

Two Channel SATA 3-Gbps Redriver

FEATURES

- Data Rates up to 3.0 Gbps
- SATA Gen 2.6, eSATA Compliant
- SATA Hot-Plug Capable
- Supports Common-Mode Biasing for OOB Signaling with Fast Turn-On
- Channel Selectable Pre-Emphasis
- Fixed Receiver Equalization
- Integrated Termination
- Low Power

- <200 mW Typ
- <5 mW (in sleep mode)

- Excellent Jitter and Loss Compensation Capability to Over 20 Inch FR4 Trace
- 20-Pin 4 × 4 QFN Package

APPLICATIONS

- Notebooks, Desktops, Docking Stations, Servers, Workstations

DESCRIPTION

The SN75LVCP412 is a dual channel, single lane SATA redriver and signal conditioner supporting data rates up to 3.0 Gbps. The device complies with SATA specification revision 2.6 and eSATA requirements.

The SN75LVCP412 operates from a single 3.3-V supply and has 100-Ω line termination with self-biasing feature making the device suitable for AC coupling. The inputs incorporate an OOB detector, which automatically squelches the output while maintaining a stable output common-mode voltage compliant to SATA link. The device is also designed to handle SSC transmission per the SATA specification.

The SN75LVCP412 handles interconnect losses at both its input and output. The built-in transmitter pre-emphasis feature is capable of applying 0 dB or 2.5 dB of relative amplification at higher frequencies to counter the expected interconnect loss. On the receive side the device applies a fixed equalization of 7 dB to boost input frequencies near 1.5 GHz. Collectively, the input equalization and output pre-emphasis features of the device work to fully restore SATA signal integrity over extended cable and backplane pathways.

The device is hot-plug capable⁽¹⁾ preventing device damage under device *hot*-insertion such as async signal plug/removal, unpowered plug/removal, powered plug/removal, or surprise plug/removal.

(1) Requires use of AC coupling capacitors at differential inputs and outputs.

ORDERING INFORMATION⁽¹⁾

PART NUMBER	PART MARKING	PACKAGE
SN75LVCP412RTJR	LVCP412	20-Pin RTJ Reel (large)

(1) For the most current package and ordering information, see the Package Option Addendum at the end of this document, or see the TI web site at www.ti.com.

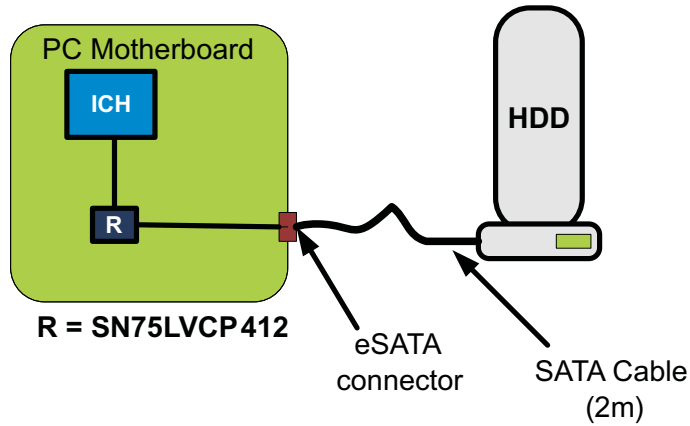


Please be aware that an important notice concerning availability, standard warranty, and use in critical applications of Texas Instruments semiconductor products and disclaimers thereto appears at the end of this data sheet.

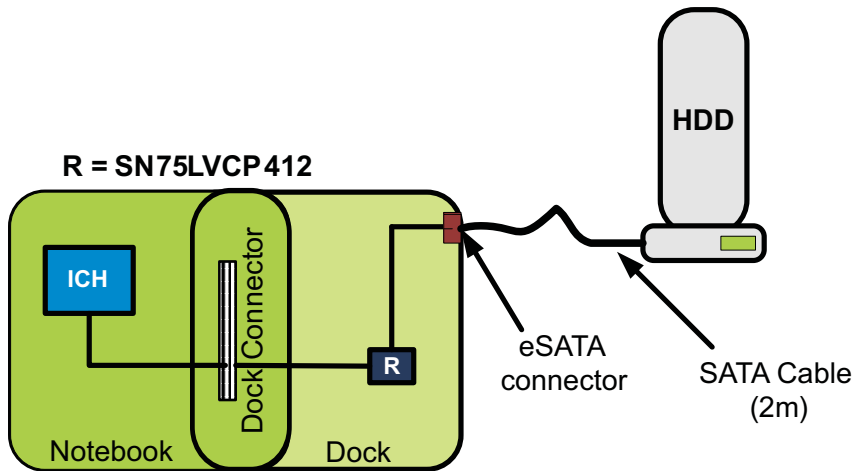


These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

TYPICAL APPLICATION



In Notebook and Desktop Motherboard



In Notebook Dock

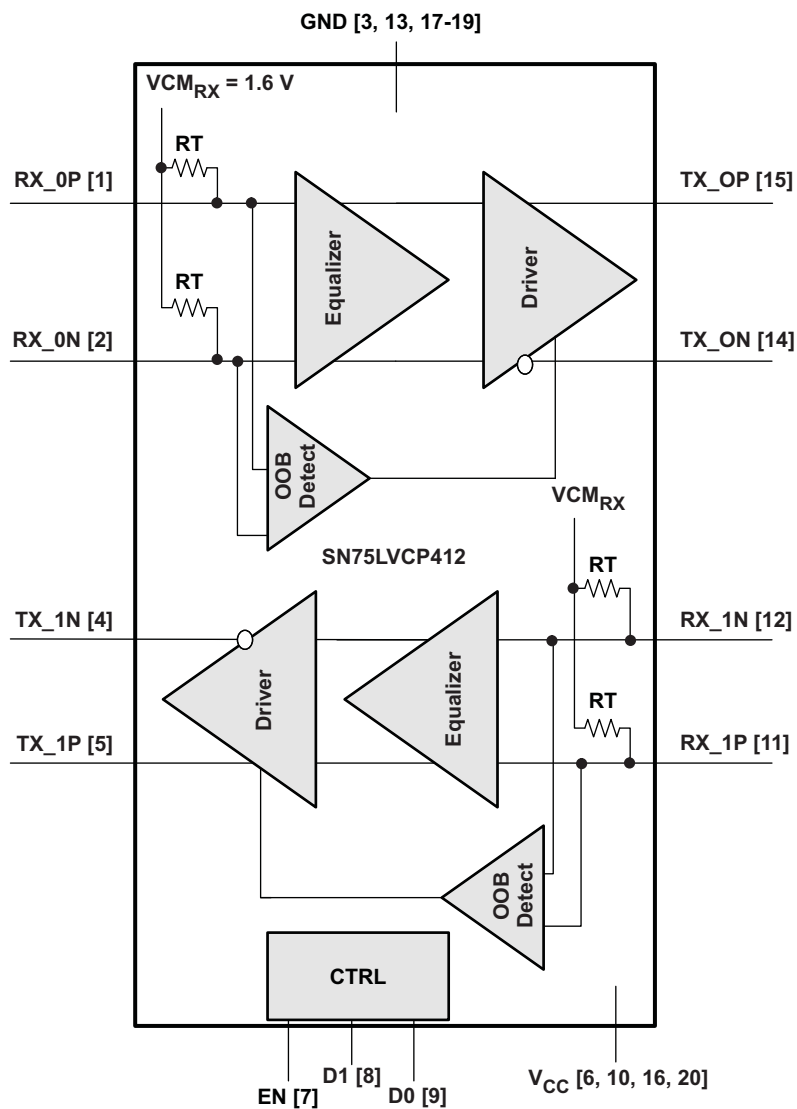
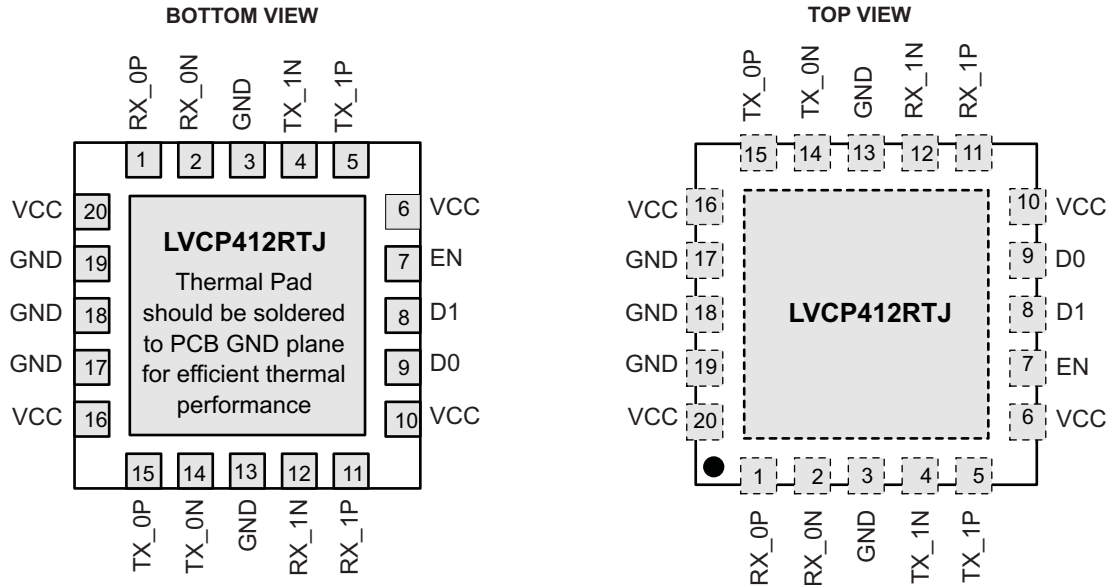


Figure 1. Data Flow Block Diagram

Table 1. Control Logic

EN	D0	D1	FUNCTION
0	X	X	Low power mode
1	0	0	Normal SATA output (default state); CH 0 and CH 1 → 0 dB
1	1	0	CH 0 → 2.5 dB pre-emphasis; CH 1 → 0 dB
1	0	1	CH 1 → 2.5 dB pre-emphasis; CH 0 → 0 dB
1	1	1	CH 0 and CH 1 → 2.5 dB pre-emphasis

PIN ASSIGNMENT

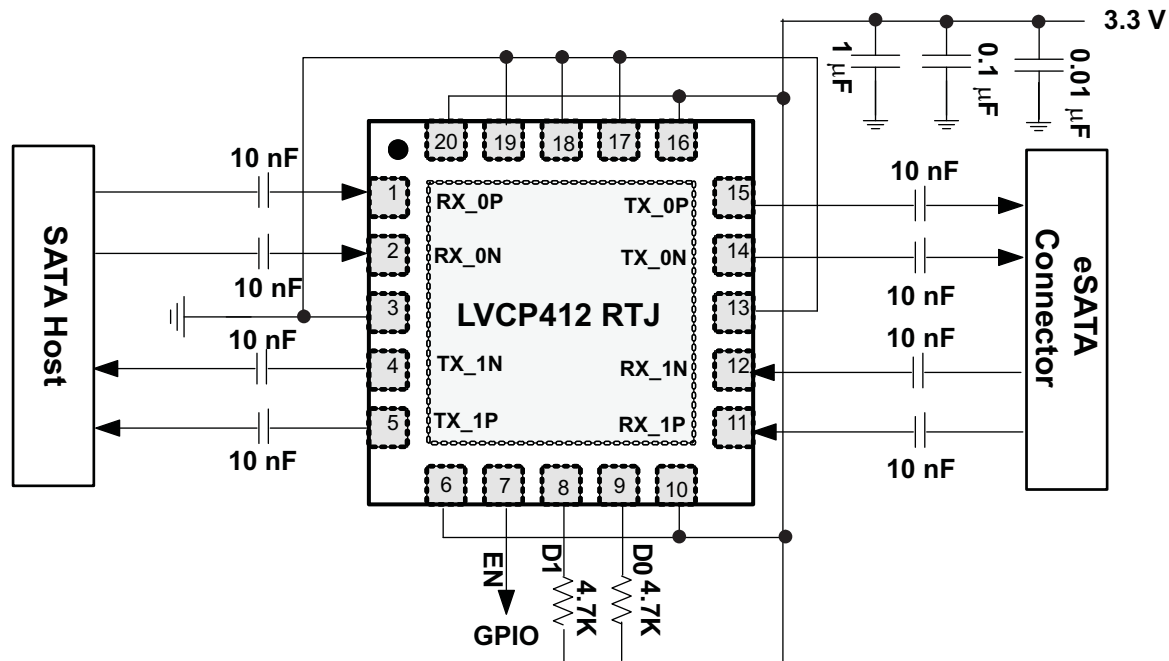


TERMINAL FUNCTIONS

PIN	NAME	DESCRIPTION	PIN	NAME	DESCRIPTION
1	RX_OP	Input 0, non-inverting	11	RX_1P	Input 1, non-inverting
2	RX_ON	Input 0, inverting	12	RX_1N	Input 1, inverting
3	GND	Ground	13	GND	Ground
4	TX_1N	Output 1, inverting	14	TX_ON	Output 0, inverting
5	TX_1P	Output 1, non-inverting	15	TX_0P	Output 0, non-inverting
6	VCC	Power	16	VCC	Power
7	EN ⁽¹⁾	Enable	17	GND	Ground
8	D1 ⁽²⁾	Pre-emphasis_1	18	GND	Ground
9	D0 ⁽²⁾	Pre-emphasis_0	19	GND	Ground
10	VCC	Power	20	VCC	Power

- (1) EN tied to VCC via internal PU resistor
- (2) D0 and D1 are tied to GND via internal PD resistor

TYPICAL DEVICE IMPLEMENTATION



Note:

- 1) Place supply caps close to device pin
- 2) EN can be left open or tied to supply when no external control is implemented
- 3) Output pre-emphasis (D1, D0) is shown enabled. Setting will depend on device placement relative to eSATA connector

DETAILED DESCRIPTION

INPUT EQUALIZATION

Each differential input of the SN75LVCP412 has 7 dB of fixed equalization in its front stage. The equalization amplifies high frequency signals to correct for loss from the transmission channel. The input equalizer is designed to recover a signal even when no eye is present at the receiver and effectively supports FR4 trace at the input anywhere from <4 inches to 20 inches or <10 cm to >50 cm.

OUTPUT PRE-EMPHASIS

The SN75LVCP412 provides single step pre-emphasis from 0 dB to 2.5 dB at each of its differential outputs. Pre-emphasis is controlled independently for each channel and is set by the control pins D0 and D1 as shown in Table 1. The pre-emphasis duration is 0.4 UI or 133 ps (typ) at SATA 3-Gbps speed.

LOW POWER MODE

Two low power modes are supported by the SN75LVCP412:

- Sleep Mode (triggered by EN pin, EN = 0V)
 - Low power mode is controlled by enable (EN) pin. In its default state this pin is internally pulled high. Pulling this pin LOW will put the device in sleep mode within 2µs (max). In this mode all active components of the device are driven to their quiescent level and differential outputs are driven to Hi-Z (open). Max power dissipation in this mode is 5 mW. Exiting from this mode to normal operation requires a maximum latency of 20 µs.
- Auto Low Power Mode (triggered when a given channel is in electrical idle state; EN = V_{CC})
 - The device enters and exits low power mode by actively monitoring input signal (V_{IDP-p}) level on each of its channel independently. When input signal on either or both channel is in the electrical idle state, i.e. V_{IDP-p} < 50 mV and stays in this state for ≥3 µS the associated channel(s) enters into the low power state. In this

state, output of the associated channel(s) is driven to VCM and device selectively shuts off some circuitry to lower power by up to 20% of its normal operating power. Exit time from auto low power mode is less than 50 ns.

- As an example, if under normal operating conditions device is consuming typical power of 200 mW. When device enters this mode, i.e. condition for auto-low power mode is met, power consumption can drop down to 160 mW. The device enters normal operation within 50 ns of signal activity detection.

OUT-OF-BAND (OOB) SUPPORT

The squelch detector circuit within the device enables full detection of OOB signaling as specified in SATA specification 2.6. Differential signal amplitude at the receiver input of 50 mV_{p-p} or less is not detected as an activity and hence is not passed to the output. Differential signal amplitude of 150 mV_{p-p} or more is detected as an activity and therefore passed to the output indicating activity. Squelch circuit on/off time is 5 ns max. While in squelch mode outputs are held to VCM.

DEVICE POWER

The SN75LVCL412 is designed to operate from a single 3.3-V supply. Always practice proper power supply sequencing procedures. Apply V_{CC} first before any input signals are applied to the device. The power down sequence is in reverse order.

ABSOLUTE MAXIMUM RATINGS

over operating free-air temperature range (unless otherwise noted)⁽¹⁾

		VALUE	UNIT
Supply voltage range ⁽²⁾	V _{CC}	–0.5 to 6	V
Voltage range	Differential I/O	–0.5 to 4	V
	Control I/O	–0.5 to V _{CC} + 0.5	V
Electrostatic discharge	Human body model ⁽³⁾	±8000	V
	Charged-device model ⁽⁴⁾	±1000	V
	Machine model ⁽⁵⁾	±200	V
Continuous power dissipation		See Dissipation Rating Table	

- (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 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 voltage values, except differential voltages, are with respect to network ground terminal.
- (3) Tested in accordance with JEDEC Standard 22, Test Method A114-B.
- (4) Tested in accordance with JEDEC Standard 22, Test Method C101-A.
- (5) Tested in accordance with JEDEC Standard 22, Test Method A115-A.

DISSIPATION RATINGS

PACKAGE	PCB JEDEC STANDARD	T _A ≤ 25°C	DERATING FACTOR ⁽¹⁾ ABOVE T _A = 25°C	T _A = 85°C POWER RATING
20-pin QFN (RTJ)	Low-K	1176 mW	11.76 mW/°C	470 mW
	High-K	2631 mW	26.3 mW/°C	1052 mW

- (1) This is the inverse of the junction-to-ambient thermal resistance when board-mounted and with no air flow.

THERMAL CHARACTERISTICS

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

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX ⁽¹⁾	UNIT
R _{θJB}	Junction-to-board thermal resistance			10		°C/W
R _{θJC}	Junction-to-case thermal resistance			60		°C/W
R _{θJP}	Junction-to-pad thermal resistance			15.2		°C/W

- (1) The maximum rating is simulated under 3.6-V V_{CC}.

THERMAL CHARACTERISTICS (continued)

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

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX ⁽¹⁾	UNIT
P _D	Device power dissipation, active mode	EN = 3.3 V, K28.5 pattern at 3 Gbps, V _{ID} = 700 mV _{p-p} , V _{CC} = 3.6 V			300	mW
P _{SD}	Device power dissipation, sleep mode	EN = 0 V, K28.5 pattern at 3 Gbps, V _{ID} = 700 mV _{p-p} , V _{CC} = 3.6 V			5	mW

RECOMMENDED OPERATING CONDITIONS

with typical values measured at V_{CC} = 3.3 V, T_A = 25°C; all temperature limits are assured by design

PARAMETER		CONDITIONS	MIN	TYP	MAX	UNITS
V _{CC}	Supply voltage		3	3.3	3.6	V
C _{COUPLING}	Coupling capacitor			12		nF
T _A	Operating free-air temperature		0		85	°C

ELECTRICAL CHARACTERISTICS

over recommended operating conditions (unless otherwise noted)

PARAMETER		CONDITIONS	MIN	TYP	MAX	UNITS
DEVICE PARAMETERS						
I _{CC}	Supply current, active mode	EN = 3.3 V, K28.5 pattern at 3 Gbps, V _{ID} = 700 mV _{p-p} , V _{CC} = 3.3 V		55	70	mA
I _{CCSLEEP}	Shutdown current, sleep mode	EN = 0V			1	mA
	Maximum data rate				3.0	Gbps
t _{PDelay}	Propagation delay	Measured using K28.5 pattern, See Figure 2		320	400	ps
t _{ENB}	Device enable time	ENB = L → H			20	μs
t _{DIS}	Device disable time	ENB = H → L			2	μs
V _{OOB}	Input OOB threshold	See Figure 3	50		150	mV _{p-p}
t _{OOB1}	OOB mode enter	See Figure 3		3	5	ns
t _{OOB2}	OOB mode exit	See Figure 3		3	5	ns
CONTROL LOGIC						
V _{IH}	High-level input voltage		1.4			V
V _{IL}	Low-level input voltage				0.5	V
V _{INHYS}	Input hysteresis			115		mV
I _{IH}	High-level input current				10	μA
I _{IL}	Low-level input current				10	μA
RECEIVER AC/DC						
Z _{DIFFRX}	Differential input impedance		85	100	115	Ω
Z _{SERX}	Single-ended input impedance		40			Ω
V _{CMRX}	Common-mode voltage			1.6		V
RL _{DIFFRX}	Differential mode return loss	f = 150 MHz–300 MHz	18			dB
		f = 300 MHz–600 MHz	14			
		f = 600 MHz–1.2 GHz	10			
		f = 1.2 GHz–2.4 GHz	8			
		f = 2.4 GHz–3.0 GHz	3			
RL _{CMRX}	Common-mode return loss	f = 150 MHz–300 MHz	5			dB
		f = 300 MHz–600 MHz	5			
		f = 600 MHz–1.2 GHz	2			
		f = 1.2 GHz–2.4 GHz	1			
		f = 2.4 GHz–3.0 GHz	1			

ELECTRICAL CHARACTERISTICS (continued)

over recommended operating conditions (unless otherwise noted)

PARAMETER		CONDITIONS	MIN	TYP	MAX	UNITS
V _{DiffRX}	Differential input voltage PP	f = 150 MHz–300 MHz	200		2000	mV/ppd
IB _{RX}	Impedance balance	f = 150 MHz–300 MHz	30			dB
		f = 300 MHz–600 MHz	30			
		f = 600 MHz–1.2 GHz	20			
		f = 1.2 GHz–2.4 GHz	10			
		f = 2.4 GHz–3.0 GHz	4			
T _{20-80RX}	Rise/fall time	Rise times and fall times measured between 20% and 80% of the signal	67		136	ps
T _{skewRX}	Differential skew	Difference between the single-ended mid-point of the RX+ signal rising/falling edge, and the single-ended mid-point of the RX– signal falling/rising edge			50	ps
TRANSMITTER AC/DC						
Z _{DiffTX}	Pair differential Impedance		85		115	Ω
Z _{SETX}	Single-ended input impedance		40			Ω
	Output pre-emphasis	At 1.5 GHz when enabled		2.5		dB
RL _{DiffTX}	Differential mode return loss	f = 150 MHz–300 MHz	14			dB
		f = 300 MHz–600 MHz	8			
		f = 600 MHz–1.2 GHz	6			
		f = 1.2 GHz–2.4 GHz	6			
		f = 2.4 GHz–3.0 GHz	3			
RL _{CMTX}	Common-mode return loss	f = 150 MHz–300 MHz	5			dB
		f = 300 MHz–600 MHz	5			
		f = 600 MHz–1.2 GHz	2			
		f = 1.2 GHz–2.4 GHz	1			
		f = 2.4 GHz–3.0 GHz	1			
IB _{TX}	Impedance balance	f = 150 MHz–300 MHz	30			dB
		f = 300 MHz–600 MHz	20			
		f = 600 MHz–1.2 GHz	10			
		f = 1.2 GHz–2.4 GHz	10			
		f = 2.4 GHz–3.0 GHz	4			
DiffV _{ppTX}	Differential output voltage PP	f = 1.5 GHz, D0/D1 = 0	400	525	600	mV/ppd
DiffV _{ppTX_PE}	Differential output voltage PP	f = 1.5 GHz, D0/D1 = 1	600	700	800	mV/ppd
t _{DE}	Pre-emphasis width	See Figure 4		0.4		UI
V _{CMTX}	Common-mode voltage			1.97		V
T _{20-80TX}	Rise/fall time	Rise times and fall times measured between 20% and 80% of the signal, D1, D0 = 0 V	67	100	136	ps
T _{skewTX}	Differential skew	Difference between the single-ended mid-point of the TX+ signal rising/falling edge, and the single-ended mid-point of the TX– signal falling/rising edge, D1, D0 = V _{CC}			20	ps
TJ _{TX}	Total jitter ⁽¹⁾	UI = 333 ps, +K28.5 control character		0.2	0.3	U _{i-p-p}
DJ _{TX}	Deterministic jitter ⁽¹⁾	UI = 333 ps, +K28.5 control character		0.13	0.2	U _{i-p-p}
RJ _{TX}	Random jitter ⁽¹⁾	UI = 333 ps, +K28.7 control character		2.0	2.15	ps/rms

(1) $T_J = (14.1 \times R_{JSD} + DJ)$ where R_{JSD} is one standard deviation value of RJ Gaussian distribution. T_J measurement is at the SATA connector and includes jitter generated at the package connection on the printed circuit board, and at the board interconnect as shown in [Figure 2](#).

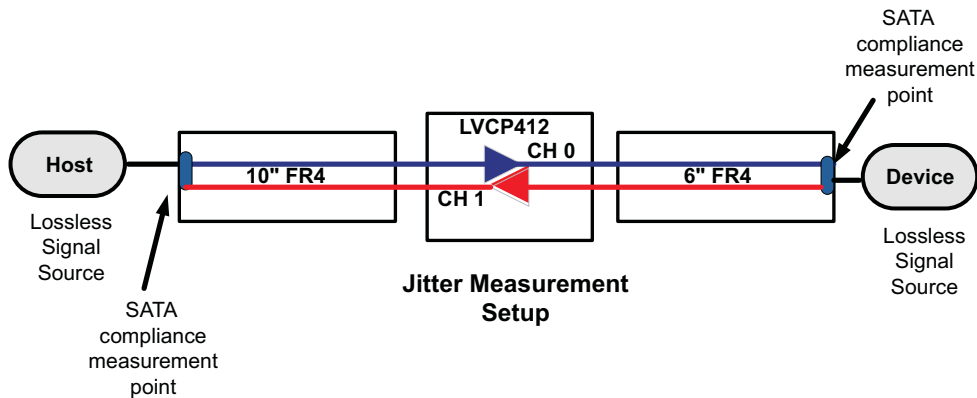


Figure 2. Jitter Measurement Test Condition

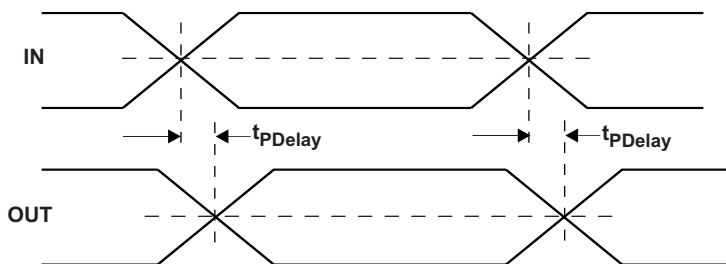


Figure 3. Propagation Delay Timing Diagram

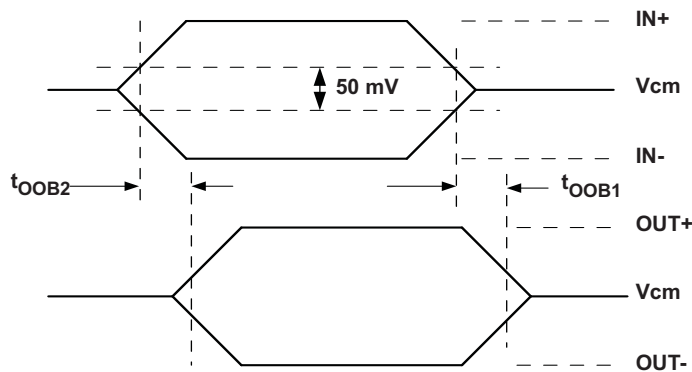


Figure 4. OOB Enter and Exit Timing

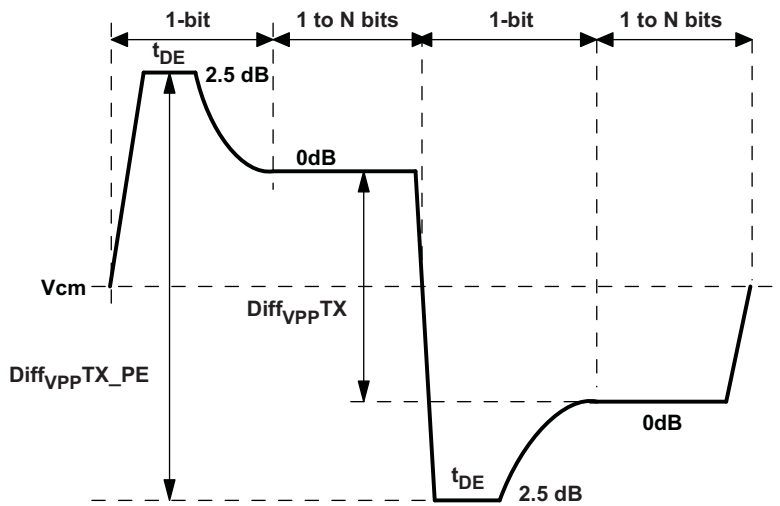


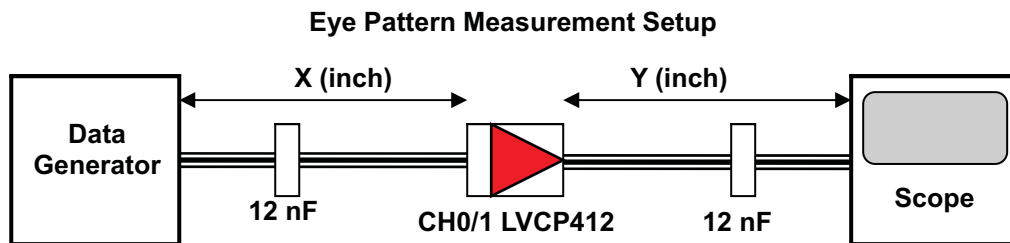
Figure 5. TX Differential Output with 2.5 dB Pre-Emphasis Step

BENCH TEST DATA

Differential Output Voltage – $Diff_{VppTX}$, 2 inches from Device Pin, $V_{CC} = 3.3 V$, $T_A = 25^\circ C$, Pattern = K28.5, Bit Rate = 3 Gbps

PARAMETER	TEST CONDITIONS	CHANNEL	INPUT VID	DO/D1	MIN	MEAN	MAXIMUM
$Diff_{VppTX}$	$V_{CC} = 3.3 V$, $T_A = 25^\circ C$, Pattern = K28.5, Bit rate = 3 Gbps	CH0	700 mV	0	524.87mV	524.87mV	525.72mV
		CH1	700 mV	0	515.68mV	516.72mV	518.85mV
$Diff_{VppTXDE}$	$V_{CC} = 3.3 V$, $T_A = 25^\circ C$, Pattern = K28.5, Bit rate = 3 Gbps	CH0	700 mV	1	665.07mV	666.48mV	668.07mV
		CH1	700 mV	1	656.32mV	658.34mV	660.40mV

EYE DIAGRAM



Test Condition

- $V_{CC} = 3.3 V$
- Temp = $25^\circ C$
- Rx input voltage = 700 mVp-p
- Input pattern K28.5+ @3 Gbps
- D1/D0/ENB = V_{CC}
- Trace Width = 4 mil on PCB

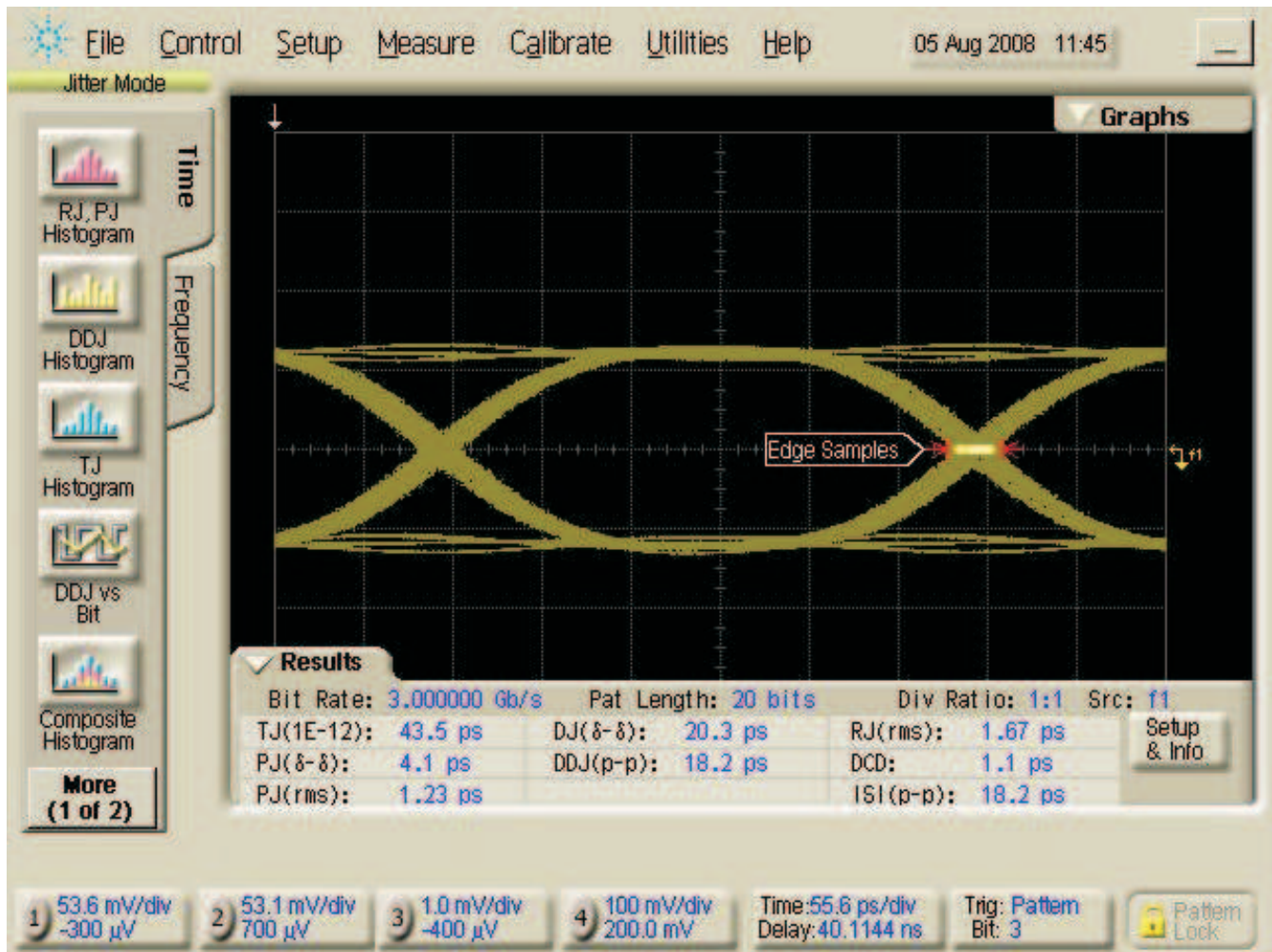


Figure 6. Eye Pattern

X=5.7", Y =5.7" (Eye Height/Width)

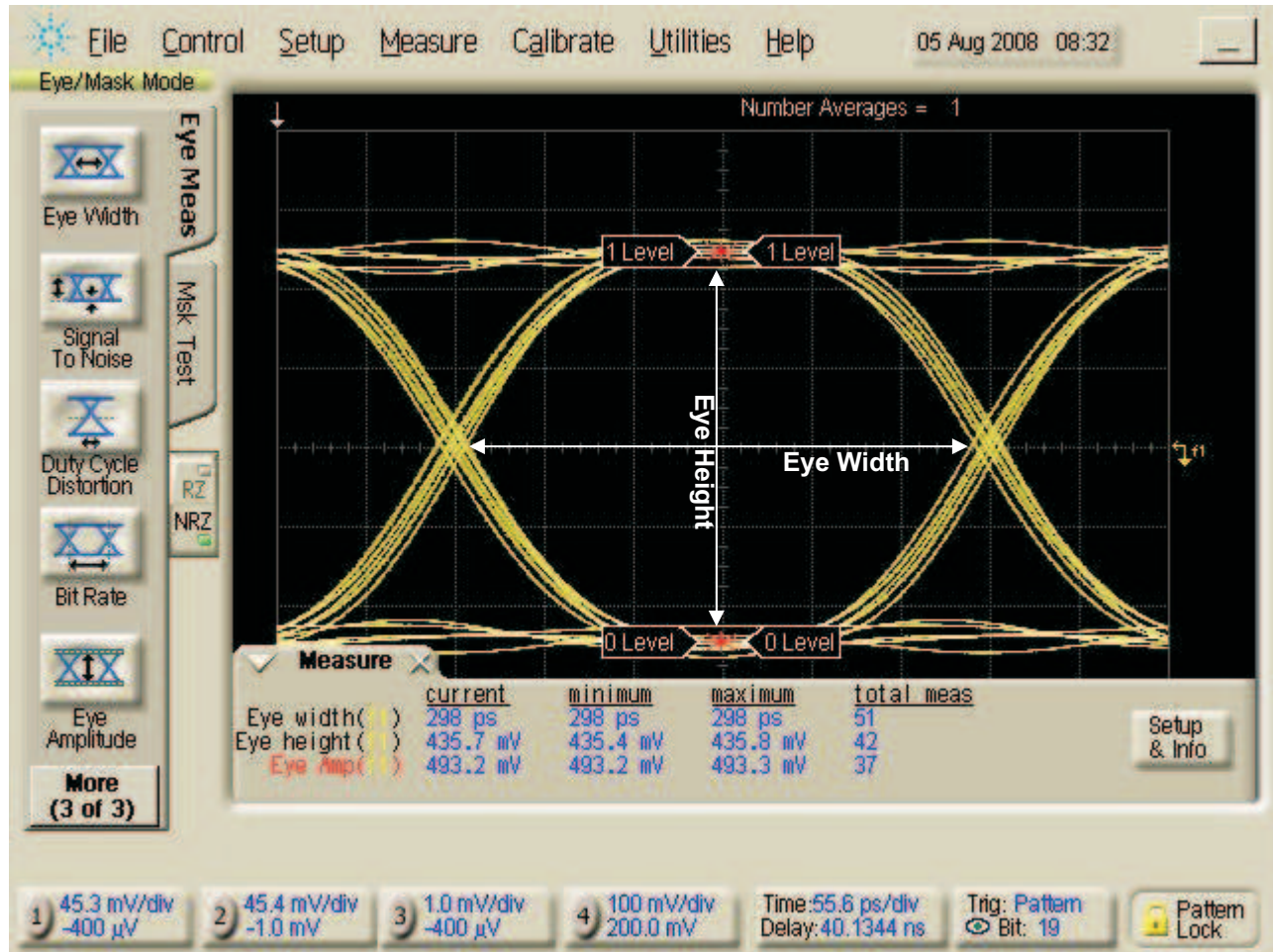


Figure 7. Eye Pattern

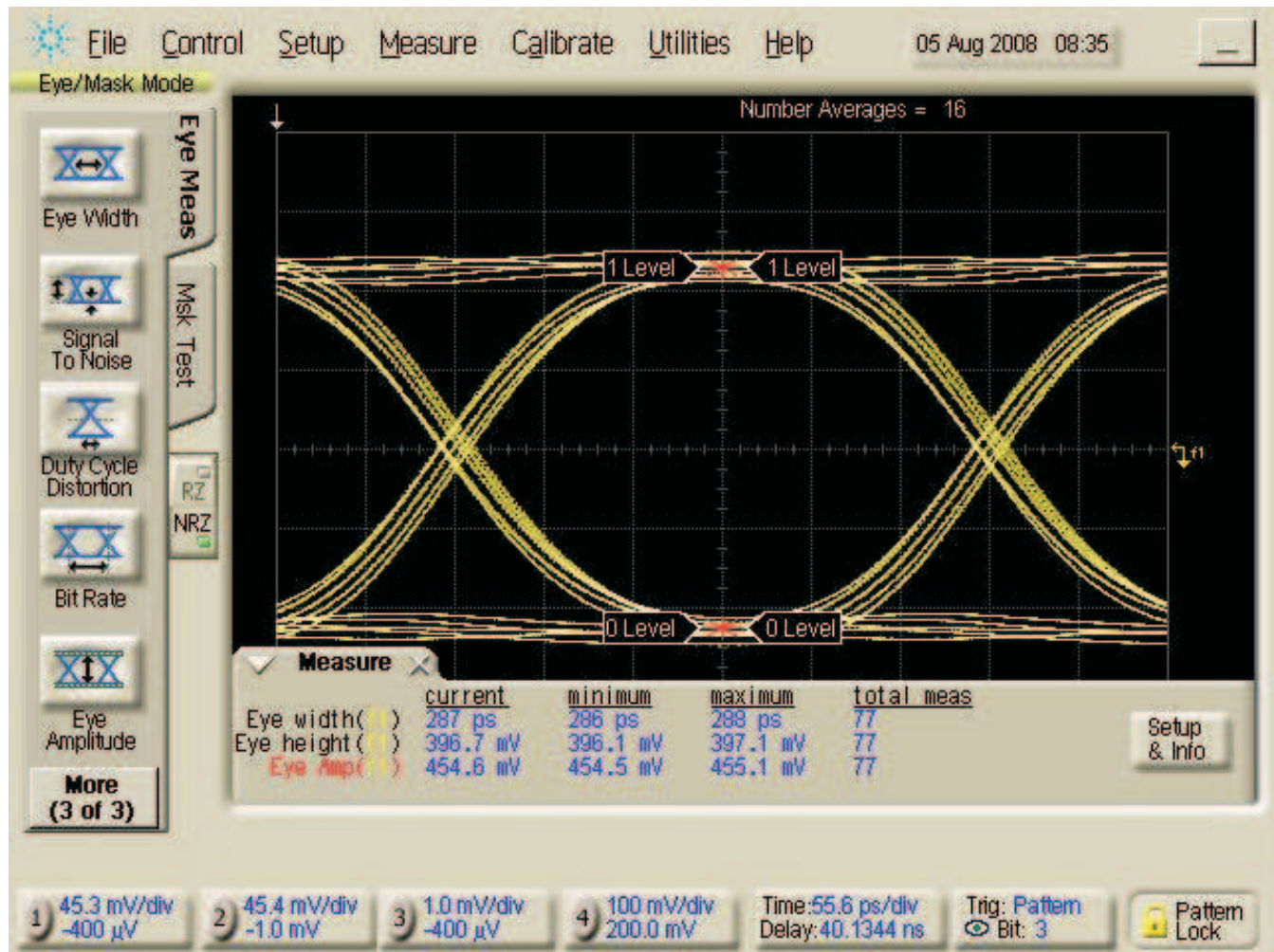


Figure 8. Eye Pattern

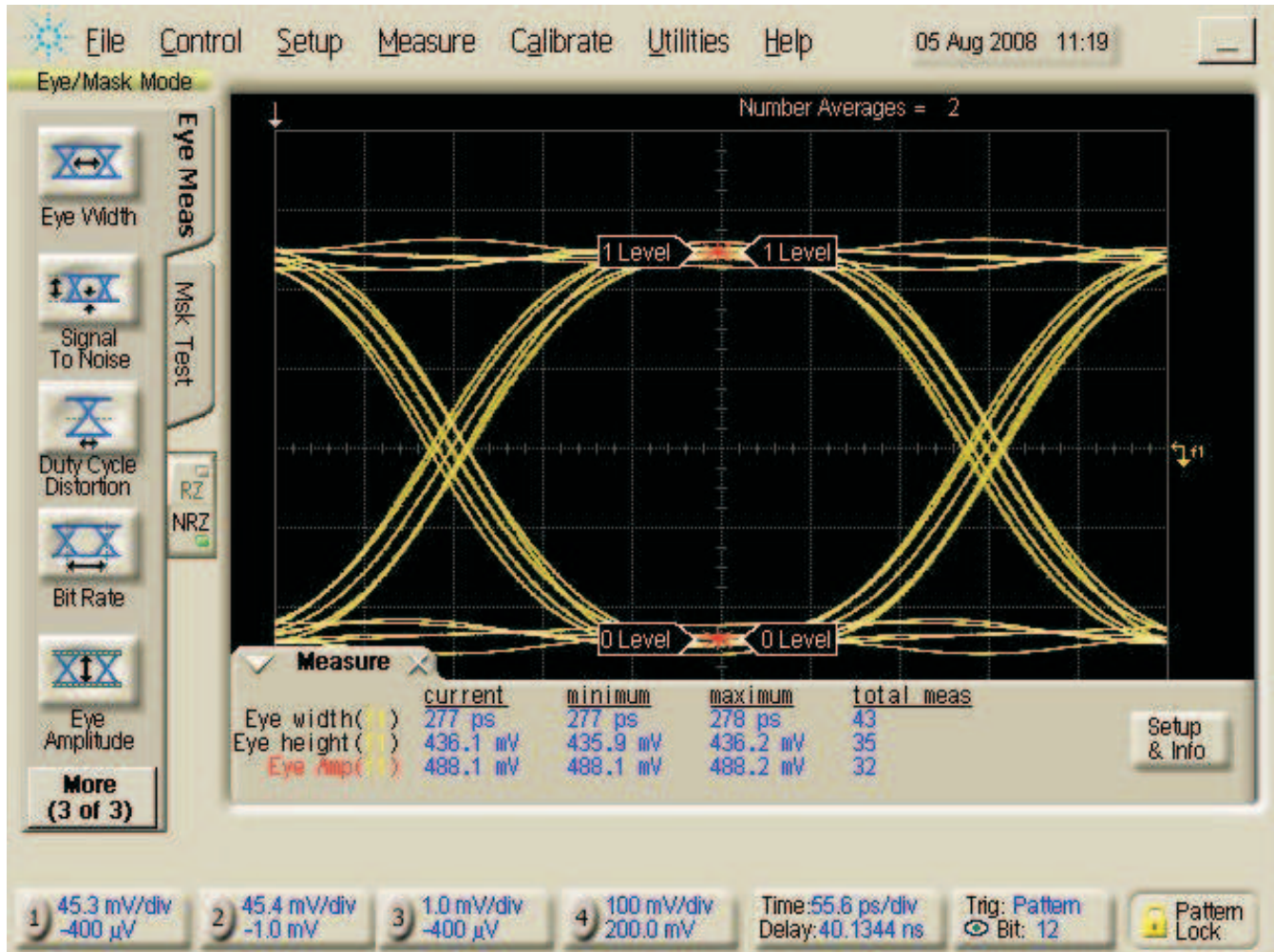


Figure 9. Eye Pattern

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead finish/ Ball material (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
SN75LVCP412RTJR	ACTIVE	QFN	RTJ	20	3000	RoHS & Green	NIPDAU	Level-2-260C-1 YEAR	0 to 85	LVCP412	Samples
SN75LVCP412RTJT	ACTIVE	QFN	RTJ	20	250	RoHS & Green	NIPDAU	Level-2-260C-1 YEAR	0 to 85	LVCP412	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) **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.

Important Information and Disclaimer:The information provided on this page represents TI's knowledge and belief as of the date that it is provided. TI bases its knowledge and belief on information provided by third parties, and makes no representation or warranty as to the accuracy of such information. Efforts are underway to better integrate information from third parties. TI has taken and continues to take reasonable steps to provide representative and accurate information but may not have conducted destructive testing or chemical analysis on incoming materials and chemicals. TI and TI suppliers consider certain information to be proprietary, and thus CAS numbers and other limited information may not be available for release.

In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

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
SN75LVCP412RTJR	QFN	RTJ	20	3000	330.0	12.4	4.25	4.25	1.15	8.0	12.0	Q2
SN75LVCP412RTJT	QFN	RTJ	20	250	180.0	12.4	4.25	4.25	1.15	8.0	12.0	Q2

TAPE AND REEL BOX DIMENSIONS


*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
SN75LVCP412RTJR	QFN	RTJ	20	3000	346.0	346.0	33.0
SN75LVCP412RTJT	QFN	RTJ	20	250	210.0	185.0	35.0

GENERIC PACKAGE VIEW

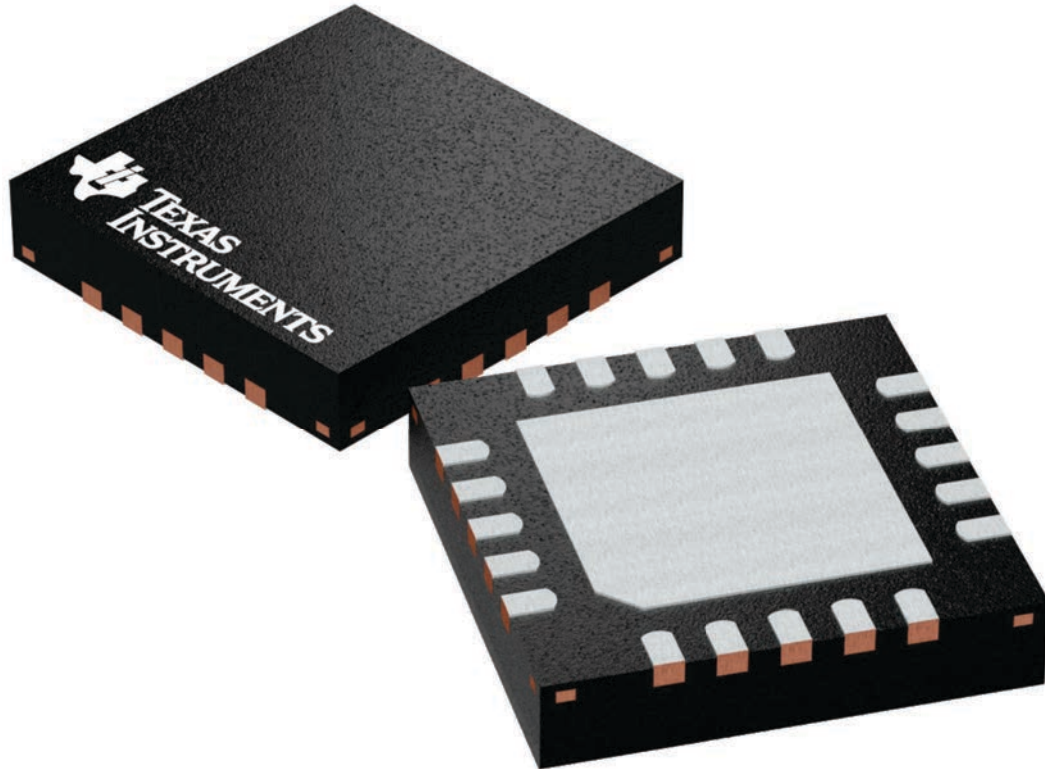
RTJ 20

WQFN - 0.8 mm max height

4 x 4, 0.5 mm pitch

PLASTIC QUAD FLATPACK - NO LEAD

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

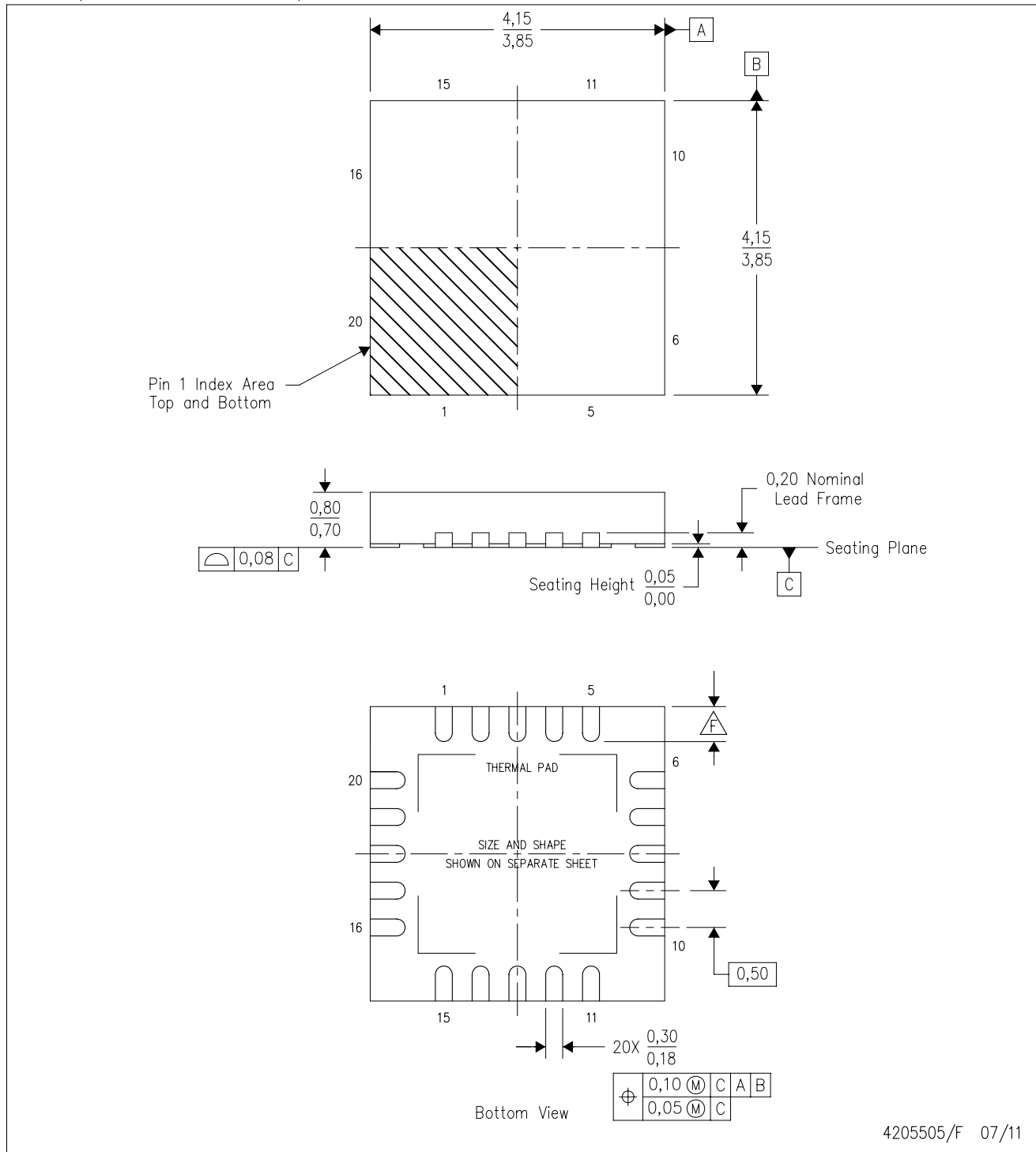


4224842/A

MECHANICAL DATA

RTJ (S-PWQFN-N20)

PLASTIC QUAD FLATPACK NO-LEAD



4205505/F 07/11

- NOTES:
- All linear dimensions are in millimeters. Dimensioning and tolerancing per ASME Y14.5-1994.
 - 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.
- ⚠ Check thermal pad mechanical drawing in the product datasheet for nominal lead length dimensions.

RTJ (S-PWQFN-N20)

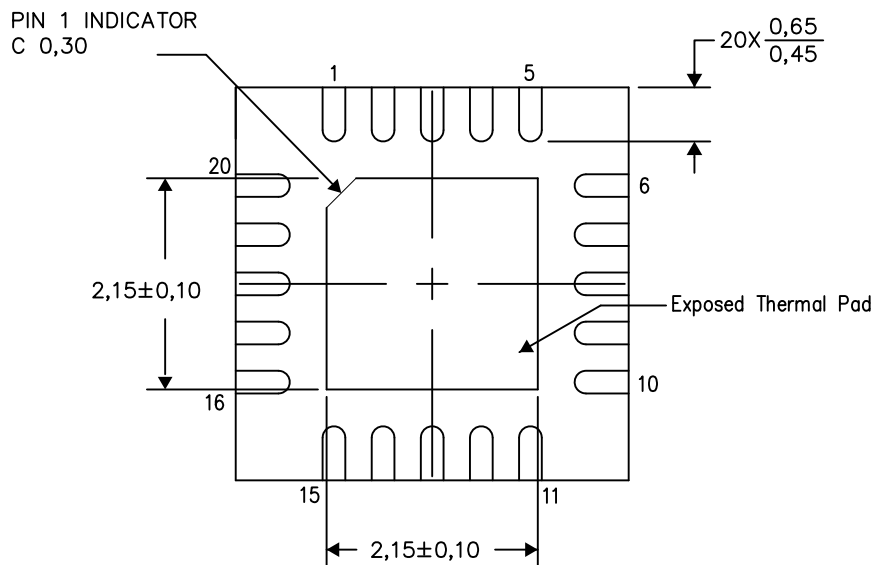
PLASTIC QUAD FLATPACK NO-LEAD

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.

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



Bottom View

Exposed Thermal Pad Dimensions

4206256-3/V 05/15

NOTE: All linear dimensions are in millimeters

IMPORTANT NOTICE AND DISCLAIMER

TI PROVIDES TECHNICAL AND RELIABILITY DATA (INCLUDING DATA SHEETS), DESIGN RESOURCES (INCLUDING REFERENCE DESIGNS), APPLICATION OR OTHER DESIGN ADVICE, WEB TOOLS, SAFETY INFORMATION, AND OTHER RESOURCES "AS IS" AND WITH ALL FAULTS, AND DISCLAIMS ALL WARRANTIES, EXPRESS AND IMPLIED, INCLUDING WITHOUT LIMITATION ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

These resources are intended for skilled developers designing with TI products. You are solely responsible for (1) selecting the appropriate TI products for your application, (2) designing, validating and testing your application, and (3) ensuring your application meets applicable standards, and any other safety, security, regulatory or other requirements.

These resources are subject to change without notice. TI grants you permission to use these resources only for development of an application that uses the TI products described in the resource. Other reproduction and display of these resources is prohibited. No license is granted to any other TI intellectual property right or to any third party intellectual property right. TI disclaims responsibility for, and you will fully indemnify TI and its representatives against, any claims, damages, costs, losses, and liabilities arising out of your use of these resources.

TI's products are provided subject to [TI's Terms of Sale](#) or other applicable terms available either on [ti.com](https://www.ti.com) or provided in conjunction with such TI products. TI's provision of these resources does not expand or otherwise alter TI's applicable warranties or warranty disclaimers for TI products.

TI objects to and rejects any additional or different terms you may have proposed.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265
Copyright © 2023, Texas Instruments Incorporated