2.5-Gbps Transimpedance Amplifier With AGC and RSSI

FEATURES

- **1.8-GHz Bandwidth**
- **2.6-kΩ Differential Transimpedance**
- **Automatic Gain Control (AGC)**
- **6.6-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 mm × 1,18 mm**

APPLICATIONS

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

DESCRIPTION

The ONET2591TA is a high-speed transimpedance amplifier used in optical receivers with data rates up to 2.5 Gbps.

It features a low input referred noise, 1.8-GHz bandwidth, automatic gain control (AGC), 2.6-kΩ transimpedance, and received signal strength indication (RSSI).

The ONET2591TA is available in die form and is optimized for use in a TO can.

The ONET2591TA requires a single 3.3-V supply, and its power-efficient design typically dissipates less than 53 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	ONET2591TAY

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BLOCK DIAGRAM

The ONET2591TA is a high-performance, 2.5-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 ONET2591TA is shown in Figure 1.

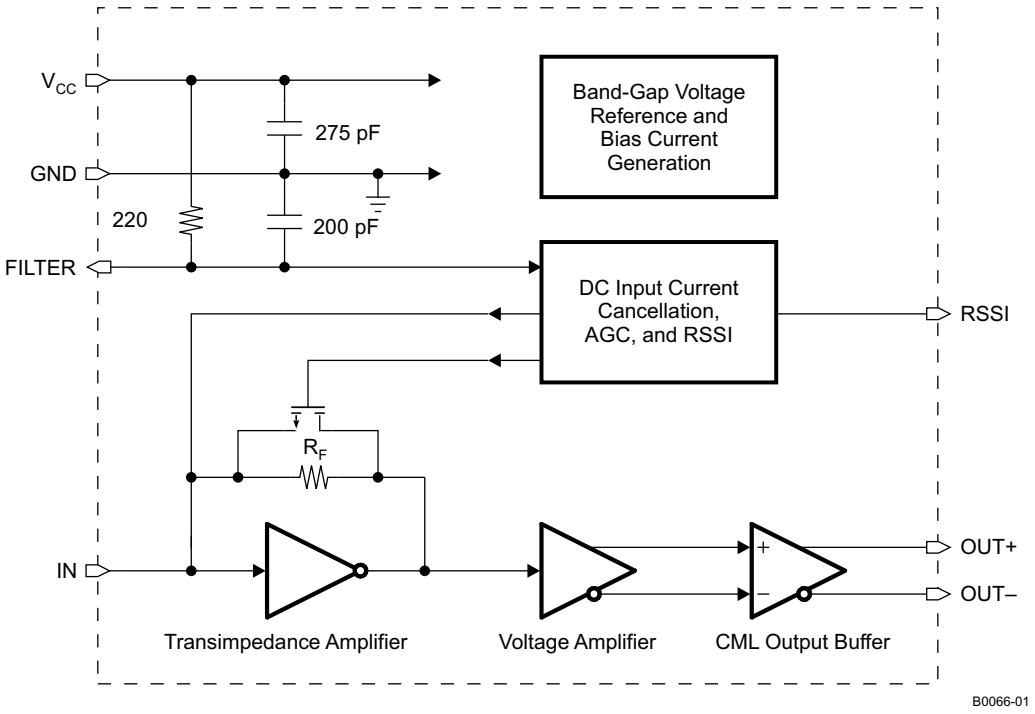


Figure 1. Simplified Block Diagram of the ONET2591TA

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.

If a lower cutoff frequency is required for the intended application, an external capacitor can be connected to one of the FILTER pins.

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.

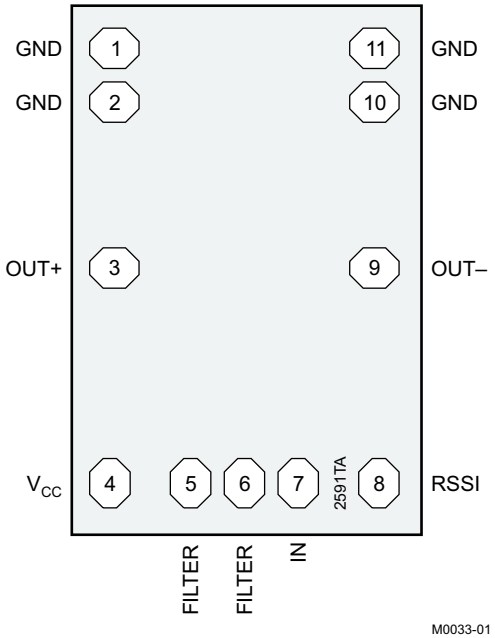
BAND-GAP VOLTAGE AND BIAS GENERATION

The ONET2591TA 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 ONET2591TA 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, 6	Analog	Bias voltage for photodiode (cathode). These pads connect through an internal 220-Ω resistor to V_{CC} and a 200-pF filter capacitor to ground (GND). Both FILTER pads are connected on-chip. For additional photodiode supply filtering, connect an external capacitor from one of the FILTER pads to GND. The FILTER pad(s) must be connected to the photodiode for the AGC to function.
GND	1, 2, 10, 11	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	7	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–	9	Analog output	Inverted data output. On-chip 50-Ω back-terminated to V_{CC}.
RSSI	8	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)	900 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

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	10	14	20	mA
		Average photodiode current I_{PD} = 1 mA	13	17	23	
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)			10	40	µA
Z_{21}	Small-signal transimpedance	Differential output; input current i_{IN} = 50 $µA_{p-p}$	2000	2600	3200	Ω
$f_{H,3dB}$	Small-signal bandwidth	C_{PD} = 0.6 pF, i_{IN} = 50 $µA_{p-p}$ (2)		1.8		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	C_{PD} = 0.6 pF, 50 kHz–2.5 GHz (3)		280	345	nA
	Input referred noise current density	C_{PD} = 0. 6 pF		6.6		pA/√Hz
DJ	Deterministic jitter	i_{IN} = 50 $µA_{p-p}$ (K28.5 pattern)		8	16	ps_{p-p}
		i_{IN} = 100 $µA_{p-p}$ (K28.5 pattern)		8.5	20	
		i_{IN} = 1 mA_{p-p} (K28.5 pattern)		3	10	
		i_{IN} = 2 mA_{p-p} (K28.5 pattern)		4	14	
$V_{OUT,D,MAX}$	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 ONET2591TA, 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 0.6 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.

TYPICAL CHARACTERISTICS

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

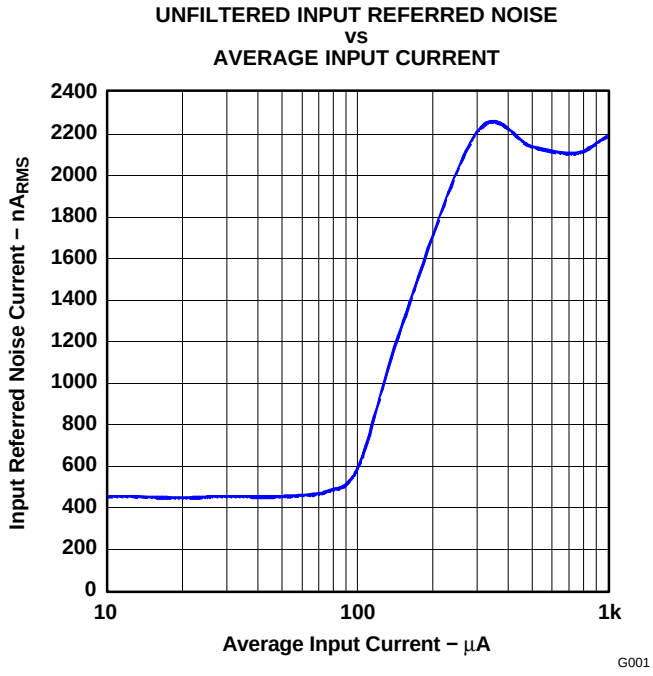


Figure 2.

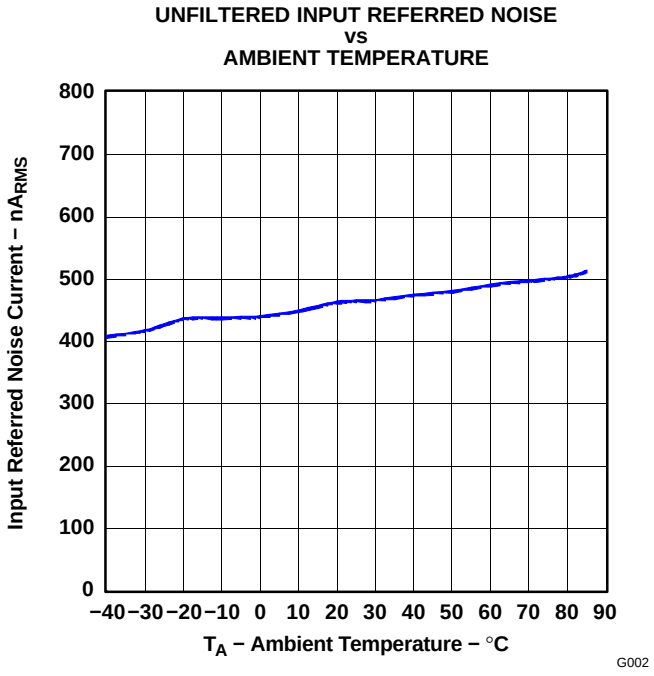


Figure 3.

TYPICAL CHARACTERISTICS (continued)

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

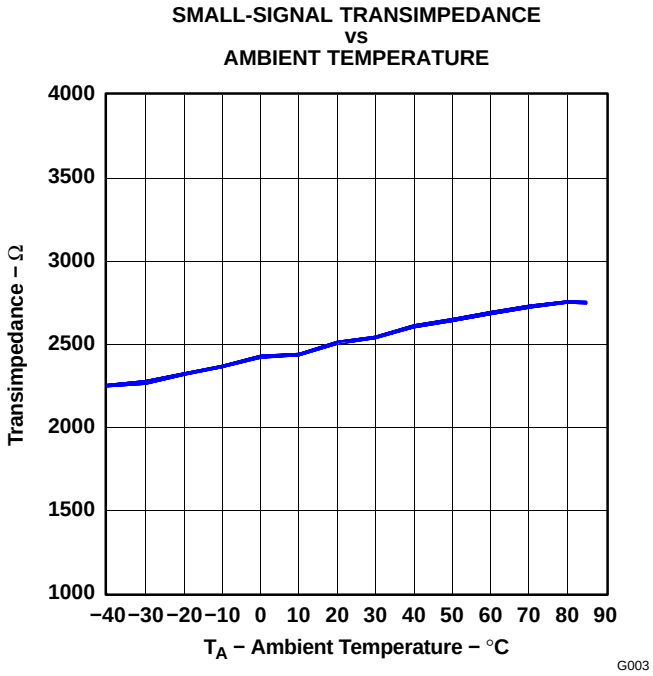


Figure 4.

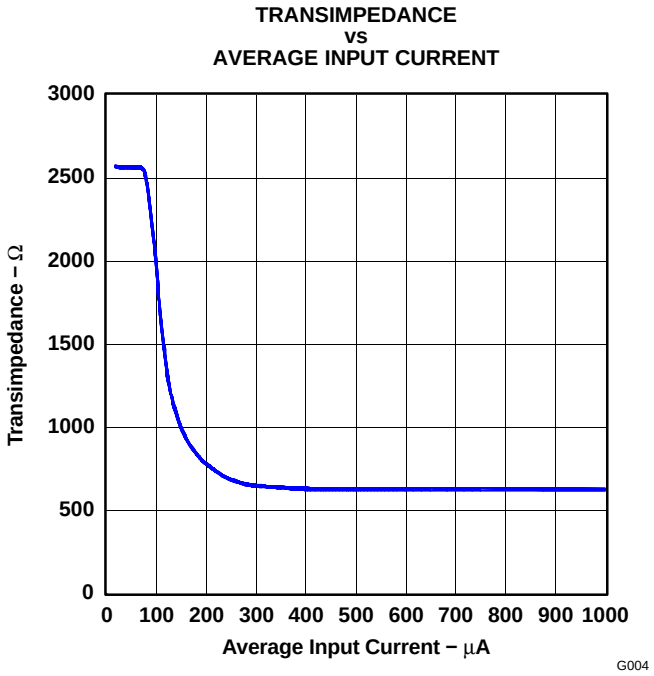


Figure 5.

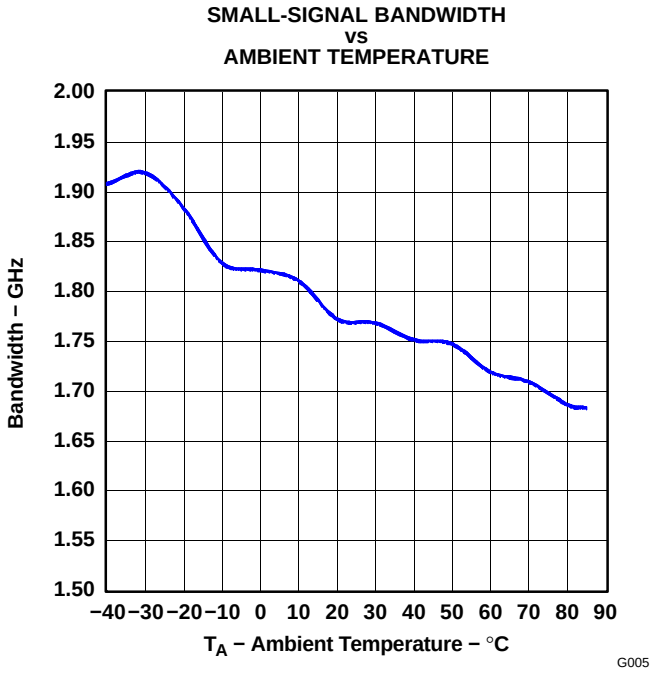


Figure 6.

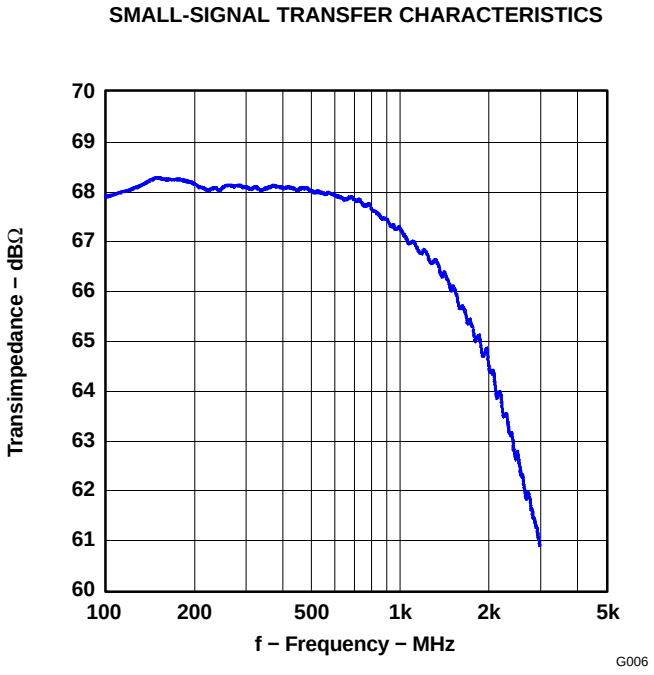


Figure 7.

TYPICAL CHARACTERISTICS (continued)

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

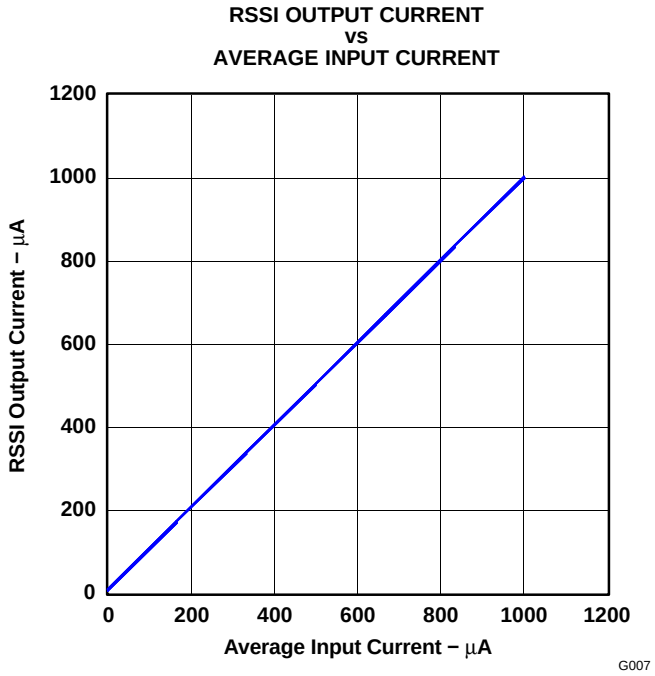


Figure 8.

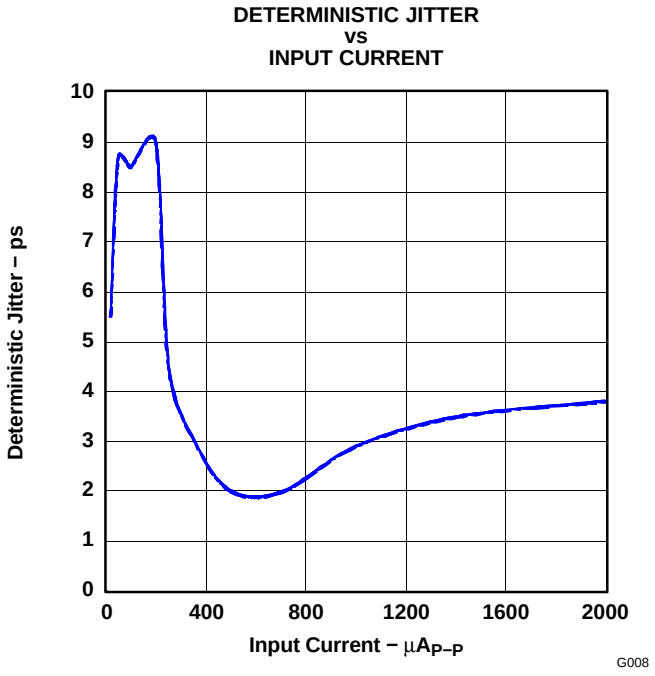


Figure 9.

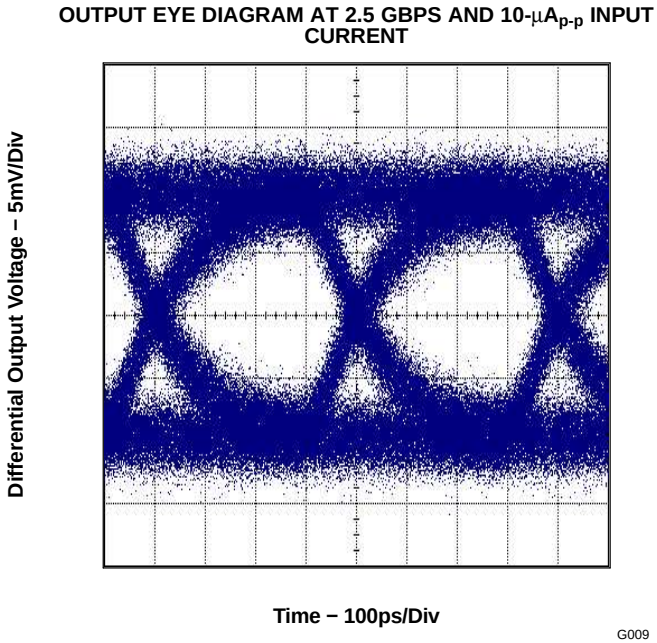


Figure 10.

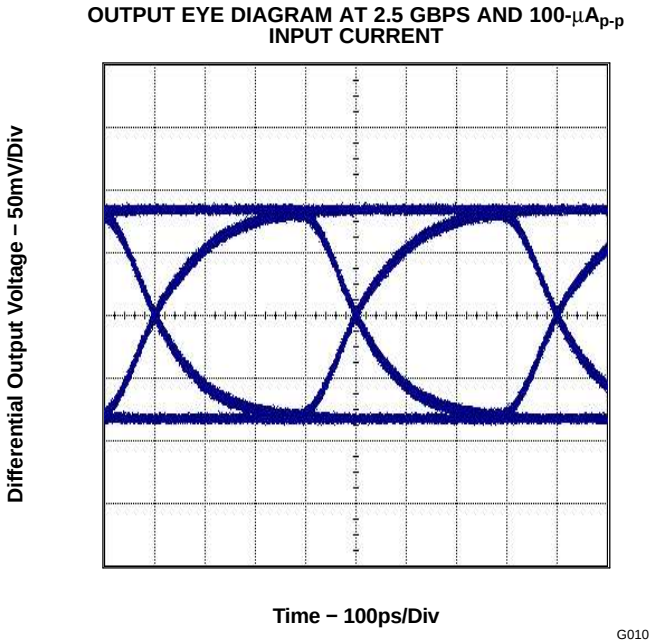


Figure 11.

TYPICAL CHARACTERISTICS (continued)

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

OUTPUT EYE DIAGRAM AT 2.5 GBPS AND 1-mA$_{p-p}$ INPUT CURRENT

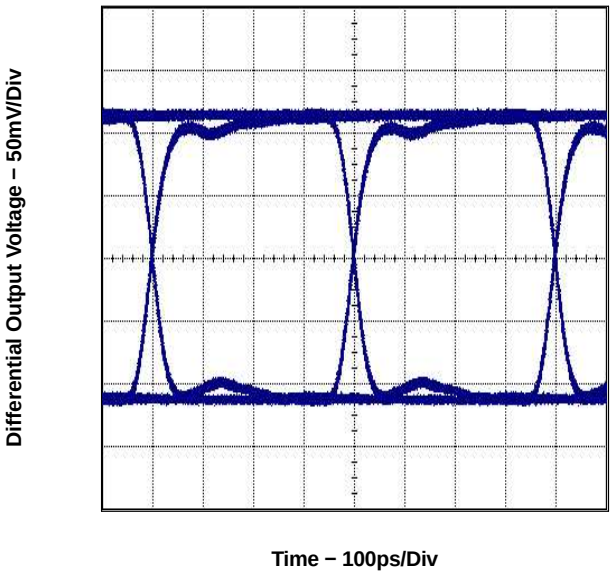


Figure 12.

OUTPUT EYE DIAGRAM AT 2.5 GBPS AND 2-mA$_{p-p}$ INPUT CURRENT

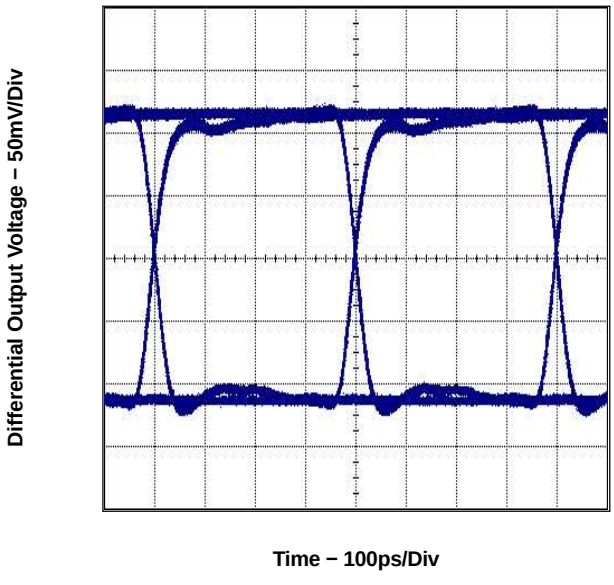


Figure 13.

APPLICATION INFORMATION

Figure 14 shows an application circuit for an ONET2591TA being used in a typical fiber-optic receiver. The ONET2591TA 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. For additional power-supply filtering, use an external capacitor, C_{FILTER}. 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 ONET2591TA, 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.

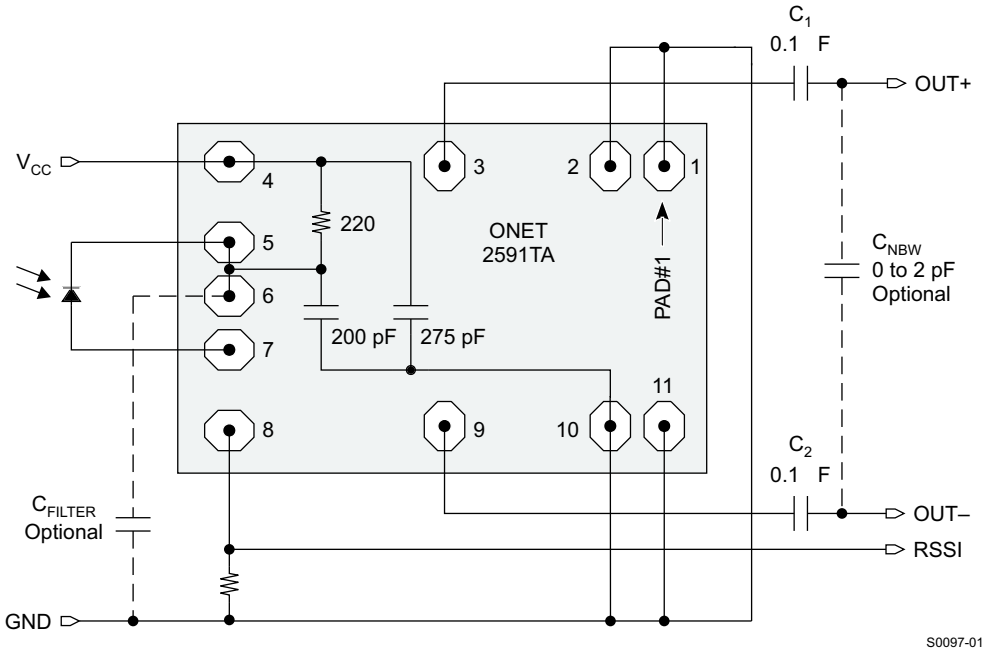


Figure 14. Basic Application Circuit

ASSEMBLY RECOMMENDATIONS

When packaging the ONET2591TA, 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 ONET2591TA die to minimize the bond wire length and thus the parasitic inductance.
2. An external filter capacitance C_{FILTER} can be used to improve photodiode supply filtering.
3. 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.
4. 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 15. Layout of the chip componentry is shown in Figure 16.

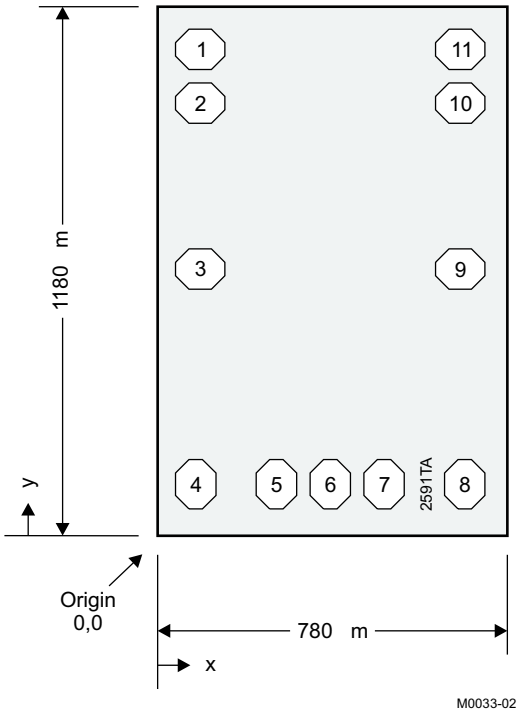


Figure 15. Chip Dimensions and Pad Locations

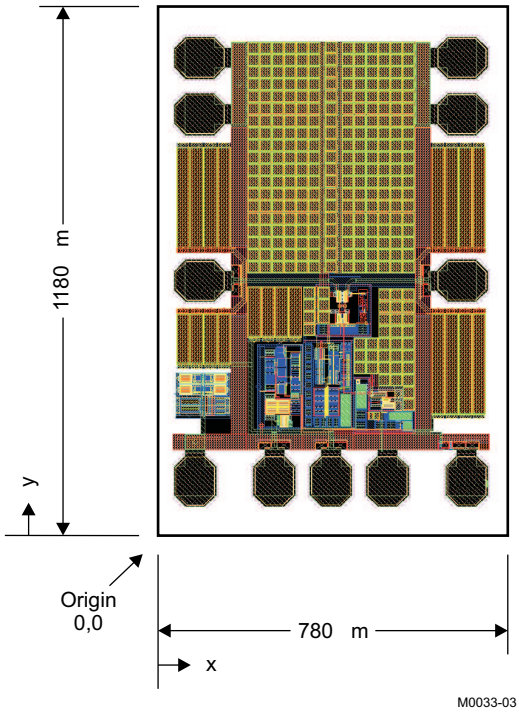


Figure 16. Chip Layout

Pad Locations and Descriptions for the ONET2591TA

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	390	127	FILTER	Analog	Bias voltage for photodiode
7	515	127	IN	Analog input	Data input to TIA
8	690	127	RSSI	Analog output	RSSI output signal
9	680	570	OUT–	Analog output	Inverted data output
10	680	938	GND	Supply	Circuit ground
11	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: 2591TA

TO46 LAYOUT EXAMPLES

Examples for layouts (top view) in 5-pin and 4-pin TO46 headers are given in Figure 17 and Figure 18, respectively.

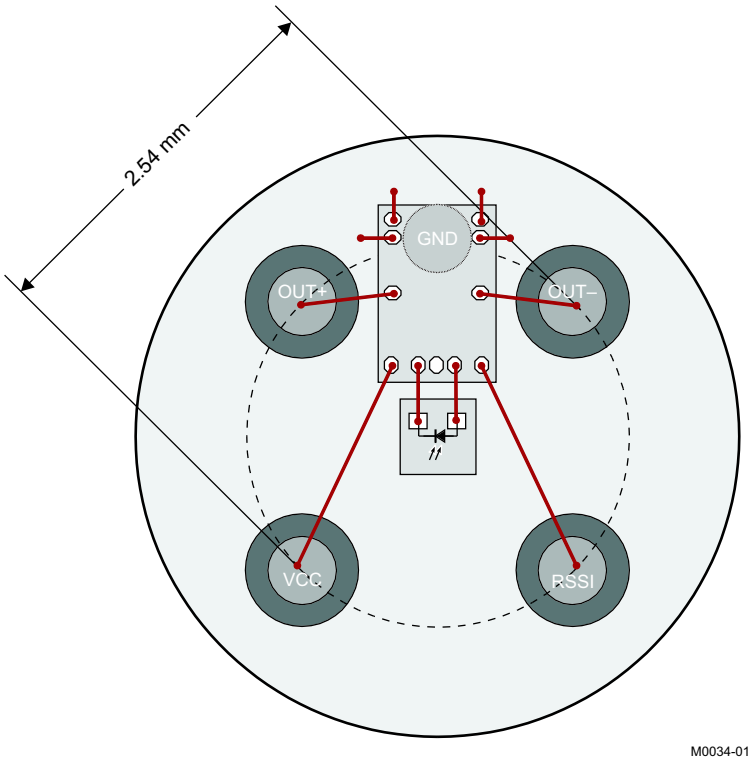


Figure 17. TO46 5-Pin Layout Example Using the ONET2591TA

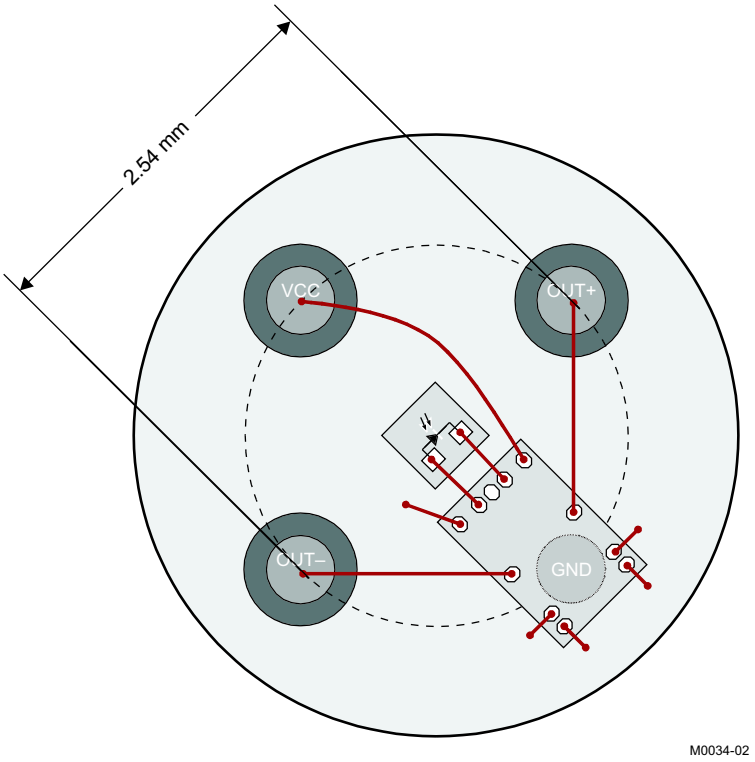


Figure 18. TO46 4-Pin Layout Example Using the ONET2591TA

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
HPA00506AY	ACTIVE	DIESALE	Y	0	1	TBD	Call TI	Call TI	-40 to 85		Samples
ONET2591TAY	ACTIVE	DIESALE	Y	0	1	TBD	Call TI	Call TI	-40 to 85		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/Ball Finish - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead/Ball Finish values may wrap to two lines if the finish value exceeds the maximum column width.

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