19-3745; Rev 0; 7/05

47MHz to 870MHz Analog CATV Transimpedance Amplifier

General Description

The MAX3654 analog transimpedance amplifier (TIA) is designed for CATV applications in fiber-to-the-home (FTTH) networks. This high-linearity amplifier is intended for 47MHz to 870MHz subcarrier multiplexed (SCM) signals in passive optical networks (PON). A gain-control input supports AGC operation with optical inputs having -6dBm to +2dBm average power. With 62dBΩ maximum gain at 47MHz and 18dB gain control range, the minimum RF output level is 14dBmV/channel at -6dBm optical input. A compact 4mm x 4mm package includes all of the active RF circuitry required to convert analog PIN photocurrent to a 75Ω CATV output.

This 700mW SiGe RF IC provides a low-cost, low-power integrated analog CATV receiver solution for FTTH ONTs.

Applications

FTTH Optical Network Termination (ONT)

Pin Configuration appears at end of data sheet.

Features

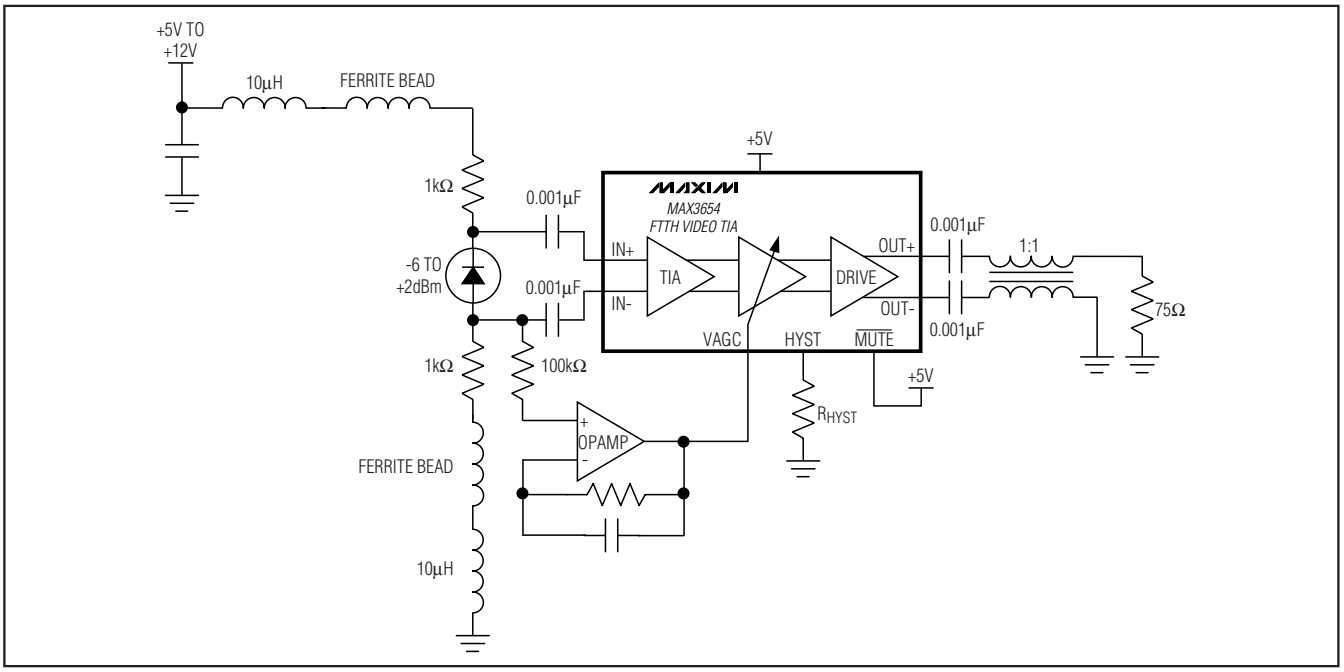
- **47MHz to 870MHz Operation**
- **-6dBm to +2dBm Optical Input Range**
- **21dBm OIP3, 47dBm OIP2**
- **5.5pA/√Hz EIN (Amplifier Alone)**
- **62dB Gain at 47MHz**
- **18dB Transimpedance (Gain) Control**
- **Integrated +4dB Gain Tilt (with Typical Photodiode)**
- **+5V Single-Supply Operation**
- **700mW Power Dissipation**
- **-40°C to +85°C Operating Temperature Range**
- **4mm x 4mm TQFN Package**

Ordering Information

PART	TEMP RANGE	PIN-PACKAGE	PKG-CODE
MAX3654ETE+	-40°C to +85°C	16 TQFN-EP*	T1644F-4-A

+ Denotes lead-free package.
**EP = Exposed pad.*

Typical Application Circuit



For pricing, delivery, and ordering information, please contact Maxim/Dallas Direct! at 1-888-629-4642, or visit Maxim's website at www.maxim-ic.com.

47MHz to 870MHz Analog CATV Transimpedance Amplifier

ABSOLUTE MAXIMUM RATINGS

Supply Voltage, VCC .....-0.3V to +6.0V
IN+, IN-, VAGC, OUT+, OUT-, $\overline{MUTE}$, HYST .....-0.3V to +5.5V
TEST1, TEST2 .....-0.3V to +5.5V
Output Current (OUT+, OUT-) 56mA

Continuous Power Dissipation, 16-Lead TQFN-EP Package (T_A = +70°C) (derate 16.9mW/°C above +70°C) 1349.1mW
Operating Temperature Range .....-40°C to +85°C
Storage Temperature Range .....-55°C to +150°C
Lead Temperature (soldering,10s) .....+300°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_{CC} = +4.75V to +5.25V, typical values at V_{CC} = +5.0V, T_A= +25°C, unless otherwise noted.) (Note 1)

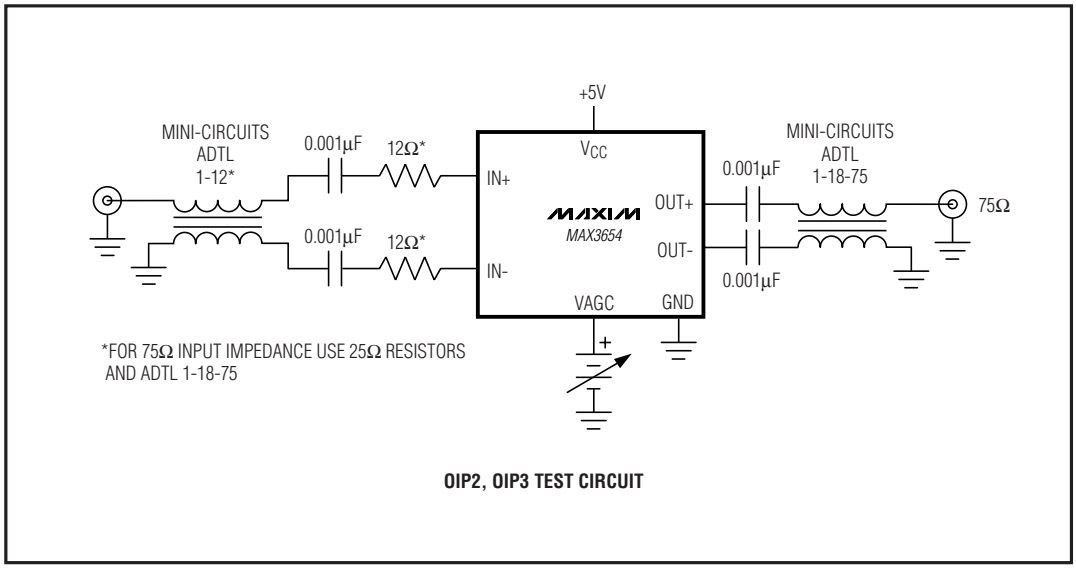
PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Supply Current	I_{CC}			136	170	mA
Gain Control Input Current		V_{AGC} = 1.4V		50	200	µA
$\overline{Mute}$ Input High	V_{IH}		2.0			V
$\overline{Mute}$ Input Low	V_{IL}				0.8	V
$\overline{Mute}$ Input Current	I_{IL}, I_{IH}				30	µA

AC ELECTRICAL CHARACTERISTICS

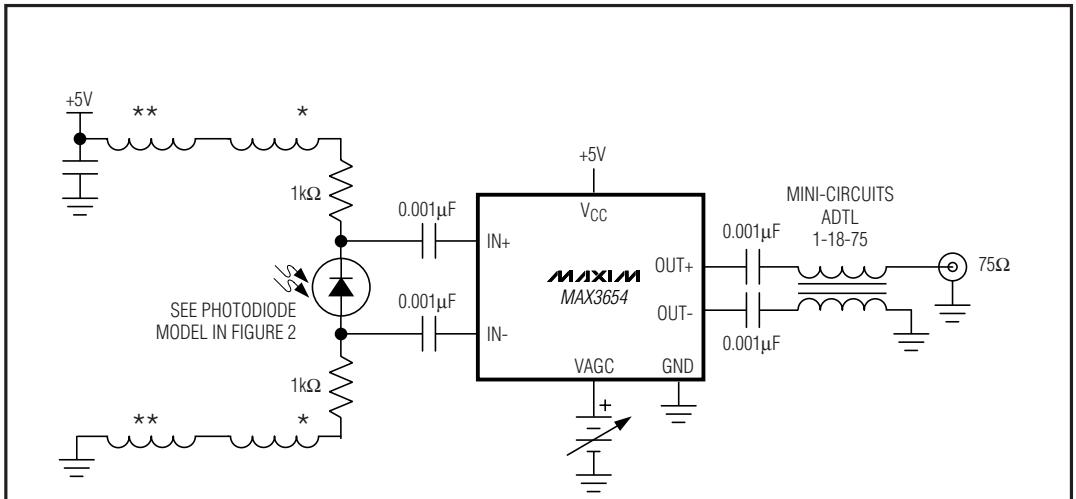
(V_{CC} = +4.75V to +5.25V, output ZL = 75Ω, typical values at V_{CC} = +5.0V, T_A = +25°C, unless otherwise noted.)

PARAMETER	SYMBOL	CONDITIONS		MIN	TYP	MAX	UNITS
Operating Frequency Range	f			47		870	MHz
Frequency Response Flatness		47MHz to 870MHz (Notes 2, 6)			±0.3	±0.75	dB
Transimpedance, Differential (Z_T)		47MHz	V_{AGC} ≤ 0.175V	60.5	62	63.5	dBΩ
			V_{AGC} = 0.500V	51.5	53	54.5	
			V_{AGC} = 1.400V	42	43.5	45	
Gain Control Stability		V_{AGC} = 0 to 1.4V, R_{HYST} = open (Note 3)			±0.75	±1.6	dB
Gain Tilt		Linear, 870MHz compared to 47MHz (Notes 4, 6)		3	4	5.5	dB
Output Second-Order Intercept	OIP2	(Note 5)			>47		dBm
Output Third-Order Intercept	OIP3	(Notes 4, 5)		18	21		dBm
Equivalent Input Noise Including Photodiode	EIN	V_{AGC} ≤ 0.175V (Notes 4, 6)				8	pA/√Hz
Gain Hysteresis, Optical		R_{HYST} = open			±0.13		dB
		R_{HYST} = GND			±0.65		
Differential Output Level, Mute		$\overline{MUTE}$ ≤ 0.8V, 50MHz			-58	-45	dBc
RF Output Return Loss	-S22	47MHz to 870MHz			13		dB

Note 1: DC parameters are tested at +25°C, and guaranteed by design and characterization at -40°C and +85°C.
Note 2: Maximum difference between frequency response at any point and a straight line connecting frequency response at end points.
Note 3: Gain control stability is the maximum variation in transimpedance (over process, voltage, and temperature) for any V_{AGC} control voltage.
Note 4: AC parameters guaranteed by design and characterization.
Note 5: OIP2 and OIP3 measured using two tones at f1 = 800MHz and f2 = 850MHz, P_{OUT} = -16dBm, V_{AGC} = 1.4V.
Note 6: Includes the effects of a packaged photodiode having the characteristics shown in Figure 2.



OIP2, OIP3 TEST CIRCUIT



GAIN, GAIN vs. VAGC, GAIN TILT, S22, IRN TEST CIRCUIT

*MURATA BLM15HD182SN **TDK MLF1608 E100K 10µH

Figure 1. Test Circuits for Characterization

47MHz to 870MHz Analog CATV Transimpedance Amplifier

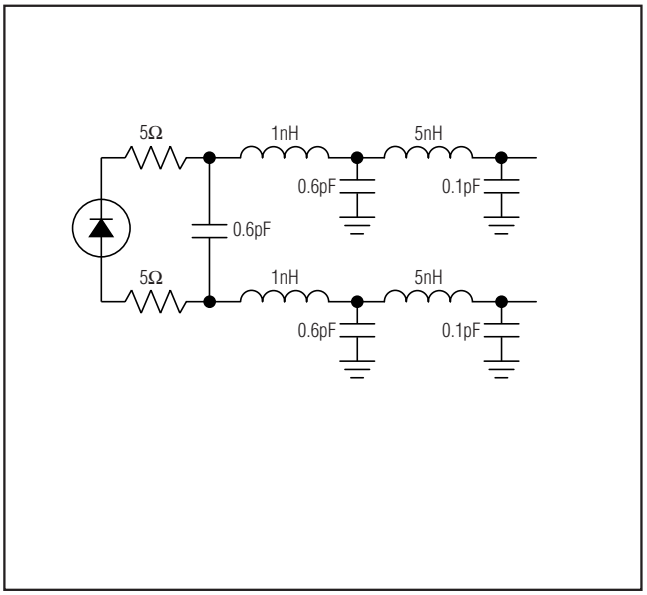


Figure 2. Photodiode and Header Model

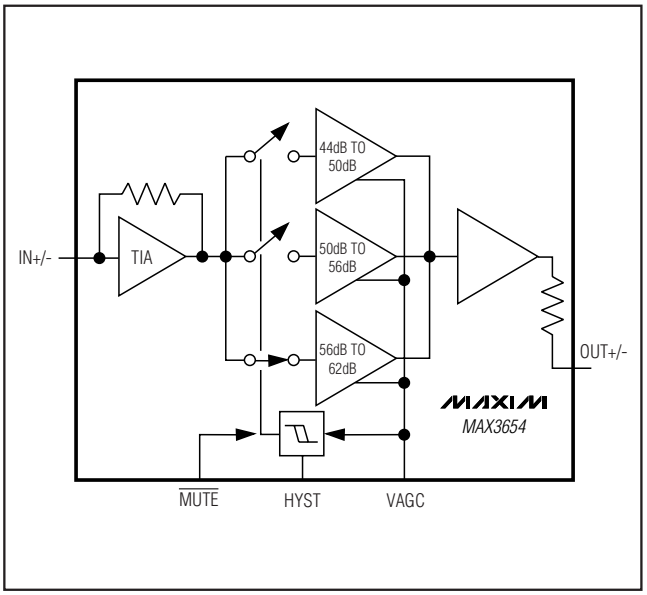
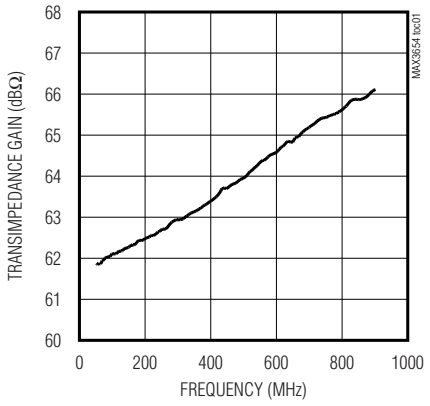


Figure 3. Functional Diagram

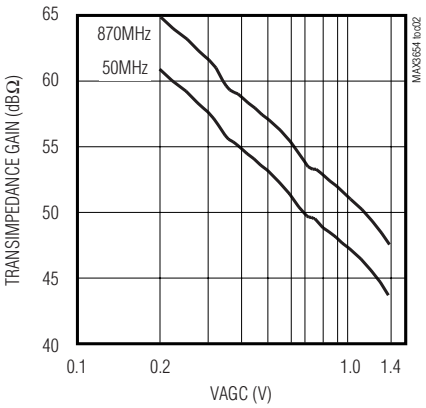
Typical Operating Characteristics

(V_{CC} = +5.0V, T_A = +25°C, unless otherwise noted.)

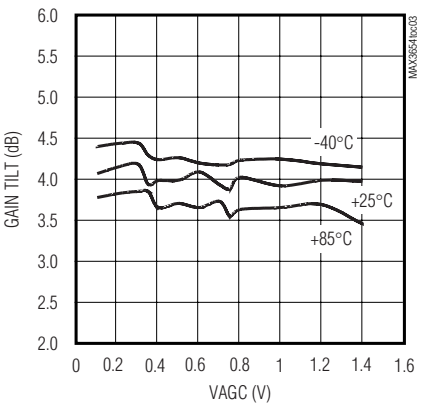
MAXIMUM GAIN vs. FREQUENCY (V_{AGC} = 0V)



GAIN vs. CONTROL VOLTAGE



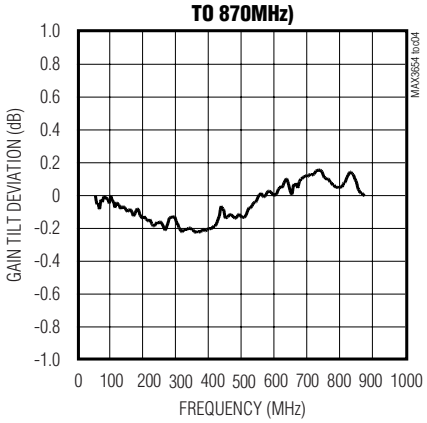
GAIN TILT vs. CONTROL VOLTAGE AND TEMPERATURE



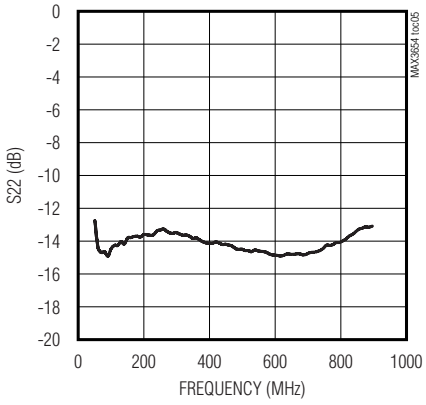
Typical Operating Characteristics (continued)

(V_{CC} = +5.0V, T_A = +25°C, unless otherwise noted.)

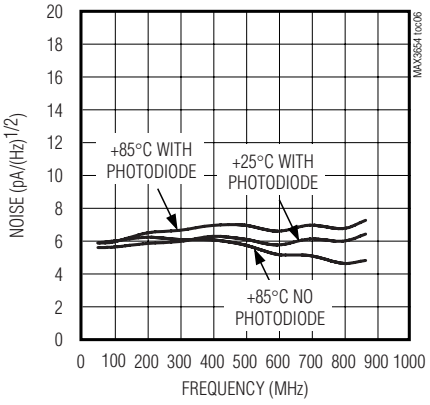
GAIN TILT DEVIATION vs. FREQUENCY (REFERRED TO A LINE FROM 50MHz TO 870MHz)



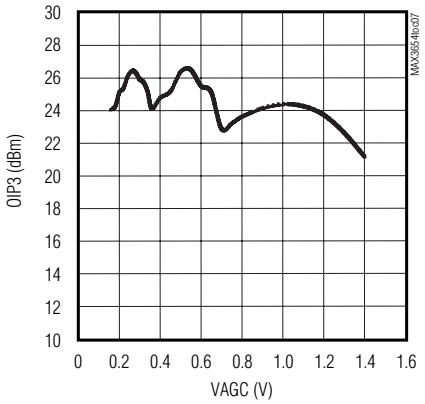
DIFFERENTIAL S22 (NORMALIZED TO 75Ω)



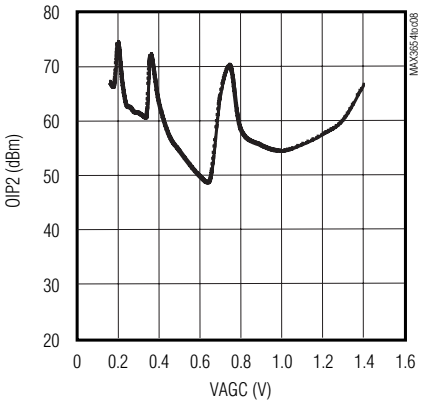
INPUT REFERRED NOISE vs. FREQUENCY (MAXIMUM GAIN, VGA = 0V)



OIP3 vs. CONTROL VOLTAGE



OIP2 vs. CONTROL VOLTAGE



47MHz to 870MHz Analog CATV Transimpedance Amplifier

Pin Description

PIN	NAME	FUNCTION
1, 4, 9, 12	V_{CC}	+5.0V Power Supply
2	IN+	Positive Analog Photodiode Input Connection. Typically connected to photodiode cathode.
3	IN-	Negative Analog Photodiode Input Connection. Typically connected to photodiode anode.
5	VAGC	AGC Control Input. Range is 0 to 1.4V. See the *Typical Operating Characteristics* Gain vs. Control Voltage graph.
6	$\overline{MUTE}$	Mute Control Input, TTL. $\overline{MUTE}$ < 0.8V to mute output.
7	HYST	AGC Hysteresis Control Input. A resistor from HYST to GND controls the hysteresis level.
8, 14, 16	GND	Ground
10	OUT-	Negative RF Output. The voltage on this pin decreases with increasing optical power when IN+ is connected to the photodiode cathode.
11	OUT+	Positive RF Output. The voltage on this pin increases with increasing optical power when IN- is connected to the photodiode anode.
13	TEST1	Reserved for Test. Connect to GND for normal operation.
15	TEST2	Reserved for Test. Connect to GND for normal operation.
EP	EP	Exposed Pad. The exposed pad must be soldered to the circuit-board ground for proper thermal and electrical performance.

Detailed Description

The MAX3654 is a broadband, high-linearity, low-noise transimpedance amplifier. The transimpedance (gain) can be adjusted between 43.5dBΩ and 62dBΩ using the voltage at an external control input (VAGC). When connected as shown in the *Typical Application Circuit*, optical input levels from -6dBm to +2dBm will produce a minimum output of 14dBmV/channel, and 4dB tilt compensation. Gain deviation over frequency from 47MHz to 870MHz is less than ±0.75dB.

Low-Noise Variable Gain Amplifier

The input stage is a low-noise analog transimpedance amplifier (TIA) connected differentially to the analog photodiode. Desired performance can be achieved with a photodiode having capacitance (C_{PD}) up to 1pF.

VAGC and Hysteresis Control

The gain-control pin VAGC sets overall TIA gain implemented as three switchable gain stages, each with a continuously variable gain control, as shown in Figure 3.

This produces a continuously variable gain ranging from 62dBΩ (at VAGC = 0.175V) to 43.5dBΩ at (VAGC=1.4V). A set of comparators examines the VAGC input to select a gain stage. As the voltage at VAGC crosses the two locations in the gain vs. VAGC curve, where the gain stage changes (350mV and 700mV), there will be small deviations in the output which may lead to a brief interruption of CATV signals. See the *Typical Operating Characteristics* for Gain vs. Control Voltage.

A hysteresis control input is provided to limit dithering when the optical level is close to a gain-switching point. The hysteresis level is controlled by the value of R_{HYST}. Hysteresis is minimum (0.13dB) when this pin is open.

RF Output and Cable Tilt Compensation

With a typical photodiode, the gain at 870MHz is 4dB higher than at 47MHz. The overall frequency response of the TIA is within ±0.75dB of a straight line connecting the values at 47MHz and 870MHz.

Mute

In normal operation, the TTL $\overline{MUTE}$ pin is held high. When $\overline{MUTE}$ is low, the output signal is attenuated by more than 45dB.

Applications Information

Photodiode Parasitics

The MAX3654 TIA is designed to operate with a low-capacitance analog photodiode. Proper system design includes considerations of lead configuration, pad, and through-hole geometry, and PC board layer selection for connections to the IC. The TIA is designed to operate correctly when the total capacitance of the photodiode, package, leads and PC board is between 1.0pF and 2.5pF.

RF Output

The differential TIA RF output should be connected (AC-coupled) to a balun transformer for normal single-ended output.

AGC Operation

For AGC operation, the optical average power can be measured from the voltage drop across the lower bias resistor, using high impedance to isolate the photodiode as shown in the EV kit schematic. TIA gain is inversely proportional to the voltage present at VAGC from 0.175V to 1.4V. From 0 to 0.175V, the gain is constant and maximum. The nominal gain is given by:

$$ZT(dB\Omega) = 62dB\Omega + 20 \times \log\left[\frac{175mV}{VAGC(mV)}\right]$$

$$(0.175V \le VAGC \le 1.4V).$$

When connected as shown in the *Typical Applications Circuit*, the MAX3654 will maintain the electrical output constant (15dBmV/ch) for optical signals in the -6dBm to +2dBm range.

Evaluation Kit and PC Board Layout

The factory-assembled EV kit for the MAX3654 provides two versions: optical input and electrical input.

The optical input circuit includes photodiode bias circuitry, an op amp to adjust VAGC according to the DC photodiode current (for AGC operation), an output balun, and a 75Ω output connector. Through-hole pads are provided to attach the triplexer analog photodiode leads. Since photodiode capacitance and package lead inductance affect the amount of uptilt, in configurations where lead inductance is significantly lower than the value shown in Figure 2, the uptilt may be increased by providing discrete inductance on the PC board. When a C_{PD} = 0.5pF (typ) photodiode is mounted with 5mm (nominal) leads into through-hole vias as in the EV kit configuration, a 4dB uptilt will normally be achieved. It is important to configure the layout with capacitance and inductance in the anode and cathode connection as symmetric as possible.

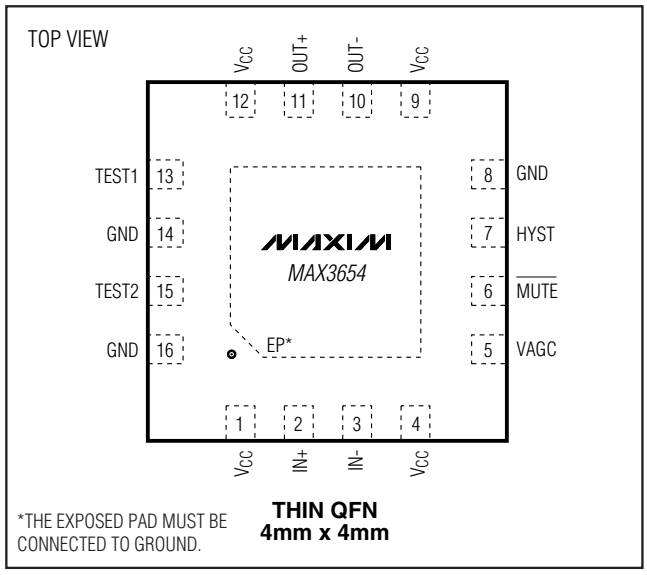
The electrical input circuit is normally configured with a 50Ω input for use with conventional test and measurement equipment. If desired, the MAX3654 input can also be terminated with 75Ω as shown in the EV kit data sheet. The 75Ω EV kit outputs should be connected to 50Ω test and measurement equipment using a minimum loss pad.

For more information, see the Maxim website:

MAX3654 EV Kit data sheet—
http://www.maxim-ic.com/Fiber.cfm

Minimum Loss Pad—
http://www.maxim-ic.com/appnotes.cfm/appnote_number/972

Pin Configuration



Chip Information

TRANSISTOR COUNT: 3376

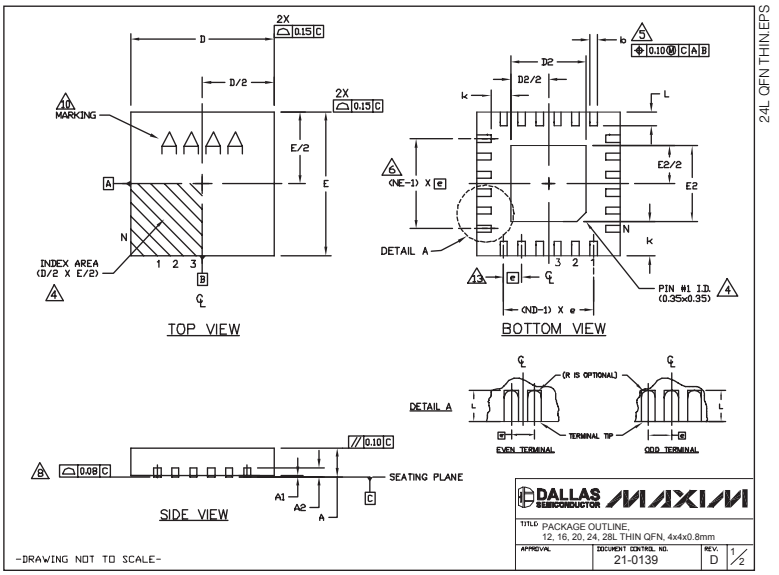
PROCESS: SiGe Bipolar

SUBSTRATE: SOI

47MHz to 870MHz Analog CATV 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.) For the latest package outline information, go to www.maxim-ic.com/packages.) (TQFN 4mm x 4mm x 0.8mm, Package Code: T1644.)



COMMON DIMENSIONS

PKG	12L 4x4			16L 4x4			20L 4x4			24L 4x4			28L 4x4		
REF.	MIN.	NOM.	MAX.	MIN.	NOM.	MAX.	MIN.	NOM.	MAX.	MIN.	NOM.	MAX.	MIN.	NOM.	MAX.
A	0.70	0.75	0.80	0.70	0.75	0.80	0.70	0.75	0.80	0.70	0.75	0.80	0.70	0.75	0.80
A1	0.0	0.02	0.05	0.0	0.02	0.05	0.0	0.02	0.05	0.0	0.02	0.05	0.0	0.02	0.05
A2	0.20 REF			0.20 REF			0.20 REF			0.20 REF			0.20 REF		
b	0.25	0.30	0.35	0.25	0.30	0.35	0.20	0.25	0.30	0.18	0.23	0.30	0.15	0.20	0.25
D	3.90	4.00	4.10	3.90	4.00	4.10	3.90	4.00	4.10	3.90	4.00	4.10	3.90	4.00	4.10
E	3.90	4.00	4.10	3.90	4.00	4.10	3.90	4.00	4.10	3.90	4.00	4.10	3.90	4.00	4.10
e	0.80 BSC.			0.65 BSC.			0.50 BSC.			0.50 BSC.			0.40 BSC.		
k	0.25	-	-	0.25	-	-	0.25	-	-	0.25	-	-	0.25	-	-
L	0.45	0.55	0.65	0.45	0.55	0.65	0.45	0.55	0.65	0.30	0.40	0.50	0.30	0.40	0.50
N	12			16			20			24			28		
ND	3			4			5			6			7		
NE	3			4			5			6			7		
JEDEC VAR.	WGGB			WGGC			WGGD-1			WGGD-2			WGGE		

EXPOSED PAD VARIATIONS

PKG. CODES	D2			E2			DOWN BONDS ALLOWED
	MIN.	NOM.	MAX.	MIN.	NOM.	MAX.	
T1244-2	1.95	2.10	2.25	1.95	2.10	2.25	NO
T1244-3	1.95	2.10	2.25	1.95	2.10	2.25	YES
T1244-4	1.95	2.10	2.25	1.95	2.10	2.25	NO
T1644-2	1.95	2.10	2.25	1.95	2.10	2.25	NO
T1644-3	1.95	2.10	2.25	1.95	2.10	2.25	YES
T1644-4	1.95	2.10	2.25	1.95	2.10	2.25	NO
T2044-1	1.95	2.10	2.25	1.95	2.10	2.25	NO
T2044-2	1.95	2.10	2.25	1.95	2.10	2.25	YES
T2044-3	1.95	2.10	2.25	1.95	2.10	2.25	NO
T2444-1	2.45	2.60	2.63	2.45	2.60	2.63	NO
T2444-2	1.95	2.10	2.25	1.95	2.10	2.25	YES
T2444-3	2.45	2.60	2.63	2.45	2.60	2.63	YES
T2444-4	2.45	2.60	2.63	2.45	2.60	2.63	NO
T2844-1	2.50	2.60	2.70	2.50	2.60	2.70	NO

NOTES:

1. DIMENSIONING & TOLERANCING CONFORM TO ASME Y14.5M-1994.
2. ALL DIMENSIONS ARE IN MILLIMETERS. ANGLES ARE IN DEGREES.
3. N IS THE TOTAL NUMBER OF TERMINALS.
4. THE TERMINAL #1 IDENTIFIER AND TERMINAL NUMBERING CONVENTION SHALL CONFORM TO JESD 95-1 SPP-012. DETAILS OF TERMINAL #1 IDENTIFIER ARE OPTIONAL, BUT MUST BE LOCATED WITHIN THE ZONE INDICATED. THE TERMINAL #1 IDENTIFIER MAY BE EITHER A MOLD OR MARKED FEATURE.
5. DIMENSION b APPLIES TO METALLIZED TERMINAL AND IS MEASURED BETWEEN 0.25 mm AND 0.30 mm FROM TERMINAL TIP.
6. ND AND NE REFER TO THE NUMBER OF TERMINALS ON EACH D AND E SIDE RESPECTIVELY.
7. DEPOPULATION IS POSSIBLE IN A SYMMETRICAL FASHION.
8. COPLANARITY APPLIES TO THE EXPOSED HEAT SINK SLUG AS WELL AS THE TERMINALS.
9. DRAWING CONFORMS TO JEDEC MO220, EXCEPT FOR T2444-1, T2444-3, T2444-4 AND T2844-1.
10. MARKING IS FOR PACKAGE ORIENTATION REFERENCE ONLY.
11. COPLANARITY SHALL NOT EXCEED 0.08mm
12. WARPAGE SHALL NOT EXCEEND 0.10mm
13. LEAD CENTERLINES TO BE AT TRUE POSITION AS DEFINED BY BASIC DIMENSION "e", ±0.05.

-DRAWING NOT TO SCALE-
DALLAS SEMICONDUCTOR MAXIM
TITLE PACKAGE OUTLINE, 12, 16, 20, 24, 28L THIN QFN, 4x4x0.8mm
DOCUMENT CONTROL NO. 21-0139
REV. D
2/2

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