

### features

- Multi-Rate Operation From 155 Mbps Up To 2.5 Gbps
- Low Power Consumption
- Input Offset Cancellation
- High Input Dynamic Range
- Output Disable
- Output Polarity Select
- CML Data Outputs
- Receive Signal Strength Indicator (RSSI)
- Loss Of Signal Detection (LOS)

- Single 3.3-V Supply
- Surface Mount Small Footprint 3 mm × 3 mm 16-Pin QFN Package

### applications

- SONET/SDH Transmission Systems at OC3, OC12, OC24, OC48
- 1.0625-Gbps and 2.125-Gbps Fibre Channel Receivers
- Gigabit Ethernet Receivers

### description

The ONET2501PA is a versatile high-speed limiting amplifier for multiple fiber optic applications with data rates up to 2.5 Gbps.

This device provides a gain of about 50 dB, which ensures a fully differential output swing for input signals as low as 3 mV<sub>p-p</sub>.

The high input signal dynamic range ensures low jitter output signals even when overdriven with input signal swings as high as 1200 mV<sub>p-p</sub>.

The ONET2501PA is available in a small footprint 3 mm × 3 mm, 16-pin QFN package. The circuit requires a single 3.3-V supply.

This power efficient limiting amplifier is characterized for operation from –40°C to 85°C



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PRODUCTION DATA information is current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.



# ONET2501PA 155-Mbps TO 2.5-Gbps LIMITING AMPLIFIER

SLLS602B – MARCH 2004 – REVISED OCTOBER 2005

## block diagram

A simplified block diagram of the ONET2501PA is shown in Figure 1.

This compact, low power 2.5-Gbps limiting amplifier consists of a high-speed data path with offset cancellation block, a loss of signal and RSSI detection block, and a bandgap voltage reference and bias current generation block.

The limiting amplifier requires a single 3.3-V supply voltage. All circuit parts are described in detail below.

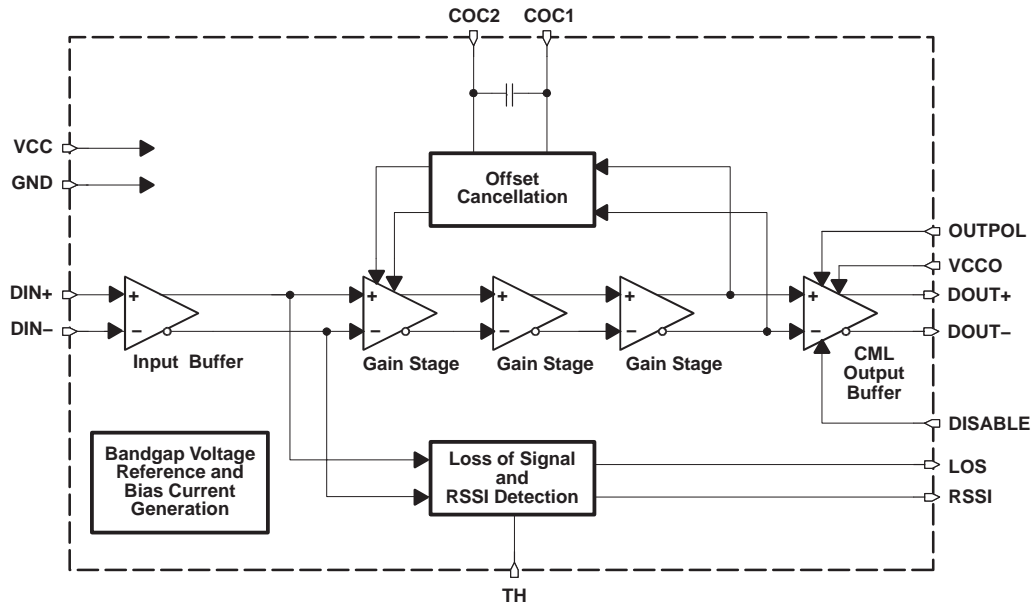


Figure 1. Block Diagram

## high-speed data path

The high-speed data signal is applied to the data path by means of the input signal pins DIN+/DIN-. The data path consists of the input stage with  $2 \times 50\text{-}\Omega$  on-chip line termination to VCC, three gain stages, which provide the required typical gain of about 50 dB, and a CML output stage. The amplified data output signal is available at the output pins DOUT+/DOUT-, which provide  $2 \times 50\text{-}\Omega$  back-termination to VCCO. The output stage also includes a data polarity switching function, which is controlled by the OUTPOL input, and a disable function, controlled by the signal applied to the DISABLE input pin.

An offset cancellation compensates inevitable internal offset voltages and thus ensures proper operation even for small input data signals.

The low frequency cutoff is as low as 45 kHz with the built-in filter capacitor.

For applications, which require even lower cutoff frequencies, an additional external filter capacitor may be connected to the COC1/COC2 pins.

## loss of signal and RSSI detection

The output signal of the input buffer is monitored by the loss of signal and RSSI detection circuitry. In this block a signal is generated, which is linearly proportional to the input amplitude over a wide input voltage range. This signal is available at the RSSI output pin.

Furthermore, this circuit block compares the input signal to a threshold, which can be programmed by means of an external resistor connected to the TH pin. If the input signal falls below the specified threshold, a loss of signal is indicated at the LOS pin.

The relationship between the LOS assert voltage  $V_{AST}$  (in mV<sub>p-p</sub>) and the external resistor  $R_{TH}$  (in k $\Omega$ ) connected to the TH pin can be approximated as given below:

$$R_{TH} = \frac{43 \text{ k}\Omega}{V_{AST}/\text{mV}_{p-p}} - 600 \Omega$$

$$V_{AST} = \frac{43 \text{ mV}_{p-p}}{R_{TH}/\text{k}\Omega + 0.6}$$

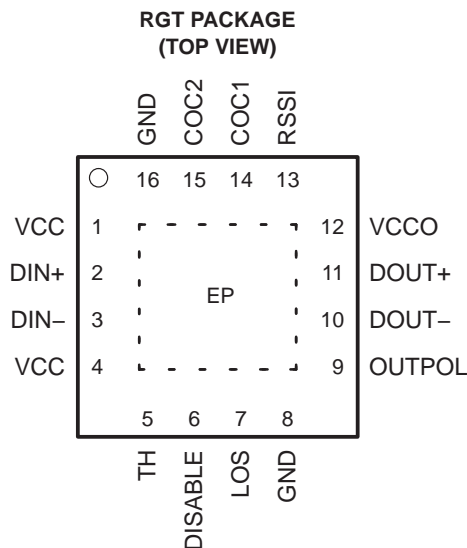
### bandgap voltage and bias generation

The ONET2501PA limiting amplifier is supplied by a single 3.3-V  $\pm 10\%$  supply voltage connected to the VCC and VCCO pins. This voltage is referred to ground (GND).

An on-chip bandgap voltage circuitry generates a supply voltage independent reference from which all other internally required voltages and bias currents are derived.

### package

For the ONET2501PA a small footprint 3 mm  $\times$  3 mm 16-pin QFN package is used, with a lead pitch of 0,5 mm. The pin out is shown in Figure 2.



**Figure 2. Pin Out of ONET2501PA in a 3 mm  $\times$  3 mm 16-Pin QFN Package, Top View**

# ONET2501PA

## 155-Mbps TO 2.5-Gbps LIMITING AMPLIFIER

SLLS602B – MARCH 2004 – REVISED OCTOBER 2005

### terminal functions

The following table shows a pin description for the ONET2501PA in a 3 mm x 3 mm 16-pin QFN package.

| TERMINAL |           | TYPE       | DESCRIPTION   |
|----------|-----------|------------|---|
| NAME     | NO.       |            |   |
| VCC      | 1, 4      | Supply     | 3.3-V $\pm$ 10% supply voltage  |
| DIN+     | 2         | Analog in  | Noninverted data input. On-chip 50- $\Omega$ terminated to VCC.   |
| DIN-     | 3         | Analog in  | Inverted data input. On-chip 50- $\Omega$ terminated to VCC.  |
| TH       | 5         | Analog in  | LOS threshold adjustment with resistor to GND.  |
| DISABLE  | 6         | CMOS in    | Disables CML output stage when set to high level.   |
| LOS      | 7         | CMOS out   | High level indicates that the input signal amplitude is below the programmed threshold level.   |
| GND      | 8, 16, EP | Supply     | Circuit ground. Exposed die pad (EP) must be grounded.  |
| OUTPOL   | 9         | CMOS in    | Output data signal polarity select (internally pulled up): Setting to high level or leaving pin open selects normal polarity. Low level selects inverted polarity.  |
| DOUT-    | 10        | CML out    | Inverted data output. On-chip 50- $\Omega$ back-terminated to VCCO  |
| DOUT+    | 11        | CML out    | Noninverted data output. On-chip 50- $\Omega$ back-terminated to VCCO   |
| VCCO     | 12        | Supply     | 3.3-V $\pm$ 10% supply voltage for output stage   |
| RSSI     | 13        | Analog out | Analog output voltage proportional to the input data amplitude. Indicates the strength of the received signal (RSSI).   |
| COC1     | 14        | Analog     | Offset cancellation filter capacitor terminal 1. Connect an additional filter capacitor between this pin and COC2 (pin 15). To disable the offset cancellation loop connect COC1 and COC2 (pins 14 and 15). |
| COC2     | 15        | Analog     | Offset cancellation filter capacitor terminal 2. Connect an additional filter capacitor between this pin and COC1 (pin 14). To disable the offset cancellation loop connect COC1 and COC2 (pins 14 and 15). |

### absolute maximum ratings

over operating free-air temperature range unless otherwise noted<sup>†</sup>

|   |   | VALUE     | UNIT     |
|---|---|-----------|----------|
| VCC, VCCO   | Supply voltage, See Note 1  | -0.3 to 4 | V        |
| VDIN+, VDIN-  | Voltage at DIN+, DIN-, See Note 1   | 0.5 to 4  | V        |
| VTH, DISABLE, LOS, OUTPOL, DOUT+, DOUT-, RSSI, COC1, and COC2 | Voltage at TH, DISABLE, LOS, OUTPOL, DOUT+, DOUT-, RSSI, COC1, and COC2, See Note 1 | -0.3 to 4 | V        |
| VCOC,DIFF   | Differential voltage between COC1 and COC2  | $\pm$ 1   | V        |
| VDIN,DIFF   | Differential voltage between DIN+ and DIN-  | $\pm$ 2.5 | V        |
| ILOS  | Current into LOS  | -1 to 9   | mA       |
| IDIN+, IDIN-, IDOUT+, IDOUT-                                  | Continuous current at inputs and outputs  | -25 to 25 | mA       |
| ESD   | ESD rating at all pins  | 3         | kV (HBM) |
| TJ(max)   | Maximum junction temperature  | 125       | °C       |
| Tstg  | Storage temperature range   | -65 to 85 | °C       |
| TA  | Characterized free-air operating temperature range                                  | -40 to 85 | °C       |
| TL  | Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds                        | 260       | °C       |

<sup>†</sup> 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.

NOTE 1: All voltage values are with respect to network ground terminal.



# ONET2501PA 155-Mbps TO 2.5-Gbps LIMITING AMPLIFIER

SLLS602B – MARCH 2004 – REVISED OCTOBER 2005

## recommended operating conditions

|                                       | MIN | TYP | MAX | UNIT |
|---------------------------------------|-----|-----|-----|------|
| Supply voltage, $V_{CC}$ , $V_{CCO}$  | 3   | 3.3 | 3.6 | V    |
| Operating free-air temperature, $T_A$ | -40 |     | 85  | °C   |

## dc electrical characteristics

over recommended operating conditions (unless otherwise noted)

| PARAMETER                                       | TEST CONDITIONS   | MIN  | TYP  | MAX  | UNIT              |
|---|---|------|------|------|-------------------|
| $V_{CC}, V_{CCO}$ Supply voltage                |   | 3    | 3.3  | 3.6  | V                 |
| $I_{CC}$ Supply current                         | DISABLE = low (excludes CML output current)                       |      | 32   | 40   | mA                |
| $V_{OD}$ Differential data output voltage swing | DISABLE = high  |      | 0.25 | 10   | mV <sub>p-p</sub> |
|   | DISABLE = low   | 600  | 780  | 1200 | mV <sub>p-p</sub> |
| $r_{IN}, r_{OUT}$ Data input/output resistance  | Single ended  |      | 50   |      | Ω                 |
| RSSI output voltage                             | Input = 2 mV <sub>p-p</sub> , $R_{RSSI} \geq 10 \text{ k}\Omega$  |      | 100  |      | mV                |
|   | Input = 80 mV <sub>p-p</sub> , $R_{RSSI} \geq 10 \text{ k}\Omega$ |      | 2800 |      |                   |
| RSSI linearity                                  | 20-dB input signal, $V_{IN} \leq 80 \text{ mVpp}$                 |      | ±3%  | ±8%  |                   |
| $V_{(IN\_MIN)}$ Data input sensitivity          | BER < $10^{-10}$  |      | 3    | 5    | mV <sub>p-p</sub> |
| $V_{(IN\_MAX)}$ Data input overload             |   | 1200 |      |      | mV <sub>p-p</sub> |
| CMOS input high voltage                         |   | 2.1  |      |      | V                 |
| CMOS input low voltage                          |   |      |      | 0.6  | V                 |
| LOS high voltage                                | $I_{SINK} = -30 \mu\text{A}$                                      | 2.4  |      |      | V                 |
| LOS low voltage                                 | $I_{SOURCE} = 1 \text{ mA}$                                       |      |      | 0.8  | V                 |
| LOS hysteresis                                  | $2^{23}-1$ PRBS (at 2.5 Gbps and 155 Mbps)                        | 2.5  | 4.5  |      | dB                |
| $V_{AST}$ LOS assert threshold range            | $2^{23}-1$ PRBS (at 2.5 Gbps and 155 Mbps)                        |      | 5-40 |      | mV <sub>p-p</sub> |
| PSNR Power supply noise rejection               | $f < 2 \text{ MHz}$   | 26   |      |      | dB                |

## ac electrical characteristics

over recommended operating conditions (unless otherwise noted) typical operating condition is at  $V_{CC} = 3.3 \text{ V}$  and  $T_A = 25^\circ\text{C}$

| PARAMETER                           | TEST CONDITIONS                                | MIN | TYP | MAX | UNIT              |
|-------------------------------------|--|-----|-----|-----|-------------------|
| Low frequency -3-dB bandwidth       | $C_{OC} = \text{open}$                         |     | 45  | 70  | kHz               |
|                                     | $C_{OC} = 100 \text{ nF}$                      |     | 0.8 |     |                   |
| Data rate                           |  | 2.5 |     |     | Gb/s              |
| $V_{NI}$ Input referred noise       |  |     |     | 300 | $\mu\text{VRMS}$  |
| DJ Deterministic jitter, See Note 2 | K28.5 pattern at 2.5 Gbps                      |     | 8.5 | 25  | ps <sub>p-p</sub> |
|                                     | $2^{23}-1$ PRBS equivalent pattern at 2.5 Gbps |     | 9.3 | 30  |                   |
|                                     | $2^{23}-1$ PRBS equivalent pattern at 155 Mbps |     | 25  | 50  |                   |
| RJ Random jitter                    | Input = 5 mVpp                                 |     | 6.5 |     | ps <sub>RMS</sub> |
|                                     | Input = 10 mVpp                                |     | 3   |     |                   |
| $t_r$ Output rise time              | 20% to 80%                                     |     | 60  | 85  | ps                |
| $t_f$ Output fall time              | 20% to 80%                                     |     | 60  | 85  | ps                |
| $t_{DIS}$ Disable response time     |  |     | 20  |     | ns                |
| $t_{LOS}$ LOS assert/deassert time  |  | 2   |     | 100 | $\mu\text{s}$     |

NOTE 2: Deterministic jitter does not include pulse-width distortion due to residual small output offset voltage.



# ONET2501PA 155-Mbps TO 2.5-Gbps LIMITING AMPLIFIER

SLLS602B – MARCH 2004 – REVISED OCTOBER 2005

## APPLICATION INFORMATION

Figure 3 shows the ONET2501PA connected with an ac-coupled interface to the data signal source as well as to the output load.

Besides the ac-coupling capacitors  $C_1$  through  $C_4$  in the input and output data signal lines, the only required external component is the LOS threshold setting resistor  $R_{TH}$ . In addition, an optional external filter capacitor ( $C_{OC}$ ) may be used if a lower cutoff frequency is desired.

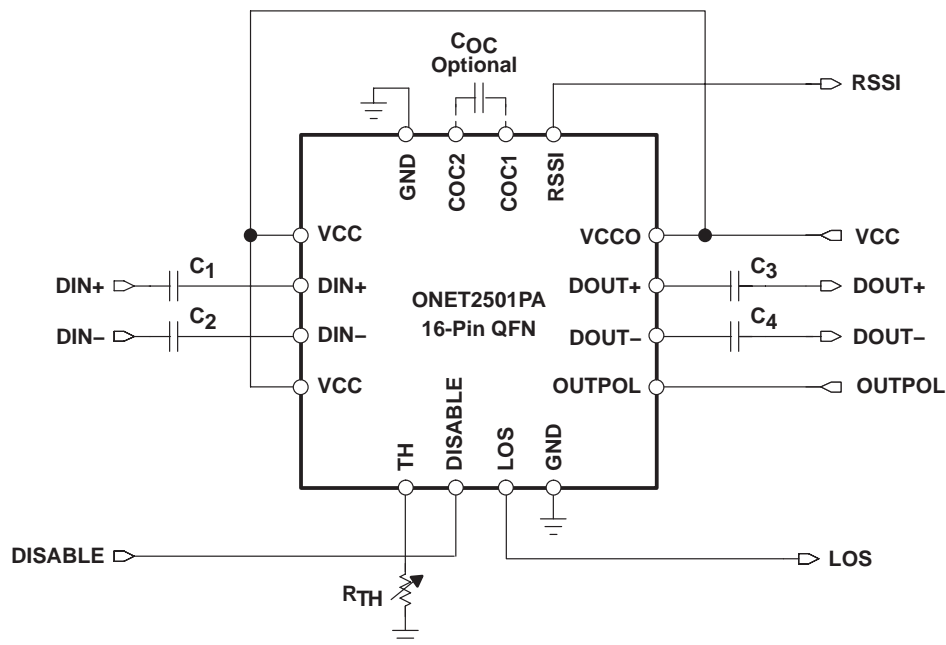


Figure 3. Basic Application Circuit With AC-Coupled I/Os

**TYPICAL CHARACTERISTICS**

Typical operating condition is at  $V_{CC} = V_{CCO} = 3.3\text{ V}$  and  $T_A = 25^\circ\text{C}$ , unless otherwise noted

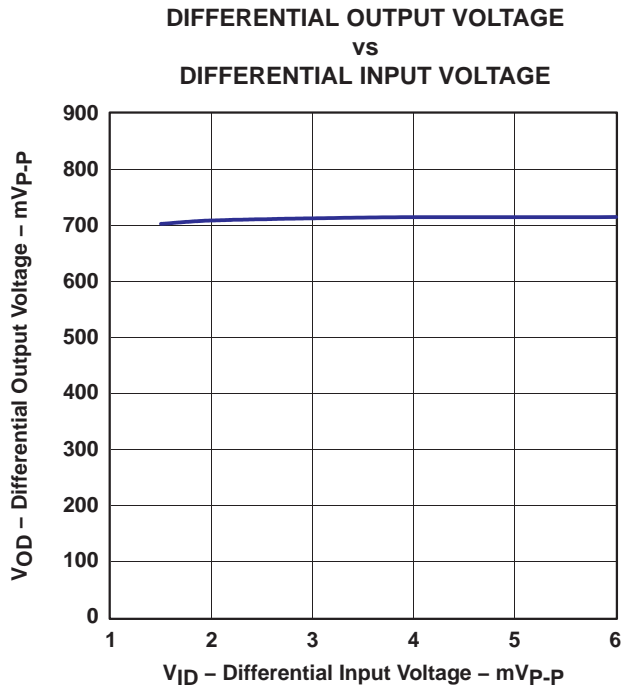


Figure 4

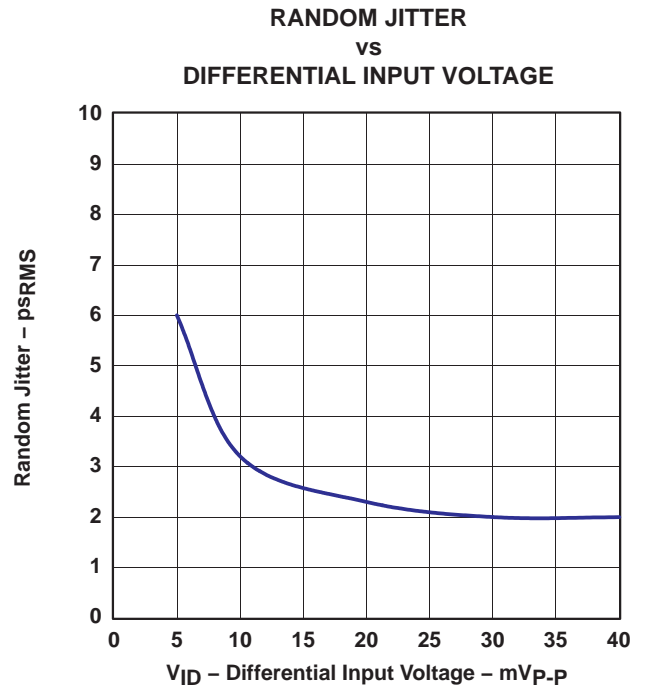


Figure 5

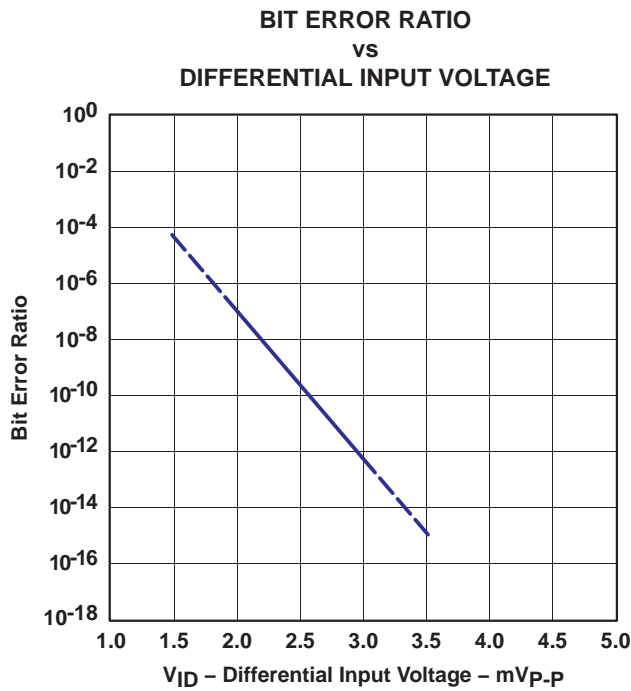


Figure 6

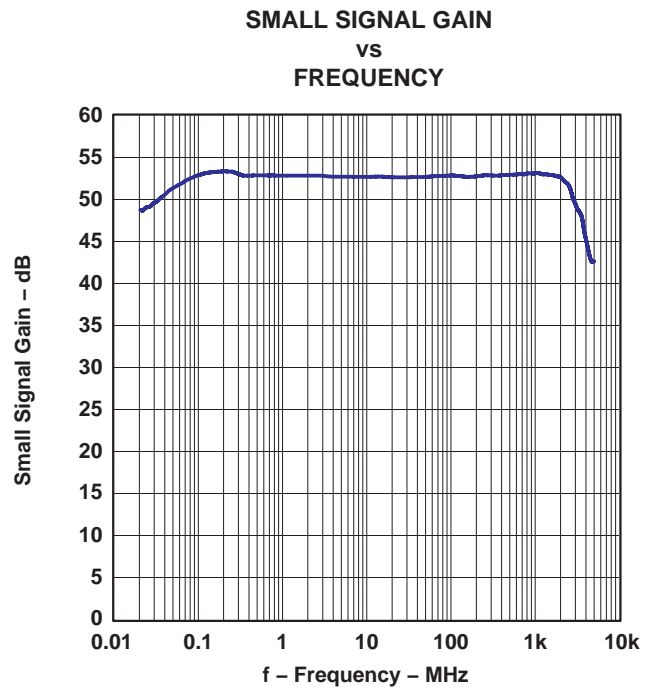
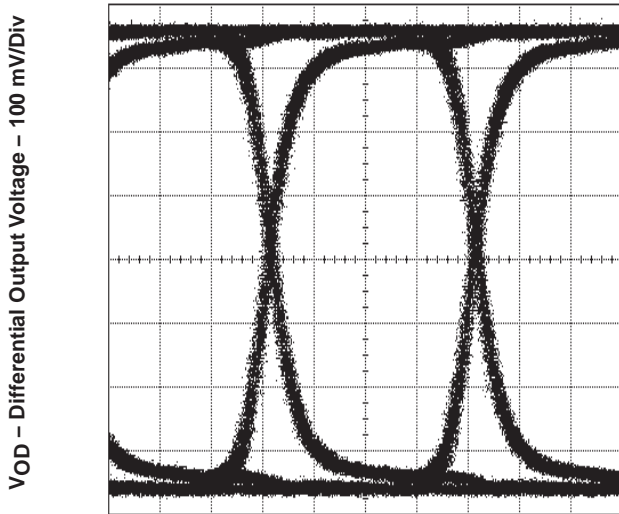


Figure 7

**TYPICAL CHARACTERISTICS**

Typical operating condition is at  $V_{CC} = V_{CCO} = 3.3\text{ V}$  and  $T_A = 25^\circ\text{C}$ , unless otherwise noted

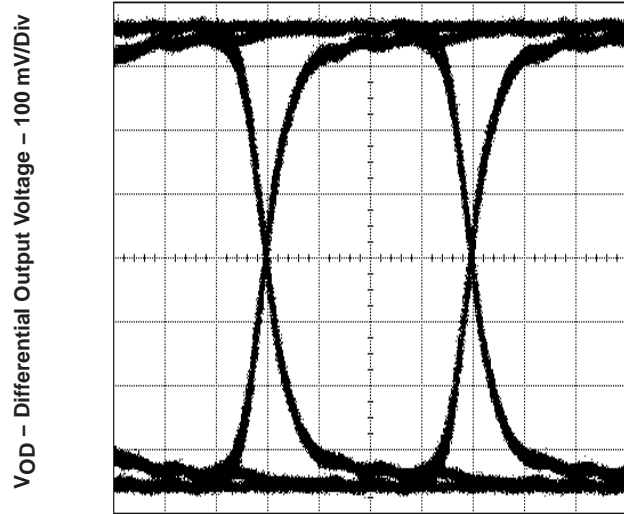
**OUTPUT EYE-DIAGRAM at 2.5 GBPS  
 and MINIMUM INPUT VOLTAGE (5 mV<sub>pp</sub>)**



t - Time - 100 ps/Div

**Figure 8**

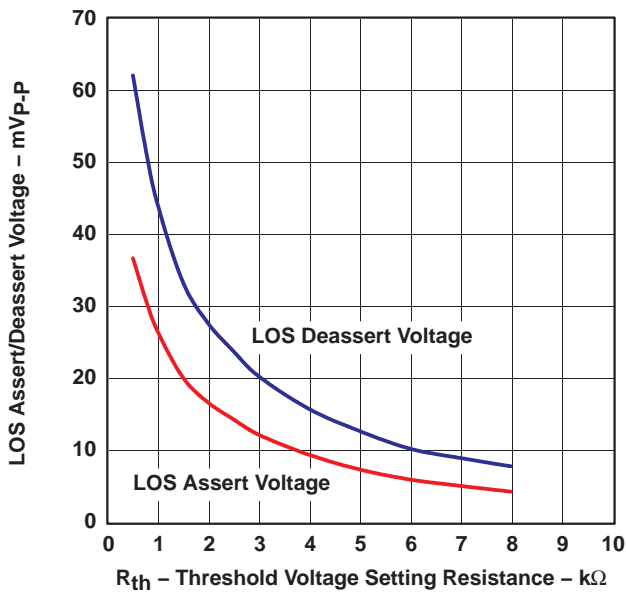
**OUTPUT EYE-DIAGRAM at 2.5 GBPS  
 and MAXIMUM INPUT VOLTAGE (1200 mV<sub>pp</sub>)**



t - Time - 100 ps/Div

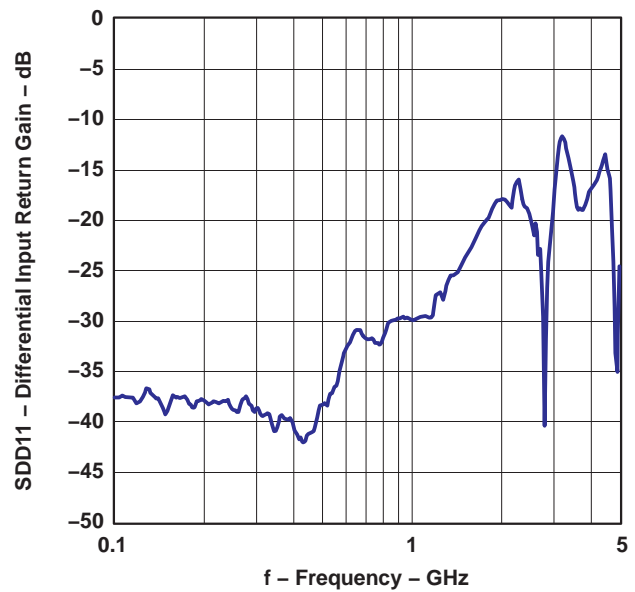
**Figure 9**

**LOS ASSERT/DEASSERT VOLTAGE  
 VS  
 THRESHOLD VOLTAGE SETTING RESISTANCE**



**Figure 10**

**DIFFERENTIAL INPUT RETURN GAIN  
 VS  
 FREQUENCY**

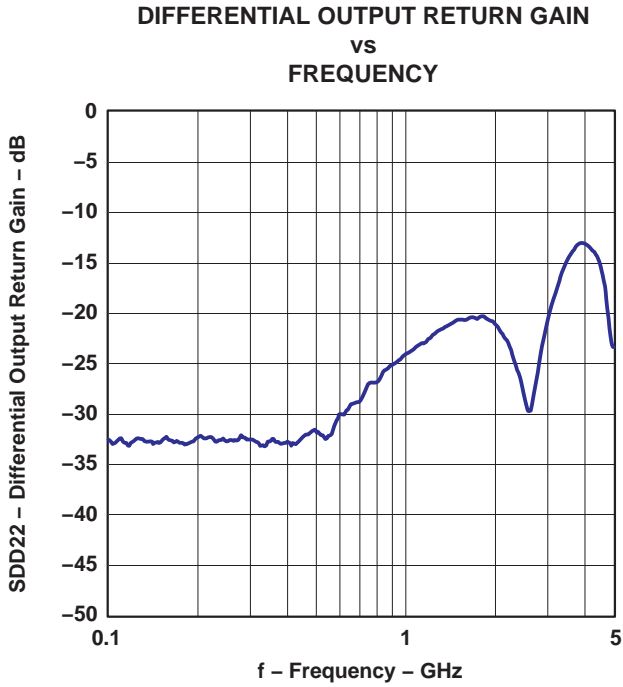


**Figure 11**

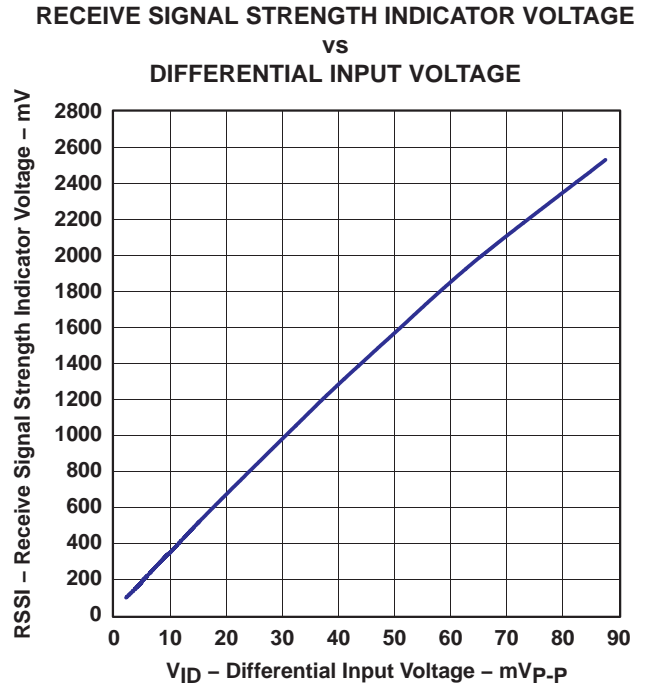


**TYPICAL CHARACTERISTICS**

Typical operating condition is at  $V_{CC} = V_{CCO} = 3.3\text{ V}$  and  $T_A = 25^\circ\text{C}$ , unless otherwise noted



**Figure 12**



**Figure 13**

**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> |
|------------------|-----------------------|--------------|-----------------|------|-------------|-------------------------|------------------|------------------------------|
| ONET2501PARGTR   | NRND                  | QFN          | RGT             | 16   | 3000        | Green (RoHS & no Sb/Br) | CU NIPDAU        | Level-2-260C-1 YEAR          |
| ONET2501PARGTRG4 | NRND                  | QFN          | RGT             | 16   | 3000        | Green (RoHS & no Sb/Br) | CU NIPDAU        | Level-2-260C-1 YEAR          |
| ONET2501PARGTT   | NRND                  | QFN          | RGT             | 16   | 250         | Green (RoHS & no Sb/Br) | CU NIPDAU        | Level-2-260C-1 YEAR          |
| ONET2501PARGTTG4 | NRND                  | QFN          | RGT             | 16   | 250         | Green (RoHS & no Sb/Br) | CU NIPDAU        | Level-2-260C-1 YEAR          |

<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.

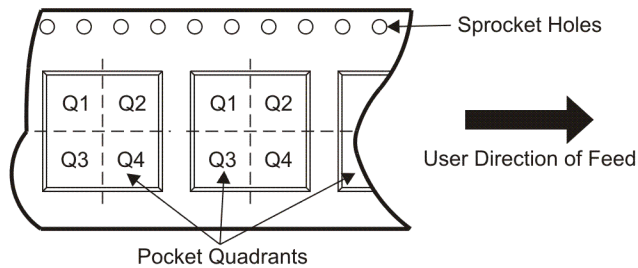
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**TAPE AND REEL INFORMATION**



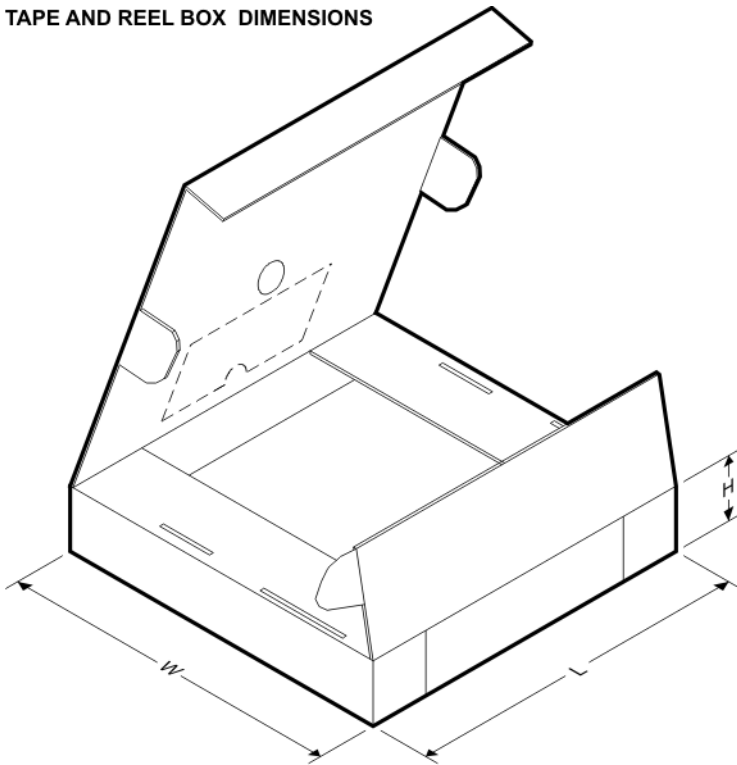
**QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE**



\*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 |
|----------------|--------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| ONET2501PARGTR | QFN          | RGT             | 16   | 3000 | 330.0              | 12.4               | 3.3     | 3.3     | 1.1     | 8.0     | 12.0   | Q2            |
| ONET2501PARGTT | QFN          | RGT             | 16   | 250  | 330.0              | 12.4               | 3.3     | 3.3     | 1.1     | 8.0     | 12.0   | Q2            |

**TAPE AND REEL BOX DIMENSIONS**

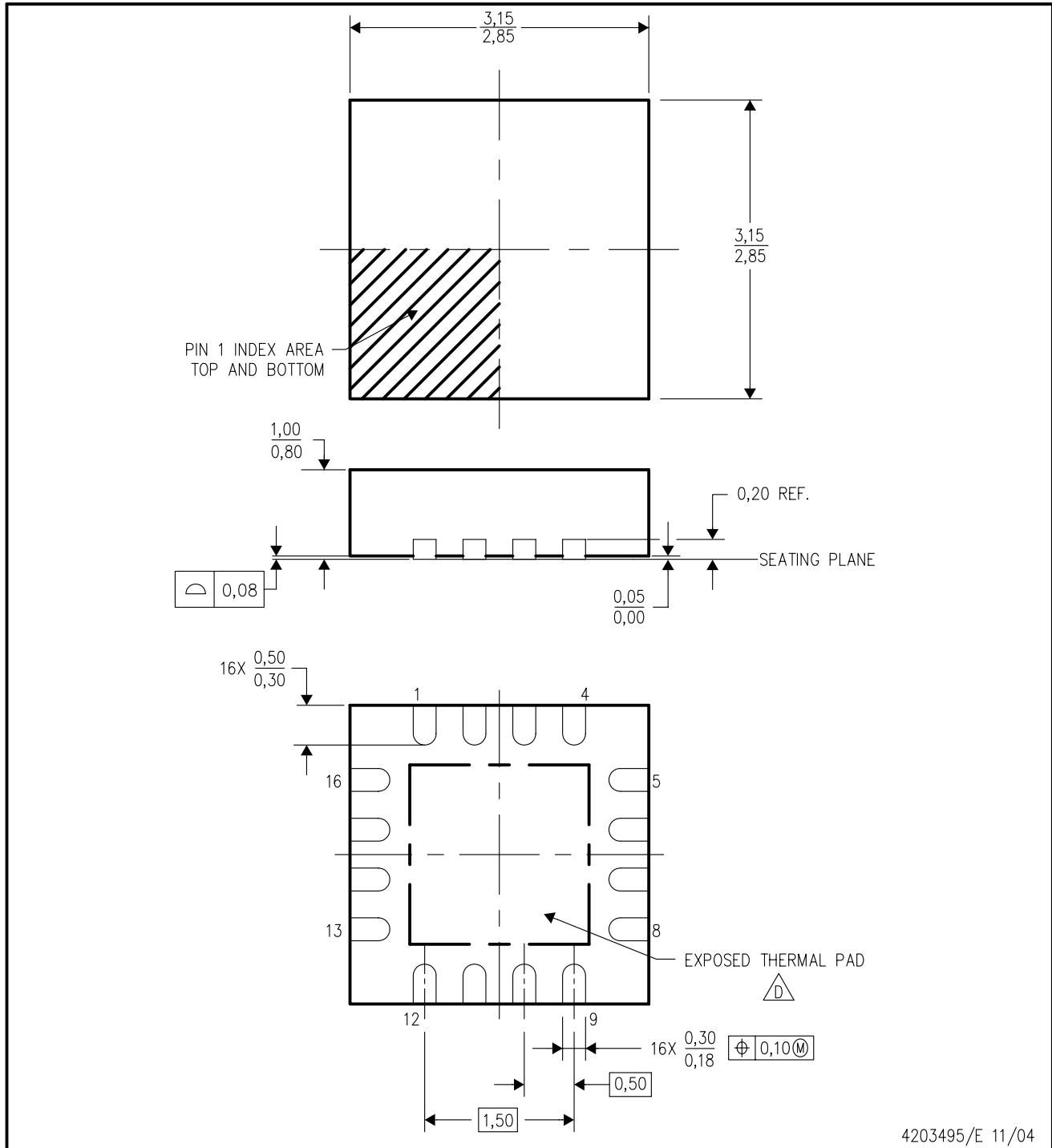


\*All dimensions are nominal

| Device         | Package Type | Package Drawing | Pins | SPQ  | Length (mm) | Width (mm) | Height (mm) |
|----------------|--------------|-----------------|------|------|-------------|------------|-------------|
| ONET2501PARGTR | QFN          | RGT             | 16   | 3000 | 340.5       | 333.0      | 20.6        |
| ONET2501PARGTT | QFN          | RGT             | 16   | 250  | 340.5       | 333.0      | 20.6        |

RGT (S-PQFP-N16)

PLASTIC QUAD FLATPACK



4203495/E 11/04

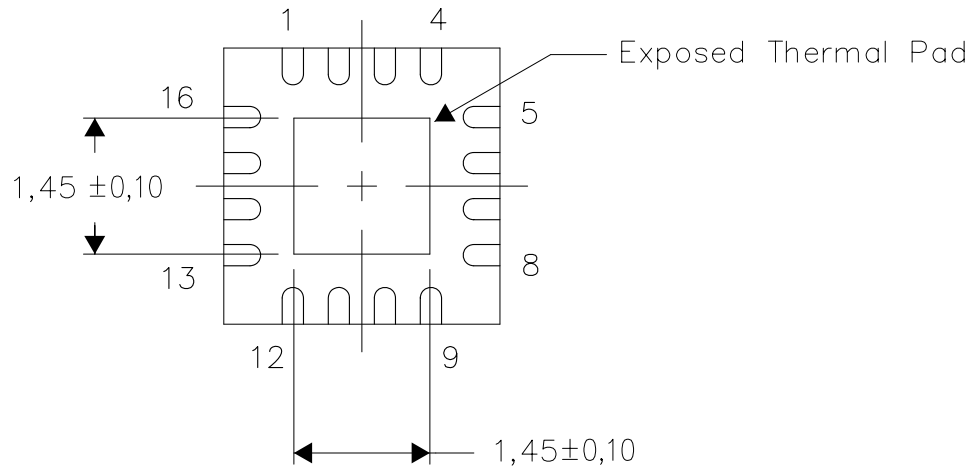
- NOTES:
- A. All linear dimensions are in millimeters. Dimensioning and tolerancing per ASME Y14.5M-1994.
  - B. This drawing is subject to change without notice.
  - C. Quad Flatpack, No-leads (QFN) package configuration.
  - D. The package thermal pad must be soldered to the board for thermal and mechanical performance. See the Product Data Sheet for details regarding the exposed thermal pad dimensions.
  - E. Falls within JEDEC MO-220.

**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, Quad Flatpack No-Lead Logic Packages, Texas Instruments Literature No. SCBA017. 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.

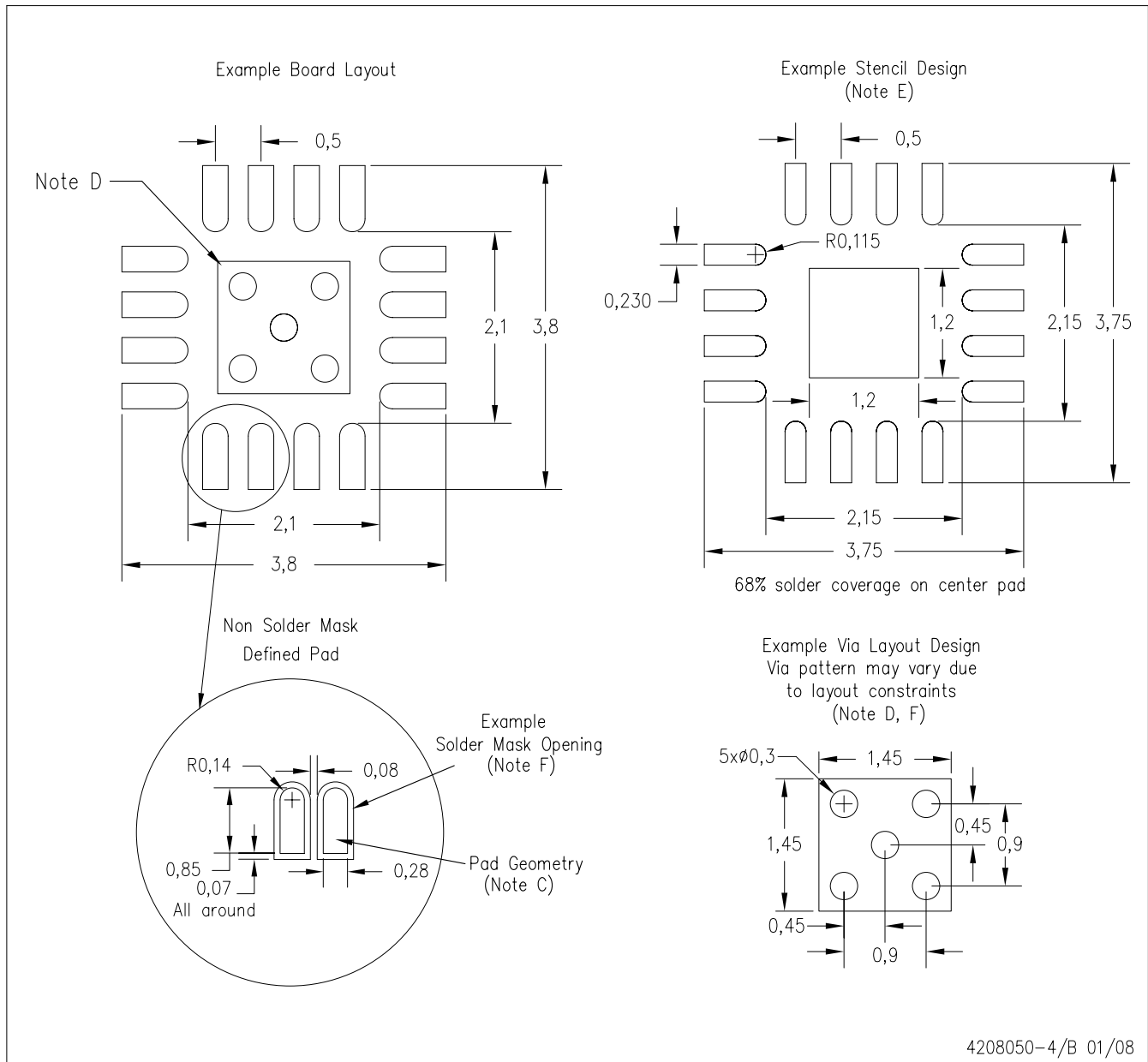


Bottom View

NOTE: All linear dimensions are in millimeters

Exposed Thermal Pad Dimensions

RGT (S-PQFP-N16)



- 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. SCBA017, 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 minimum solder mask web tolerances between signal pads.

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