4.25-Gbps Transimpedance Amplifier With AGC and RSSI

FEATURES

- **2.8-GHz Bandwidth**
- **3.2-kΩ Differential Transimpedance**
- **Automatic Gain Control (AGC)**
- **8.8-pA/√Hz Typical Input Referred Noise**
- **2-mA$_{p-p}$ Maximum Input Current**
- **Received Signal Strength Indication (RSSI)**
- **CML Data Outputs With On-Chip 50-Ω Back-Termination**
- **On-Chip Supply Filter Capacitor**
- **Single 3.3-V Supply**
- **Die Size: 0,78 × 1,18 mm**

APPLICATIONS

- **SONET/SDH Transmission Systems at OC24 and OC48**
- **4.25-Gbps, 2.125-Gbps, and 1.0625-Gbps Fiber-Channel Receivers**
- **Gigabit Ethernet Receivers**
- **PIN Preamplifier-Receivers**

DESCRIPTION

The ONET4291TA is a high-speed transimpedance amplifier used in optical receivers with data rates up to 4.25 Gbps.

It features a low input referred noise, 2.8-GHz bandwidth, automatic gain control (AGC), 3.2-kΩ transimpedance, and received signal strength indication (RSSI).

The ONET4291TA is available in die form and is optimized for use in a TO can.

The ONET4291TA requires a single 3.3-V supply, and its power-efficient design typically dissipates less than 56 mW. The device is characterized for operation from –40°C to 85°C ambient temperature.

AVAILABLE OPTIONS

T_A	DIE
–40°C to 85°C	ONET4291TAY

BLOCK DIAGRAM

The ONET4291TA is a high-performance, 4.25-Gbps transimpedance amplifier consisting of the signal path, supply filter, a control block for dc input current cancellation, automatic gain control (AGC), received signal strength indication (RSSI), and a band-gap voltage reference and bias current generation block.

The signal path comprises a transimpedance amplifier stage, a voltage amplifier, and a CML output buffer.

The on-chip filter circuit provides filtered V_{CC} for the photodiode and for the transimpedance amplifier. The dc input current cancellation and AGC use internal low-pass filters to cancel the dc current on the input and to adjust the transimpedance amplifier gain. Furthermore, circuitry to monitor the received signal strength is provided.

A simplified block diagram of the ONET4291TA is shown in Figure 1.

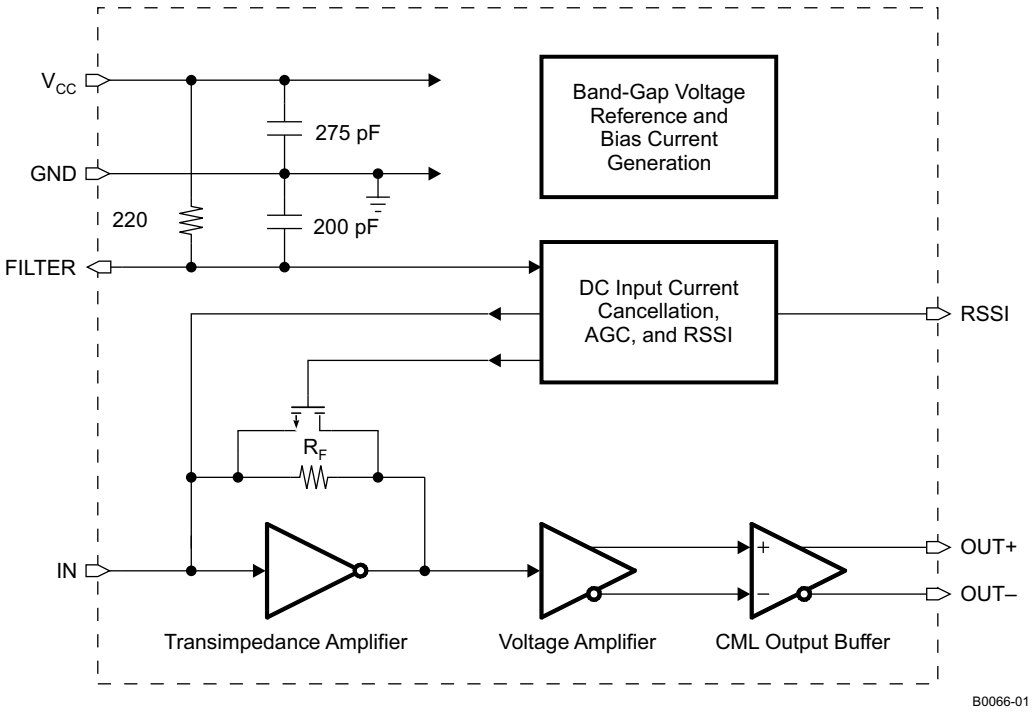


Figure 1. Simplified Block Diagram of the ONET4291TA

SIGNAL PATH

The first stage of the signal path is a transimpedance amplifier that takes the photodiode current and converts it into a voltage signal.

If the input signal current exceeds a certain value, the transimpedance gain is reduced by means of AGC circuitry.

The second stage is a voltage amplifier that provides additional gain and converts its single-ended input voltage into a differential data signal.

The third signal-path stage is the output buffer, which provides CML outputs with on-chip, 50-Ω back-termination to V_{CC}.

FILTER CIRCUITRY

The filter pin provides filtered V_{CC} for the photodiode bias. The on-chip, low-pass filter for the photodiode V_{CC} is implemented using a filter resistor of 220 Ω and an internal 200-pF capacitor. The corresponding corner frequency is below 4 MHz.

The supply voltage for the whole amplifier is filtered by means of an on-chip, 275-pF capacitor as well, thus avoiding the necessity to use an external supply-filter capacitor.

DC INPUT CURRENT CANCELLATION, AGC, AND RSSI

The voltage drop across the internal photodiode supply-filter resistor is monitored by means of a dc input current cancellation, AGC, and RSSI control circuit block.

If the dc input current exceeds a certain level, it is partially cancelled by means of a controlled current source. This measure keeps the transimpedance amplifier stage within sufficient operating point limits for optimum performance. Furthermore, disabling the dc input cancellation at low input currents leads to superior noise performance.

The AGC circuitry lowers the effective transimpedance feedback resistor R_F by means of a MOSFET device acting as a controlled shunt. This prevents the transimpedance amplifier from being overdriven at high input currents, which leads to improved jitter behavior within the complete input-current dynamic range. Because the voltage drop across the supply-filter resistor is sensed and used by the AGC circuit, the photodiode must be connected to a FILTER pad for the AGC to function correctly.

Finally, this circuit block senses the current through the filter resistor and generates a mirrored current, which is proportional to the input signal strength. The mirrored current is available at the RSSI output and must be sunk to ground (GND) using an external resistor. The RSSI gain can be adjusted by choosing the external resistor; however, for proper operation, ensure that the voltage at the RSSI pad never exceeds V_{CC} – 0.65 V.

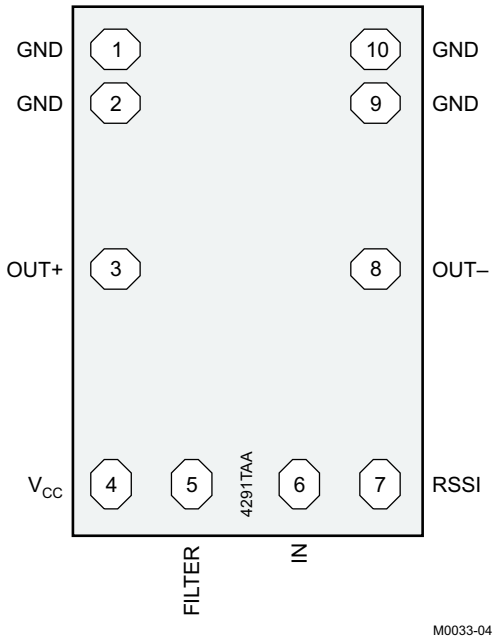
BAND-GAP VOLTAGE AND BIAS GENERATION

The ONET4291TA transimpedance amplifier is supplied by a single, 3.3-V supply voltage connected to the V_{CC} pad. This voltage is referred to GND.

On-chip band-gap voltage circuitry generates a supply-voltage-independent reference from which all other internally required voltages and bias currents are derived.

BOND PAD ASSIGNMENT

The ONET4291TA is available as a bare die. The locations of the bond pads are shown in the following figure.



BOND PAD DESCRIPTION

PAD		TYPE	DESCRIPTION
NAME	NO.		
FILTER	5	Analog	Bias voltage for photodiode (cathode). This pads connects through an internal 220-Ω resistor to V_{CC} and a 200-pF filter capacitor to ground (GND). The FILTER pad(s) must be connected to the photodiode for the AGC to function.
GND	1, 2, 9, 10	Supply	Circuit ground. All GND pads are connected on die. Bonding all pads is optional; however, for optimum performance a good ground connection is mandatory.
IN	6	Analog input	Data input to TIA (photodiode anode)
OUT+	3	Analog output	Non-inverted data output. On-chip 50-Ω back-terminated to V_{CC}.
OUT–	8	Analog output	Inverted data output. On-chip 50-Ω back-terminated to V_{CC}.
RSSI	7	Analog output	Analog output current proportional to the input data amplitude. Indicates the strength of the received signal (RSSI). Must be sunk through an external resistor to ground (GND). The RSSI gain can be adjusted by choosing the external resistor; however, for proper operation, ensure that the voltage at the RSSI pad never exceeds V_{CC} – 0.65 V. If the RSSI feature is not used, this pad must be bonded to ground (GND) to ensure proper operation.
V_{CC}	4	Supply	3.3-V, +10%/–12% supply voltage

ABSOLUTE MAXIMUM RATINGS

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

V_{CC}	Supply voltage (2)	–0.3 V to 4 V
V_{FILTER}, V_{OUT+}, $V_{OUT–}$, V_{RSSI}	Voltage at FILTER, OUT+, OUT–, RSSI (2)	–0.3 V to 4 V
I_{IN}	Current into IN	–0.7 mA to 2.5 mA
I_{FILTER}	Current into FILTER	– 8 mA to 8 mA
I_{OUT+}, $I_{OUT–}$	Continuous current at outputs	– 8 mA to 8 mA
ESD	ESD rating at all pins except IN (3)	1.5 kV (HBM)
	ESD rating at IN (3)	300 V (HBM)
$T_{J,max}$	Maximum junction temperature	125°C
T_{stg}	Storage temperature range	–65°C to 85°C
T_A	Operating free-air temperature range	–40°C to 85°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 voltage values are with respect to network ground terminal.
(3) For optimum high-frequency performance, the input pin has reduced ESD protection.

RECOMMENDED OPERATING CONDITIONS

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

		MIN	NOM	MAX	UNIT
V_{CC}	Supply voltage	2.9	3.3	3.6	V
T_A	Operating free-air temperature	–40		85	°C
L_{FILTER}, L_{IN}	Wire-bond inductor at pins FILTER and IN			0.8	nH
C_{PD}	Photodiode capacitance		0.2		pF

DC ELECTRICAL CHARACTERISTICS

over recommended operating conditions (unless otherwise noted). Typical values are at V_{CC} = 3.3 V and T_A = 25°C.

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
V_{CC}	Supply voltage		2.9	3.3	3.6	V
I_{VCC}	Supply current	Average photodiode current I_{PD} = 0 mA	11	17	25	mA
V_{IN}	Input bias voltage			0.85	1.05	V
R_{OUT}	Output resistance	Single-ended to V_{CC}	40	50	60	Ω
R_{FILTER}	Photodiode filter resistance			220		Ω

AC ELECTRICAL CHARACTERISTICS

over recommended operating conditions (unless otherwise noted). Typical values are at V_{CC} = 3.3 V and T_A = 25°C.

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
i_{IN-OVL}	AC input overload current		2			mA_{p-p}
A_{RSSI}	RSSI gain	Resistive load to GND (1)	0.95	1	1.05	A/A
	RSSI output offset current (no light)			15	30	µA
Z_{21}	Small-signal transimpedance	Differential output; input current i_{IN} = 50 μA_{p-p}	2300	3200	3900	Ω
$f_{H,3dB}$	Small-signal bandwidth	i_{IN} = 50 μA_{p-p} (2)	2.2	2.8		GHz
$f_{L,3dB}$	Low-frequency, –3-dB bandwidth	– 3 dB, input current i_{IN} < 50 μA_{p-p}		40	70	kHz
$f_{H,3dB,RSSI}$	RSSI bandwidth			3.5		MHz
i_{N-IN}	Input referred RMS noise	50 kHz–4 GHz (3)		465	590	nA
	Input referred noise current density			8.8		pA/√Hz
DJ	Deterministic jitter	i_{IN} = 50 μA_{p-p} (K28.5 pattern) (4)		10	23	ps_{p-p}
		i_{IN} = 100 μA_{p-p} (K28.5 pattern) (4)		10	30	
		i_{IN} = 1 mA_{p-p} (K28.5 pattern)		8	28	
		i_{IN} = 2 mA_{p-p} (K28.5 pattern)		13	42	
$V_{OUT,D,MAX}$	Maximum differential output voltage	Input current i_{IN} = 1 mA_{p-p}	140	200	310	mV_{p-p}

(1) The RSSI output is a current output, which requires a resistive load to ground (GND). The voltage gain can be adjusted for the intended application by choosing the external resistor. However, for proper operation of the ONET4291TA, ensure that the voltage at RSSI never exceeds V_{CC} – 0.65 V.

(2) The minimum small-signal bandwidth is specified over process corners, temperature, and supply voltage variation. The assumed photodiode capacitance is 0.2 pF. The bond-wire inductance is 0.8 nH. The small-signal bandwidth strongly depends on environmental parasitics. Careful attention to layout parasitics and external components is necessary to achieve optimal performance.

(3) Input referred RMS noise is (RMS output noise)/(gain @ 100 MHz). The maximum input referred noise is specified over process corners, temperature, and supply voltage variation.

(4) At small input currents a significant portion of the deterministic jitter (DJ) is caused by duty-cycle distortion (DCD) due to residual offset in the output signal. Because the TIA is not limiting, the DCD portion of the DJ is removed by the following limiting amplifier. The given maximum values include DCD as well as six-sigma margin.

TYPICAL CHARACTERISTICS

Typical operating condition is at V_{CC} = 3.3 V and T_A = 25°C.

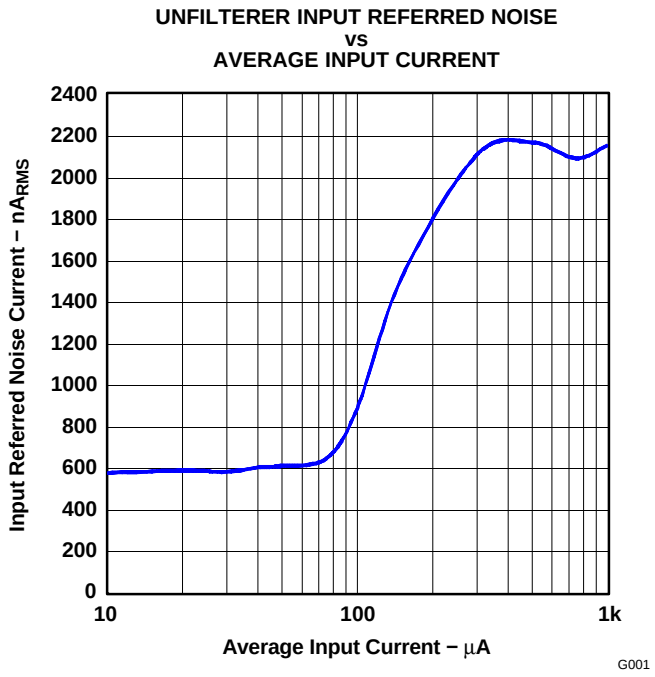


Figure 2.

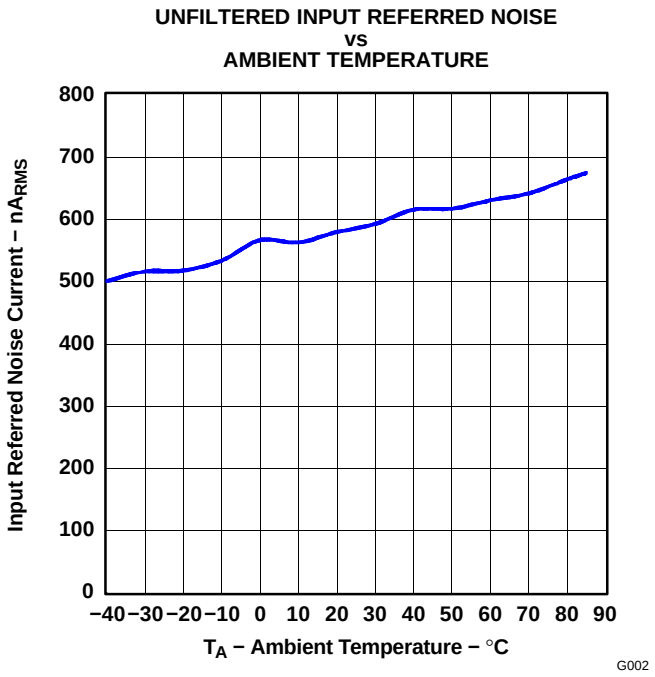


Figure 3.

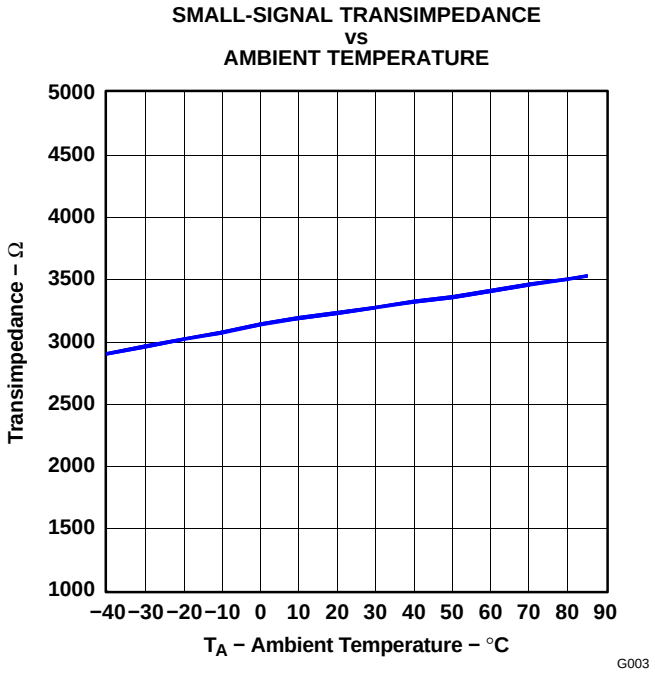


Figure 4.

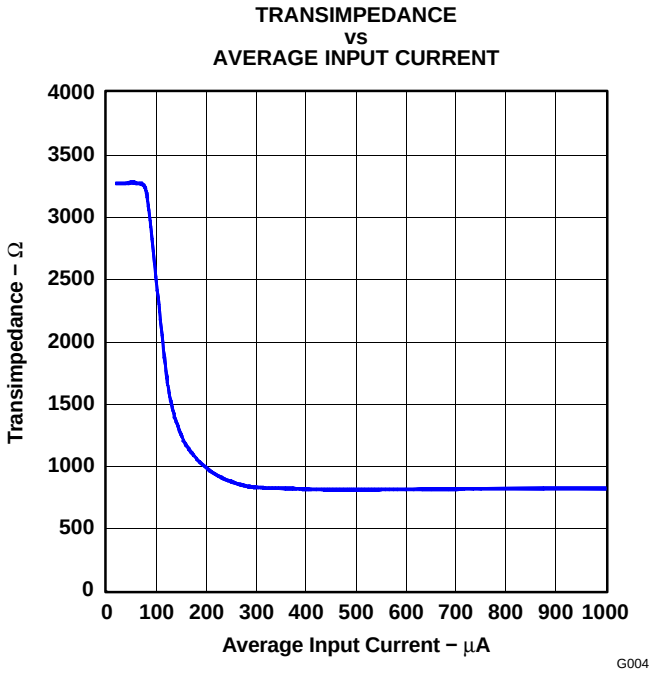


Figure 5.

TYPICAL CHARACTERISTICS (continued)

Typical operating condition is at V_{CC} = 3.3 V and T_A = 25°C.

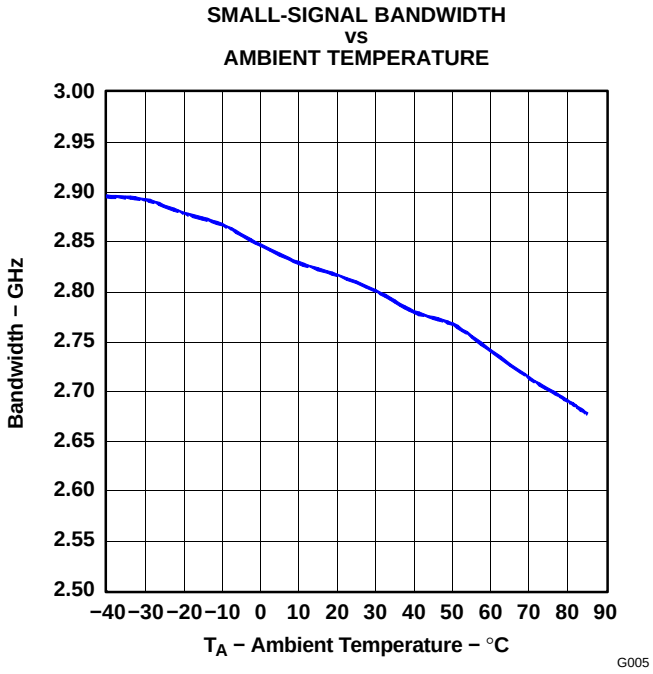


Figure 6.

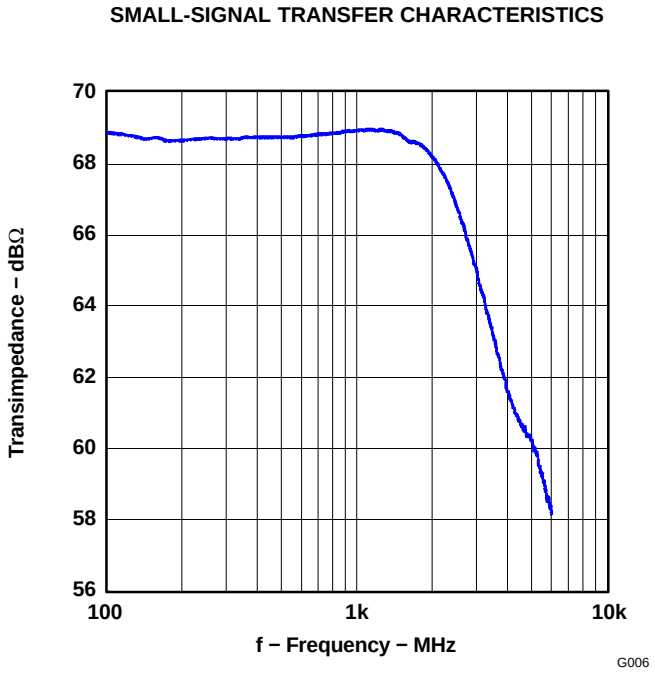


Figure 7.

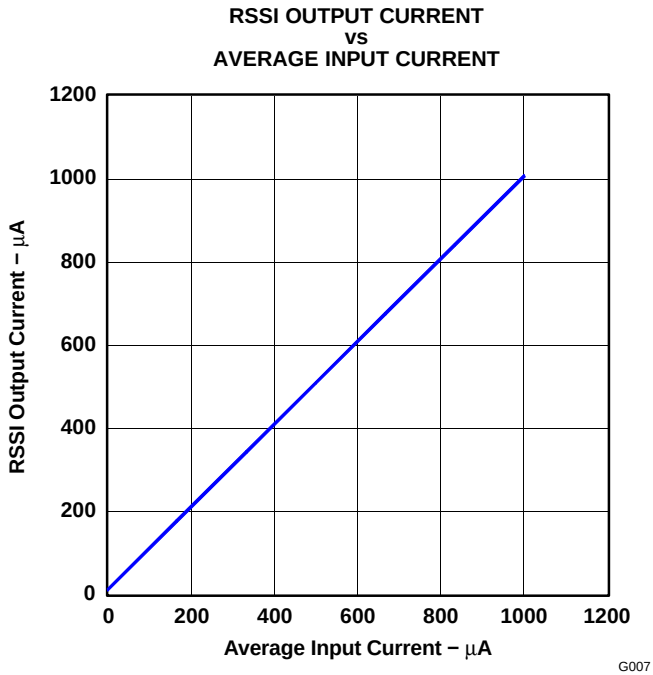


Figure 8.

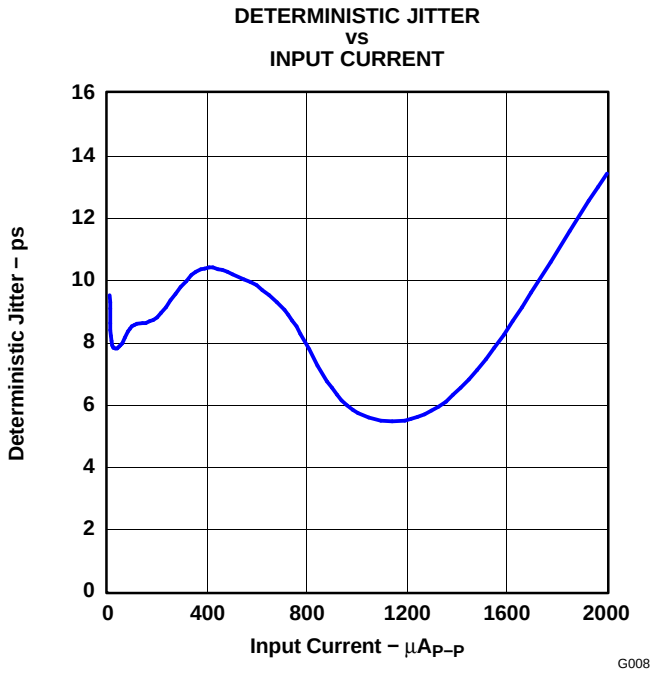


Figure 9.

TYPICAL CHARACTERISTICS (continued)

Typical operating condition is at V_{CC} = 3.3 V and T_A = 25°C.

OUTPUT EYE DIAGRAM AT 4.25 Gbps AND 10-μA_{p-p} INPUT CURRENT

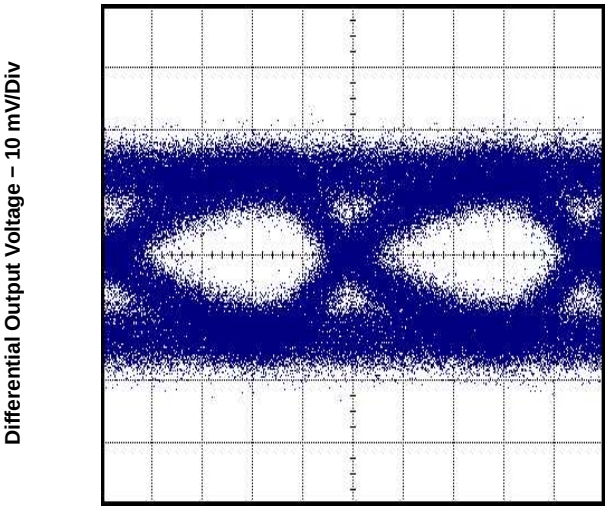


Figure 10.

OUTPUT EYE DIAGRAM AT 4.25 Gbps AND 20-μA_{p-p} INPUT CURRENT

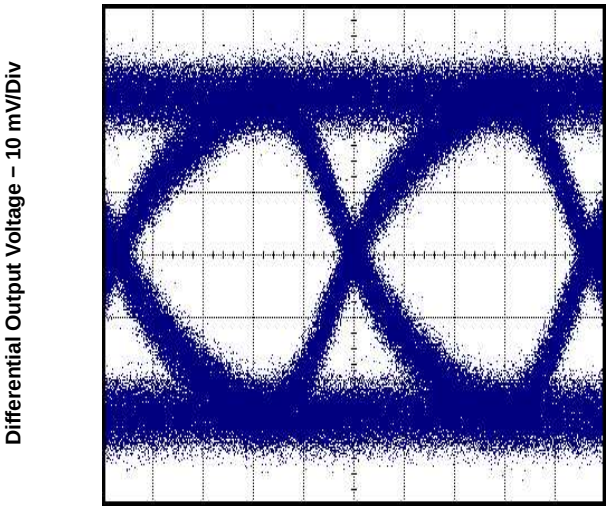


Figure 11.

OUTPUT EYE DIAGRAM AT 4.25 Gbps AND 100-μA_{p-p} INPUT CURRENT

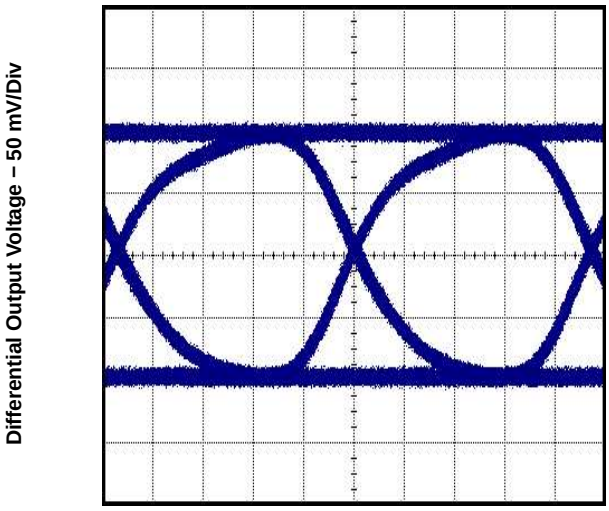


Figure 12.

OUTPUT EYE DIAGRAM AT 4.25 Gbps AND 1-mA_{p-p} INPUT CURRENT

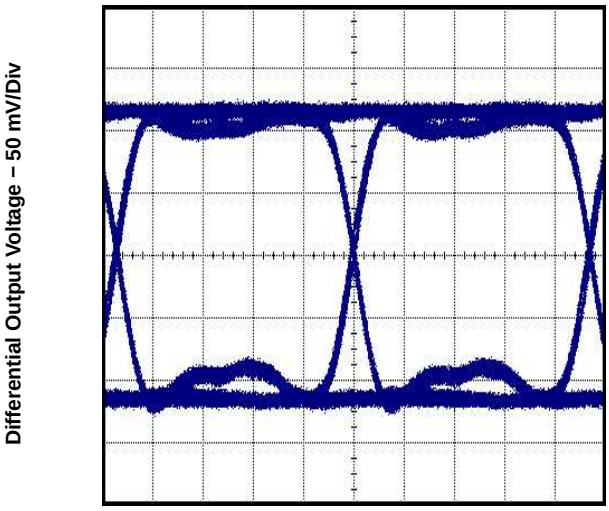


Figure 13.

TYPICAL CHARACTERISTICS (continued)

Typical operating condition is at V_{CC} = 3.3 V and T_A = 25°C.

OUTPUT EYE DIAGRAM AT 4.25 Gbps AND 2-mA_{p-p} INPUT CURRENT

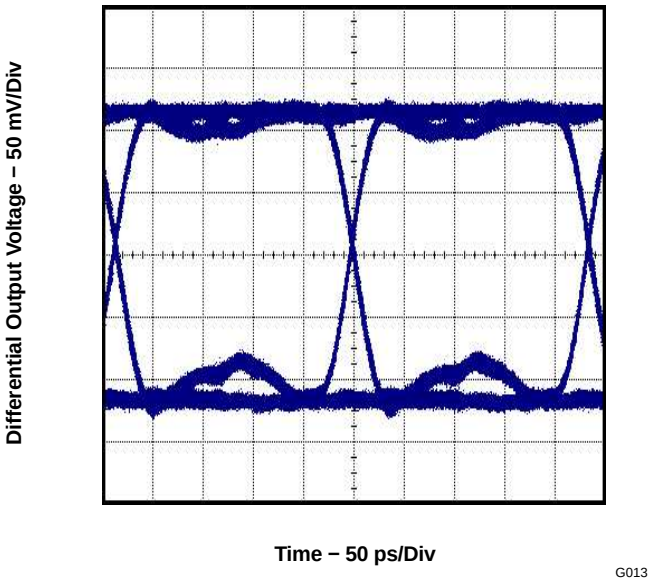


Figure 14.

APPLICATION INFORMATION

Figure 15 shows an application circuit for an ONET4291TA being used in a typical fiber-optic receiver. The ONET4291TA converts the electrical current generated by the PIN photodiode into a differential output voltage. The FILTER input provides a dc bias voltage for the PIN that is low-pass filtered by the combination of the internal 220-Ω resistor and 200-pF capacitor. Because the voltage drop across the 220-Ω resistor is sensed and used by the AGC circuit, the photodiode must be connected to a FILTER pad for the AGC to function correctly.

The RSSI output is used to mirror the photodiode average current and must be connected via a resistor to GND. The voltage gain can be adjusted for the intended application by choosing the external resistor. However, for proper operation of the ONET4291TA, ensure that the voltage at RSSI never exceeds V_{CC} – 0.65 V. If the RSSI output is not used, it must be grounded.

The OUT+ and OUT– pads are internally terminated by 50-Ω pullup resistors to V_{CC}. The outputs must be ac-coupled (e.g., using C1 = C2 = 0.1 μF) to the succeeding device. An additional capacitor, C_{NBW}, which is differentially connected between the two output pins OUT+ and OUT–, can be used to limit the noise bandwidth and thus optimize the noise performance.

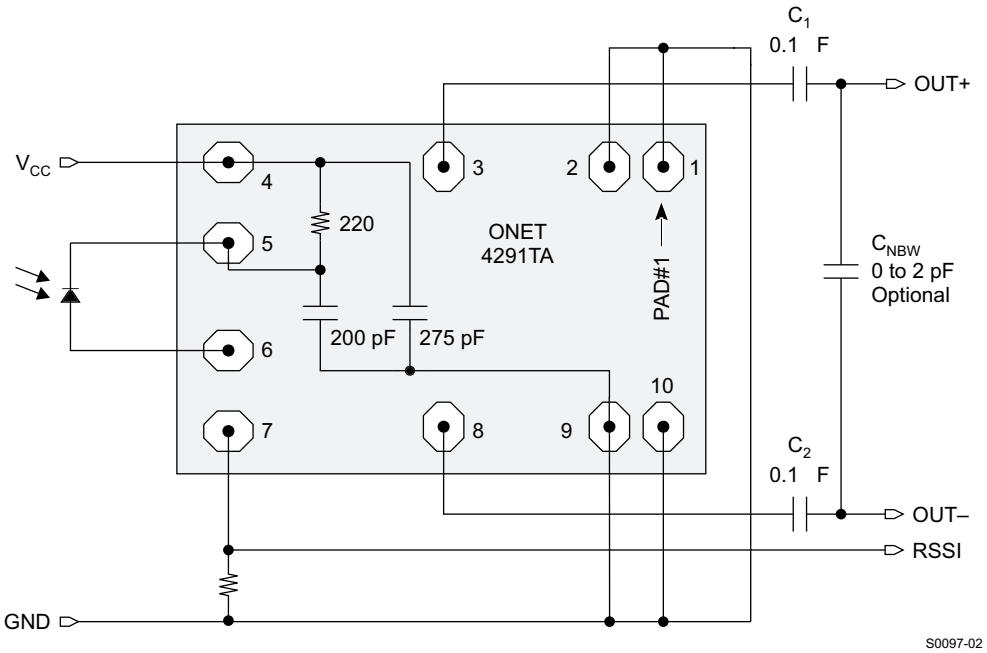


Figure 15. Basic Application Circuit

ASSEMBLY RECOMMENDATIONS

When packaging the ONET4291TA, careful attention to parasitics and external components is necessary to achieve optimal performance. Recommendations that optimize performance include:

1. Minimize total capacitance on the IN pad by using a low-capacitance photodiode and paying attention to stray capacitances. Place the photodiode close to the ONET4291TA die to minimize the bond wire length and thus the parasitic inductance.
2. Use identical termination and symmetrical transmission lines at the ac-coupled differential output pins OUT+ and OUT–. A differential capacitor C_{NBW} can be used to limit the noise bandwidth.
3. Use short bond-wire connections for the supply terminals V_{CC} and GND. Supply-voltage filtering is provided on-chip. Filtering can be improved by using an additional external capacitor.

CHIP DIMENSIONS AND PAD LOCATIONS

Overall chip dimensions and depiction of the bond-pad locations are given in Figure 16. Layout of the chip componentry is shown in Figure 17.

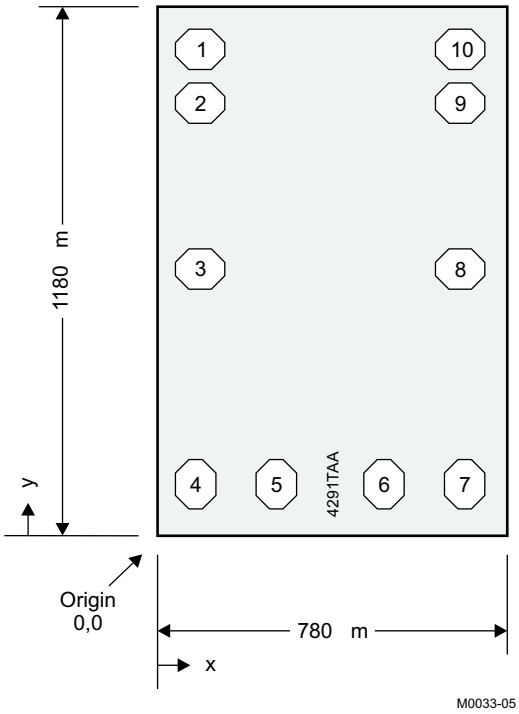


Figure 16. Chip Dimensions and Pad Locations

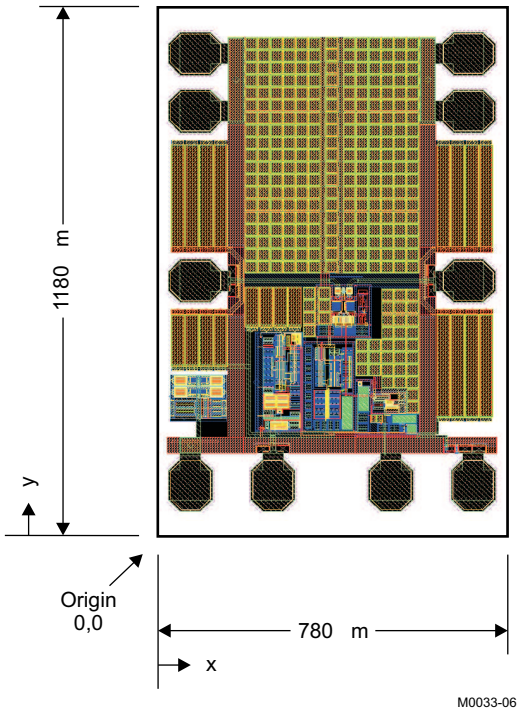


Figure 17. Chip Layout

Pad Locations and Descriptions for the ONET4291TA

PAD	COORDINATES		SYMBOL	TYPE	DESCRIPTION
	x (μm)	y (μm)			
1	100	1063	GND	Supply	Circuit ground
2	100	938	GND	Supply	Circuit ground
3	100	570	OUT+	Analog output	Non-inverted data output
4	90	127	V_{CC}	Supply	3.3-V supply voltage
5	265	127	FILTER	Analog	Bias voltage for photodiode
6	515	127	IN	Analog input	Data input to TIA
7	690	127	RSSI	Analog output	RSSI output signal
8	680	570	OUT–	Analog output	Inverted data output
9	680	938	GND	Supply	Circuit ground
10	680	1063	GND	Supply	Circuit ground

DIE INFORMATION

Die size: 1180 μm × 780 μm
Die thickness: 8 mils (203 μm)
Pad metallization: 99.5% Al, 0.5% Cu
Pad size: octagonal pads 120 μm × 100 μm
Passivation composition: 6000-Å silicon nitride
Backside contact: none
Die ID: 4291TAA

TO46 LAYOUT EXAMPLES

Examples for layouts (top view) in 5-pin and 4-pin TO46 headers are given in Figure 18 and Figure 19, respectively.

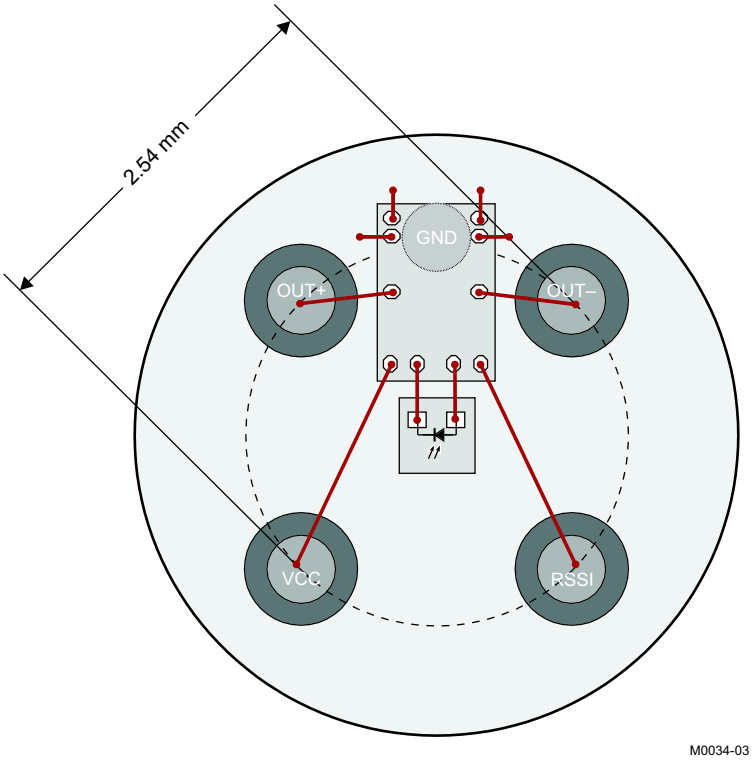


Figure 18. TO46 5-Pin Layout Example Using the ONET4291TA

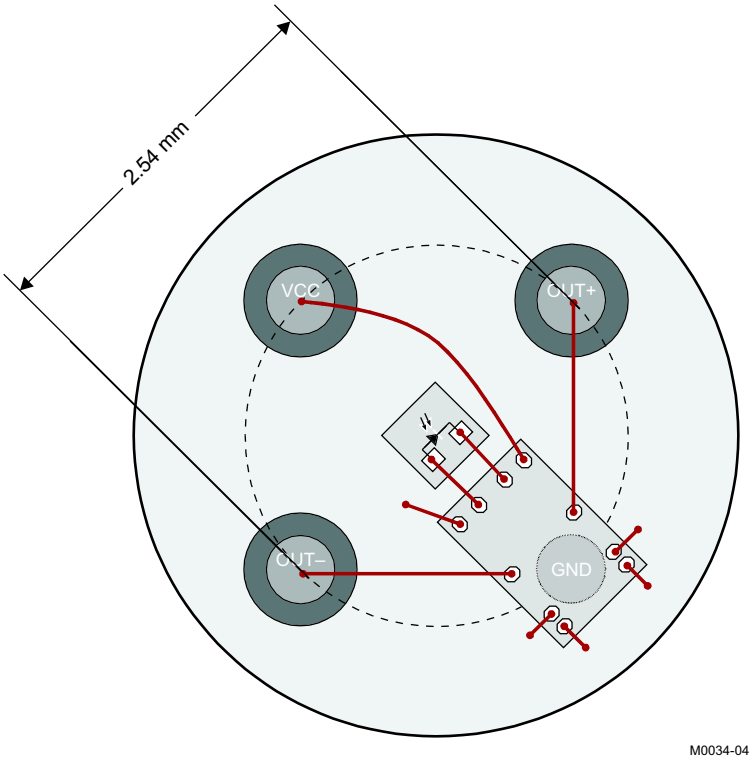


Figure 19. TO46 4-Pin Layout Example Using the ONET4291TA

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/ Ball Finish	MSL Peak Temp (3)	Samples (Requires Login)
ONET4291TAY	ACTIVE	DIESALE	Y	0	1	Green (RoHS & no Sb/Br)	Call TI	N / A for Pkg Type	
ONET4291TAYS	ACTIVE	WAFERSALE	YS	0	1	Green (RoHS & no Sb/Br)	Call TI	N / A for Pkg Type	

(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.

IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, modifications, enhancements, improvements, and other changes to its products and services at any time and to discontinue any product or service without notice. Customers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All products are sold subject to TI's terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its hardware products to the specifications applicable at the time of sale in accordance with TI's standard warranty. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by government requirements, testing of all parameters of each product is not necessarily performed.

TI assumes no liability for applications assistance or customer product design. Customers are responsible for their products and applications using TI components. To minimize the risks associated with customer products and applications, customers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any TI patent right, copyright, mask work right, or other TI intellectual property right relating to any combination, machine, or process in which TI products or services are used. Information published by TI regarding third-party products or services does not constitute a license from TI to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of TI information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. Reproduction of this information with alteration is an unfair and deceptive business practice. TI is not responsible or liable for such altered documentation. Information of third parties may be subject to additional restrictions.

Resale of TI products or services with statements different from or beyond the parameters stated by TI for that product or service voids all express and any implied warranties for the associated TI product or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

TI products are not authorized for use in safety-critical applications (such as life support) where a failure of the TI product would reasonably be expected to cause severe personal injury or death, unless officers of the parties have executed an agreement specifically governing such use. Buyers represent that they have all necessary expertise in the safety and regulatory ramifications of their applications, and acknowledge and agree that they are solely responsible for all legal, regulatory and safety-related requirements concerning their products and any use of TI products in such safety-critical applications, notwithstanding any applications-related information or support that may be provided by TI. Further, Buyers must fully indemnify TI and its representatives against any damages arising out of the use of TI products in such safety-critical applications.

TI products are neither designed nor intended for use in military/aerospace applications or environments unless the TI products are specifically designated by TI as military-grade or "enhanced plastic." Only products designated by TI as military-grade meet military specifications. Buyers acknowledge and agree that any such use of TI products which TI has not designated as military-grade is solely at the Buyer's risk, and that they are solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI products are neither designed nor intended for use in automotive applications or environments unless the specific TI products are designated by TI as compliant with ISO/TS 16949 requirements. Buyers acknowledge and agree that, if they use any non-designated products in automotive applications, TI will not be responsible for any failure to meet such requirements.

Following are URLs where you can obtain information on other Texas Instruments products and application solutions:

Products		**Applications**	
Audio	www.ti.com/audio	Automotive and Transportation	www.ti.com/automotive
Amplifiers	amplifier.ti.com	Communications and Telecom	www.ti.com/communications
Data Converters	dataconverter.ti.com	Computers and Peripherals	www.ti.com/computers
DLP® Products	www.dlp.com	Consumer Electronics	www.ti.com/consumer-apps
DSP	dsp.ti.com	Energy and Lighting	www.ti.com/energy
Clocks and Timers	www.ti.com/clocks	Industrial	www.ti.com/industrial
Interface	interface.ti.com	Medical	www.ti.com/medical
Logic	logic.ti.com	Security	www.ti.com/security
Power Mgmt	power.ti.com	Space, Avionics and Defense	www.ti.com/space-avionics-defense
Microcontrollers	microcontroller.ti.com	Video and Imaging	www.ti.com/video
RFID	www.ti-rfid.com		
OMAP Mobile Processors	www.ti.com/omap		
Wireless Connectivity	www.ti.com/wirelessconnectivity		
	TI E2E Community Home Page		e2e.ti.com

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265