19-3467; Rev 1; 11/05

# 1Gbps to 4.25Gbps Multirate Transimpedance Amplifier with Photocurrent Monitor



## 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 MAX3794 limiting amplifiers provide a complete solution for multirate receiver applications.

## 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)**

## Applications

SFF/SFP Transceiver Modules from 1Gbps to 4.25Gbps

Gigabit Ethernet Optical Receivers

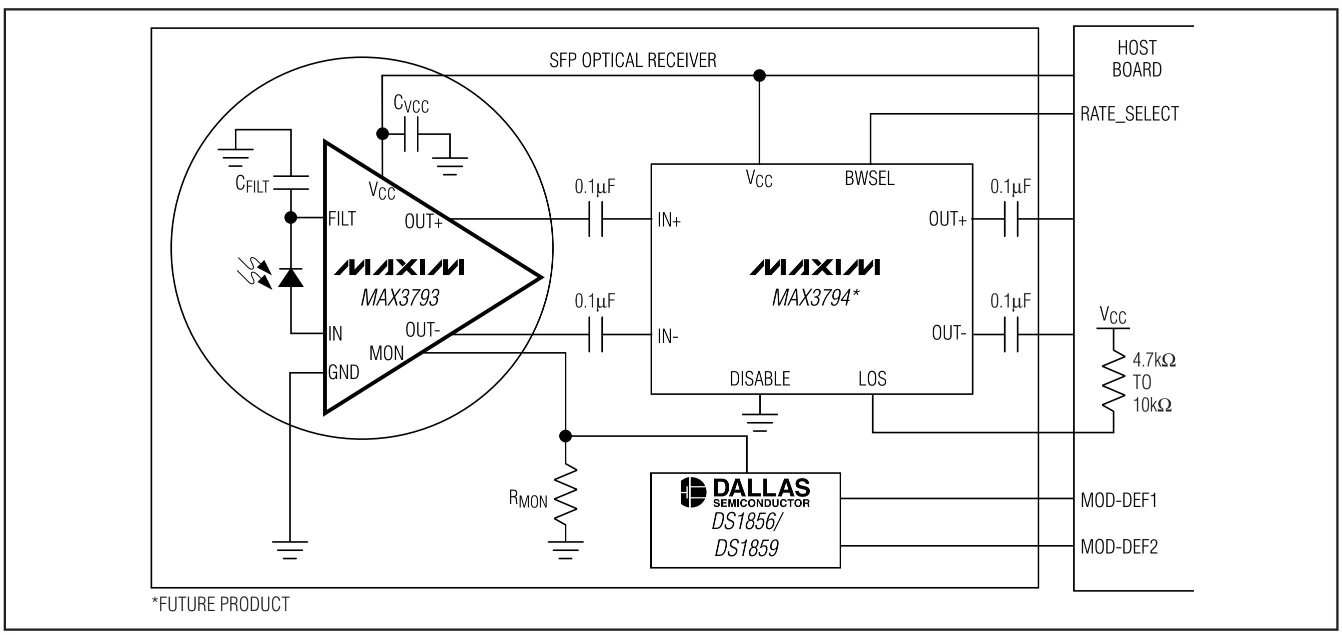
Multirate Fibre-Channel Optical Receivers

## 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



# 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 | | $I_{IN}$ = 20µ$A_{AVE}$ | | 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, $I_{IN}$ = 20µ$A_{AVE}$ (Note 3) | | | | 70 | kHz |
| Deterministic Jitter (Notes 3, 6) | DJ | $I_{IN}$ = 20µ$A_{P-P}$, K28.5, at 4.25Gbps | | | 4.7 | 11 | $ps_{P-P}$ |
| | | 20µ$A_{P-P}$ < $I_{IN}$ < 100µ$A_{P-P}$, K28.5, at 4.25Gbps | | | 6 | 16 | |
| | | 100µ$A_{P-P}$ < $I_{IN}$ < 2.2m$A_{P-P}$, K28.5, at 4.25Gbps | | | 10 | 27 | |
| | | | $T_A$ = +100°C | | 10 | | |
| | | $T_A$ = +100°C, 100µ$A_{P-P}$ < $I_{IN}$ < 2.2m$A_{P-P}$, 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 $V_{CC}$, $I_{IN}$ > 100µ$A_{P-P}$ | | 220 | | 480 | $mV_{P-P}$ |
| Output Edge Transition Time | | Outputs terminated by 50Ω to $V_{CC}$ 20% to 80%, $I_{IN}$ > 200µ$A_{P-P}$ (Note 3) | | | 73 | 95 | ps |
| | | | $T_A$ = +100°C | | 90 | | |

## 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) | $I_{IN}$ = 0µ$A_{P-P}$ | | | 10 | µA |
| Photocurrent Monitor Output Offset Temperature Dependency | $\Delta I_{MON}$ (OFFSET) | $I_{IN}$ = 0µ$A_{P-P}$<br>$\Delta I_{MON(OFFSET)}$ = 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:

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

**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($\Delta V_{OUT}$ / $\Delta V_{CC}$), where $\Delta V_{OUT}$ is the change in differential output voltage and $\Delta V_{CC}$ is the noise on $V_{CC}$.

**Note 8:** Gain stability is defined as

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

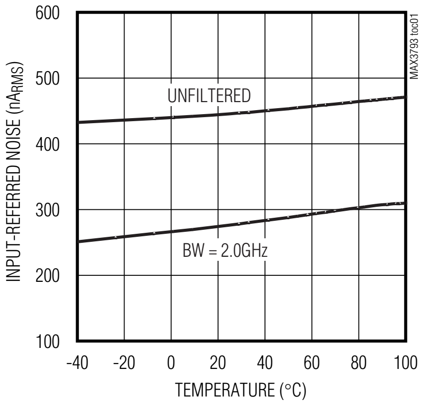
over the listed current range, temperature, and supply variation. Nominal gain is measured at $V_{CC}$ = +3.3V and +25°C.

# 1Gbps to 4.25Gbps Multirate Transimpedance Amplifier with Photocurrent Monitor

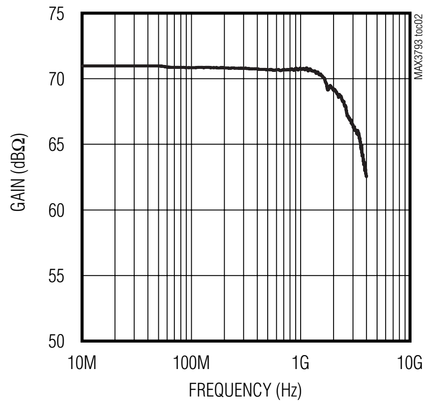
## Typical Operating Characteristics

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

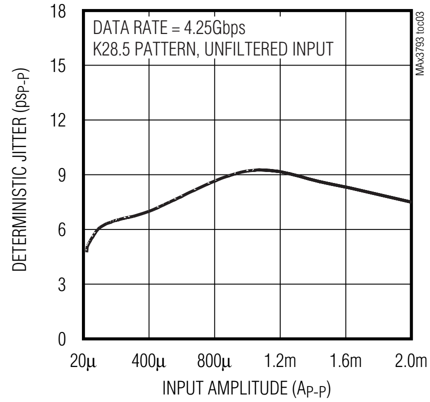
**INPUT-REFERRED NOISE vs. TEMPERATURE**



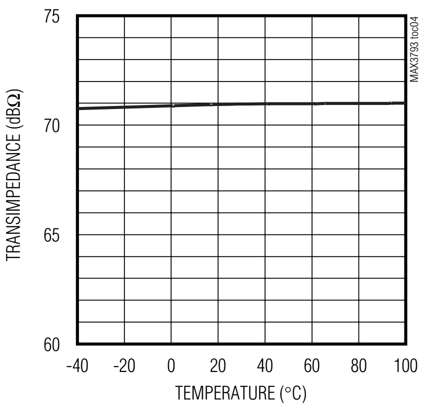

**FREQUENCY RESPONSE**



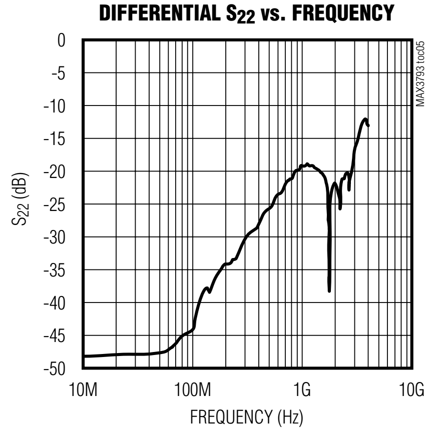

**DETERMINISTIC JITTER vs. INPUT AMPLITUDE**



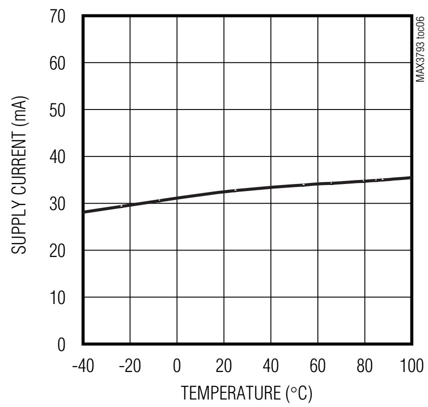

**SMALL-SIGNAL TRANSIMPEDANCE vs. TEMPERATURE**



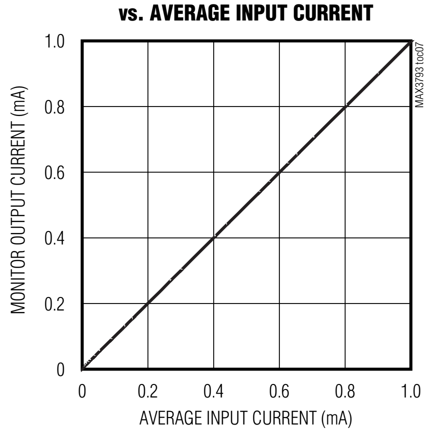

**DIFFERENTIAL $S_{22}$ vs. FREQUENCY**



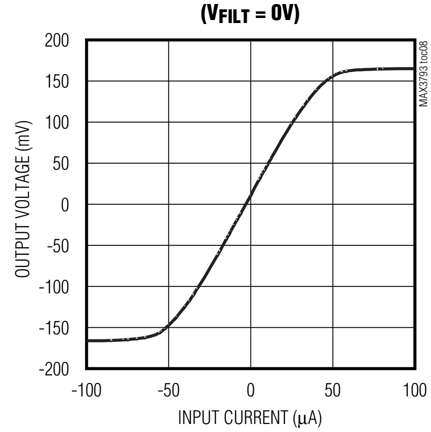

**SUPPLY CURRENT vs. TEMPERATURE**




**MONITOR OUTPUT CURRENT vs. AVERAGE INPUT CURRENT**



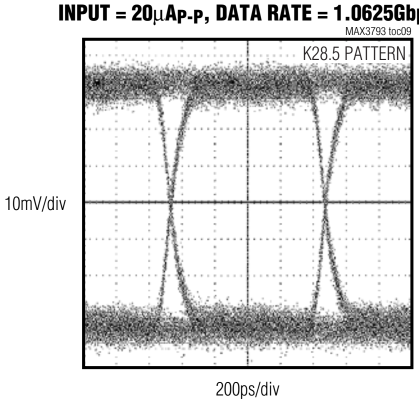

**DC TRANSFER FUNCTION ($V_{FILT}$ = 0V)**



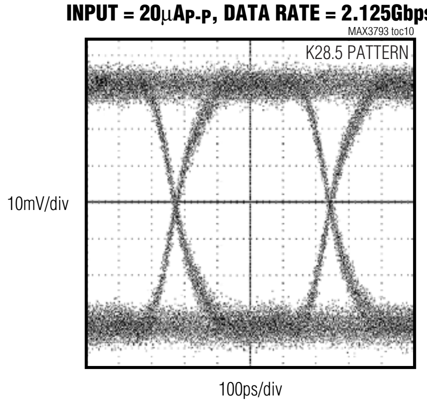
## Typical Operating Characteristics (continued)

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

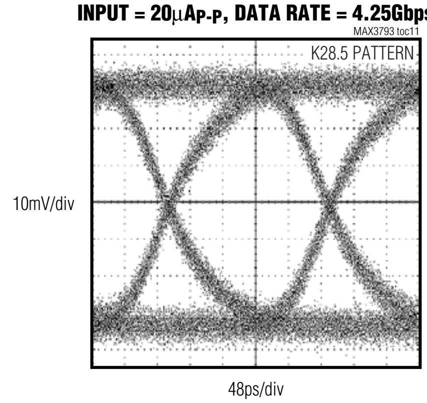
**EYE DIAGRAM**
**INPUT = 20µA$_{P-P}$, DATA RATE = 1.0625Gbps**



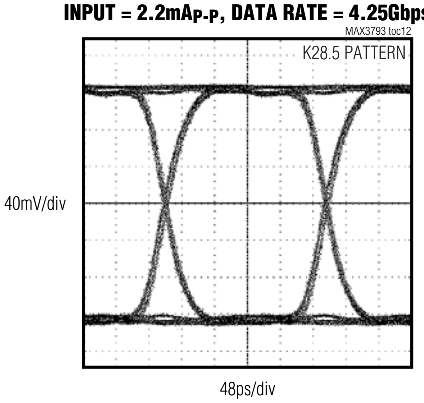

**EYE DIAGRAM**
**INPUT = 20µA$_{P-P}$, DATA RATE = 2.125Gbps**



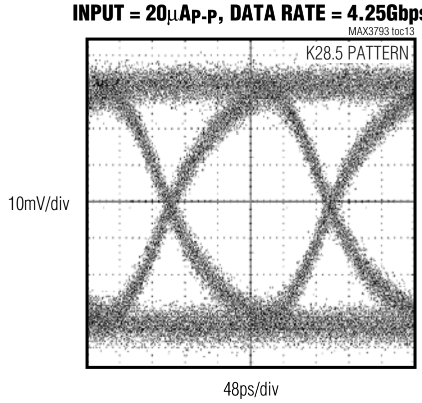

**EYE DIAGRAM**
**INPUT = 20µA$_{P-P}$, DATA RATE = 4.25Gbps**



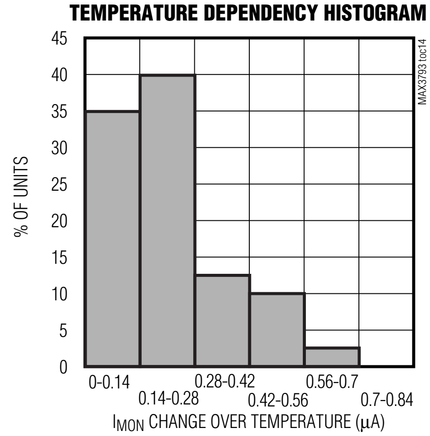

**EYE DIAGRAM**
**INPUT = 2.2mA$_{P-P}$, DATA RATE = 4.25Gbps**




**EYE DIAGRAM $T_A$ = +100°C**
**INPUT = 20µA$_{P-P}$, DATA RATE = 4.25Gbps**




**PHOTOCURRENT MONITOR OFFSET TEMPERATURE DEPENDENCY HISTOGRAM**



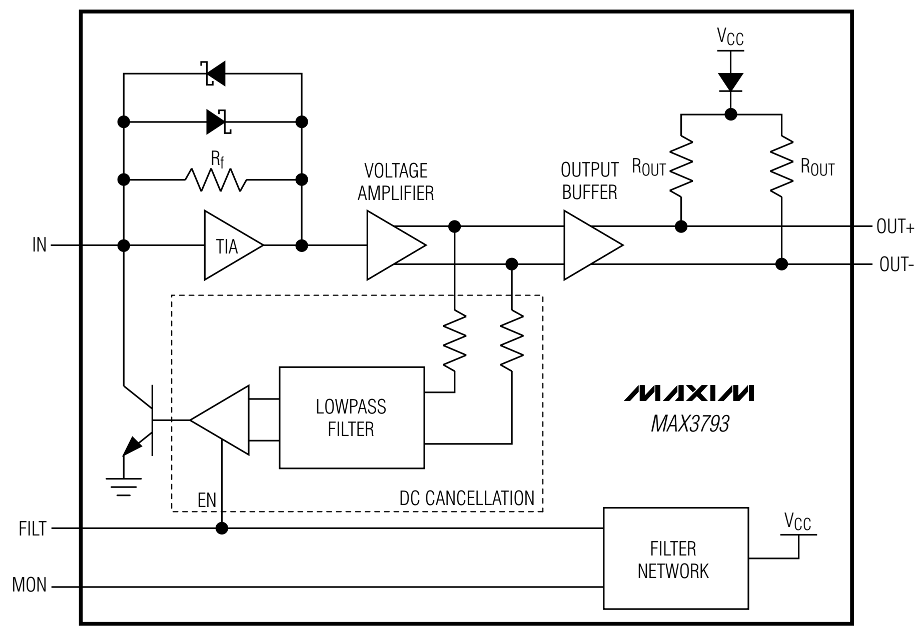
# 1Gbps to 4.25Gbps Multirate Transimpedance Amplifier with Photocurrent Monitor

## Pin Description

| 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



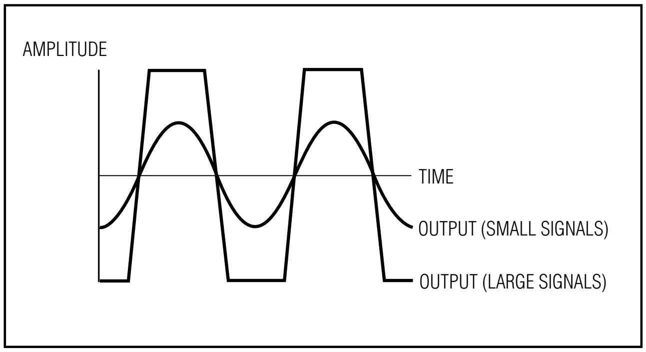



*Figure 1. MAX3793 Limited Output*

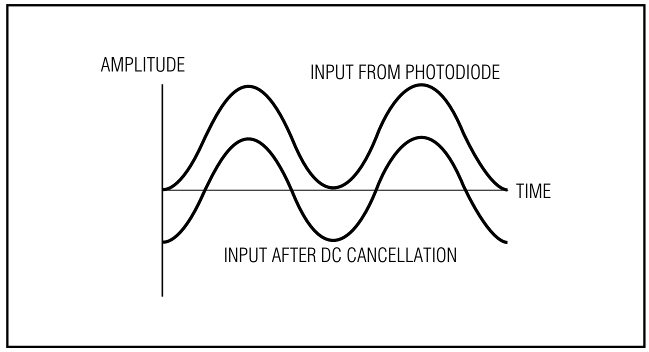



*Figure 2. DC-Cancellation Effect on Input*

## 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-1.1: *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:

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

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.

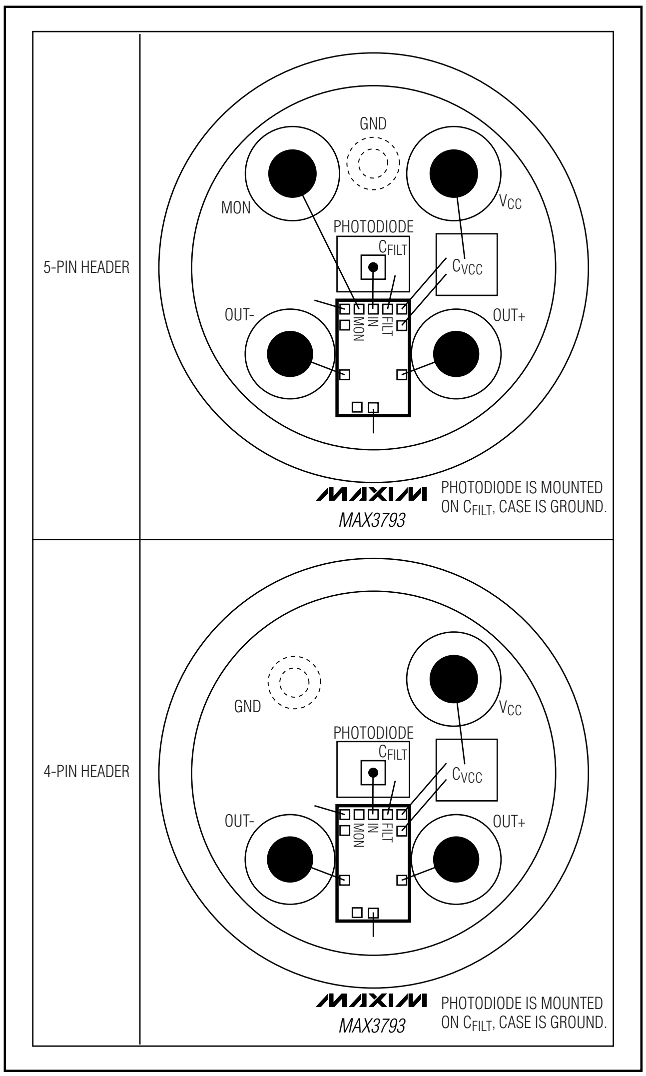



*Figure 3. Suggested TO Header Layouts*

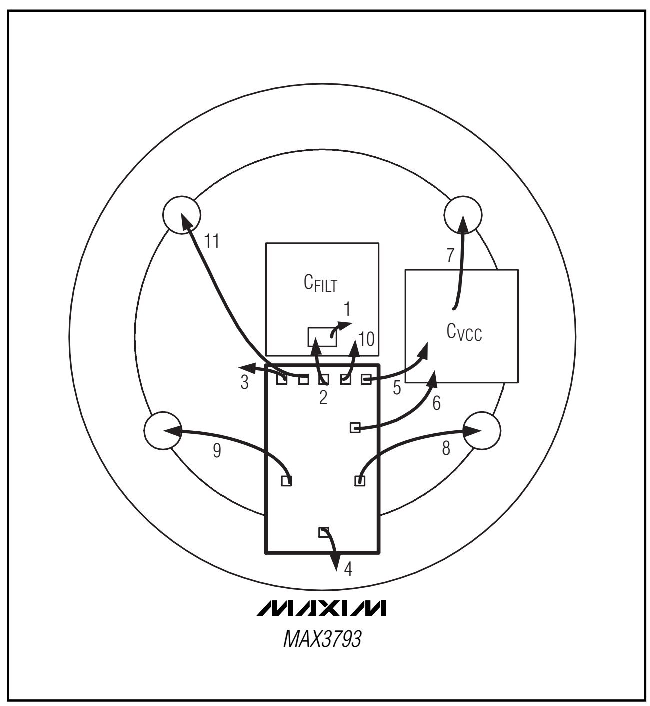



*Figure 4. Recommended MAX3793 Bonding Scheme*

## 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.

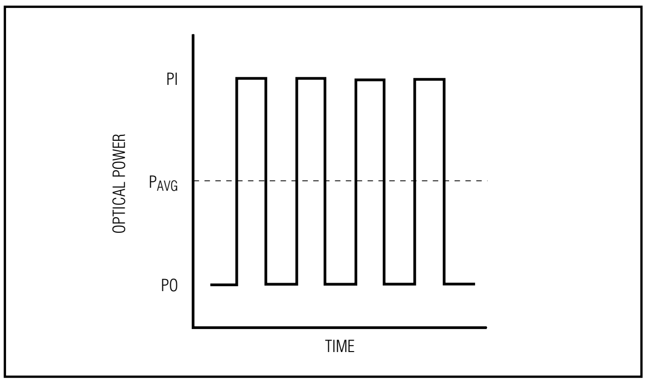



*Figure 5. Optical Power Relations*

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 | $P1 = 2P_{AVG} \frac{r_e}{r_e + 1}$ |
| Optical power of a 0 | P0 | $P0 = 2P_{AVG} / (r_e + 1)$ |
| Optical modulation amplitude | $P_{IN}$ | $P_{IN} = P1 - P0 = 2P_{AVG} \frac{r_e -}{r_e +}$ |

*Assuming a 50% average mark density.

# 1Gbps to 4.25Gbps Multirate Transimpedance Amplifier with Photocurrent Monitor

## Interface Schematics

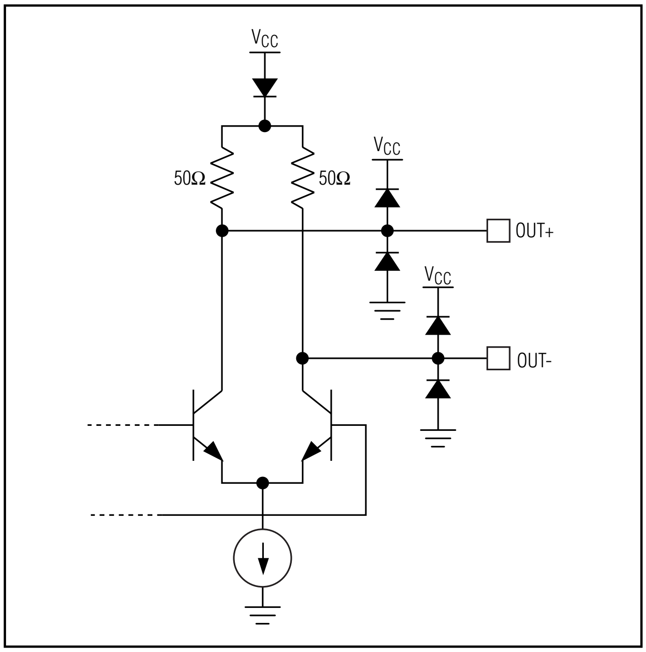



*Figure 6. Equivalent Output*

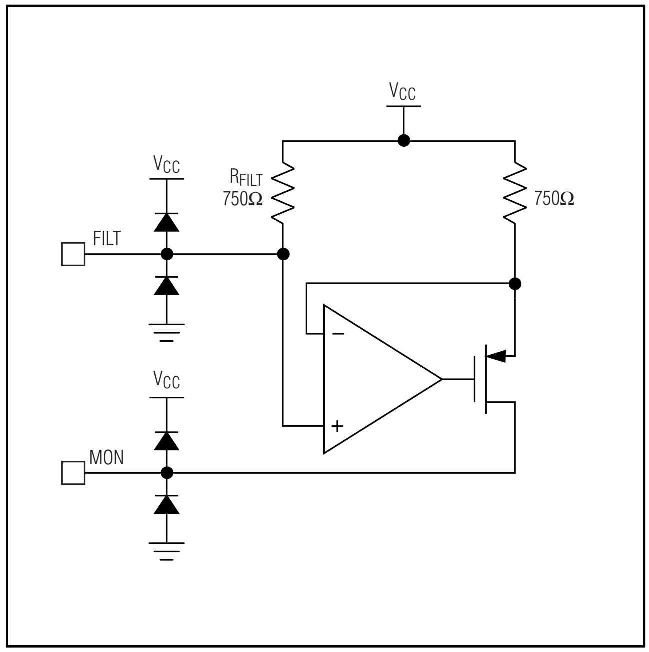



*Figure 7. FILT and MON Interface*

### 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-8.0.1: *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**.

## Pin Configuration/Chip Topography