19-2834; Rev 0; 4/03

155Mbps Low-Noise Transimpedance Amplifier

MAX3657

General Description

The MAX3657 is a transimpedance preamplifier for receivers operating up to 155Mbps. The low noise, high gain, and low power dissipation make it ideal for Class-B and Class-C passive optical networks (PON).

The circuit features 14nA input-referred noise, 130MHz bandwidth, and 2mA input overload. Low jitter is achieved without external compensation capacitors. Operating from a +3.3V supply, the MAX3657 consumes only 76mW power. 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 MAX3657 includes an average photocurrent monitor.

The MAX3657 has a typical optical sensitivity of -38dBm (0.9A/W), which exceeds the Class-C PON requirements. Typical overload is 0dBm. The MAX3657 is available in die and 3mm x 3mm 12-pin QFN packages.

Applications

Optical Receivers (Up to 155Mbps Operation)

Passive Optical Networks (PON)

SFP/SFF Transceivers

BiDi Transceivers

Features

- **$14nA_{RMS}$ Input-Referred Noise**
- **54kΩ Transimpedance Gain**
- **130MHz (typ) Bandwidth**
- **$2mA_{P-P}$ Input Current—0dBm Overload Capability**
- **76mW (typ) Power Dissipation**
- **3.3V Single-Supply Operation**
- **Average Photocurrent Monitor**

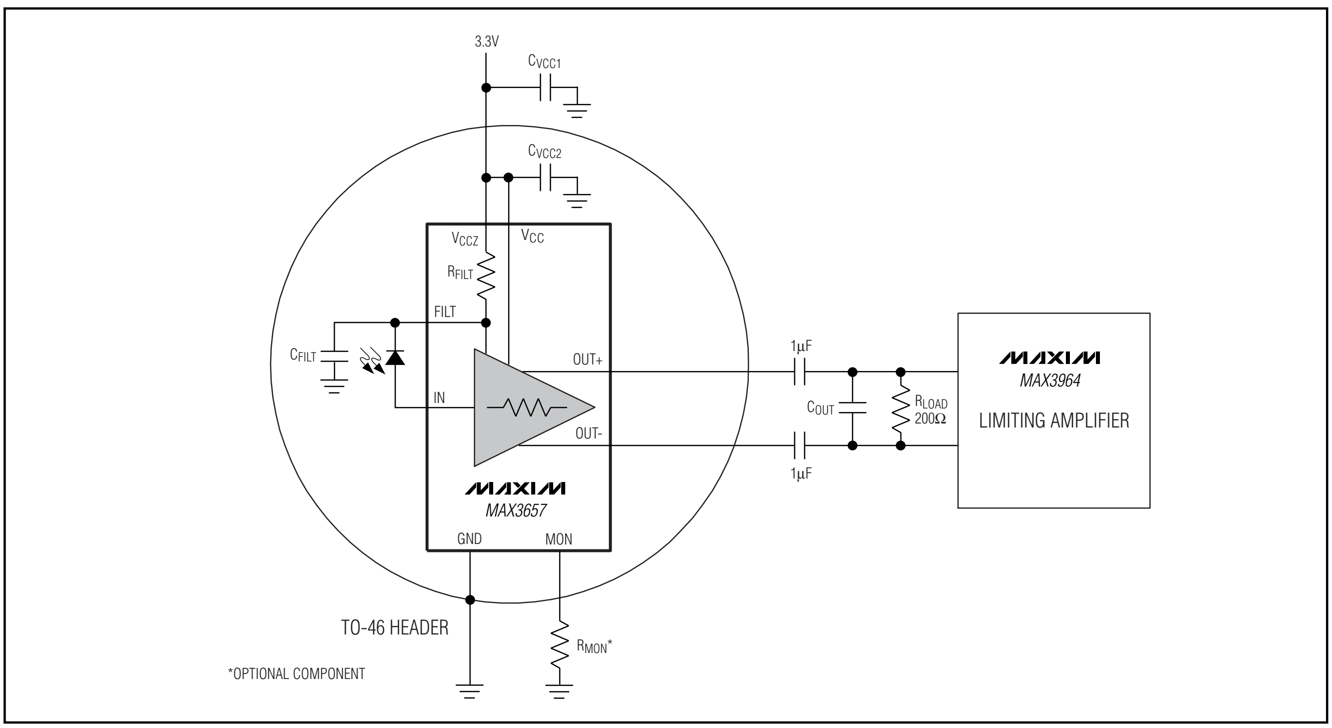
Ordering Information

PART	TEMP RANGE	PIN-PACKAGE
MAX3657EGG*	-40°C to +85°C	12 QFN
MAX3657E/D	-40°C to +85°C	Die**

**Future product—contact factory for availability.*
***Dice are designed to operate over a -40°C to +110°C junction temperature (T_J) range, but are tested and guaranteed at T_A = +25°C.*

Pin Configuration appears at end of data sheet.

Typical Application Circuit



155Mbps Low-Noise Transimpedance Amplifier

ABSOLUTE MAXIMUM RATINGS

Power-Supply Voltage ....-0.5V to +6.0V
Input Continuous Current ....±3.5mA
Voltage at OUT+, OUT- ....(V_{CC} - 1.5V) to (V_{CC} + 0.5V)
Voltage at FILT, MON ....-0.5V to (V_{CC} + 0.5V)
Continuous Power Dissipation
12-Pin QFN (derate 14.7mW/°C above +70°C) 1176mW
Operating Temperature Range
12-Pin QFN ....-40°C to +85°C
Operating Junction Temperature Range
Die ....-40°C to +150°C
Storage Temperature Range ....-55°C to +150°C
Lead Temperature (soldering, 10s) ....+300°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.

DC ELECTRICAL CHARACTERISTICS

(V_{CC1} = +2.97V to +3.63V, 200Ω load between OUT+ and OUT-, T_A = -40°C to +85°C. Typical values are at V_{CC} = +3.3V, T_A = +25°C, unless otherwise noted.) (Note 1)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Supply Current	I_{CC}			23	34	mA
Input Bias Voltage	V_{IN}	I_{IN} ≤ 1mA		1	1.3	V
Transimpedance Linear Range		0.95 < linearity < 1.05, referred to gain at 1µA_{P-P} input	2			µA_{P-P}
Small-Signal Transimpedance	Z_{21}	Differential output, I_{IN} < 200nA_{P-P}	44	54	65	kΩ
Output Common-Mode Voltage		AC-coupled outputs		V_{CC} - 0.225		V
Output Resistance (Per Side)	R_{OUT}	Single-ended output resistance	85	100	115	Ω
Maximum Differential Output Voltage	$V_{OUT(max)}$	I_{IN} = 2mA_{P-P}, V_{OUT} = (V_{OUT+}) - (V_{OUT-})	170	250	450	mV_{P-P}
Filter Resistor	R_{FILT}		640	800	960	Ω
DC Input Overload			1	1.5		mA
Monitor Nominal Gain	G_{NOM}	V_{CC} = +3.3V, +25°C (Note 2)	0.8	1	1.2	A/A
Monitor Gain Stability (Die Only, Note 3)	ΔG	I_{IN} = 100µA to 1mA	-1.5		+1.5	dB
		I_{IN} = 5µA	-1.5		+2.2	
		I_{IN} = 2µA	-4.0		+3.4	
		I_{IN} = 1µA		±2.0		

AC ELECTRICAL CHARACTERISTICS

(V_{CC} = +2.97V to +3.63V, 200Ω load between OUT+ and OUT-, C_{IN} = 0.5pF, C_{FILT} = 400pF, C_{VCC2} = 680pF, T_A = -40°C to +85°C. Typical values are at V_{CC} = +3.3V, T_A = +25°C, unless otherwise noted.) (Note 1)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Small-Signal Bandwidth	BW_{-3dB}	Relative to gain at 1MHz	110	130		MHz
Low-Frequency Cutoff		-3dB, I_{IN} = 1µA		5	25	kHz
AC Overload			2			mA_{P-P}
Pulse-Width Distortion	PWD	300nA_{P-P} ≤ I_{IN} ≤ 2mA_{P-P}		22		ps_{P-P}
Input-Referred Noise Current	I_n	f = 100MHz (Note 4)			15	nA_{RMS}
		f = 117MHz		14		
RMS Noise Density		f = 100MHz		1.3		pA/√Hz
Monitor Bandwidth		I_{IN} = 1µA		5		kHz

AC ELECTRICAL CHARACTERISTICS (12-PIN QFN)

(V_{CC} = +2.97V to +3.63V, R_{LOAD} = 200Ω, C_{IN} = 1.0pF, C_{FILT} = 1000pF, C_{VCC2} = 0.01µF, T_A = -40°C to +85°C. Typical values are at V_{CC} = +3.3V, T_A = +25°C, unless otherwise noted.) (Note 1)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Small-Signal Bandwidth	BW_{-3dB}	Relative to gain at 1MHz		95		MHz
Low-Frequency Cutoff		-3dB, I_{IN} = 1µA		5	25	kHz
AC Overload			2			mA
Pulse-Width Distortion	PWD	$1µA_{P-P} \le I_{IN} \le 2mA_{P-P}$		22		ps_{P-P}
Input-Referred Noise Current	I_n	f = 50MHz (Note 4)		5		nA_{RMS}
		f = 100MHz		13		
RMS Noise Density		f = 100MHz		1.3		pA/√Hz

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

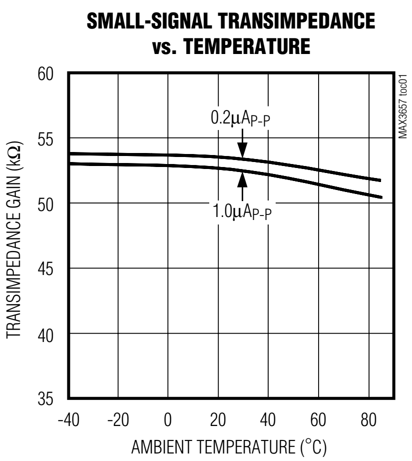
Note 2: $G_{NOM} = [I_{MON}(1mA) - I_{MON}(5µA)] / [(1mA) - (5µA)]$.

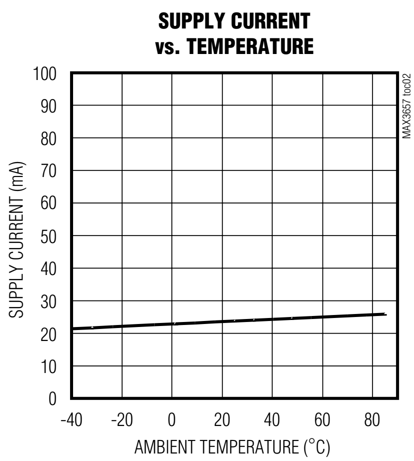
Note 3: Stability is relative to the nominal gain at V_{CC} = +3.3V, T_A = +25°C. $\Delta G(I_{IN})$ dB = 10 log_{10} [$I_{MON}(I_{IN})$] / [$I_{MON}(1mA)$ - G_{NOM} x (1mA - I_{IN})], V_{MON} ≤ 2.1V, Input t_r, t_f > 550ps (20% to 80%).

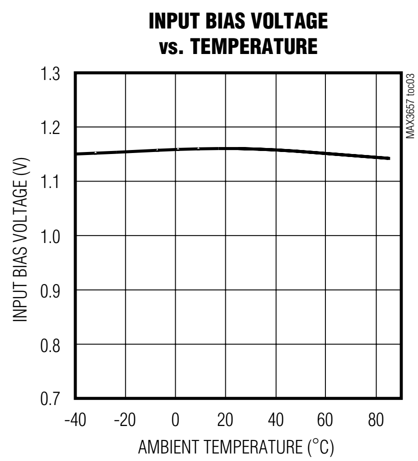
Note 4: Total noise integrated from 0 to f.

Typical Operating Characteristics

(MAX3657 E/D. V_{CC} = 3.3V, C_{IN} = 0.5pF, T_A = +25°C, unless otherwise noted.)







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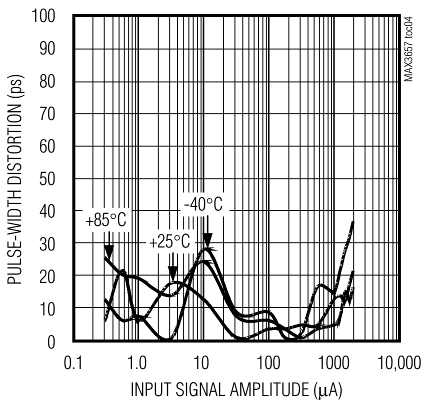
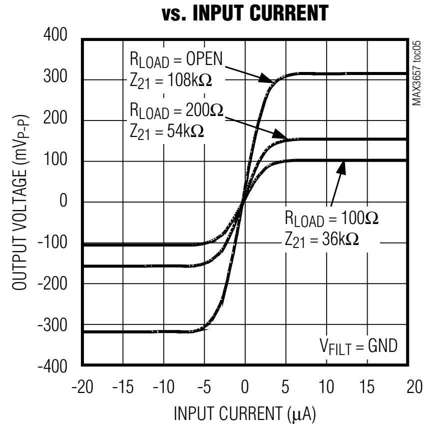
Typical Operating Characteristics (continued)

(MAX3657 E/D. V_{CC} = 3.3V, C_{IN} = 0.5pF, T_A = +25°C, unless otherwise noted.)

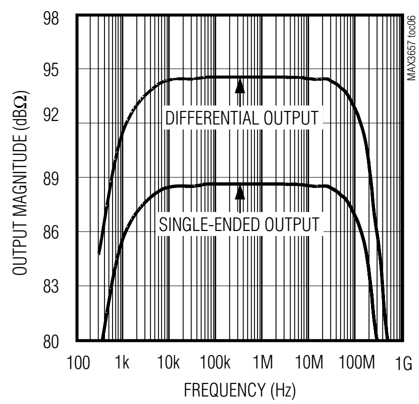
PULSE-WIDTH DISTORTION vs. INPUT CURRENT AMPLITUDE



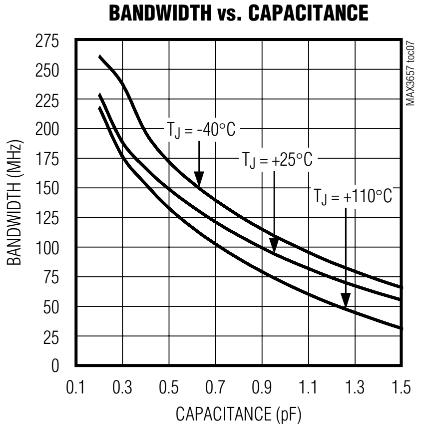
DIFFERENTIAL OUTPUT VOLTAGE vs. INPUT CURRENT



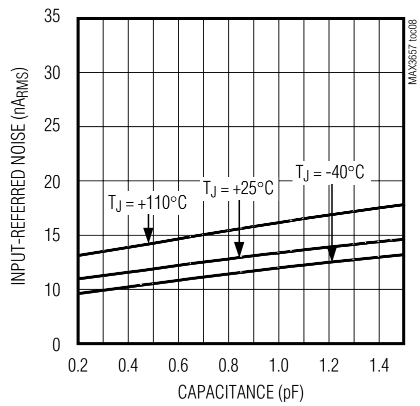
FREQUENCY RESPONSE



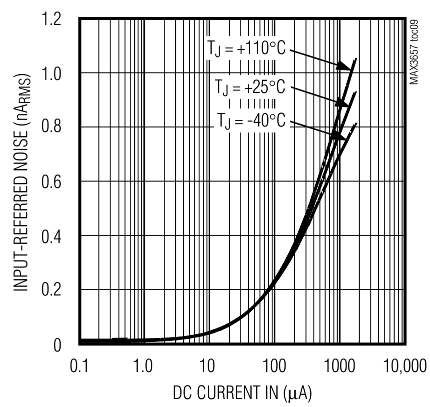
BANDWIDTH vs. CAPACITANCE



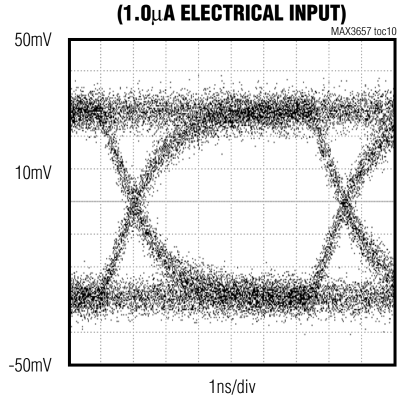
INPUT-REFERRED RMS NOISE vs. CAPACITANCE



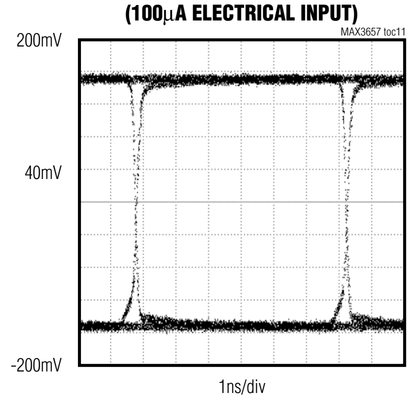
INPUT-REFERRED RMS NOISE vs. DC INPUT CURRENT



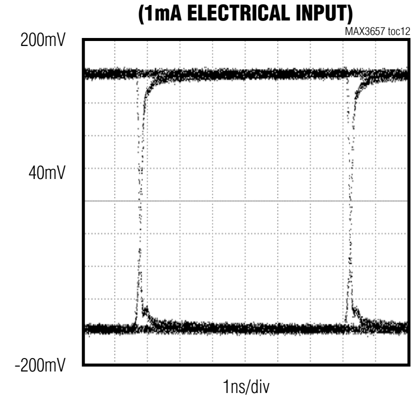
OUTPUT EYE DIAGRAM (1.0µA ELECTRICAL INPUT)



OUTPUT EYE DIAGRAM (100µA ELECTRICAL INPUT)



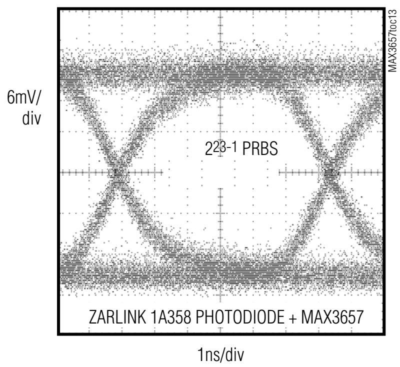
OUTPUT EYE DIAGRAM (1mA ELECTRICAL INPUT)



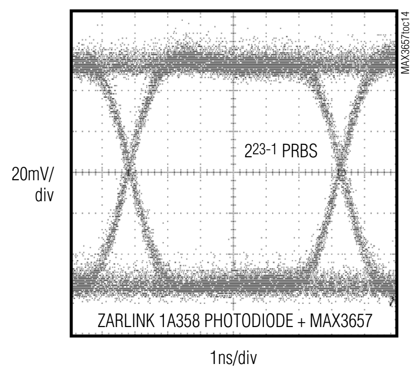
Typical Operating Characteristics (continued)

(MAX3657 E/D. V_{CC} = 3.3V, C_{IN} = 0.5pF, T_A = +25°C, unless otherwise noted.)

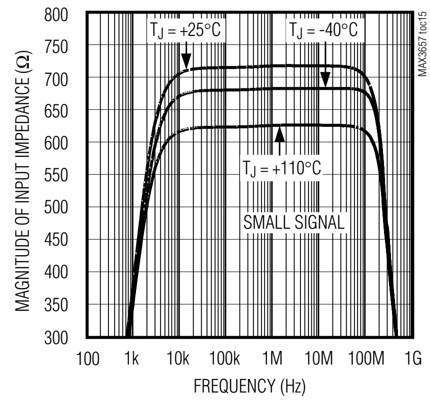
OUTPUT EYE DIAGRAM (-30dBm OPTICAL INPUT)



OUTPUT EYE DIAGRAM (-1dBm OPTICAL INPUT)



INPUT IMPEDANCE vs. FREQUENCY



Pin Description

PIN	NAME	FUNCTION
1, 9, 11	N.C.	No Connection. Do not connect.
2	GND	Negative Supply Voltage. Both GND and GNDZ must be connected to ground.
3	GNDZ	Negative Supply Voltage. Both GND and GNDZ must be connected to ground.
4	MON	Photocurrent Monitor. This is a current output. Connect a resistor between MON and ground to monitor the average photocurrent.
5	IN	Signal Input. Connect to photodiode anode.
6	FILT	Filter Connection (Optional). Use to bias the photodiode cathode. An internal 800Ω on-chip resistor is connected between this pin and V_{CCZ} , an external decoupling capacitor connected to this pin forms a filter (see the *Design Procedure* section).
7	V_{CCZ}	Power-Supply Voltage. Both V_{CC} and V_{CCZ} must be connected to the supply.
8	V_{CC}	Power-Supply Voltage. Both V_{CC} and V_{CCZ} must be connected to the supply.
10	OUT+	Positive Data Output. This output has 100Ω back termination, increasing input current causes OUT+ to increase.
12	OUT-	Negative Data Output. This output has 100Ω back termination, increasing input current causes OUT- to decrease.

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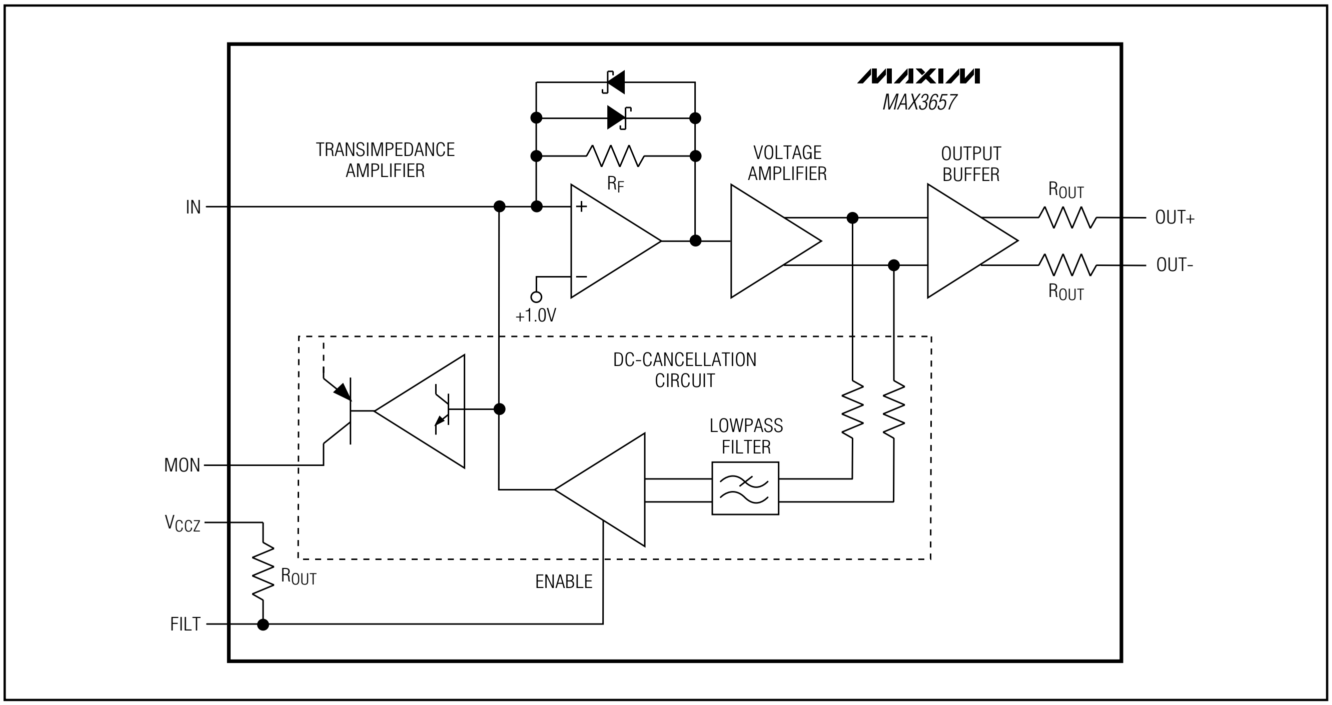
Functional Diagram



Detailed Description

The MAX3657 transimpedance amplifier is designed for 155Mbps fiber optic applications. The functional diagram of the MAX3657 is comprised of a transimpedance amplifier, a voltage amplifier, a DC-cancellation circuit, and a CML output buffer.

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 provides a reverse-terminated voltage output and is designed to drive a 200Ω differential load between OUT+ and OUT-. For optimum supply-noise rejection, the MAX3657 should be terminated with a differential load. The MAX3657 single-ended outputs do not drive a DC-coupled grounded load. The outputs should be AC-coupled or terminated to V_{CC}. If a single-ended output is required, both the used and the unused outputs should be terminated in a similar manner.

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 MAX3657 to generate pulse-width distortion. Grounding the FILT pin disables the DC-cancellation circuit. For normal operation, the DC-cancellation circuit must be enabled.

The DC-cancellation current is drawn from the input and creates noise. For low-level signals with little or no DC component, the added noise is insignificant. However, amplifier noise increases for signals with significant DC component (see the *Typical Operating Characteristics*).

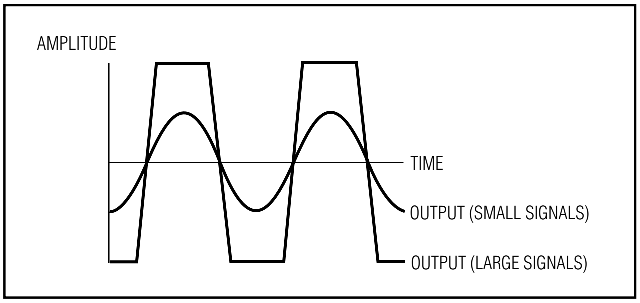


Figure 1. MAX3657 Limited Outputs

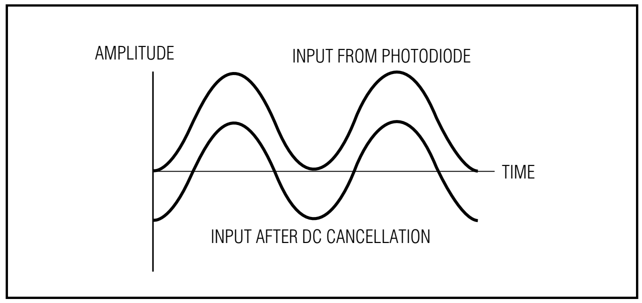


Figure 2. Effects of DC Cancellation on Input

Photocurrent Monitor

The MAX3657 includes an average photocurrent monitor. The current at MON is approximately equal to the DC current at IN. Best monitor accuracy is obtained when data input edge time is longer than 500ps.

Design Procedure

Select Photodiode

Noise performance and bandwidth are adversely affected by stray capacitance on the TIA input node. Select a low-capacitance photodiode to minimize the total input capacitance on this pin. The MAX3657 is optimized for 0.5pF of capacitance on the input. Assembling the MAX3657 in die form using chip and wire technology provides the lowest capacitance input and the best possible performance.

Select C_{FILT}

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 MAX3657, combined with an external capacitor, can be used to reduce the noise (see the *Typical Application Circuit*). Current generated by supply-noise voltage is divided between C_{FILT} and C_{PD}. To obtain a good optical sensitivity, select C_{FILT} > 400pF.

Select Supply Filter

The MAX3657 requires wideband power-supply decoupling. Power-supply bypassing should provide low impedance between V_{CC} and ground for frequencies between 10kHz and 200MHz. Use LC filtering at the main supply terminal and decoupling capacitors as close to the die as possible.

Select R_{MON}

Connect a resistor between MON and ground to monitor the average photocurrent. Select R_{MON} as large as possible:

$$R_{MON} = \frac{2.1V}{I_{MONMAX}}$$

where I_{MONMAX} is the largest average input current observed.

Select Coupling Capacitors

A receiver built with the MAX3657 has a bandpass frequency response. The low-frequency cutoff due to the coupling capacitors and load resistors is:

$$LFC_{TERM} = \frac{1}{2\pi \times R_{LOAD} \times C_{COUPLE}}$$

Select C_{COUPLE} so the low-frequency cutoff due to the load resistors and coupling capacitors is much lower than the low-frequency cutoff of the MAX3657. The coupling capacitor should be 0.1µF or larger, but 1.0µF is recommended for lowest jitter. Refer to Maxim Application Note HFAN-1.1: *Choosing AC-Coupling Capacitors* for more information.

Layout Considerations

Figure 3 shows a suggested layout for a TO header for the MAX3657.

Wire Bonding

For high-current density and reliable operation, the MAX3657 uses gold metalization. For best results, use gold-wire ball-bonding techniques. Use caution if attempting wedge bonding. Die-size is 41 mils x 48 mils, (1040µm x 1220µm) and die thickness is 15 mils (380µm). The bond pad is 94.4µm x 94.4µm and its metal thickness is 1.2µm. Refer to Maxim Application Note HFAN- 8.0.1:

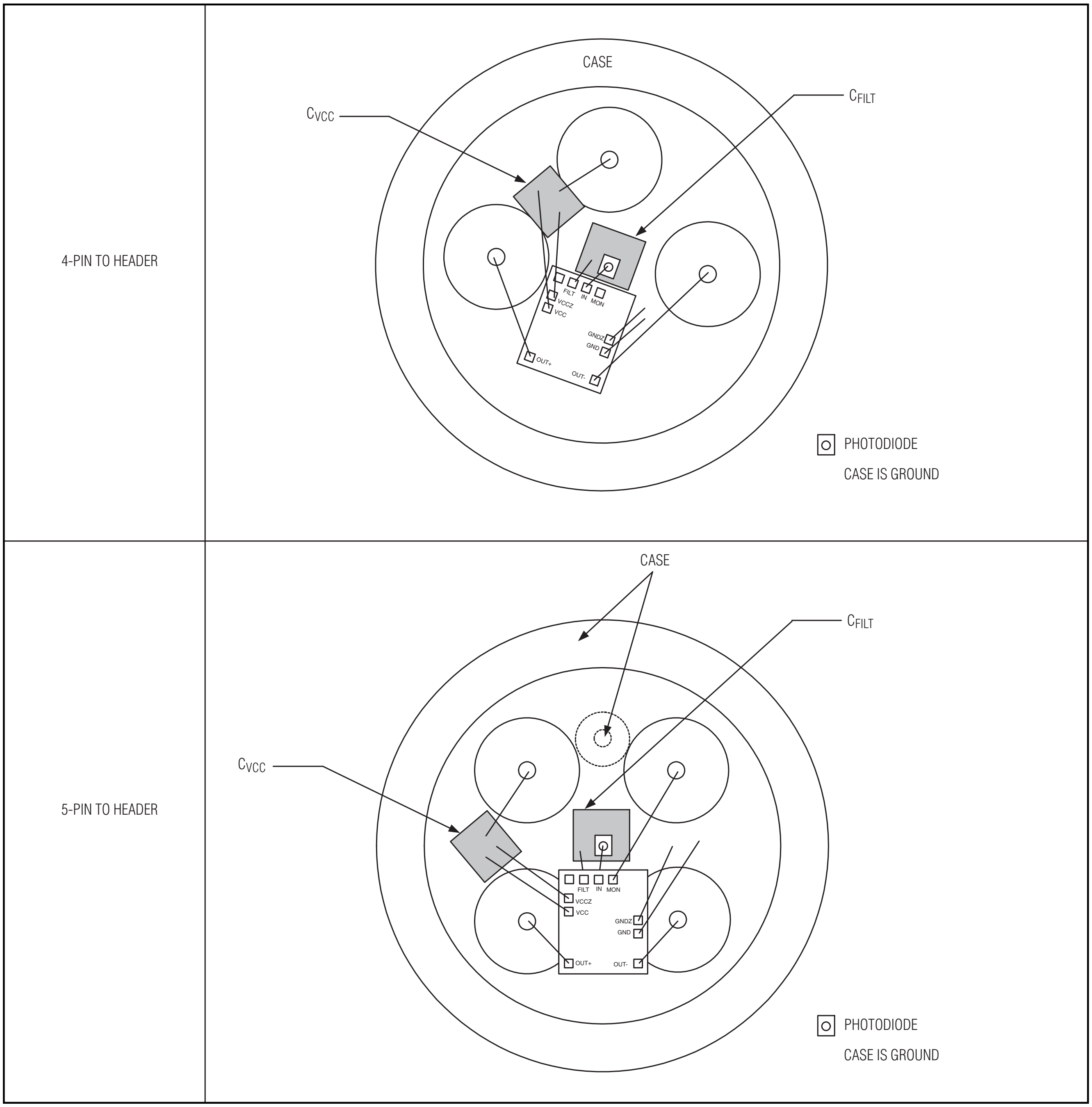


Figure 3. Suggested TO Header Layout

Understanding Bonding Coordinates and Physical Die Size for more information on bond-pad coordinates.

Applications Information

Optical Power Relations

Many of the MAX3657 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 4 and Table 1 show relations that are helpful for converting optical power to input signal when designing with the MAX3657.

Optical Sensitivity Calculation

The input-referred RMS noise current (i_n) of the MAX3657 generally determines the receiver sensitivity. To obtain a system bit-error rate (BER) of 1E-10, the signal-to-noise ratio must always exceed 12.7. The input sensitivity, expressed in average power, can be estimated as:

$$\text{Sensitivity} = 10\log\left(\frac{12.7 \times i_n \times (r_e + 1)}{2 \times \rho \times (r_e - 1)} \times 1000\right) \text{dBm}$$

where ρ is the photodiode responsivity in A/W and i_n is the RMS noise current in amps. For example, with photodiode responsivity of 0.9A/W, an extinction ratio of 10 and 15nA input-referred noise, the sensitivity of the MAX3657 is:

$$\text{Sensitivity} = 10\log\left(\frac{12.7 \times 15\text{nA} \times 11}{2 \times 0.9\text{A/W} \times 9} \times 1000\right) \text{dBm} = -38\text{dBm}$$

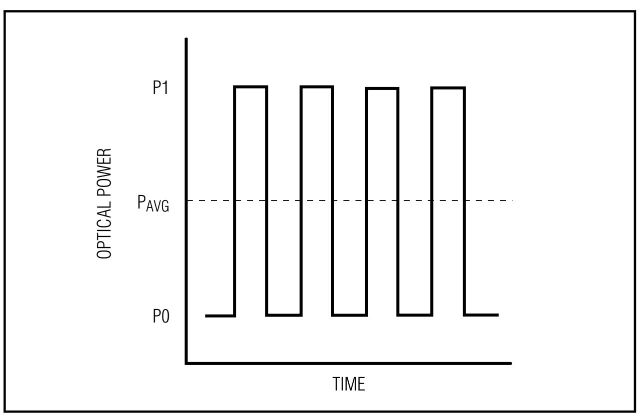


Figure 4. Optical Power Relations

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}	$P_{IN} = P1 - P0 = 2P_{AVG} \frac{r_e}{r_e + 1}$

**Assuming a 50% average mark density.*

Actual results may vary depending on supply noise, output filter, limiting amplifier sensitivity, and other factors (refer to Maxim Application Note HFAN-3.0.0: *Accurately Estimating Optical Receiver Sensitivity*).

Input Optical Overload

Overload is the largest input the MAX3657 accepts while meeting the pulse-width distortion specification. Optical overload can be estimated in terms of average power with the following equation:

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

For example, if photodiode responsitivity is 1.0A/W, the input overload is 0dBm.

Optical Linear Range

The MAX3657 has high gain, which limits the output for large input signals. The MAX3657 operates in a linear range for inputs not exceeding:

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

For example, with photodiode responsivity of 0.9A/W and an extinction ratio of 10 the linear range is:

$$\text{Linear Range} = 10\log\left(\frac{2\mu\text{A} \times 11}{2 \times 0.9 \times 9} \times 1000\right) \text{dBm} = -28\text{dBm}$$

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Interface Schematics

Equivalent Output Interface

The MAX3657 has a differential CML output structure with 100Ω back termination (200Ω differentially). Figure 5 is a simplified diagram of the output interface. The output current is divided between the internal 100Ω resistor and the external load resistance. Because of the CML structure, the maximum output-signal amplitude is affected by load impedance. Note that the internal back termination is 100Ω single ended and external termination is recommended to interface the device to 50Ω test equipment. For example, if single-ended operation in a 50Ω system is required, first match the output of the MAX3657 to the 50Ω controlled impedance by placing a 100Ω pullup resistor in parallel with the output. Then establish similar loading conditions on the unused output. Note that the loading conditions affect the overall gain of the MAX3657. Figures 6a, 6b, and 6c show alternate interface schemes for the MAX3657.

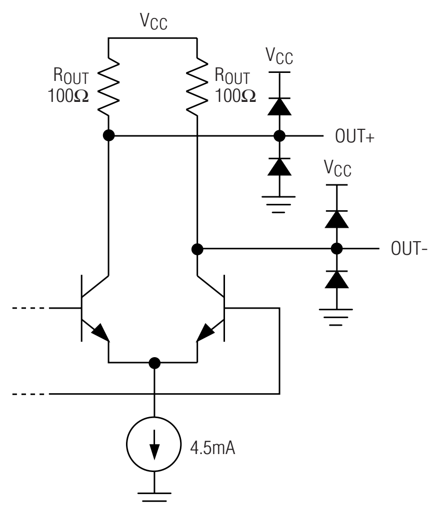


Figure 5. Equivalent Output Interface

Pad Coordinates

Table 2 lists center-pad coordinates for the MAX3657 bond pads. Refer to Maxim Application Note HFAN-8.0.1: *Understanding Bonding Coordinates and Physical Die Size* for more information on bond-pad coordinates.

Table 2. Bond-Pad Information

PAD	NAME	COORDINATES	
		X	Y
BP1	OUT-	47.2	994.8
BP2	GND	52.2	484.6
BP3	GNDZ	52.2	357.7
BP4	MON	395.5	47.2
BP5	IN	522.3	47.2
BP6	FILT	648.5	47.2
BP7	N.C.	808.5	49.9
BP8	V_{CCZ}	808.5	176.8
BP9	V_{CC}	808.5	303.7
BP10	OUT+	808.5	994.8
BP11	N.C.	741.1	859.9

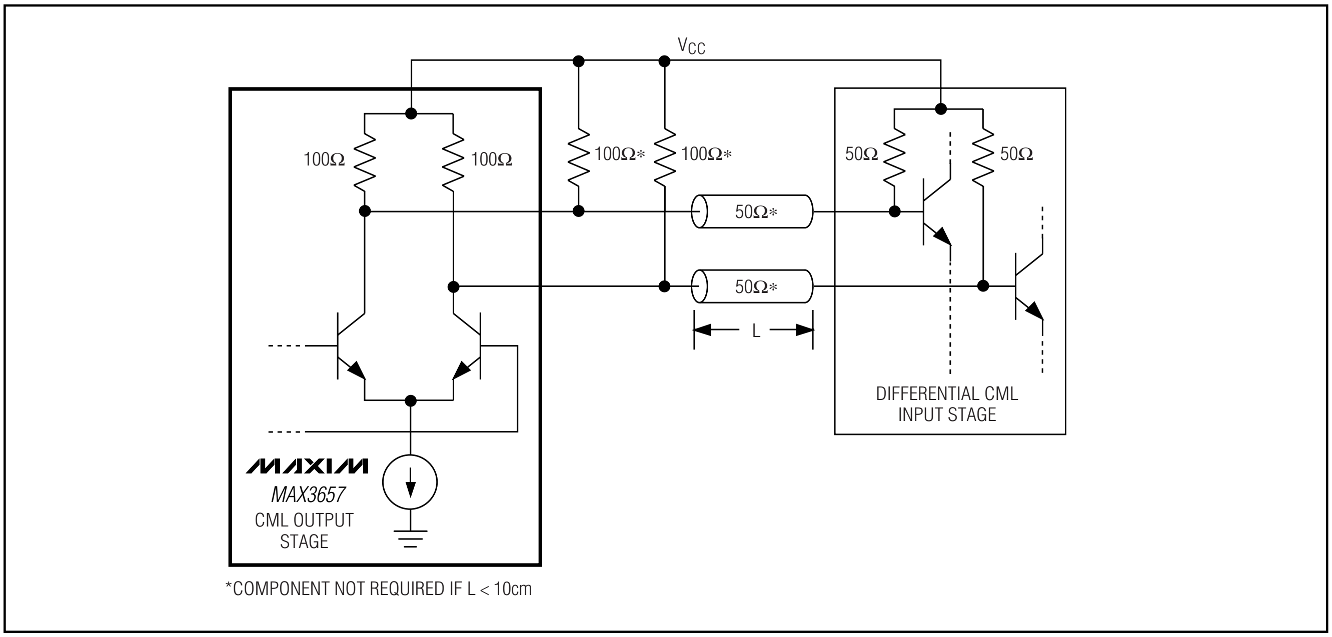


Figure 6a. 50Ω DC-Coupled Interface

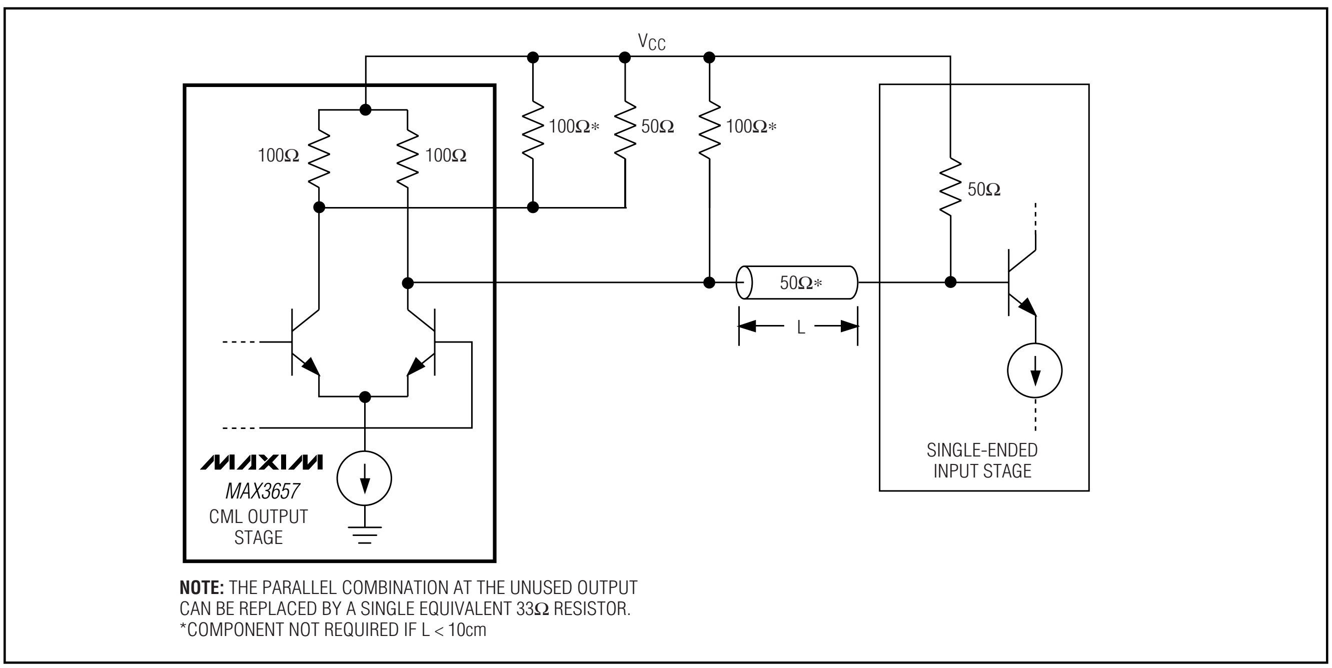


Figure 6b. 50Ω DC-Coupled Single-Ended Output Interface

155Mbps Low-Noise Transimpedance Amplifier

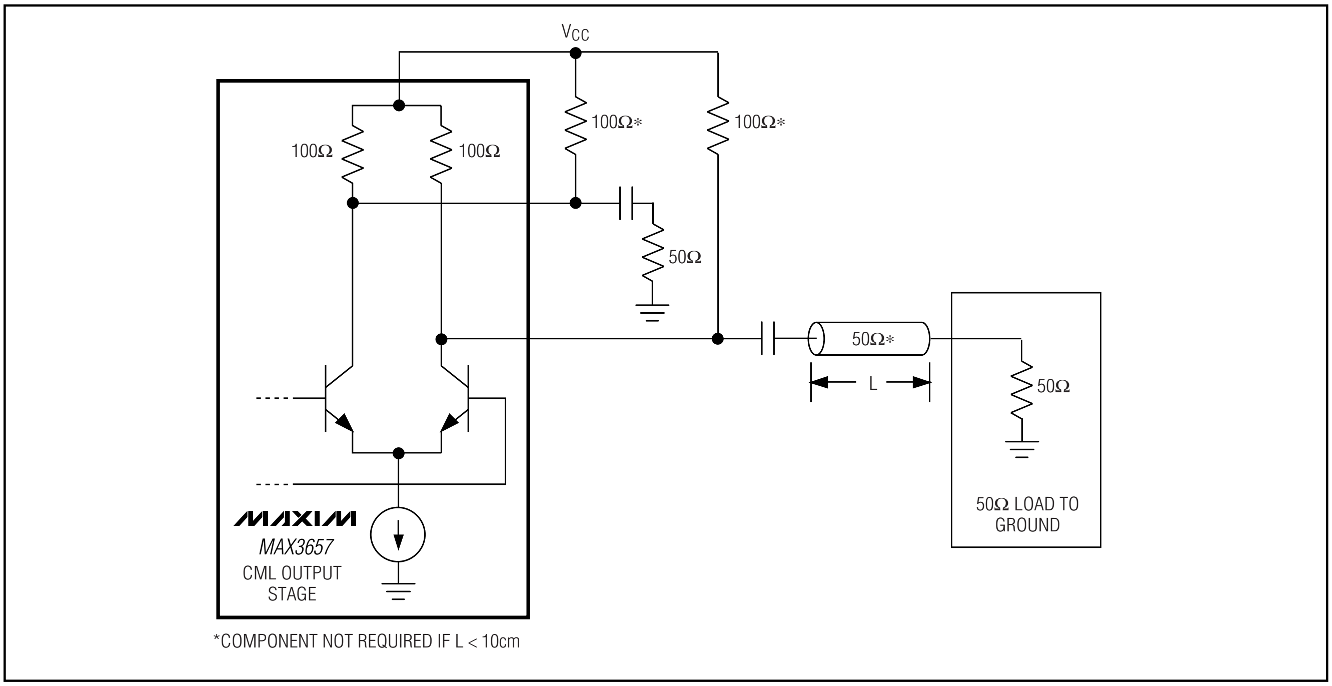


Figure 6c. 50Ω AC-Coupled Single-Ended Output Interface

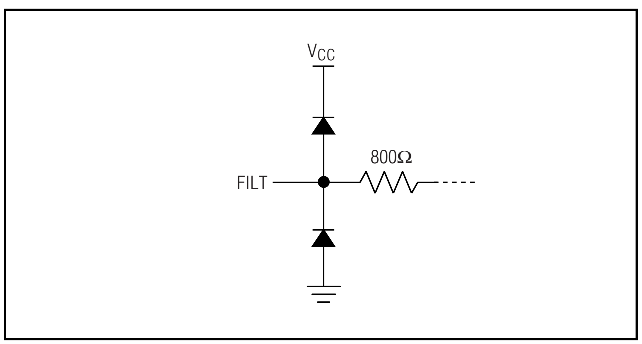


Figure 7. FILT Interface

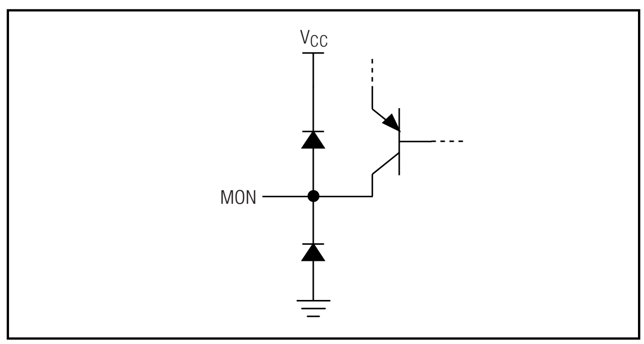
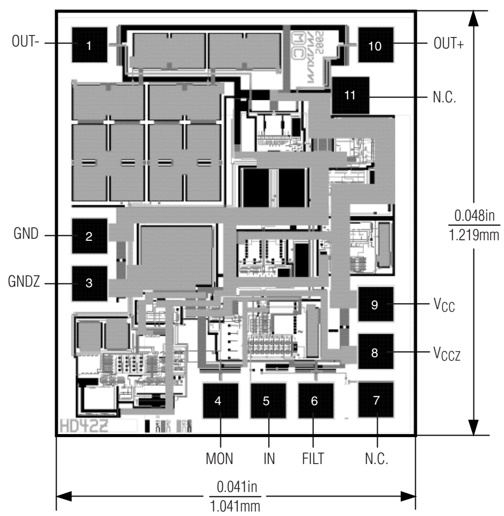
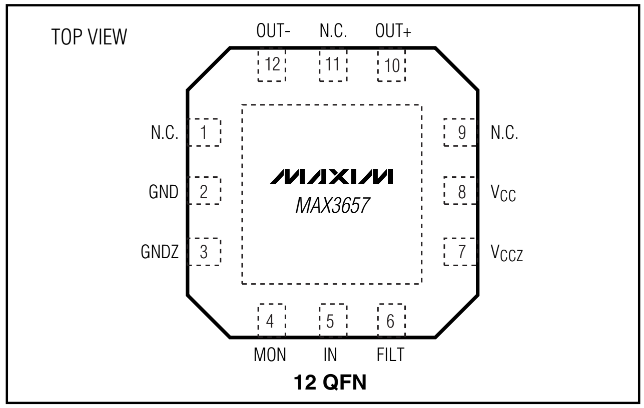


Figure 8. MON Interface

Chip Topography



Pin Configuration



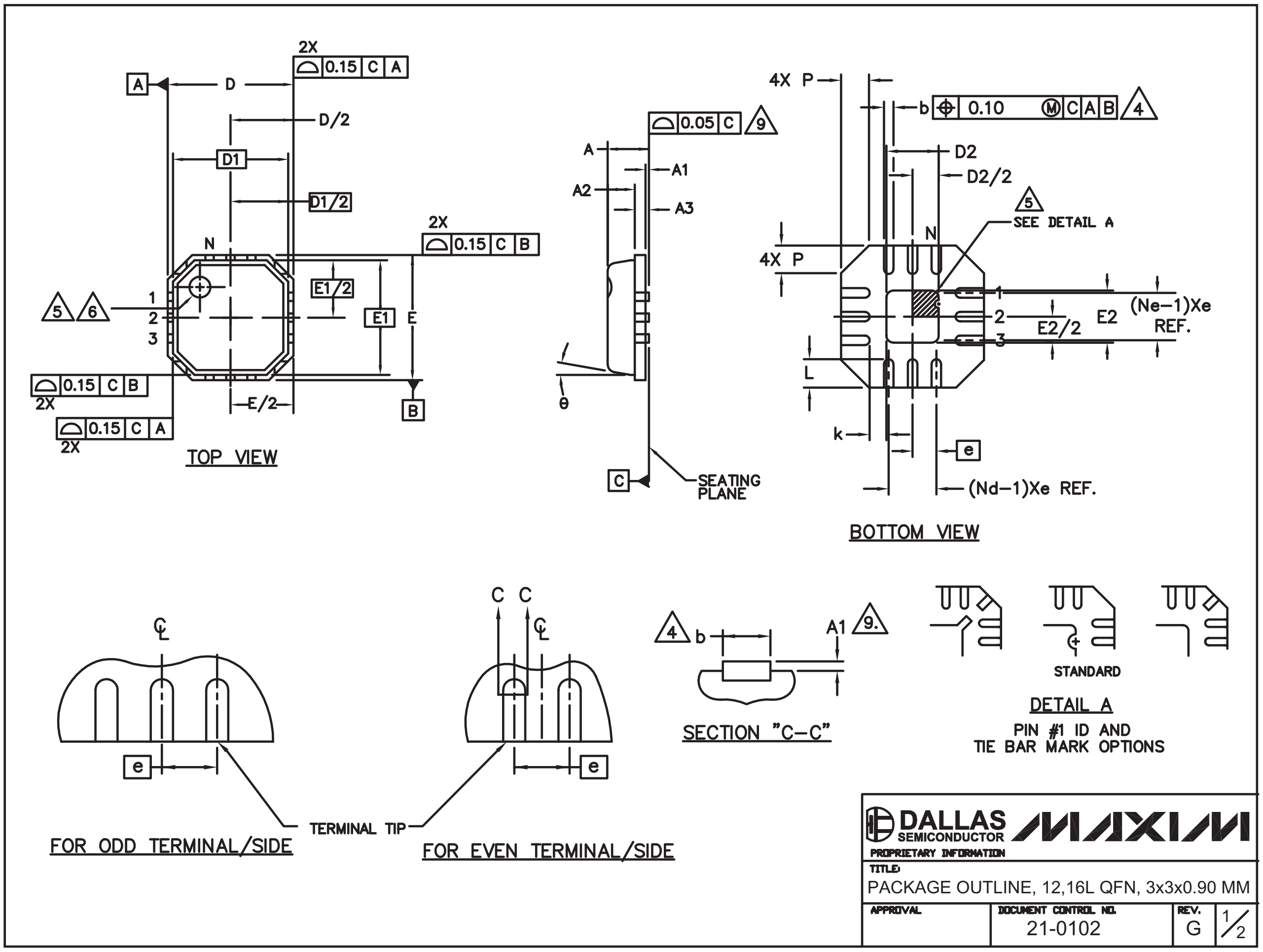
Chip Information

TRANSISTOR COUNT: 417
PROCESS: Silicon Bipolar
SUBSTRATE: Connected to GND
DIE SIZE: 1.04mm x 1.22mm

155Mbps Low-Noise Transimpedance Amplifier

Package Information

(The package drawing(s) in this data sheet may not reflect the most current specifications. For the latest package outline information, go to **www.maxim-ic.com/packages**.)



12, 16L QFN.EPS

Package Information (continued)

(The package drawing(s) in this data sheet may not reflect the most current specifications. For the latest package outline information, go to **www.maxim-ic.com/packages**.)

COMMON DIMENSIONS						
PKG	12L 3x3			16L 3x3		
SYMBOL	MIN.	NOM.	MAX.	MIN.	NOM.	MAX.
A	0.80	0.90	1.00	0.80	0.90	1.00
A1	0.00	0.01	0.05	0.00	0.01	0.05
A2	0.00	0.65	1.00	0.00	0.65	1.00
A3	0.20 REF			0.20 REF		
b	0.18	0.23	0.30	0.18	0.23	0.30
D	2.90	3.00	3.10	2.90	3.00	3.10
D1	2.75 BSC			2.75 BSC		
E	2.90	3.00	3.10	2.90	3.00	3.10
E1	2.75 BSC			2.75 BSC		
e	0.50 BSC			0.50 BSC		
k	0.25	–	–	0.25	–	–
L	0.35	0.55	0.75	0.30	0.40	0.50
N	12			16		
ND	3			4		
NE	3			4		
P	0.00	0.42	0.60	0.00	0.42	0.60
θ	0°		12°	0°		12°

EXPOSED PAD VARIATIONS						
PKG. CODES	D2			E2		
	MIN.	NOM.	MAX.	MIN.	NOM.	MAX.
G1233-1	0.95	1.10	1.25	0.95	1.10	1.25
G1633-2	0.95	1.10	1.25	0.95	1.10	1.25

NOTES:

1. DIE THICKNESS ALLOWABLE IS 0.305mm MAXIMUM (.012 INCHES MAXIMUM).
2. DIMENSIONING & TOLERANCES CONFORM TO ASME Y14.5M. – 1994.
3. N IS THE NUMBER OF TERMINALS. Nd IS THE NUMBER OF TERMINALS IN X-DIRECTION & Ne IS THE NUMBER OF TERMINALS IN Y-DIRECTION.
4. DIMENSION b APPLIES TO PLATED TERMINAL AND IS MEASURED BETWEEN 0.20 AND 0.25mm FROM TERMINAL TIP.
5. THE PIN #1 IDENTIFIER MUST EXIST ON THE TOP SURFACE OF THE PACKAGE BY USING INDENTATION MARK OR INK/LASER MARKED. DETAILS OF PIN #1 IDENTIFIER IS OPTIONAL, BUT MUST BE LOCATED WITHIN ZONE INDICATED.
6. EXACT SHAPE AND SIZE OF THIS FEATURE IS OPTIONAL.
7. ALL DIMENSIONS ARE IN MILLIMETERS.
8. PACKAGE WARPAGE MAX 0.05mm.
9. APPLIED FOR EXPOSED PAD AND TERMINALS. EXCLUDE EMBEDDING PART OF EXPOSED PAD FROM MEASURING.
10. MEETS JEDEC MO220.
11. THIS PACKAGE OUTLINE APPLIES TO ANVIL SINGULATION (STEPPED SIDES).

DALLAS SEMICONDUCTOR MAXIM

PROPRIETARY INFORMATION

TITLE: PACKAGE OUTLINE, 12,16L QFN, 3x3x0.90 MM

APPROVAL	DOCUMENT CONTROL NO.	REV.	
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