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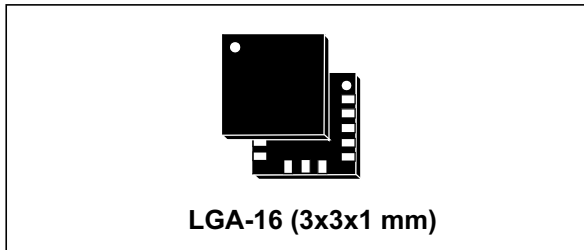
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MEMS digital output motion sensor: ultra-low-power high-performance 3-axis "nano" accelerometer

Datasheet - production data



Features

- Wide supply voltage, 1.71 V to 3.6 V
- Independent IO supply (1.8 V) and supply voltage compatible
- Ultra-low-power mode consumption down to 2 μ A
- $\pm 2g/\pm 4g/\pm 8g/\pm 16g$ dynamically selectable full scale
- I²C/SPI digital output interface
- 16-bit data output
- 2 independent programmable interrupt generators for free-fall and motion detection
- 6D/4D orientation detection
- Free-fall detection
- Motion detection
- Embedded temperature sensor
- Embedded self-test
- Embedded 32 levels of 16-bit data output FIFO
- 10000 g high shock survivability
- ECOPACK[®], RoHS and "Green" compliant

Applications

- Motion activated functions
- Free-fall detection
- Click/double-click recognition
- Intelligent power saving for handheld devices
- Pedometers

- Display orientation
- Gaming and virtual reality input devices
- Impact recognition and logging
- Vibration monitoring and compensation

Description

The LIS3DH is an ultra-low-power high-performance three-axis linear accelerometer belonging to the "nano" family, with digital I²C/SPI serial interface standard output. The device features ultra-low-power operational modes that allow advanced power saving and smart embedded functions.

The LIS3DH has dynamically user-selectable full scales of $\pm 2g/\pm 4g/\pm 8g/\pm 16g$ and is capable of measuring accelerations with output data rates from 1 Hz to 5.3 kHz. The self-test capability allows the user to check the functioning of the sensor in the final application. The device may be configured to generate interrupt signals using two independent inertial wake-up/free-fall events as well as by the position of the device itself. Thresholds and timing of interrupt generators are programmable by the end user on the fly. The LIS3DH has an integrated 32-level first-in, first-out (FIFO) buffer allowing the user to store data in order to limit intervention by the host processor. The LIS3DH is available in small thin plastic land grid array package (LGA) and is guaranteed to operate over an extended temperature range from -40 °C to +85 °C.

Table 1. Device summary

Order codes	Temp. range [°C]	Package	Packaging
LIS3DHTR	-40 to +85	LGA-16	Tape and reel

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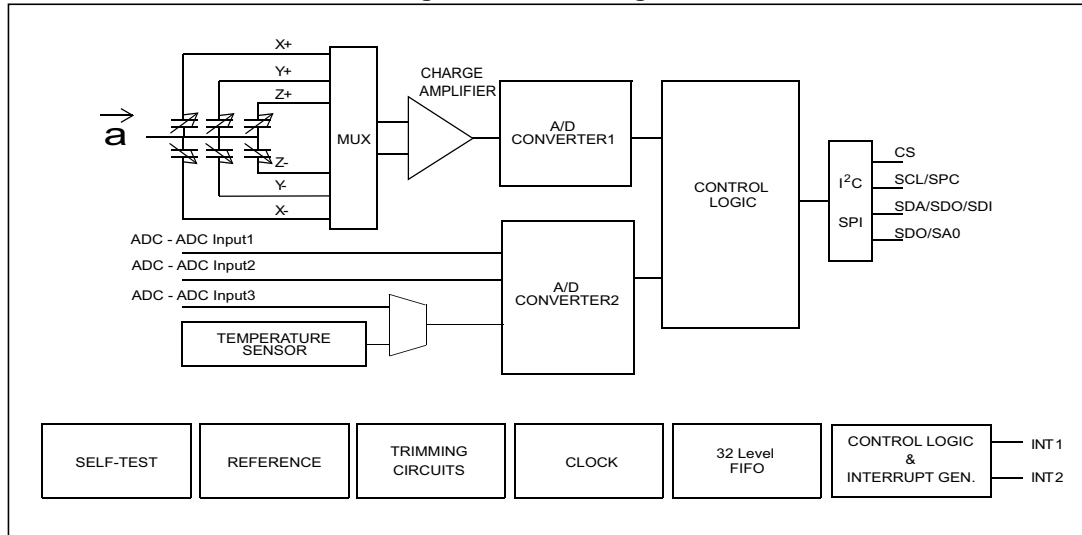
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1 Block diagram and pin description

1.1 Block diagram

Figure 1. Block diagram



1.2 Pin description

Figure 2. Pin connections

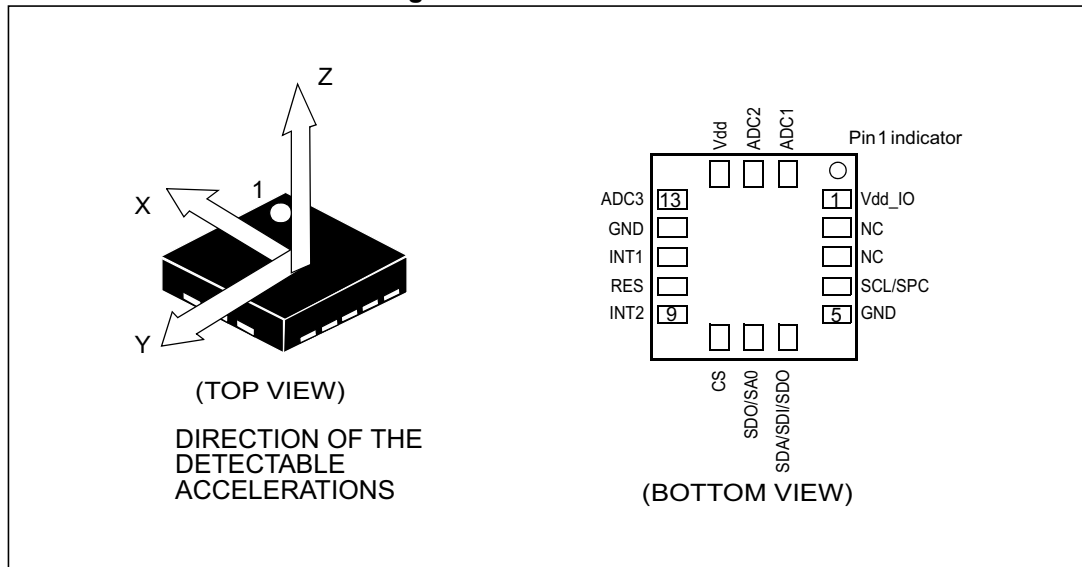


Table 2. Pin description

Pin#	Name	Function
1	Vdd_IO	Power supply for I/O pins
2	NC	Not connected
3	NC	Not connected
4	SCL SPC	I ² C serial clock (SCL) SPI serial port clock (SPC)
5	GND	0 V supply
6	SDA SDI SDO	I ² C serial data (SDA) SPI serial data input (SDI) 3-wire interface serial data output (SDO)
7 ⁽¹⁾	SDO SA0	SPI serial data output (SDO) I ² C less significant bit of the device address (SA0)
8	CS	SPI enable I ² C/SPI mode selection: 1: SPI idle mode / I ² C communication enabled 0: SPI communication mode / I ² C disabled
9	INT2	Inertial interrupt 2
10	RES	Connect to GND
11	INT1	Inertial interrupt 1
12	GND	0 V supply
13	ADC3	Analog-to-digital converter input 3
14	Vdd	Power supply
15	ADC2	Analog-to-digital converter input 2
16	ADC1	Analog-to-digital converter input 1

1. SDO/SA0 pin is internally pulled up. Refer to [Table 3](#) for the internal pull-up values (typ.).

Table 3. Internal pull-up values (typ.) for SDO/SA0 pin

Vdd_IO	Resistor value for SDO/SA0 pin
	Typ. (k Ω)
1.7 V	54.4
1.8 V	49.2
2.5 V	30.4
3.6 V	20.4

2 Mechanical and electrical specifications

2.1 Mechanical characteristics

Vdd = 2.5 V, T = 25 °C unless otherwise noted ^(a)

Table 4. Mechanical characteristics

Symbol	Parameter	Test conditions	Min.	Typ. ⁽¹⁾	Max.	Unit
FS	Measurement range ⁽²⁾	FS bit set to 00		±2.0		
		FS bit set to 01		±4.0		
		FS bit set to 10		±8.0		
		FS bit set to 11		±16.0		g
So	Sensitivity	FS bit set to 00; High-resolution mode		1		mg/digit
		FS bit set to 00; Normal mode		4		
		FS bit set to 00; Low-power mode		16		
		FS bit set to 01; High-resolution mode		2		mg/digit
		FS bit set to 01; Normal mode		8		
		FS bit set to 01; Low-power mode		32		
		FS bit set to 10; High-resolution mode		4		mg/digit
		FS bit set to 10; Normal mode		16		
		FS bit set to 10; Low-power mode		64		
		FS bit set to 11; High-resolution mode		12		mg/digit
		FS bit set to 11; Normal mode		48		
		FS bit set to 11; Low-power mode		192		
TCS _o	Sensitivity change vs temperature	FS bit set to 00		0.01		%/°C
TyOff	Typical zero-g level offset accuracy ^{(3),(4)}	FS bit set to 00		±40		mg

a. The product is factory calibrated at 2.5 V. The operational power supply range is from 1.71 V to 3.6 V.

Table 4. Mechanical characteristics

Symbol	Parameter	Test conditions	Min.	Typ. ⁽¹⁾	Max.	Unit
TCOff	Zero-g level change vs temperature	Max delta from 25 °C		±0.5		mg/°C
An	Acceleration noise density	FS bit set to 00, High-Resolution mode (Table 10), ODR > 1300 Hz		220		µg/√Hz
Vst	Self-test output change ⁽⁵⁾⁽⁶⁾⁽⁷⁾	FS bit set to 00 X-axis; Normal mode	17		360	LSb
		FS bit set to 00 Y-axis; Normal mode	17		360	LSb
		FS bit set to 00 Z-axis; Normal mode	17		360	LSb
Top	Operating temperature range		-40		+85	°C

1. Typical specifications are not guaranteed.
2. Verified by wafer level test and measurement of initial offset and sensitivity.
3. Typical zero-g level offset value after MSL3 preconditioning.
4. Offset can be eliminated by enabling the built-in high-pass filter.
5. The sign of "Self-test output change" is defined by the ST bits in [CTRL_REG4 \(23h\)](#), for all axes.
6. "Self-test output change" is defined as the absolute value of:
 $OUTPUT[LSb]_{(Self\ test\ enabled)} - OUTPUT[LSb]_{(Self\ test\ disabled)}$. 1LSb = 4 mg at 10-bit representation, ±2 g full scale.
7. After enabling the self-test, correct data is obtained after two samples (low-power mode / normal mode) or after eight samples (high-resolution mode).

2.2 Temperature sensor characteristics

Vdd = 2.5 V, T = 25 °C unless otherwise noted ^(b)

Table 5. Temperature sensor characteristics

Symbol	Parameter	Test condition	Min.	Typ. ⁽¹⁾	Max.	Unit
TSDr	Temperature sensor output change vs temperature			1		digit/°C ⁽²⁾
TODR	Temperature refresh rate			ODR		Hz
Top	Operating temperature range		-40		+85	°C

1. Typical specifications are not guaranteed.
2. 8-bit resolution.

2.3 Electrical characteristics

Vdd = 2.5 V, T = 25 °C unless otherwise noted ^(c)

Table 6. Electrical characteristics

Symbol	Parameter	Test conditions	Min.	Typ. ⁽¹⁾	Max.	Unit
Vdd	Supply voltage		1.71	2.5	3.6	V
Vdd_IO	I/O pins supply voltage ⁽²⁾		1.71		Vdd+0.1	V
Idd	Current consumption in normal mode	50 Hz ODR		11		µA
Idd	Current consumption in normal mode	1 Hz ODR		2		µA
IddLP	Current consumption in low-power mode	50 Hz ODR		6		µA
IddPdn	Current consumption in power-down mode			0.5		µA
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
BW	System bandwidth ⁽³⁾			ODR/2		Hz
Top	Operating temperature range		-40		+85	°C

1. Typical specification are not guaranteed.
2. It is possible to remove Vdd maintaining Vdd_IO without blocking the communication busses, in this condition the measurement chain is powered off.
3. Refer to [Table 25](#) for the ODR value and configuration.

b. The product is factory calibrated at 2.5 V. Temperature sensor operation is guaranteed in the range 2 V - 3.6 V.
 c. The product is factory calibrated at 2.5 V. The operational power supply range is from 1.71 V to 3.6 V.

2.4 Communication interface characteristics

2.4.1 SPI - serial peripheral interface

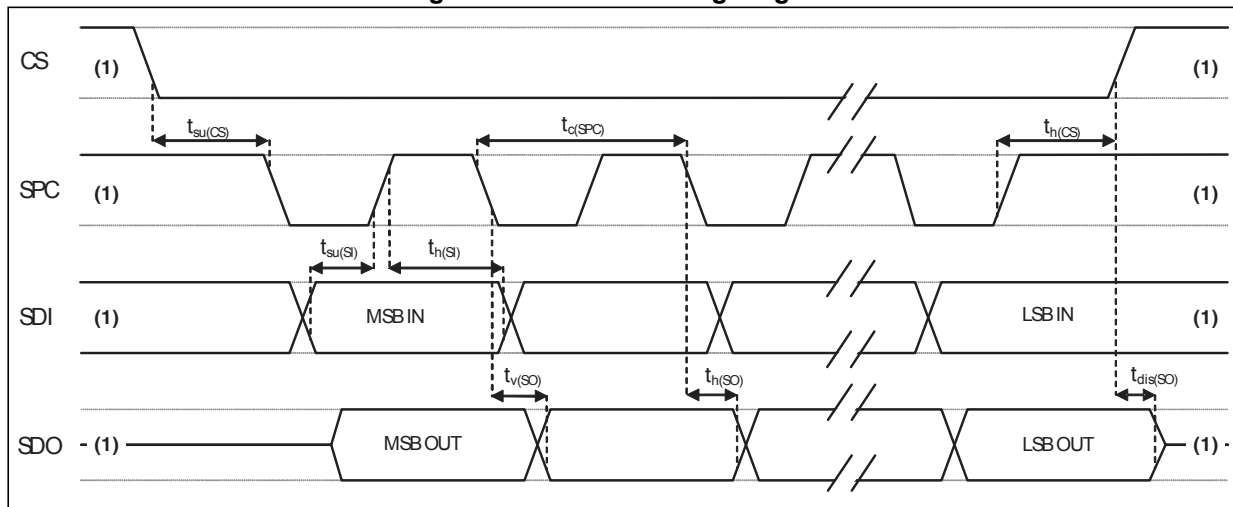
Subject to general operating conditions for Vdd and Top.

Table 7. SPI slave timing values

Symbol	Parameter	Value ⁽¹⁾		Unit
		Min	Max	
$t_{c(SPC)}$	SPI clock cycle	100		ns
$f_{c(SPC)}$	SPI clock frequency		10	MHz
$t_{su(CS)}$	CS setup time	5		ns
$t_{h(CS)}$	CS hold time	20		
$t_{su(SI)}$	SDI input setup time	5		
$t_{h(SI)}$	SDI input hold time	15		
$t_{v(SO)}$	SDO valid output time		50	
$t_{h(SO)}$	SDO output hold time	5		
$t_{dis(SO)}$	SDO output disable time		50	

1. Values are guaranteed at 10 MHz clock frequency for SPI with both 4 and 3 wires, based on characterization results, not tested in production.

Figure 3. SPI slave timing diagram



1. When no communication is ongoing, data on SDO is driven by internal pull-up resistors.

Note: Measurement points are done at $0.2 \cdot V_{dd_IO}$ and $0.8 \cdot V_{dd_IO}$, for both input and output ports.

2.4.2 I²C - Inter IC control interface

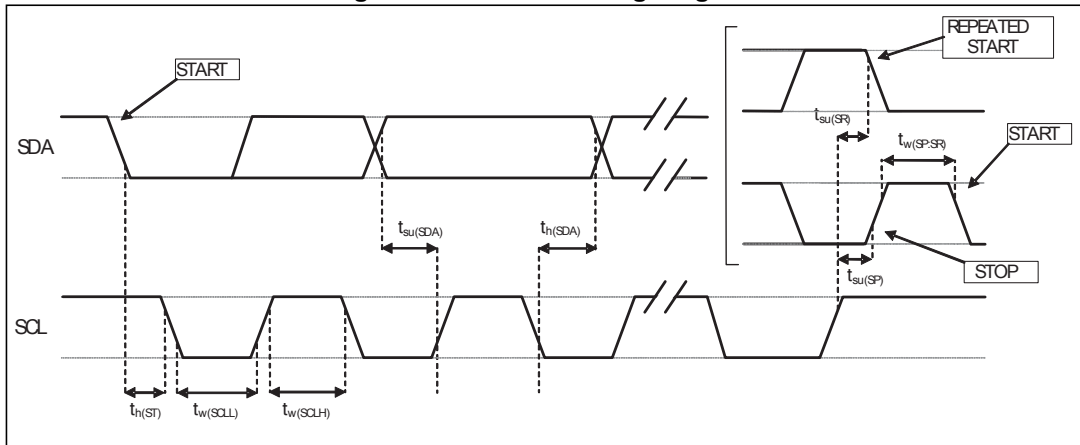
Subject to general operating conditions for Vdd and top.

Table 8. I²C slave timing values

Symbol	Parameter	I ² C standard		I ² C fast mode ⁽¹⁾		Unit
		Min	Max	Min	Max	
f _(SCL)	SCL clock frequency	0	100	0	400	kHz
t _{w(SCLL)}	SCL clock low time	4.7		1.3		μs
t _{w(SCLH)}	SCL clock high time	4.0		0.6		
t _{su(SDA)}	SDA setup time	250		100		ns
t _{h(SDA)}	SDA data hold time	0	3.45	0	0.9	μs
t _{h(ST)}	START condition hold time	4		0.6		μs
t _{su(SR)}	Repeated START condition setup time	4.7		0.6		
t _{su(SP)}	STOP condition setup time	4		0.6		
t _{w(SP:SR)}	Bus free time between STOP and START condition	4.7		1.3		

1. Data based on standard I²C protocol requirement, not tested in production.

Figure 4. I²C slave timing diagram



Note: Measurement points are done at 0.2·Vdd_{IO} and 0.8·Vdd_{IO}, for both ports.

2.5 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 9. Absolute maximum ratings

Symbol	Ratings	Maximum value	Unit
V _{dd}	Supply voltage	-0.3 to 4.8	V
V _{dd_IO}	I/O pins Supply voltage	-0.3 to 4.8	V
V _{in}	Input voltage on any control pin (CS, SCL/SPC, SDA/SDI/SDO, SDO/SA0)	-0.3 to V _{dd_IO} +0.3	V
A _{POW}	Acceleration (any axis, powered, V _{dd} = 2.5 V)	3000 g for 0.5 ms	
		10000 g for 0.2 ms	
A _{UNP}	Acceleration (any axis, unpowered)	3000 g for 0.5 ms	
		10000 g for 0.2 ms	
T _{OP}	Operating temperature range	-40 to +85	°C
T _{STG}	Storage temperature range	-40 to +125	°C
ESD	Electrostatic discharge protection	2 (HBM)	kV

Note: Supply voltage on any pin should never exceed 4.8 V



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



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

3 Terminology and functionality

3.1 Terminology

3.1.1 Sensitivity

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

3.1.2 Zero-*g* level

The zero-*g* level offset (TyOff) describes the deviation of an actual output signal from the ideal output signal if no acceleration is present. A sensor in a steady state on a horizontal surface measures 0 *g* for the X-axis and 0 *g* for the Y-axis whereas the Z-axis measures 1 *g*. The output is ideally in the middle of the dynamic range of the sensor (content of OUT registers 00h, 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 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 [Table 4](#) "Zero-*g* level change vs. temperature" (TCOff). The zero-*g* level tolerance (TyOff) describes the standard deviation of the range of zero-*g* levels of a population of sensors.

3.2 Functionality

3.2.1 High-resolution, normal mode, low-power mode

LIS3DH provides three different operating modes: *high-resolution mode*, *normal mode* and *low-power mode*.

The table below summarizes how to select the operating mode.

Table 10. Operating mode selection

Operating mode	CTRL_REG1[3] (LPen bit)	CTRL_REG4[3] (HR bit)	BW [Hz]	Turn-on time [ms]	So @ $\pm 2g$ [mg/digit]
Low-power mode (8-bit data output)	1	0	ODR/2	1	16
Normal mode (10-bit data output)	0	0	ODR/2	1.6	4
High-resolution mode (12-bit data output)	0	1	ODR/9	7/ODR	1
Not allowed	1	1	--	--	--

The turn-on time to transition to another operating mode is given in [Table 11](#).

Table 11. Turn-on time for operating mode transition

Operating mode change	Turn-on time [ms]
12-bit mode to 8-bit mode	1/ODR
12-bit mode to 10-bit mode	1/ODR
10-bit mode to 8-bit mode	1/ODR
10-bit mode to 12-bit mode	7/ODR
8-bit mode to 10-bit mode	1/ODR
8-bit mode to 12-bit mode	7/ODR

Table 12. Current consumption of operating modes

Operating mode [Hz]	Low-power mode (8-bit data output) [μ A]	Normal mode (10-bit data output) [μ A]	High resolution (12-bit data output) [μ A]
1	2	2	2
10	3	4	4
25	4	6	6
50	6	11	11
100	10	20	20
200	18	38	38
400	36	73	73
1344	--	185	185
1620	100	--	--
5376	185	--	--

3.2.2 Self-test

The self-test allows the user to check the sensor functionality without moving it. The self-test function is off when the self-test bit (ST) is programmed to '0'. When the self-test bit is programmed to '1', an actuation force is applied to the sensor, simulating a definite input acceleration. In this case the sensor outputs exhibit a change in their DC levels which are related to the selected full scale through the device sensitivity. When the 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 4](#), then the sensor is working properly and the parameters of the interface chip are within the defined specifications.

3.2.3 6D / 4D orientation detection

The LIS3DH provides the capability to detect the orientation of the device in space, enabling easy implementation of energy-saving procedures and automatic image rotation for mobile devices.

The 4D detection is a subset of the 6D function especially defined to be implemented in mobile devices for portrait and landscape computation. In 4D configuration, the Z-axis position detection is disabled.

3.2.4 “Sleep-to-wake” and “Return-to-sleep”

The LIS3DH can be programmed to automatically switch to low-power mode upon recognition of a determined event.

Once the event condition is over, the device returns back to the preset normal or high-resolution mode.

To enable this function the desired threshold value must be stored inside the *ACT_THS (3Eh)* register while the duration value is written inside the *ACT_DUR (3Fh)* register.

When the acceleration falls below the threshold value, the device automatically switches to low-power mode (10 Hz ODR).

During this condition, the ODR[3:0] bits and the LPen bit inside *CTRL_REG1 (20h)* and the HR bit in *CTRL_REG4 (23h)* are not considered.

As soon as the acceleration rises above threshold, the module restores the operating mode and ODRs as determined by the *CTRL_REG1 (20h)* and *CTRL_REG4 (23h)* settings.

3.3 Sensing element

A proprietary process is used to create a surface micro-machined accelerometer. The technology allows carrying 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 capacitor.

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

3.4 IC interface

The complete measurement chain is composed by a low-noise capacitive amplifier which converts the capacitive unbalancing of the MEMS sensor into an analog voltage that is finally available to the user by an analog-to-digital converter.

The acceleration data may be accessed through an I²C/SPI interface thus making the device particularly suitable for direct interfacing with a microcontroller.

The LIS3DH features a Data-Ready signal (DRDY) which indicates when a new set of measured acceleration data is available, thus simplifying data synchronization in the digital system that uses the device.

The LIS3DH may also be configured to generate an inertial wake-up and free-fall interrupt signal accordingly to a programmed acceleration event along the enabled axes. Both free-fall and wake-up can be available simultaneously on two different pins.

3.5 Factory calibration

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

The trim values are stored inside the device in non-volatile memory. Any time the device is turned on, these values are downloaded into the registers to be used during active operation. This allows using the device without further calibration.

3.6 FIFO

The LIS3DH contains a 10-bit, 32-level FIFO. Buffered output allows 4 operation modes: FIFO, Stream, Stream-to-FIFO and FIFO bypass. When FIFO bypass mode is activated, FIFO is not operating and remains empty. In FIFO mode, measurement data from acceleration detection on the x, y, and z axes are stored in the FIFO buffer.

3.7 Auxiliary ADC and temperature sensor

The LIS3DH contains an auxiliary ADC with 3 separate dedicated inputs: pins ADC1, ADC2, ADC3.

The user can retrieve the converted data from registers *OUT_ADC1_L (08h)*, *OUT_ADC1_H (09h)*, *OUT_ADC2_L (0Ah)*, *OUT_ADC2_H (0Bh)* and *OUT_ADC3_L (0Ch)*, *OUT_ADC3_H (0Dh)*.

In order to use the auxiliary ADC, the user must set the BDU bit (bit 7) to 1 in *CTRL_REG4 (23h)* and the ADC_EN bit (bit 7) to 1 in *TEMP_CFG_REG (1Fh)*. The ADC sampling frequency is the same as that of the ODR in *CTRL_REG1 (20h)*.

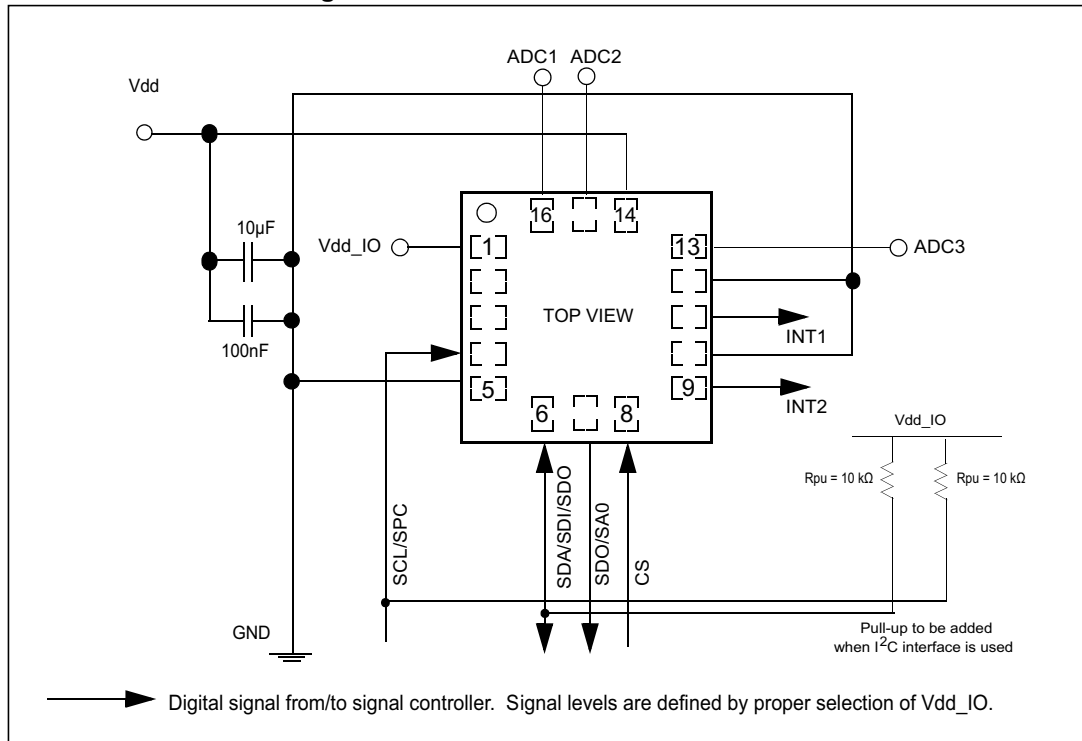
The input range is 1200 mV \pm 400 mV and the data output is expressed in 2's complement left-aligned.

The ADC resolution is 10 bits if the LPen (bit 3) in *CTRL_REG1 (20h)* is cleared (high-resolution / normal mode), otherwise, in low-power mode, the ADC resolution is 8-bit.

Channel 3 of the ADC can be connected to the temperature sensor by setting the TEMP_EN bit (bit 6) to 1 in *TEMP_CFG_REG (1Fh)*. Refer to *Table 5: Temperature sensor characteristics* for the conversion factor.

4 Application hints

Figure 5. LIS3DH electrical connections



The device core is supplied through the Vdd line while the I/O pads are supplied through the Vdd_IO line. Power supply decoupling capacitors (100 nF ceramic, 10 µF aluminum) should be placed as near as possible to pin 14 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 [Figure 5](#)). It is possible to remove Vdd maintaining Vdd_IO without blocking the communication bus, in this condition the measurement chain is powered off.

The functionality of the device and the measured acceleration data is selectable and accessible through the I²C or SPI interfaces. When using the I²C, CS must be tied high.

ADC1, ADC2 & ADC3 if not used can be left floating or connected to Vdd or GND.

The functions, the threshold and the timing of the two interrupt pins (INT1 and INT2) can be completely programmed by the user through the I²C/SPI interface.

Table 13. Internal pin status

Pin#	Name	Function	Pin status
1	Vdd_IO	Power supply for I/O pins	
2	NC	Not connected	
3	NC	Not connected	
4	SCL SPC	I ² C serial clock (SCL) SPI serial port clock (SPC)	Default: input high impedance
5	GND	0 V supply	
6	SDA SDI SDO	I ² C serial data (SDA) SPI serial data input (SDI) 3-wire interface serial data output (SDO)	Default: (SDA) input high impedance
7	SDO SA0	SPI serial data output (SDO) I ² C less significant bit of the device address (SA0)	Default: input with internal pull-up ⁽¹⁾
8	CS	SPI enable I ² C/SPI mode selection: 1: SPI idle mode / I ² C communication enabled 0: SPI communication mode / I ² C disabled	Default: input high impedance
9	INT2	Inertial interrupt 2	Default: push-pull output forced to GND
10	RES	Connect to GND	
11	INT1	Inertial interrupt 1	Default: push-pull output forced to GND
12	GND	0 V supply	
13	ADC3	Analog-to-digital converter input 3	Default: input high impedance
14	Vdd	Power supply	
15	ADC2	Analog-to-digital converter input 2	Default: input high impedance
16	ADC1	Analog-to-digital converter input 1	Default: input high impedance

1. In order to disable the internal pull-up on the SDO/SA0 pin, write 90h in [CTRL_REG0 \(1Eh\)](#).

4.1 Soldering information

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

Leave “Pin 1 Indicator” unconnected during soldering.

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

5 Digital main blocks

5.1 FIFO

The LIS3DH embeds a 32-level FIFO for each of the three output channels, X, Y and Z.

This allows consistent power saving for the system, since the host processor does not need to continuously poll data from the sensor, but it can wake up only when needed and burst the significant data out from the FIFO.

In order to enable the FIFO buffer, the FIFO_EN bit in [CTRL_REG5 \(24h\)](#) must be set to '1'.

This buffer can work according to the following different modes: Bypass mode, FIFO mode, Stream mode and Stream-to-FIFO mode. Each mode is selected by the FM [1:0] bits in [FIFO_CTRL_REG \(2Eh\)](#). Programmable FIFO watermark level, FIFO empty or FIFO overrun events can be enabled to generate dedicated interrupts on the INT1 pin (configuration through [CTRL_REG3 \(22h\)](#)).

In the [FIFO_SRC_REG \(2Fh\)](#) register the EMPTY bit is equal to '1' when all FIFO samples are ready and FIFO is empty.

In the [FIFO_SRC_REG \(2Fh\)](#) register the WTM bit goes to '1' if new data is written in the buffer and [FIFO_SRC_REG \(2Fh\)](#) (FSS [4:0]) is greater than or equal to [FIFO_CTRL_REG \(2Eh\)](#) (FTH [4:0]). [FIFO_SRC_REG \(2Fh\)](#) (WTM) goes to '0' if reading an X, Y, Z data slot from FIFO and [FIFO_SRC_REG \(2Fh\)](#) (FSS [4:0]) is less than or equal to [FIFO_CTRL_REG \(2Eh\)](#) (FTH [4:0]).

In the [FIFO_SRC_REG \(2Fh\)](#) register the OVRN_FIFO bit is equal to '1' if the FIFO slot is overwritten.

5.1.1 Bypass mode

In Bypass mode the FIFO is not operational and for this reason it remains empty. For each channel only the first address is used. The remaining FIFO levels are empty.

Bypass mode must be used in order to reset the FIFO buffer when a different mode is operating (i.e. FIFO mode).

5.1.2 FIFO mode

In FIFO mode, the buffer continues filling data from the X, Y and Z accelerometer channels until it is full (a set of 32 samples stored). When the FIFO is full, it stops collecting data from the input channels and the FIFO content remains unchanged.

An overrun interrupt can be enabled, I1_OVERRUN = '1' in the [CTRL_REG3 \(22h\)](#) register, in order to be raised when the FIFO stops collecting data. When the overrun interrupt occurs, the first data has been overwritten and the FIFO stops collecting data from the input channels.

After the last read it is necessary to exit Bypass mode in order to reset the FIFO content. After this reset command, it is possible to restart FIFO mode just by selecting the FIFO mode configuration (FM[1:0] bits) in register [FIFO_CTRL_REG \(2Eh\)](#).

5.1.3 Stream mode

In Stream mode the FIFO continues filling data from the X, Y, and Z accelerometer channels until the buffer is full (a set of 32 samples stored) at which point the FIFO buffer index restarts from the beginning and older data is replaced by the current data. The oldest values continue to be overwritten until a read operation frees the FIFO slots.

An overrun interrupt can be enabled, `I1_OVERRUN = '1'` in the [CTRL_REG3 \(22h\)](#) register, in order to read the entire contents of the FIFO at once. If, in the application, it is mandatory not to lose data and it is not possible to read at least one sample for each axis within one ODR period, a watermark interrupt can be enabled in order to read partially the FIFO and leave memory slots free for incoming data.

Setting the FTH [4:0] bit in the [FIFO_CTRL_REG \(2Eh\)](#) register to an N value, the number of X, Y and Z data samples that should be read at the rise of the watermark interrupt is up to (N+1).

5.1.4 Stream-to-FIFO mode

In Stream-to-FIFO mode, data from the X, Y and Z accelerometer channels are collected in a combination of Stream mode and FIFO mode. The FIFO buffer starts operating in Stream mode and switches to FIFO mode when the selected interrupt occurs.

The FIFO operating mode changes according to the INT1 pin value if the TR bit is set to '0' in the [FIFO_CTRL_REG \(2Eh\)](#) register or the INT2 pin value if the TR bit is set to '1' in the [FIFO_CTRL_REG \(2Eh\)](#) register.

When the interrupt pin is selected and the interrupt event is configured on the corresponding pin, the FIFO operates in Stream mode if the pin value is equal to '0' and it operates in FIFO mode if the pin value is equal to '1'. Switching modes is dynamically performed according to the pin value.

Stream-to-FIFO can be used in order to analyze the sampling history that generates an interrupt. The standard operation is to read the contents of FIFO when the FIFO mode is triggered and the FIFO buffer is full and stopped.

5.1.5 Retrieving data from FIFO

FIFO data is read from [OUT_X_L \(28h\)](#), [OUT_X_H \(29h\)](#), [OUT_Y_L \(2Ah\)](#), [OUT_Y_H \(2Bh\)](#) and [OUT_Z_L \(2Ch\)](#), [OUT_Z_H \(2Dh\)](#). When the FIFO is in Stream, Stream-to-FIFO or FIFO mode, a read operation from the [OUT_X_L \(28h\)](#), [OUT_X_H \(29h\)](#), [OUT_Y_L \(2Ah\)](#), [OUT_Y_H \(2Bh\)](#) or [OUT_Z_L \(2Ch\)](#), [OUT_Z_H \(2Dh\)](#) registers provides the data stored in the FIFO. Each time data is read from the FIFO, the oldest X, Y and Z data are placed in the [OUT_X_L \(28h\)](#), [OUT_X_H \(29h\)](#), [OUT_Y_L \(2Ah\)](#), [OUT_Y_H \(2Bh\)](#) and [OUT_Z_L \(2Ch\)](#), [OUT_Z_H \(2Dh\)](#) registers and both single read and read burst operations can be used.

The address to be read is automatically updated by the device and it rolls back to 0x28 when register 0x2D is reached. In order to read all FIFO levels in a multiple byte read, 192 bytes (6 output registers of 32 levels) have to be read.

6 Digital interfaces

The registers embedded inside the LIS3DH may be accessed through both the I²C 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 I²C interface, the CS line must be tied high (i.e. connected to Vdd_IO).

Table 14. Serial interface pin description

Pin name	Pin description
CS	SPI enable I ² C/SPI mode selection: 1: SPI idle mode / I ² C communication enabled 0: SPI communication mode / I ² C disabled
SCL SPC	I ² C serial clock (SCL) SPI serial port clock (SPC)
SDA SDI SDO	I ² C serial data (SDA) SPI serial data input (SDI) 3-wire interface serial data output (SDO)
SA0 SDO	I ² C less significant bit of the device address (SA0) SPI serial data output (SDO)

6.1 I²C serial interface

The LIS3DH I²C is a bus slave. The I²C is employed to write data into registers whose content can also be read back.

The relevant I²C terminology is given in the table below.

Table 15. I²C terminology

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 I²C 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 must be connected to Vdd_IO through external pull-up resistor. When the bus is free both the lines are high.

The I²C interface is compliant with fast mode (400 kHz) I²C standards as well as with normal mode.

6.1.1 I²C 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 LIS3DH is 001100xb. The **SDO/SA0** pad can be used to modify the less significant bit of the device address. If the SA0 pad is connected to the voltage supply, LSb is '1' (address 0011001b) else if SA0 pad is connected to ground, the LSb value is '0' (address 0011000b). This solution permits to connect and address two different accelerometers to the same I²C lines.

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 received.

The I²C embedded inside the LIS3DH 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, an 8-bit sub-address (SUB) is 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) is automatically increased to allow multiple data read/writes.

The slave address is completed with a Read/Write bit. If the bit was '1' (Read), a repeated START (SR) condition must be issued after the two sub-address bytes; if the bit is '0' (Write) the Master transmit to the slave with direction unchanged. *Table 16* explains how the SAD+Read/Write bit pattern is composed, listing all the possible configurations.

Table 16. SAD+Read/Write patterns

Command	SAD[6:1]	SAD[0] = SA0	R/W	SAD+R/W
Read	001100	0	1	00110001 (31h)
Write	001100	0	0	00110000 (30h)
Read	001100	1	1	00110011 (33h)
Write	001100	1	0	00110010 (32h)

Table 17. Transfer when master is writing one byte to slave

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

Table 18. Transfer when master is writing multiple bytes to slave

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