	0		$V_{DD}$	V
$T_A$	Operating free air temperature	0		85	°C

## ELECTRICAL CHARACTERISTICS FOR 1.8-V SUPPLY<sup>(1)</sup>

$V_{DD} = 1.5 \text{ V to } 2.0 \text{ V}$ ,  $T_A = -40^\circ\text{C to } 85^\circ\text{C}$  (unless otherwise noted)

PARAMETER		TEST CONDITIONS		MIN	TYP <sup>(2)</sup>	MAX	UNIT
$V_{IK}$	SEL	$V_{DD} = 2.0 \text{ V}$ ,	$I_{IN} = -18 \text{ mA}$		-0.7	-1.3	V
$I_{IH}$	SEL	$V_{DD} = 2.0 \text{ V}$ ,	$V_{IN} = V_{DD}$			$\pm 1$	$\mu\text{A}$
$I_{IL}$	SEL	$V_{DD} = 2.0 \text{ V}$ ,	$V_{IN} = \text{GND}$			$\pm 1$	$\mu\text{A}$
$I_{off}$		$V_{DD} = 0$ ,	$V_O = 0 \text{ to } 2 \text{ V}$ ,	$V_I = 0$		1	$\mu\text{A}$
$I_{CC}$		$V_{DD} = 2.0 \text{ V}$ ,	$I_{I/O} = 0$ ,	Switch ON or OFF	200	400	$\mu\text{A}$
$C_{IN}$	SEL	$f = 10 \text{ MHz}$ , $V_{IN} = 0 \text{ V}$			1		pF
$C_{OFF}$	B port	$V_I = 0 \text{ V}$ , $f = 10 \text{ MHz}$ ,	Outputs open,	Switch OFF	1.5	1.5	pF
$C_{ON}$		$V_I = 0 \text{ V}$ , $f = 10 \text{ MHz}$ ,	Outputs open,	Switch ON	4.5	4.5	pF
$r_{ON}$		$V_{DD} = 1.8 \text{ V}$ ,	$\text{GND} \leq V_I \leq V_{DD}$ ,	$I_O = -40 \text{ mA}$	12	18	$\Omega$
$r_{ON(\text{flat})}$ <sup>(3)</sup>		$V_{DD} = 1.8 \text{ V}$ ,	$V_I = 1.65 \text{ to } 1.8 \text{ V}$ ,	$I_O = -40 \text{ mA}$	0.5		$\Omega$
$\Delta r_{ON}$ <sup>(4)</sup>		$V_{DD} = 1.8 \text{ V}$ ,	$\text{GND} \leq V_I \leq V_{DD}$ ,	$I_O = -40 \text{ mA}$	0.2	0.8	$\Omega$
<b>Dynamic</b>							
$X_{TALK}$	$R_L = 100 \Omega$ , $f = 10 \text{ MHz}$		See Figure 9		-81		dB
	$R_L = 100 \Omega$ , $f = 1.25 \text{ GHz}$				-32		
$O_{IRR}$	$R_L = 100 \Omega$ , $f = 10 \text{ MHz}$		See Figure 10		-74		dB
	$R_L = 100 \Omega$ , $f = 1.25 \text{ GHz}$				-36		
BW		$R_L = 50 \Omega$ ,	See Figure 8		2.1		GHz
Max data rate		$R_L = 50 \Omega$ ,	See Figure 8		4.2		Gbps

- (1)  $V_I$ ,  $V_O$ ,  $I_I$ , and  $I_O$  refer to I/O pins.  $V_{IN}$  refers to the control inputs.  
(2) All typical values are at  $V_{DD} = 1.8 \text{ V}$  (unless otherwise noted),  $T_A = 25^\circ\text{C}$ .  
(3)  $r_{ON(\text{flat})}$  is the difference of  $r_{ON}$  in a given channel at specific voltages.  
(4)  $\Delta r_{ON}$  is the difference of  $r_{ON}$  from center ports to any other port.

## SWITCHING CHARACTERISTICS

over recommended operating free-air temperature range,  $V_{DD} = 1.5 \text{ V to } 2.0 \text{ V}$ ,  $R_L = 200 \Omega$ ,  $C_L = 10 \text{ pF}$   
(unless otherwise noted)

PARAMETER	FROM (INPUT)	TO (OUTPUT)	MIN	TYP <sup>(1)</sup>	MAX	UNIT
$t_{pd}$ <sup>(2) (3)</sup>	$A_n$ or $nB_n$	$nB_n$ or $A_n$		0.28		ns
$t_{PZH}$ , $t_{PZL}$	SEL	$A_n$ or $nB_n$		7.8	9	ns
$t_{PHZ}$ , $t_{PLZ}$	SEL	$A_n$ or $nB_n$		2.5	4	ns
$t_{sk(O)}$ <sup>(4)</sup>	$A_n$ or $nB_n$	$nB_n$ or $A_n$		0.06	0.1	ns
$t_{sk(p)}$ <sup>(5) (6)</sup>				0.06	0.1	ns

- (1) All typical values are at  $V_{DD} = 1.8 \text{ V}$  (unless otherwise noted)  $T_A = 25^\circ\text{C}$ .  
(2) The propagation delay is the calculated RC time constant of the typical ON-state resistance of the switch and the specified load capacitance when driven by an ideal voltage source (zero output impedance).  
(3) See Figure 6  
(4) Output skew between center port to any other port  
(5) Skew between opposite transitions of the same output in a given device  $t_{PHL} - t_{PLH}$   
(6) See Figure 7

TYPICAL PERFORMANCE

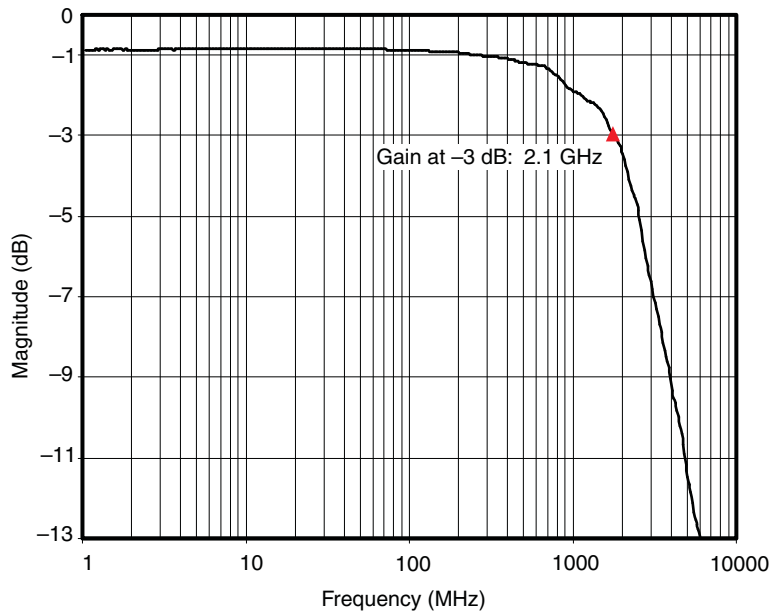


Figure 1. Frequency Response (Insertion Loss)

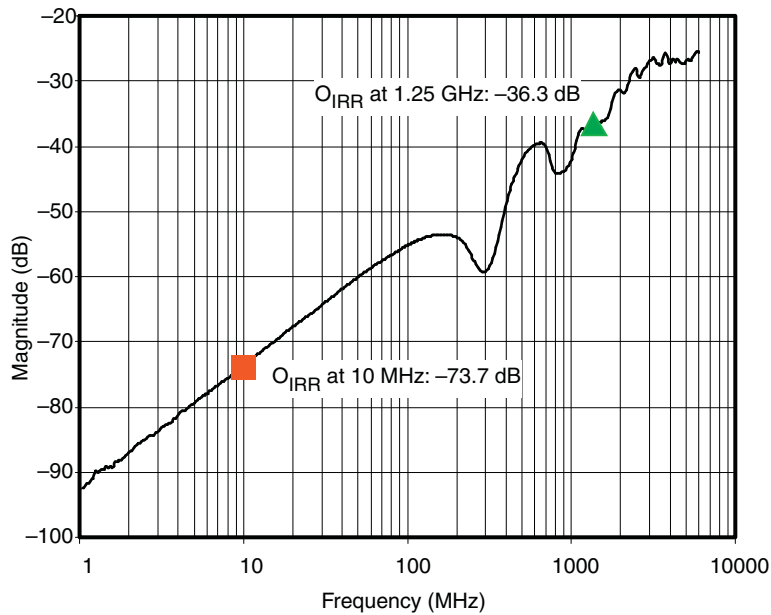


Figure 2. OFF Isolation vs Frequency

**TYPICAL PERFORMANCE (continued)**

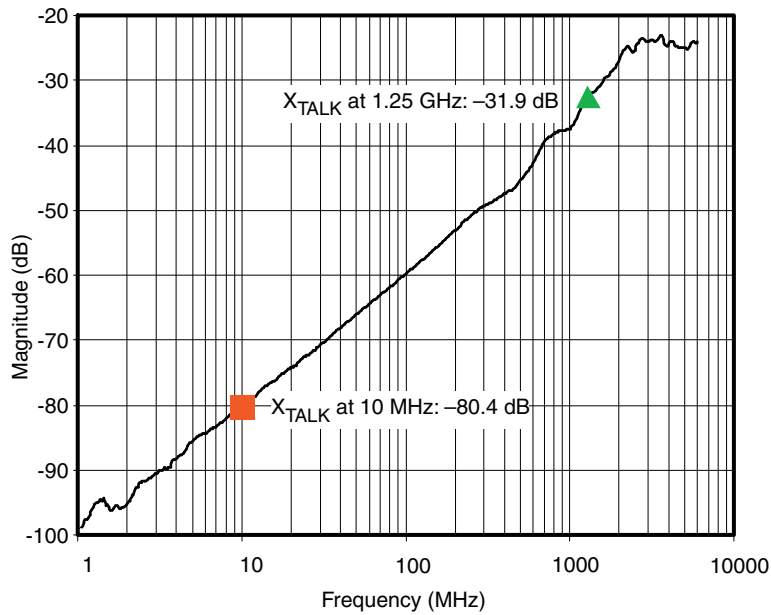


Figure 3. Crosstalk vs Frequency

**Eye Diagrams**

10-inch trace board for real implementation,  $V_{DD} = 1.8\text{ V}$ ,  $f = 1.25\text{ GHz}$ , transitional signal and non-transitional signal eye from Tektronix TDS6154C and Tektronix RT-Eye = software

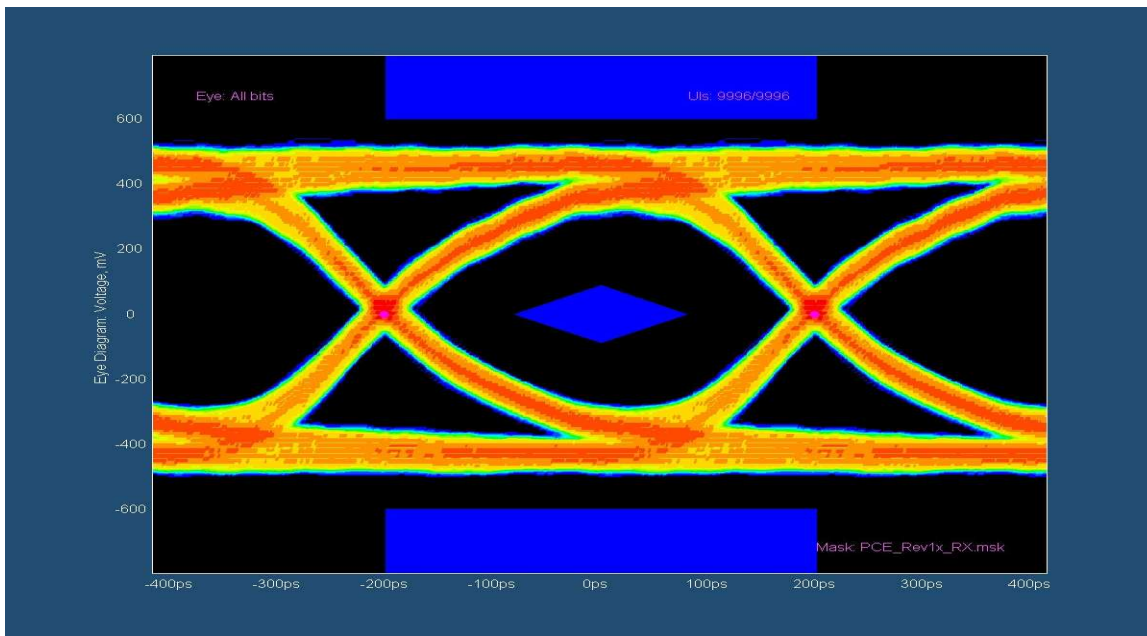


Figure 4. Transitional Signal Eye for TS2PCIE412 Using a 10-inch Trace

### TYPICAL PERFORMANCE (continued)

10-inch trace board for real implementation,  $V_{DD} = 1.8\text{ V}$ ,  $f = 1.25\text{ GHz}$ , transitional signal and non-transitional signal eye from Tektronix TDS6154C and Tektronix RT-Eye = software

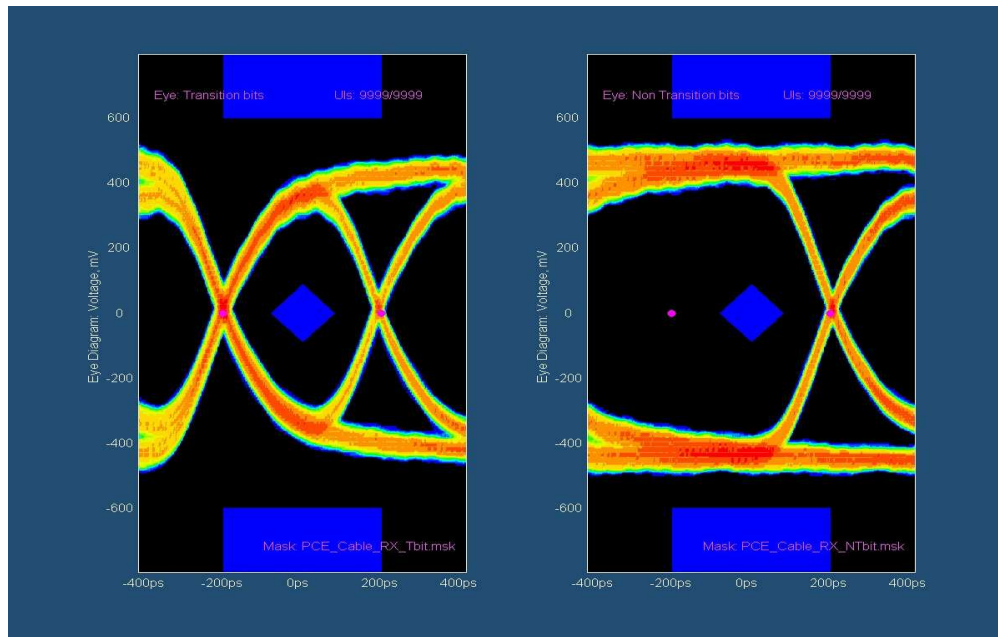
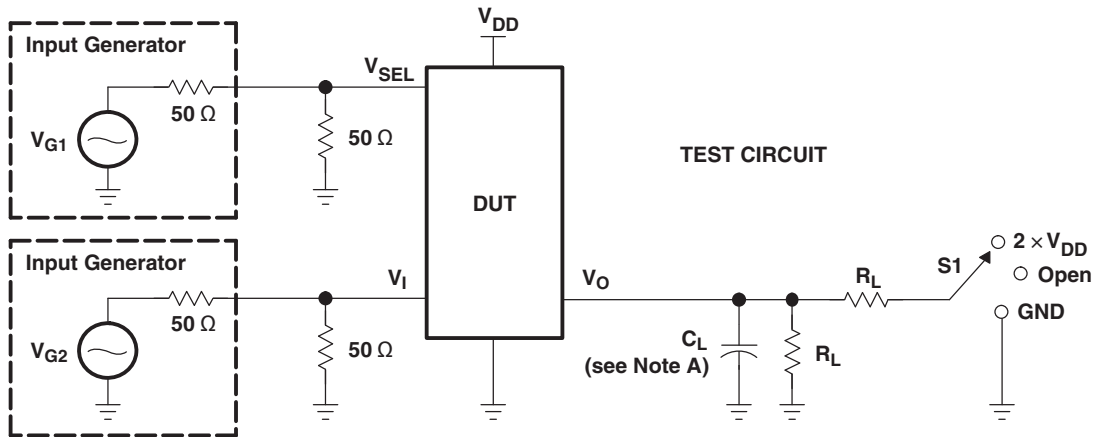
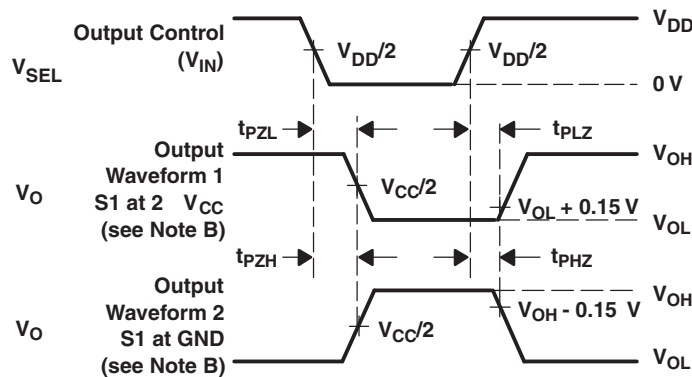


Figure 5. Transitional Signal Eye (Left) and Non-Transitional Signal Eye (Right) for TS2PCIE412 Using a 10-inch Trace

**PARAMETER MEASUREMENT INFORMATION  
(Enable and Disable Times)**



TEST	V <sub>DD</sub>	S1	R <sub>L</sub>	V <sub>I</sub>	C <sub>L</sub>	V <sub>Δ</sub>
t <sub>PLZ</sub> /t <sub>PZL</sub>	1.5 V to 2 V	2 × V <sub>DD</sub>	200 Ω	GND	10 pF	0.15 V
t <sub>PHZ</sub> /t <sub>PZH</sub>	1.5 V to 2 V	GND	200 Ω	V <sub>DD</sub>	10 pF	0.15 V



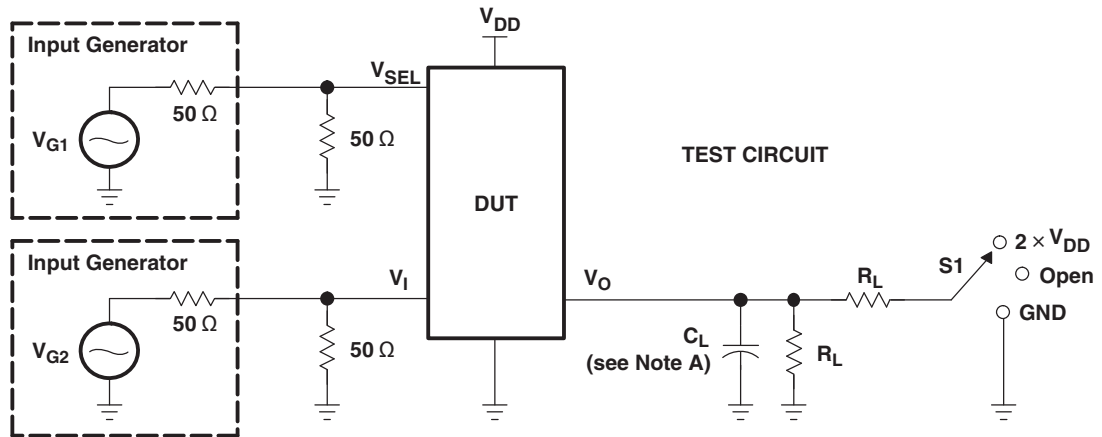
**VOLTAGE WAVEFORMS  
ENABLE AND DISABLE TIMES**

- A. C<sub>L</sub> includes probe and jig capacitance.
- B. Waveform 1 is for an output with internal conditions such that the output is low, except when disabled by the output control. Waveform 2 is for an output with internal conditions such that the output is high, except when disabled by the output control.
- C. All input pulses are supplied by generators having the following characteristics: PRR ≤ 10 MHz, Z<sub>O</sub> = 50 Ω, t<sub>r</sub> ≤ 2.5 ns, t<sub>f</sub> ≤ 2.5 ns.
- D. The outputs are measured one at a time, with one transition per measurement.
- E. t<sub>PLZ</sub> and t<sub>PHZ</sub> are the same as t<sub>dis</sub>.
- F. t<sub>PZL</sub> and t<sub>PZH</sub> are the same as t<sub>en</sub>.

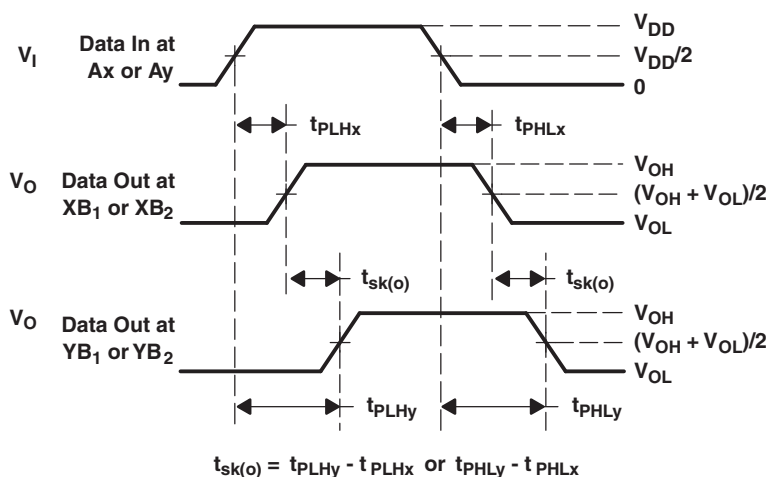
**Figure 6. Test Circuit and Voltage Waveforms**



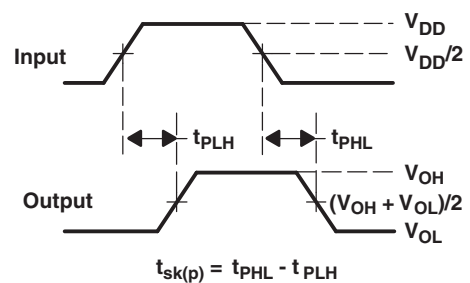
PARAMETER MEASUREMENT INFORMATION (Skew)



TEST	V <sub>DD</sub>	S1	R <sub>L</sub>	V <sub>SEL</sub>	C <sub>L</sub>
t <sub>sk(o)</sub>	1.5 V to 2 V	Open	200 Ω	V <sub>DD</sub> or GND	10 pF
t <sub>sk(p)</sub>	1.5 V to 2 V	Open	200 Ω	V <sub>DD</sub> or GND	10 pF



VOLTAGE WAVEFORMS OUTPUT SKEW [t<sub>sk(o)</sub>]

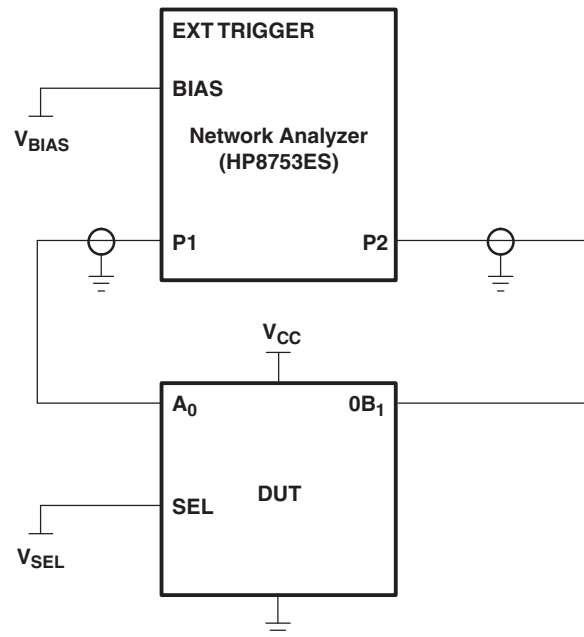


VOLTAGE WAVEFORMS PULSE SKEW [t<sub>sk(p)</sub>]

- A. C<sub>L</sub> includes probe and jig capacitance.
- B. Waveform 1 is for an output with internal conditions such that the output is low, except when disabled by the output control. Waveform 2 is for an output with internal conditions such that the output is high, except when disabled by the output control.
- C. All input pulses are supplied by generators having the following characteristics: PRR ≤ 10 MHz, Z<sub>O</sub> = 50 Ω, t<sub>r</sub> ≤ 2.5 ns, t<sub>f</sub> ≤ 2.5 ns.
- D. The outputs are measured one at a time, with one transition per measurement.

Figure 7. Test Circuit and Voltage Waveforms

## PARAMETER MEASUREMENT INFORMATION



**Figure 8. Test Circuit for Frequency Response (BW)**

Frequency response is measured at the output of the ON channel. For example, when  $V_{SEL} = 0\text{ V}$  and  $A_0$  is the input, the output is measured at  $0B_1$ . All unused analog I/O ports are left open.

### HP8753ES Setup

Average = 4  
 RBW = 3 kHz  
 $V_{BIAS} = 0.35\text{ V}$   
 ST = 2 s  
 P1 = 0 dBm

PARAMETER MEASUREMENT INFORMATION (continued)

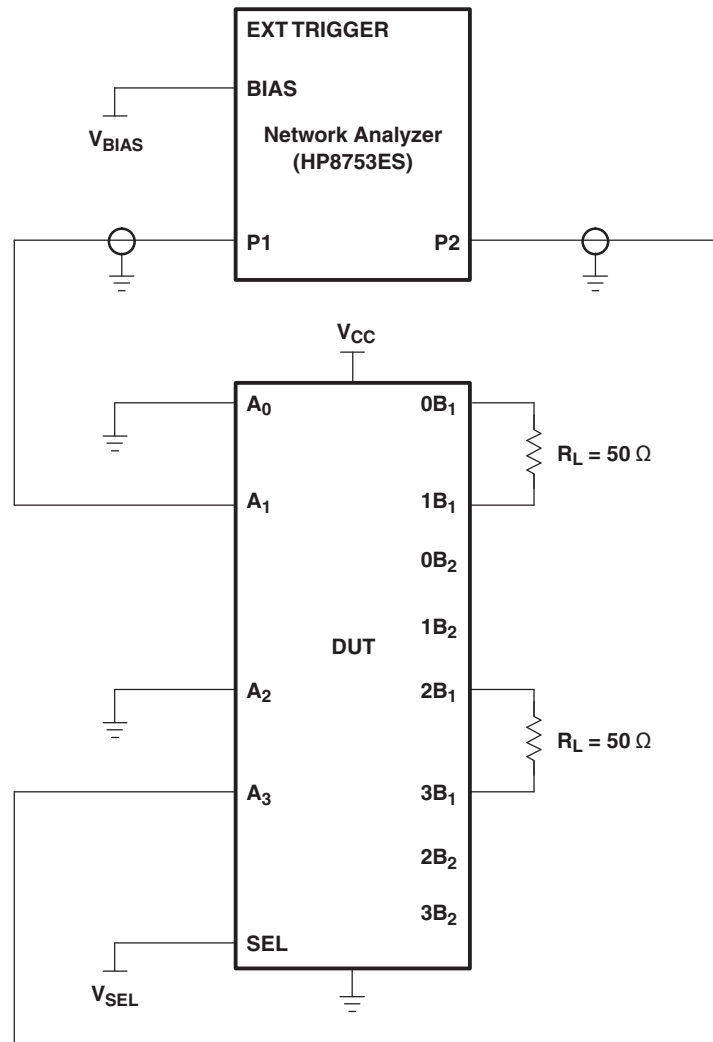


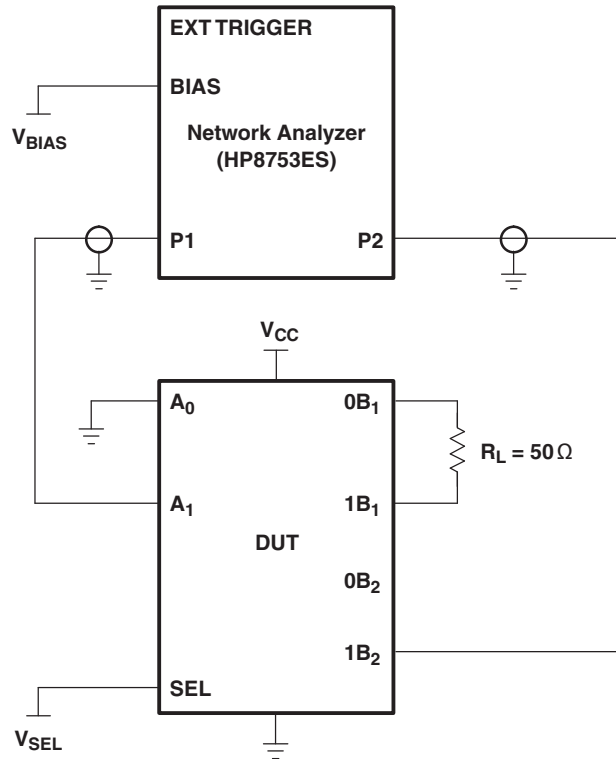
Figure 9. Test Circuit for Crosstalk ( $X_{TALK}$ )

Crosstalk is measured at the input of the nonadjacent ON channel. For example, when  $V_{SEL} = 0$  V and  $A_1$  is the input, the output is measured at  $A_3$ . All unused analog input (A) ports are connected to GND, and output (B) ports are connected to GND through 50-Ω pulldown resistors.

**HP8753ES Setup**

Average = 4  
 RBW = 3 kHz  
 $V_{BIAS} = 0.35$  V  
 ST = 2 s  
 P1 = 0 dBm

### PARAMETER MEASUREMENT INFORMATION (continued)



**Figure 10. Test Circuit for Off Isolation ( $O_{IRR}$ )**

OFF isolation is measured at the output of the OFF channel. For example, when  $V_{SEL} = 0$  V and  $A_1$  is the input, the output is measured at  $1B_2$ . All unused analog input (A) ports are left open, and output (B) ports are connected to GND through 50- $\Omega$  pulldown resistors.

#### HP8753ES Setup

Average = 4  
 RBW = 3 kHz  
 $V_{BIAS} = 0.35$  V  
 ST = 2 s  
 P1 = 0 dBm

## PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish	MSL Peak Temp (3)	Op Temp (°C)	Top-Side Markings (4)	Samples
TS2PCIE412RUAR	ACTIVE	WQFN	RUA	42	3000	TBD	Call TI	Call TI	-40 to 85	SH412	Samples

(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) 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)

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

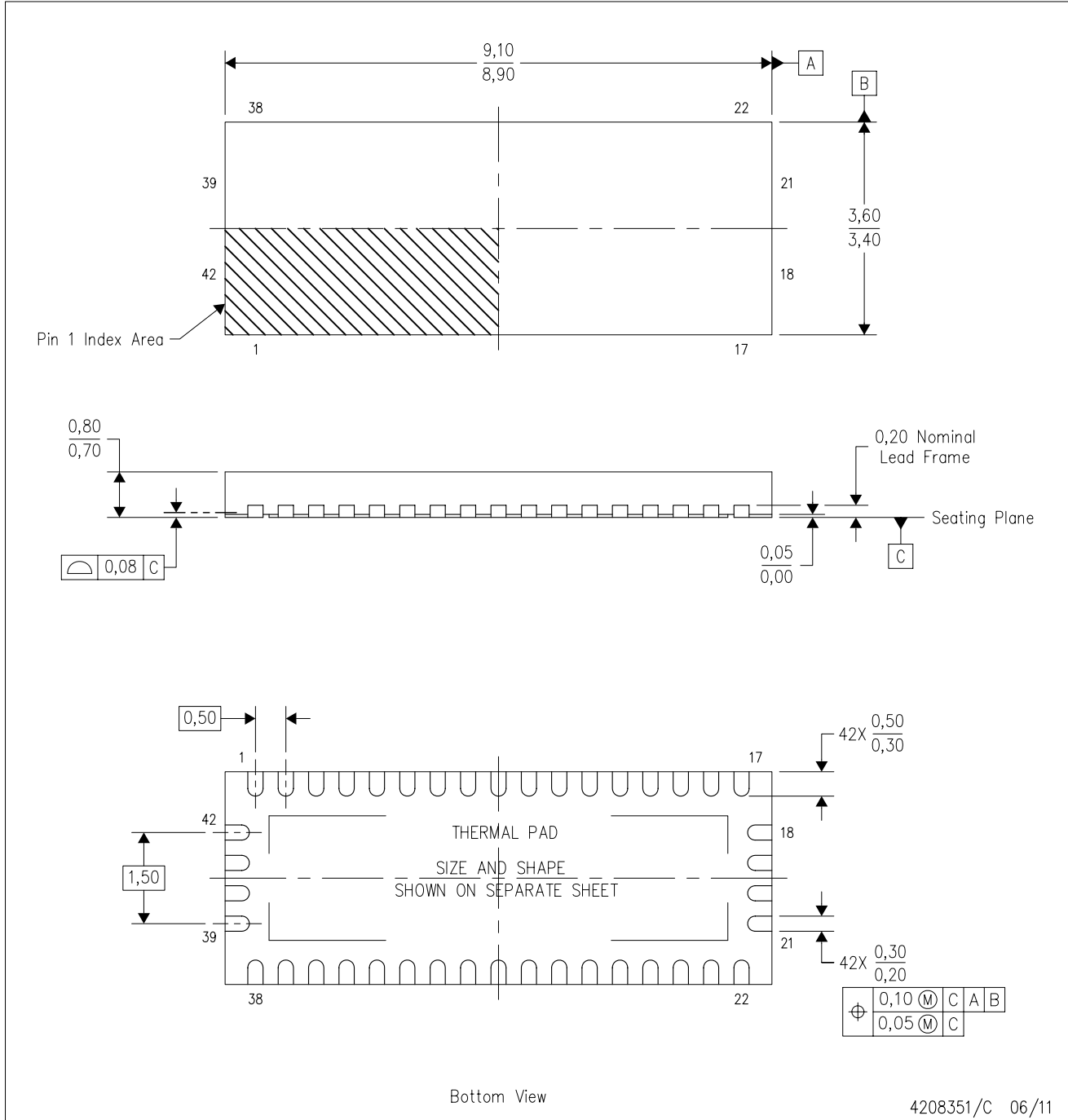
(4) Only one of markings shown within the brackets will appear on the physical device.

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RUA (R-PWQFN-N42)

PLASTIC QUAD FLATPACK NO-LEAD



- NOTES:
- All linear dimensions are in millimeters. Dimensioning and tolerancing per ASME Y14.5M-1994.
  - This drawing is subject to change without notice.
  - QFN (Quad Flatpack No-Lead) package configuration.
  - The package thermal pad must be soldered to the board for thermal and mechanical performance.
  - See the additional figure in the Product Data Sheet for details regarding the exposed thermal pad features and dimensions.

## THERMAL PAD MECHANICAL DATA

RUA (R-PWQFN-N42)

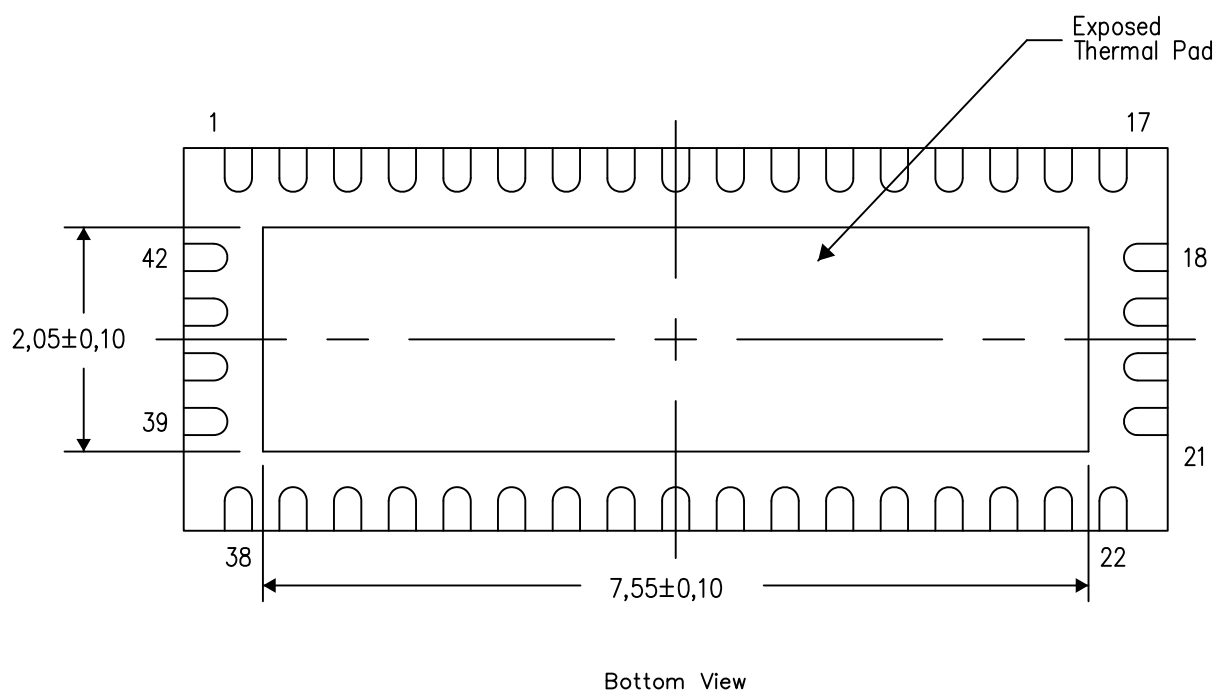
PLASTIC QUAD FLATPACK NO-LEAD

### THERMAL INFORMATION

This package incorporates an exposed thermal pad that is designed to be attached directly to an external heatsink. The thermal pad must be soldered directly to the printed circuit board (PCB). After soldering, the PCB can be used as a heatsink. In addition, through the use of thermal vias, the thermal pad can be attached directly to the appropriate copper plane shown in the electrical schematic for the device, or alternatively, can be attached to a special heatsink structure designed into the PCB. This design optimizes the heat transfer from the integrated circuit (IC).

For information on the Quad Flatpack No-Lead (QFN) package and its advantages, refer to Application Report, QFN/SON PCB Attachment, Texas Instruments Literature No. SLUA271. This document is available at [www.ti.com](http://www.ti.com).

The exposed thermal pad dimensions for this package are shown in the following illustration.



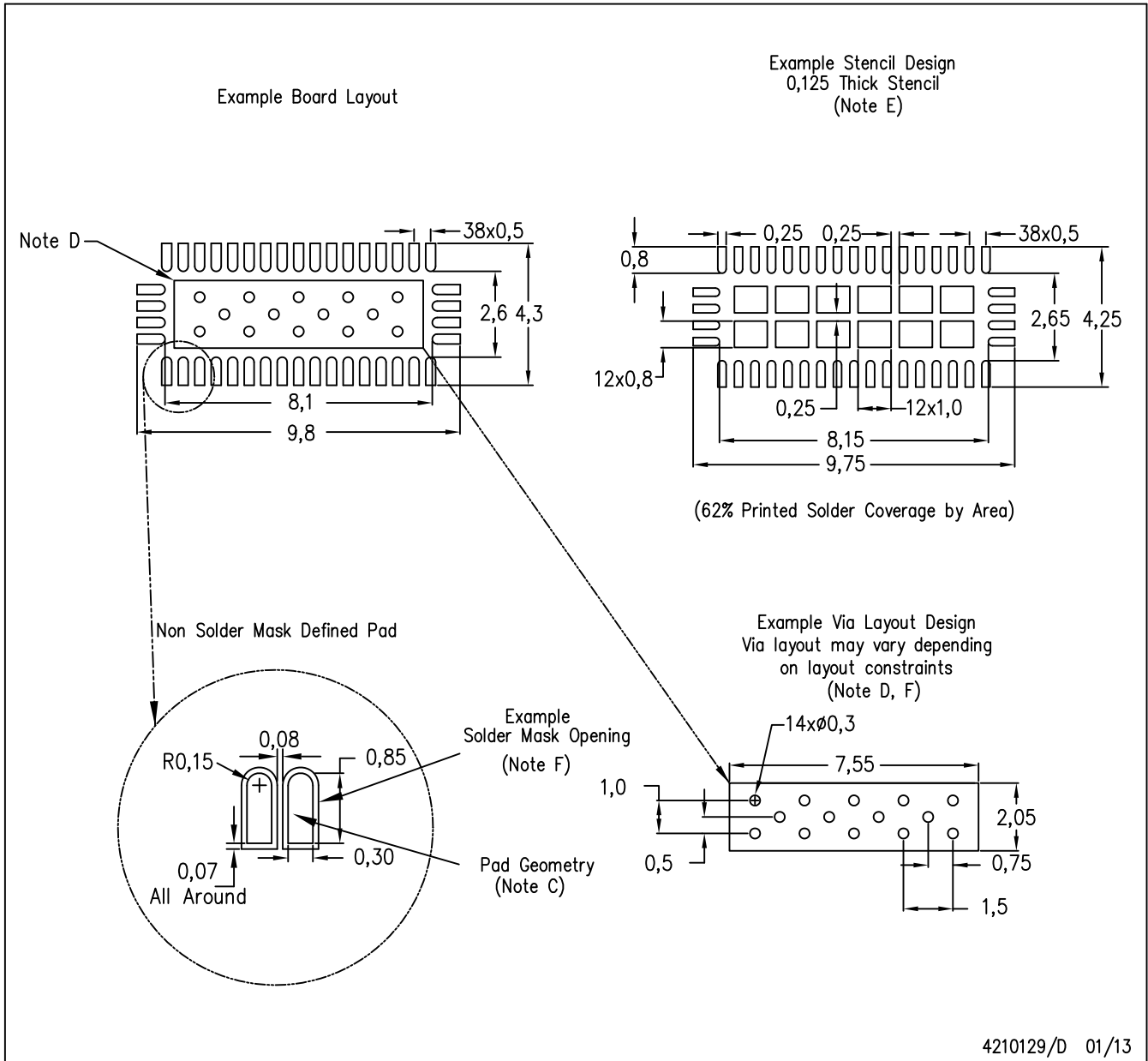
Exposed Thermal Pad Dimensions

4208352/E 01/13

NOTE: All linear dimensions are in millimeters

RUA (R-PWQFN-N42)

PLASTIC QUAD FLATPACK NO-LEAD



- NOTES:
- A. All linear dimensions are in millimeters.
  - B. This drawing is subject to change without notice.
  - C. Publication IPC-7351 is recommended for alternate designs.
  - D. This package is designed to be soldered to a thermal pad on the board. Refer to Application Note, Quad Flat-Pack Packages, Texas Instruments Literature No. SLUA271, and also the Product Data Sheets for specific thermal information, via requirements, and recommended board layout. These documents are available at [www.ti.com](http://www.ti.com) <<http://www.ti.com>>.
  - E. Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Refer to IPC 7525 for stencil design considerations.
  - F. Customers should contact their board fabrication site for recommended solder mask tolerances and via tenting recommendations for vias placed in the thermal pad.



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