MAXIM

1Gbps to 4.25Gbps Multirate Transimpedance Amplifier with Photocurrent Monitor

MAX3793

General Description

The MAX3793 transimpedance amplifier provides a compact low-power solution for applications from 1Gbps up to 4.25Gbps.

The MAX3793 features 195nA input-referred noise, 3.5kΩ transimpedance gain, 2.9GHz bandwidth (C_{IN} = 0.3pF) and 2.8mA$_{P-P}$ input overload. Operating from a +3.3V supply, the MAX3793 consumes only 106mW. An integrated filter resistor provides positive bias for the photodiode. These features, combined with a small die size, allow easy assembly into a TO-46 header with a photodiode. The MAX3793 also includes an average photocurrent monitor.

The MAX3793 has a typical optical sensitivity of -20dBm (0.55A/W) at 4.25Gbps. Typical optical overload is at 4dBm. The MAX3793 and the MAX3748A limiting amplifiers provide a complete solution for multirate receiver applications.

Applications

SFF/SFP Transceiver Modules from 1Gbps to 4.25Gbps

Gigabit Ethernet Optical Receivers

Multirate Fibre-Channel Optical Receivers

Features

♦ **4.7ps$_{P-P}$ Deterministic Jitter (DJ)**

♦ **195nA$_{RMS}$ Input-Referred Noise**

♦ **2.9GHz Small-Signal Bandwidth**

♦ **2.8mA$_{P-P}$ AC Overload**

♦ **Photocurrent Output Monitor**

♦ **3.5kΩ Differential Gain**

♦ **Compact Die Size (30 mils x 50 mils)**

Ordering Information

PART	TEMP RANGE	PIN-PACKAGE
MAX3793E/D	-40°C to +85°C	Dice*

*Dice are designed to operate from -40°C to +85°C ambient temperature, but are tested and guaranteed only at T_A = +25°C.

Typical Application Circuit

MAXIM _____ *Maxim Integrated Products* **1**
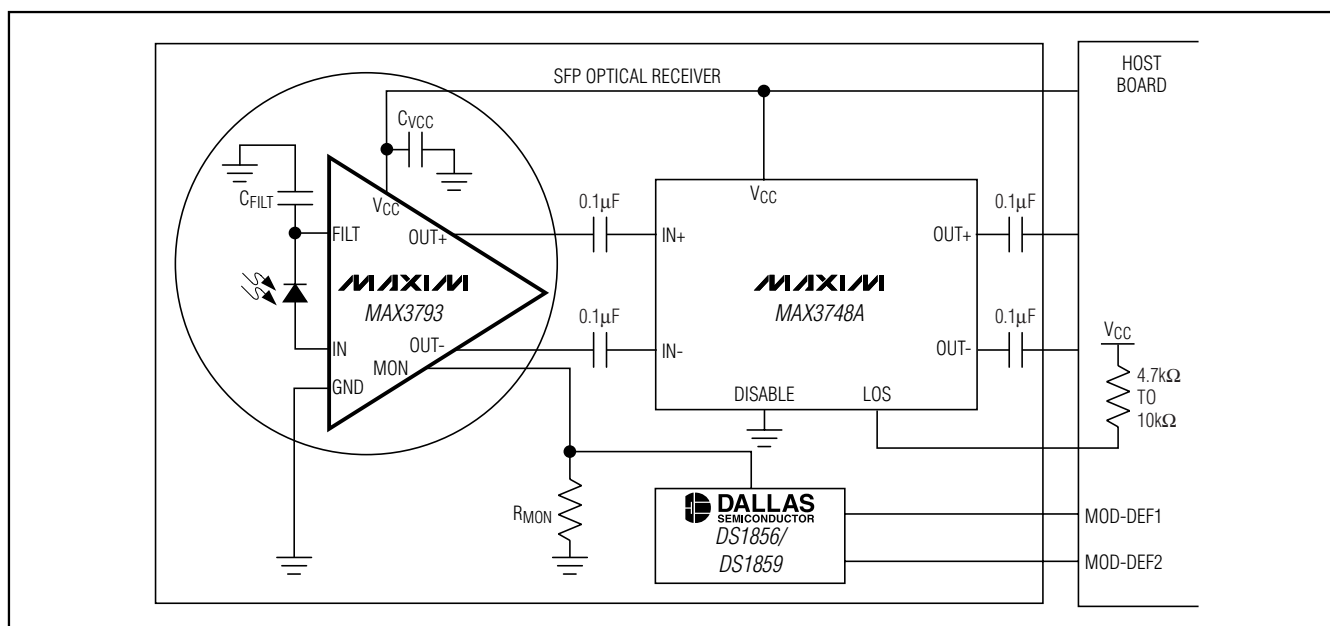
1Gbps to 4.25Gbps Multirate Transimpedance Amplifier with Photocurrent Monitor

ABSOLUTE MAXIMUM RATINGS

Power-Supply Voltage (V_{CC})..................................-0.5V to +4.5V
Continuous CML Output Current
  (OUT+, OUT-) ....-25mA to +25mA
Continuous Input Current (IN)..............................-4mA to +4mA

Continuous Input Current (FILTER).......................-8mA to +8mA
Operating Junction Temperature Range (T_J)....-55°C to +150°C
Storage Ambient Temperature Range (T_{STG}) ...-55°C to +150°C
Die Attach Temperature..+400°C

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 in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

ELECTRICAL CHARACTERISTICS

(V_{CC} = +2.97V to +3.63V, T_A = -40°C to +85°C. Typical values are at V_{CC} = +3.3V, source capacitance C_{IN} = 0.60pF, T_A = +25°C, unless otherwise noted.) (Notes 1, 2)

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
Power-Supply Current	I_{CC}	Measured with AC-coupled output			32	46	mA
Input Bias Voltage						1.0	V
Input Overload	I_{OL}	(Note 3)		2.2	2.8		mA_{P-P}
Optical Input Sensitivity (850nm, r_e = 10dB, Responsiveness = 0.55A/W)		BER = 10^{-12}, K28.5, at 1.0625Gbps			-23.5		dBm
		BER = 10^{-12}, K28.5, at 2.125Gbps			-23		
		BER = 10^{-12}, K28.5, at 4.25Gbps			-20		
Input-Referred Noise (Notes 3, 4)		BW = 933MHz, 4th-order Bessel filter			195	264	nA_{RMS}
		BW = 2000MHz, 4th-order Bessel filter			377	420	
		Unfiltered output			449	615	
Differential Transimpedance		I_{IN} = 20μA_{AVE}		2.8	3.5	4.5	kΩ
Small-Signal Bandwidth	BW	-3dB, C_{IN} = 0.6pF (Note 3)		1.9	2.5	3.2	GHz
		-3dB, C_{IN} = 0.3pF (Note 5)		2.36	2.9	3.56	
Gain Peaking		(Note 3)			0		dB
Low-Frequency Cutoff		-3dB, I_{IN} = 20μA_{AVE} (Note 3)				70	kHz
Deterministic Jitter (Notes 3, 6)	DJ	I_{IN} = 20μA_{P-P}, K28.5, at 4.25Gbps			4.7	11	ps_{P-P}
		20μA_{P-P} < I_{IN} < 100μA_{P-P}, K28.5, at 4.25Gbps			6	16	
		100μA_{P-P} < I_{IN} < 2.2mA_{P-P}, K28.5, at 4.25Gbps			10	27	
			T_A = +100°C		10		
		T_A = +100°C, 100μA_{P-P} < I_{IN} < 2.2mA_{P-P}, K28.5, at 4.25Gbps			10		
Photodiode Resistor	R_{FILT}			600	750	930	Ω
Differential Output Resistance	R_{OUT}			85	100	115	Ω
Maximum Differential Output Voltage	$V_{OD(MAX)}$	Outputs terminated by 50Ω to V_{CC}, I_{IN} > 100μA_{P-P}		220		480	mV_{P-P}
Output Edge Transition Time		Outputs terminated by 50Ω to V_{CC} 20% to 80%, I_{IN} > 200μA_{P-P} (Note 3)			73	95	ps
			T_A = +100°C		90		

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ELECTRICAL CHARACTERISTICS (continued)

(V_{CC} = +2.97V to +3.63V, T_A = -40°C to +85°C. Typical values are at V_{CC} = +3.3V, source capacitance C_{IN} = 0.60pF, T_A = +25°C, unless otherwise noted.) (Notes 1, 2)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Differential Output Return Loss		Frequency ≤ 1GHz		18		dB
		1GHz < frequency ≤ 4GHz		9		
Single-Ended Output Return Loss		Frequency ≤ 1GHz		14		dB
		1GHz < frequency ≤ 4GHz		11		
Power-Supply Noise Rejection (Note 7)	PSNR	I_{IN} = 0, f < 1MHz		47		dB
		I_{IN} = 0, 1MHz ≤ f < 10MHz		22		
Minimum Photocurrent to be Detected	I_{AVGMIN}				2	µA
Maximum Photocurrent to be Detected	I_{AVGMAX}		1			mA
Maximum Photocurrent Monitor Output Offset	$I_{MON(OFFSET)}$	I_{IN} = 0µA$_{P-P}$			10	µA
Photocurrent Monitor Output Offset Temperature Dependency	$\Delta I_{MON(OFFSET)}$	I_{IN} = 0µA$_{P-P}$ $\Delta I_{MON(OFFSET)}$ = ABS ($I_{MON(OFFSET)}$ (-40°C) - $I_{MON(OFFSET)}$ (+100°C))		0.21		µA
Monitor Output Compliance Voltage	V_{MON}		0		2	V
Photocurrent Monitor Gain	A_{MON}	2µA ≤ I_{AVG} ≤ 1.0mA		1		A/A
Photocurrent Monitor Gain Stability		2µA ≤ I_{AVG} ≤ 1.0mA (Notes 3, 8)	-10		+10	%
Photocurrent Monitor Gain Bandwidth		2µA ≤ I_{AVG} ≤ 1.0mA		7		MHz

Note 1: Die parameters are production tested at room temperature only, but are guaranteed by design and characterization from -40°C to +85°C.

Note 2: Source capacitance represents the total external capacitance at the IN pad during characterization of the noise and bandwidth parameters.

Note 3: Guaranteed by design and characterization.

Note 4: Input-referred noise is:

$$\left(\frac{\text{RMS Output Noise}}{\text{Gain at f} = 100\text{MHz}} \right)$$

Note 5: Values are derived by calculation from the C_{IN} = 0.6pF measurements.

Note 6: DJ is the sum of pulse-width distortion (PWD) and pattern-dependent jitter (PDJ). DJ is measured using a 3.2GHz 4th-order Bessel filter on the input.

Note 7: Power-supply noise rejection PSNR = -20log(ΔV_{OUT} / ΔV_{CC}), where ΔV_{OUT} is the change in differential output voltage and ΔV_{CC} is the noise on V_{CC}.

Note 8: Gain stability is defined as

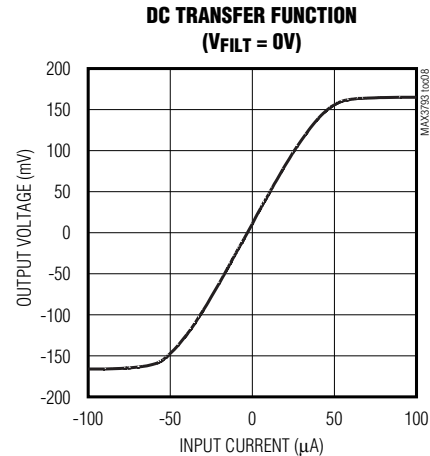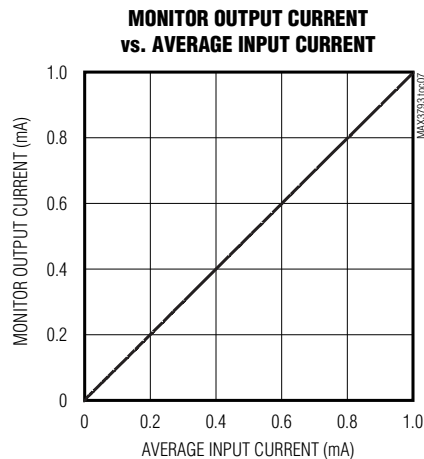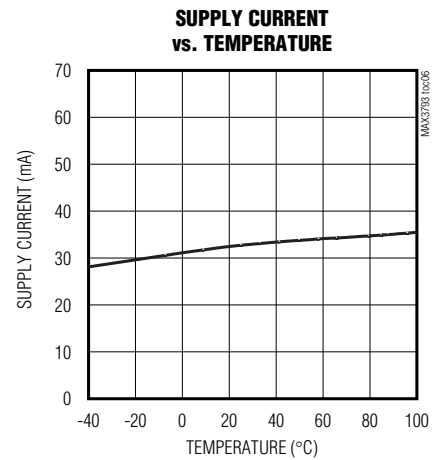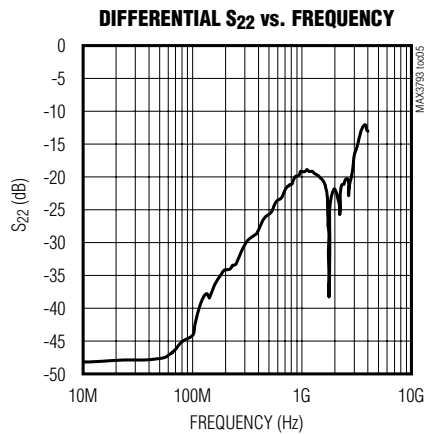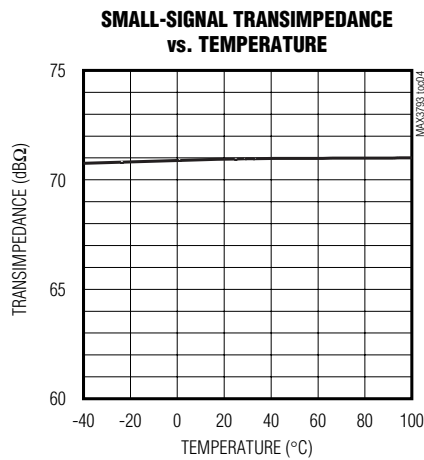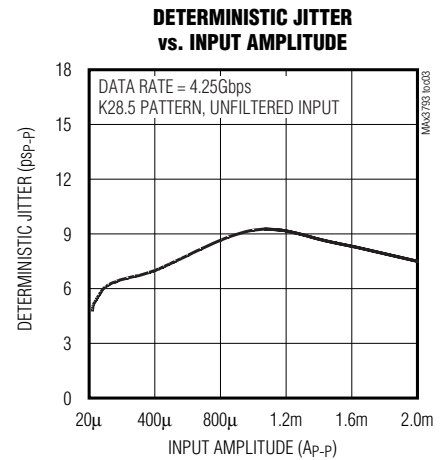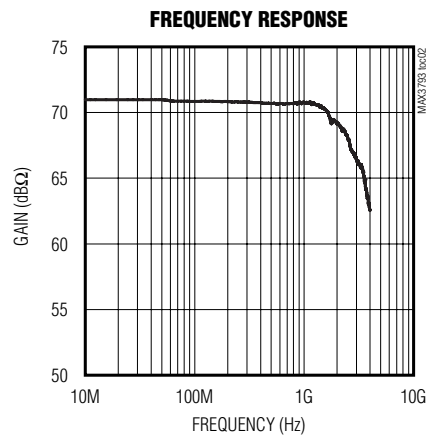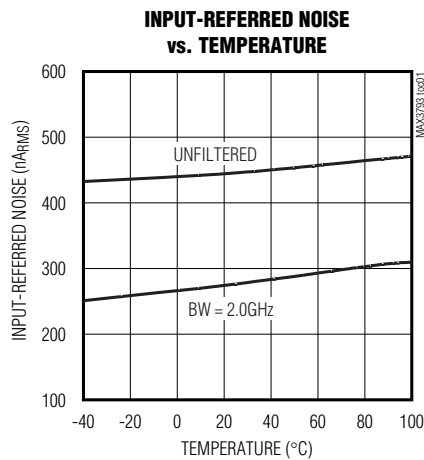$$(A_{MON} - A_{MON-NOM}) / (A_{MON-NOM})$$

over the listed current range, temperature, and supply variation. Nominal gain is measured at V_{CC} = +3.3V and +25°C.
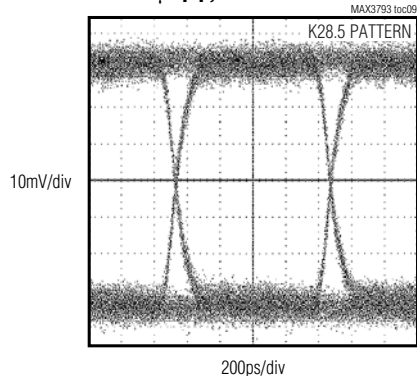
1Gbps to 4.25Gbps Multirate Transimpedance Amplifier with Photocurrent Monitor

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_____Typical Operating Characteristics

(V_{CC} = +3.3V, C_{IN} = 0.6pF, T_A = +25°C, unless otherwise noted.)

INPUT-REFERRED NOISE vs. TEMPERATURE

FREQUENCY RESPONSE

DETERMINISTIC JITTER vs. INPUT AMPLITUDE

SMALL-SIGNAL TRANSIMPEDANCE vs. TEMPERATURE

DIFFERENTIAL S$_{22}$ vs. FREQUENCY

SUPPLY CURRENT vs. TEMPERATURE

MONITOR OUTPUT CURRENT vs. AVERAGE INPUT CURRENT

DC TRANSFER FUNCTION (V_{FILT} = 0V)

4

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1Gbps to 4.25Gbps Multirate Transimpedance Amplifier with Photocurrent Monitor

_____*Typical Operating Characteristics (continued)*

(V_{CC} = +3.3V, C_{IN} = 0.6pF, T_A = +25°C, unless otherwise noted.)
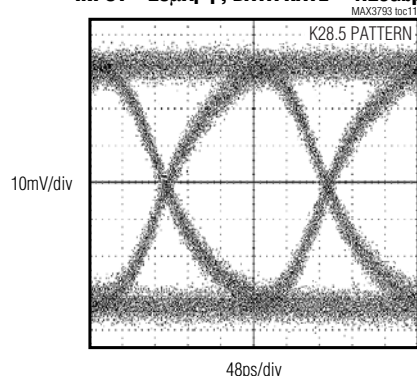
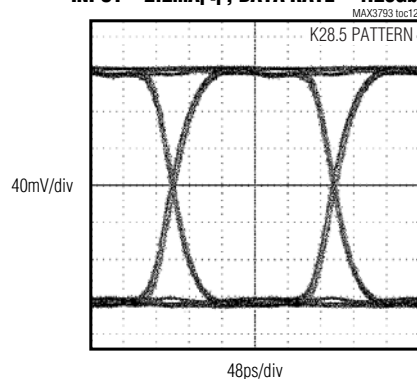**EYE DIAGRAM**
INPUT = 20μA$_{P-P}$, DATA RATE = 1.0625Gbps
MAX3793 toc09
K28.5 PATTERN

10mV/div

200ps/div

EYE DIAGRAM
INPUT = 20μA$_{P-P}$, DATA RATE = 2.125Gbps
MAX3793 toc10
K28.5 PATTERN

10mV/div

100ps/div

EYE DIAGRAM
INPUT = 20μA$_{P-P}$, DATA RATE = 4.25Gbps
MAX3793 toc11
K28.5 PATTERN

10mV/div

48ps/div
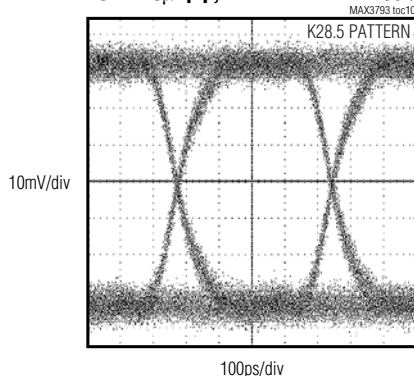
EYE DIAGRAM
INPUT = 2.2mA$_{P-P}$, DATA RATE = 4.25Gbps
MAX3793 toc12
K28.5 PATTERN

40mV/div

48ps/div

EYE DIAGRAM T_A = +100°C
INPUT = 20μA$_{P-P}$, DATA RATE = 4.25Gbps
MAX3793 toc13
K28.5 PATTERN

10mV/div

48ps/div
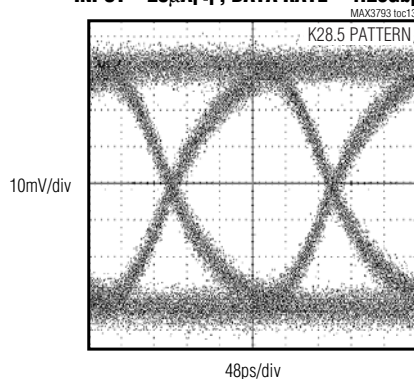
PHOTOCURRENT MONITOR OFFSET
TEMPERATURE DEPENDENCY HISTOGRAM
MAX3793 toc14
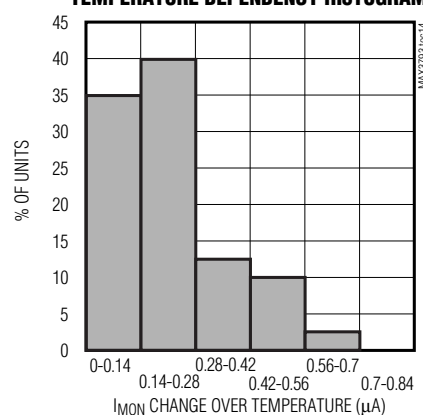
% OF UNITS

45
40
35
30
25
20
15
10
5
0

0-0.14
0.14-0.28
0.28-0.42
0.42-0.56
0.56-0.7
0.7-0.84

I_{MON} CHANGE OVER TEMPERATURE (μA)

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BOND PAD	NAME	FUNCTION
1	OUT+	Noninverting Data Output. Current flowing into IN causes the voltage at OUT+ to increase.
2, 3	V_{CC}	+3.3V Supply Voltage. The pads are not internally connected. Therefore, they must always be externally bonded.
4	FILT	Provides bias voltage for the photodiode through a 750Ω resistor to V_{CC}. When grounded, this pin disables the DC-cancellation amplifier to allow a DC path from IN to OUT+ and OUT- for testing.
5	IN	TIA Input. Signal current from photodiode flows into this pin.
6	MON	Photocurrent Monitor. Output current from MON is proportional to the average current in R_{FILT}. Connect a resistor between MON and ground to monitor the average photocurrent.
7, 11	GND	Circuit Ground. The pads are not internally connected. Therefore, they must always be externally bonded.
8, 10	N.C.	No Connection
9	OUT-	Inverting Data Output. Current flowing into IN causes the voltage at OUT- to decrease.

See the Wire Bonding section for recommended bonding sequence, Figure 4.

Functional Diagram
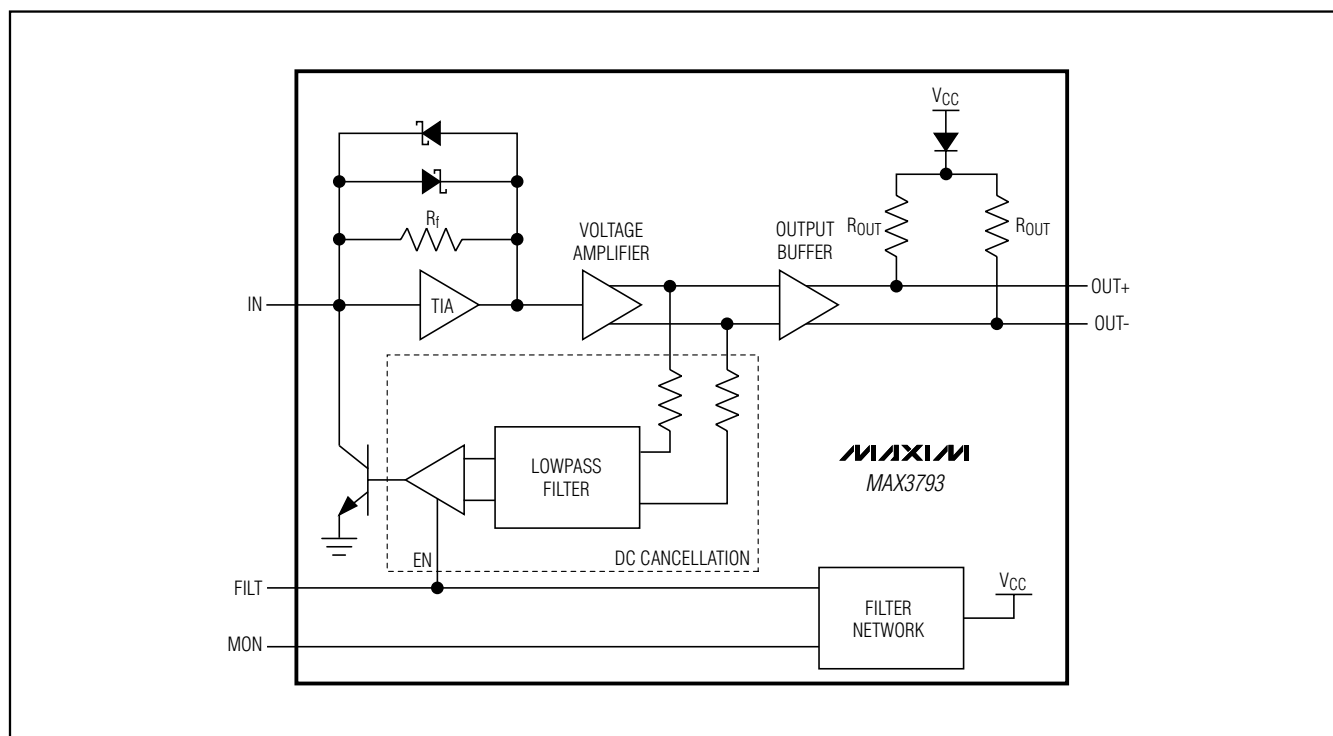
MAXIM

Figure 1. MAX3793 Limited Output

Figure 2. DC-Cancellation Effect on Input
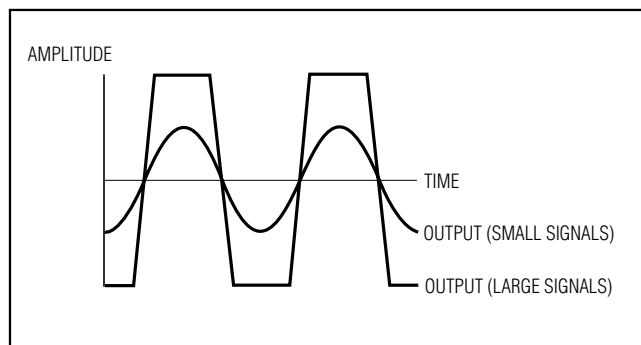
Detailed Description

The MAX3793 transimpedance amplifier is designed for 1Gbps to 4.25Gbps fiber optic applications. The MAX3793 is comprised of a transimpedance amplifier, a voltage amplifier, an output buffer, a DC-cancellation circuit, a photodiode biasing resistor, and a photocurrent monitor (see the *Functional Diagram*).

Transimpedance Amplifier

The signal current at the input flows into the summing node of a high-gain amplifier. Shunt feedback through resistor R_F converts this current into a voltage. Schottky diodes clamp the output signal for large input currents (Figure 1).

Voltage Amplifier

The voltage amplifier provides additional gain and converts the transimpedance amplifier single-ended output signal into a differential signal.

Output Buffer

The output buffer is designed to drive a 100Ω differential load between OUT+ and OUT-. For optimum supply noise rejection, the MAX3793 should be terminated with a matched load. The MAX3793 outputs do not drive a DC-coupled grounded load. The outputs should always be AC-coupled. Refer to Application Note HFAN-01.1: *Choosing AC-Coupling Capacitors* for a more detailed discussion on selecting capacitors. If a single-ended output is required, both the used and the unused outputs should be terminated in a similar manner. See Figure 6.

DC-Cancellation Circuit

The DC-cancellation circuit uses low-frequency feedback to remove the DC component of the input signal (Figure 2). This feature centers the input signal within the transimpedance amplifier's linear range, thereby reducing pulse-width distortion.
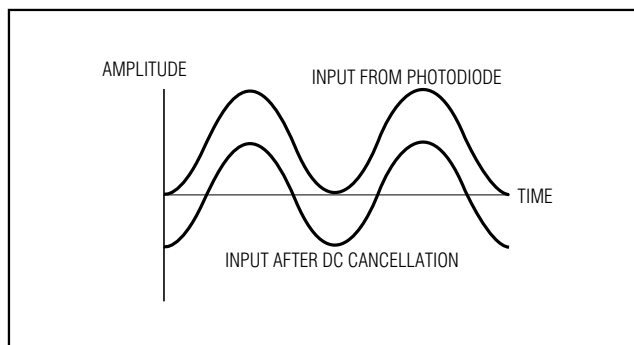
The DC-cancellation circuit is internally compensated and does not require external capacitors. This circuit minimizes pulse-width distortion for data sequences that exhibit a 50% mark density. A mark density significantly different from 50% causes the MAX3793 to generate pulse-width distortion. Grounding the FILT pin disables the DC-cancellation circuit. For normal operation, the DC-cancellation circuit must be enabled.

Photocurrent Monitor

The MAX3793 includes an average photocurrent monitor. The current sourced from MON to ground is proportionally equal to the average R_{FILT} current (see the *Typical Operating Characteristics*). This R_{FILT} is used to bias the photodiode, see Figure 7.

R_{FILT} is an internal 750Ω resistor between V_{CC} and FILT. This resistor is to be used in conjunction with an external C_{FILT} to bias the photodiode. The current through this resistor is monitored and creates the photocurrent monitor output. For test purposes, driving FILT below 0.5V disables the DC-cancellation circuit.

Design Procedure

Select Photodiode

Noise performance and bandwidth are adversely affected by capacitance on the TIA input node. Select a low-capacitance photodiode to minimize the total input capacitance on this pin. The MAX3793 is optimized for 0.6pF of capacitance on the input.

Select C_{FILT}

The filter resistor of the MAX3793, combined with an external capacitor, can be used to reduce noise (see the *Typical Application Circuit*). Current generated by supply noise voltage is divided between C_{FILT} and C_{IN}. Assuming the filter capacitor is much larger than the photodiode capacitance, the input noise current due to supply noise is:

$$I_{NOISE} = (V_{NOISE} \times C_{IN}) / (R_{FILT} \times C_{FILT})$$

MAX3793

If the amount of tolerable noise is known, the filter capacitor can be easily selected:

$$C_{FILT} = (V_{NOISE} \times C_{IN}) / (R_{FILT} \times I_{NOISE})$$

For example, with maximum noise voltage = 100mV$_{P-P}$, C_{IN} = 0.6pF, R_{FILT} = 750Ω, and I_{NOISE} at 350nA, the filter capacitor is:

$$C_{FILT} = (100mV \times 0.6pF) / (750\Omega \times 350nA) = 229pF$$

Select R$_{MON}$

If photocurrent monitoring is desired, connect a resistor between MON and ground to monitor the average photocurrent. Select the largest R$_{MON}$ possible:

$$R_{MON} = \frac{2.0V}{I_{MONMAX}}$$

where, I$_{MONMAX}$ is the largest average input current observed. An ammeter can also be used to monitor the current out of the MON pin.

Layout Considerations

Figure 3 shows suggested layouts for 4-pin and 5-pin TO headers.

Wire Bonding

For high-current density and reliable operation, the MAX3793 uses gold metalization. For best results, use gold-wire ball-bonding techniques. Exercise caution if attempting wedge bonding. The die size is 30 mils x 50 mils (0.762mm x 1.27mm), and the die thickness is 15 mils (380µm). Bond-pad size for the V$_{CC}$, GND, OUT+, and OUT- pads is 94µm x 94µm. Bond-pad size for the FILT, IN, and MON pads is 79µm x 79µm; all bond-pad metal thickness is 1.2µm. Refer to Maxim Application Note HFAN-08.0.1: *Understanding Bonding Coordinates and Physical Die Size* for additional information on bond-pad coordinates. Recommended bonding sequence is shown in Figure 4.
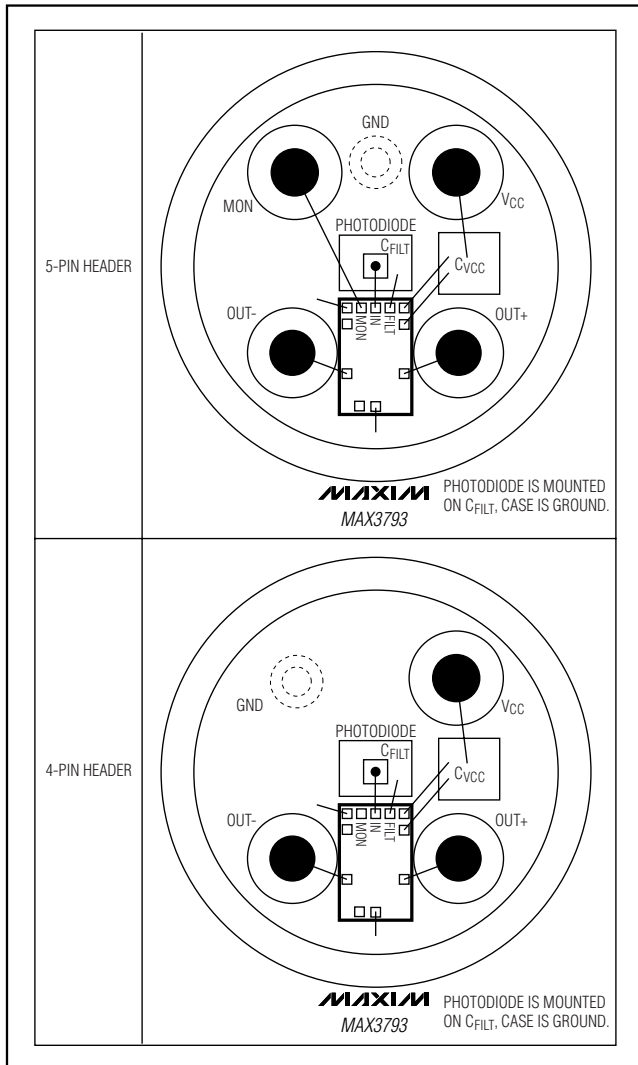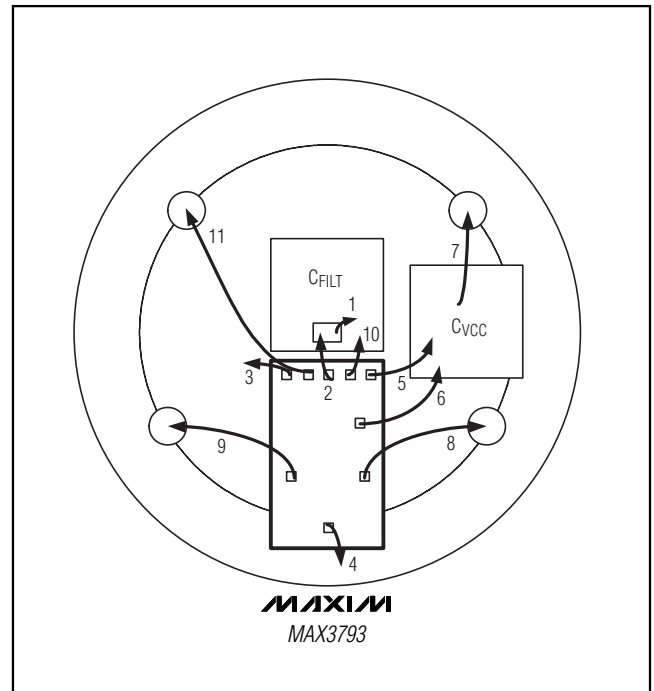

Figure 3. Suggested TO Header Layouts

Figure 4. Recommended MAX3793 Bonding Scheme

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Applications Information

Optical Power Relations

Many of the MAX3793 specifications relate to the input signal amplitude. When working with optical receivers, the input is sometimes expressed in terms of average optical power and extinction ratio. Figure 5 and Table 1 show relations that are helpful for converting optical power to input signal when designing with the MAX3793.

Optical Sensitivity Calculation

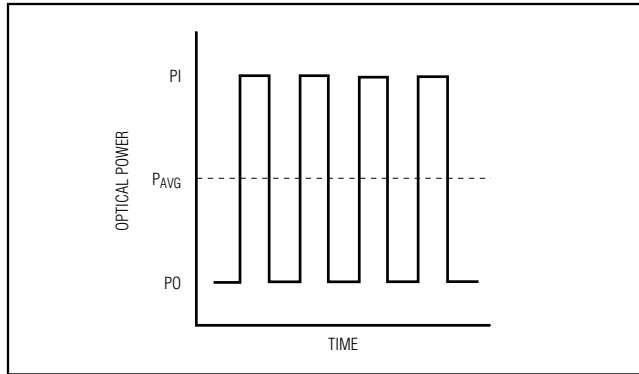The input-referred RMS noise current (I_N) of the MAX3793 generally determines the receiver sensitivity.

Figure 5. Optical Power Relations

To obtain a system bit-error rate (BER) of 1E-12, the signal-to-noise ratio must always exceed 14:1. The input sensitivity, expressed in average power, can be estimated as:

$$\text{Sensitivity} = 10\log\left(\frac{14.1 \times I_N \ (r_e + 1)}{2 \times \rho \times (r_e - 1)} \times 1000\right) \text{dBm}$$

where, ρ is the photodiode responsivity in A/W, and I_N is the RMS noise current in amps.

Input Optical Overload

Overload is the largest input that the MAX3793 accepts while meeting DJ specifications. Optical overload can be estimated in terms of average power with the following equation:

$$\text{Overload} = 10\log\left(\frac{I_{OL}}{2 \times \rho} \times 1000\right) \text{dBm}$$

Optical Linear Range

The MAX3793 has high gain, which limits the output when the input signal exceeds $50\mu A_{P-P}$. The MAX3793 operates in a linear range for inputs not exceeding:

$$\text{Linear Range} = 10\log\left(\frac{50\mu A \times (r_e + 1)}{2 \times \rho \times (r_e - 1)} \times 1000\right) \text{dBm}$$

Table 1. Optical Power Relations*

PARAMETER	SYMBOL	RELATION
Average power	P_{AVG}	$P_{AVG} = (P0 + P1) / 2$
Extinction ratio	r_e	$r_e = P1 / P0$
Optical power of a 1	P1	$P1 = 2P_{AVG} \dfrac{r_e}{r_e + 1}$
Optical power of a 0	P0	$P0 = 2P_{AVG} / (r_e + 1)$
Optical modulation amplitude	P_{IN}	$P_{IN} = P1 - P0 = 2P_{AVG} \dfrac{r_e -}{r_e +}$

*Assuming a 50% average mark density.

1Gbps to 4.25Gbps Multirate Transimpedance Amplifier with Photocurrent Monitor
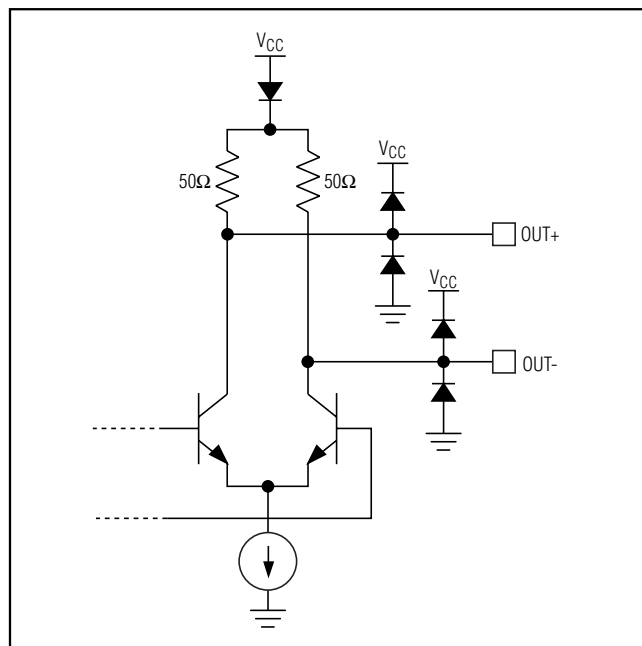
Interface Schematics
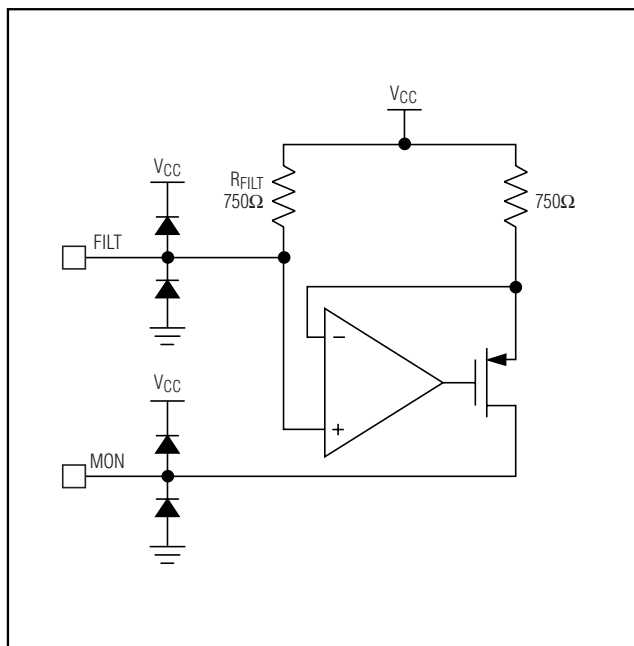

Figure 6. Equivalent Output

Figure 7. FILT and MON Interface

Table 2. Bond-Pad Coordinates

PAD	NAME	COORDINATES (µm)	
		X	Y
BP1	OUT+	40.2	650.6
BP2	V_{CC}	40.2	391.6
BP3	V_{CC}	47.2	47.2
BP4	FILT	166.2	40.2
BP5	IN	278.2	40.2
BP6	MON	390.2	40.2
BP7	GND	509.2	47.2
BP8	N.C.	516.2	289.2
BP9	OUT-	509.2	650.6
BP10	N.C.	393.0	1032.8
BP11	GND	274.0	1025.8

Pad Coordinates

Table 2 gives center pad coordinates for the MAX3793 bondpads. See Application Note HFAN-08.0.1: *Understanding Bonding Coordinates and Physical Die Size* for more information on bondpad coordinates.

Chip Information
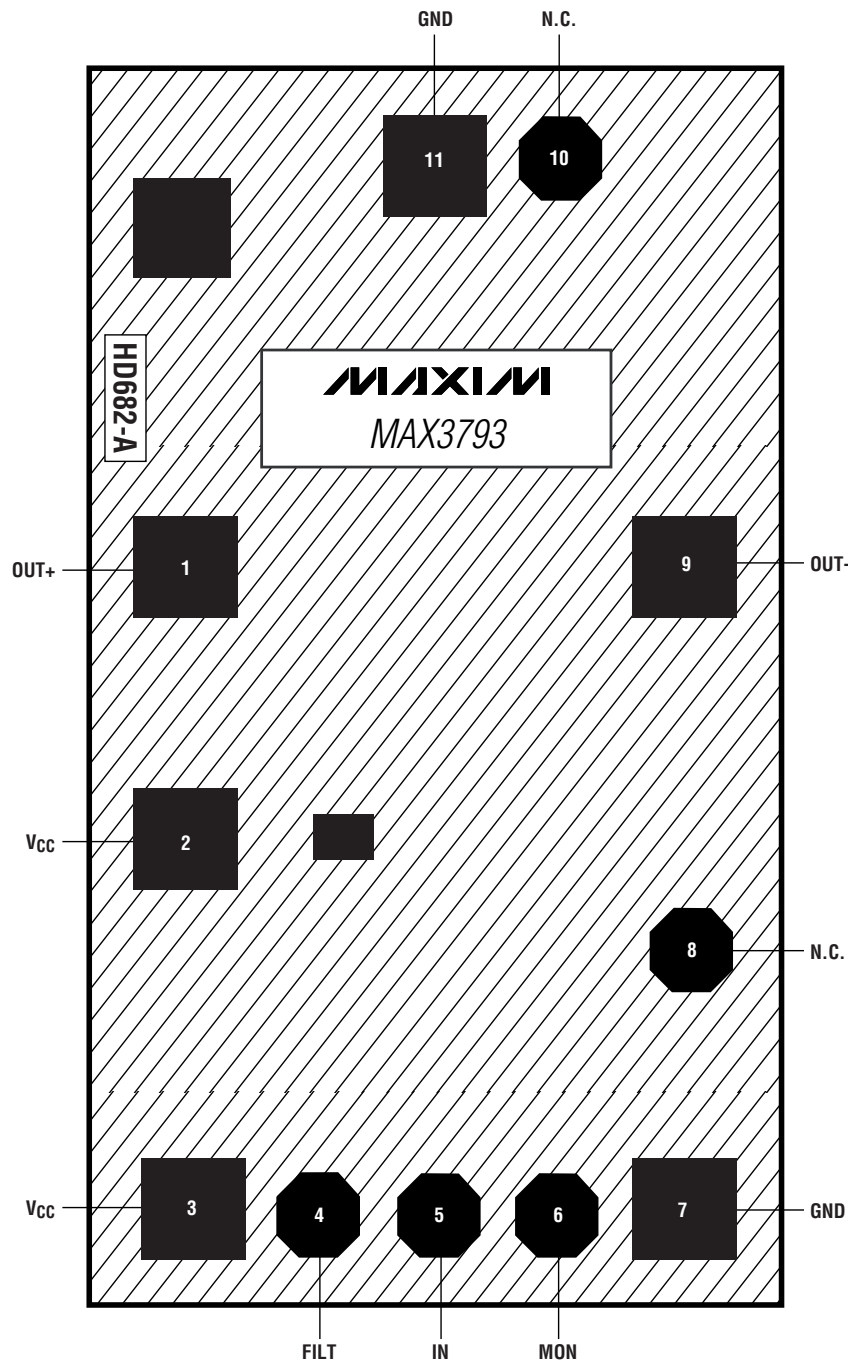
TRANSISTOR COUNT: 475
PROCESS: SiGe Bipolar

Package Information

For the latest package outline information, go to **www.maxim-ic.com/packages**.

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1Gbps to 4.25Gbps Multirate Transimpedance Amplifier with Photocurrent Monitor

_____**Revision History**

Rev 0;   10/04:   Initial data sheet release.

Rev 1;   11/05:   Changed Figure 3 (page 8).

Rev 2;   12/06:   Removed references to MAX3794 and replaced with MAX3748A (page 1).

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