



# LIS3LV02DQ

## MEMS INERTIAL SENSOR

### 3-Axis - $\pm 2g/\pm 6g$ Digital Output Low Voltage Linear Accelerometer

#### Features

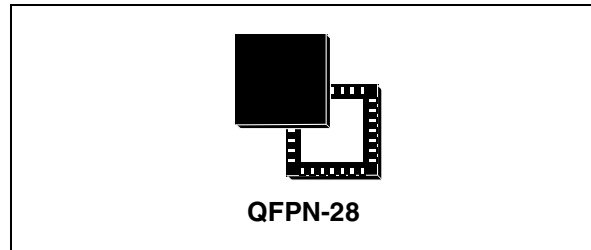
- 2.16V TO 3.6V SINGLE SUPPLY OPERATION
- 1.8V COMPATIBLE IOs
- I<sup>2</sup>C/SPI DIGITAL OUTPUT INTERFACES
- PROGRAMMABLE 12 or 16 BIT DATA REPRESENTATION
- INTERRUPT ACTIVATED BY MOTION
- PROGRAMMABLE INTERRUPT THRESHOLD
- EMBEDDED SELF TEST
- HIGH SHOCK SURVIVABILITY
- ECO-PACK COMPLIANT

#### Description

The LIS3LV02DQ is a three axes digital output linear accelerometer that includes a sensing element and an IC interface able to take the information from the sensing element and to provide the measured acceleration signals to the external world through an I<sup>2</sup>C/SPI serial interface.

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

The IC interface instead is manufactured using a CMOS process that allows high level of integration to design a dedicated circuit which is factory



trimmed to better match the sensing element characteristics.

The LIS3LV02DQ has a user selectable full scale of  $\pm 2g$ ,  $\pm 6g$  and it is capable of measuring acceleration over a bandwidth of 640 Hz for all axes. The device bandwidth may be selected accordingly to the application requirements. A self-test capability allows the user to check the functioning of the system

The device may be configured to generate an inertial wake-up/free-fall interrupt signal when a programmable acceleration threshold is crossed at least in one of the three axes.

The LIS3LV02DQ is available in plastic SMD package and it is specified over a temperature range extending from  $-40^{\circ}\text{C}$  to  $+85^{\circ}\text{C}$ .

The LIS3LV02DQ belongs to a family of products suitable for a variety of applications:

- Free-Fall detection
- Motion activated functions in portable terminals
- Antitheft systems and Inertial navigation
- Gaming and Virtual Reality input devices
- Vibration Monitoring and Compensation

#### Order codes

| Part number   | Op. Temp. range, $^{\circ}\text{C}$ | Package | Packing       |
|---------------|-------------------------------------|---------|---------------|
| LIS3LV02DQ    | -40 to +85                          | QFPN-28 | Tray          |
| LIS3LV02DQ-TR | -40 to +85                          | QFPN-28 | Tape and Reel |

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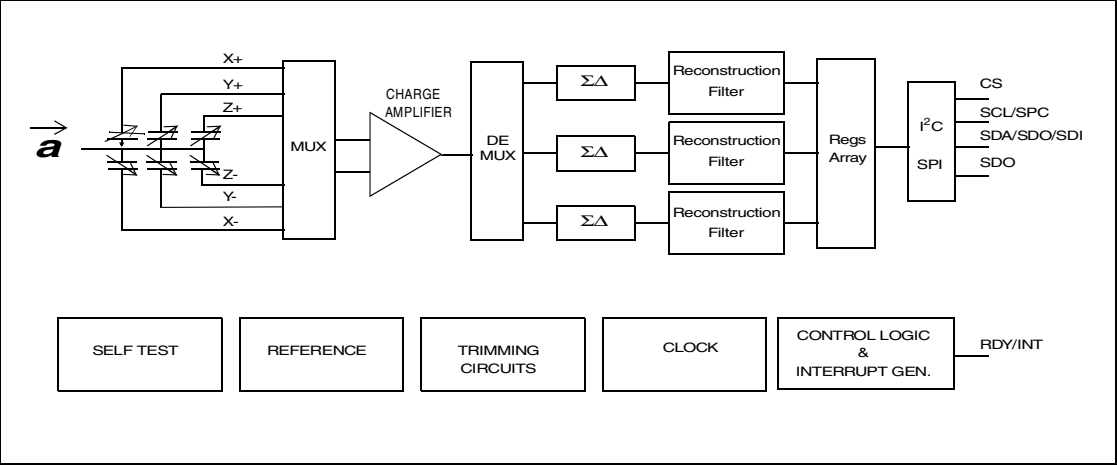
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# 1 Block Diagram & Pin Description

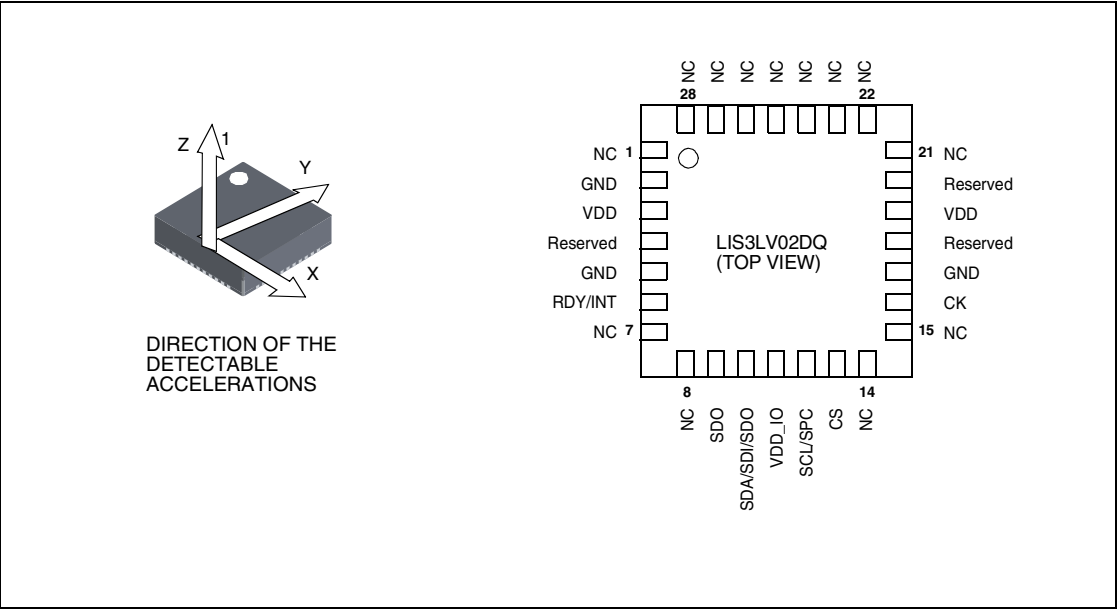
## 1.1 Block diagram

Figure 1. Block Diagram



## 1.2 QFPN-28 Pin description

Figure 2. Pin Connection



**Table 1. Pin description**

| Pin#   | Name                | Function   |
|--------|---------------------|--|
| 1      | NC                  | Internally not connected   |
| 2      | GND                 | 0V supply  |
| 3      | Vdd                 | Power supply   |
| 4      | Reserved            | Either leave unconnected or connect to GND   |
| 5      | GND                 | 0V supply  |
| 6      | RDY/INT             | Data ready/inertial wake-up and free-fall interrupt  |
| 7, 8   | NC                  | Internally not connected   |
| 9      | SDO                 | SPI Serial Data Output   |
| 10     | SDA/<br>SDI/<br>SDO | I <sup>2</sup> C Serial Data (SDA)<br>SPI Serial Data Input (SDI)<br>3-wire Interface Serial Data Output (SDO) |
| 11     | Vdd_IO              | Power supply for I/O pads  |
| 12     | SCL/SPC             | I <sup>2</sup> C Serial Clock (SCL)<br>SPI Serial Port Clock (SPC)   |
| 13     | CS                  | SPI enable<br>I <sup>2</sup> C/SPI mode selection (1: I <sup>2</sup> C mode; 0: SPI enabled)                   |
| 14, 15 | NC                  | Internally not connected   |
| 16     | CK                  | Optional External clock, if not used either leave unconnected or connect to GND                                |
| 17     | GND                 | 0V supply  |
| 18     | Reserved            | Either leave unconnected or connect to Vdd_IO  |
| 19     | Vdd                 | Power supply   |
| 20     | Reserved            | Connect to Vdd   |
| 21-28  | NC                  | Internally not connected   |

## 2 Mechanical and Electrical specifications

### 2.1 Mechanical characteristics<sup>1</sup>

**Table 2. Mechanical Characteristics**

(All the parameters are specified @ Vdd=2.5V, T=25°C unless otherwise noted)

| Symbol | Parameter   | Test conditions                        | Min. | Typ. <sup>2</sup> | Max. | Unit  |
|--------|---|--|------|-------------------|------|-------|
| FS     | Measurement range <sup>3</sup>                      | FS bit set to 0                        | ±1.8 | ±2.0              |      | g     |
|        |   | FS bit set to 1                        | ±5.6 | ±6.0              |      | g     |
| Dres   | Device Resolution                                   | Full-scale = 2g<br>BW=40Hz             |      | 1.0               |      | mg    |
| So     | Sensitivity   | Full-scale = 2g, 12 bit representation | 974  | 1024              | 1074 | LSb/g |
|        |   | Full-scale = 6g, 12 bit representation | 323  | 340               | 357  | LSb/g |
| TCS0   | Sensitivity Change Vs Temperature                   | Full-scale = 2g, 12 bit representation |      | 0.025             |      | %/°C  |
| Off    | Zero-g Level Offset Accuracy <sup>4,5</sup>         | Full-scale = 2g<br>X, Y axis           | -20  |                   | +20  | mg    |
|        |   | Full-scale = 2g<br>Z axis              | -40  |                   | +40  | mg    |
|        |   | Full-scale = 6g<br>X, Y axis           | -40  |                   | +40  | mg    |
|        |   | Full-scale = 6g<br>Z axis              | -60  |                   | +60  | mg    |
| LTOff  | Zero-g Level Offset Long Term Accuracy <sup>6</sup> | Full-scale = 2g<br>X, Y axis           | -2   |                   | +2   | %FS   |
|        |   | Full-scale = 2g<br>Z axis              | -5   |                   | +5   | %FS   |
|        |   | Full-scale = 6g<br>X, Y axis           | -1   |                   | +1   | %FS   |
|        |   | Full-scale = 6g<br>Z axis              | -2   |                   | +2   | %FS   |
| TCOff  | Zero-g Level Change Vs Temperature                  | Max Delta from 25°C                    |      | 0.2               |      | mg/°C |

**Table 2. Mechanical Characteristics (continued)**

(All the parameters are specified @ Vdd=2.5V, T=25°C unless otherwise noted)

| Symbol          | Parameter                              | Test conditions   | Min. | Typ. <sup>2</sup> | Max. | Unit |
|-----------------|--|---|------|-------------------|------|------|
| NL              | Non Linearity                          | Best fit straight line<br>X, Y axis<br>Full-scale = 2g<br>BW=40Hz |      | ±2                |      | %FS  |
|                 |  | Best fit straight line<br>Z axis<br>Full-scale = 2g<br>BW=40Hz    |      | ±3                |      | %FS  |
| CrAx            | Cross Axis                             |   | -3.5 |                   | 3.5  | %    |
| V <sub>st</sub> | Self test Output Change <sup>7,8</sup> | Full-scale=2g<br>X axis   | 100  | 240               | 400  | LSb  |
|                 |  | Full-scale=2g<br>Y axis   | 100  | 240               | 400  | LSb  |
|                 |  | Full-scale=2g<br>Z axis   | 30   | 150               | 350  | LSb  |
|                 |  | Full-scale=6g<br>X axis   | 30   | 80                | 130  | LSb  |
|                 |  | Full-scale=6g<br>Y axis   | 30   | 80                | 130  | LSb  |
|                 |  | Full-scale=6g<br>Z axis   | 10   | 50                | 120  | LSb  |
| BW              | System Bandwidth <sup>9</sup>          |   |      | ODRx/4            |      | Hz   |
| Top             | Operating Temperature Range            |   | -40  |                   | +85  | °C   |
| Wh              | Product Weight                         |   |      | 0.2               |      | gram |

Note: 1 The product is factory calibrated at 2.5V. The device can be used from 2.16V to 3.6V

2 Typical specifications are not guaranteed

3 Verified by wafer level test and measurement of initial offset and sensitivity

4 Zero-g level offset value after MSL3 preconditioning

5 Offset can be eliminated by enabling the built-in high pass filter (HPF)

6 Results of accelerated reliability tests. Report available upon request

7 Self Test output changes with the power supply. Self test "output change" is defined as  $OUTPUT[LSb]_{(Self-test\ bit\ on\ ctrl\_reg1=1)} - OUTPUT[LSb]_{(Self-test\ bit\ on\ ctrl\_reg1=0)}$ . 1LSb=1g/1024 at 12bit representation, 2g Full-Scale

8 Output data reach 99% of final value after 5/ODR when enabling Self-Test mode due to device filtering

9 ODR is output data rate. Refer to table 4 for specifications



**Table 3. Mechanical Characteristics**

(All the parameters are specified @ Vdd=3.3V, T=25°C unless otherwise noted)

| Symbol | Parameter   | Test conditions   | Min. | Typ. <sup>2</sup> | Max. | Unit  |
|--------|---|---|------|-------------------|------|-------|
| FS     | Measurement range <sup>3</sup>                      | FS bit set to 0   | ±1.7 | ±2.0              |      | g     |
|        |   | FS bit set to 1   | ±5.3 | ±6.0              |      | g     |
| Dres   | Device Resolution                                   | Full-scale = 2g<br>BW=40Hz  |      | 1.0               |      | mg    |
| So     | Sensitivity   | Full-scale = 2g, 12 bit representation                            | 920  | 1024              | 1126 | LSb/g |
|        |   | Full-scale = 6g, 12 bit representation                            | 306  | 340               | 374  | LSb/g |
| TCS0   | Sensitivity Change Vs Temperature                   | Full-scale = 2g, 12 bit representation                            |      | 0.025             |      | %/°C  |
| Off    | Zero-g Level Offset Accuracy <sup>4,5</sup>         | Full-scale = 2g<br>X, Y axis                                      | -70  |                   | 70   | mg    |
|        |   | Full-scale = 2g<br>Z axis   | -90  |                   | 90   | mg    |
|        |   | Full-scale = 6g<br>X, Y axis                                      | -90  |                   | 90   | mg    |
|        |   | Full-scale = 6g<br>Z axis   | -100 |                   | 100  | mg    |
| LTOff  | Zero-g Level Offset Long Term Accuracy <sup>6</sup> | Full-scale = 2g<br>X, Y axis                                      | -4.5 |                   | +4.5 | %FS   |
|        |   | Full-scale = 2g<br>Z axis   | -6   |                   | +6   | %FS   |
|        |   | Full-scale = 6g<br>X, Y axis                                      | -1.8 |                   | +1.8 | %FS   |
|        |   | Full-scale = 6g<br>Z axis   | -2.2 |                   | +2.2 | %FS   |
| TCOff  | Zero-g Level Change Vs Temperature                  | Max Delta from 25°C   |      | 0.2               |      | mg/°C |
| NL     | Non Linearity                                       | Best fit straight line<br>X, Y axis<br>Full-scale = 2g<br>BW=40Hz |      | ±2                |      | %FS   |
|        |   | Best fit straight line<br>Z axis<br>Full-scale = 2g<br>BW=40Hz    |      | ±3                |      | %FS   |
| CrAx   | Cross Axis  |   | -3.5 |                   | 3.5  | %     |

**Table 3. Mechanical Characteristics (continued)**

(All the parameters are specified @ Vdd=3.3V, T=25°C unless otherwise noted)

| Symbol          | Parameter                              | Test conditions         | Min. | Typ. <sup>2</sup> | Max. | Unit |
|-----------------|--|-------------------------|------|-------------------|------|------|
| V <sub>st</sub> | Self test Output Change <sup>7,8</sup> | Full-scale=2g<br>X axis | 250  | 550               | 900  | LSb  |
|                 |  | Full-scale=2g<br>Y axis | 250  | 550               | 900  | LSb  |
|                 |  | Full-scale=2g<br>Z axis | 100  | 350               | 600  | LSb  |
|                 |  | Full-scale=6g<br>X axis | 80   | 180               | 300  | LSb  |
|                 |  | Full-scale=6g<br>Y axis | 80   | 180               | 300  | LSb  |
|                 |  | Full-scale=6g<br>Z axis | 30   | 120               | 200  | LSb  |
| BW              | System Bandwidth <sup>9</sup>          |                         |      | ODRx/4            |      | Hz   |
| Top             | Operating Temperature Range            |                         | -40  |                   | +85  | °C   |
| Wh              | Product Weight                         |                         |      | 0.2               |      | gram |

Note: 1 The product is factory calibrated at 2.5V. The device can be used from 2.16V to 3.6V

2 Typical specifications are not guaranteed

3 Verified by wafer level test and measurement of initial offset and sensitivity

4 Zero-g level offset value after MSL3 preconditioning

5 Offset can be eliminated by enabling the built-in high pass filter (HPF)

6 Results of accelerated reliability tests

7 Self Test output changes with the power supply. Self test "output change" is defined as  $OUTPUT[LSb]_{(Self-test\ bit\ on\ ctrl\_reg1=1)} - OUTPUT[LSb]_{(Self-test\ bit\ on\ ctrl\_reg1=0)}$ . 1LSb=1g/1024 at 12bit representation, 2g Full-Scale

8 Output data reach 99% of final value after 5/ODR when enabling Self-Test mode due to device filtering

9 ODR is output data rate. Refer to table 4 for specifications

## 2.2 Electrical characteristics<sup>1</sup>

**Table 4. Electrical Characteristics**

(All the parameters are specified @ Vdd=2.5V, T=25°C unless otherwise noted)

| Symbol | Parameter                              | Test conditions    | Min.       | Typ. <sup>2</sup> | Max.       | Unit |
|--------|--|--------------------|------------|-------------------|------------|------|
| Vdd    | Supply voltage                         |                    | 2.16       | 2.5               | 3.6        | V    |
| Vdd_IO | I/O pads Supply voltage                |                    | 1.71       |                   | Vdd        | V    |
| Idd    | Supply current                         | T = 25°C, Vdd=2.5V |            | 0.60              | 0.75       | mA   |
|        |  | T = 25°C, Vdd=3.3V |            | 0.65              | 0.80       | mA   |
| VIH    | Digital High level Input voltage       |                    | 0.8*Vdd_IO |                   |            | V    |
| VIL    | Digital Low level Input voltage        |                    |            |                   | 0.2*Vdd_IO | V    |
| VOH    | High level Output Voltage              |                    | 0.9*Vdd_IO |                   |            | V    |
| VOL    | Low level Output Voltage               |                    |            |                   | 0.1*Vdd_IO | V    |
| IddPdn | Current consumption in Power-down mode | T = 25°C           |            | 1                 | 10         | μA   |
| ODR1   | Output Data Rate1                      | Dec factor = 512   |            | 40                |            | Hz   |
| ODR2   | Output Data Rate 2                     | Dec factor = 128   |            | 160               |            | Hz   |
| ODR3   | Output Data Rate 3                     | Dec factor = 32    |            | 640               |            | Hz   |
| ODR4   | Output Data Rate 4                     | Dec factor = 8     |            | 2560              |            | Hz   |
| BW     | System Bandwidth <sup>3</sup>          |                    |            | ODRx/4            |            | Hz   |
| Ton    | Turn-on time <sup>4</sup>              |                    |            | 5/ODRx            |            | s    |
| Top    | Operating Temperature Range            |                    | -40        |                   | +85        | °C   |

Note: 1 The product is factory calibrated at 2.5V. The device can be used from 2.16V to 3.6V

2 Typical specifications are not guaranteed

3 Digital filter cut-off frequency

4 Time to obtain valid data after exiting Power-Down mode

## 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 |
|--------------------|--|---------------------------------|------|
| V <sub>DD</sub>    | Supply voltage   | -0.3 to 6                       | V    |
| V <sub>DD_IO</sub> | I/O pins Supply voltage  | -0.3 to V <sub>DD</sub> +0.1    | V    |
| V <sub>IN</sub>    | Input voltage on any control pin<br>(CS, SCL/SPC, SDA/SDI/SDO, CK) | -0.3 to V <sub>DD_IO</sub> +0.3 | V    |
| A <sub>POW</sub>   | Acceleration (Any axis, Powered, V <sub>DD</sub> =2.5V)            | 3000g for 0.5 ms                |      |
|                    |  | 10000g for 0.1 ms               |      |
| A <sub>UNP</sub>   | Acceleration (Any axis, Unpowered)                                 | 3000g for 0.5 ms                |      |
|                    |  | 10000g for 0.1 ms               |      |
| T <sub>OP</sub>    | Operating Temperature Range  | -40 to +85                      | °C   |
| T <sub>STG</sub>   | Storage Temperature Range  | -40 to +125                     | °C   |
| ESD                | Electrostatic discharge protection                                 | 4.0 (HBM)                       | kV   |
|                    |  | 200 (MM)                        | V    |
|                    |  | 1.5 (CDM)                       | kV   |

*Note: 1 Supply voltage on any pin should never exceed 6.0V.*



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

## 2.4 Terminology

### 2.4.1 Sensitivity

Sensitivity describes the gain of the sensor and can be determined e.g. by applying 1g 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. By doing so,  $\pm 1g$  acceleration is applied to the sensor. Subtracting the larger output value from the smaller one and divide the result by 2 leads to the actual sensitivity of the sensor. This value changes very little over temperature and also very little over time. The Sensitivity Tolerance describes the range of Sensitivities of a large population of sensor.

### 2.4.2 Zero-g level

Zero-g level Offset (Off) describes the deviation of an actual output signal from the ideal output signal if there is no acceleration present. A sensor in a steady state on a horizontal surface will measure 0g in X axis and 0g in Y axis whereas the Z axis will measure 1g. The output is ideally in the middle of the dynamic range of the sensor (content of OUT registers 00h, 00h with 16 bit representation, data expressed as 2's complement number). A deviation from ideal value in this case is called Zero-g offset. Offset is to some extent a result of stress to a precise 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". The Zero-g level of an individual sensor is stable over lifetime. The Zero-g level tolerance describes the range of Zero-g levels of a population of sensors.

### 2.4.3 Self Test

Self Test allows to test the mechanical and electric part 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 self-test bit of ctrl\_reg1 (control register 1) is programmed to '0'. When the self-test bit of ctrl\_reg1 is programmed to '1' an actuation force is applied to the sensor, simulating a definite input acceleration. In this case the sensor outputs will exhibit a change in their DC levels which is related to the selected full scale and depending on the Supply Voltage through the device sensitivity. When Self Test 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 inside table 2 or table 3, then the sensor is working properly and the parameters of the interface chip are within the defined specification.

## 3 Functionality

The LIS3LV02DQ is a high performance, low-power, digital output 3-axis linear accelerometer packaged in a QFN package. The complete device includes a sensing element and an IC interface able to take the information from the sensing element and to provide a signal to the external world through an I<sup>2</sup>C/SPI serial interface.

### 3.1 Sensing element

A proprietary process is used to create a surface micro-machined accelerometer. The technology allows to carry out 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. To be compatible with the traditional packaging techniques a cap is placed on top of the sensing element to avoid blocking the moving parts during the moulding 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 up to 100fF.

### 3.2 IC Interface

The complete measurement chain is composed by a low-noise capacitive amplifier which converts into an analog voltage the capacitive unbalancing of the MEMS sensor and by three  $\Sigma\Delta$  analog-to-digital converters, one for each axis, that translate the produced signal into a digital bitstream.

The  $\Sigma\Delta$  converters are coupled with dedicated reconstruction filters which remove the high frequency components of the quantization noise and provide low rate and high resolution digital words.

The charge amplifier and the  $\Sigma\Delta$  converters are operated respectively at 61.5 kHz and 20.5 kHz.

The data rate at the output of the reconstruction depends on the user selected Decimation Factor (DF) and spans from 40 Hz to 2560 Hz.

The acceleration data may be accessed through an I<sup>2</sup>C/SPI interface thus making the device particularly suitable for direct interfacing with a microcontroller.

The LIS3LV02DQ features a Data-Ready signal (RDY) which indicates when a new set of measured acceleration data is available thus simplifying data synchronization in digital system employing the device itself.

The LIS3LV02DQ may also be configured to generate an inertial Wake-Up, Direction Detection and Free-Fall interrupt signal accordingly to a programmed acceleration event along the enabled axes.

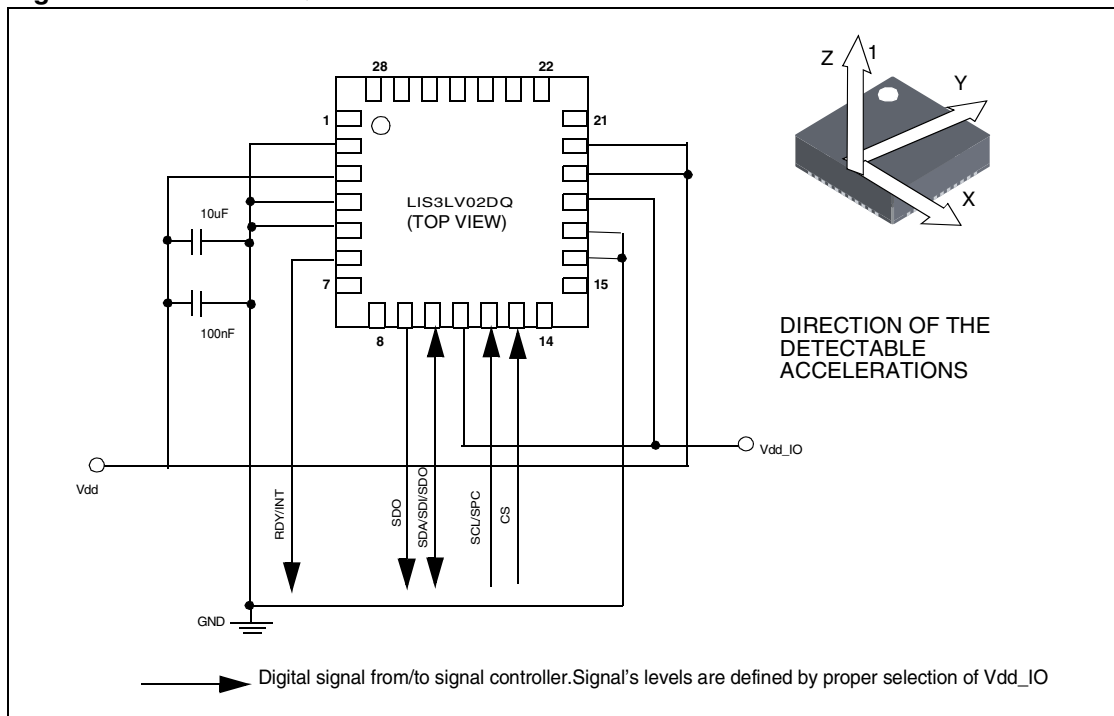
### 3.3 Factory calibration

The IC interface is factory calibrated for sensitivity (So) and Zero-g level (Off).

The trimming values are stored inside the device by a non volatile structure. Any time the device is turned on, the trimming parameters are downloaded into the registers to be employed during the normal operation. This allows the user to employ the device without further calibration.

## 4 Application Hints

**Figure 3. LIS3LV02DQ Electrical Connection**



The device core is supplied through Vdd line while the I/O pads are supplied through Vdd\_IO line. Power supply decoupling capacitors (100 nF ceramic, 10 µF Al) should be placed as near as possible to the pin 3 of the device (common design practice).

All the voltage and ground supplies must be present at the same time to have proper behavior of the IC (refer to Fig. 3). It is possible to remove Vdd maintaining Vdd\_IO without blocking the communication busses.

The functionality of the device and the measured acceleration data is selectable and accessible through the I<sup>2</sup>C/SPI interface. When using the I<sup>2</sup>C, CS must be tied high while SDO must be left floating. Refer to application note AN2041 for further information on device usage.

### 4.1 Soldering Information

The QFN-28 package is lead free and green package qualified for soldering heat resistance according to JEDEC J-STD-020C. Central die pad and pin #1 indicator are physically connected to GND. Land pattern and soldering recommendations are available upon request.



## 5 Digital Interfaces

The registers embedded inside the LIS3LV02DQ may be accessed through both the I<sup>2</sup>C and SPI serial interfaces. The latter may be SW configured to operate either in 3-wire or 4-wire interface mode.

The serial interfaces are mapped onto the same pads. To select/exploit the I<sup>2</sup>C interface, CS line must be tied high (i.e connected to Vdd\_IO).

**Table 6. Serial interface pin description**

| PIN Name    | PIN Description  |
|-------------|--|
| CS          | SPI enable<br>I <sup>2</sup> C/SPI mode selection (1: I <sup>2</sup> C mode; 0: SPI enabled)                   |
| SCL/SPC     | I <sup>2</sup> C Serial Clock (SCL)<br>SPI Serial Port Clock (SPC)   |
| SDA/SDI/SDO | I <sup>2</sup> C Serial Data (SDA)<br>SPI Serial Data Input (SDI)<br>3-wire Interface Serial Data Output (SDO) |
| SDO         | SPI Serial Data Output (SDO)   |

### 5.1 I<sup>2</sup>C Serial Interface

The LIS3LV02DQ I<sup>2</sup>C is a bus slave. The I<sup>2</sup>C is employed to write the data into the registers whose content can also be read back.

The relevant I<sup>2</sup>C terminology is given in the table below

**Table 7. Serial interface pin description**

| Term        | Description  |
|-------------|--|
| Transmitter | The device which sends data to the bus   |
| Receiver    | The device which receives data from the bus  |
| Master      | The device which initiates a transfer, generates clock signals and terminates a transfer |
| Slave       | The device addressed by the master   |

There are two signals associated with the I<sup>2</sup>C bus: the Serial Clock Line (SCL) and the Serial Data line (SDA). The latter is a bidirectional line used for sending and receiving the data to/from the interface. Both the lines are connected to Vdd\_IO through a pull-up resistor embedded inside the LIS3LV02DQ. When the bus is free both the lines are high.

The I<sup>2</sup>C interface is compliant with Fast Mode (400 kHz) I<sup>2</sup>C standards as well as the Normal Mode.

### 5.1.1 I<sup>2</sup>C Operation

The transaction on the bus is started through a START (ST) signal. A START condition is defined as a HIGH to LOW transition on the data line while the SCL line is held HIGH. After this has been transmitted by the Master, the bus is considered busy. The next byte of data transmitted after the start condition contains the address of the slave in the first 7 bits and the eighth bit tells whether the Master is receiving data from the slave or transmitting data to the slave. When an address is sent, each device in the system compares the first seven bits after a start condition with its address. If they match, the device considers itself addressed by the Master. The Slave Address (SAD) associated to the LIS3LV02DQ is 0011101b.

Data transfer with acknowledge is mandatory. The transmitter must release the SDA line during the acknowledge pulse. The receiver must then pull the data line LOW so that it remains stable low during the HIGH period of the acknowledge clock pulse. A receiver which has been addressed is obliged to generate an acknowledge after each byte of data has been received.

The I<sup>2</sup>C embedded inside the LIS3LV02DQ behaves like a slave device and the following protocol must be adhered to. After the start condition (ST) a slave address is sent, once a slave acknowledge (SAK) has been returned, a 8-bit sub-address will be transmitted: the 7 LSB represent the actual register address while the MSB enables address auto increment. If the MSb of the SUB field is 1, the SUB (register address) will be automatically incremented to allow multiple data read/write.

The slave address is completed with a Read/Write bit. If the bit was '1' (Read), a repeated START (SR) condition will have to be issued after the two sub-address bytes; if the bit is '0' (Write) the Master will transmit to the slave with direction unchanged.

Transfer when Master is writing one byte to slave

|        |    |         |     |     |     |      |     |    |
|--------|----|---------|-----|-----|-----|------|-----|----|
| Master | ST | SAD + W |     | SUB |     | DATA |     | SP |
| Slave  |    |         | SAK |     | SAK |      | SAK |    |

Transfer when Master is writing multiple bytes to slave:

|        |    |         |     |     |     |      |     |      |     |    |
|--------|----|---------|-----|-----|-----|------|-----|------|-----|----|
| Master | ST | SAD + W |     | SUB |     | DATA |     | DATA |     | SP |
| Slave  |    |         | SAK |     | SAK |      | SAK |      | SAK |    |

Transfer when Master is receiving (reading) one byte of data from slave:

|        |    |         |     |     |     |    |         |     |      |      |    |
|--------|----|---------|-----|-----|-----|----|---------|-----|------|------|----|
| Master | ST | SAD + W |     | SUB |     | SR | SAD + R |     |      | NMAK | SP |
| Slave  |    |         | SAK |     | SAK |    |         | SAK | DATA |      |    |

Transfer when Master is receiving (reading) multiple bytes of data from slave

|        |    |         |     |     |     |    |         |     |      |     |
|--------|----|---------|-----|-----|-----|----|---------|-----|------|-----|
| Master | ST | SAD + W |     | SUB |     | SR | SAD + R |     |      | MAK |
| Slave  |    |         | SAK |     | SAK |    |         | SAK | DATA |     |

|        |  |      |     |  |      |      |    |
|--------|--|------|-----|--|------|------|----|
| Master |  |      | MAK |  |      | NMAK | SP |
| Slave  |  | DATA |     |  | DATA |      |    |

Data are transmitted in byte format (DATA). Each data transfer contains 8 bits. The number of bytes transferred per transfer is unlimited. Data is transferred with the Most Significant bit (MSb) first. If a receiver can't receive another complete byte of data until it has performed some other

function, it can hold the clock line, SCL LOW to force the transmitter into a wait state. Data transfer only continues when the receiver is ready for another byte and releases the data line. If a slave receiver doesn't acknowledge the slave address (i.e. it is not able to receive because it is performing some real time function) the data line must be left HIGH by the slave. The Master can then abort the transfer. A LOW to HIGH transition on the SDA line while the SCL line is HIGH is defined as a STOP condition. Each data transfer must be terminated by the generation of a STOP (SP) condition.

In order to read multiple bytes, it is necessary to assert the most significant bit of the sub-address field. In other words, SUB(7) must be equal to 1 while SUB(6-0) represents the address of first register to read.

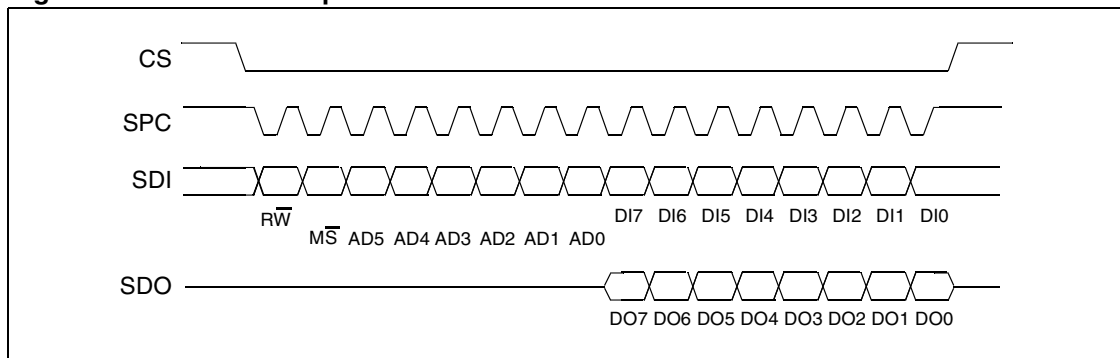
In the presented communication format MAK is Master Acknowledge and NMAK is No Master Acknowledge.

## 5.2 SPI Bus Interface

The LIS3LV02DQ SPI is a bus slave. The SPI allows to write and read the registers of the device.

The Serial Interface interacts with the outside world with 4 wires: **CS**, **SPC**, **SDI** and **SDO**.

**Figure 4. Read & write protocol**



**CS** is the Serial Port Enable and it is controlled by the SPI master. It goes low at the start of the transmission and goes back high at the end. **SPC** is the Serial Port Clock and it is controlled by the SPI master. It is stopped high when **CS** is high (no transmission). **SDI** and **SDO** are respectively the Serial Port Data Input and Output. Those lines are driven at the falling edge of **SPC** and should be captured at the rising edge of **SPC**.

Both the Read Register and Write Register commands are completed in 16 clock pulses or in multiple of 8 in case of multiple byte read/write. Bit duration is the time between two falling edges of **SPC**. The first bit (bit 0) starts at the first falling edge of **SPC** after the falling edge of **CS** while the last bit (bit 15, bit 23, ...) starts at the last falling edge of **SPC** just before the rising edge of **CS**.

**bit 0:** **RW** bit. When 0, the data **DI(7:0)** is written into the device. When 1, the data **DO(7:0)** from the device is read. In latter case, the chip will drive **SDO** at the start of bit 8.

**bit 1:** **M $\overline{S}$**  bit. When 0, the address will remain unchanged in multiple read/write commands. When 1, the address will be auto incremented in multiple read/write commands.

**bit 2-7:** address **AD(5:0)**. This is the address field of the indexed register.

**bit 8-15:** data DI(7:0) (write mode). This is the data that will be written into the device (MSb first).

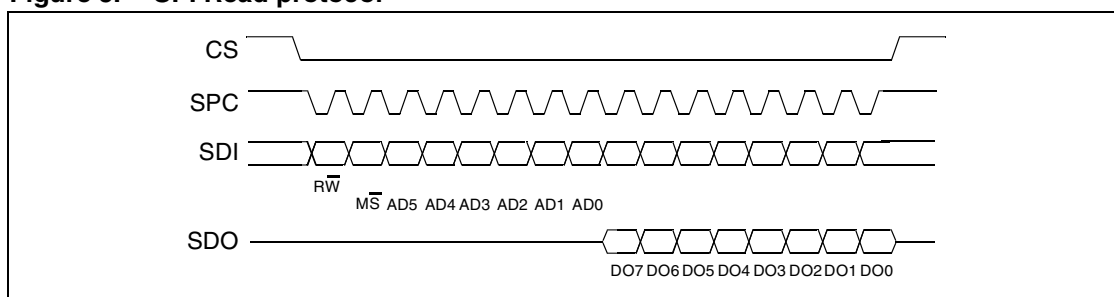
**bit 8-15:** data DO(7:0) (read mode). This is the data that will be read from the device (MSb first).

In multiple read/write commands further blocks of 8 clock periods will be added. When  $\overline{MS}$  bit is 0 the address used to read/write data remains the same for every block. When  $\overline{MS}$  bit is 1 the address used to read/write data is incremented at every block.

The function and the behavior of **SDI** and **SDO** remain unchanged.

## 5.2.1 SPI Read

**Figure 5. SPI Read protocol**



The SPI Read command is performed with 16 clock pulses. Multiple byte read command is performed adding blocks of 8 clock pulses at the previous one.

**bit 0:** READ bit. The value is 1.

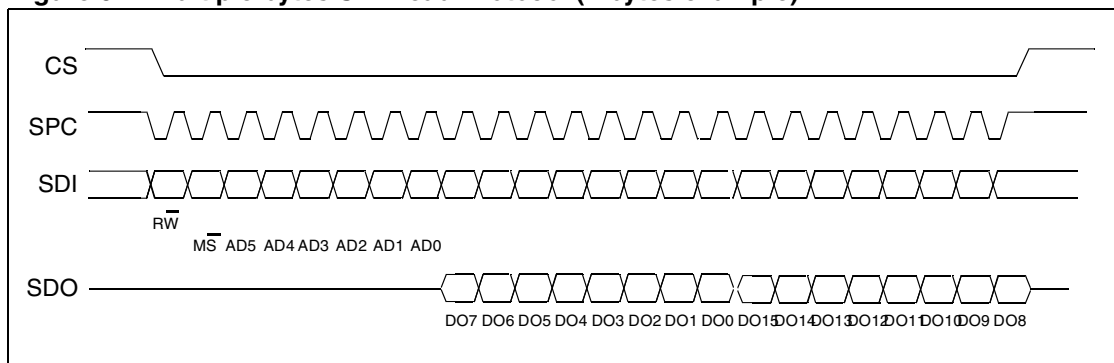
**bit 1:**  $\overline{MS}$  bit. When 0 do not increment address, when 1 increment address in multiple reading.

**bit 2-7:** address AD(5:0). This is the address field of the indexed register.

**bit 8-15:** data DO(7:0) (read mode). This is the data that will be read from the device (MSb first).

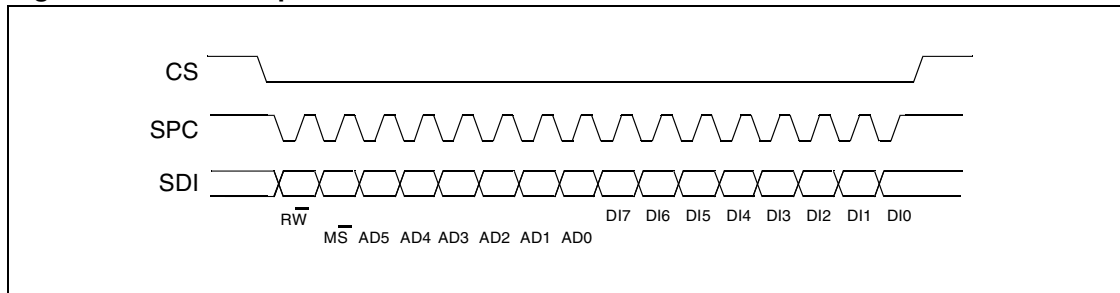
**bit 16-...** : data DO(...-8). Further data in multiple byte reading.

**Figure 6. Multiple bytes SPI Read Protocol (2 bytes example)**



## 5.2.2 SPI Write

Figure 7. SPI Write protocol



The SPI Write command is performed with 16 clock pulses. Multiple byte write command is performed adding blocks of 8 clock pulses at the previous one.

**bit 0:** WRITE bit. The value is 0.

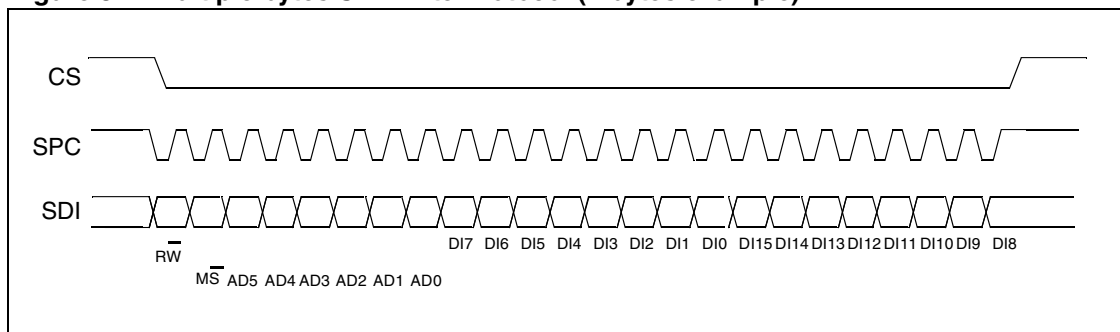
**bit 1:**  $\overline{MS}$  bit. When 0 do not increment address, when 1 increment address in multiple writing.

**bit 2 -7:** address AD(5:0). This is the address field of the indexed register.

**bit 8-15:** data DI(7:0) (write mode). This is the data that will be written inside the device (MSb first).

**bit 16-...** : data DI(...-8). Further data in multiple byte writing.

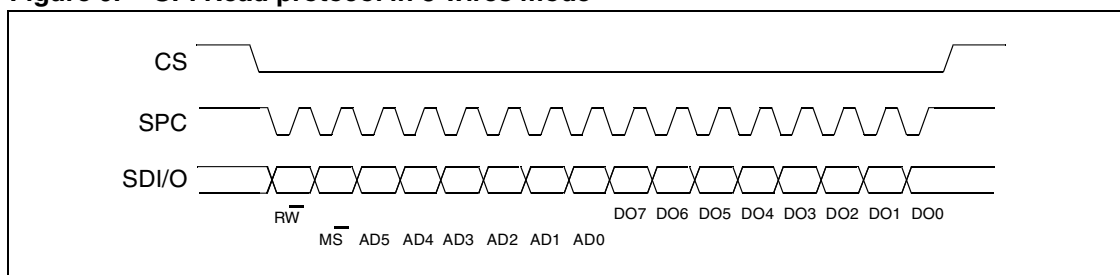
Figure 8. Multiple bytes SPI Write Protocol (2 bytes example)



## 5.2.3 SPI Read in 3-wires mode

3-wires mode is entered by setting to 1 bit SIM (SPI Serial Interface Mode selection) in CTRL\_REG2.

Figure 9. SPI Read protocol in 3-wires mode



The SPI Read command is performed with 16 clock pulses:

**bit 0:** READ bit. The value is 1.

**bit 1:**  $\overline{\text{MS}}$  bit. When 0 do not increment address, when 1 increment address in multiple reading.

**bit 2-7:** address AD(5:0). This is the address field of the indexed register.

**bit 8-15:** data DO(7:0) (read mode). This is the data that will be read from the device (MSb first).

Multiple read command is also available in 3-wires mode.

## 6 Register mapping

The table given below provides a listing of the 8 bit registers embedded in the device and the related address.

**Table 8. Registers address map**

| Reg. Name       | Type | Register Address  |         | Default     | Comment        |
|-----------------|------|-------------------|---------|-------------|----------------|
|                 |      | Binary            | Hex     |             |                |
|                 | rw   | 0000000 - 0001110 | 00 - 0E |             | Reserved       |
| WHO_AM_I        | r    | 0001111           | 0F      | 00111010    | Dummy register |
|                 | rw   | 0010000 - 0010101 | 10 - 15 |             | Reserved       |
| OFFSET_X        | rw   | 0010110           | 16      | Calibration | Loaded at boot |
| OFFSET_Y        | rw   | 0010111           | 17      | Calibration | Loaded at boot |
| OFFSET_Z        | rw   | 0011000           | 18      | Calibration | Loaded at boot |
| GAIN_X          | rw   | 0011001           | 19      | Calibration | Loaded at boot |
| GAIN_Y          | rw   | 0011010           | 1A      | Calibration | Loaded at boot |
| GAIN_Z          | rw   | 0011011           | 1B      | Calibration | Loaded at boot |
|                 |      | 0011100 -0011111  | 1C-1F   |             | Reserved       |
| CTRL_REG1       | rw   | 0100000           | 20      | 00000111    |                |
| CTRL_REG2       | rw   | 0100001           | 21      | 00000000    |                |
| CTRL_REG3       | rw   | 0100010           | 22      | 00001000    |                |
| HP_FILTER RESET | r    | 0100011           | 23      | dummy       | Dummy register |
|                 |      | 0100100-0100110   | 24-26   |             | Not Used       |
| STATUS_REG      | rw   | 0100111           | 27      | 00000000    |                |
| OUTX_L          | r    | 0101000           | 28      | output      |                |
| OUTX_H          | r    | 0101001           | 29      | output      |                |
| OUTY_L          | r    | 0101010           | 2A      | output      |                |
| OUTY_H          | r    | 0101011           | 2B      | output      |                |
| OUTZ_L          | r    | 0101100           | 2C      | output      |                |
| OUTZ_H          | r    | 0101101           | 2D      | output      |                |
|                 | r    | 0101110           | 2E      |             | Reserved       |
|                 |      | 0101111           | 2F      |             | Not Used       |
| FF_WU_CFG       | rw   | 0110000           | 30      | 00000000    |                |
| FF_WU_SRC       | rw   | 0110001           | 31      | 00000000    |                |
| FF_WU_ACK       | r    | 0110010           | 32      | dummy       | Dummy register |
|                 |      | 0110011           | 33      |             | Not Used       |
| FF_WU_THS_L     | rw   | 0110100           | 34      | 00000000    |                |

**Table 8. Registers address map (continued)**

| Reg. Name      | Type | Register Address |       | Default  | Comment        |
|----------------|------|------------------|-------|----------|----------------|
|                |      | Binary           | Hex   |          |                |
| FF_WU_THS_H    | rw   | 0110101          | 35    | 00000000 |                |
| FF_WU_DURATION | rw   | 0110110          | 36    | 00000000 |                |
|                |      | 0110111          | 37    |          | Not Used       |
| DD_CFG         | rw   | 0111000          | 38    | 00000000 |                |
| DD_SRC         | rw   | 0111001          | 39    | 00000000 |                |
| DD_ACK         | r    | 0111010          | 3A    | dummy    | Dummy register |
|                |      | 0111011          | 3B    |          | Not Used       |
| DD_THSI_L      | rw   | 0111100          | 3C    | 00000000 |                |
| DD_THSI_H      | rw   | 0111101          | 3D    | 00000000 |                |
| DD_THSE_L      | rw   | 0111110          | 3E    | 00000000 |                |
| DD_THSE_H      | rw   | 0111111          | 3F    | 00000000 |                |
|                |      | 1000000-1111111  | 40-7F |          | Reserved       |

Registers marked as reserved must not be changed. The writing to those registers may cause permanent damages to the device.

The content of the registers that are loaded at boot should not be changed. They contain the factory calibration values. Their content is automatically restored when the device is powered-up.



## 7 Register Description

The device contains a set of registers which are used to control its behavior and to retrieve acceleration data. The registers 7.2 to 7.7 contain the factory calibration values, it is not necessary to change their value for normal device operation.

### 7.1 WHO\_AM\_I (0Fh)

|    |    |    |    |    |    |    |    |
|----|----|----|----|----|----|----|----|
| W7 | W6 | W5 | W4 | W3 | W2 | W1 | W0 |
|----|----|----|----|----|----|----|----|

|        |  |
|--------|--|
| W7, W0 | LIS3LV02DQ Physical Address equal to 3Ah |
|--------|--|

Addressing this register the physical address of the device is returned. For LIS3LV02DQ the physical address assigned in factory is 3Ah.

### 7.2 OFFSET\_X (16h)

|     |     |     |     |     |     |     |     |
|-----|-----|-----|-----|-----|-----|-----|-----|
| OX7 | OX6 | OX5 | OX4 | OX3 | OX2 | OX1 | OX0 |
|-----|-----|-----|-----|-----|-----|-----|-----|

|          |                                    |
|----------|------------------------------------|
| OX7, OX0 | Digital Offset Trimming for X-Axis |
|----------|------------------------------------|

### 7.3 OFFSET\_Y (17h)

|     |     |     |     |     |     |     |     |
|-----|-----|-----|-----|-----|-----|-----|-----|
| OY7 | OY6 | OY5 | OY4 | OY3 | OY2 | OY1 | OY0 |
|-----|-----|-----|-----|-----|-----|-----|-----|

|            |                                    |
|------------|------------------------------------|
| DOY7, DOY0 | Digital Offset Trimming for Y-Axis |
|------------|------------------------------------|

### 7.4 OFFSET\_Z (18h)

|     |     |     |     |     |     |     |     |
|-----|-----|-----|-----|-----|-----|-----|-----|
| OZ7 | OZ6 | OZ5 | OZ4 | OZ3 | OZ2 | OZ1 | OZ0 |
|-----|-----|-----|-----|-----|-----|-----|-----|

|          |                                    |
|----------|------------------------------------|
| OZ7, OZ0 | Digital Offset Trimming for Z-Axis |
|----------|------------------------------------|

## 7.5 GAIN\_X (19h)

|     |     |     |     |     |     |     |     |
|-----|-----|-----|-----|-----|-----|-----|-----|
| GX7 | GX6 | GX5 | GX4 | GX3 | GX2 | GX1 | GX0 |
|-----|-----|-----|-----|-----|-----|-----|-----|

|          |                                  |
|----------|----------------------------------|
| GX7, GX0 | Digital Gain Trimming for X-Axis |
|----------|----------------------------------|

## 7.6 GAIN\_Y (1Ah)

|     |     |     |     |     |     |     |     |
|-----|-----|-----|-----|-----|-----|-----|-----|
| GY7 | GY6 | GY5 | GY4 | GY3 | GY2 | GY1 | GY0 |
|-----|-----|-----|-----|-----|-----|-----|-----|

|          |                                  |
|----------|----------------------------------|
| GY7, GY0 | Digital Gain Trimming for Y-Axis |
|----------|----------------------------------|

## 7.7 GAIN\_Z (1Bh)

|     |     |     |     |     |     |     |     |
|-----|-----|-----|-----|-----|-----|-----|-----|
| GZ7 | GZ6 | GZ5 | GZ4 | GZ3 | GZ2 | GZ1 | GZ0 |
|-----|-----|-----|-----|-----|-----|-----|-----|

|          |                                  |
|----------|----------------------------------|
| GZ7, GZ0 | Digital Gain Trimming for Z-Axis |
|----------|----------------------------------|

## 7.8 CTRL\_REG1 (20h)

|     |     |     |     |    |     |     |     |
|-----|-----|-----|-----|----|-----|-----|-----|
| PD1 | PD0 | DF1 | DF0 | ST | Zen | Yen | Xen |
|-----|-----|-----|-----|----|-----|-----|-----|

|          |  |
|----------|--|
| PD1, PD0 | Power Down Control<br>(00: power-down mode; 01, 10, 11: device on)   |
| DF1, DF0 | Decimation Factor Control<br>(00: decimate by 512; 01: decimate by 128; 10: decimate by 32; 11: decimate by 8) |
| ST       | Self Test Enable<br>(0: normal mode; 1: self-test active)  |
| Zen      | Z-axis enable<br>(0: axis off; 1: axis on)   |
| Yen      | Y-axis enable<br>(0: axis off; 1: axis on)   |
| Xen      | X-axis enable<br>(0: axis off; 1: axis on)   |

**PD1, PD0** bit allows to turn on the turn the device out of power-down mode. The device is in power-down mode when PD1, PD0= "00" (default value after boot). The device is in normal mode when either PD1 or PD0 is set to 1.

**DF1, DF0** bit allows to select the data rate at which acceleration samples are produced. The default value is 00 which corresponds to a data-rate of 40Hz. By changing the content of DF1, DF0 to "01", "10" and "11" the selected data-rate will be set respectively equal to 160Hz, 640Hz and to 2560Hz.

**ST** bit is used to activate the self test function. When the bit is set to one, an output change will occur to the device outputs (refer to table 2 and 3 for specification) thus allowing to check the functionality of the whole measurement chain.

**Zen** bit enables the Z-axis measurement channel when set to 1. The default value is 1.

**Yen** bit enables the Y-axis measurement channel when set to 1. The default value is 1.

**Xen** bit enables the X-axis measurement channel when set to 1. The default value is 1.

## 7.9 CTRL\_REG2 (21h)

|    |     |     |      |     |      |     |     |
|----|-----|-----|------|-----|------|-----|-----|
| FS | BDU | BLE | BOOT | IEN | DRDY | SIM | DAS |
|----|-----|-----|------|-----|------|-----|-----|

|      |  |
|------|--|
| FS   | Full Scale selection<br>(0: $\pm 2g$ ; 1: $\pm 6g$ )   |
| BDU  | Block Data Update<br>(0: continuous update; 1: output registers not updated until MSB and LSB reading) |
| BLE  | Big/Little Endian selection<br>(0: little endian; 1: big endian)                                       |
| BOOT | Reboot memory content  |
| IEN  | Interrupt ENable<br>(0: data ready on RDY pad; 1: int req on RDY pad)                                  |
| DRDY | Enable Data-Ready generation   |
| SIM  | SPI Serial Interface Mode selection<br>(0: 4-wire interface; 1: 3-wire interface)                      |
| DAS  | Data Alignment Selection<br>(0: 12 bit right justified; 1: 16 bit left justified)                      |

**FS** bit is used to select Full Scale value. After the device power-up the default full scale value is  $\pm 2g$ . In order to obtain a  $\pm 6g$  full scale it is necessary to set FS bit to '1'.

**BDU** bit is used to inhibit output registers update until both upper and lower register parts are read. In default mode (BDU= '0') the output register values are updated continuously. If for any reason it is not sure to read faster than output data rate it is recommended to set BDU bit to '1'. In this way the content of output registers is not updated until both MSB and LSB are read avoiding to read values related to different sample time.

**BLE** bit is used to select Big Endian or Little Endian representation for output registers. In Big Endian's one MSB acceleration value is located at addresses 28h (X-axis), 2Ah (Y-axis) and 2Ch (Z-axis) while LSB acceleration value is located at addresses 29h (X-axis), 2Bh (Y-axis) and 2Dh (Z-axis). In Little Endian representation (Default, BLE='0') the order is inverted (refer to data register description for more details).

**BOOT** bit is used to refresh the content of internal registers stored in the flash memory block. At the device power up the content of the flash memory block is transferred to the internal registers related to trimming functions to permit a good behavior of the device itself. If for any reason the content of trimming registers was changed it is sufficient to use this bit to restore correct values. When BOOT bit is set to '1' the content of internal flash is copied inside corresponding internal registers and it is used to calibrate the device. These values are factory

trimmed and they are different for every accelerometer. They permit a good behavior of the device and normally they have not to be changed. At the end of the boot process the BOOT bit is set again to '0'.

**IEN** bit is used to switch the value present on data-ready pad between Data-Ready signal and Interrupt signal. At power up the Data-ready signal is chosen. It is however necessary to modify DRDY bit to enable Data-Ready signal generation.

**DRDY** bit is used to enable Data-Ready (RDY/INT) pin activation. If DRDY bit is '0' (default value) on Data-Ready pad a '0' value is present. If a Data-Ready signal is desired it is necessary to set to '1' DRDY bit. Data-Ready signal goes to '1' whenever a new data is available for all the enabled axis. For example if Z-axis is disabled, Data-Ready signal goes to '1' when new values are available for both X and Y axis. Data-Ready signal comes back to '0' when all the registers containing values of the enabled axis are read. To be sure not to lose any data coming from the accelerometer data registers must be read before a new Data-Ready rising edge is generated. In this case Data-ready signal will have the same frequency of the data rate chosen.

**SIM** bit selects the SPI Serial Interface Mode. When SIM is '0' (default value) the 4-wire interface mode is selected. The data coming from the device are sent to SDO pad. In 3-wire interface mode output data are sent to SDA\_SDI pad.

**DAS** bit permits to decide between 12 bit right justified and 16 bit left justified representation of data coming from the device. The first case is the default case and the most significant bits are replaced by the bit representing the sign.

## 7.10 CTRL\_REG3 (22h)

|     |      |      |     |     |     |      |      |
|-----|------|------|-----|-----|-----|------|------|
| ECK | HPDD | HPFF | FDS | res | res | CFS1 | CFS0 |
|-----|------|------|-----|-----|-----|------|------|

|            |  |
|------------|--|
| ECK        | External Clock. Default value: 0<br>(0: clock from internal oscillator; 1: clock from external pad)                              |
| HPDD       | High Pass filter enabled for Direction Detection. Default value: 0<br>(0: filter bypassed; 1: filter enabled)                    |
| HPFF       | High Pass filter enabled for Free-Fall and Wake-Up. Default value: 0<br>(0: filter bypassed; 1: filter enabled)                  |
| FDS        | Filtered Data Selection. Default value: 0<br>(0: internal filter bypassed; 1: data from internal filter)                         |
| CFS1, CFS0 | High-pass filter Cut-off Frequency Selection. Default value: 00<br>(00: Hpc=512<br>01: Hpc=1024<br>10: Hpc=2048<br>11: Hpc=4096) |

**FDS** bit enables (FDS=1) or bypass (FDS=0) the high pass filter in the signal chain of the sensor

**CFS1, CFS0** bits defines the coefficient Hpc to be used to calculate the -3dB cut-off frequency of the high pass filter:

$$f_{\text{cutoff}} = \frac{0.318}{H_{\text{pc}}} \cdot \frac{\text{ODRx}}{2}$$

### 7.11 HP\_FILTER\_RESET (23h)

Dummy register. Reading at this address zeroes instantaneously the content of the internal high pass-filter. Read data is not significant.

### 7.12 STATUS\_REG (27h)

|       |     |     |     |       |     |     |     |
|-------|-----|-----|-----|-------|-----|-----|-----|
| ZYXOR | ZOR | YOR | XOR | ZYXDA | ZDA | YDA | XDA |
|-------|-----|-----|-----|-------|-----|-----|-----|

|       |                                    |
|-------|------------------------------------|
| ZYXOR | X, Y and Z axis Data Overrun       |
| ZOR   | Z axis Data Overrun                |
| YOR   | Y axis Data Overrun                |
| XOR   | X axis Data Overrun                |
| ZYXDA | X, Y and Z axis new Data Available |
| ZDA   | Z axis new Data Available          |
| YDA   | Y axis new Data Available          |
| XDA   | X axis new Data Available          |

### 7.13 OUTX\_L (28h)

|     |     |     |     |     |     |     |     |
|-----|-----|-----|-----|-----|-----|-----|-----|
| XD7 | XD6 | XD5 | XD4 | XD3 | XD2 | XD1 | XD0 |
|-----|-----|-----|-----|-----|-----|-----|-----|

|          |                              |
|----------|------------------------------|
| XD7, XD0 | X axis acceleration data LSB |
|----------|------------------------------|

In Big Endian Mode (bit BLE\_CTRL\_REG2 set to '1') the content of this register is the MSB acceleration data and depends by bit DAS in CTR\_REG2 reg as described in the following section.

### 7.14 OUTX\_H (29h)

|      |      |      |      |      |      |     |     |
|------|------|------|------|------|------|-----|-----|
| XD15 | XD14 | XD13 | XD12 | XD11 | XD10 | XD9 | XD8 |
|------|------|------|------|------|------|-----|-----|

|           |                              |
|-----------|------------------------------|
| XD15, XD8 | X axis acceleration data MSB |
|-----------|------------------------------|

When reading the register in "12 bit right justified" mode the most significant bits (15:12) are replaced with bit 11 (i.e. XD15-XD12=XD11, XD11, XD11, XD11).

In Big Endian Mode (bit BLE\_CTRL\_REG2 set to '1') the content of this register is the LSB acceleration data.

## 7.15 OUTY\_L (2Ah)

|     |     |     |     |     |     |     |     |
|-----|-----|-----|-----|-----|-----|-----|-----|
| YD7 | YD6 | YD5 | YD4 | YD3 | YD2 | YD1 | YD0 |
|-----|-----|-----|-----|-----|-----|-----|-----|

|          |                              |
|----------|------------------------------|
| YD7, YD0 | Y axis acceleration data LSB |
|----------|------------------------------|

In Big Endian Mode (bit BLE\_CTRL\_REG2 set to '1') the content of this register is the MSB acceleration data and depends by bit DAS in CTR\_REG2 reg as described in the following section.

## 7.16 OUTY\_H (2Bh)

|      |      |      |      |      |      |     |     |
|------|------|------|------|------|------|-----|-----|
| YD15 | YD14 | YD13 | YD12 | YD11 | YD10 | YD9 | YD8 |
|------|------|------|------|------|------|-----|-----|

|           |                              |
|-----------|------------------------------|
| YD15, YD8 | Y axis acceleration data MSB |
|-----------|------------------------------|

When reading the register in "12 bit right justified" mode the most significant bits (15:12) are replaced with bit 11 (i.e. YD15-YD12=YD11, YD11, YD11, YD11).

In Big Endian Mode (bit BLE\_CTRL\_REG2 set to '1') the content of this register is the LSB acceleration data.

## 7.17 OUTZ\_L (2Ch)

|     |     |     |     |     |     |     |     |
|-----|-----|-----|-----|-----|-----|-----|-----|
| ZD7 | ZD6 | ZD5 | ZD4 | ZD3 | ZD2 | ZD1 | ZD0 |
|-----|-----|-----|-----|-----|-----|-----|-----|

|          |                              |
|----------|------------------------------|
| ZD7, ZD0 | Z axis acceleration data LSB |
|----------|------------------------------|

In Big Endian Mode (bit BLE\_CTRL\_REG2 set to '1') the content of this register is the MSB acceleration data and depends by bit DAS in CTR\_REG2 reg as described in the following section.

## 7.18 OUTZ\_H (2Dh)

|      |      |      |      |      |      |     |     |
|------|------|------|------|------|------|-----|-----|
| ZD15 | ZD14 | ZD13 | ZD12 | ZD11 | ZD10 | ZD9 | ZD8 |
|------|------|------|------|------|------|-----|-----|

|           |                              |
|-----------|------------------------------|
| ZD15, ZD8 | Z axis acceleration data MSB |
|-----------|------------------------------|

When reading the register in "12 bit right justified" mode the most significant bits (15:12) are replaced with bit 11 (i.e. ZD15-ZD12=ZD11, ZD11, ZD11, ZD11).

In Big Endian Mode (bit BLE\_CTRL\_REG2 set to '1') the content of this register is the LSB acceleration data

## 7.19 FF\_WU\_CFG (30h)

|     |     |      |      |      |      |      |      |
|-----|-----|------|------|------|------|------|------|
| AOI | LIR | ZHIE | ZLIE | YHIE | YLIE | XHIE | XLIE |
|-----|-----|------|------|------|------|------|------|

|      |   |
|------|---|
| AOI  | And/Or combination of Interrupt events interrupt request. Default value: 0.<br>(0: OR combination of interrupt events;<br>1: AND combination of interrupt events)                   |
| LIR  | Latch interrupt request. Default value: 0.<br>(0: interrupt request not latched;<br>1: interrupt request latched)   |
| ZHIE | Enable Interrupt request on Z high event. Default value: 0.<br>(0: disable interrupt request;<br>1: enable interrupt request on measured accel. value higher than preset threshold) |
| ZLIE | Enable Interrupt request on Z low event. Default value: 0.<br>(0: disable interrupt request;<br>1: enable interrupt request on measured accel. value lower than preset threshold)   |
| YHIE | Enable Interrupt request on Y high event. Default value: 0.<br>(0: disable interrupt request;<br>1: enable interrupt request on measured accel. value higher than preset threshold) |
| YLIE | Enable Interrupt request on Y low event. Default value: 0.<br>(0: disable interrupt request;<br>1: enable interrupt request on measured accel. value lower than preset threshold)   |
| XHIE | Enable Interrupt request on X high event. Default value: 0.<br>(0: disable interrupt request;<br>1: enable interrupt request on measured accel. value higher than preset threshold) |
| XLIE | Enable Interrupt request on X low event. Default value: 0.<br>(0: disable interrupt request;<br>1: enable interrupt request on measured accel. value lower than preset threshold)   |

Free-fall and inertial wake-up configuration register.

## 7.20 FF\_WU\_SRC (31h)

|   |    |    |    |    |    |    |    |
|---|----|----|----|----|----|----|----|
| X | IA | ZH | ZL | YH | YL | XH | XL |
|---|----|----|----|----|----|----|----|

|    |  |
|----|--|
| IA | Interrupt Active. Default value: 0<br>(0: no interrupt has been generated;<br>1: one or more interrupt event has been generated) |
| ZH | Z High. Default value: 0<br>(0: no interrupt; 1: ZH event has occurred)  |
| ZL | Z Low. Default value: 0<br>(0: no interrupt; 1: ZL event has occurred)   |
| YH | Y High. Default value: 0<br>(0: no interrupt; 1: YH event has occurred)  |
| YL | Y Low. Default value: 0<br>(0: no interrupt; 1: YL event has occurred)   |
| XH | X High. Default value: 0<br>(0: no interrupt; 1: XH event has occurred)  |
| XL | X Low. Default value: 0<br>(0: no interrupt; 1: XL event has occurred)   |

## 7.21 FF\_WU\_ACK (32h)

Dummy register. If LIR bit in FF\_WU\_CFG=1 allows the refresh of FF\_WU\_SRC. Read data is not significant.



**7.22 FF\_WU\_THS\_L (34h)**

|      |      |      |      |      |      |      |      |
|------|------|------|------|------|------|------|------|
| THS7 | THS6 | THS5 | THS4 | THS3 | THS2 | THS1 | THS0 |
|------|------|------|------|------|------|------|------|

|            |   |
|------------|---|
| THS7, THS0 | Free-fall / Inertial Wake Up Acceleration Threshold LSB |
|------------|---|

**7.23 FF\_WU\_THS\_H (35h)**

|       |       |       |       |       |       |      |      |
|-------|-------|-------|-------|-------|-------|------|------|
| THS15 | THS14 | THS13 | THS12 | THS11 | THS10 | THS9 | THS8 |
|-------|-------|-------|-------|-------|-------|------|------|

|             |   |
|-------------|---|
| THS15, THS8 | Free-fall / Inertial Wake Up Acceleration Threshold MSB |
|-------------|---|

**7.24 FF\_WU\_DURATION (36h)**

|      |      |      |      |      |      |      |      |
|------|------|------|------|------|------|------|------|
| FWD7 | FWD6 | FWD5 | FWD4 | FWD3 | FWD2 | FWD1 | FWD0 |
|------|------|------|------|------|------|------|------|

|            |   |
|------------|---|
| FWD7, FWD0 | Minimum duration of the Free-fall/Wake-up event |
|------------|---|

Set the minimum duration of the free-fall/wake-up event to be recognized.

$$\text{Duration(s)} = \frac{\text{FF\_WU\_Duration (Dec)}}{\text{ODR}}$$

## 7.25 DD\_CFG (38h)

|      |     |      |      |      |      |      |      |
|------|-----|------|------|------|------|------|------|
| IEND | LIR | ZHIE | ZLIE | YHIE | YLIE | XHIE | XLIE |
|------|-----|------|------|------|------|------|------|

|      |   |
|------|---|
| IEND | Interrupt enable on Direction change. Default value: 0<br>(0: disabled;<br>1: interrupt signal enabled)   |
| LIR  | Latch Interrupt request into DD_SRC reg with the DD_SRC reg cleared by reading DD_ACK reg. Default value: 0.<br>(0: interrupt request not latched;<br>1: interrupt request latched)   |
| ZHIE | Enable interrupt generation on Z high event. Default value: 0<br>(0: disable interrupt request;<br>1: enable interrupt request on measured accel. value higher than preset threshold) |
| ZLIE | Enable interrupt generation on Z low event. Default value: 0<br>(0: disable interrupt request;<br>1: enable interrupt request on measured accel. value lower than preset threshold)   |
| YHIE | Enable interrupt generation on Y high event. Default value: 0<br>(0: disable interrupt request;<br>1: enable interrupt request on measured accel. value higher than preset threshold) |
| YLIE | Enable interrupt generation on Y low event. Default value: 0<br>(0: disable interrupt request;<br>1: enable interrupt request on measured accel. value lower than preset threshold)   |
| XHIE | Enable interrupt generation on X high event. Default value: 0<br>(0: disable interrupt request;<br>1: enable interrupt request on measured accel. value higher than preset threshold) |
| XLIE | Enable interrupt generation on X low event. Default value: 0<br>(0: disable interrupt request;<br>1: enable interrupt request on measured accel. value lower than preset threshold)   |

Direction-detector configuration register

## 7.26 DD\_SRC (39h)

|   |    |    |    |    |    |    |    |
|---|----|----|----|----|----|----|----|
| X | IA | ZH | ZL | YH | YL | XH | XL |
|---|----|----|----|----|----|----|----|

|    |  |
|----|--|
| IA | Interrupt event from direction change.<br>(0: no direction changes detected;<br>1: direction has changed from previous measurement)            |
| ZH | Z High. Default value: 0<br>(0: Z below THSI threshold;<br>1: Z accel. exceeding THSE threshold along positive direction of acceleration axis) |
| ZL | Z Low. Default value: 0<br>(0: Z below THSI threshold;<br>1: Z accel. exceeding THSE threshold along negative direction of acceleration axis)  |
| YH | Y High. Default value: 0<br>(0: Y below THSI threshold;<br>1: Y accel. exceeding THSE threshold along positive direction of acceleration axis) |
| YL | Y Low. Default value: 0<br>(0: Y below THSI threshold;<br>1: Y accel. exceeding THSE threshold along negative direction of acceleration axis)  |
| XH | X High. Default value: 0<br>(0: X below THSI threshold;<br>1: X accel. exceeding THSE threshold along positive direction of acceleration axis) |
| XL | X Low. Default value: 0<br>(0: X below THSI threshold;<br>1: X accel. exceeding THSE threshold along negative direction of acceleration axis)  |

Direction detector source register

## 7.27 DD\_ACK (3Ah)

Dummy register. If LIR bit in DD\_CFG=1 allows the refresh of DD\_SRC. Read data is not significant.

**7.28 DD\_THSI\_L (3Ch)**

|       |       |       |       |       |       |       |       |
|-------|-------|-------|-------|-------|-------|-------|-------|
| THSI7 | THSI6 | THSI5 | THSI4 | THSI3 | THSI2 | THSI1 | THSI0 |
|-------|-------|-------|-------|-------|-------|-------|-------|

|              |  |
|--------------|--|
| THSI7, THSI0 | Direction detection Internal Threshold LSB |
|--------------|--|

**7.29 DD\_THSI\_H (3Dh)**

|        |        |        |        |        |        |       |       |
|--------|--------|--------|--------|--------|--------|-------|-------|
| THSI15 | THSI14 | THSI13 | THSI12 | THSI11 | THSI10 | THSI9 | THSI8 |
|--------|--------|--------|--------|--------|--------|-------|-------|

|               |  |
|---------------|--|
| THSI15, THSI8 | Direction detection Internal Threshold MSB |
|---------------|--|

**7.30 DD\_THSE\_L (3Eh)**

|       |       |       |       |       |       |       |       |
|-------|-------|-------|-------|-------|-------|-------|-------|
| THSE7 | THSE6 | THSE5 | THSE4 | THSE3 | THSE2 | THSE1 | THSE0 |
|-------|-------|-------|-------|-------|-------|-------|-------|

|              |  |
|--------------|--|
| THSE7, THSE0 | Direction detection External Threshold LSB |
|--------------|--|

**7.31 DD\_THSE\_H (3Fh)**

|        |        |        |        |        |        |       |       |
|--------|--------|--------|--------|--------|--------|-------|-------|
| THSE15 | THSE14 | THSE13 | THSE12 | THSE11 | THSE10 | THSE9 | THSE8 |
|--------|--------|--------|--------|--------|--------|-------|-------|

|               |  |
|---------------|--|
| THSE15, THSE8 | Direction detection External Threshold MSB |
|---------------|--|

# 8 Typical performance characteristics

## 8.1 Mechanical Characteristics at 25°C

Figure 10. x-axis 0-g level at 2.5V

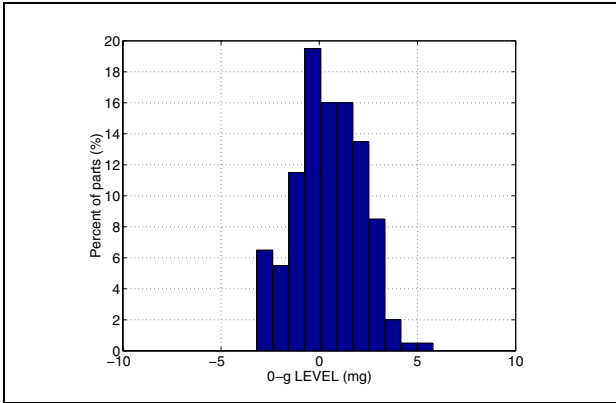


Figure 11. y-axis 0-g level at 2.5V

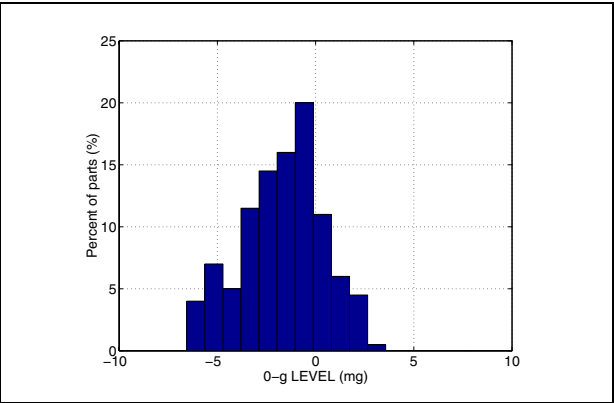


Figure 12. z-axis 0-g level at 2.5V

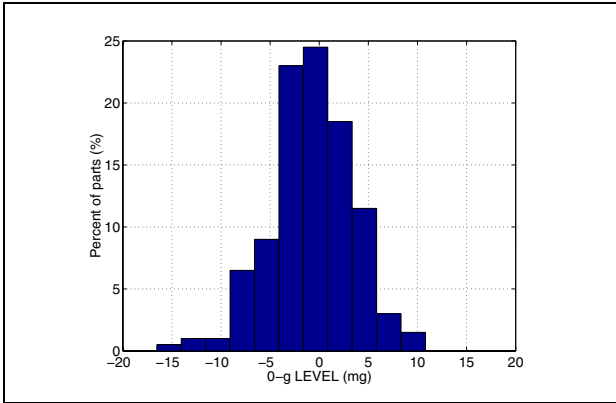


Figure 13. x-axis sensitivity at 2.5V

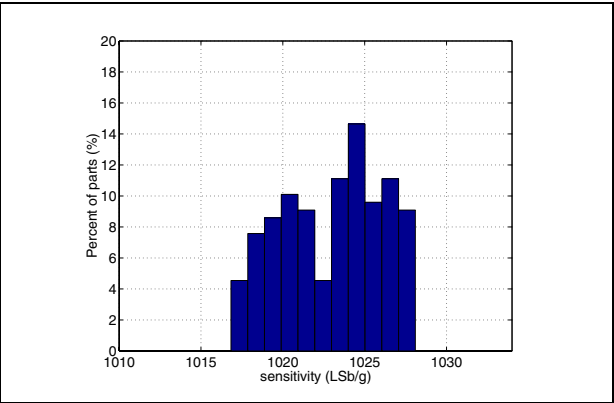


Figure 14. y-axis sensitivity at 2.5V

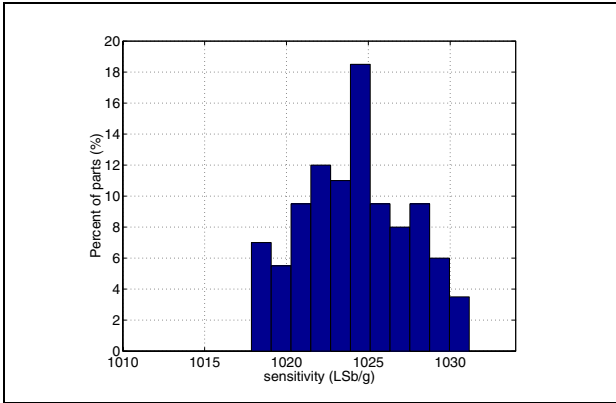
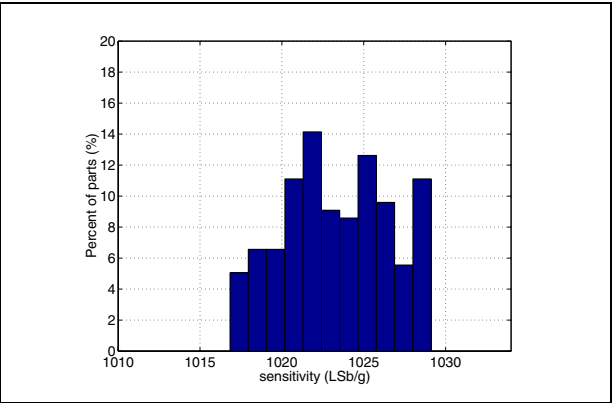


Figure 15. z-axis sensitivity at 2.5V



## 8.2 Mechanical Characteristics derived from measurement in the -40°C to +85°C temperature range

Figure 16. x-axis 0-g level change vs. temperature at 2.5V

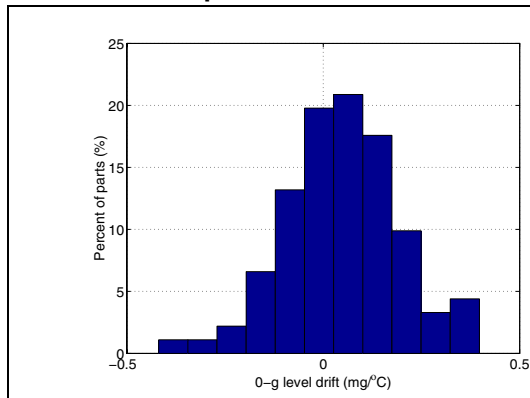


Figure 17. y-axis 0-g level change vs. temperature at 2.5V

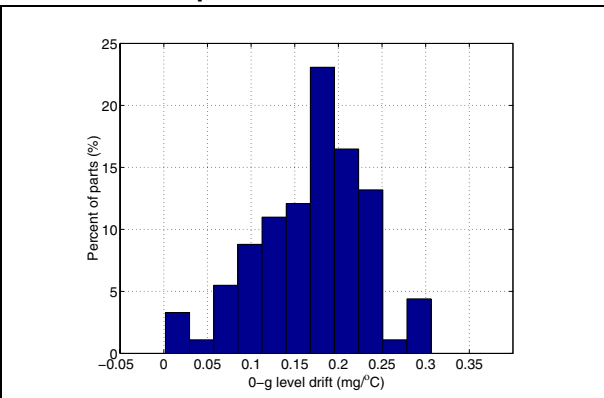


Figure 18. z-axis 0-g level change vs. temperature at 2.5V

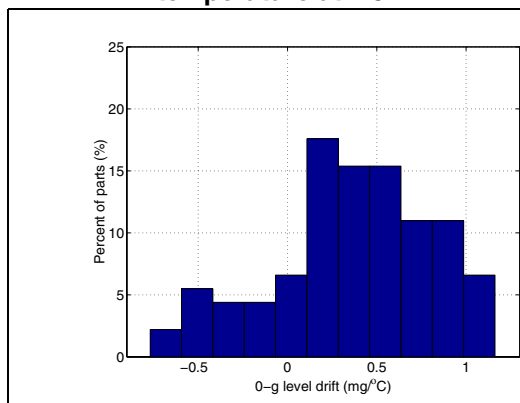


Figure 19. x-axis sensitivity change vs. temperature at 2.5V

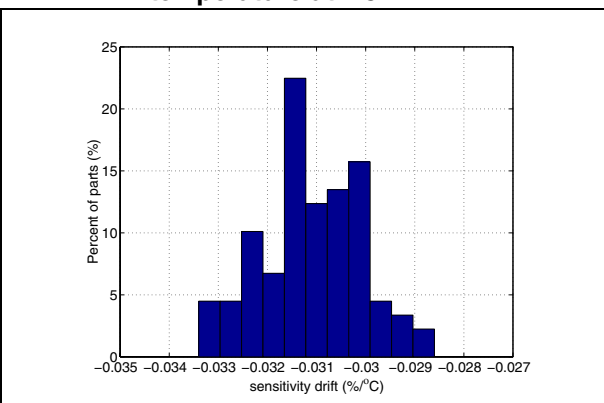


Figure 20. y-axis sensitivity change vs. temperature at 2.5V

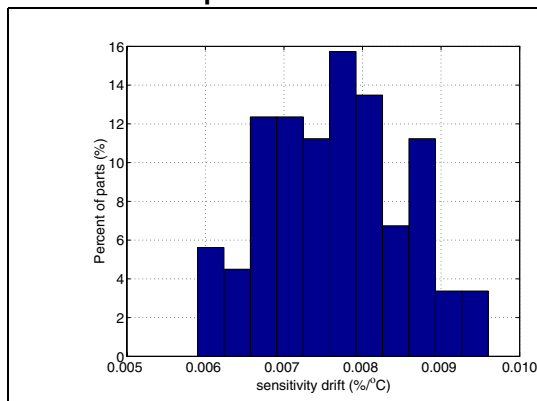
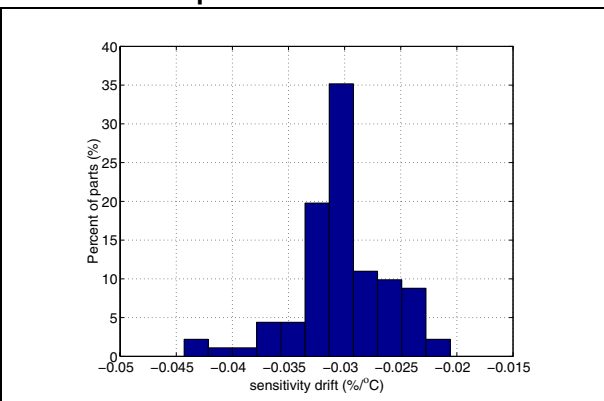


Figure 21. z-axis sensitivity change vs. temperature at 2.5V



### 8.3 Electro-Mechanical characteristics at 25°C

Figure 22. x and y axis 0-g level as function of supply voltage

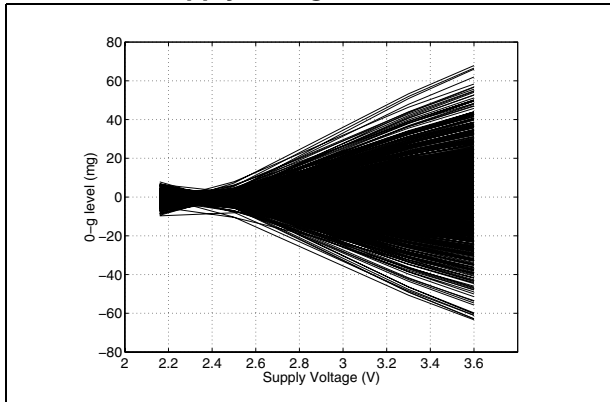


Figure 23. z axis 0-g level as function of supply voltage

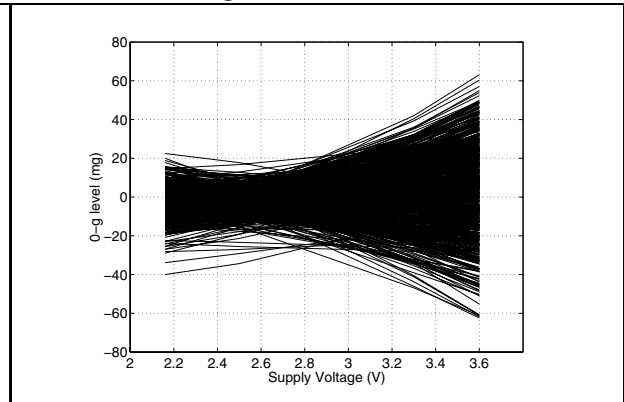


Figure 24. Current consumption in Power-Down mode (Vdd=2.5V)

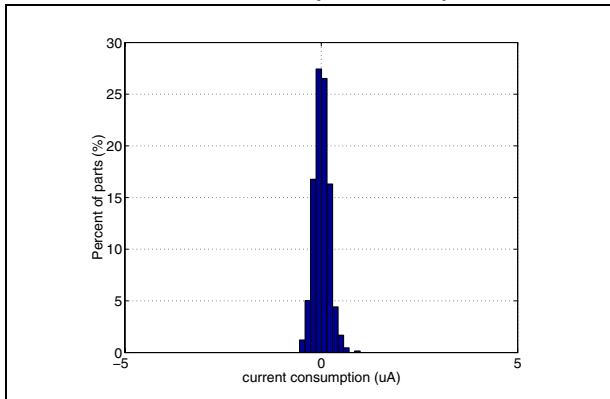
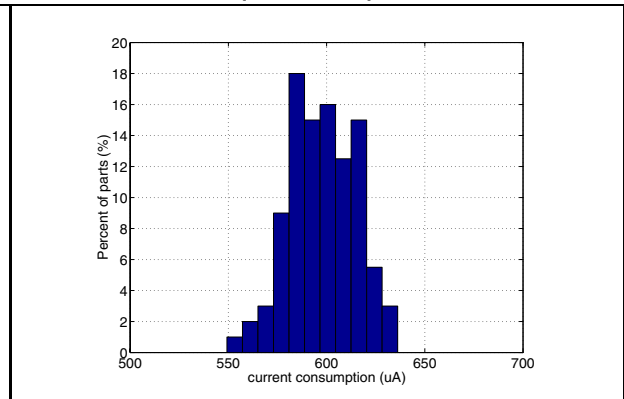


Figure 25. Current consumption in Operational mode (Vdd=2.5V)

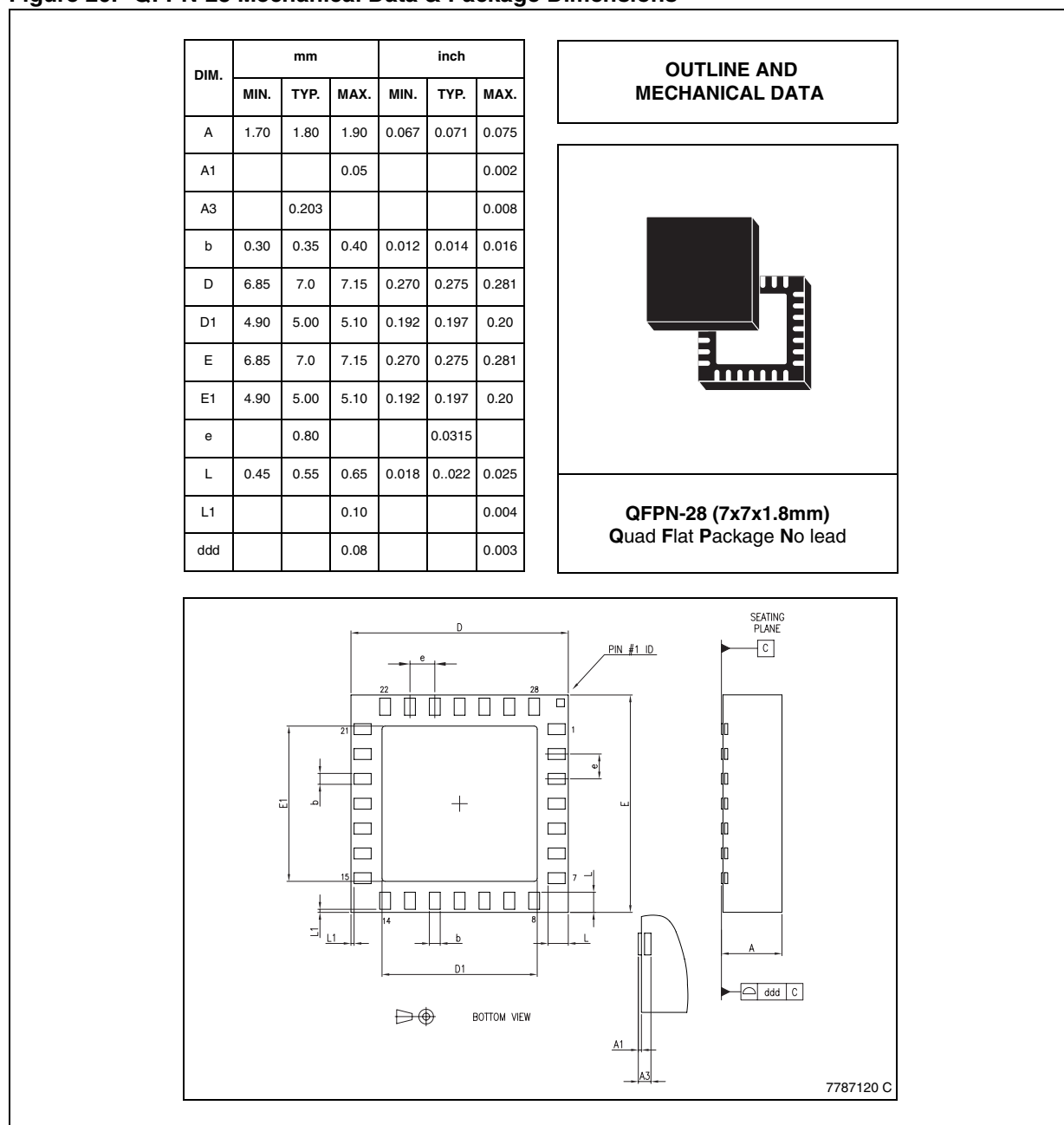


## 9 Package Information

In order to meet environmental requirements, ST offers these devices in ECOPACK® packages. These packages have a Lead-free second level interconnect. The category of second Level Interconnect is marked on the package and on the inner box label, in compliance with JEDEC Standard JESD97. The maximum ratings related to soldering conditions are also marked on the inner box label. ECOPACK is an ST trademark.

ECOPACK specifications are available at: [www.st.com](http://www.st.com).

**Figure 26. QFPN-28 Mechanical Data & Package Dimensions**





## 10 Revision history

| Date       | Revision | Changes          |
|------------|----------|------------------|
| 7-Oct-2005 | 1        | Initial release. |

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