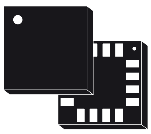
LIS344AHH

MEMS inertial sensor: high full-scale, high-bandwidth, low-noise analog accelerometer

Datasheet - preliminary data



LGA 16 (4x4x1.5 mm)

Features

- 2.4 V to 3.6 V single supply operation
- High full-scale ±6 *g* / ±18 *g* user-selectable
- High bandwidth
- Low noise
- Output voltage, offset and sensitivity are ratiometric to the supply voltage
- Factory-trimmed device sensitivity and offset
- Embedded self test
- RoHS/ECOPACK® compliant
- High shock survivability (10000 *g*)

Applications

- Portable devices
- Gaming and virtual reality input devices
- Antitheft systems and inertial navigation
- Appliances and robotics

Description

The LIS344AHH is a high-performance, high-bandwidth, low-noise three-axis linear accelerometer that includes a sensing element and an IC interface able to take information from the sensing element and provide an analog signal to the external world.

The sensing element, capable of detecting linear acceleration, is manufactured using a dedicated process developed by ST to produce inertial sensors and actuators in silicon.

The IC interface is manufactured using an ST proprietary CMOS process with a high level of integration. The dedicated circuit is trimmed to better match the characteristics of the sensing element.

The LIS344AHH has a user-selectable full scale of ±6 *g* or ±18 *g* and it is capable of measuring accelerations over a high bandwidth of 2.5 kHz for all axes. The device bandwidth may be reduced by using external capacitances.

The self-test capability allows the user to check the functioning of the system.

The LIS344AHH is available in a land grid array package (LGA) manufactured by ST.
It is guaranteed to operate over an extended temperature range of -40 °C to +85 °C.

Table 1. Device summary

Order codes	Temp range [°C]	Package	Packaging
LIS344AHH	-40 to +85	LGA-16	Tray
LIS344AHHTR	-40 to +85	LGA-16	Tape and reel

This is preliminary information on a new product now in development or undergoing evaluation. Details are subject to change without notice.

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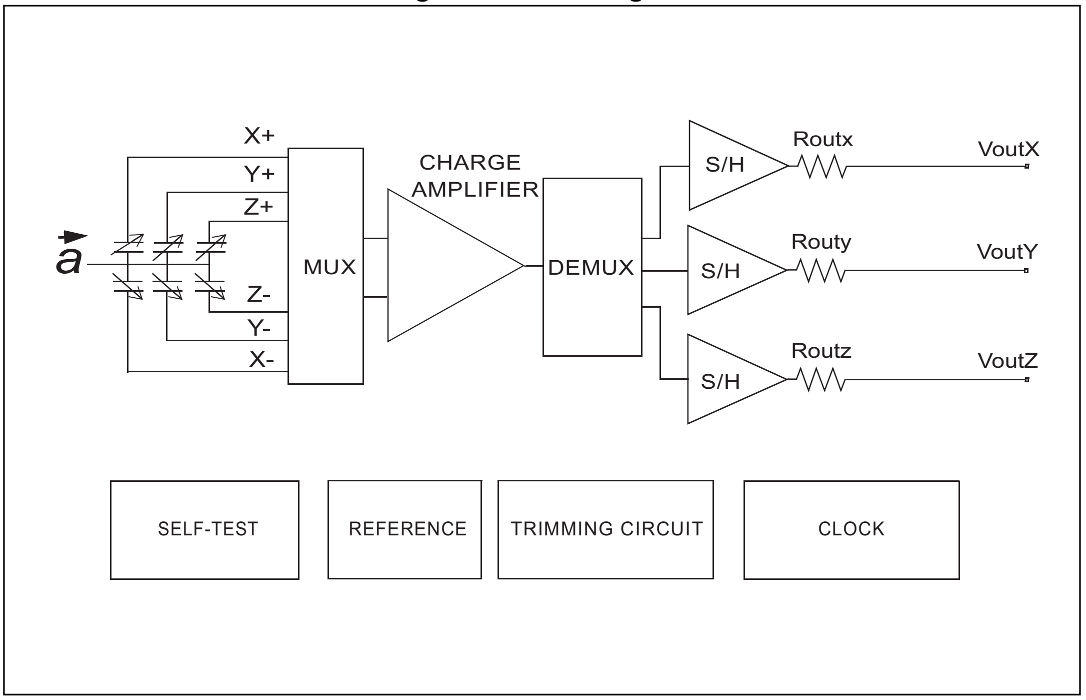
1.1 Block diagram

Figure 1. Block diagram



1.2 Pin description

Figure 2. Pin connections

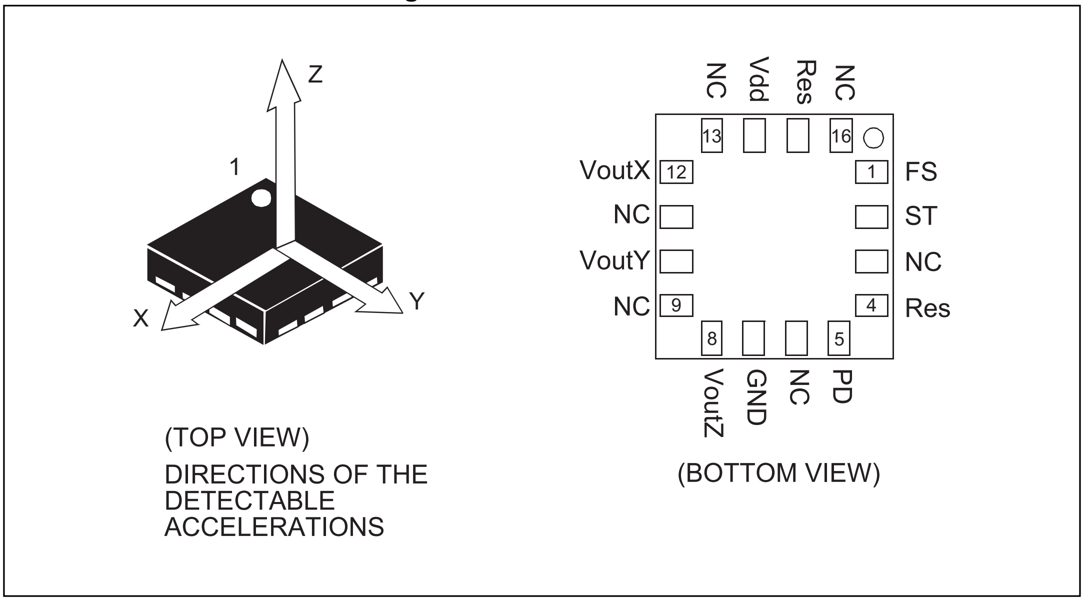


Table 2. Pin description

Pin #	Pin name	Function
1	FS	Full-scale selection (Logic 0: ±6 *g* full scale; Logic 1: ±18 *g* full scale)
2	ST	Self-test (Logic 0: normal mode; Logic 1: self-test mode)
3	NC	Internally not connected
4	Res	Leave unconnected or connect to Vdd
5	PD	Power-down (Logic 0: normal mode; Logic 1: power-down mode)
6	NC	Internally not connected
7	GND	0 V supply
8	VoutZ	Output voltage Z-channel
9	NC	Internally not connected
10	VoutY	Output voltage Y-channel
11	NC	Internally not connected
12	VoutX	Output voltage X-channel
13	NC	Internally not connected
14	Vdd	Power supply
15	Res	Connect to Vdd
16	NC	Internally not connected

2 Mechanical and electrical specifications

2.1 Mechanical characteristics

Table 3. Mechanical characteristics @ Vdd = 3.3 V, T = 25 °C unless otherwise noted(1)

Symbol	Parameter	Test condition	Min.	Typ.(2)	Max.	Unit
Ar	Acceleration range(3)	FS pin connected to GND		± 6		*g*
		FS pin connected to Vdd		± 18		
So	Sensitivity(4)	Full scale = ±6 *g*	Vdd/15 - 10%	Vdd/15	Vdd/15+10%	V/*g*
		Full scale = ±18 *g*	Vdd/45 - 10%	Vdd/45	Vdd/45+10%	
SoDr	Sensitivity change Vs Temperature	Delta from +25 °C		± 0.01		%/°C
Voff	Zero-g level(4)	Full scale = ±6 *g* T = 25 °C		Vdd/2		V
OffDr	Zero-g level change vs. temperature	Delta from +25 °C		±0.4		m*g*/°C
NL	Non-linearity(5)	Best-fit straight line Full scale = ±6 g		±0.5		% FS
CrossAx	Cross-axis(6)			±2		%
An	Acceleration noise density	Vdd = 3.3 V; Full scale = ±6 *g*		100		$\mu g/\sqrt{Hz}$
Vt	Self-test output voltage change(7),(8),(9)	X-axis T = 25 °C; Vdd = 3.3 V				mV
		Y-axis T = 25 °C; Vdd = 3.3 V				mV
		Z-axis T = 25 °C; Vdd=3.3 V				mV
Fres	Sensing element resonant frequency(10)	X-, Y-, Z-axis	2.5			kHz
Top	Operating temperature range		-40		+85	°C

1. The product is factory calibrated at 3.3 V. The operational power supply range is from 2.4 V to 3.6 V. Voff, So and Vt parameters will vary with supply voltage.
2. Typical specifications are not guaranteed.
3. Guaranteed by wafer level test and measurement of initial offset and sensitivity.
4. Zero-g level and sensitivity are essentially ratiometric to supply voltage at the calibration level ±8%.
5. By design
6. Contribution to the measuring output of an inclination/acceleration along any perpendicular axis.
7. “Self-test output voltage change” is defined as $Vout_{(Vst=Logic1)}$-$Vout_{(Vst=Logic0)}$.
8. “Self-test output voltage change” varies cubically with supply voltage.
9. When full scale is set to ±18 *g*, “Self-test output voltage change” is one third of the specified value at ±6 *g*.
10. Minimum resonance frequency Fres = 2.5 kHz. Sensor bandwidth = 1/(2*π*110kΩ*Cload), with Cload > 0.4 nF.

2.2 Electrical characteristics

Table 4. Electrical characteristics @ Vdd = 3.3 V, T = 25 °C unless otherwise noted(1)

Symbol	Parameter	Test condition	Min.	Typ.(2)	Max.	Unit
Vdd	Supply voltage		2.4	3.3	3.6	V
Idd	Supply current	Normal mode		680		µA
		Power-down mode		1	5	
Vfs Vst Vpd	Full-scale input Self-test input Power-down input	Logic 0 level	0		0.3*Vdd	V
		Logic 1 level	0.7*Vdd		Vdd	V
Rout	Output impedance of VoutX, VoutY, VoutZ		90	110	130	kΩ
Cload	Capacitive load drive(3) for VoutX, VoutY, VoutZ		0.4			nF
Ton	Turn-on time upon exiting power-down mode	Cload expressed in µF		550*Cload+ 0.3		ms
Top	Operating temperature range		-40		+85	°C

1. The product is factory calibrated at 3.3 V.
2. Typical specifications are not guaranteed.
3. Minimum resonance frequency Fres = 2.5 kHz. Device bandwidth = 1/(2*π*110 kΩ*Cload), with Cload > 0.4 nF.

2.3 Absolute maximum ratings

Stresses above those listed as “Absolute maximum ratings” may cause permanent damage to the device. This is a stress rating only and functional operation of the device under these conditions is not implied. Exposure to maximum rating conditions for extended periods may affect device reliability.

Table 5. Absolute maximum ratings

Symbol	Ratings	Maximum value	Unit
Vdd	Supply voltage	-0.3 to 6	V
Vin	Input voltage on any control pin (FS, ST, PD)	-0.3 to Vdd +0.3	V
A_{POW}	Acceleration (any axis, powered, Vdd = 3.3 V)	3000 *g* for 0.5 ms	
		10000 *g* for 0.1 ms	
A_{UNP}	Acceleration (any axis, not powered)	3000 *g* for 0.5 ms	
		10000 *g* for 0.1 ms	
T_{STG}	Storage temperature range	-40 to +125	°C
ESD	Electrostatic discharge protection	4 (HBM)	kV
		1.5 (CDM)	kV
		400 (MM)	V

This device is sensitive to mechanical shock, improper handling can cause permanent damage to the part.

This is an electrostatic-sensitive device (ESD), improper handling can cause permanent damage to the part.

2.4 Terminology

Sensitivity describes the gain of the sensor and can be determined by applying 1 *g* acceleration to it. As the sensor can measure DC accelerations, this can be done easily by pointing the axis of interest towards the center of the Earth, noting the output value, rotating the sensor by 180 degrees (point to the sky) and noting the output value again, thus applying ±1 *g* acceleration to the sensor. Subtracting the larger output value from the smaller one, and dividing the result by 2, will give the actual sensitivity of the sensor. This value changes very little over temperature (see sensitivity change vs. temperature) and also very little over time. The sensitivity tolerance describes the range of sensitivities of a large population of sensors.

Zero-g level describes the actual output signal if there is no acceleration present. A sensor in a steady-state on a horizontal surface will measure 0 *g* for the X-axis and 0 *g* for the Y-axis whereas the Z-axis will measure 1 *g*. The output is ideally for a 3.3 V powered sensor Vdd/2 = 1650 mV. A deviation from the ideal 0-g level (1650 mV in this case) is called Zero-g offset. Offset of highly accurate MEMS sensors is to some extent a result of stress to the sensor and therefore the offset can slightly change after mounting the sensor on a printed circuit board or exposing it to extensive mechanical stress. Offset changes little over temperature - see “Zero-g level change vs temperature” - the Zero-g level of an individual sensor is very stable over its lifetime. The Zero-g level tolerance describes the range of Zero-g levels of a population of sensors.

The **self-test** allows testing the mechanical and electrical parts of the sensor, allowing the seismic mass to be moved by means of an electrostatic test-force. The self-test function is off when the ST pin is connected to GND. When the ST pin is tied to Vdd, an actuation force is applied to the sensor, simulating a definite input acceleration. In this case the sensor outputs will exhibit a voltage change in their DC levels which is related to the selected full scale and dependent on the supply voltage through the device sensitivity. When ST is activated, the device output level is given by the algebraic sum of the signals produced by the acceleration acting on the sensor and by the electrostatic test-force. If the output signals change within the amplitude specified in *Table 3*, then the sensor is working properly and the parameters of the interface chip are within the defined specifications.

Output impedance describes the resistor inside the output stage of each channel. This resistor is part of a filter consisting of an external capacitor of at least 0.4 nF and the internal resistor. Due to the high resistor level, only small inexpensive external capacitors are needed to generate low corner frequencies. When interfacing with an ADC it is important to use high input impedance input circuitries to avoid measurement errors. Note that the minimum load capacitance forms a corner frequency close to the resonance frequency of the sensor. In general the smallest possible bandwidth for a particular application should be chosen to get the best results.

3 Functionality

The LIS344AHH is an ultra-compact low-power, analog output three-axis linear accelerometer packaged in an LGA package. The complete device includes a sensing element and an IC interface able to take information from the sensing element and provide an analog signal to the external world.

3.1 Sensing element

A proprietary process is used to create a surface micromachined accelerometer. The technology allows processing suspended silicon structures which are attached to the substrate in a few points called anchors and are free to move in the direction of the sensed acceleration. In order to be compatible with traditional packaging techniques a cap is placed on top of the sensing element to avoid blocking the moving parts during the molding phase of the plastic encapsulation.

When an acceleration is applied to the sensor, the proof mass displaces from its nominal position, causing an imbalance in the capacitive half-bridge. This imbalance is measured using charge integration in response to a voltage pulse applied to the sense capacitor.

At steady-state the nominal value of the capacitors are few pF and when an acceleration is applied, the maximum variation of the capacitive load is in the fF range.

3.2 IC interface

The complete signal processing uses a fully differential structure, while the final stage converts the differential signal into a single-ended signal in order to be compatible with the external world.

The first stage is a low-noise capacitive amplifier that implements a Correlated Double Sampling (CDS) at its output to cancel the offset and the 1/f noise. The resulting signal is then sent to three different S&Hs, one for each channel, and made available to the outside.

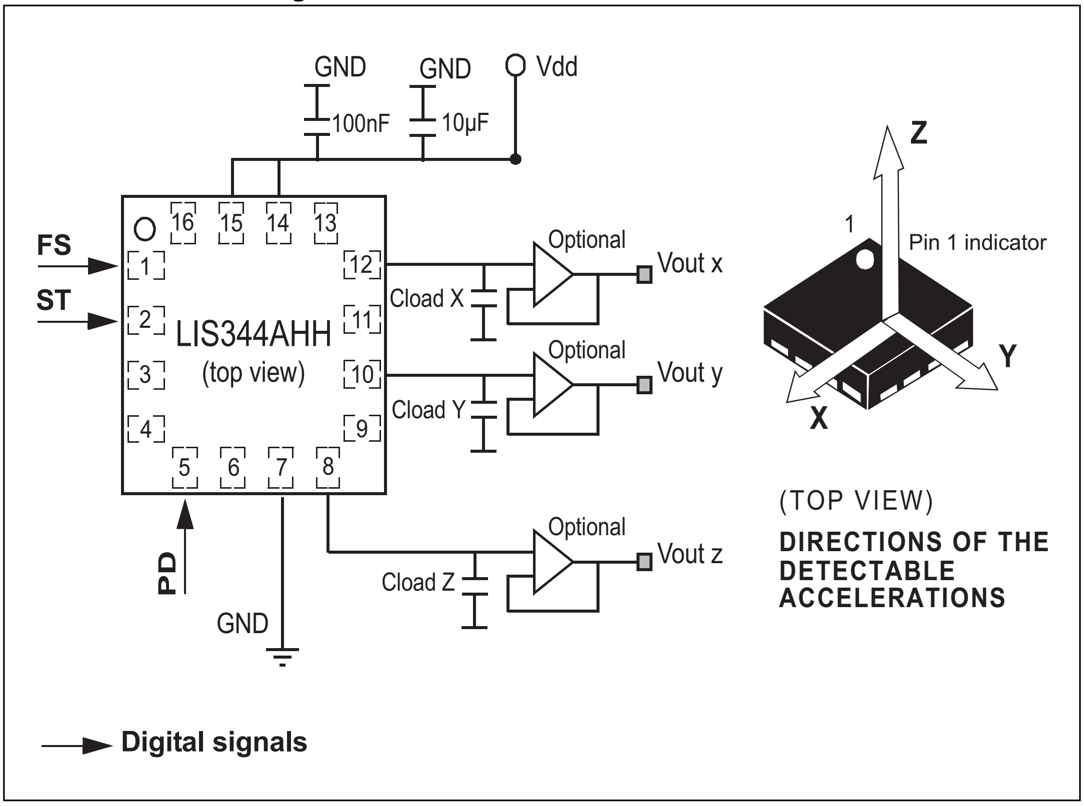
Both analog parameters (output offset voltage and sensitivity) are ratiometric to the voltage supply. Increasing or decreasing the voltage supply, the sensitivity and the offset will increase or decrease linearly. This feature provides the cancellation of the error related to the voltage supply along an analog-to-digital conversion chain.

3.3 Factory calibration

The IC interface is factory calibrated for sensitivity (So) and Zero-g level (Voff).
The trim values are stored inside the device in a nonvolatile structure. Anytime the device is turned on, the trimming parameters are downloaded into the registers to be employed during normal operation. This allows the user to employ the device without further calibration.

4 Application hints

Figure 3. LIS344AHH electrical connections



Power supply decoupling capacitors (100 nF ceramic or polyester + 10 µF aluminum) should be placed as near as possible to the device (common design practice).

The LIS344AHH allows to band limit VoutX, VoutY and VoutZ through the use of external capacitors. The recommended frequency range spans from DC up to 2.5 kHz. In particular, capacitors are added at output VoutX, VoutY, VoutZ pins to implement low-pass filtering for antialiasing and noise reduction. The equation for the cutoff frequency (f_t) of the external filters is in this case:

$$= \frac{1}{2\pi \cdot R_{out} \cdot C_{load}(x, y, z)}$$

Taking into account that the internal filtering resistor (R_{out}) has a nominal value equal to 110 kΩ, the equation for the external filter cutoff frequency may be simplified as follows:

$$f_t = \frac{1.45\mu F}{C_{load}(x, y, z)}[Hz]$$

The tolerance of the internal resistor can vary typically from ±20% of its nominal value of 110 kΩ, thus the cutoff frequency will vary accordingly. A minimum capacitance of 0.4 nF for $C_{load}(x, y, z)$ is required.

4.1 Soldering information

The LGA package is compliant with the ECOPACK, RoHs and “Green” standard.
It is qualified for soldering heat resistance according to JEDEC J-STD-020C.

Leave “Pin 1 Indicator” unconnected during soldering.

Land pattern and soldering recommendations are available at www.st.com/mems.

4.2 Output response vs. orientation

Figure 4. Output response vs. orientation

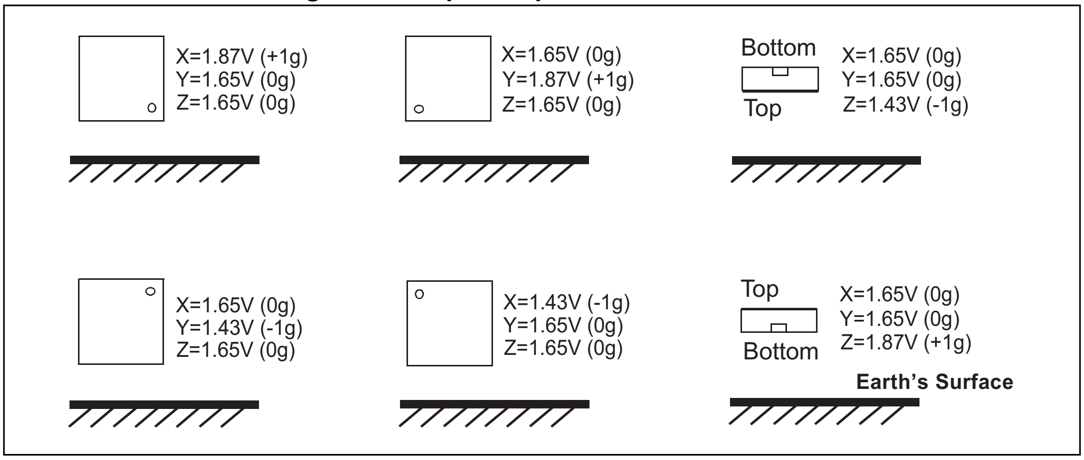


Figure 4 shows the output voltage values of the LIS344AHH, powered at 3.3 V, with full scale ±6 *g*.

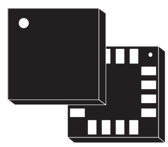
5 Package Information

In order to meet environmental requirements, ST offers these devices in different grades of ECOPACK® packages, depending on their level of environmental compliance. ECOPACK® specifications, grade definitions and product status are available at: *www.st.com*. ECOPACK® is an ST trademark.

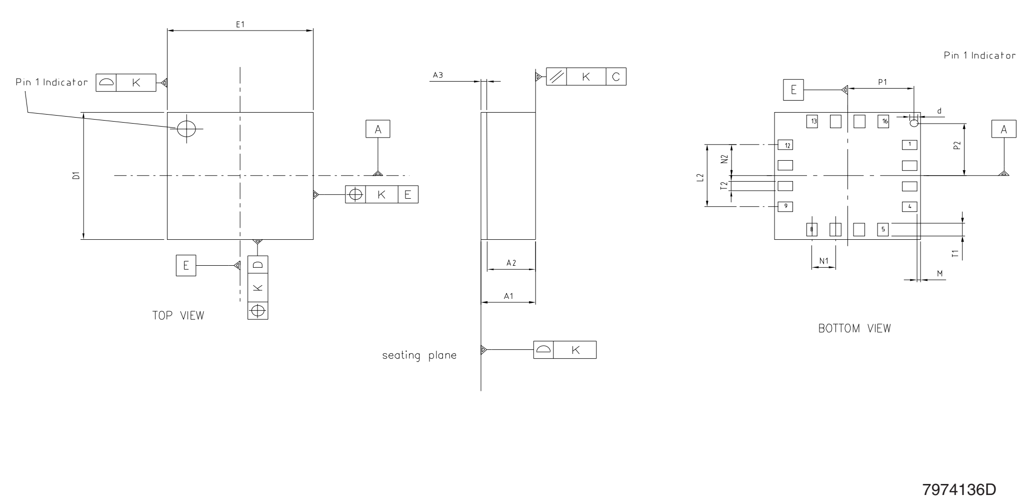
Figure 5. LGA 16: mechanical data and package dimensions

Ref.	Dimensions					
	mm					
	Min.	Typ.	Max.	Min.	Typ.	Max.
A1		1.500	1.600		0.0591	0.0630
A2			1.330			0.0524
A3	0.160	0.200	0.240	0.0063	0.0079	0.0094
d		0.300			0.0118	
D1	3.850	4.000	4.150	0.1516	0.1575	0.1634
E1	3.850	4.000	4.150	0.1516	0.1575	0.1634
L2		1.950			0.0768	
M		0.100			0.0039	
N1		0.650			0.0256	
N2		0.980			0.0386	
P1		1.750			0.0689	
P2		1.525			0.0600	
T1		0.400			0.0157	
T2		0.300			0.0118	
k		0.050			0.0020	

Outline and mechanical data



LGA16L (4x4x1.5mm) Land Grid Array Package



6 Revision history

Table 6. Document revision history

Date	Revision	Changes
23-Aug-2013	1	Initial release.