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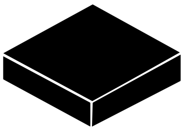
LSM9DS0

iNEMO inertial module: 3D accelerometer, 3D gyroscope, 3D magnetometer

Datasheet - production data



LGA-24 (4x4x1.0 mm)

Features

- 3 acceleration channels, 3 angular rate channels, 3 magnetic field channels
- ±2/±4/±6/±8/±16 *g* linear acceleration full scale
- ±2/±4/±8/±12 gauss magnetic full scale
- ±245/±500/±2000 dps angular rate full scale
- 16-bit data output
- SPI / I^2C serial interfaces
- Analog supply voltage 2.4 V to 3.6 V
- Power-down mode / low-power mode
- Programmable interrupt generators
- Embedded self-test
- Embedded temperature sensor
- Embedded FIFO
- Position and motion detection functions
- Click/double-click recognition
- Intelligent power saving for handheld devices
- ECOPACK®, RoHS and “Green” compliant

Applications

- Indoor navigation
- Smart user interfaces
- Advanced gesture recognition
- Gaming and virtual reality input devices
- Display/map orientation and browsing

Description

The LSM9DS0 is a system-in-package featuring a 3D digital linear acceleration sensor, a 3D digital angular rate sensor, and a 3D digital magnetic sensor.

The LSM9DS0 has a linear acceleration full scale of ±2*g*/±4*g*/±6g/±8*g*/±16*g,* a magnetic field full scale of ±2/±4/±8/±12 gauss and an angular rate of ±245/±500/±2000 dps.

The LSM9DS0 includes an I^2C serial bus interface supporting standard and fast mode (100 kHz and 400 kHz) and an SPI serial standard interface.

The system can be configured to generate interrupt signals on dedicated pins and is capable of motion and magnetic field detection. Thresholds and timing of interrupt generators are programmable by the end user.

Magnetic, accelerometer and gyroscope sensing can be enabled or set in power-down mode separately for smart power management.

The LSM9DS0 is available in a plastic land grid array package (LGA) and it is guaranteed to operate over an extended temperature range from -40 °C to +85 °C.

Table 1. Device summary

Part number	Temperature range [°C]	Package	Packing
LSM9DS0	-40 to +85	LGA-24	Tray
LSM9DS0TR	-40 to +85	LGA-24	Tape and reel

Contents

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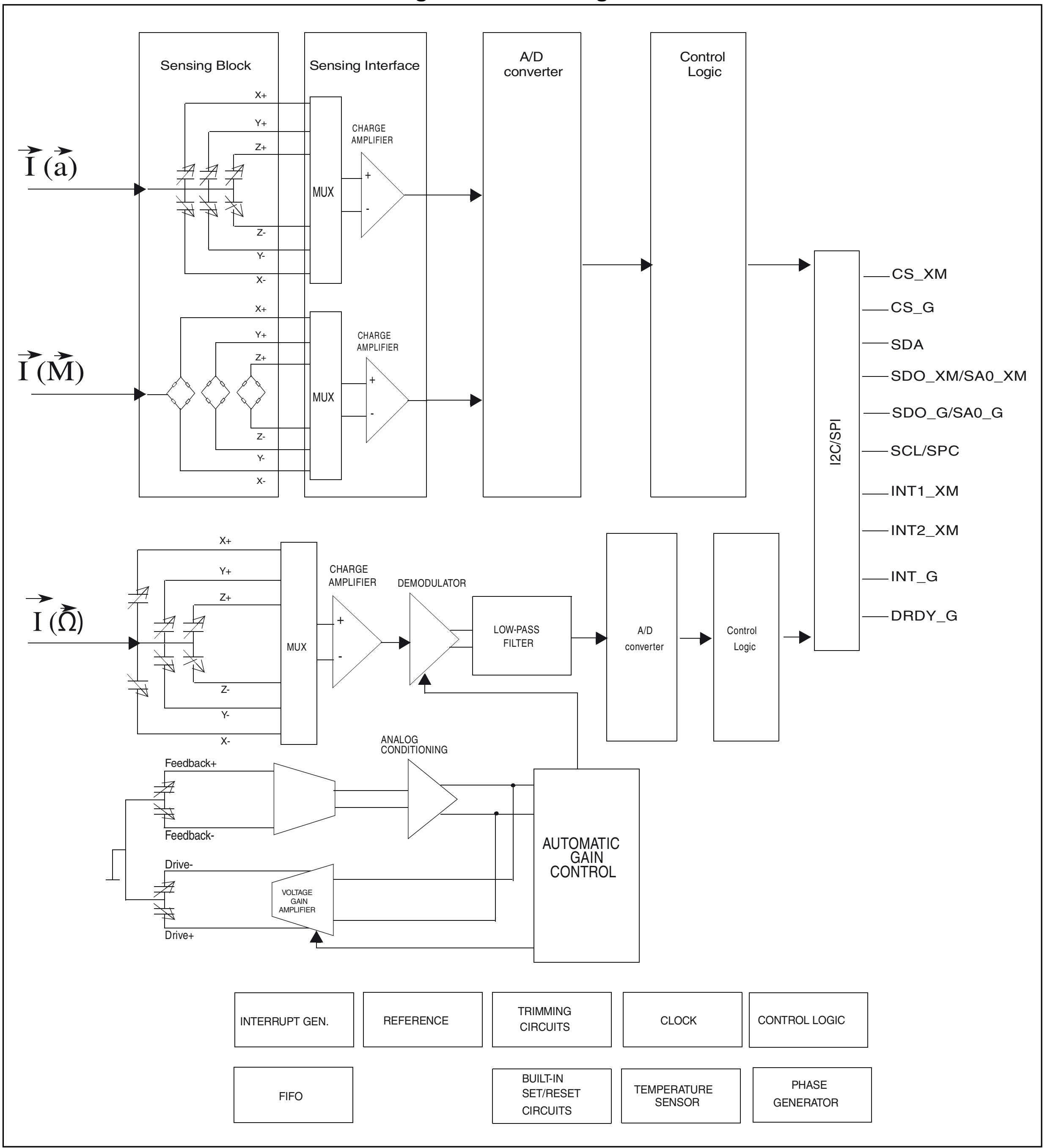
1 Block diagram and pin description

1.1 Block diagram

Figure 1. Block diagram



1.2 Pin description

Figure 2. Pin connections

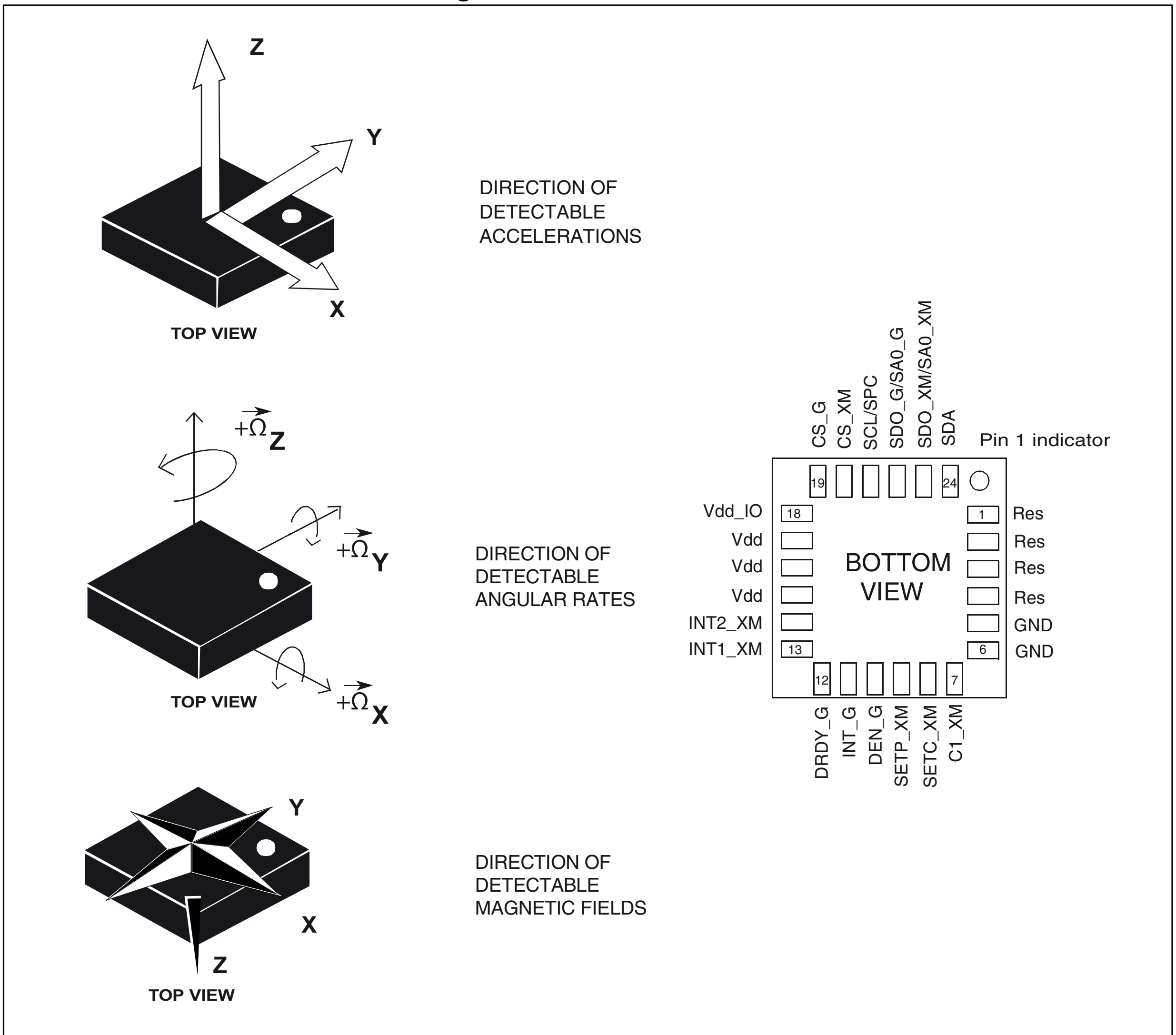


Table 2. Pin description

Pin#	Name	Function
1	Reserved	Leave unconnected
2	Reserved	Connect to GND
3	Reserved	Connect to GND
4	Reserved	Connect to GND
5	GND	0 V supply
6	GND	0 V supply
7	C1_XM	Capacitor connection (C1)
8	SETC_XM	S/R capacitor connection (C2)
9	SETP_XM	S/R capacitor connection (C2)
10	DEN_G	Gyroscope data enable
11	INT_G	Gyroscope programmable interrupt
12	DRDY_G	Gyroscope data ready
13	INT1_XM	Accelerometer and magnetic sensor interrupt 1
14	INT2_XM	Accelerometer and magnetic sensor interrupt 2
15	Vdd	Power supply
16	Vdd	Power supply
17	Vdd	Power supply
18	Vdd_IO	Power supply for I/O pins
19	CS_G	Gyroscope I^2C/SPI mode selection 1: SPI idle mode / I^2C communication enabled 0: SPI communication mode / I^2C disabled
20	CS_XM	Accelerometer and magnetic sensor SPI enabled I^2C/SPI mode selection 1: SPI idle mode / I^2C communication enabled 0: SPI communication mode / I^2C disabled
21	SCL SPC	I^2C serial clock (SCL) SPI serial port clock (SPC)
22	SDO_G SA0_G	Gyroscope serial data output (SDO) Angular rate sensor I^2C less significant bit of the device address (SA0)
23	SDO_XM SA0_XM	Accelerometer and magnetic sensor SPI serial data output (SDO) Accelerometer and magnetic sensor I^2C less significant bit of the device address (SA0)
24	SDA	I^2C serial data (SDA)

2 Module specifications

2.1 Sensor characteristics

@ Vdd = 3.0 V, T = 25 °C unless otherwise noted[a]

Table 3. Sensor characteristics

Symbol	Parameter	Test conditions	Min.	Typ.[1]	Max.	Unit
LA_FS	Linear acceleration measurement range[2]			±2		g
				±4		
				±6		
				±8		
				±16		
M_FS	Magnetic measurement range			±2		gauss
				±4		
				±8		
				±12		
G_FS	Angular rate measurement range			±245		dps
				±500		
				±2000		
LA_So	Linear acceleration sensitivity	Linear acceleration FS = ±2 *g*		0.061		m*g*/LSB
		Linear acceleration FS = ±4 *g*		0.122		
		Linear acceleration FS = ±6 *g*		0.183		
		Linear acceleration FS = ±8 *g*		0.244		
		Linear acceleration FS = ±16 *g*		0.732		
M_GN	Magnetic sensitivity	Magnetic FS = ±2 gauss		0.08		mgauss/ LSB
		Magnetic FS = ±4 gauss		0.16		
		Magnetic FS = ±8 gauss		0.32		
		Magnetic FS = ±12 gauss		0.48		
G_So	Angular rate sensitivity	Angular rate FS = ±245 dps		8.75		mdps/ digit
		Angular rate FS = ±500 dps		17.50		
		Angular rate FS = ±2000 dps		70		
LA_TCSo	Linear acceleration sensitivity change vs. temperature	From -40 °C to +85 °C		±1.5		%
M_TCSo	Magnetic sensitivity change vs. temperature	From -40 °C to +85 °C		±3		%

a. The product is factory calibrated at 3.0 V. The operational power supply range is from 2.4 V to 3.6 V.

Table 3. Sensor characteristics (continued)

Symbol	Parameter	Test conditions	Min.	Typ.(1)	Max.	Unit
G_SoDr	Angular rate sensitivity change vs. temperature	From -40 °C to +85 °C		±2		%
LA_TyOff	Linear acceleration typical zero-g level offset accuracy(3)(4)			±60		m*g*
G_TyOff	Angular rate typical zero-rate level	FS = 245 dps		±10		dps
		FS = 500 dps		±15		
		FS = 2000 dps		±25		
LA_TCOff	Linear acceleration zero-g level change vs. temperature	Max delta from 25 °C		±0.5		m*g*/°C
G_TCOff	Zero-rate level change vs. temperature			±0.05		dps/°C
M_EF	Maximum exposed field	No perming effect on zero reading			10000	gauss
M_DF	Magnetic disturbing field	Sensitivity starts to degrade. Automatic S/R pulse restores the sensitivity(5)			20	gauss
LA_ST	Linear acceleration self-test positive difference (6)(7)	±2 *g* range, X, Y, Z-axis AST1:0 = 01 see *Table 74*	60		1700	m*g*
G_ST	Angular rate self-test output change (8)(9)	FS = 245 dps	20		250	dps
		FS = 500 dps	70		400	
		FS = 2000 dps	150		1000	
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. Set / Reset Pulse is automatically applied at each conversion cycle
6. "Self-test output change" is defined as: $\text{OUTPUT[mg]}_{(\textit{CTRL\_REG2\_XM (21h)}\ \text{AST1:0 enabled})}$ - $\text{OUTPUT[mg]}_{(\textit{CTRL\_REG2\_XM (21h)}\ \text{AST1:0 disabled})}$
7. For polarity refer to *Table 77: Self-test mode configuration*
8. "Self-test output change" is defined as: $\text{OUTPUT[mg]}_{(\textit{CTRL\_REG4\_G (23h)}\ \text{ST1:0 enabled})}$ - $\text{OUTPUT[mg]}_{(\textit{CTRL\_REG4\_G (23h)}\ \text{ST1:0 disabled})}$
9. For polarity refer to *Table 31: Self-test mode configuration*

2.2 Temperature sensor characteristics

The electrical characteristics concerning the temperature sensor are given in the table below.

@ Vdd = 3.0 V, T=25 °C unless otherwise noted.

Table 4. Temperature sensor electrical characteristics

Symbol	Parameter	Test conditions	Min.	Typ.(1)	Max.	Unit
TSDr	Temperature sensor output change vs. temperature	-		8		LSB/°C
TODR	Temperature refresh rate			M_ODR [2:0](2)		Hz
Top	Operating temperature range		-40		+85	°C

1. Typical specifications are not guaranteed.
2. Refer to *Table 84: Magnetic data rate configuration*.

2.3 Electrical characteristics

@ Vdd = 3.0V, T = 25 °C unless otherwise noted[b]

Table 5. Electrical characteristics

Symbol	Parameter	Test conditions	Min.	Typ.[1]	Max.	Unit
Vdd	Supply voltage		2.4		3.6	V
Vdd_IO	Module power supply for I/O		1.71	1.8	Vdd+0.1	
Idd_XM	Current consumption of the accelerometer and magnetic sensor in normal mode [2]		HR setting CTRL_REG5 _XM (M_RES [1,0]) = 11b, see *CTRL_REG5 _XM (24h)*	350		µA
Idd_G	Gyroscope current consumption in normal mode[3]			6.1		mA
Idd_G_LP	Gyroscope supply current in sleep mode[4]			2		mA
Idd_Pdn	Current consumption in power-down mode[5]			6		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
Top	Operating temperature range		-40		+85	°C

1. Typical specifications are not guaranteed
2. Magnetic sensor setting ODR =6.25 Hz, Accelerometer sensor ODR =50 Hz, gyroscope in power-down mode
3. Accelerometer and magnetic sensor in power-down mode
4. Sleep mode introduces a faster turn-on time compared to power-down mode. Accelerometer and magnetic sensor in power-down mode.
5. Linear accelerometer, magnetic sensor and gyroscope in power-down mode

b. LSM9DS0 is factory calibrated at 3.0 V

2.4 Communication interface characteristics

2.4.1 SPI - serial peripheral interface

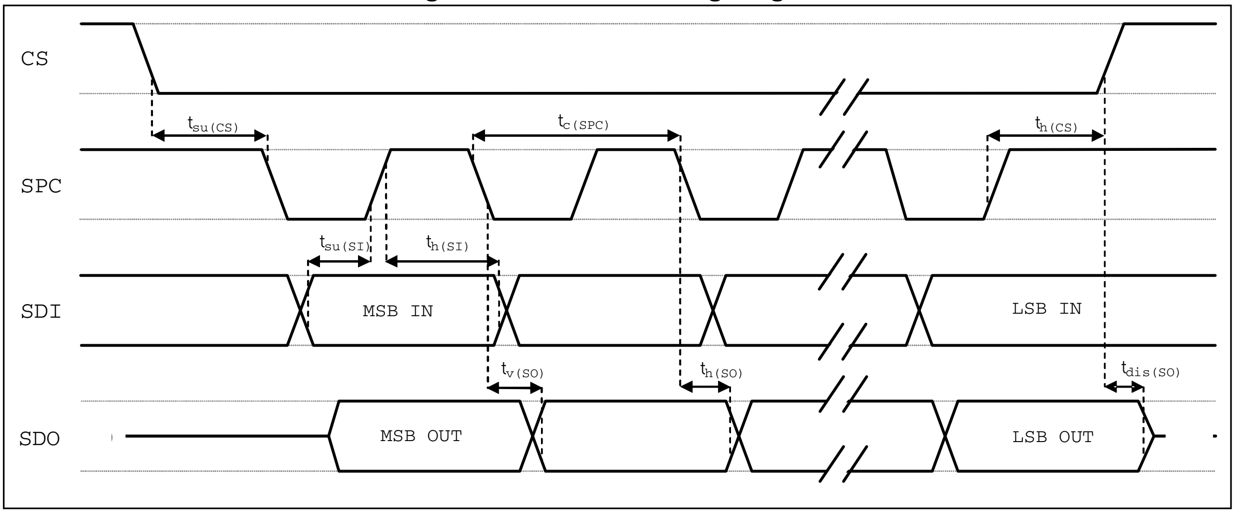
Subject to general operating conditions for Vdd and Top.

Table 6. SPI slave timing values

Symbol	Parameter	Value(1)		Unit
		Min	Max	
$t_{c(SPC)}$	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



Note: Measurement points are done at 0.2·Vdd_IO and 0.8·Vdd_IO, for both input and output ports.

2.4.2 Sensor I²C - inter-IC control interface

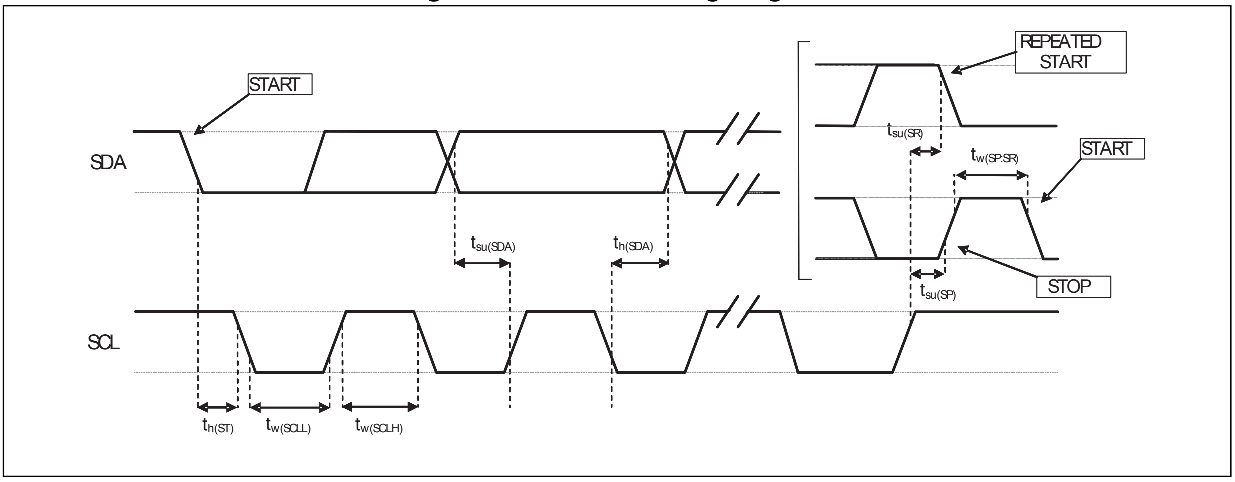
Subject to general operating conditions for Vdd and Top.

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		μs
$t_{su(SDA)}$	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		μs
$t_{su(SP)}$	STOP condition setup time	4		0.6		μs
$t_{w(SP:SR)}$	Bus free time between STOP and START condition	4.7		1.3		μs

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 8. Absolute maximum ratings

Symbol	Ratings	Maximum value	Unit
Vdd	Supply voltage	-0.3 to 4.8	V
Vdd_IO	I/O pins supply voltage	-0.3 to 4.8	V
Vin	Input voltage on any control pin (SCL/SPC, SDA, SDO_XM/SA0_XM, SDO_G/SA0_G, CS_G, CS_XM, DEN_G)	-0.3 to Vdd_IO +0.3	V
A_{POW}	Acceleration (any axis, powered, Vdd = 2.5 V)	3,000 for 0.5 ms	g
		10,000 for 0.1 ms	g
A_{UNP}	Acceleration (any axis, unpowered)	3,000 for 0.5 ms	g
		10,000 for 0.1 ms	g
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 is an electrostatic-sensitive device (ESD), improper handling can cause permanent damage to the part.

3 Terminology

3.1 Set / reset pulse

The set / reset pulse is an automatic operation performed before each magnetic acquisition cycle to degauss the sensor and to ensure alignment of the magnetic dipoles and thus the linearity of the sensor itself.

3.2 Sensitivity

The methods to determine sensitivity and offset are given below in the following paragraphs.

3.2.1 Linear acceleration sensor sensitivity

Sensitivity describes the gain of the sensor and can be determined 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 time. The sensitivity tolerance describes the range of sensitivities of a large population of sensors.

3.2.2 Magnetic sensor sensitivity

Sensitivity describes the gain of the sensor and can be determined by applying a magnetic field of 1 *gauss* to it.

3.2.3 Angular rate sensitivity

An angular rate gyroscope is a device that produces a positive-going digital output for counter-clockwise rotation around the sensitive axis considered. Sensitivity describes the gain of the sensor and can be determined by applying a defined angular velocity to it. This value changes very little over temperature and time.

3.2.4 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 will measure 0 *g* for the X-axis and 0 *g* for the Y-axis whereas the Z-axis will measure 1 *g*. The output is ideally in the middle of the dynamic range of the sensor (content of OUT registers 00h, data expressed as two's complement number). A deviation from the ideal value in this case is called Zero-*g* offset. Offset is to some extent a result of stress to the MEMS sensor and therefore the offset can slightly change after mounting the sensor onto a printed circuit board or exposing it to extensive mechanical stress. Offset changes little over temperature, see "Zero-*g* level change vs. temperature" (LA_TCOff in *Table 3*). The Zero-*g* level tolerance (TyOff) describes the standard deviation of the range of Zero-*g* levels of a population of sensors.

3.2.5 Zero-*gauss* level

The zero-*g*auss level offset describes the deviation of an actual output signal from the ideal output if no magnetic field is present. Thanks to the Set/Reset Pulse and to the magnetic sensor readout chain, the offset is dynamically cancelled. The Zero-*g*auss level does not show any dependency on temperature or power supply.

3.2.6 Zero-rate level

The zero-rate level describes the actual output signal if there is no angular rate present. The zero-rate level of highly accurate MEMS sensors is, to some extent, a result of stress to the sensor and therefore the zero-rate level can slightly change after mounting the sensor onto a printed circuit board or after exposing it to extensive mechanical stress. This value changes very little over temperature and time.

4 Functionality

The LSM9DS0 is a system-in-package featuring a 3D digital accelerometer, a 3D digital magnetometer, and a 3D digital gyroscope.

The device includes specific sensing elements and two IC interfaces capable of measuring both the acceleration/magnetometer and angular rate applied to the module and to provide a signal to external applications through an SPI/I^{2}C serial interface.

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

The LSM9DS0 may also be configured to generate an inertial *wake-up* and *free-fall* interrupt signal according to a programmed acceleration event along the enabled axes.

4.1 Self-test

4.1.1 Accelerometer

The self-test allows the linear acceleration sensor functionality to be tested 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 *Section 2.1: Sensor characteristics*, then the sensor is working properly and the parameters of the interface chip are within the defined specifications.

4.1.2 Gyroscope

The 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. When the ST is activated by the IC, an actuation force is applied to the sensor, emulating a definite Coriolis force. In this case the sensor output will exhibit an output change.
When the ST is active, the device output is given by the algebraic sum of the signals produced by the velocity acting on the sensor and by the electrostatic test-force.

For polarity please refer to *Table 31: Self-test mode configuration*.

4.2 Linear acceleration main digital blocks

4.2.1 FIFO

The LSM9DS0 embeds 32 slots of data 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. This buffer can work accordingly in four different modes: Bypass mode, FIFO mode, Stream mode and Stream-to-FIFO mode. Each mode is selected by the FIFO_MODE bits in *FIFO_SRC_REG (2Fh)*. Programmable watermark level, FIFO_Empty or FIFO_Full events can be enabled to generate dedicated interrupts on the INT1_XM/INT2_XM pin (configured through *FIFO_SRC_REG (2Fh)*).

4.2.2 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 slots are empty.

4.2.3 FIFO mode

In FIFO mode, data from the X, Y and Z channels are stored in the FIFO. A watermark interrupt can be enabled (FIFO_WTMK_EN bit in *FIFO_CTRL_REG (2Eh)*) in order to be raised when the FIFO is filled to the level specified in the FIFO_WTMK_LEVEL bits of *FIFO_CTRL_REG (2Eh)*. The FIFO continues filling until it is full (32 slots of data for X, Y and Z). When full, the FIFO stops collecting data from the input channels.

4.2.4 Stream mode

In Stream mode, data from the X, Y and Z measurements are stored in the FIFO. A watermark interrupt can be enabled and set as in FIFO mode. The FIFO continues filling until it is full (32 slots of data for X, Y and Z). When full, the FIFO discards the older data as the new data arrives.

4.2.5 Stream-to-FIFO mode

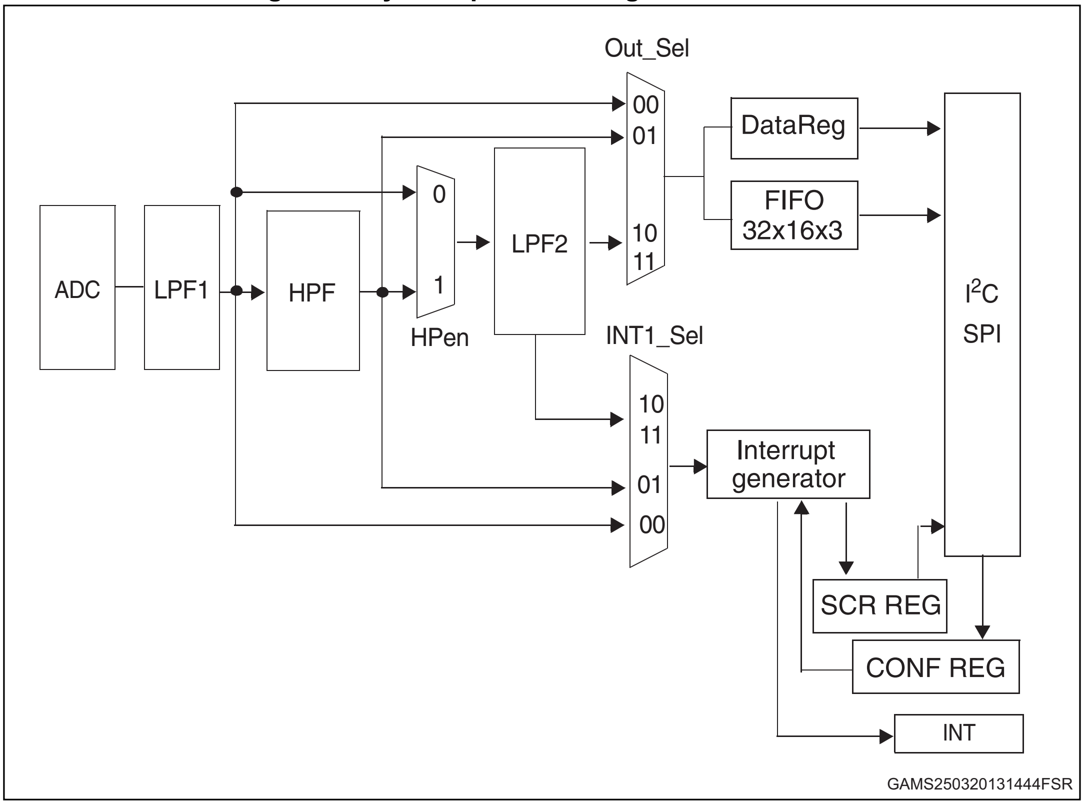
In Stream-to-FIFO mode, data from the X, Y and Z measurements is stored in the FIFO. A watermark interrupt can be enabled (FIFO_WTMK_EN bit in *FIFO_CTRL_REG (2Eh)*) in order to be raised when the FIFO is filled to the level specified in the FIFO_WTMK_LEVEL bits of *FIFO_CTRL_REG (2Eh)*. The FIFO continues filling until it is full (32 slots of 8-bit data for X, Y and Z). When full, the FIFO discards the older data as the data new arrives. Once a trigger event occurs, the FIFO starts operating in FIFO mode.

4.2.6 Retrieving data from FIFO

A read operation to the *OUT_X_L_A (28h), OUT_X_H_A (29h)*, *OUT_Y_L_A (2Ah), OUT_Y_H_A (2Bh)* or *OUT_Z_L_A (2Ch), OUT_Z_H_A (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_A (28h), OUT_X_H_A (29h)*, *OUT_Y_L_A (2Ah), OUT_Y_H_A (2Bh)* and *OUT_Z_L_A (2Ch), OUT_Z_H_A (2Dh)* registers and both single read and read_burst operations can be used.

4.3 Gyroscope digital main blocks

Figure 5. Gyroscope block diagram



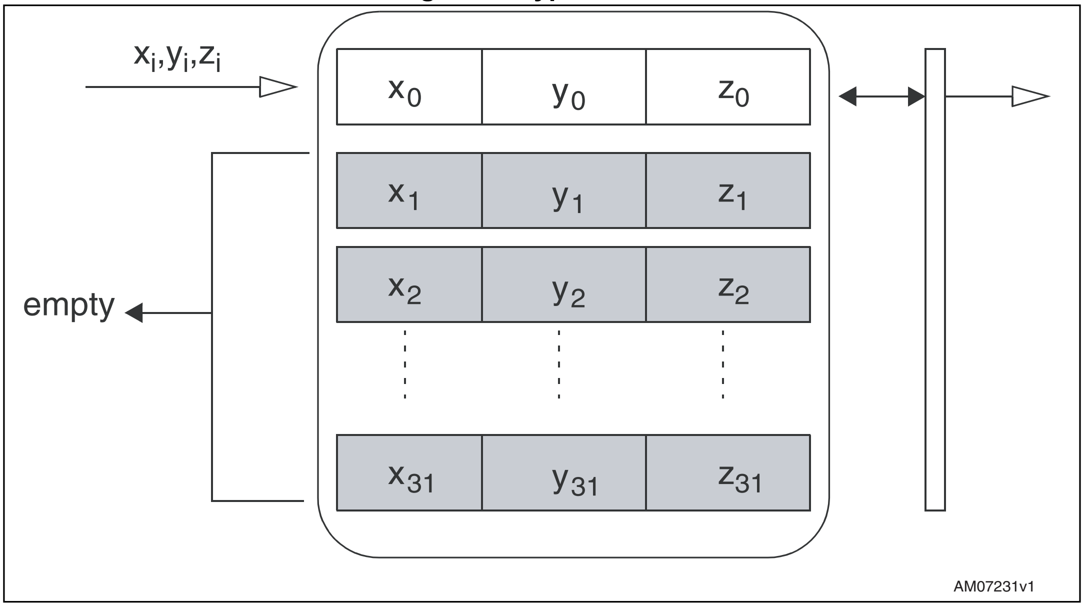
4.3.1 FIFO

The LSM9DS0 embeds 32 slots of 16-bit data FIFO for each of the three output channels: yaw, pitch and roll. This allows consistent power saving for the system, since the host processor does not need to continuously poll data from the sensor, but can wake up only when needed and burst the significant data out from the FIFO. This buffer can work accordingly in five different modes: Bypass mode, FIFO mode, Stream mode, Bypass-to-Stream mode and Stream-to-FIFO mode. Each mode is selected by the FIFO_MODE bits in *FIFO_CTRL_REG_G (2Eh)*. A programmable watermark level, FIFO_Empty or FIFO_Full events can be enabled to generate dedicated interrupts on the DRDY_G pin (configured through *CTRL_REG3_G (22h)* and event detection information is available in *FIFO_SRC_REG_G (2Fh)*. The watermark level can be configured to WTM4:0 in *FIFO_CTRL_REG_G (2Eh)*.

4.3.2 Bypass mode

In Bypass mode, the FIFO is not operational and for this reason it remains empty. As described in *Figure 6*, for each channel only the first address is used. The remaining FIFO slots are empty. When new data is available, the old data is overwritten.

Figure 6. Bypass mode



4.3.3 FIFO mode

In FIFO mode, data from the yaw, pitch and roll channels is stored in the FIFO. A watermark interrupt can be enabled (I2_WMK bit in *CTRL_REG3_G (22h)*) in order to be raised when the FIFO is filled to the level specified in the WTM 4:0 bits of *FIFO_CTRL_REG_G (2Eh)*. The FIFO continues filling until it is full (32 slots of 16-bit data for yaw, pitch and roll). When full, the FIFO stops collecting data from the input channels. To restart data collection, *FIFO_CTRL_REG_G (2Eh)* must be written back to Bypass mode.

FIFO mode is represented in *Figure 7*.

Figure 7. FIFO mode