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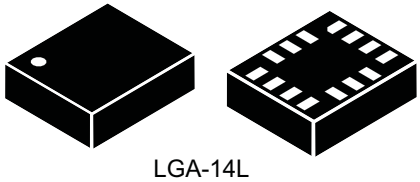
LSM6DSL

iNEMO inertial module: always-on 3D accelerometer and 3D gyroscope

Datasheet - production data



LGA-14L
(2.5 x 3 x 0.83 mm) typ.

Features

- Power consumption: 0.4 mA in combo normal mode and 0.65 mA in combo high-performance mode
- “Always-on” experience with low power consumption for both accelerometer and gyroscope
- Smart FIFO up to 4 kbyte based on features set
- Android M compliant
- Hard, soft ironing for external magnetic sensor corrections
- ±2/±4/±8/±16 *g* full scale
- ±125/±245/±500/±1000/±2000 dps full scale
- Analog supply voltage: 1.71 V to 3.6 V
- Independent IOs supply (1.62 V)
- Compact footprint, 2.5 mm x 3 mm x 0.83 mm
- SPI & I^2C serial interface with main processor data synchronization feature
- Pedometer, step detector and step counter
- Significant motion and tilt function
- Standard interrupts: free-fall, wakeup, 6D/4D orientation, click and double-click
- Embedded temperature sensor
- ECOPACK®, RoHS and “Green” compliant

Applications

- Motion tracking and gesture detection
- Collecting sensor data
- Indoor navigation
- IoT and connected devices
- Intelligent power saving for handheld devices
- Vibration monitoring and compensation

Description

The LSM6DSL is a system-in-package featuring a 3D digital accelerometer and a 3D digital gyroscope performing at 0.65 mA in high-performance mode and enabling always-on low-power features for an optimal motion experience for the consumer.

The LSM6DSL supports main OS requirements, offering real, virtual and batch sensors with 4 kbyte for dynamic data batching.

ST’s family of MEMS sensor modules leverages the robust and mature manufacturing processes already used for the production of micromachined accelerometers and gyroscopes.

The various sensing elements are manufactured using specialized micromachining processes, while the IC interfaces are developed using CMOS technology that allows the design of a dedicated circuit which is trimmed to better match the characteristics of the sensing element.

The LSM6DSL has a full-scale acceleration range of ±2/±4/±8/±16 *g* and an angular rate range of ±125/±245/±500/±1000/±2000 dps.

High robustness to mechanical shock makes the LSM6DSL the preferred choice of system designers for the creation and manufacturing of reliable products.

The LSM6DSL is available in a plastic land grid array (LGA) package.

Table 1. Device summary

Part number	Temp. range [°C]	Package	Packing
LSM6DSL	-40 to +85	LGA-14L (2.5x3x0.83mm)	Tray
LSM6DSLTR	-40 to +85		Tape & Reel

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1 Overview

The LSM6DSL is a system-in-package featuring a high-performance 3-axis digital accelerometer and 3-axis digital gyroscope.

The integrated power-efficient modes are able to reduce the power consumption down to 0.65 mA in high-performance mode, combining always-on low-power features with superior sensing precision for an optimal motion experience for the consumer thanks to ultra-low noise performance for both the gyroscope and accelerometer.

The LSM6DSL delivers best-in-class motion sensing that can detect orientation and gestures in order to empower application developers and consumers with features and capabilities that are more sophisticated than simply orienting their devices to portrait and landscape mode.

The event-detection interrupts enable efficient and reliable motion tracking and contextual awareness, implementing hardware recognition of free-fall events, 6D orientation, click and double-click sensing, activity or inactivity, and wakeup events.

The LSM6DSL supports main OS requirements, offering real, virtual and batch mode sensors. In addition, the LSM6DSL can efficiently run the sensor-related features specified in Android, saving power and enabling faster reaction time. In particular, the LSM6DSL has been designed to implement hardware features such as significant motion detection, tilt, pedometer functions, timestamping and to support the data acquisition of an external magnetometer with ironing correction (hard, soft).

The LSM6DSL offers hardware flexibility to connect the pins with different mode connections to external sensors to expand functionalities such as adding a sensor hub, etc.

Up to 4 kbyte of FIFO with dynamic allocation of significant data (i.e. external sensors, timestamp, etc.) allows overall power saving of the system.

Like the entire portfolio of MEMS sensor modules, the LSM6DSL leverages the robust and mature in-house manufacturing processes already used for the production of micromachined accelerometers and gyroscopes. The various sensing elements are manufactured using specialized micromachining processes, while the IC interfaces are developed using CMOS technology that allows the design of a dedicated circuit which is trimmed to better match the characteristics of the sensing element.

The LSM6DSL is available in a small plastic land grid array (LGA) package of 2.5 x 3.0 x 0.83 mm to address ultra-compact solutions.

2 Embedded low-power features

The LSM6DSL has been designed to be fully compliant with Android, featuring the following on-chip functions:

- 4 kbyte data buffering
  - 100% efficiency with flexible configurations and partitioning
  - Possibility to store timestamp
- Event-detection interrupts (fully configurable):
  - Free-fall
  - Wakeup
  - 6D orientation
  - Click and double-click sensing
  - Activity / inactivity recognition
- Specific IP blocks with negligible power consumption and high-performance:
  - Pedometer functions: step detector and step counters
  - Tilt (refer to *Section 2.1: Tilt detection* for additional information
  - Absolute Wrist Tilt (refer to *Section 2.2: Absolute wrist tilt* for additional information)
  - Significant Motion Detection
- Sensor hub
  - Up to 6 total sensors: 2 internal (accelerometer and gyroscope) and 4 external sensors
- Data rate synchronization with external trigger for reduced sensor access and enhanced fusion

2.1 Tilt detection

The tilt function helps to detect activity change and has been implemented in hardware using only the accelerometer to achieve both the targets of ultra-low power consumption and robustness during the short duration of dynamic accelerations.

It is based on a trigger of an event each time the device's tilt changes. For a more customized user experience, in the LSM6DSL the tilt function is configurable through:

- a programmable average window
- a programmable average threshold

The tilt function can be used with different scenarios, for example:

a) Triggers when phone is in a front pants pocket and the user goes from sitting to standing or standing to sitting;

b) Doesn’t trigger when phone is in a front pants pocket and the user is walking, running or going upstairs.

2.2 Absolute wrist tilt

The LSM6DSL implements in hardware the Absolute Wrist Tilt (AWT) function which allows detecting when the angle between a selectable accelerometer semi-axis and the horizontal plane becomes higher than a specific user-selectable value.

Configurable threshold and latency parameters are associated with the AWT function: the threshold parameter defines the amplitude of the tilt angle; the latency parameter defines the minimum duration of the AWT event to be recognized. The AWT interrupt signal is generated if the tilt angle is higher than the threshold angle for a period of time equal to or greater than the latency period.

The AWT function is based on the accelerometer sensor only and works at 26 Hz, so the accelerometer ODR must be set at a value of 26 Hz or higher.

By default, the AWT algorithm is applied to the positive X-axis.

In order to enable the AWT function it is necessary to set to 1 both the FUNC_EN bit and the WRIST_TILT_EN bit of *CTRL10_C (19h)*.

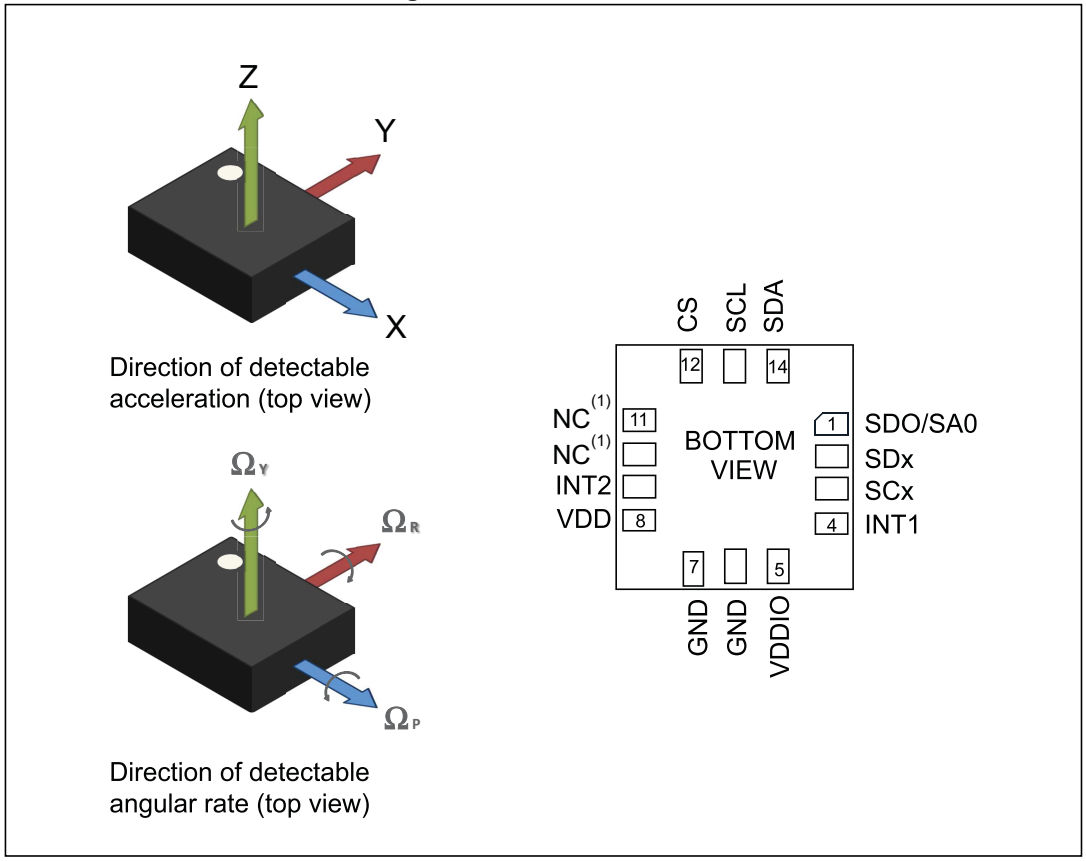
The AWT interrupt signal can be driven to the INT2 interrupt pin by setting to 1 the INT2_WRIST_TILT bit of the *DRDY_PULSE_CFG_G (0Bh)* register; it can also be checked by reading the WRIST_TILT_IA bit of the *FUNC_SRC2 (54h)* register (it will also clear the interrupt signal if latched).

WRIST_TILT_IA (55h) is the status register to be used to detect which axis has triggered the AWT event (not applicable when using one axis side only).

The full description and an example is given in the dedicated application note.

3 Pin description

Figure 1. Pin connections



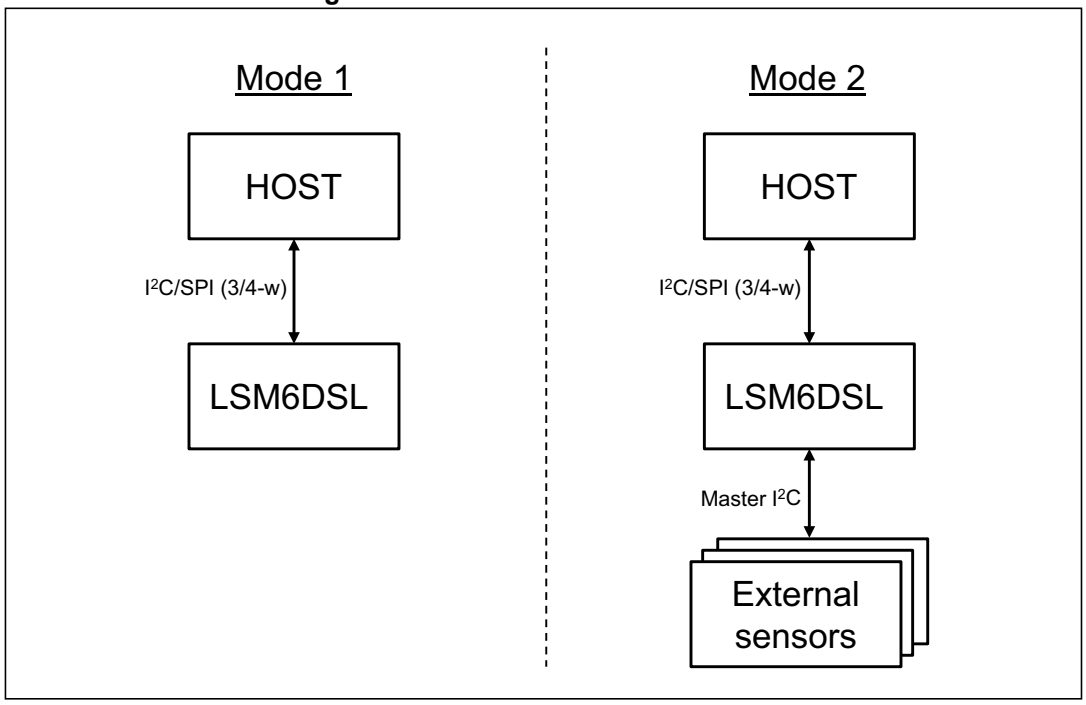
1. Leave pin electrically unconnected and soldered to PCB.

3.1 Pin connections

The LSM6DSL offers flexibility to connect the pins in order to have two different mode connections and functionalities. In detail:

- **Mode 1**: I²C slave interface or SPI (3- and 4-wire) serial interface is available;
- **Mode 2**: I²C slave interface or SPI (3- and 4-wire) serial interface and I²C interface master for external sensor connections are available;

Figure 2. LSM6DSL connection modes



In the following table each mode is described for the pin connection and function.

Table 2. Pin description

Pin#	Name	Mode 1 function	Mode 2 function
1	SDO/SA0	SPI 4-wire interface serial data output (SDO) I^2C least significant bit of the device address (SA0)	SPI 4-wire interface serial data output (SDO) I^2C least significant bit of the device address (SA0)
2	SDx	Connect to VDDIO or GND	I^2C serial data master (MSDA)
3	SCx	Connect to VDDIO or GND	I^2C serial clock master (MSCL)
4	INT1	Programmable interrupt 1	
5	VDDIO(1)	Power supply for I/O pins	
6	GND	0 V supply	
7	GND	0 V supply	
8	VDD(1)	Power supply	
9	INT2	Programmable interrupt 2 (INT2) / Data enable (DEN)	Programmable interrupt 2 (INT2)/ Data enable (DEN)/ I^2C master external synchronization signal (MDRDY)
10	NC(2)	Leave unconnected	
11	NC(2)	Leave unconnected	
12	CS	I^2C/SPI mode selection (1: SPI idle mode / I^2C communication enabled; 0: SPI communication mode / I^2C disabled)	I^2C/SPI mode selection (1: SPI idle mode / I^2C communication enabled; 0: SPI communication mode / I^2C disabled)
13	SCL	I^2C serial clock (SCL) SPI serial port clock (SPC)	I^2C serial clock (SCL) SPI serial port clock (SPC)
14	SDA	I^2C serial data (SDA) SPI serial data input (SDI) 3-wire interface serial data output (SDO)	I^2C serial data (SDA) SPI serial data input (SDI) 3-wire interface serial data output (SDO)

1. Recommended 100 nF filter capacitor.
2. Leave pin electrically unconnected and soldered to PCB.

4 Module specifications

4.1 Mechanical characteristics

@ Vdd = 1.8 V, T = 25 °C unless otherwise noted.

Table 3. Mechanical characteristics

Symbol	Parameter	Test conditions	Min.	Typ.(1)	Max.	Unit
LA_FS	Linear acceleration measurement range			±2		*g*
				±4		
				±8		
				±16		
G_FS	Angular rate measurement range			±125		dps
				±245		
				±500		
				±1000		
				±2000		
LA_So	Linear acceleration sensitivity(2)	FS = ±2		0.061		mg/LSB
		FS = ±4		0.122		
		FS = ±8		0.244		
		FS = ±16		0.488		
G_So	Angular rate sensitivity(2)	FS = ±125		4.375		mdps/LSB
		FS = ±245		8.75		
		FS = ±500		17.50		
		FS = ±1000		35		
		FS = ±2000		70		
G_So%	Sensitivity tolerance(3)	at component level		±1		%
LA_SoDr	Linear acceleration sensitivity change vs. temperature(4)	from -40° to +85°		±0.01		%/°C
G_SoDr	Angular rate sensitivity change vs. temperature(4)	from -40° to +85°		±0.007		%/°C
LA_TyOff	Linear acceleration zero-*g* level offset accuracy(5)			±40		mg
G_TyOff	Angular rate zero-rate level(4)			±3		dps
LA_OffDr	Linear acceleration zero-*g* level change vs. temperature(4)			±0.1		mg/ °C
G_OffDr	Angular rate typical zero-rate level change vs. temperature(4)			±0.015		dps/°C
Rn	Rate noise density in high-performance mode(6)			4		mdps/√Hz

Table 3. Mechanical characteristics (continued)

Symbol	Parameter	Test conditions	Min.	Typ.(1)	Max.	Unit
RnRMS	Gyroscope RMS noise in normal/low-power mode(7)			75		mdps
An	Acceleration noise density in high-performance mode(8)	FS = ±2 *g*		90		µ*g*/√Hz
		FS = ±4 *g*		90		
		FS = ±8 *g*		90		
		FS = ±16 *g*		130		
RMS	Acceleration RMS noise in normal/low-power mode(9)(10)	FS = ±2 *g*		1.8		m*g*(RMS)
		FS = ±4 *g*		2.0		
		FS = ±8 *g*		2.4		
		FS = ±16 *g*		3.0		
LA_ODR	Linear acceleration output data rate			1.6(11) 12.5 26 52 104 208 416 833 1666 3332 6664		Hz
G_ODR	Angular rate output data rate			12.5 26 52 104 208 416 833 1666 3332 6664		
Vst	Linear acceleration self-test output change(12)(13)(14)		90		1700	m*g*
	Angular rate self-test output change(15)(16)	FS = 245 dps	20		80	dps
		FS = 2000 dps	150		700	dps
Top	Operating temperature range		-40		+85	°C

1. Typical specifications are not guaranteed.
2. Sensitivity values after factory calibration test and trimming
3. Subject to change.
4. Measurements are performed in a uniform temperature setup and they are based on characterization data in a limited number of samples. Not measured during final test for production.
5. Values after factory calibration test and trimming.

6. Gyroscope rate noise density in high-performance mode is independent of the ODR and FS setting.
7. Gyroscope RMS noise in normal/low-power mode is independent of the ODR and FS setting.
8. Accelerometer noise density in high-performance mode is independent of the ODR.
9. Accelerometer RMS noise in normal/low-power mode is independent of the ODR.
10. Noise RMS related to BW = ODR /2 (for ODR /9, typ value can be calculated by Typ *0.6).
11. This ODR is available when accelerometer is in low-power mode.
12. The sign of the linear acceleration self-test output change is defined by the STx_XL bits in *CTRL5_C (14h)*, *Table 63* for all axes.
13. The linear acceleration self-test output change is defined with the device in stationary condition as the absolute value of: OUTPUT[LSb] (self-test enabled) - OUTPUT[LSb] (self-test disabled). 1LSb = 0.061 m*g* at ±2 *g* full scale.
14. Accelerometer self-test limits are full-scale independent.
15. The sign of the angular rate self-test output change is defined by the STx_G bits in *CTRL5_C (14h)*, *Table 62* for all axes.
16. The angular rate self-test output change is defined with the device in stationary condition as the absolute value of: OUTPUT[LSb] (self-test enabled) - OUTPUT[LSb] (self-test disabled). 1LSb = 70 mdps at ±2000 dps full scale.

4.2 Electrical characteristics

@ Vdd = 1.8 V, T = 25 °C unless otherwise noted.

Table 4. Electrical characteristics

Symbol	Parameter	Test conditions	Min.	Typ.(1)	Max.	Unit
Vdd	Supply voltage		1.71	1.8	3.6	V
Vdd_IO	Power supply for I/O		1.62		3.6	V
IddHP	Gyroscope and accelerometer current consumption in high-performance mode	ODR = 1.6 kHz		0.65		mA
IddNM	Gyroscope and accelerometer current consumption in normal mode	ODR = 208 Hz		0.45		mA
IddLP	Gyroscope and accelerometer current consumption in low-power mode	ODR = 52 Hz		0.29		mA
LA_IddHP	Accelerometer current consumption in high-performance mode	ODR < 1.6 kHz ODR ≥ 1.6 kHz		150 160		µA
LA_IddNM	Accelerometer current consumption in normal mode	ODR = 208 Hz		85		µA
LA_IddLM	Accelerometer current consumption in low-power mode	ODR = 52 Hz ODR = 12.5 Hz ODR = 1.6 Hz		25 9 4.5		µA
IddPD	Gyroscope and accelerometer current consumption during power-down			3		µA
Ton	Turn-on time			35		ms
V_{IH}	Digital high-level input voltage		0.7 *VDD_IO			V
V_{IL}	Digital low-level input voltage				0.3 *VDD_IO	V
V_{OH}	High-level output voltage	I_{OH} = 4 mA (2)	VDD_IO - 0.2			V
V_{OL}	Low-level output voltage	I_{OL} = 4 mA (2)			0.2	V
Top	Operating temperature range		-40		+85	°C

1. Typical specifications are not guaranteed.
2. 4 mA is the maximum driving capability, i.e. the maximum DC current that can be sourced/sunk by the digital pad in order to guarantee the correct digital output voltage levels V_{OH} and V_{OL}.

4.3 Temperature sensor characteristics

@ Vdd = 1.8 V, T = 25 °C unless otherwise noted.

Table 5. Temperature sensor characteristics

Symbol	Parameter	Test condition	Min.	Typ.(1)	Max.	Unit
TODR(2)	Temperature refresh rate			52		Hz
Toff	Temperature offset(3)		-15		+15	°C
TSen	Temperature sensitivity			256		LSB/°C
TST	Temperature stabilization time(4)				500	µs
T_ADC_res	Temperature ADC resolution			16		bit
Top	Operating temperature range		-40		+85	°C

1. Typical specifications are not guaranteed.
2. When the accelerometer is in Low-Power mode and the gyroscope part is turned off, the TODR value is equal to the accelerometer ODR.
3. The output of the temperature sensor is 0 LSB (typ.) at 25 °C.
4. Time from power ON bit to valid data based on characterization data.