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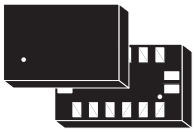
LIS3LV02DL

MEMS inertial sensor
3-axis - ±2g/±6g digital output low voltage linear accelerometer

Features

- 2.16 V to 3.6 V single supply operation
- 1.8 V compatible IOs
- I^2C/SPI digital output interfaces
- Programmable 12 or 16 bit data representation
- Interrupt activated by motion
- Programmable interrupt threshold
- Embedded self test
- High shock survivability
- ECOPACK® compliant (see *Section 9*)



LGA-16

Description

The LIS3LV02DL 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^2C/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 LIS3LV02DL has a user selectable full scale of ±2g, ±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.

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

The device may be also 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 LIS3LV02DL is available in plastic SMD package and it is specified over a temperature range extending from -40°C to +85°C.

The LIS3LV02DL 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

Table 1. Device summary

Order code	Operating temperature range [° C]	Package	Packing
LIS3LV02DL	-40 to +85	LGA-16	Tray
LIS3LV02DLTR	-40 to +85	LGA-16	Tape and reel

Content

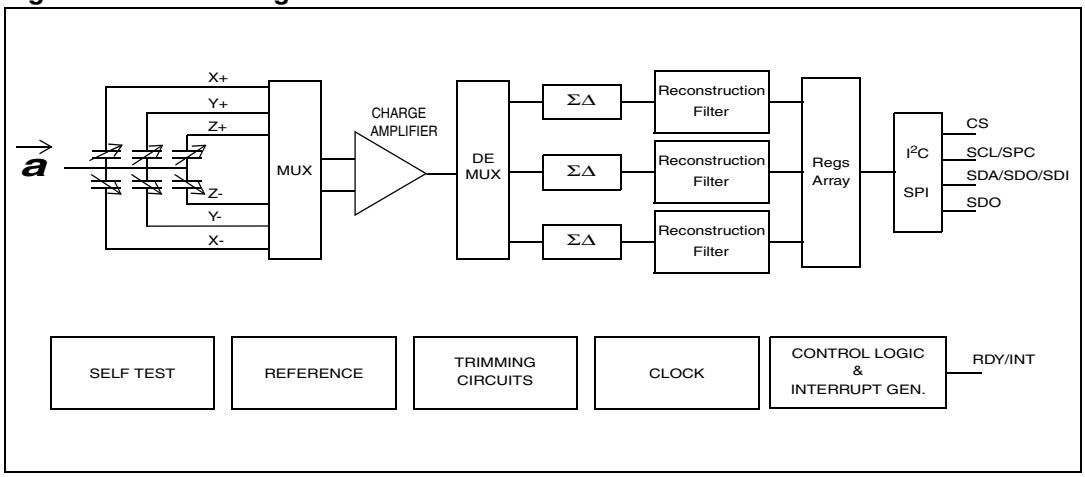
List of figures

List of tables

1 Block diagram and pin description

1.1 Block diagram

Figure 1. Block diagram



1.2 LGA-16 pin description

Figure 2. Pin connection

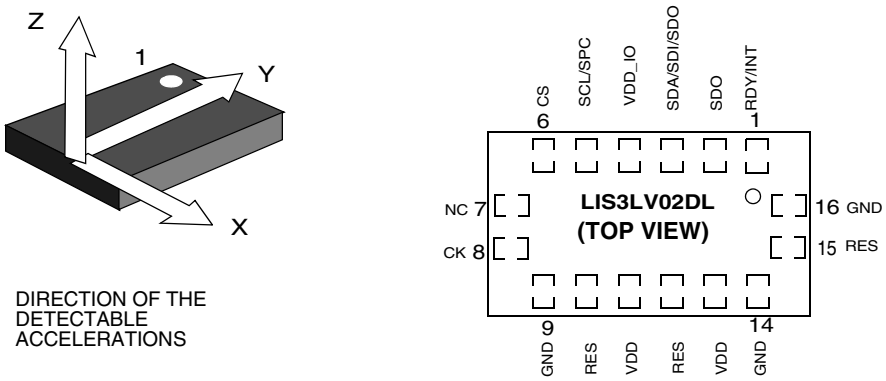


Table 2. Pin description

Pin#	Name	Function
1	RDY/INT	Data ready/inertial wake-up interrupt
2	SDO	SPI Serial Data Output

Table 2. Pin description

Pin#	Name	Function
3	SDA/ SDI/ SDO	I^2C Serial Data (SDA) SPI Serial Data Input (SDI) 3-wire Interface Serial Data Output (SDO)
4	Vdd_IO	Power supply for I/O pads
5	SCL/SPC	I^2C Serial Clock (SCL) SPI Serial Port Clock (SPC)
6	CS	SPI enable I^2C/SPI mode selection (1: I^2C mode; 0: SPI enabled)
7	NC	Internally not connected
8	CK	Optional external clock, if not used either leave unconnected or connect to GND
9	GND	0 V supply
10	Reserved	Either leave unconnected or connect to Vdd_IO
11	Vdd	Power supply
12	Reserved	Connect to Vdd
13	Vdd	Power supply
14	GND	0 V supply
15	Reserved	Either leave unconnected or connect to GND
16	GND	0 V supply

2 Mechanical and electrical specifications

2.1 Mechanical characteristics

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

Symbol	Parameter	Test conditions	Min.	Typ.(2)	Max.	Unit
FS	Measurement range(3)	FS bit set to 0	±1.7	±2.0		g
		FS bit set to 1	±5.3	±6.0		
Dres	Device resolution	Full-scale = ±2 g ODR1=40 Hz		1.0		mg
		Full-scale = ±2 g ODR2=160 Hz		2.0		
		Full-scale = ±2 g ODR3=640 Hz		3.9		
		Full-scale = ±2 g ODR4=2560 Hz		15.6		
So	Sensitivity	Full-scale = ±2 g 12 bit representation	920	1024	1126	LSb/g
		Full-scale = ±6 g 12 bit representation	306	340	374	
TCSo	Sensitivity change vs temperature	Full-scale = ±2 g 12 bit representation		0.025		%/°C
Off	Zero-g level offset accuracy(4),(5)	Full-scale = ±2 g X, Y axis	-70		70	mg
		Full-scale = ±2 g Z axis	-90		90	
		Full-scale = ±6 g X, Y axis	-90		90	
		Full-scale = ±6 g Z axis	-100		100	
LTOff	Zero-g Level offset long term accuracy(6)	Full-scale = ±2 g X, Y axis	-4.5		4.5	%FS
		Full-scale = ±2 g Z axis	-6		6	
		Full-scale = ±6 g X, Y axis	-1.8		1.8	
		Full-scale = ±6 g Z axis	-2.2		2.2	
TCOff	Zero-g Level Change Vs Temperature	Max Delta from 25°C		0.2		mg/°C

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

Symbol	Parameter	Test conditions	Min.	Typ.(2)	Max.	Unit
NL	Non Linearity	Best fit straight line X, Y axis Full-scale = ±2 g ODR=40 Hz		±2		%FS
		Best fit straight line Z axis Full-scale = ±2 g ODR=40 Hz		±3		
CrAx	Cross axis		-3.5		3.5	%
V_{st}	Self test output change(7),(8)	Full-scale= ±2g X axis	250	550	900	LSb
		Full-scale= ±2 g Y axis	250	550	900	LSb
		Full-scale= ±2 g Z axis	-100	-350	-600	LSb
		Full-scale= ±6 g X axis	80	180	300	LSb
		Full-scale= ±6 g Y axis	80	180	300	LSb
		Full-scale= ±6 g Z axis	-30	-120	-200	LSb
BW	System Bandwidth(9)			ODRx/4		Hz
Top	Operating Temperature Range		-40		+85	°C
Wh	Product Weight			72		mgram

1. The product is factory calibrated at 3.3 V. The device can be used from 2.16 V to 3.6 V
2. Typical specifications are not guaranteed
3. Verified by wafer level test and specification 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 $OUTPUT[LSb]_{(Self\text{-}test\ bit\ on\ ctrl\_reg1=1)} - OUTPUT[LSb]_{(Self\text{-}test\ bit\ on\ ctrl\_reg1=0)}$. 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. ODRx is output data rate. Refer to *Table 5* for specifications

Table 4. Mechanical characteristics @ Vdd=2.5 V, T=25 °C unless otherwise noted(1)

Symbol	Parameter	Test conditions	Min.	Typ.(2)	Max.	Unit
FS	Measurement range(3)	FS bit set to 0	±1.7	±2.0		g
		FS bit set to 1	±5.3	±6.0		
Dres	Device resolution	Full-scale = ±2g ODR1=40Hz		1.0		mg
		Full-scale = ±2g ODR2=160Hz		2.0		
		Full-scale = ±2g ODR3=640Hz		3.9		
		Full-scale = ±2g ODR4=2560Hz		15.6		
So	Sensitivity	Full-scale = ±2g 12 bit representation	920	1024	1126	LSb/g
		Full-scale = ±6g 12 bit representation	306	340	374	
TCSo	Sensitivity change vs temperature	Full-scale = ±2g 12 bit representation		0.025		%/°C
Off	Zero-g level offset accuracy(4),(5)	Full-scale = ±2g X, Y axis	-90		90	mg
		Full-scale = ±2g Z axis	-110		110	
		Full-scale = ±6g X, Y axis	-110		110	
		Full-scale = ±6g Z axis	-120		120	
LTOff	Zero-g level offset long term accuracy(6)	Full-scale = ±2g X, Y axis	-5.5		5.5	%FS
		Full-scale = ±2g Z axis	-7		7	
		Full-scale = ±6g X, Y axis	-2.8		2.8	
		Full-scale = ±6g Z axis	-3.2		3.2	
TCOff	Zero-g level change vs temperature	Max Delta from 25°C		0.2		mg/°C

Table 4. Mechanical characteristics @ Vdd=2.5 V, T=25 °C unless otherwise noted(1) (continued)

Symbol	Parameter	Test conditions	Min.	Typ.(2)	Max.	Unit
NL	Non linearity	Best fit straight line X, Y axis Full-scale = ±2g ODR=40Hz		±2		%FS
		Best fit straight line Z axis Full-scale = ±2g ODR=40Hz		±3		
CrAx	Cross axis		-3.5		3.5	%
V_{st}	Self test output change(7),(8)	Full-scale= ±2g X axis	100	240	400	LSb
		Full-scale= ±2g Y axis	100	240	400	LSb
		Full-scale= ±2g Z axis	-30	-150	-350	LSb
		Full-scale= ±6g X axis	30	80	130	LSb
		Full-scale= ±6g Y axis	30	80	130	LSb
		Full-scale= ±6g Z axis	-10	-50	-120	LSb
BW	System bandwidth(9)			ODRx/4		Hz
Top	Operating temperature range		-40		+85	°C
Wh	Product weight			72		mgram

1. The product is factory calibrated at 3.3 V. The device can be used from 2.16 V to 3.6 V
2. Typical specifications are not guaranteed
3. Verified by wafer level test and specification 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 $OUTPUT[LSb]_{(Self\text{-}test\ bit\ on\ ctrl\_reg1=1)} - OUTPUT[LSb]_{(Self\text{-}test\ bit\ on\ ctrl\_reg1=0)}$. 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. ODRx is output data rate. Refer to *Table 5* for specifications

2.2 Electrical characteristics

Table 5. Electrical characteristics @ Vdd=3.3 V, T=25 °C unless otherwise noted (1)

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

1. The product is factory calibrated at 3.3 V. The device can be used from 2.16 V to 3.6 V
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 Communication interface characteristics

2.3.1 SPI - serial peripheral interface

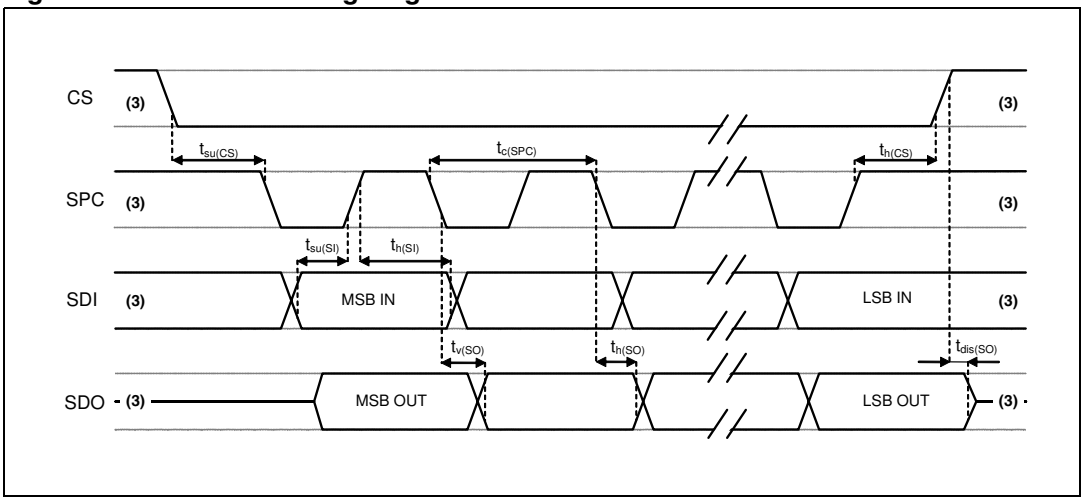
Subject to general operating conditions for Vdd and Top.

Table 6. SPI Slave Timing Values

Symbol	Parameter	Value(1)		Unit
		Min	Max	
tc(SPC)	SPI clock cycle	125		ns
fc(SPC)	SPI clock frequency		8	MHz
tsu(CS)	CS setup time	5		ns
th(CS)	CS hold time	10		
tsu(SI)	SDI input setup time	5		
th(SI)	SDI input hold time	15		
tv(SO)	SDO valid output time		55	
th(SO)	SDO output hold time	7		
tdis(SO)	SDO output disable time		50	

1. Values are guaranteed at 8 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 (2)



2. Measurement points are done at 0.2·Vdd_IO and 0.8·Vdd_IO, for both input and output port
3. When no communication is on-going, data on CS, SPC, SDI and SDO are driven by internal pull-up resistors

2.3.2 I²C - Inter IC control interface

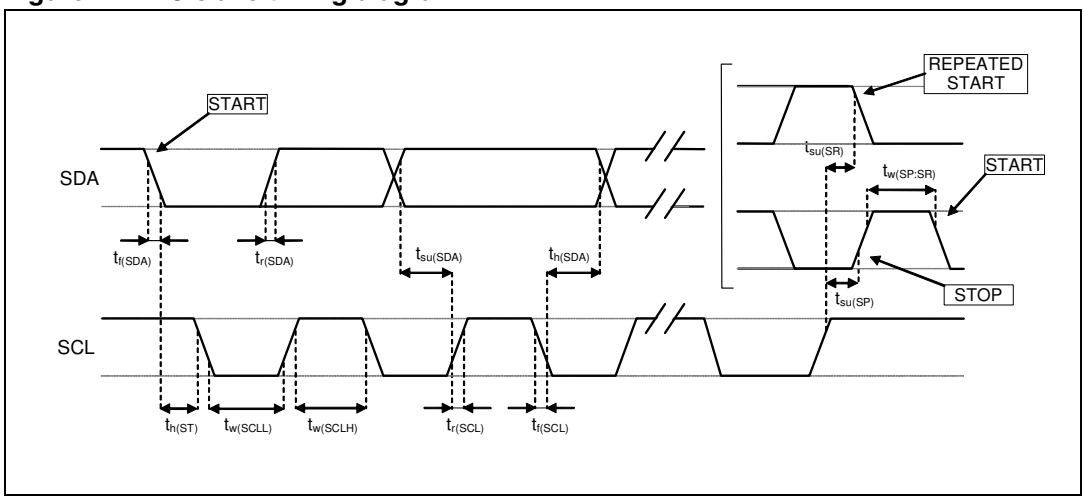
Subject to general operating conditions for Vdd and Top.

Table 7. I2C slave timing values

Symbol	Parameter	I²C standard mode (1)		I²C 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(2)	3.45	0(2)	0.9	µs
$t_{r(SDA)}$ $t_{r(SCL)}$	SDA and SCL rise time		1000	20 + 0.1C_b (3)	300	ns
$t_{f(SDA)}$ $t_{f(SCL)}$	SDA and SCL fall time		300	20 + 0.1C_b (3)	300	
$t_{h(ST)}$	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
2. A device must internally provide an hold time of at least 300ns for the SDA signal (referred to VIHmin of the SCL signal) to bridge the undefined region of the falling edge of SCL
3. Cb = total capacitance of one bus line, in pF

Figure 4. I²C slave timing diagram (4)



4.Measurement points are done at 0.2·Vdd_IO and 0.8·Vdd_IO, for both port

2.4 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 8. Absolute maximum ratings

Symbol	Ratings	Maximum Value	Unit
Vdd	Supply voltage	-0.3 to 6	V
Vdd_IO	I/O pins Supply voltage	-0.3 to Vdd +0.1	V
Vin	Input voltage on any control pin (CS, SCL/SPC, SDA/SDI/SDO, CK)	-0.3 to Vdd_IO +0.3	V
A_{POW}	Acceleration (Any axis, Powered, Vdd=3.3 V)	3000g for 0.5 ms	
		10000g for 0.1 ms	
A_{UNP}	Acceleration (any axis, unpowered)	3000g for 0.5 ms	
		10000g for 0.1 ms	
T_{OP}	Operating temperature range	-40 to +85	°C
T_{STG}	Storage temperature range	-40 to +125	°C
ESD	Electrostatic discharge protection	4.0 (HBM)	kV
		200 (MM)	V
		1.5 (CDM)	kV

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

This is a Mechanical Shock sensitive device, improper handling can cause permanent damages to the part

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

2.5 Terminology

2.5.1 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, ±1g 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 very little over time. The Sensitivity Tolerance describes the range of Sensitivities of a large population of sensors.

2.5.2 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.

2.5.3 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 3* or *4* then the sensor is working properly and the parameters of the interface chip are within the defined specification.

3 Functionality

The LIS3LV02DL is a high performance, low-power, digital output 3-axis linear accelerometer packaged in an LGA 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^2C/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^2C/SPI interface thus making the device particularly suitable for direct interfacing with a microcontroller.

The LIS3LV02DL 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 LIS3LV02DL 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.

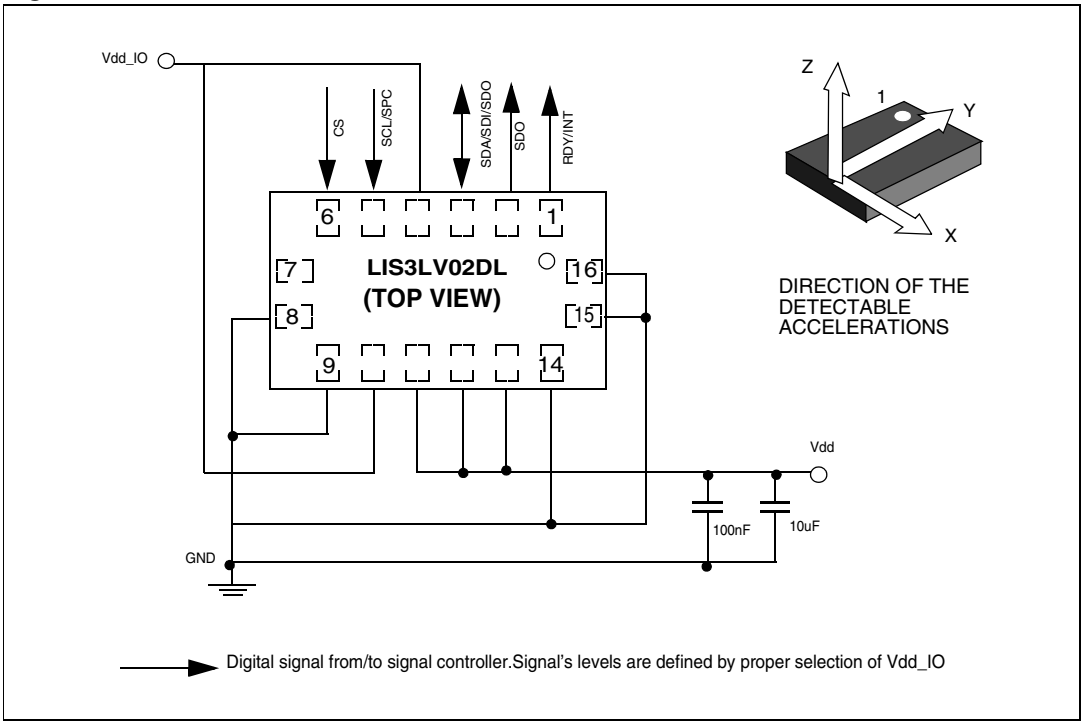
3.3 Factory calibration

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 5. LIS3LV02DL 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 13 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 7*). It is possible to remove Vdd maintaining Vdd_IO without blocking the communication busses. 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 I^2C/SPI interface.When using the I^2C, CS must be tied high while SDO must be left floating. Refer to dedicated application note for further information on device usage.

The functions, the trasholds and the timing of the interrupt pin (INT) can be completely programmed by the user through the I^2C/SPI interface.

4.1 Soldering Information

The LGA-16 package is compliant with the ECOPACK®, RoHS and “Green” standard. It is qualified for soldering heat resistance according to JEDEC J-STD-020C.

Leave “Pin 1 Indicator” unconnected during soldering.

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

5 Digital interfaces

The registers embedded inside the LIS3LV02DL may be accessed through both the I^2C 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^2C interface, CS line must be tied high (i.e connected to Vdd_IO).

Table 9. Serial interface pin description

Pin name	Pin description
CS	SPI enable I^2C/SPI mode selection (1: I^2C mode; 0: SPI enabled)
SCL/SPC	I^2C Serial Clock (SCL) SPI Serial Port Clock (SPC)
SDA/SDI/SDO	I^2C Serial Data (SDA) SPI Serial Data Input (SDI) 3-wire Interface Serial Data Output (SDO)
SDO	SPI Serial Data Output (SDO)

5.1 I^2C serial interface

The LIS3LV02DL I^2C is a bus slave. The I^2C is employed to write the data into the registers whose content can also be read back.

The relevant I^2C terminology is given in the table below.

Table 10. 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^2C 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 LIS3LV02DL. When the bus is free both the lines are high.

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

5.1.1 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 LIS3LV02DL 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 received.

The I²C embedded inside the LIS3LV02DL behaves like a slave device and the following protocol must be adhered to. After the start condition (ST) a salve 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.

Table 11. Transfer when master is writing one byte to slave

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

Table 12. Transfer when master is writing multiple bytes to slave

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

Table 13. 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		

Table 14. Transfer when master is receiving (reading) multiple bytes of data from slave

Master	ST	SAD+W		SUB		SR	SAD+R			MAK		MAK		NMAK	SP
Slave			SAK		SAK			SAK	DATA		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.

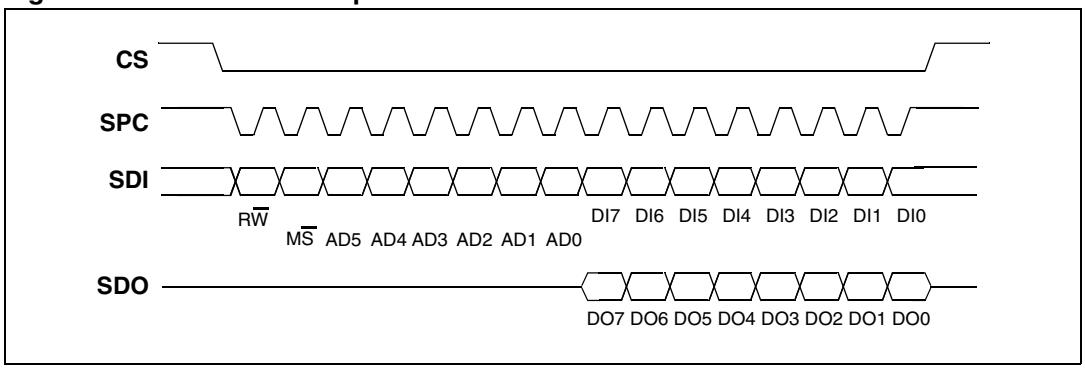
In the presented communication format MAK is Master Acknowledge and NMAK is No Master Acknowledge.

5.2 SPI bus interface

The LIS3LV02DL 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 6. Read and 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: R$\overline{W}$ 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).

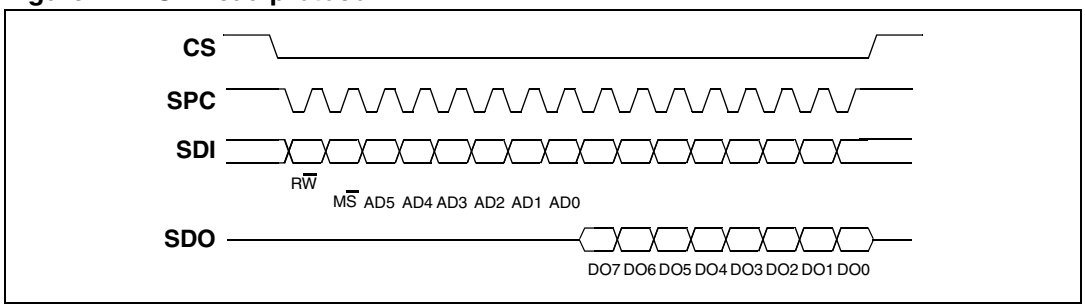
bit 8-15: data DO(7:0) (read mode). This is the data that will be read from the device (MSb first).

In multiple read/write commands further blocks of 8 clock periods will be added. When M$\overline{S}$ bit is 0 the address used to read/write data remains the same for every block. When M$\overline{S}$ 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 7. 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: M$\overline{S}$ 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.