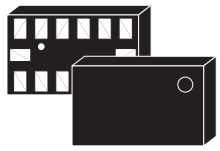
# LIS352AR

## MEMS motion sensor: 3-axis ±2 *g* analog-output "piccolo" accelerometer

## Features

- Single voltage supply operation
- ±2 *g* full-scale
- 3 acceleration channels plus multiplexed analog output
- Ratiometric output voltage
- Power-down mode
- Embedded self-test
- 10000 *g* high shock survivability
- ECOPACK® RoHS and “Green” compliant (see *Section 7*)



**LGA-14 (3x5x0.9mm)**

## Applications

- Free-fall detection for data protection
- Tilting applications
- Gaming and virtual reality input devices
- Antitheft systems and inertial navigation

## Description

The LIS352AR is a miniaturized low-power 3-axis linear accelerometer belonging to the “piccolo” family of ST motion sensors. It includes a sensing element and an IC interface to provide an analog signal to the external world.

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

The IC interface is manufactured using a CMOS process that allows the design of a dedicated circuit which is trimmed to better match the sensing element characteristics.

The LIS352AR has a full-scale of ±2 *g* and is capable of measuring accelerations over a maximum bandwidth of 2.0 kHz. The device bandwidth may be reduced by using external capacitors. The self-test capability allows the user to check the functioning of the sensor in the final application.

The device has three analog acceleration outputs, plus an embedded multiplexer that allows for redirection of the analog outputs onto a single pin for operation with a single-channel A/D converter.

ST is already in the field with several hundred million sensors which have received excellent acceptance from the market in terms of quality, reliability and performance

The LIS352AR is provided in a plastic land grid array (LGA) package.

Several years ago ST successfully pioneered the usage of this package for accelerometers. Today, ST has the widest manufacturing capability and strongest expertise in the world for production of sensors in plastic LGA packages.

**Table 1. Device summary**

| Order code | Temp. range [°C] | Package | Packing |
|---|---|---|---|
| LIS352AR | -40 to +85 | LGA-14 | Tray |
| LIS352ARTR | -40 to +85 | LGA-14 | Tape and reel |

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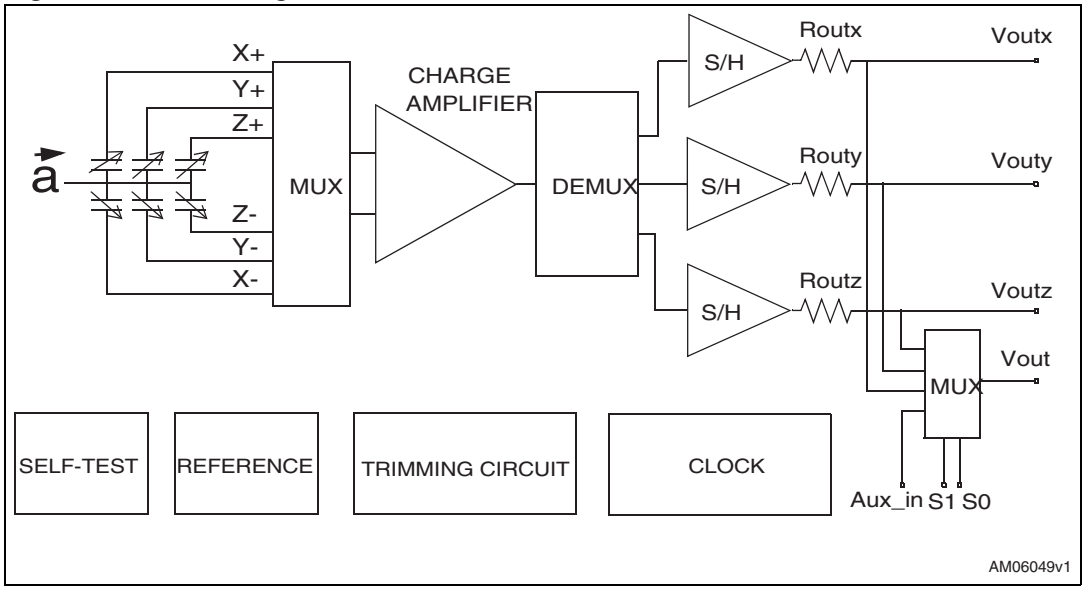
# 1 Block diagram and pin description

**Figure 1. Block diagram**




## 1.1 Pin connections and description

**Figure 2. Pin connection**

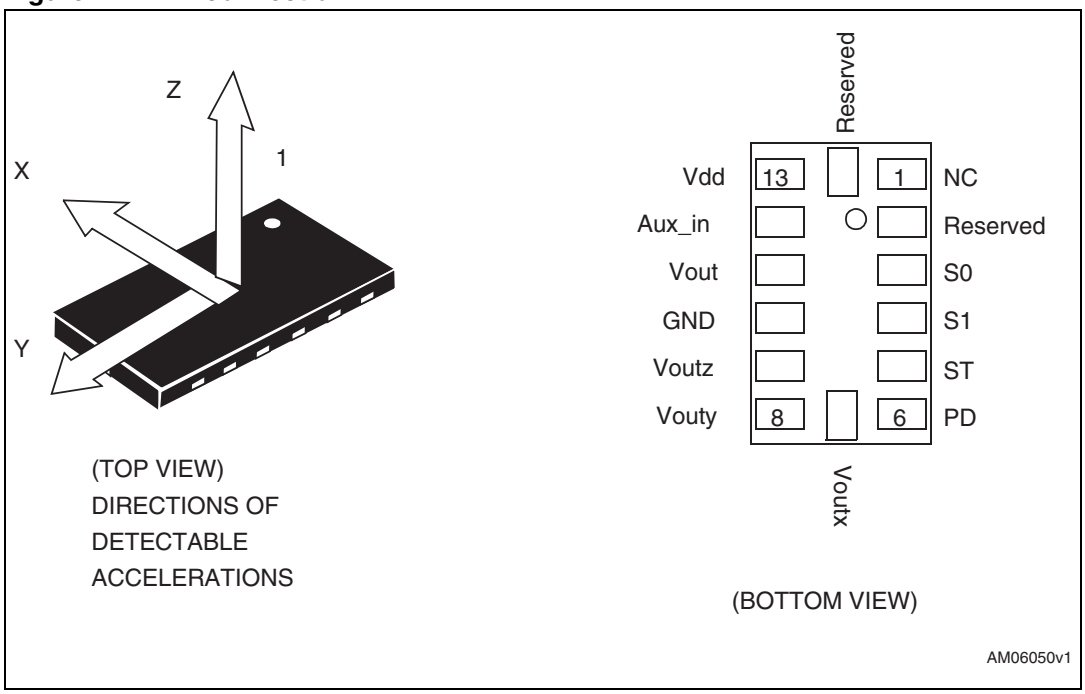


**Table 2. Pin description**

| Pin # | Pin name | Function |
|---|---|---|
| 1 | NC | Internally not connected |
| 2 | Reserved | Connect to Vdd |
| 3 | S0 | Mux selector 0 (connect to Vdd or to GND) |
| 4 | S1 | Mux selector 1 (connect to Vdd or to GND) |
| 5 | ST | Self-test (logic 0: normal mode; logic 1: self-test) |
| 6 | PD | Power-down (logic 0: normal mode; logic 1: power-down mode) |
| 7 | Voutx | Output voltage X channel |
| 8 | Vouty | Output voltage Y channel |
| 9 | Voutz | Output voltage Z channel |
| 10 | GND | 0 V supply |
| 11 | Vout | Multiplexer output |
| 12 | Aux_In | Auxiliary input |
| 13 | Vdd | Power supply |
| 14 | Reserved | Connect to Vdd |

# 2 Mechanical and electrical specifications

## 2.1 Mechanical characteristics

@ Vdd=3.3 V, T=25 °C unless otherwise noted[a].

**Table 3. Mechanical characteristics**

| Symbol | Parameter | Test condition | Min. | Typ.[1] | Max. | Unit |
|---|---|---|---|---|---|---|
| Ar | Acceleration range[2] | | | ±2 | | g |
| So | Sensitivity[3] | | 0.145*Vdd –5% | 0.145*Vdd | 0.145*Vdd + 5% | V/g |
| SoDr | Sensitivity change vs. temperature | Delta from +25 °C | | ±0.01 | | %/°C |
| Voff | Zero-*g* level[4] | T = 25 °C | Vdd/2-6% | Vdd/2 | Vdd/2+6% | V |
| OffDr | Zero-*g* level change Vs temperature | Delta from +25 °C | | ±0.3 | | mg/°C |
| NL | Non linearity[4] | Best fit straight line | | ±0.5 | | % FS |
| CrossAx | Cross-axis[5] | | | ±2 | | % |
| An | Acceleration noise density | Vdd=3.3 V | | 100 | | $\mu g/\sqrt{Hz}$ |
| Vt | Self-test output voltage change[6],[7] | T = 25 °C Vdd=3.3 V X axis | 60 | | 900 | mV |
| | | T = 25 °C Vdd=3.3 V Y axis | 60 | | 900 | mV |
| | | T = 25 °C Vdd=3.3 V Z axis | 60 | | 900 | mV |
| Fres | Sensing element resonant frequency[8] | All axes | 2.0 | | | kHz |
| Top | Operating temperature range | | -40 | | +85 | °C |
| Wh | Product weight | | | 30 | | mgram |

1. Typical specifications are not guaranteed
2. Guaranteed by wafer level test and measurement of initial offset and sensitivity
3. Zero-*g* level and sensitivity are ratiometric to supply voltage
4. Guaranteed by design

a. The product is factory calibrated at 3.3 V. The operational power supply range is specified in *Table 4*. Since the device is ratiometric, Voff, So and Vt parameters will vary with supply voltage.

5. Contribution to the measuring output of an inclination/acceleration along any perpendicular axis
6. “Self-test output voltage change” is defined as $Vout_{(Vst=logic\ 1)}$-$Vout_{(Vst=logic\ 0)}$
7. “Self-test output voltage change” varies cubically with supply voltage
8. Minimum resonance frequency Fres=2.0 kHz. Sensor bandwidth=1/(2*π*32kΩ*Cload), with Cload>2.5 nF

## 2.2 Electrical characteristics

@ Vdd=3.3 V, T=25 °C unless otherwise noted[b]

**Table 4. Electrical characteristics**

| Symbol | Parameter | Test condition | Min. | Typ.[1] | Max. | Unit |
|---|---|---|---|---|---|---|
| Vdd | Supply voltage | | 2.16 | 3.3 | 3.6 | V |
| Idd | Supply current | Mean value<br>PD pin connected to GND | | 0.3 | | mA |
| IddPdn | Supply current in power-down mode | PD pin connected to Vdd | | 1 | | µA |
| Vst<br>Vpd | Self-test input<br>Power-down input | Logic 0 level at Vdd=3.3 V | 0 | | 0.2*Vdd | V |
| | | Logic 1 level at Vdd=3.3 V | 0.8*Vdd | | Vdd | |
| Vs0 | S0 Input | Logic 0 level at Vdd=3.3 V | 0 | | 0.2*Vdd | V |
| | | Logic 1 level at Vdd=3.3 V | 0.8*Vdd | | Vdd | |
| Vs1 | S1 input | Logic 0 level at Vdd=3.3 V | 0 | | 0.2*Vdd | V |
| | | Logic 1 level at Vdd=3.3 V | 0.8*Vdd | | Vdd | |
| Rout | Output impedance of Voutx, Vouty, Voutz | | | 32 | | kΩ |
| Cload | Capacitive load drive for Voutx, Vouty, Voutz[2] | | 2.5 | | | nF |
| Rmux | Series resistance of multiplexer input vs. Vout | | | 1 | | kΩ |
| Cloadmux | Capacitive load drive for multiplexed output Vout | | | 10 | | pF |
| Ton | Turn-on time at exit from power-down mode | $C_{LOAD}$ in µF | | 160*$C_{LOAD}$+0.3 | | ms |
| Top | Operating temperature range | | -40 | | +85 | °C |

1. Typical specifications are not guaranteed
2. Minimum resonance frequency $F_{RES}$=2.0 kHz. Device bandwidth=1/(2*π*32kΩ*$C_{LOAD}$), with $C_{LOAD}$>2.5 nF

b. The product is factory calibrated at 3.3 V.

# 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 (PD, ST, S0, S1) | -0.3 to Vdd +0.3 | V |
| $V_{Aux_in}$ | Aux_in input voltage | -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 |
| | | 200 (MM) | V |

*Note: Supply voltage on any pin should never exceed 6.0 V.*

This is a mechanical shock sensitive device, improper handling can cause permanent damages to the part

This is an ESD sensitive device, improper handling can cause permanent damages to the part

# 4 Terminology

## 4.1 Sensitivity

Sensitivity describes the gain of the sensor and can be determined by applying 1 *g* acceleration to it. Because the sensor can measure DC accelerations, this can be done easily by pointing the selected axis towards the ground, noting the output value, rotating the sensor 180 degrees (pointing towards the sky) and noting the output value again. By doing so, a ±1 *g* acceleration is applied to the sensor. Subtracting the larger output value from the smaller one, and dividing the result by 2, produces the actual sensitivity of the sensor. This value changes very little over temperature (see sensitivity change vs. temperature) and over time. The sensitivity tolerance describes the range of sensitivities of a large number of sensors.

## 4.2 Zero-*g* level

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* on both the X and Y axes, whereas the Z axis will measure 1 *g*. Ideally, the output for a 3.3 V powered sensor Vdd/2 = 1650 mV. A deviation from ideal 0 *g* level (1500 mV, in this case) is called Zero-*g* offset. Offset is to some extent a result of stress to the MEMS sensor and therefore the offset can slightly change after mounting the sensor onto a printed circuit board or exposing it to extensive mechanical stress. Offset changes little over temperature (see “Zero-*g* level change vs. temperature” in *Table 3: Mechanical characteristics*). The Zero-*g* level of an individual sensor is also very stable over its lifetime. The Zero-*g* level tolerance describes the range of Zero-*g* levels of a group of sensors.

## 4.3 Self-test

Self-test (ST) allows the checking of sensor functionality without moving it. 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 exhibit a voltage change in their DC levels. 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.

## 4.4 Output impedance

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 2.5 nF and the internal resistor. Due to the 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 resonant frequency of the sensor. In general, the smallest possible bandwidth for a particular application should be chosen to obtain the best results.

# 5 Functionality

The LIS352AR is a 3-axis “piccolo”, low-power, analog output linear accelerometer packaged in an LGA package. The complete device includes a sensing element and an IC interface capable of taking information from the sensing element providing an analog signal to the external world. The sensor provides three acceleration channels and one multiplexed analog output.

## 5.1 Sensing element

A proprietary process is used to create a surface micro-machined accelerometer. The technology allows the creation of suspended silicon structures which are attached to the substrate at several points called “anchors” and are free to move in the direction of the sensed acceleration. To be compatible with traditional packaging techniques, a cap is placed on top of the sensing element to prevent blocking of the moving parts during the moulding phase of plastic encapsulation.

When an acceleration is applied to the sensor, the proof mass shifts 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 a few pF, and when an acceleration is applied the maximum variation of the capacitive load is in the fF range.

## 5.2 IC interface

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

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 signal produced is then sent to three different S&Hs, one for each channel, and made available to the outside.

The device provides an embedded multiplexer to allow the redirection of either the analog output signals Voutx, Vouty, and Voutz, or of an auxiliary input signal onto a single pin for operation with a single-channel A/D converter.

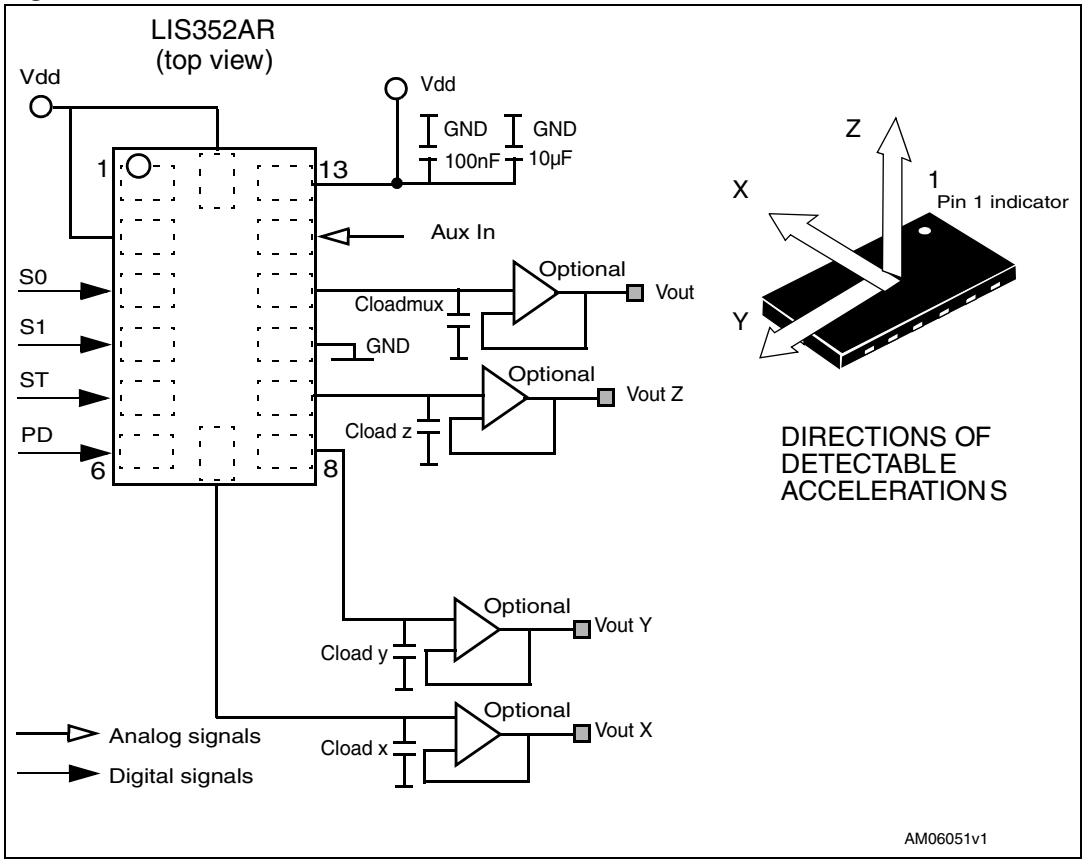
All the analog parameters (output offset voltage and sensitivity) are ratiometric to the voltage supply. Increasing or decreasing the voltage supply, the sensitivity and the offset increases or decreases linearly. This feature provides for cancellation of the error related to the voltage supply along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

## 5.3 Factory calibration

The IC interface is factory-calibrated for sensitivity (So) and Zero-*g* level (Voff). The trimming values are stored in the device in a non-volatile structure. Any time the device is turned on, the trimming parameters are downloaded to the registers to be employed during normal operation. This allows the user to use the device without further calibration.

# 6 Application hints

**Figure 3. LIS352AR electrical connection**




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 LIS352AR allows band limiting of Voutx, Vouty and Voutz through the use of external capacitors. The recommended frequency range spans from DC up to 2.0 kHz. Capacitors must be added at the output pins to implement low-pass filtering for anti-aliasing and noise reduction, even if only the multiplexed output (Vout) is used. The equation for the cut-off frequency ( $f_t$ ) of the external filters is:

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

Taking into account that the internal filtering resistor ($R_{out}$) has a nominal value of 32 kΩ, the equation for the external filter cut-off frequency may be simplified as follows:

$$f_t = \frac{5\mu F}{C_{load}(x, y, z)}[Hz]$$

The tolerance of the internal resistor can vary ±15% (typ) from its nominal value of 32 kΩ; thus the cut-off frequency will vary accordingly. A minimum capacitance of 2.5 nF for $C_{LOAD}$ (x, y, z) is required.

An external capacitor can be added to the Vout pin. Values below 10 pF are recommended.

**Table 6. Filter capacitor selection, $C_{LOAD}$ (x,y,z)**

| Cut-off frequency | Capacitor value |
|---|---|
| 1 Hz | 5 µF |
| 10 Hz | 0.5 µF |
| 20 Hz | 250 nF |
| 50 Hz | 100 nF |
| 100 Hz | 50 nF |
| 200 Hz | 25 nF |
| 500 Hz | 10 nF |

**Table 7. MUX I/O table**

| S1 pin | S0 pin | MUX status |
|---|---|---|
| 0 | 0 | Vout = Voutx |
| 0 | 1 | Vout = Vouty |
| 1 | 0 | Vout = Voutz |
| 1 | 1 | Vout = Aux_in |

## 6.1 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.

## 6.2 Output response vs. orientation

**Figure 4. Output response vs. orientation**

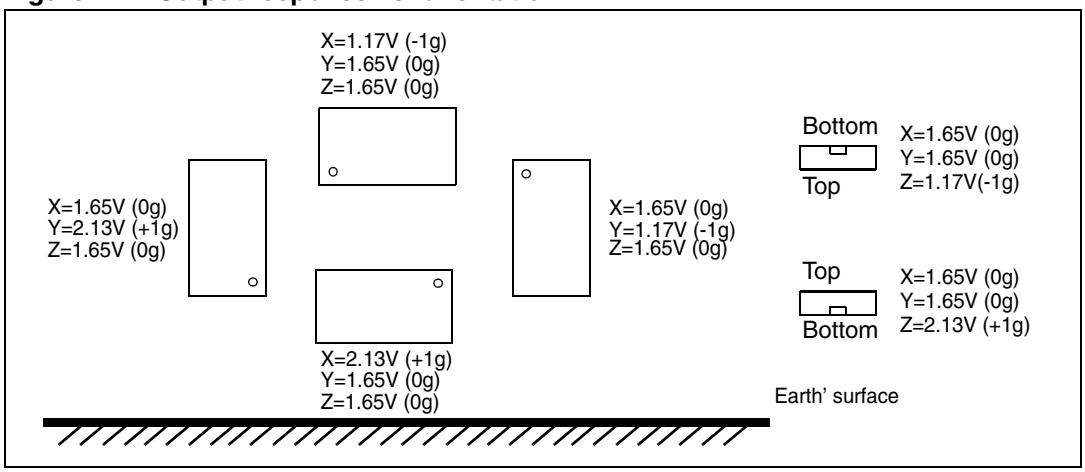



*Figure 4* refers to the LIS352AR powered at 3.3 V.

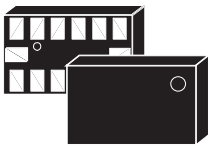
# 7 Package information

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.

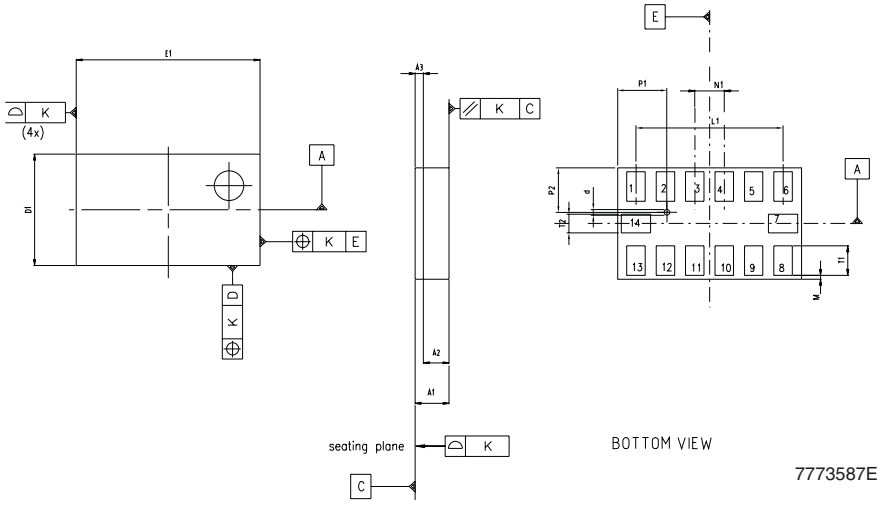
**Figure 5. LGA-14: mechanical data and package dimensions**

| Dimensions | | | | | | |
|---|---|---|---|---|---|---|
| Ref. | mm | | | inch | | |
| | Min. | Typ. | Max. | Min. | Typ. | Max. |
| A1 | | 0.90 | 1 | 0.033 | 0.035 | 0.037 |
| A2 | | | 0.7 | | | 0.027 |
| A3 | 0.16 | 0.2 | 0.24 | 0.006 | 0.007 | 0.009 |
| D1 | 2.85 | 3 | 3.15 | 0.116 | 0.118 | 0.120 |
| E1 | 4.85 | 5 | 5.15 | 0.194 | 0.196 | 0.198 |
| N1 | | 0.8 | | | 0.031 | |
| L1 | | 4 | | | 0.157 | |
| P1 | | 1.34 | | | 0.052 | |
| P2 | | 1.2 | | | 0.047 | 0.048 |
| T1 | | 0.8 | | | 0.031 | |
| T2 | | 0.5 | | | 0.019 | |
| d | | 0.15 | | | 0.005 | |
| M | | 0.1 | | | 0.003 | |
| k | | 0.05 | | | 0.002 | |

**Outline and mechanical data**



**LGA-14 (3x5x0.9mm)**
**pitch 0.8mm**
**Land Grid Array Package**



# 8 Revision history

Table 8. Document revision history

| Date | Revision | Changes |
|---|---|---|
| 02-Feb-2010 | 1 | Initial release. |

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