



# **+3.3V, 2.5Gbps Quad Transimpedance Amplifier for System Interconnects**

## **General Description**

The MAX3825 is a quad transimpedance amplifier (TIA) intended for 2.5Gbps system interconnect applications. Each of the four channels converts a small photodiode current to a measurable differential voltage with a transimpedance gain of  $3.7\text{k}\Omega$ . The circuit features 460nARMS of input-referred noise per channel corresponding to an optical input sensitivity of  $-22.3\text{dBm}$  ( $\text{BER} \leq 1 \times 10^{-14}$ ). The quad transimpedance amplifier has 20ps of deterministic jitter and a 2.4GHz small-signal bandwidth. The MAX3825 is optimized for use with a quad PIN photodetector array with a standard fiber pitch of  $250\mu\text{m}$ .

The MAX3825 operates from a single +3.3V supply over a  $0^\circ\text{C}$  to  $+85^\circ\text{C}$  temperature range. With a +3.3V supply, each channel dissipates 93mW of power. A DC cancellation circuit on each channel provides a true differential output swing over a wide range of input currents.

Each channel has an independent supply and ground to allow all or any combination of channels to be connected. This device is available in dice only.

*Typical Operating Circuit appears at end of data sheet.*

## **Features**

- ◆ Single +3.3V Supply
- ◆ 93mW per Channel Power Dissipation
- ◆ 460nARMS Input-Referred Noise
- ◆ 20ps Deterministic Jitter
- ◆ 2.4GHz Small-Signal Bandwidth
- ◆ No External Compensation
- ◆ 40dB Power-Supply Rejection Ratio
- ◆ Compact Die with  $250\mu\text{m}$  Channel Pitch
- ◆  $100\Omega$  Differential Output Impedance

## **Ordering Information**

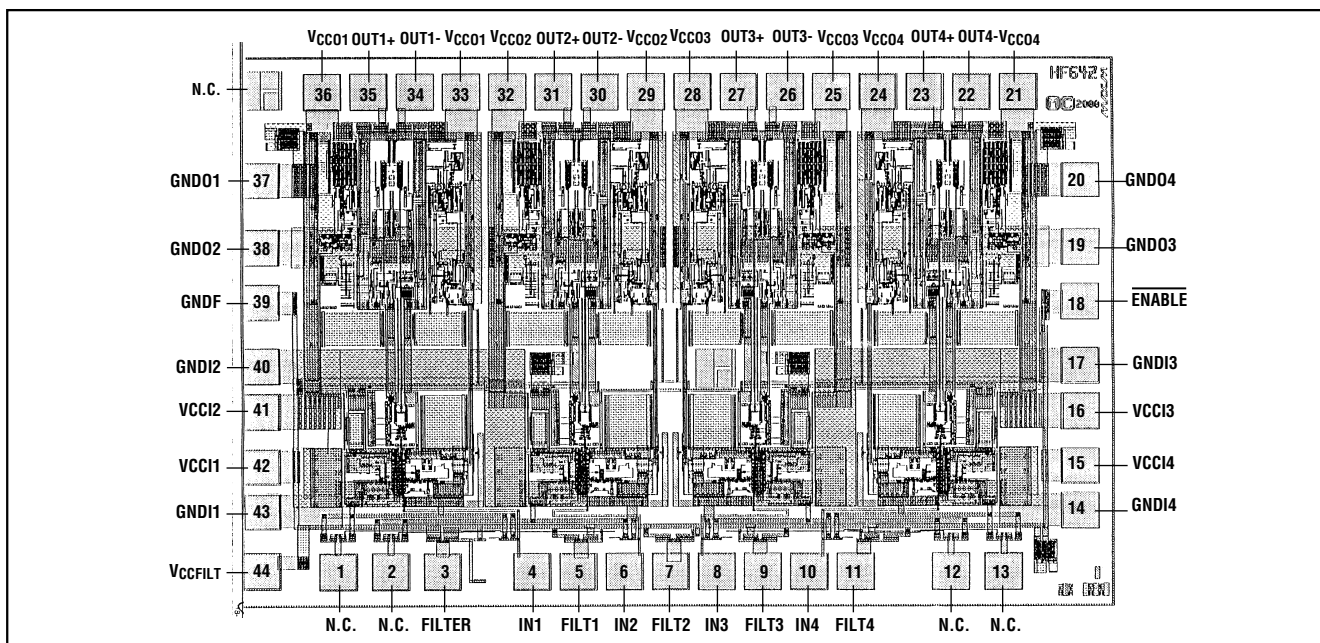
PART	TEMP. RANGE	PIN-PACKAGE
MAX3825U/D	$0^\circ\text{C}$ to $+85^\circ\text{C}$	Dice*

\*Dice are designed to operate with a  $0^\circ\text{C}$  to  $+120^\circ\text{C}$  junction temperature, but are tested and guaranteed only at  $T_A = +25^\circ\text{C}$ .

## **Applications**

System Interconnects	ATM Switching
SDH/SONET	Networks
Backplanes	High-Speed Parallel
Dense Digital Cross-Connects	Optical Links

## **Chip Topography/Pad Configuration**



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## ABSOLUTE MAXIMUM RATINGS

Supply Voltage

VCCO1, VCCO2, VCCO3, VCCO4,

VCCI1, VCCI2, VCCI3, VCCI4, VCCFILT .....-0.5V to +6.0V

Input Current: IN1, IN2, IN3, IN4.....-4mA to +4mA

FILTER Current.....-24mA to +24mA

Filter Current: FILT1, FILT2, FILT3, FILT4 .....-6mA to +6mA

Output Voltage OUT1±, OUT2±,

OUT3±, OUT4±.....(VCC - 1.5V) to (VCC + 0.5V)

ENABLE Voltage.....-0.5V to (VCC + 0.5V)

Operating Temperature Range (TA).....0°C to +85°C

Storage Temperature Range .....-55°C to +150°C

Operating Junction Temperature (TJ).....-55°C to +150°C

Processing 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.

## DC ELECTRICAL CHARACTERISTICS

(VCC = +3.14V to +3.6V, TA = 0°C to +85°C. Typical values are at +3.3V, TA = +25°C, unless otherwise noted.)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Supply Current	ICC	Single channel		28	40	mA
		Dual channel		56	80	
		Quad channel		112	160	
Input Bias Voltage		IIN = 0		0.89	0.99	V
DC Input Overload			1.7			mA
Transimpedance	Z21	10μAp-p, 100 Ω differential load	3.0	3.7	4.5	kΩ
Filter Resistor RFILTER	RFILTER			180		Ω
Filter Resistors RFILT1–4	RFILT_			720		Ω
Single-Ended Output Impedance	RO		43	50	57	Ω
Transimpedance Linear Range		(Note 1)	50			μAp-p
Maximum Differential Output Range		IIN = 2mAp-p	230	340	480	mVp-p
Output Offset Voltage	Voffset	IIN = 10μAp-p	-5		+5	mV
Output Common Mode Voltage		50Ω loads to VCC		VCC - 0.09		V

**Note 1:** Gain at 50μAp-p is within 10% of the small signal gain.

## AC ELECTRICAL CHARACTERISTICS

(VCC = +3.14V to +3.6V, TA = 0°C to +85°C. Typical values are at +3.3V, TA = +25°C, unless otherwise noted. Total source capacitance = 0.7pF.) (Note 2)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
AC Input Overload		(Note 3)	2			mAp-p
Input Referred Noise	IN			460	600	nArms
Low-Frequency Cutoff		(Note 4)		60	100	kHz
Deterministic Jitter (Note 5)	DJ	IIN > 100μAp-p		20	45	ps
Power-Supply Rejection Ratio	PSRR	(Note 6)		40		dB
Small-Signal Bandwidth	BW			2.4		GHz
Maximum Skew (Note 7)		Any two channels within a chip			50	ps

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## AC ELECTRICAL CHARACTERISTICS (continued)

( $V_{CC} = +3.14V$  to  $+3.6V$ ,  $T_A = 0^{\circ}C$  to  $+85^{\circ}C$ . Typical values are at  $+3.3V$ ,  $T_A = +25^{\circ}C$ , unless otherwise noted. Total source capacitance =  $0.7pF$ .) (Note 2)

**Note 2:** AC characteristics are guaranteed by design and characterization.

**Note 3:** The maximum input current is specified with output deterministic jitter  $\leq 45ps$ .

**Note 4:** No external compensation capacitors are used. Measured with  $I_{IN} = 30\mu A_{avg}$ .

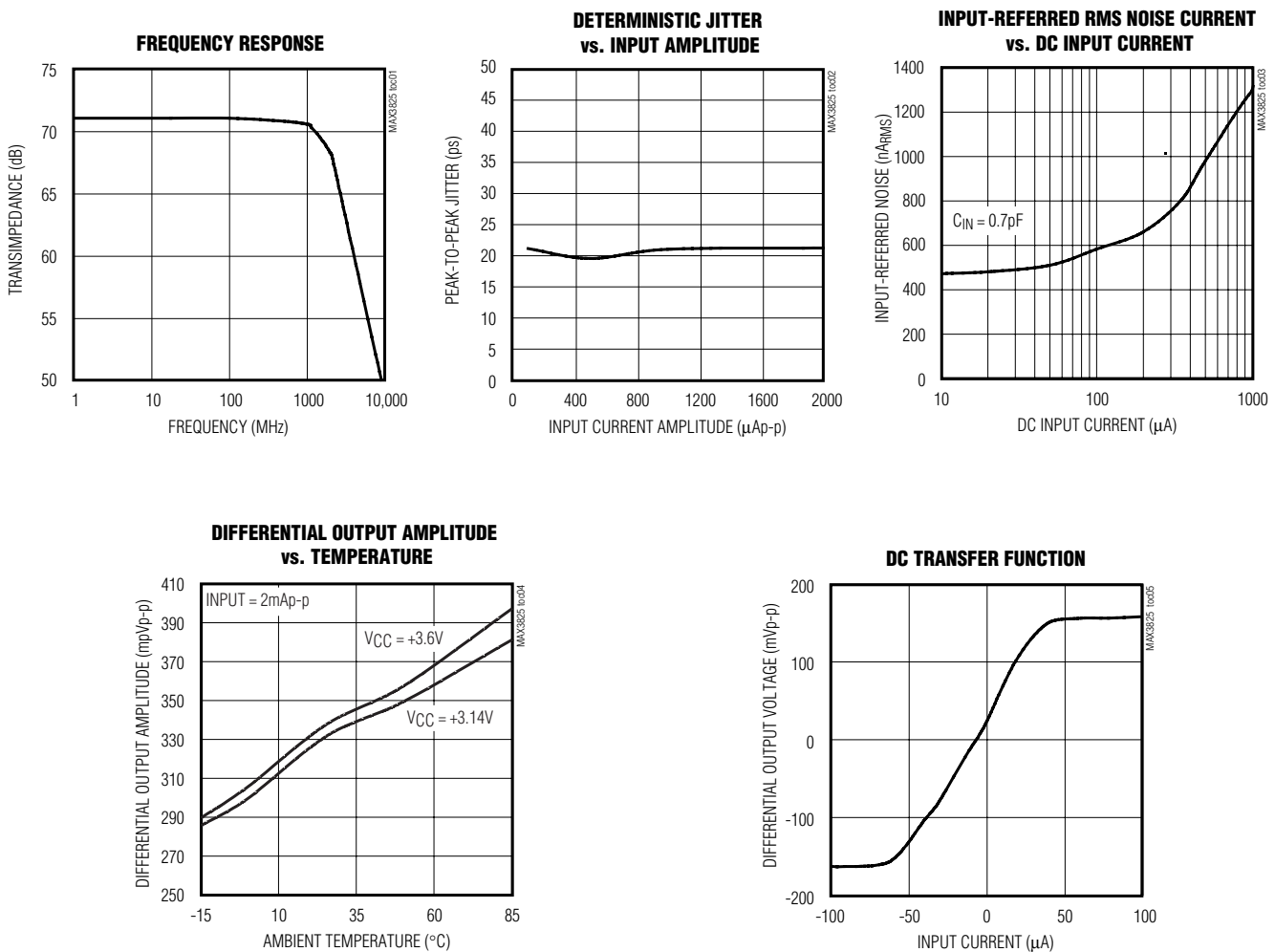
**Note 5:** Deterministic jitter is the arithmetic sum of pattern-dependent jitter and pulse width distortion. Measured with a  $2^{13}-1$  PRBS with 100 consecutive 0s and 100 consecutive 1s applied to a single channel. See *Typical Operating Characteristics*.

**Note 6:** PSRR =  $-20\log(\Delta V_{OUT} / V_{noise(on VCC)})$ ,  $f \leq 2MHz$ . Measured by applying DC current =  $30\mu A$ , and applying  $100mVp-p$  signal at power supply.

**Note 7:** Measured by applying the same input signal to all channels. Skew measurements are made at the 50% point of the transition.

## Typical Operating Characteristics

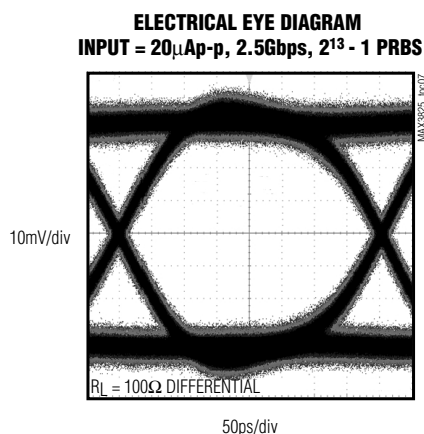
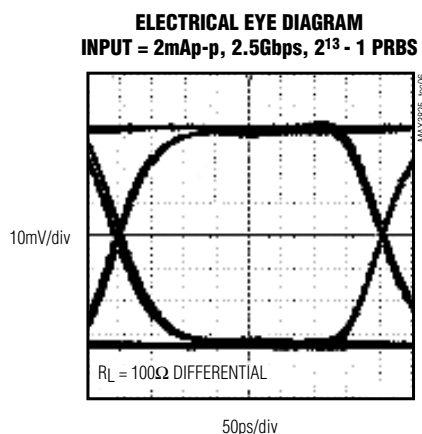
( $V_{CC} = +3.3V$ ,  $T_A = +25^{\circ}C$ , unless otherwise noted.)



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## Typical Operating Characteristics (continued)

( $V_{CC} = +3.3V$ ,  $T_A = +25^\circ C$ , unless otherwise noted.)



## Pad Description

PAD	NAME	FUNCTION
1, 2, 12, 13	N.C.	No Connection. Leave open and unconnected.
3	FILTER	Connection to internal 180 $\Omega$ Filter Resistor to $V_{CCFILT}$ for Photodiode Array Cathode Bias
4, 6, 8, 10	IN1 to IN4	Signal Inputs. Channel 1 to channel 4 signal inputs.
5, 7, 9, 11	FILT1 to FILT4	Filter Connections. Channel 1 to channel 4 connection to internal filter resistors (720 $\Omega$ to $V_{CCFILT}$ ).
14, 17, 40, 43	GNDI4 to GNDI1	Input Stage Ground Connections. Channel 4 to channel 1 input stage ground.
15, 16, 41, 42	VCCI4 to VCCI1	Input Stage Supply Connections. Channel 4 to channel 1 input stage positive supply.
18	$\overline{ENABLE}$	DC Feedback Disable. Disables DC feedback of all four channels when connected to the positive supply ( $V_{CC}$ ). Left unconnected for normal operation.
20, 19, 38, 37	GNDO4 to GNDO1	Output Stage Ground Connections. Channel 4 to channel 1 output stage ground.
21, 24	VCCO4	Channel 4 Output Stage Positive Supply
22, 26, 30, 34	OUT4- to OUT1-	Inverting Outputs. Channel 4 to channel 1 negative outputs.
23, 27, 31, 35	OUT4+ to OUT1+	Noninverting Outputs. Channel 4 to channel 1 positive outputs.
25, 28	VCCO3	Channel 3 Output Stage Positive Supply
29, 32	VCCO2	Channel 2 Output Stage Positive Supply
33, 36	VCCO1	Channel 1 Output Stage Positive Supply
39	GNDF	Ground Connection for the Filters. Filter grounds.
44	VCCFILT	Power Supply Connection for Filter Resistor

## MAX 3825

The schematic diagram illustrates the internal architecture of the MAX3825 precision centration and clipping circuit. The input stage features a differential pair of transistors (Q1, Q5) with a feedback resistor  $R_F = 1.3k\Omega$  and diodes (D1, D2) for clipping. The output stage includes a PARAPHASE AMP, a REFERENCE AMP, and a DC CANCELLATION AMP. The output is taken from the collector of Q2, which is biased by a current source (Q3, R3, R4) and a resistor network (R1, R2). The circuit is powered by  $V_{CC\_FILT}$  and  $GND0\_$ .

### Detailed Description

### Transimpedance Amplifier

## DC Cancellation Loop

The output of the paraphrase amplifier is sensed through resistors R3 and R4 and then filtered, amplified, and fed back to the base of transistor Q4. The transistor draws the DC component of the input signal away from the transimpedance amplifier's summing node.

The MAX3825 DC cancellation loop is internally compensated and does not require external capacitors in most 2.5Gbps applications. The DC cancellation loop for all channels can be disabled by connecting ENABLE to the positive supply (VCC). ENABLE is inter-

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nally pulled low, so it does not need to be bonded out for the DC cancellation loop to function.

The MAX3825 minimizes pulse-width distortion for data sequences exhibiting a 50% duty cycle and mark density. An input signal with a duty cycle and mark density significantly different from 50% will cause the MAX3825 to operate improperly.

DC cancellation current drawn from the input creates noise. This is not a problem for a low-level signal with little or no DC component. Preamplifier noise increases for a signal with significant DC component (see *Typical Operating Characteristics*).

## Paraphase Amplifier and Output Stage

The paraphase amplifier converts single-ended inputs to differential outputs, and introduces a voltage gain of 2.8. This signal drives an internally biased emitter coupled pair, Q2 and Q3, which forms the output stage (Figure 1). Resistors R1 and R2 provide back-termination at the outputs, absorbing reflections between the MAX3825 and its load.

The differential outputs are designed to drive a 100Ω load between OUT\_+ and OUT\_-. The MAX3825 can also drive higher output impedances, resulting in increased gain and output voltage swing.

## Applications Information

The MAX3825 is a quad TIA that is ideal for 2.5Gbps SONET/SDH receivers. Its features allow easy design into a fiberoptic module.

### Optical Power Relations

Many of the MAX3825 specifications relate to the input signal amplitude. When working with fiberoptic receivers, the input is usually expressed in terms of average optical power and extinction ratio. Table 1 shows relations that are helpful for converting optical power to an input signal when designing with the MAX3825 (Figure 2). The definitions are true if the mark density and duty cycle of the input data are 50%.

### Optical Sensitivity Calculation

The input-referred RMS noise current ( $I_N$ ) of the MAX3825 generally determines the receiver sensitivity. To obtain a system bit error rate (BER) of  $1 \times 10^{-14}$ , the signal-to-noise ratio must always exceed 15.3. The input sensitivity, expressed in average power, can be estimated as:

$$\text{Sensitivity} = 10 \log_{10} \left( \frac{15.3 I_N (r_e + 1)}{2p(r_e - 1) \times 1000} \right)$$

**Table 1. Optical Power Relations**

PARAMETER	SYMBOL	RELATION
Average Power	$P_{AVG}$	$P_{AVG} = (P_0 + P_1)/2$
Extinction Ratio	$r_e$	$r_e = P_1/P_0$
Optical Power of a "1"	$P_1$	$P_1 = 2P_{AVG}(r_e)/(r_e + 1)$
Optical Power of a "0"	$P_0$	$P_0 = 2P_{AVG}/(r_e + 1)$
Signal Amplitude	$P_{IN}$	$P_{IN} = P_1 - P_0 = 2P_{AVG}(r_e - 1)/(r_e + 1)$

**Note:** Assuming a 50% input duty cycle and mark density

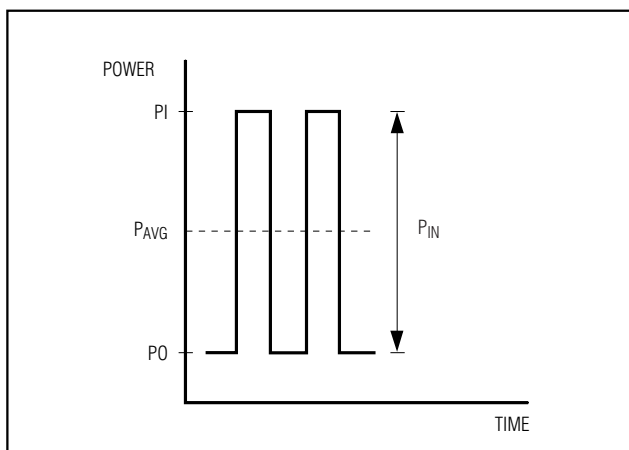


Figure 2. Optical Power Definitions

where  $p$  is the photodiode responsivity in A/W and  $I_N$  is in  $\mu A$ .

### Input Optical Overload

The overload is the largest input that the MAX3825 accepts while meeting specifications. The optical overload can be estimated in terms of average power with the following equation:

$$\text{Overload} = 10 \log_{10} \left( \frac{I_{MAX}}{2p} \right) \text{dBm}$$

where  $p$  is the photodiode responsivity in A/W and  $I_{MAX}$  is in mA.

### Optical Linear Range

The MAX3825's outputs limit when the input signal exceeds 50μAp-p. The MAX3825 operates in a linear range for inputs not exceeding:



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MAX3825

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

where  $\rho$  is the photodiode responsivity in A/W.

## Ground

Connect all input ground connections as close as possible to the AC ground of the photodiode diode. The photodiode AC ground is usually the ground of the filter capacitor from the photodiode cathode. The total loop (from GNDI<sub>-</sub>, through the bypass capacitor and the diode, and back to IN<sub>-</sub>) should be as short as possible.

## Photodiode Filter

Supply voltage noise at the cathode of the photodiode produces a current  $I = C_{PD} \Delta V / \Delta t$ , which reduces the receiver sensitivity ( $C_{PD}$  is the photodiode capacitance). The filter resistor of the MAX3825, combined with an external capacitor, can be used to reduce this noise (see the *Typical Application Circuit*). Current generated by the supply noise voltage is divided between  $C_{FILTER}$  and  $C_{PD}$ . The input noise current due to supply noise is (assuming the filter capacitor is much larger than the photodiode capacitance):

$$I_{NOISE} = \frac{(V_{NOISE})(C_{PD})}{(R_{FILTER})(C_{FILTER})}$$

Another important parameter is the inductance at the photodiode array's common cathode. It is important to keep this inductance to a minimum to reduce the coupling between the photodiodes. To keep this inductance small, keep all bond wires as short as possible.

## Wire Bonding

For high current density and reliable operation, the MAX3825 uses gold metalization. Connections to the die should be made with gold wire only, using ball bonding techniques. Wedge bonding is not recommended. Die thickness is typically 14 mils (mm).

## Interface Models

Refer to Figures 3 and 4 for the equivalent input and output circuits of the MAX3825.

## Chip Information

TRANSISTOR COUNT: 1469

PROCESS: BIPOLAR (SILICON GERMANIUM)

DIE SIZE: 65 × 99mils/(1651 × 2515 microns)

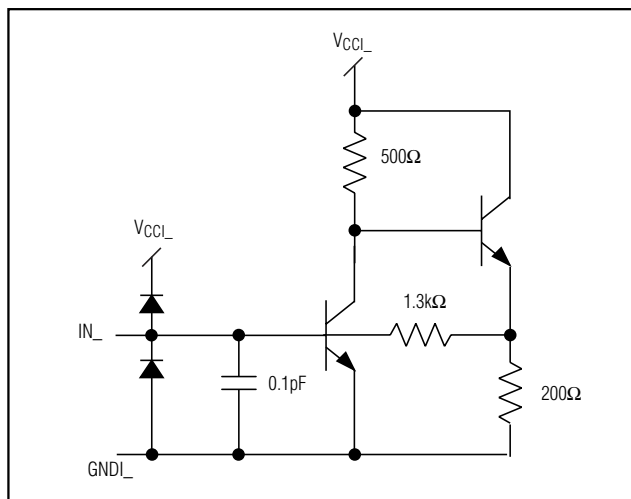


Figure 3. Equivalent Input Circuit

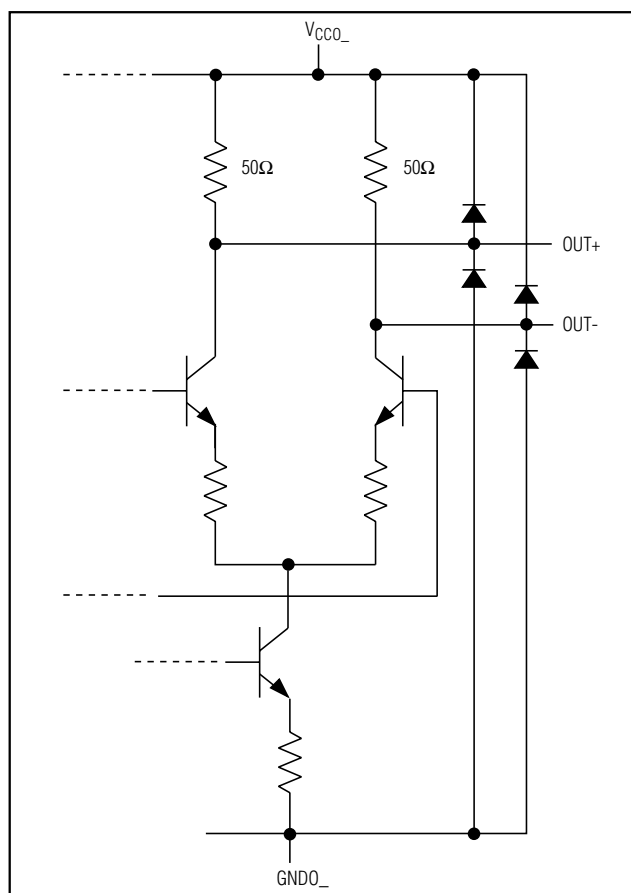
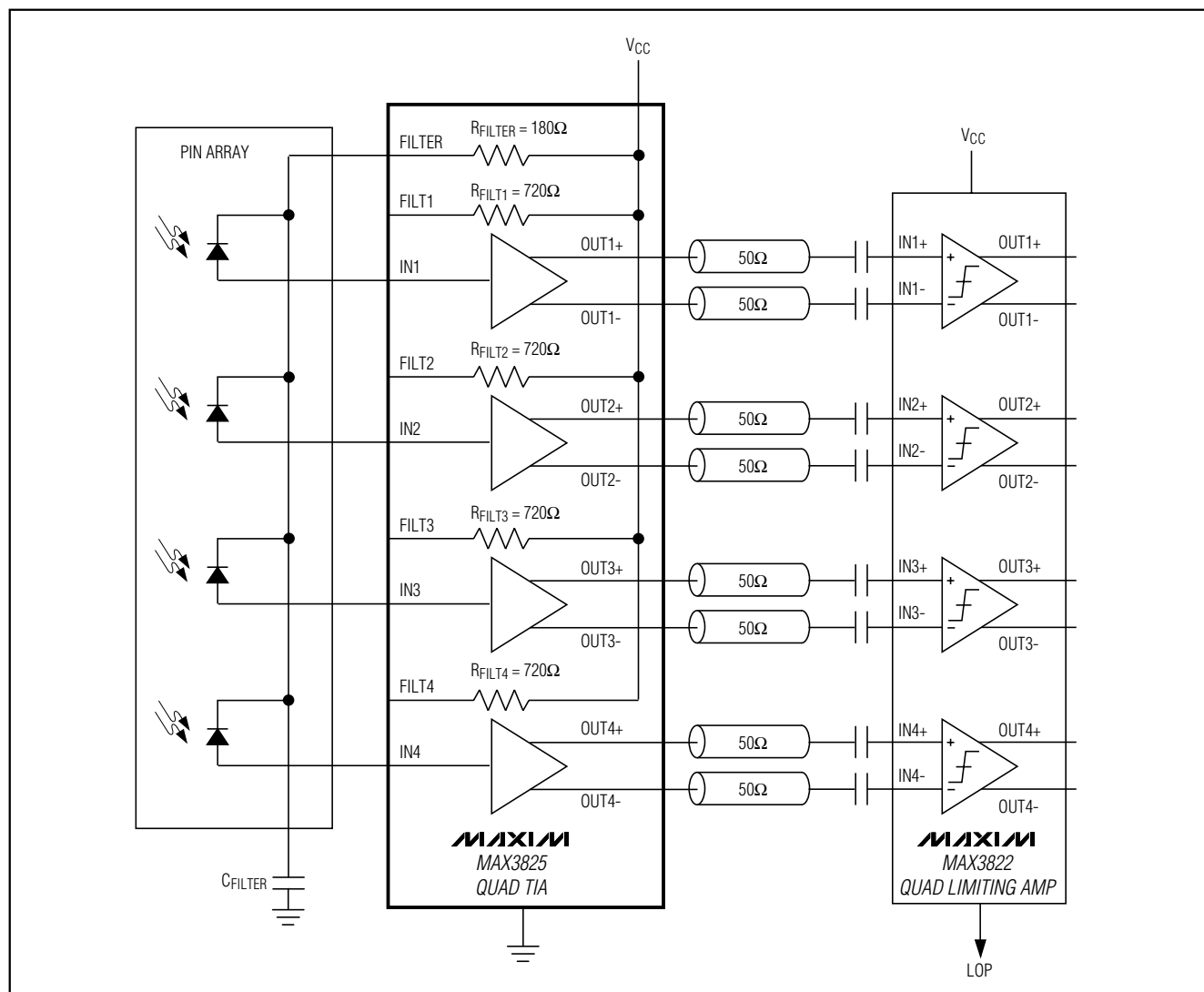


Figure 4. Equivalent Output Circuit

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## Typical Application Circuit



Maxim cannot assume responsibility for use of any circuitry other than circuitry entirely embodied in a Maxim product. No circuit patent licenses are implied. Maxim reserves the right to change the circuitry and specifications without notice at any time.

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