Technical Product Description
SMI230
Inertial Sensor (6DoF) for Non-Safety Automotive Applications

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1 Product Identification

The SMI230 is a combined triaxial accelerometer (ACC) and triaxial gyroscope (GYR) for non-safety related applications, e.g. for in-dash navigation in the passenger compartment. Within one package, the SMI230 offers the detection of acceleration and angular rate for the x-, y-, and z-axis. The digital standard serial peripheral interface (SPI) of the SMI230 allows for bi-directional data transmission. To increase flexibility, both gyroscope and accelerometer can be operated individually, but can also be tied together for data synchronization purposes.

Sensor	Bosch Part Nr.	Type	Range	Resolution
SMI230	0273 142 144	Accelerometer	±2, ±4, ±8, ±16 g	16 bit
		Gyroscope	±125 ... ±2000 °/s	16 bit

1.1 Main Functions and Properties

Key Feature	Description
2 inertial sensors in one device	Advanced triaxial 16 bit gyroscope and a versatile, leading edge triaxial 16 bit accelerometer for reduced PCB space and simplified signal routing
Small package	LGA, 16 pins, footprint 3.0 x 4.5 mm², height 0.95 mm
Common voltage supplies	VDD voltage range: 2.4 ... 3.6 V
Digital interface	SPI, TWI (compatible with I^2C)
Smart operation and integration	Gyroscope and accelerometer can be operated individually or synchronized
Consumer electronics suite	MSL1, RoHS compliant, halogen-free
Operating temperature	-40 ... +105 °C
Programmable functionality	Acceleration and rate ranges selectable Low-pass filter bandwidths selectable
On-chip temperature sensor	-104 °C ... 150 °C factory trimmed, 11 bit, typical

Provided that SMI230 is used within the conditions (environment, application, installation, loads) as described in the TCD and the corresponding agreed upon documents, Bosch ensures that the product complies with the agreed properties. Agreements beyond this require the written approval by Bosch. The product is considered fit for the intended use when the product successfully has passed the tests in accordance with the TCD and agreed upon documents.

It is the responsibility of the customer to ensure the proper application of the product in the overall system/vehicle.

Bosch does not assume any responsibility for changes to the environment of the product that deviate from the TCD and the agreed upon documents.

2 General Product Description

2.1 Sensor Structure

The inertial sensor SMI230 is based upon a combined two-chip stacked concept. The accelerometer and gyroscope sensing parts consist of sensitive micro-mechanical sensing elements (MEMS) mounted side-by-side on the PCB. The read out ASICs are stacked on top of the respective sensing elements. All of these elements are packed in one LGA package.

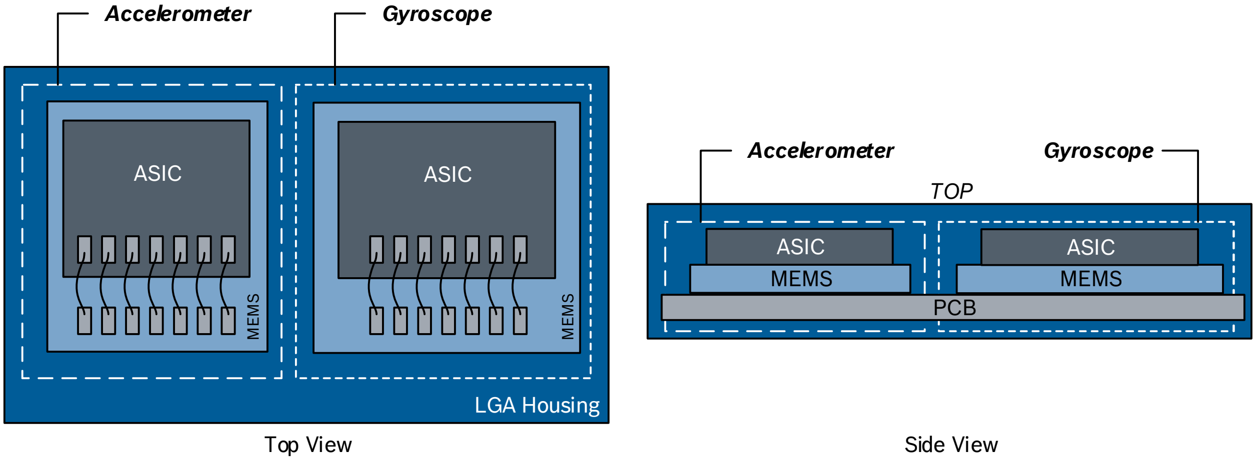

Figure 1 Schematics of the SMI230 mechanical design (left: top view; right: side view)

2.2 Block Diagram

Figure 2 shows the basic building blocks of the SMI230. As stated in Figure 2, the accelerometer and the gyroscope MEMS elements are each evaluated by their own ASIC. Both sensing elements detect voltage (V) variations, feeding into the analog-digital converter (ADC). The digital signals are further processed and accessible via SPI or TWI.

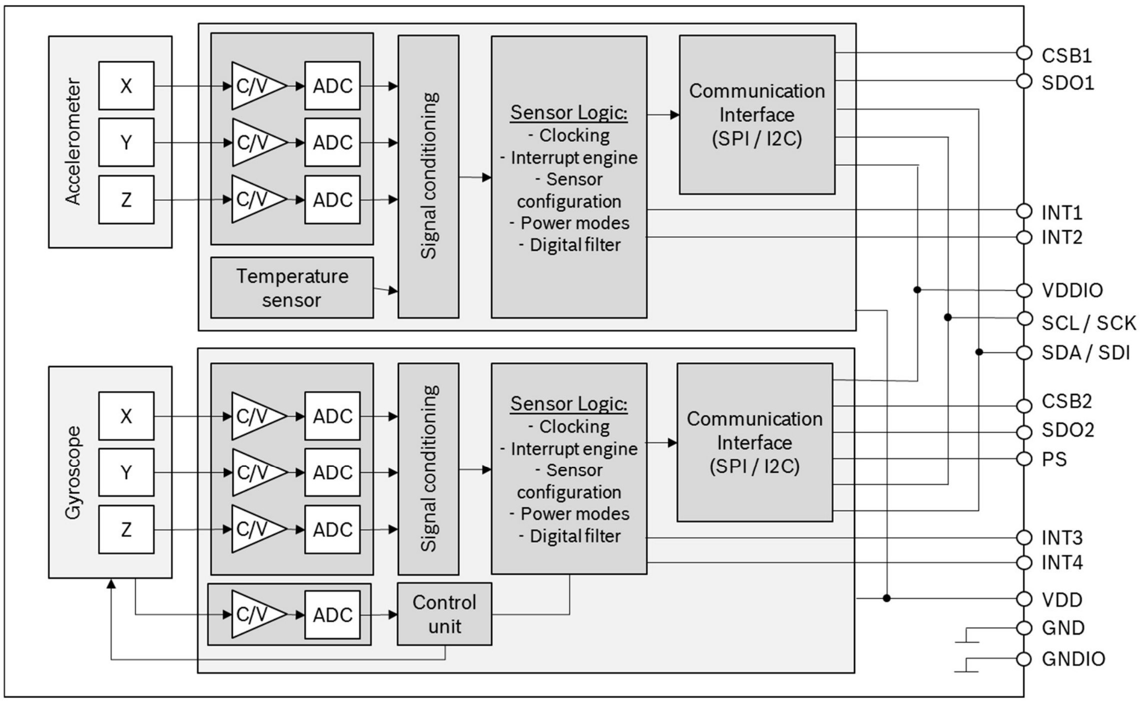

Figure 2 Simplified block diagram of the SMI230

2.3 Signal Path

2.3.1 Accelerometer

The accelerometer offers temperature and acceleration data for all three spatial dimensions. For the latter, the differential capacitance change (C) of the corresponding sensing element is detected. These signals correspond to the voltage (V) entering the hybrid algorithmic analog-digital-converter (ADC), translating the formerly analog signals into digital serial bit streams at a rate of 400 kHz. Then, the detected signal is translated into a data word of max. 16 bits and enters the digital signal processor (DSP).

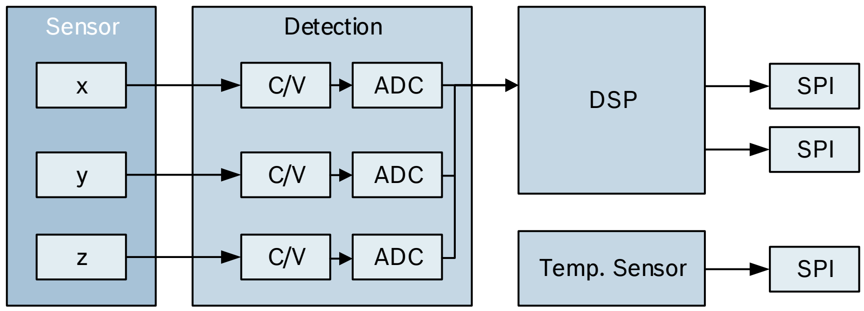

Figure 3 Simplified signal path of the accelerometer

Within the DSP (see Figure 4), the data is corrected for the analog-digital conversion, the gain and offset corrected. A low-pass filter provides an adjustable data bandwidth. Here, the sampling rate is directly connected with the selected bandwidth.

The low-pass filter can be bypassed so that unfiltered data is accessible.

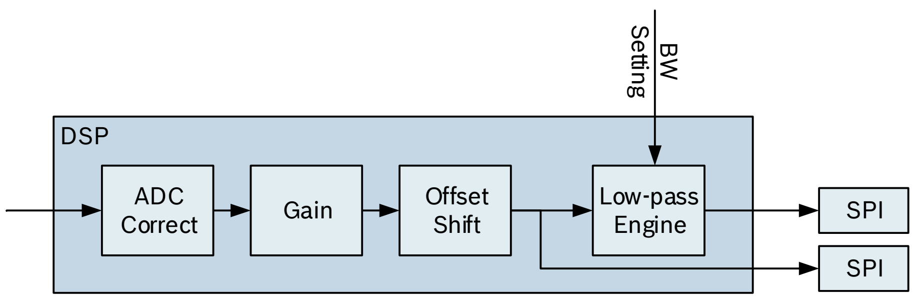

Figure 4 Simplified signal path of the accelerometer

2.3.2 Gyroscope

The signal path of the gyroscope is sketched in Figure . For proper data acquisition, five blocks are necessary for each rate axis, i.e., the drive, the (MEMS) sensor, the detection, the controller & demodulator, and the digital signal processor (DSP). In addition, a temperature signal is provided by the temperature sensor.

The drive is a closed-loop system that actively moves each sensor element at ~25 kHz.

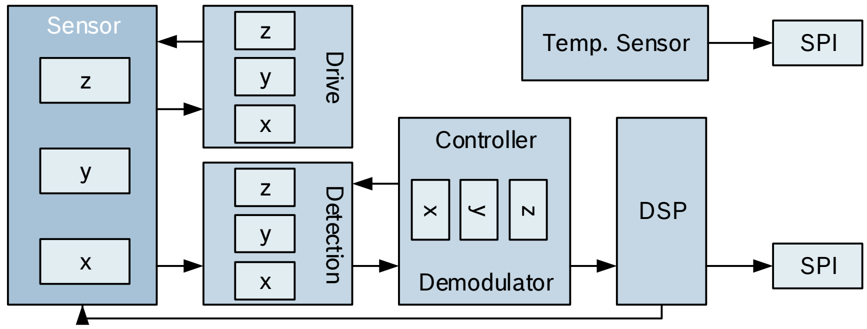

Figure 5 Simplified signal path of the gyroscope

Data acquisition is independent from the drive and the temperature sensor. A more detailed sketch of the signal path of one axis is given in Figure 6.

The block 'Detection' corresponds to the analog part of the SMI230. The differential capacitance change (C) of each sensing element corresponds to the rate data of the respective sensing axis. The latter corresponds to the voltage (V) entering the 25 kHz filter which is equal to the drive frequency. The 1-bit Σ/Δ-converter (ADC) translates the signal into a digital serial bit stream at a rate of 400 kHz.

This bit stream is fed into both the common mode controller and the demodulator. The first back-couples to 'C/V' in order to negate mass deviation of the sensor element. The latter demodulates the 25 kHz data signal which then enters the DSP.

In the DSP, the signal is both fed into the quadrature correction and the offset is shifted. Afterwards, it passes a fine gain block and low pass filter before being accessible via e.g. SPI.

The block 'Quad. Corr.' back-couples onto distinctive pads on the sensing element to compensate for possible deviations from the oscillation axis.

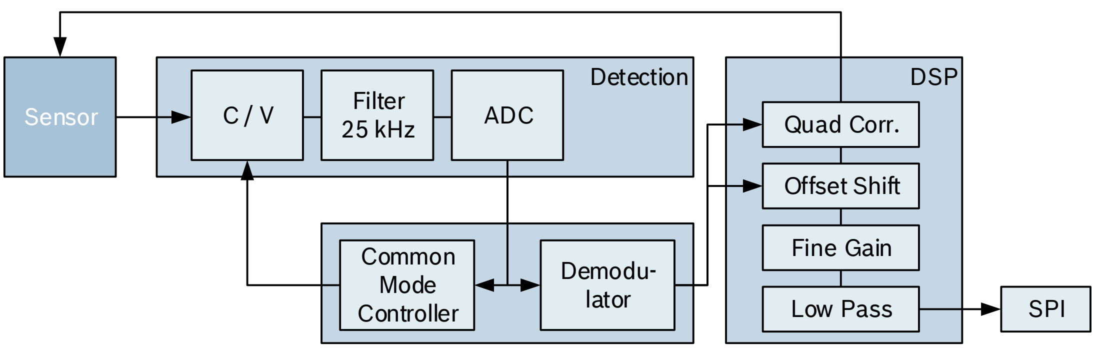

Figure 6 Path of the detection signal for one axis (gyroscope)

2.4 Power Management

The SMI230 has two distinct power supply pins:

- VDD is the main power supply for the internal blocks.
- VDDIO is a separate power supply pin mainly used for the supply of the interface.

There are no limitations on the voltage levels of both pins relative to each other, as long as each of them lies within its operating range. Furthermore, the device can be completely switched off (VDD = 0V) while keeping the VDDIO supply on (VDDIO > 0V) or vice versa.

In the case that the VDDIO supply is off, all interface pins (CSB, SDI, SCK, PS) must be kept close to GNDIO potential.

The SMI230 provides a **power-on reset (POR)** generator. It resets the logic part and the register values after powering-on VDD and VDDIO. This means that all application specific settings which are not equal to the default settings, must be changed back to their designated values after POR.

!	The POR resets also the interface. For the gyroscope part, the interface is defined by the voltage level on the PS pin. The interface of the accelerometer part is defined by the voltage level of the CSB1 pin at the moment when the POR is initiated (see chapter 2.4).

2.4.1 Power Modes Accelerometer

The power state of the SMI230 accelerometer is controlled through the register ACC_PWR_CTRL. The register ACC_PWR_CTRL enables and disables the accelerometer and the temperature sensor.

To enter **normal mode**, and the value 0x04 must be written to ACC_PWR_CTRL.

To enter **suspend mode**, register ACC_PWR_CTRL must be cleared.

SMI230 accelerometer is in suspend mode after reset (POR or soft-reset), thus the user actively needs to enter normal mode in order to obtain acceleration values.

After POR or soft-reset, the acceleration sensor needs up to 1ms boot time. When changing power modes, the sensor needs up to 5ms to settle. Any communication with the sensor during this time should be avoided.

2.4.2 Power Modes Gyroscope

The gyroscope has 3 different power modes. Besides **normal mode**, which represents the fully operational state of the device, there are 2 energy saving modes: suspend mode and deep-suspend mode.

After power-up gyro is in normal mode so that all parts of the device are held powered-up and data acquisition is performed continuously.

In **suspend mode** the whole analog part is powered down. No data acquisition is performed. While in suspend mode the latest rate data and the content of all configuration registers are kept. The registers can still be read (though they are not updated).

Suspend mode is entered by writing 0x80 to the Register GYRO_LPM1. It can be left by writing 0x00 to GYRO_LPM1 or by a soft reset.

Although write access to registers is supported at the full interface clock speed (SCL or SCK), a waiting period must be inserted between two consecutive write cycles.

In **deep suspend mode** the device reaches the lowest possible power consumption. Only the interface section is kept alive. No data acquisition is performed and the content of the configuration registers is lost.

Deep suspend mode is entered by writing 0x20 to the register GYRO_LPM1. It can be left by writing 0x00 to GYRO_LPM1 or by a soft reset.

Please note, that all application specific settings, which are not equal to the default settings, must be re-set to its designated values after leaving deep-suspend mode.

After POR or soft-reset, or when switching between the different power modes, the gyroscope sensor needs up to 30 ms time to reach the new state. Any communication with the sensor during this time should be avoided.

2.5 Sensor Data

The width of the gyroscope and accelerometer sensor data is 16 bits (11 bits for the temperature sensor) given in two´s complement representation.

The bits for each axis are split into an MSB upper part and an LSB lower part. Reading the sensor data registers shall always start with the LSB part. In order to ensure the integrity of the sensor data, the content of an MSB register is locked by reading the corresponding LSB register (shadowing procedure).

The **burst-access** mechanism provides an efficient way to read out the angular rate data in I2C or SPI mode. During a burst-access, the sensor automatically increments the starting read address after each byte. The burst-access allows data to be transferred over the I2C bus with an up to 50% reduced data density. The sensor data (angular rate or acceleration data) in all read-out registers is locked as long as the burst read access is active. Reading the sensor data registers of each gyroscope and accelerometer part in burst read access mode ensures that the sensor values in all readout registers belong to the same sample.

2.6 Sensor Time

The accelerometer part of SMI230 has a built-in counter with a width of 24 bits. It increments periodically with a resolution of 39.0625 µs.

2.7 Sensing Axes Orientation

If the sensor is accelerated and/or rotated in the indicated directions, the corresponding channels of the device will deliver a positive acceleration and/or yaw rate signal (dynamic acceleration). If the sensor is at rest without any rotation, and the force of gravity is acting contrary to the indicated directions, the output of the corresponding acceleration channel will be positive and the output of the corresponding gyroscope channel will be 'zero' (static acceleration).

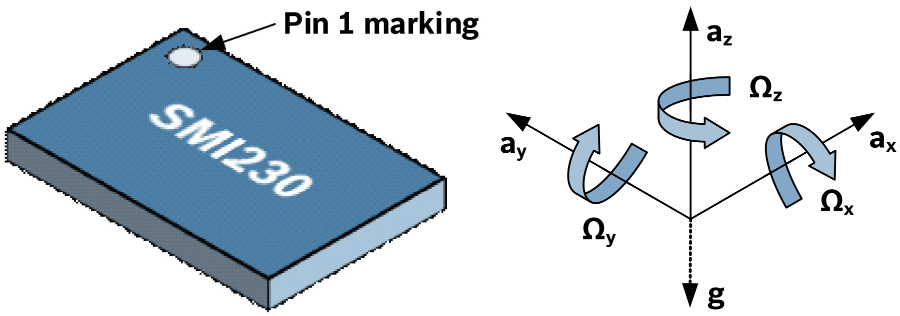

Figure 7 Sensing axis orientation

Example:
According to Figure 5, if the sensor is at rest, or at uniform motion in a gravity field, the output signals are:

- ±0 for the ACC x-channel ±0 for the GYR Ω_X-channel
- ±0 for the ACC y-channel ±0 for the GYR Ω_Y-channel
- +1 g for the ACC z-channel ±0 for the GYR Ω_Z -channel

The table below lists all corresponding output signals of x, y, and z, and Ω_X, Ω_Y, and Ω_Z, while the sensor is at rest, or at uniform motion in a gravity field. This assumes a ±2 g accelerometer range setting and a top down gravity vector as shown above.

Sensor Orientation	SMI230 Earth	SMI230 Earth	SMI230 Earth	SMI230 Earth	Earth	Earth
Output Signal x	0 0	+1 g +1024 LSB	0 0	-1 g -1024 LSB	0 0	0 0
Output Signal y	-1 g -1024 LSB	0 0	+1 g +1024 LSB	0 0	0 0	0 0
Output Signal z	0 0	0 0	0 0	0 0	+1 g +1024 LSB	-1 g -1024 LSB
Output Signal Ω_X	0 0	0 0	0 0	0 0	0 0	0 0
Output Signal Ω_Y	0 0	0 0	0 0	0 0	0 0	0 0
Output Signal Ω_Z	0 0	0 0	0 0	0 0	0 0	0 0

3 Hardware Interface Description and Packaging

3.1 Package Parameters

Parameter	Value	Unit
Width	3.00	mm
Length	4.50	mm
Height	0.95	mm
Weight	27.48	mg

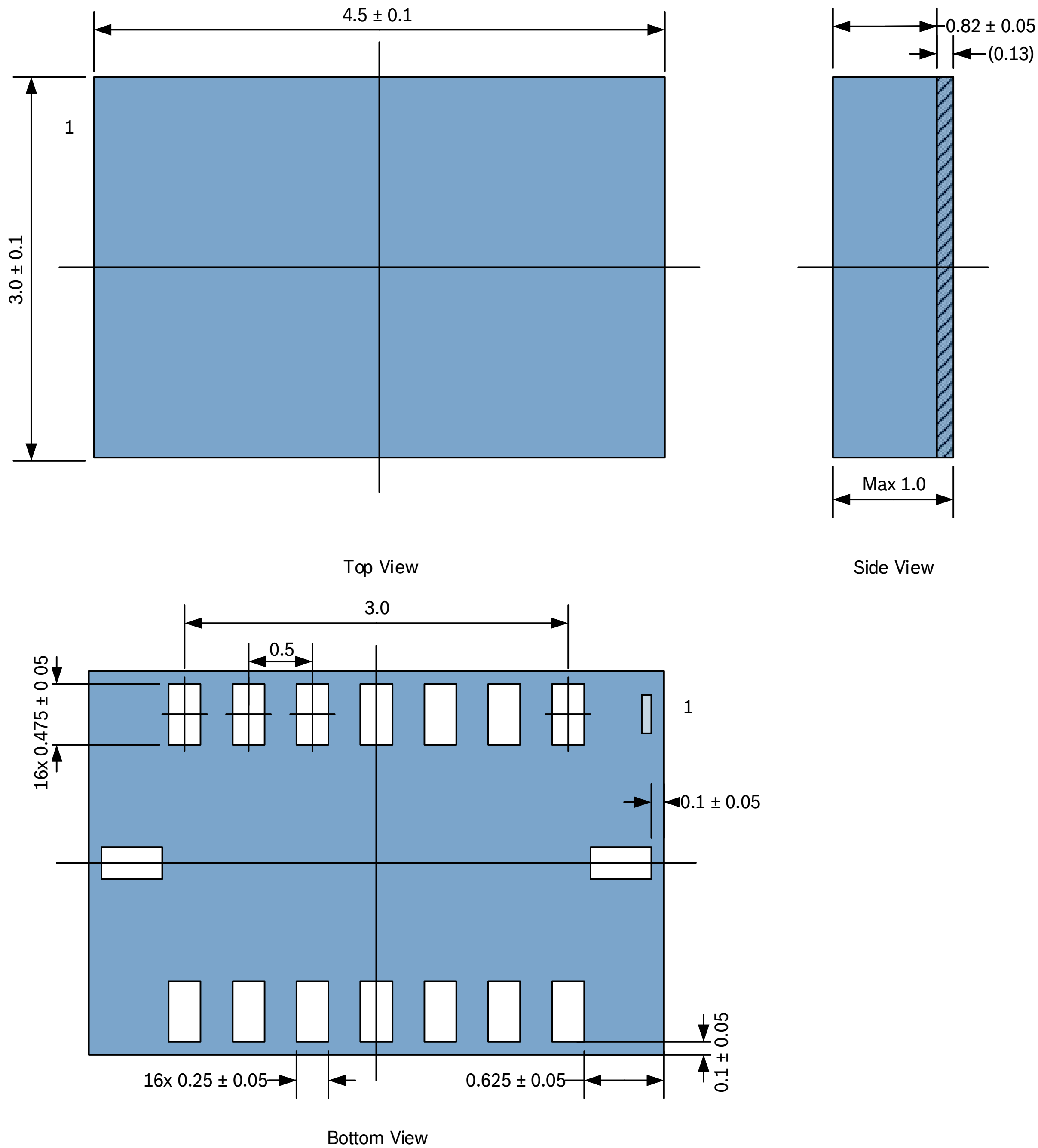

Figure 8 SMI230 package outline drawing

The dimensions are given in mm. Note: Unless otherwise specified, the tolerance is ± 0.05 mm.

The SMI230 sensor meets the requirements of the EC restriction of hazardous substances (RoHS) directive, see also:

Directive 2002/95/EC of the European Parliament and of the Council of 27 January 2003 on the restriction of the use of certain hazardous substances in electrical and electronic equipment.

The sensor module is recyclable according to the norm WEEE - 2012/19/EU.

The sensor housing is a standard LGA package.

Halogen content:

The SMI230 is halogen-free. For more details on the analysis results, please contact your Bosch representative.

3.2 Transport Package

3.2.1 Tape on Reel Specification

The SMI230 is shipped in a standard cardboard box.

The box dimensions for one reel are L x W x H = 35 cm x 35 cm x 6 cm.

SMI230 quantity: 5000 pcs per reel. Please handle with care

3.2.1.1 Tape Dimensions

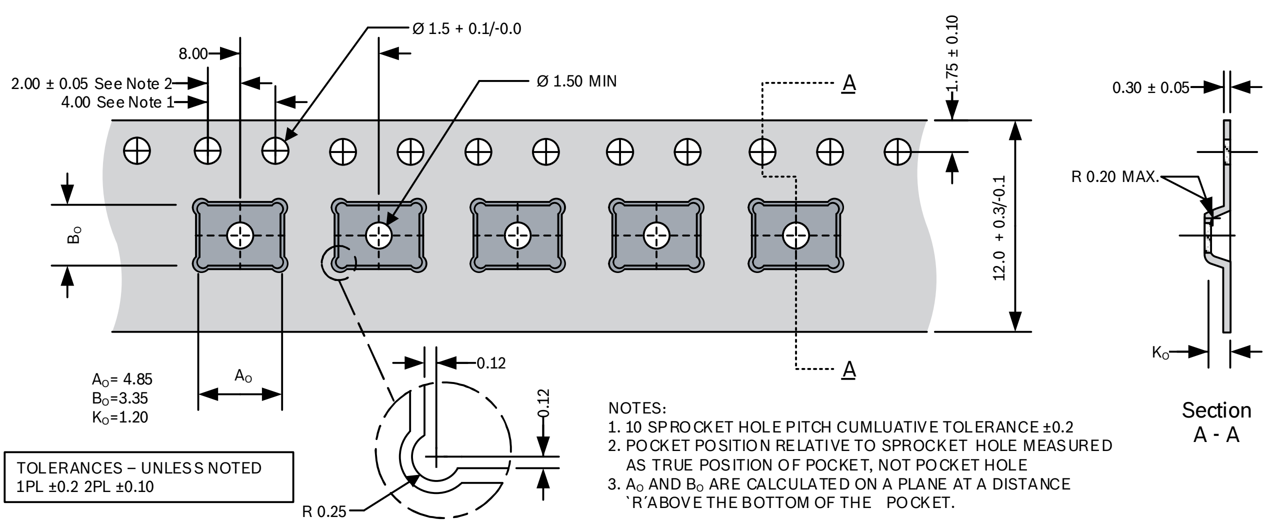

Figure 9 Tape dimensions in mm

3.2.1.2 Reel Dimensions

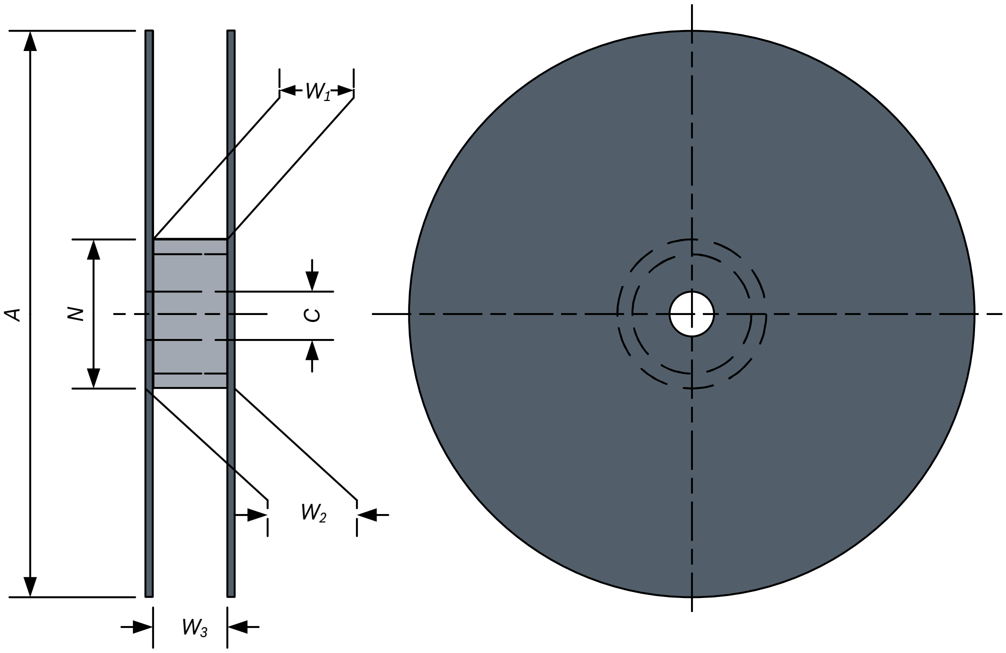

Figure 10 Reel dimensions

Parameter	Meaning	Dimensions [mm]
W (not depicted)	tape width	12
A	reel diameter	330
N	hub diameter	100
W_1	inner width of reel	12.4 +2
W_2	total width of reel	18.4
W_3, min	inner width of reel, minimum	11.9
W_3, max	inner width of reel, maximum	15.4

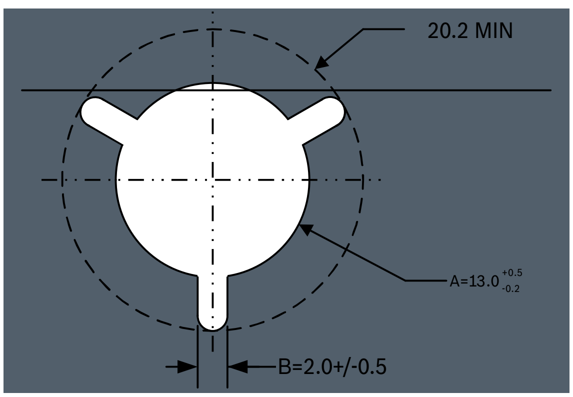

Figure 11 Details on hub hole dimension C in mm

3.2.2 Orientation within Reel

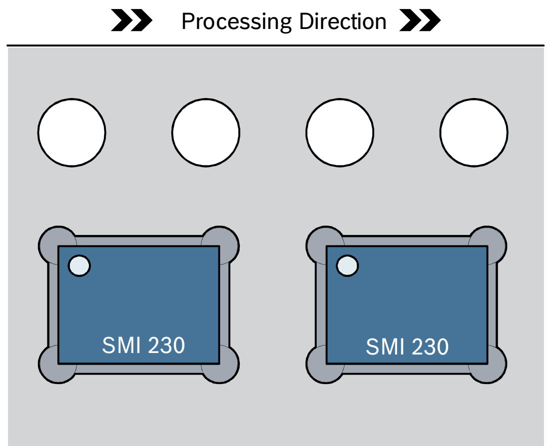

Figure 12 Orientation of the SMI230 devices relative to the tape

3.3 Labeling of the Product

Labeling	Name	Symbol	Remark
	Product number	xxx	144, fixed to identify product type
	Subcon ID	A	1 alphanumeric digit, variable to identify sub-con
	Date code	YYWW	4 numeric digits, fixed to identify YY: “year”, WW: “working week”
	Counter ID	CCC	3 numeric digits, variable to generate trace-code
	Pin 1 identifier	●	--

3.4 Pinning

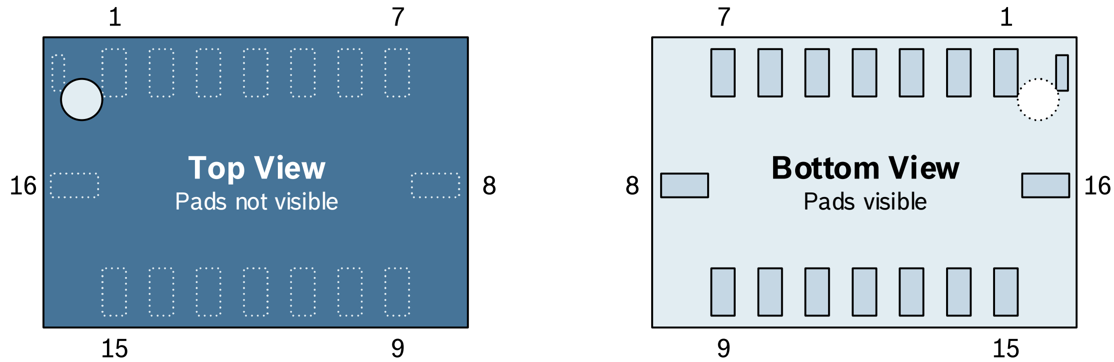

Figure 13 Pin-out top (left) and bottom (right) view

Pin	Name	I/O Type	Description	Connect to - SPI -	Connect to - TWI -
1	INT2	Digital I/O	Interrupt pin (ACC #2)	INT2 / DNC	INT2 / DNC
2	NC	--	--	GND	GND
3	VDD	Supply	Power supply analog & digital domain	VDD	VDD
4	GNDA	Ground	Ground for analog domain	GND	GND
5	CSB2	Digital in	SPI chip select GYR	CSB2	DNC (float)
6	GNDIO	Ground	Ground for I/O	GND	GND
7	PS	Digital in	Protocol select	GND	VDDIO
8	SCx	Digital in	Serial clock	SCK	SCL
9	SDx	Digital I/O	SPI: serial data in; TWI: serial data in/out	SDI	SDA
10	SDO2	Digital out	SPI: serial data out GYR	SDO2	SDO2
11	VDDIO	Supply	Digital I/O supply voltage	VDDIO	VDDIO
12	INT3	Digital I/O	Interrupt pin (GYR int #1)	INT3 / DNC	INT3 / DNC
13	INT4	Digital I/O	Interrupt pin (GYR int #2)	INT4 / DNC	INT4 / DNC
14	CSB1	Digital in	SPI chip select ACC	CSB1	DNC (float)
15	SDO1	Digital out	SPI: serial data out ACC	SDO1	SDO1
16	INT1	Digital I/O	Interrupt pin 1 (ACC int #1)	INT1 / DNC	INT1 / DNC

DNC: Do not connect

INTx: If not needed, DNC

3.5 Footprint

For the design of the landing patterns, the dimensioning shown in Figure 14 is recommended. The dimensions are given in mm.

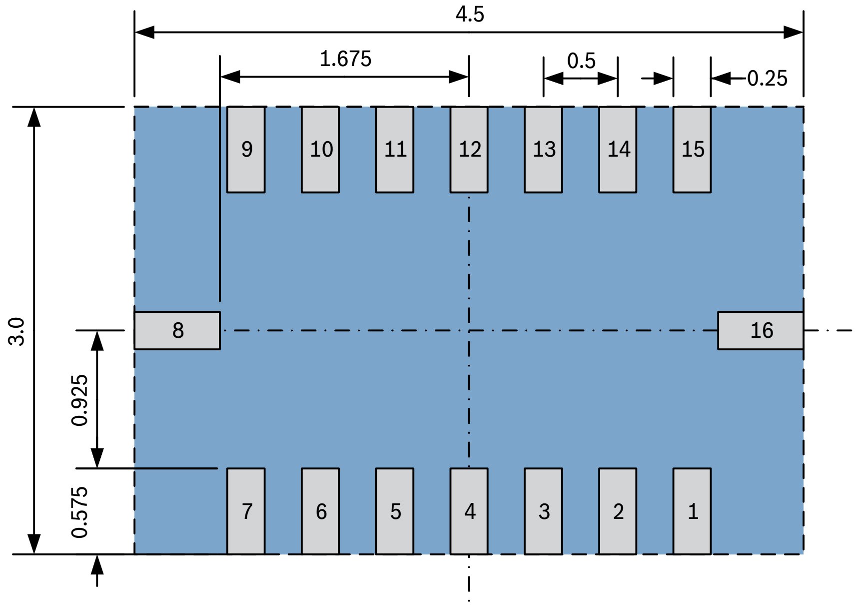

Figure 14 SMI230 footprint

3.6 Moisture Sensitivity Level

The moisture sensitivity level (MSL) of BOSCH SMI230 corresponds to JEDEC Level 1, see also

- IPC/JEDEC J-STD-020C "Joint Industry Standard: Moisture/Reflow Sensitivity Classification for non-hermetic Solid State Surface Mount Devices"
- IPC/JEDEC J-STD-033A "Joint Industry Standard: Handling, Packing, Shipping and Use of Moisture/Reflow Sensitivity Surface Mount Devices"

The sensor IC fulfils the lead-free soldering requirements of the above-mentioned IPC/JEDEC standard, i.e. reflow soldering with a peak temperature up to 260°C.

3.7 Mounting Recommendations

In general, MEMS sensors are high-precision measurement devices that consist of electronic as well as mechanical structures. BOSCH sensor devices are designed for precision, efficiency, and mechanical robustness.

However, in order to achieve best possible results of your design, the following recommendations should be taken into consideration when mounting the sensor on a printed circuit board (PCB).

In order to evaluate and optimize the considered placement position of the sensor on the PCB, it is recommended to use additional tools during the design in phase. For example:

- Regarding thermal aspects: infrared camera
- Regarding mechanical stress: warpage measurements and/or FEM-simulations
- Regarding shock robustness: drop test of the devices after soldering on the target application PCB

Recommendations in Detail

- It is recommended to keep a reasonable distance between the sensor mounting location on the PCB and the critical points described in the following examples. The exact value for a “reasonable distance” depends on many customer specific variables and therefore must be determined case by case.
- It is generally recommended to minimize the PCB thickness (recommended: ≤0.8 mm) since a thin PCB shows less intrinsic stress.
- It is not recommended to place the sensor directly under or next to push-button contacts as this can result in mechanical stress.
- It is not recommended to place the sensor in the direct vicinity of extremely high temperature spots (e.g. a µController or a graphic chip) as this can result in the PCB heating up and consequently the sensor as well.
- It is not recommended to place the sensor in the direct vicinity of a mechanical stress maximum (e.g. in the center of a diagonal crossover). Mechanical stress can lead to bending of the PCB and the sensor.
- Do not mount the sensor too closely to a PCB anchor point, where the PCB is attached to a shelf (or similar), as this could also result in mechanical stress. To reduce potential mechanical stress, minimize redundant anchor points and/or loosen respective screws.
- Avoid mounting the sensor in areas where resonant amplitudes (vibrations) of the PCB are likely or expected.
- Please avoid partial coverage of the sensor by any kind of (epoxy) resin, as this can result in mechanical stress.
- Avoid mounting (and operation) of the sensor in the vicinity of strong magnetic, strong electric, and/or strong infrared radiation fields (IR).
- Avoid electrostatic charging of the sensor and of the device in which the sensor is mounted.

If the above mentioned recommendations cannot be realized appropriately, a specific in-line offset-calibration after placement of the device onto your PCB may help to minimize the potentially remaining effects.

3.8 Soldering

3.8.1 Reflow Soldering Recommendation for Sensors in LGA Package

Please make sure that the edges of the LGA substrate of the sensor are free of solder material. Avoid solder material forming a high meniscus covering the edge of the LGA substrate (see Figure 15).

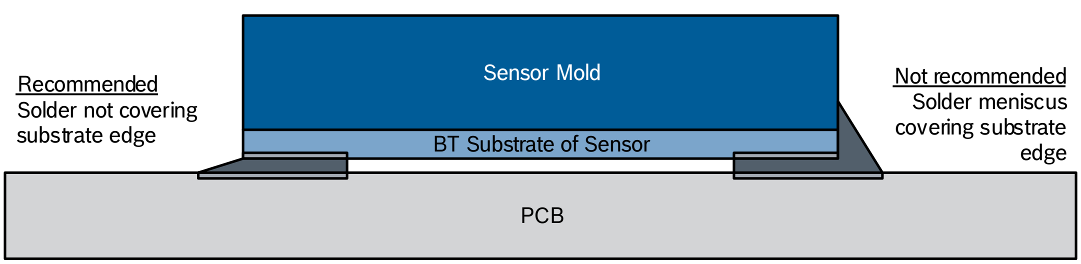

Figure 15 Reflow soldering recommendation

3.8.2 Classification Reflow Profiles

Profile Feature	Pb-Free Assembly
Average ramp-up rate (T_{Smax} to T_p)	3 °C/s max.
Preheat Temperature min (T_{Smin}) Temperature max (T_{Smax}) Time (t_{Smin} to t_{Smax})	 150 °C 200 °C 60 – 180 s
Time maintained above: Temperature (T_L) Time (t_L)	 217 °C 60 s – 150 s
Peak classification temperature (T_P)	260 °C
Time within 5 °C of actual peak temperature (t_p)	20 s – 40 s
Ramp-down rate	6 °C/s max.
Time 25 °C to peak temperature	8 min max.

Note: All temperatures refer to the topside of package, measured on the package body surface.

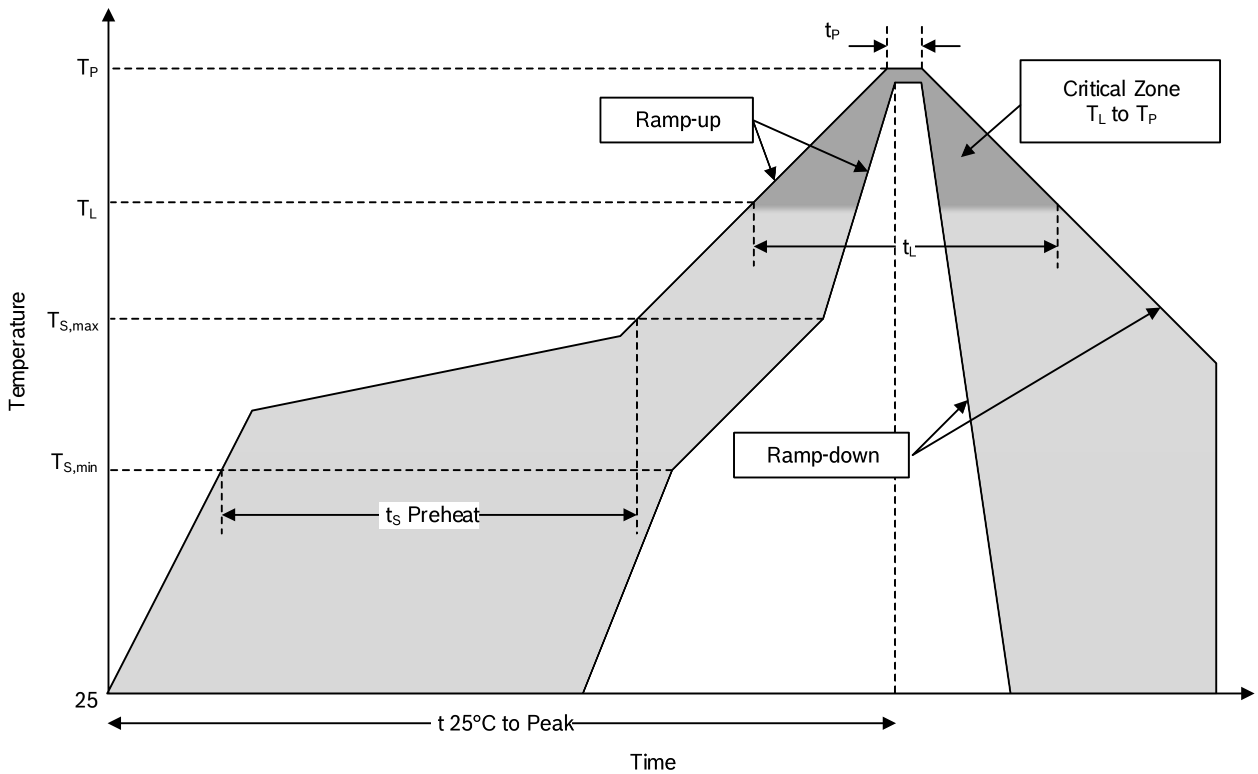

Figure 16 Soldering profile

3.8.3 Multiple Reflow Soldering Cycles

The product can withstand up to 3 reflow soldering cycles in total. This could be a situation where a PCB is mounted with devices from both sides (i.e., 2 reflow cycles necessary) and where, in the next step, an additional re-work cycle could be required (1 reflow).

3.9 Further Important Mounting and Assembly Recommendations

The SMI230 is designed to sense angular rates and accelerations with high accuracy even at low amplitudes and contains highly sensitive structures inside the sensor element. The MEMS sensor can tolerate mechanical shocks up to several thousand g's. However, these limits might be exceeded in conditions with extreme shock loads such as a hammer blow on or next to the sensor, dropping the sensor onto hard surfaces, etc.

It is strongly recommended to avoid any g forces beyond the limits specified in the data sheet during transport, handling, and mounting of the sensors. A defined and qualified installation process on customer side is required.

This device has built-in protections against high electrostatic discharges or electric fields (2 kV HBM). However, anti-static precautions should be taken as with any other CMOS component.

Unless otherwise specified, proper operation can only occur when all terminal voltages are kept within the supply voltage range. Unused inputs must always be connected to a defined logic voltage level.

4 Environment and Parameter Specification

The data in this section, unless otherwise noted, applies for the valid operation conditions given in section 4.2. All of the following figures include voltage, temperature, and lifetime effects if not noted otherwise. All figures, except sensitivity, are only valid without an external stimulus applied. All figures except for the noise itself exclude noise effects.

Proper function of the sensor in the overall system must be validated by the customer.

In any case, the electrical stability (power supply and EMC) of each system design including the SMI230 must be evaluated in advance to guarantee proper functionality during operation.

In any case, the mechanical stability of each system design including the SMI230 must be evaluated in advance to guarantee proper functionality during operation.

4.1 Maximum Ratings

Any values beyond the given ratings may seriously damage the device. The sensor must be discarded when exceeding these limits.

Parameter	Condition	Min	Max	Unit
Voltage at supply pin	VDD pin	-0.3	4	V
Voltage at supply pin	VDDIO pin	-0.3	4	V
Voltage at any logic pin	non-supply pin	-0.3	VDDIO +0.3	V
Passive storage temp. range	≤ 65% rel. H.	-50	+150	°C
Mechanical shock	duration ≤ 200 µs		10000	g
Mechanical shock	duration ≤1 ms		2000	g
Mechanical shock	Free fall onto hard surfaces		1.8	m
ESD	HBM, any pin		2	kV
ESD	CDM		500	V
ESD	MM		200	V

4.2 Operating Conditions

Parameter	Symbol	Condition	Min	Typical	Max	Unit
Supply voltage internal domains	VDD		2.4	3.3	3.6	V
Supply voltage I/O domain	VDDIO		1.62	3.3	3.6	V
Voltage input low level	V_{IL}				0.3 VDDIO	-
Voltage input high level	V_{IH}		0.7 VDDIO			-
Voltage output low level	V_{OL}	I_{OL} ≤ 2 mA, SPI			0.23 VDDIO	-
Voltage output high level	V_{OH}	I_{OH} ≤ 2 mA, SPI	0.8 VDDIO			-
Operating temperature	T		-40		105	°C

4.3 Lifetime Conditions

Parameter	Condition
Lifetime	according to AEC-Q100 grade 2 requirements

4.4 Accelerometer

Unless otherwise specified, the sensor is configured with the default settings. The measurement range is set to 2 g and the bandwidth is set to 40.5 Hz (100 Hz ODR).

Parameter	Symbol	Condition / Comment	Typical	Max*	Unit
Supply current in Normal mode	I_{DD}	VDD = VDDIO =3.0V, 25°C, g_{FS4g}	150		µA
Supply current in Suspend mode	I_{DDsum}	VDD = VDDIO =3.0V, 25°C	3		µA
Start-up time	$t_{s,up}$	time to first valid sample from suspend mode	1		ms
Measurement range	g_{FS}	selectable	±2 ±4 ±8 ±16		g
Sensitivity	S	g_{FS2g}, T_A=25°C g_{FS4g}, T_A=25°C g_{FS8g}, T_A=25°C g_{FS16g}, T_A=25°C	16384 8192 4096 2048		LSB/g
Sensitivity error		T = 25 °C over lifetime	±1.5		%
Sensitivity error		including temperature and lifetime effects	±2		%
Sensitivity temperature drift	TCS		±0.002		% / K
Zero-g offset		T = 25 °C over lifetime	±20		mg
Zero-g offset		including temperature and lifetime effects	±40		mg
Zero-g offset temperature drift	TCO	nominal VDD supply, over full temperature range	±0.2		mg / K
Output Data Rate	ODR	selectable between	12.5 - 1600		Hz
Bandwidth	BW	3dB cutoff frequency of the accelerometer depends on ODR and OSR	5.06 – 684 (max. 353 for Z axis)		Hz
Nonlinearity	NL	best fit straight line, no life-time	0.5		%FS
Output Noise Density	n_{rms}	T_A = 25 °C, nominal VDD supply no lifetime	120		µg/√Hz
Cross axis sensitivity	S	relative contribution between any two of the three axes	0.5		%
Alignment Error	E_A	relative to package outline	0.5		°
Temperature Sensor Measurement Range			-104…+150		°C
Temperature Sensor Slope			0.125		K/LSB
Temperature Sensor Offset Error		T_A = 25 °C	±1		K

* For specified maximum values, please refer to the Technical Customer Documentation.

4.5 Gyroscope

Unless otherwise specified, the sensor is configured with default settings. The measurement range is set to 2000 °/s and the bandwidth is set to 47 Hz.

Parameter	Symbol	Condition / Comment	Typical	Max*	Unit
Measurement range	R_{FS}	selectable	±125 ±250 ±500 ±1000 ±2000		°/s
Supply current	I_{DD}	w/o SPI communication	5.5		mA
Start-up time	$t_{s,up}$	POR	0.1		s
Sensitivity error		including temperature and lifetime effects	±4		%
Sensitivity error		T = 25 °C over lifetime	±1		%
Sensitivity temperature drift	TCS	nominal VDD supply, over full temperature range	±0.03		% / K
Zero-rate offset		lifetime and temperature effects	±0.5		°/s
Zero-rate offset		T = 25 °C over lifetime	±0.5		°/s
Zero-rate offset temperature drift	TCO	nominal VDD supply, over full temperature range	±0.015		°/s / K
Bandwidth	BW		12, 23, 32, 47, 64, 116, 230, 523 (unfiltered)		Hz
Nonlinearity range: ±125 °/s	NL	best fit straight line, no life-time	0.05		%FS
Noise rms		T = 25 °C, nominal VDD supply no lifetime	0.1		°/s
Temperature sensor slope			0.5		K / LSB
Temperature sensor offset		T = 25 °C	±5		K
Cross axis sensitivity		including temperature and lifetime effects	±2		%

* For specified maximum values, please refer to the Technical Customer Documentation.

5 Software Interface Description

5.1 Serial Peripheral Interface (SPI)

5.1.1 SPI Connection

For communication, the SMI230 supports the SPI 4-wire protocol as a slave with a host device. The connection diagram is shown in Figure 17. The mapping for the interface of both accelerometer and gyroscope is given in the table below:

Pin	Name	Description
15	SDO1	ACC data output
10	SDO2	GYR data output
9	SDx	SDI serial data in
14	CSB1	ACC chip select (enable)
5	CSB2	GYR chip select (enable)
8	SCx	SCK serial clock

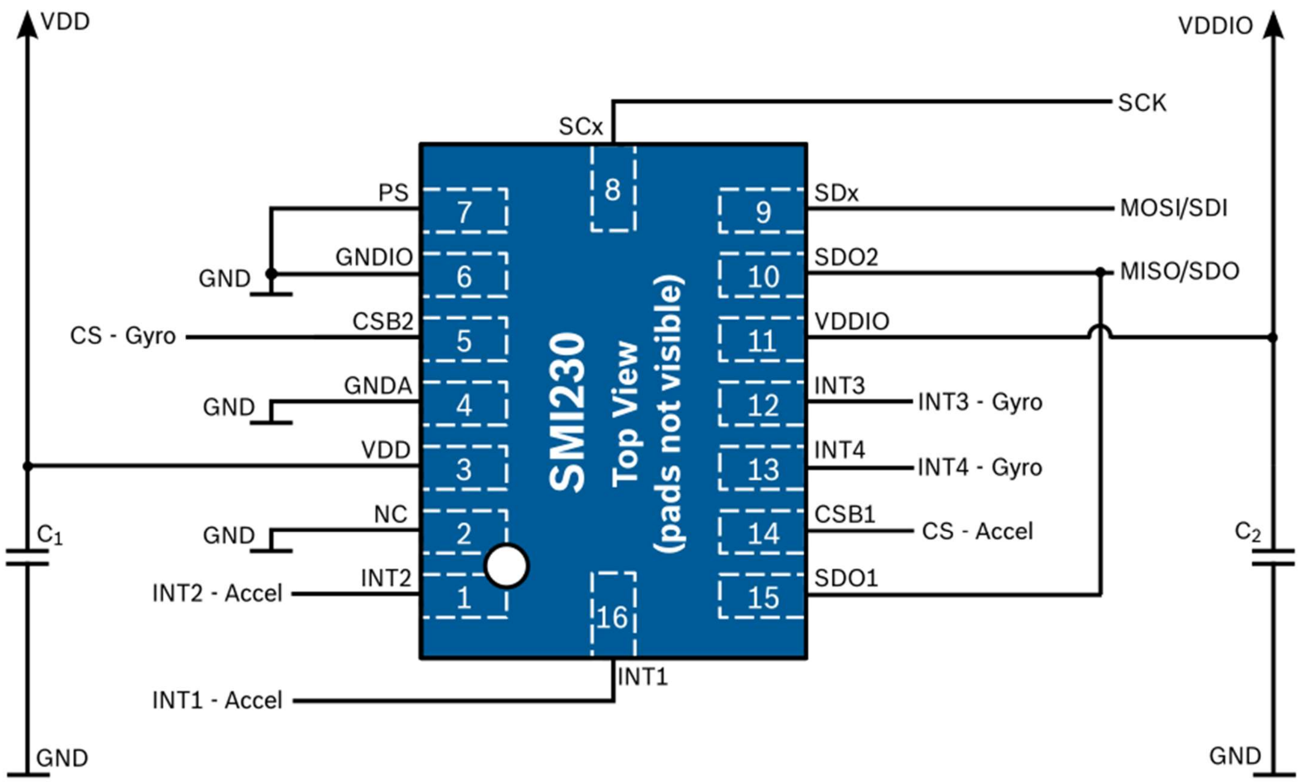

Figure 17 SPI connection diagram

C_1, C_2: 100 nF

INT1, INT2: see register ACC 0x53, 0x54

INT3, INT4: see register GYR 0x16

Note:

For a proper functionality defined voltage levels at SDI, SDO and SCK are required. In case this cannot be guaranteed by the SPI controller, additional pull-up or pull-down resistors are required.

5.1.2 SPI Timing

The SPI timing specification of the SMI230 is given in the following table:

Parameter	Symbol	Condition	Min	Max	Units
Clock frequency	f_{SPI}	max. load on SDI or SDO = 25 pF		10	MHz
SCK low pulse	t_{SCKL}		20		ns
SCK high pulse	t_{SCKH}		48		ns
SDI setup time	t_{SDI_setup}		20		ns
SDI hold time	t_{SDI_hold}		20		ns
SDO output delay	t_{SDO_OD}	load = 25 pF		40	ns
		load = 250 pF, VDDIO = 2.4 V		40	ns
CSB setup time	t_{CSB_setup}		20		ns
CSB hold time	t_{CSB_hold}		40		ns
Idle time between write accesses	$t_{IDLE\_wacc\_nm}$		2		µs

Figure 18 shows the definition of the SPI timing.

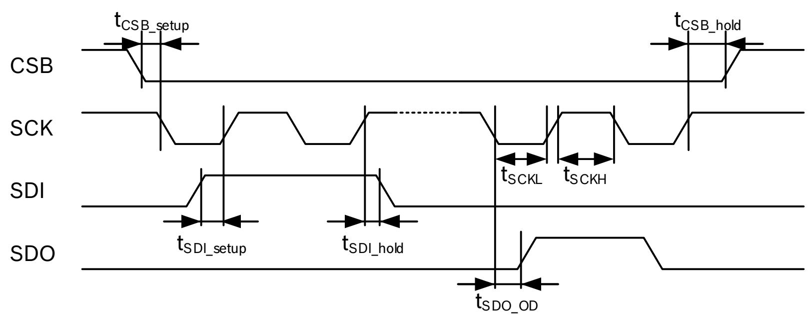

Figure 18 SPI timing diagram

The SPI interface of the SMI230 is compatible with two modes: 00 and 11. The automatic selection between [CPOL = 0 and CPHA = 0] and [CPOL = 1 and CPHA = 1] is controlled based on the value of SCK after a falling edge of CSB (1 or 2). For single byte read as well as write operations, 16 bit protocols are used. The SMI230 also supports multiple-byte read operations (burst-read).

For standard SPI configuration, CSB (1 or 2 - chip select low active), SCK (serial clock), SDI (serial data input), and SDO (1 or 2 - serial data output) pins are used. The communication starts when CSB (1 or 2) is pulled low by the SPI master and stops when CSB (1 or 2) is pulled high. SCK is also controlled by the SPI master. SDI and SDO (1 or 2) are driven at the falling edge of SCK and should be captured at the rising edge of SCK.

The basic write operation waveform for the 4-wire configuration is depicted in Figure 19. During the full write cycle, SDO remains in high-impedance state.

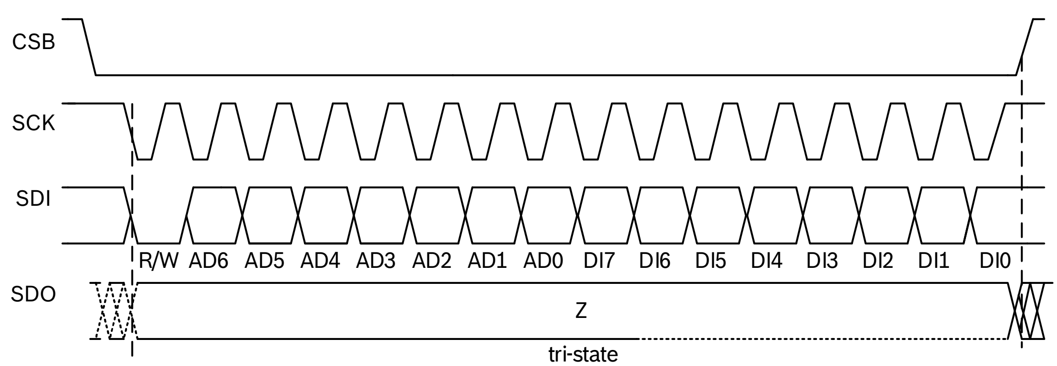

Figure 19 4-wire basic SPI write sequence (mode 11)

The basic read operation waveform for the 4-wire configuration is depicted in Figure 20.

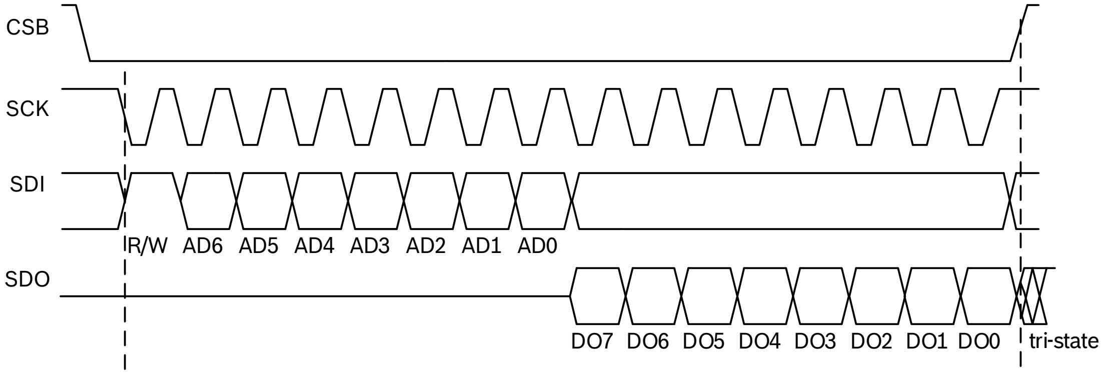

Figure 20 4-wire basic SPI read sequence (mode 11)

The data bits are used as follows:

Bit <15>: Read/write bit. When 0, the data SDI is written into the chip. When 1, the data SDO from the chip is read.

Bits <14:8>: Address AD (6:0)

Bits <7:0>: When in write mode, these bits are the data SDI which will be written into the address. When in read mode, these bits are the data SDO which are read from the address.

Multiple read operations (burst-read) are possible by keeping CSB low and continuing the data transfer. Only the first register address has to be written. Addresses are automatically incremented after each read access as long as CSB stays active low.

The principle of multiple read is shown in Figure 21.

<table>
<tr><td></td><td colspan="8">Control Byte</td><td colspan="8">Data Byte</td><td colspan="8">Data Byte</td><td colspan="8">Data Byte</td><td></td></tr>
<tr><td>Start</td><td>RW</td><td colspan="7">Register address (02h)</td><td colspan="8">Data register – address 02h</td><td colspan="8">Data register – address 03h</td><td colspan="8">Data register – address 04h</td><td>Stop</td></tr>
<tr><td>CSB = 0</td><td>1</td><td>0</td><td>0</td><td>0</td><td>0</td><td>0</td><td>1</td><td>0</td><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td><td>CSB = 1</td></tr>
</table>

Figure 21 SPI multiple read

5.1.3 SPI interface of accelerometer

In case of read operations of the accelerometer part, the **requested data is not sent immediately, but instead first a dummy byte** is sent, and after this dummy byte the actual requested register content is transmitted.

This means that – in contrast to the description in section 5.1.2– a **single byte read operation requires to read 2 bytes in burst mode**, of which the first received byte can be discarded, while the second byte contains the desired data.
The same applies to burst-read operations. For example, to read the accelerometer values in SPI mode, the user has to read 7 bytes, starting from address 0x12 (ACC data). From these bytes the user must discard the first byte and finds the acceleration information in byte #2 – #7 (corresponding to the content of the addresses 0x12 – 0x17).

5.2 Two-wire Interface (TWI)

With some exceptions, the TWI interface of the SMI230 is compatible to the I2C specification UM10204 Rev. 03 (19 June 2007), available at http://www.nxp.com.

- The SMI230 supports the I²C standard and fast mode, but only the 7-bit address mode.
- For VDDIO = 1.2 ... 1.8 V the granted voltage output levels are slightly relaxed compared to the specification.
- The internal data hold time (t_{HDDAT}) of 300 ns is not met under all operation conditions. The device achieves a minimum value of 120 ns across process corners and temperature.
- The minimum data fall time (t_F) of 20 ns cannot be met.
- Only single byte write is supported.
- Detection of a stop condition is not supported. All data transfer protocols are fully operational by means of detecting the start condition only.
- The device does not support the high-impedance mode while VDDIO is tied to GND.
- The device does not perform clock stretching, i.e. clock frequencies may not exceed the one specified in the parameter section and wait times between subsequent write accesses (as specified in section 5.2.2) have to be ensured by the bus master.

5.2.1 TWI Connection

The TWI interface uses SCL (= SCx pin, serial clock) and SDA (= SDx pin, serial data input and output) signal lines. Both lines are connected to VDDIO externally via pull-up resistors so that they are pulled high when the bus is free.

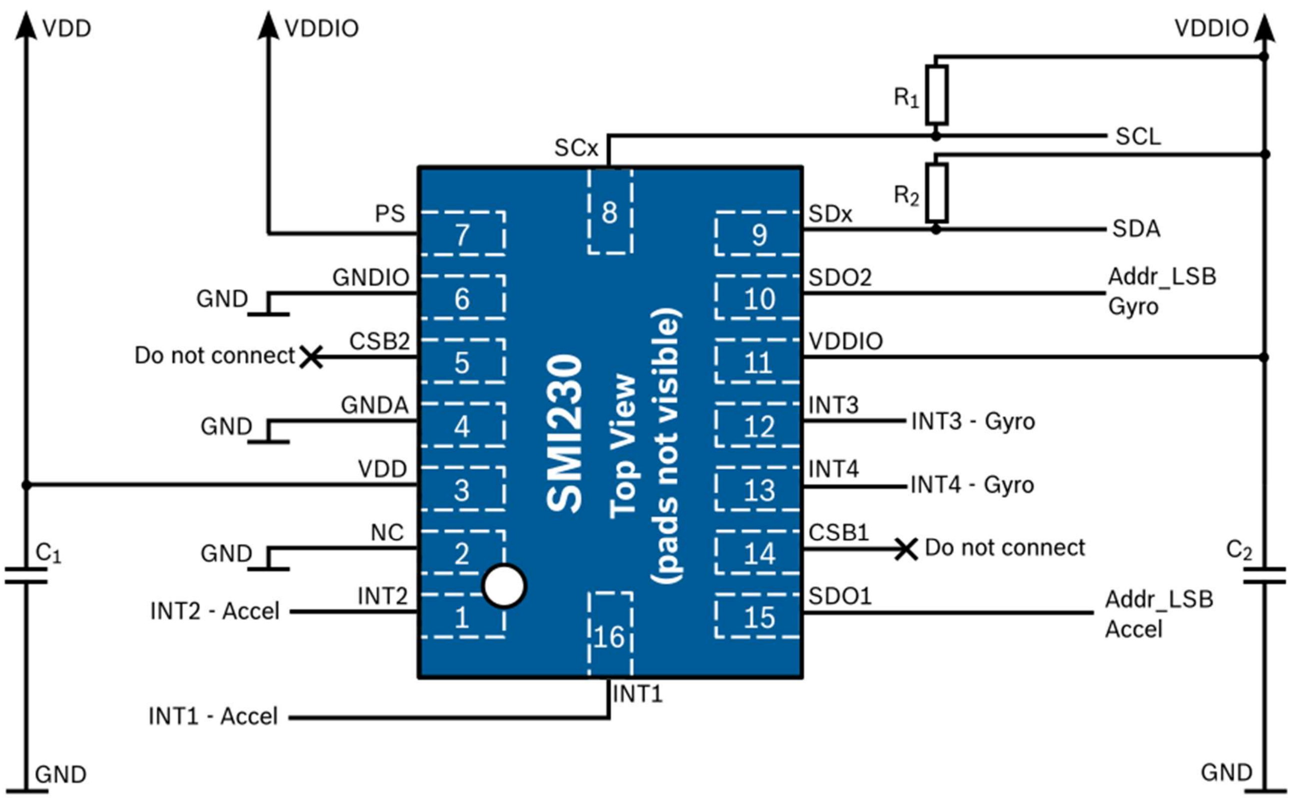

Figure 22 TWI connection diagram

C_1, C_2:	100 nF	R_1, R_2:	pull-up resistors
INT1, INT2: see register GYR 0x16		INT3, INT4: see registers ACC 0x53, 0x54	

SDO1 and SDO2 are used to define the TWI address of accelerometer and gyroscope. The default TWI address of the SMI230 accelerometer is 0x18 and the one of the gyroscope is 0x68. It is used if both SDO pins are pulled to GND. The alternative address is selected by pulling the corresponding SDO pin to VDDIO.

	Accelerometer address	Gyroscope address
SDO1 and SDO2 to GND	0x18 (ACC: 0011000)	0x68 (GYR: 1101000)
SDO1 and/or SDO2 to VDDIO	0x19 (ACC: 0011001)	0x69 (GYR: 1101001)

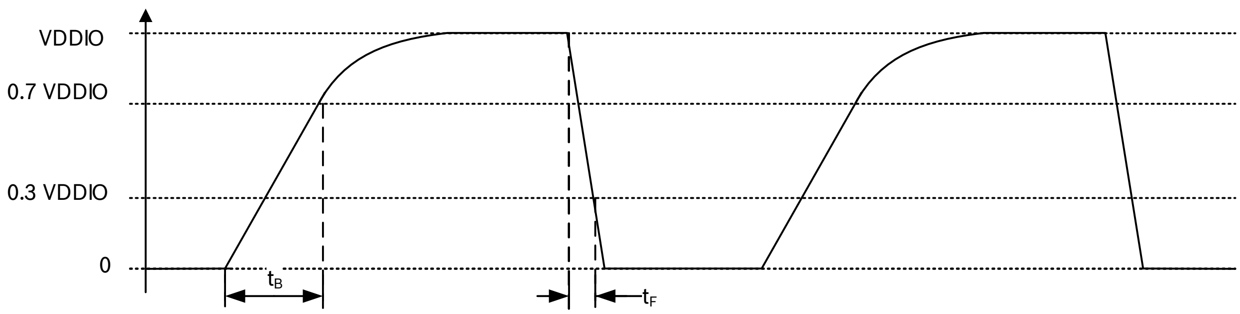

Figure 23 Definition of the rise and fall time of TWI signals

5.2.2 TWI Timing

The TWI timing specification of the SMI230 is given in the table below.

Parameter	Symbol	Min	Max	Units
Clock frequency	f_{SCL}	0	400	kHz
SCL low period	t_{LOW}	1.3		µs
SCL high period	t_{HIGH}	0.6		
SDA setup time	t_{SUDAT}	0.1		
SDA hold time	t_{HDDAT}	0.0		
Setup time for a repeated start condition	t_{SUSTA}	0.6		
Hold time for a start condition	t_{HDSTA}	0.6		
Setup time for a stop condition	t_{SUSTO}	0.6		
Time before a new transmission can start	t_{BUF}	1.3		
Idle time between write accesses normal mode	$t_{IDLE\ wacc\ nm}$	2		
Fall time	t_F	0	300	ns
Rise time (determined by external pull-up resistance)	t_R	20	300	ns

Figure 24 shows the definition of the TWI timing given in the table above.

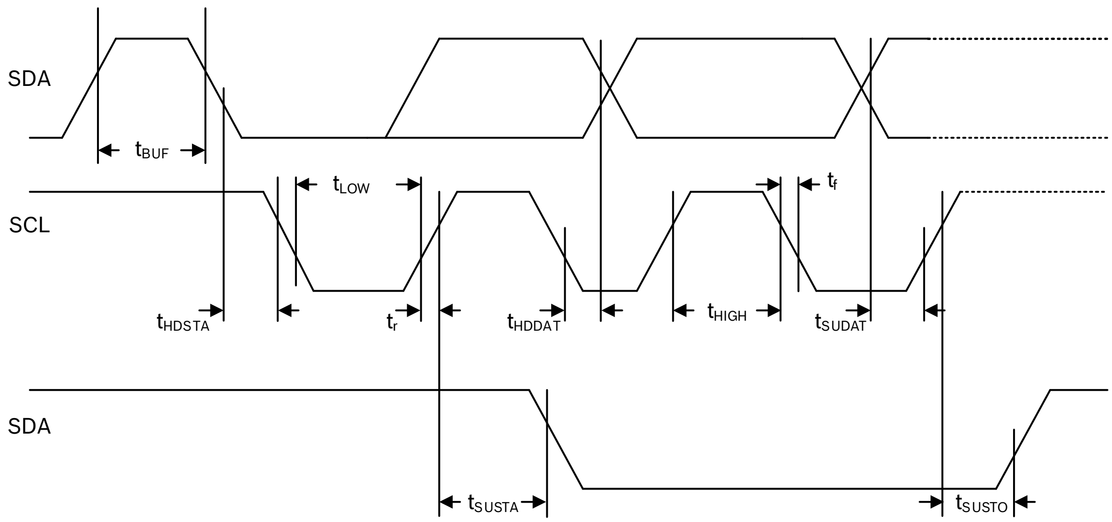

Figure 24 SMI230 TWI timing specification

The TWI protocol works as follows:

Mode	Description
START:	Data transmission on the bus begins with a high to low transition on the SDA line while SCL is held high (start condition (S) indicated by the TWI bus master). Once the start signal is transferred by the master, the bus is considered busy.
STOP:	Each data transfer should be terminated by a stop signal (P) generated by the master. The stop condition is a low to high transition on the SDA line while SCL is held high.
ACK:	Each byte of data transferred must be acknowledged. It is indicated by an acknowledge bit sent by the receiver. The transmitter must release the SDA line (no pull down) during the acknowledge pulse while the receiver must then pull the SDA line low so that it remains stable low during the high period of the acknowledge clock cycle.

In the following diagrams these abbreviations are used:

S	Start	**P**	Stop
ACKS	Acknowledge by slave	**ACKM**	Acknowledge by master
NACKM	Not acknowledge by master	**RW**	Read / Write

A start (S) immediately followed by a stop (P) (without SCL toggling from VDDIO to GND) is not supported and not recognized by the SMI230.

TWI write access can be used to write a data byte in one sequence.

The sequence begins with a start condition generated by the master, followed by 7 bits of the slave address and a write bit (RW = 0). The slave sends an acknowledge bit (ACK = 0) and releases the bus. Then the master sends the one-byte register address. The slave again acknowledges the transmission and waits for the 8 bits of data, which shall be written to the specified register address. After the slave acknowledges the data byte, the master generates a stop signal and terminates the writing protocol. Figure 25 shows an example of a TWI write access to the accelerometer.

										Control Byte									Data Byte									
Start	Slave Address							RW	ACKS	Register Address (0x10)								ACKS	Data (0x09)								ACKS	Stop
S	0	0	1	1	0	0	0	0		0	0	0	1	0	0	0	0		X	X	X	X	X	X	X	X		P

Figure 25 Example of a TWI write access to the accelerometer

TWI read access can be used to read one or multiple data bytes in one sequence.

A read sequence consists of a one-byte TWI write phase followed by the TWI read phase. Both parts of the transmission must be separated by a repeated start condition (Sr). The TWI write phase addresses the slave and sends the register address to be read. After the slave acknowledges the transmission, the master again generates a start condition and sends the slave address together with a read bit (RW = 1). Then the master releases the bus and waits for the data bytes to be read out from the slave. After each data byte, the master has to generate an acknowledge bit (ACK = 0) to enable further data transfer. A NACKM (ACK = 1) from the master stops the data being transferred from the slave. The slave releases the bus so that the master can generate a stop condition and terminate the transmission.

The register address is automatically incremented. Hence, more than one byte can be sequentially read out. Once a new data read transmission starts, the start address will be set to the register address specified in the latest TWI write command. By default, the start address is set as 0x00. In this way, repetitive multi-byte reads from the same starting address are possible.

In order to prevent the TWI slave from locking the TWI bus, a watchdog timer (WDT) is implemented. The WDT observes internal TWI signals and resets the TWI interface if the bus is locked up. The activity and timer period of the WDT can be configured via bits 2 (*i2c_wdt_en*) and 1 (*i2c_wdt_sel*) in register GYR 0x34 (*BGW_SPI3_WDT*).

- Writing 1 (0) to *i2c_wdt_en* activates (de-activates) the WDT.
- Writing 0 (1) to *i2c_wdt_se* sets a timer period of 1 ms (50 ms).

Figure 26 shows an example of a TWI read access to the accelerometer.

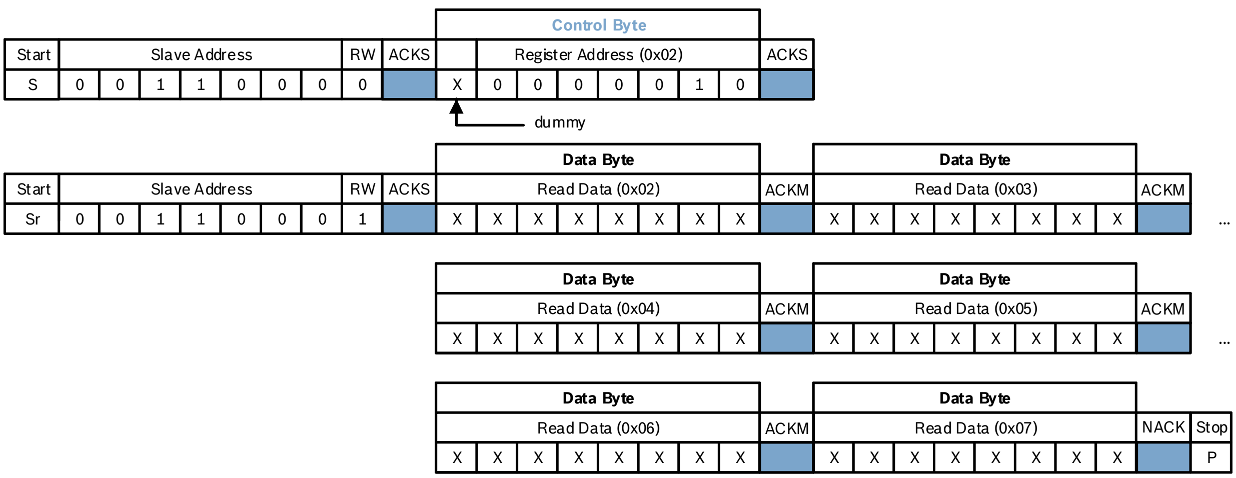

Figure 26 Example of a TWI read access to the accelerometer

Note (Gyroscope Soft Reset):

The SMI230 shows a specific behavior after performing a soft reset of the gyroscope. After carrying out the soft reset, the TWI slave is reset. This releases the bus before completing the command and a NACK is sent instead of an ACK. The user may ignore the first NACK after a soft reset of the gyroscope.

5.3 Access Restrictions (SPI and TWI)

In order to allow for the correct internal synchronization of data written to the SMI230, certain access restrictions apply for consecutive write accesses or a write/read sequence through the SPI and TWI interface.

As illustrated in Figure 27, an interface idle time of at least 2 µs is required following a write operation when the device operates.

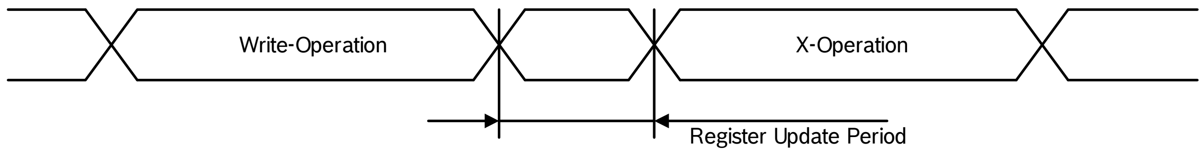

Figure 27 Post-write access timing constraints

6 Application Details

In Figure 28 the basic flow chart for the sensor application is shown. Three different categories of functional elements are shown:

- Required: these blocks are mandatory for a proper sensor functionality and retrieving data (e.g. read data)
- Recommended: these blocks are useful to detect potential sensor failure and to allow further configuration of the sensor (e.g. self-test, sensor setup)
- Optional: depending on the customer specific application, these blocks might be required (e.g. interrupt configuration)

The functional elements are described in the following sections. Proper function of the sensor in the overall system must be validated by the customer.

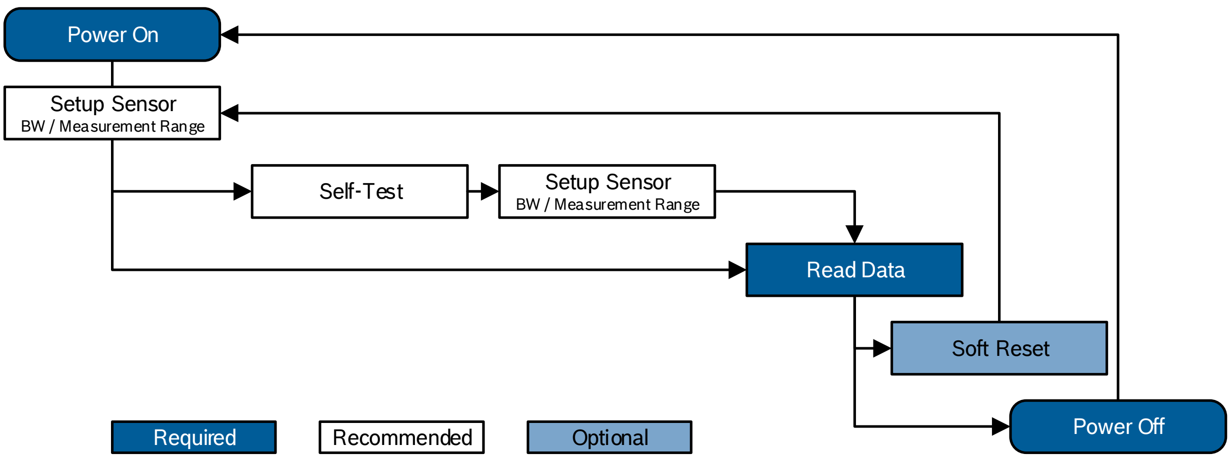

Figure 28 Basic flow chart for SMI230 application with key functional elements

6.1 Sensor Setup

The basic sensor setup includes selection of the bandwidth and measurement range for accelerometer and gyroscope.

6.1.1 Accelerometer

The **bandwidth** (and thus the 3db cutoff frequency) of the digital low-pass filter depends on the chosen ODR as well as on the over-sampling-ratio (OSR). Both can be configured in register ACC 0x40 (*ACC_CONF*). The following table lists the possible options:

Accelerometer ODR [Hz]	3dB cutoff frequency [Hz]		
	Normal	OSR = 2	OSR = 4
12.5	5.06	3	1
25	10.12	5	3
50	20.25	10	5
100	40.5	20	10
200	80	41	20
400	162 (155 for Z channel)	80	41
800	324 (252 for Z channel)	162 (155 for Z channel)	80
1600	684 (353 for Z channel)	324 (262 for Z channel)	162

The acceleration measurement **range** can be selected via bits <1:0> (*acc_range*) in register ACC 0x41 (*ACC_RANGE*) according to the table below.

acc_range <1:0>	Measurement Range	Resolution
00	± 2 g	16384 LSB/g
01	± 4 g	8192 LSB/g
10	± 8 g	4096 LSB/g
11	± 16 g	2048 LSB/g

6.1.2 Gyroscope

The **bandwidth** of filtered rate data is determined by setting bits <3:0> (*bw*) in register GYR 0x10 (*BW*) as shown in the following table.

bw <3:0>	Filter Bandwidth [Hz]	ODR [Hz]	Decimation Factor
0111	32	100	20
0110	64	200	10
0101	12	100	20
0100	23	200	10
0011	47	400	5
0010	116	1000	2
0001	230	2000	0
0000	523 (unfiltered)	2000	0
1xxx	reserved	reserved	reserved

The rate measurement **range** can be selected via bits <2:0> (*range*) in register GYR 0x0F (*RANGE*) according to the table below.

range <2:0>	Measurement Range	Resolution
000	±2000 °/s	16.38 LSB/°/s
001	±1000 °/s	32.77 LSB/°/s
010	±500 °/s	65.54 LSB/°/s
011	±250 °/s	131.07 LSB/°/s
100	±125 °/s	262.14 LSB/°/s
others	reserved	-

6.2 Device Initialization

For a proper device initialization, the following steps need to be considered:

- The user must decide on the interface (I2C or SPI) already during hardware design: with the PS pin the user determines which interface the sensor should listen to.
- The gyroscope part of the SMI230 initializes its I/O pins according to the selection given by the PS pin.
  The accelerometer part starts in I2C mode. It will stay in I2C mode until it detects a rising edge on the CSB1 pin (chip select of the accelerometer), on which the accelerometer part switches to SPI mode and stays in this mode until the next power-on-reset (POR). To change the sensor to SPI mode in the initialization phase, the user has to perform a dummy SPI read or write operation, e.g. reading of register ACC_CHIP_ID. Any obtained value will be invalid.
- After the POR the gyroscope is in normal mode, while the accelerometer is in suspend mode. To switch the accelerometer into normal mode, the user must perform the following steps:
  a. Power up the sensor.
  b. Wait 1 ms.
  c. Enter normal mode by writing ‘4’ to ACC_PWR_CTRL.
  d. Wait for 5 ms.

6.3 Self-test

6.3.1 Accelerometer

The self-test feature allows for checking the sensor functionality by applying electrostatic forces to the sensor core instead of external accelerations. By physically deflecting the seismic mass, the entire signal path of the sensor is tested. Activation of the self-test results in a static offset in the acceleration data. Any external acceleration or gravitational force that is applied to the sensor during a self-test will be observed in the sensor output as a superposition of the acceleration and the self-test signal.

The recommended self-test procedure is as follows:

1) Set ±16 g range by writing 0x03 to register ACC_RANGE (0x41)
2) Set ODR=1.6 kHz, continuous sampling mode, “normal mode” (norm_avg4) by writing 0xAC to register ACC_CONF (0x40)
3) Wait for > 2 ms
4) Enable the positive self-test polarity by writing 0x0D to register ACC_SELF_TEST (0x6D)
5) Wait for > 50 ms
6) Read the accelerometer offset values for each axis (positive self-test response)
7) Enable the negative self-test polarity by writing 0x09 to register ACC_SELF_TEST (0x6D)
8) Wait for > 50 ms
9) Read the accelerometer offset values for each axis (negative self-test response)
10) Disable the self-test by writing 0x00 to register ACC_SELF_TEST (0x6D)
11) Calculate the difference of positive and negative self-test response and compare with the expected values (see table below)
12) Wait for > 50 ms to let the sensor settle to normal mode steady state operation

The minimum difference for each axis is shown in the table below. The measured signal differences can be significantly larger.

	x-axis	y-axis	z-axis
minimum difference signal	1000 mg	1000 mg	500 mg

After performing a self-test, a reset of the device is recommended. If the reset cannot be performed, the following sequence must be kept to prevent unwanted interrupt generation:

A. Disable interrupts
B. Change parameters of interrupts
C. Wait for at least 50 ms
D. Enable desired interrupts

Note: An external stimulus during the self-test procedure might lead to wrong sensor reading for the specific axis. This might result in a failure of the self-test. A repetition of the self-test is recommended in this case.

6.3.2 Gyroscope

A built-in self-test (BIST) has been implemented, which provides a quick way to determine if the gyroscope is operational within the specifications.

The BIST uses three parameters for the evaluation of proper device operation:

- Drive voltage regulator
- Sense frontend offset regulator of x-, y- and z-channel
- Quad regulator for x-, y- and z-channel

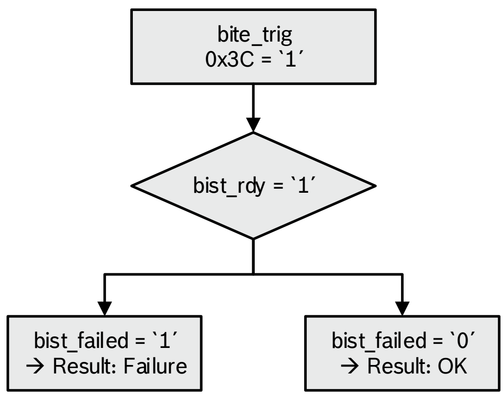

Figure 29 SMI230 BIST sequence

If any of the three parameters is not within the limits, the BIST results in a ‘fail’.

To trigger the BIST, set bit 0 (*trig_bist*) in register GYR 0x3C (*BIST*) to 1.

Two bits (read-only) have to be checked in register GYR 0x3C (*BIST*):

- bit 1(*bist_rdy*)
- bit 2 (*bist_fail*)

bist_rdy = 1 indicates that a test was performed. *bist_fail* contains the result of the BIST. *bist_fail* = 1 corresponds to a ‘fail’.

A simple option to check for the sensor status is to read out bit 4 (*rate_ok*) in register GYR 0x3C (*BIST*). No trigger is needed for this, and proper sensor function is indicated by a 1.

A waiting time of 50 ms is mandatory after enabling the self-test.

Note: In contrast to the self-test of the accelerometer, the BIST of the gyroscope is fully decoupled from the sensing element. This means that the MEMS element is not deflected, and the current state of the MEMS element (e.g. its orientation) has no influence on the result of the BIST.

6.4 Interrupt Engine

6.4.1 New Data Interrupt

Both accelerometer and gyroscope part offer a new data ready interrupt, which fires whenever a new data sample set is complete and made available in the corresponding sensor data registers. This allows a low latency data readout.

6.4.1.1 Acceleration

The new data interrupt flag can be found in the register ACC_INT_STAT_1 (bit #7). It is set whenever new data is available in the data registers and cleared automatically.

The interrupt can be mapped to the interrupt pins INT1 and/or INT2 in register INT1_INT2_MAP_DATA.

Both interrupt pins INT1 and INT2 can be configured regarding their electrical behavior (see INT1_IO_CONF and INT2_IO_CONF).

6.4.1.2 Gyroscope

The gyroscope provides a new data interrupt, which will generate an interrupt every time after storing a new value of z-axis angular rate data in the data register. The interrupt is cleared automatically after 280-400 μs.

In contrast to the accelerometer part, for the gyro the new data interrupt must be explicitly enabled by writing 0x80 to the register GYRO_INT_CTRL.

The interrupt can be mapped to the interrupt pins INT3 and/or INT4 in register INT3_INT4_IO_MAP.

Both interrupt pins INT3 and INT4 can be configured regarding their electrical behavior (see INT3_INT4_IO_CONF).

6.5 Reading Data

6.5.1 Accelerometer

For each axis the sensor output is stored as signed 16-bit number in 2's complement format in each 2 registers, split into a MSB upper part (bits <15:8> of acceleration data) and a LSB lower part (bits <7:0> of acceleration data). From the registers, the acceleration values can be calculated as follows:

Accel_X_int16 = ACC_X_MSB * 256 + ACC_X_LSB
Accel_Y_int16 = ACC_Y_MSB * 256 + ACC_Y_LSB
Accel_Z_int16 = ACC_Z_MSB * 256 + ACC_Z_LSB

An example for the range setting of ±2 g is shown in the table below.

LSB	1111 1111		0000 0000		0000 0000
MSB	0111 1111		0000 0000		1000 0000
LSB + MSB [bin]	0111 1111 1111 1111		0000 0000 0000 0000		1000 0000 0000 0000
LSB + MSB [dec]	+32767	...	0	...	-32768
Acceleration value	+2 g	...	0 g	...	-2 g

When a register is read containing the LSB value of an acceleration value, the corresponding MSB register is locked internally, until it is read. By this mechanism, it is ensured that both LSB and MSB values belong to the same acceleration value and are not updated between the readouts of the individual registers. Therefore is recommended to always start reading out the LSB register first followed by the corresponding MSB register. Acceleration data may be read from register LSB and/or MSB at any time except during power-up.

6.5.2 Gyroscope

For each axis the sensor output is stored as signed 16-bit number in 2's complement format in each 2 registers, split into a MSB upper part (bits <15:8> of rate data) and a LSB lower part (bits <7:0> of rate data). From the registers, the acceleration values can be calculated as follows:

Rate_X_int16: RATE_X_MSB * 256 + RATE_X_LSB
Rate_Y_int16: RATE_Y_MSB * 256 + RATE_Y_LSB
Rate_Z_int16: RATE_Z_MSB * 256 + RATE_Z_LSB

An example for the range setting of ±125 °/s is shown in the table below.

LSB	1111 1111		0000 0000		0000 0000
MSB	0111 1111		0000 0000		1000 0000
LSB + MSB [bin]	0111 1111 1111 1111		0000 0000 0000 0000		1000 0000 0000 0000
LSB + MSB [dec]	+32767	...	0	...	-32768
Angular rate value	+125 °/s	...	0 °/s	...	-125 °/s

When a register is read containing the LSB value of a rate value, the corresponding MSB register is locked internally, until it is read. By this mechanism, it is ensured that both LSB and MSB values belong to the same rate value and are not updated between the readouts of the individual registers. Therefore is recommended to always start reading out the LSB register first followed by the corresponding MSB register. Rate data may be read from register LSB and/or MSB at any time except during power-up.

6.5.3 Temperature Sensor

The temperature sensor data is stored in an 11-bit value in 2's complement format in 2 registers, split into a MSB upper part (bits <10:3> of temperature data) and a LSB lower part (bits <2:0> of temperature data). The resolution is 0.125 °C / LSB, the temperature values can be calculated as follows:

```
Temp_uint11 = (TEMP_MSB * 8) + (TEMP_LSB / 32)
if Temp_uint11 > 1023:
        Temp_int11 = Temp_uint11 – 2048
else:
     Temp_int11 = Temp_uint11
Temperature = Temp_int11 * 0,125°C/LSB + 23°C
```

An example for the temperature values is shown in the table below.

LSB	111x xxxx		000x xxxx		000x xxxx	xxxx xxxx
MSB	0111 1111		0000 0000		1000 0001	1000 000
LSB + MSB [bin]	0111 1111 111		0000 0000 000		1000 0001 000	1000 0000 xxx
LSB + MSB [dec]	+1023	...	0	...	-1016	-1017...-1024
Temperature value	+150 °C	...	23 °C	...	-104 °C	Invalid

Note: If the MSB register of the temperature data is 0x80, regardless the value of the LSB register, the temperature value is invalid.

The temperature sensor data is updated every 1.28 s.

6.6 Soft Reset

A soft reset causes all user configuration settings to be overwritten with their default value and the sensor to enter normal mode. A waiting time of 30 ms after a soft reset of the SMI230 accelerometer and gyroscope is recommended.

6.6.1 Accelerometer

A soft reset is initiated by writing the value 0xB6 to register ACC 0x7E (ACC_*SOFTRESET*).

6.6.2 Gyroscope

A soft reset is initiated by writing the value 0xB6 to register GYR 0x14 (*GYRO_SOFTRESET*).

6.7 Register Description Accelerometer

6.7.1 Accelerometer - Register Map

The following table shows the register map of the SMI230 accelerometer.

Reg. Addr.	Register Name	Reset Value	bit7	bit6	bit5	bit4	bit3	bit2	bit1	bit0
0x7E	ACC_SOFTRESET	0x00	softreset_cmd (0xb6)							
0x7D	ACC_PWR_CTRL	0x00	acc_enable							
0x7C	ACC_PWR_CONF	0x03	pwr_save_mode							
0x6D	ACC_SELF_TEST	0x00	acc_self_test							
0x58	INT_MAP_DATA	0x00		int2_drdy				int1_drdy		
0x54	INT2_IO_CTRL	0x00				int2_in	int2_out	int2_od	int2_lvl	
0x53	INT1_IO_CTRL	0x00				int1_in	int1_out	int1_od	int1_lvl	
0x41	ACC_RANGE	0x01							acc_range	
0x40	ACC_CONF	0xA8	1	acc_bwp			acc_odr			
0x23	TEMP_LSB	0x00	temperature[2:0]							
0x22	TEMP_MSB	0x00	temperature[10:3]							
0x1D	ACC_INT_STAT_1	0x00	acc_drdy_int							
0x1A	SENSORTIME_2	0x00	sensor_time[23:16]							
0x19	SENSORTIME_1	0x00	sensor_time[15:8]							
0x18	SENSORTIME_0	0x00	sensor_time[7:0]							
0x17	ACC_Z_MSB	0x00	acc_z[15:8]							
0x16	ACC_Z_LSB	0x00	acc_z[7:0]							
0x15	ACC_Y_MSB	0x00	acc_y[15:8]							
0x14	ACC_Y_LSB	0x00	acc_y[7:0]							
0x13	ACC_X_MSB	0x00	acc_x[15:8]							
0x12	ACC_X_LSB	0x00	acc_x[7:0]							
0x03	ACC_STATUS	0x10	acc_drdy							
0x02	ACC_ERR_REG	0x00				error_code				fatal_err
0x00	ACC_CHIP_ID	0x1F	acc_chip_id							

(light grey)	read / write
(dark grey)	write only
(blue)	read only
(white)	reserved

The entire communication with the device is performed by reading from and writing to registers. Registers have a width of 8 bits and are mapped to 8-bit address space. Within this range some registers are either completely or partially marked as ‘reserved’. Any reserved bit is ignored when it is written and no specific value is guaranteed when the bit is read. It is recommended not to use registers which are completely marked as ‘reserved’. Furthermore, it is recommended to mask out (logical and with zero) reserved bits of registers which are partially marked as ‘reserved’.

Registers with addresses from ACC 0x00 up to ACC 0x23 are read-only. Any attempt to write to these registers will be ignored. There are bits within some registers which trigger internal sequences. These bits are configured for write-only access and read as 0. An example for such a write-only access is the entire register ACC 0x7E (ACC_*SOFTRESET*).

6.7.2 ACC Register 0x00 (*ACC_CHIP_ID*)

This register contains the chip identification code.

0x00	***ACC_CHIP ID***							
Bit	7	6	5	4	3	2	1	0
Read/Write	R	R	R	R	R	R	R	R
Reset Value	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Content	*chip_id* <7:0>							

Register	**Description**
chip_id <7:0>	Fixed value 10001111 = 1F

6.7.3 ACC Register 0x02 (*ACC_ERR_REG*)

This register contains the error conditions of SMI230.

0x02	***ACC_ERR_REG***							
Bit	7	6	5	4	3	2	1	0
Read/Write	R	R	R	R	R	R	R	R
Reset Value	n/a	n/a	n/a	0	0	0	n/a	0
Content				*error_code*				*fatal_err*

Register	**Description**
error_code <4:2>	Error codes for persistent errors: 000: no error 001: error occurred in accelerometer configuration (invalid data in register ACC_CONF)
fatal_err <0>	0: no error 1: fatal error, chip is not in operation state. Reset by POR or soft-reset.
undefined	Random data, to be ignored

6.7.4 ACC Register 0x03 (*ACC_STATUS*)

This register contains the data ready flag of acceleration registers.

0x03	***ACC_ERR_REG***							
Bit	7	6	5	4	3	2	1	0
Read/Write	R	R	R	R	R	R	R	R
Reset Value	0	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Content	acc_drdy							

Register	**Description**
acc_drdy <7>	0: acceleration data is being updated 1: data ready for accelerometer. Reset when one acceleration data register is read out
undefined	Random data, to be ignored

6.7.5 ACC Register 0x12 (*ACC_X_LSB*)

This register contains the least significant bits of x-channel acceleration readout.

0x12	ACC_X_LSB							
Bit	7	6	5	4	3	2	1	0
Read/Write	R	R	R	R	R	R	R	R
Reset Value	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Content	*acc_x_lsb* <7:0>							

Register	Description
acc_x_lsb <7:0>	Least significant 8 bits of acceleration x-channel read-back value (two's complement format)

6.7.6 ACC Register 0x13 (*ACC_X_MSB*)

This register contains the most significant bits of x-channel acceleration readout value.

0x13	ACC_X_MSB							
Bit	7	6	5	4	3	2	1	0
Read/Write	R	R	R	R	R	R	R	R
Reset Value	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Content	*acc_x_msb* <15:8>							

Register	Description
acc_x_msb <15:8>	Most significant 8 bits of acceleration x-channel read-back value (two's complement format)

6.7.7 ACC Register 0x14 (*ACC_Y_LSB*)

This register contains the least significant bits of y-channel acceleration readout value.

0x14	ACC_Y_LSB							
Bit	7	6	5	4	3	2	1	0
Read/Write	R	R	R	R	R	R	R	R
Reset Value	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Content	*acc_y_lsb* <7:0>							

Register	Description
acc_y_lsb <7:0>	Least significant 8 bits of acceleration y-channel read-back value (two's complement format)

6.7.8 ACC Register 0x15 (*ACC_Y_MSB*)

This register contains the most significant bits of y-channel acceleration readout value.

0x15	ACC_Y_MSB							
Bit	7	6	5	4	3	2	1	0
Read/Write	R	R	R	R	R	R	R	R
Reset Value	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Content	*acc_y_msb* <15:8>							

Register	Description
acc_y_msb <15:8>	Most significant 8 bits of acceleration y-channel read-back value (two's complement format)

6.7.9 ACC Register 0x16 (*ACC_Z_LSB*)

This register contains the least significant bits of z-channel acceleration readout value.

0x16	*ACC_Z_LSB*							
Bit	7	6	5	4	3	2	1	0
Read/Write	R	R	R	R	R	R	R	R
Reset Value	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Content	*acc_z_lsb* <7:0>							

Register	Description
acc_z_lsb <7:0>	Least significant 8 bits of acceleration z-channel read-back value (two's complement format)

6.7.10 ACC Register 0x17 (*ACC_Z_MSB*)

This register contains the most significant bits of z-channel acceleration readout value.

0x17	*ACC_Z_MSB*							
Bit	7	6	5	4	3	2	1	0
Read/Write	R	R	R	R	R	R	R	R
Reset Value	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Content	*acc_z_msb* <15:8>							

Register	Description
acc_z_msb <15:8>	Most significant 8 bits of acceleration z-channel read-back value (two's complement format)

6.7.11 ACC Register 0x18 (*SENSORTIME_0*)

This register contains the lower 8 bits value of the internal 24-bit counter. This register is incremented every 39.0625 µs.

0x18	*SENSORTIME_0*							
Bit	7	6	5	4	3	2	1	0
Read/Write	R	R	R	R	R	R	R	R
Reset Value	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Content	*sensortime_0* <7:0>							

Register	Description
sensortime_0 <7:0>	Lower 8 bits of internal counter

6.7.12 ACC Register 0x19 (*SENSORTIME_1*)

This register contains the middle 8 bits value of the internal 24-bit counter. This register is incremented on SENSORTIME_0 overflow, which is every 10 ms.

0x19	*SENSORTIME_1*							
Bit	7	6	5	4	3	2	1	0
Read/Write	R	R	R	R	R	R	R	R
Reset Value	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Content	*sensortime_1* <15:8>							

Register	Description
sensortime_1 <15:8>	Middle 8 bits of internal counter

6.7.13 ACC Register 0x1A (*SENSORTIME_2*)

This register contains the higher 8 bits value of the internal 24-bit counter. This register is incremented on SENSORTIME_1 overflow, which is every 2.56 s.

0x1a	*SENSORTIME_2*							
Bit	7	6	5	4	3	2	1	0
Read/Write	R	R	R	R	R	R	R	R
Reset Value	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Content	*sensortime_2* <23:16>							

Register	Description
sensortime_2 <23:16>	Higher 8 bits of internal counter

6.7.14 ACC Register 0x1D (*ACC_INT_STAT_1*)

This register contains the new data interrupt status.

0x1d	*ACC_ERR_REG*							
Bit	7	6	5	4	3	2	1	0
Read/Write	R	R	R	R	R	R	R	R
Reset Value	0	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Content	acc_drdy_int							

Register	Description
acc_drdy_int <7>	0: acceleration data ready interrupt inactive 1: acceleration data ready interrupt active. Cleared on read of this register.
undefined	Random data, to be ignored

6.7.15 ACC Register 0x22 (*TEMP_MSB*)

This register contains the most significant 8 bits of the 11-bit internal temperature sensor.

0x22	*TEMP_MSB*							
Bit	7	6	5	4	3	2	1	0
Read/Write	R	R	R	R	R	R	R	R
Reset Value	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Content	*temp_msb* <10:3>							

Register	Description
temp_msb <10:3>	Most significant 8 bits of temperature channel (two's complement format)

6.7.16 ACC Register 0x23 (*TEMP_LSB*)

This register contains the most significant 8 bits of the 11-bit internal temperature sensor.

0x23	*TEMP_LSB*							
Bit	7	6	5	4	3	2	1	0
Read/Write	R	R	R	R	R	R	R	R
Reset Value	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Content	*temp_lsb* <2:0>							

Register	Description
temp_lsb <2:0>	Least significant 3 bits of temperature channel (two's complement format
undefined	Random data, to be ignored

6.7.17 ACC Register 0x40 (*ACC_CONF*)

This register contains accelerometer BW and ODR configuration.

0x40	***ACC_CONF***							
Bit	7	6	5	4	3	2	1	0
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Reset Value	1	0	1	0	1	0	0	0
Content	*reserved*	*acc_bwp*			*acc_odr*			

Register	**Description**
reserved <7>	This bit must always be '1'.
acc_bwp <6:4>	This parameter influences the bandwidth of the accelerometer low pass filter.

acc_bwp	**filter setting**
000	OSR4 (4-fold oversampling)
001	OSR2 (2-fold oversampling)
010	Normal
011…111	*reserved*

Register	**Description**
acc_odr <3:0>	This parameter sets the output data rate ODR.

acc_odr	**ODR in Hz**
0000…0100	*reserved*
0101	12.5
0110	25
0111	50
1000	100
1001	200
1010	400
1011	800
1100	1600
1101…1111	*reserved*

6.7.18 ACC Register 0x41 (*ACC_RANGE*)

This register allows for the selection of the accelerometer g-range.

0x41	***ACC_RANGE***							
Bit	7	6	5	4	3	2	1	0
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Reset Value	n/a	n/a	n/a	n/a	n/a	n/a	0	1
Content	*reserved*						*acc_range* <1:0>	

Register	**Description**
acc_range <1:0>	Selection of the accelerometer g-range

***range* <1:0>**	**g-range**	**Resolution [LSB / g]**
00	±2 g	16384
01	±4 g	8192
10	±8 g	4096
11	±16 g	2048

Register	**Description**
reserved	write 0

6.7.19 ACC Register 0x53 (*INT1_IO_CONF*)

This register allows for the configuration of the input/output pin INT1.

0x53	*INT1_IO_CONF*							
Bit	7	6	5	4	3	2	1	0
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Reset Value	0	0	0	0	0	0	0	0
Content	*reserved*			*int1_in*	*int1_out*	*int1_od*	*int1_lvl*	*reserved*

Register	**Description**
reserved <7:5>	write 0
int1_in	enable INT1 as input pin
int1_out	enable INT1 as output pin
int1_od	configures pin behavior of INT1 pin 0: push-pull 1: open-drain
int1_lvl	configures active state of INT1 pin 0: active low 1: active high
reserved <0>	write 0

6.7.20 ACC Register 0x54 (*INT2_IO_CONF*)

This register allows for the configuration of the input/output pin INT1.

0x54	*INT2_IO_CONF*							
Bit	7	6	5	4	3	2	1	0
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Reset Value	0	0	0	0	0	0	0	0
Content	*reserved*			*int2_in*	*int2_out*	*int2_od*	*int2_lvl*	*reserved*

Register	**Description**
reserved <7:5>	write 0
int2_in	enable INT2 as input pin
int2_out	enable INT2 as output pin
int2_od	configures pin behavior of INT2 pin 0: push-pull 1: open-drain
int2_lvl	configures active state of INT2 pin 0: active low 1: active high
reserved <0>	write 0

6.7.21 ACC Register 0x58 (*INT1_INT2_MAP_DATA*)

This register controls the data ready interrupt signals to be mapped to output pin INT1 and/or INT2.

0x58	*INT1_INT2_MAP_DATA*							
Bit	7	6	5	4	3	2	1	0
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Reset Value	0	0	0	0	0	0	0	0
Content	*reserved*	*int2_drdy*	*reserved*			*int1_drdy*	*reserved*	

Register	Description
reserved <7>	write 0
int2_drdy <6>	map data ready interrupt to pin INT2
reserved <5:3>	write 0
int1_drdy <2>	map data ready interrupt to pin INT1
reserved <1:0>	write 0

6.7.22 ACC Register 0x6D (*ACC_SELF_TEST*)

This register enables the sensor self-test signal, occurring as a steady offset to the sensor output. Note that the self-test needs to be switched off actively by the user.

0x6d	*ACC_SELF_TEST*							
Bit	7	6	5	4	3	2	1	0
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Reset Value	0	0	0	0	0	0	0	0
Content	*acc_self_test*							

Register	Description
acc_self_test <7:0>	enable or disable self-test 0x00: self-test is switched off 0x0D: enable positive self-test signal 0x09: enable negative self-test signal

6.7.23 ACC Register 0x7C (*ACC_PWR_CONF*)

This register enables the accelerometer to be switched into suspend mode for saving power. In this mode the data acquisition is stopped.

0x7c	*ACC_PWR_CONF*							
Bit	7	6	5	4	3	2	1	0
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Reset Value	0	0	0	0	0	0	1	1
Content	*acc_pwr_save*							

Register	Description
acc_pwr_save <7:0>	switches the accelerometer into suspend or normal mode 0x03: suspend mode 0x00: normal mode

6.7.24 ACC Register 0x7D (*ACC_PWR_CTRL*)

This register enables the accelerometer to be switched on or off. Required to do after every reset in order to obtain acceleration values.

0x7d	*ACC_PWR_CTRL*							
Bit	7	6	5	4	3	2	1	0
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Reset Value	0	0	0	0	0	0	0	0
Content	*acc_pwr_ctrl*							

Register	Description
acc_pwr_ctrl <7:0>	switches the accelerometer on or off 0x00: accelerometer off 0x04: accelerometer on

6.7.25 ACC Register 0x7E (*ACC_SOFTRESET*)

This register controls the user triggered reset of the sensor.

0x7E	*ACC_SOFTRESET*							
Bit	7	6	5	4	3	2	1	0
Read/Write	W	W	W	W	W	W	W	W
Reset Value	0	0	0	0	0	0	0	0
Content	*softreset*							

Register	Description
softreset	Writing 0xB6 to the register triggers a reset. Other values are ignored. After a delay, all user configuration settings are overwritten with their default values. Please note that all application specific settings which are not equal to the default settings must be reconfigured to their designated values.

6.8 Register Description Gyroscope

The following table shows the register map of the SMI230 gyroscope.

Reg. Addr.	Register Name	Reset Value	bit7	bit6	bit5	bit4	bit3	bit2	bit1	bit0
0x3C	BIST	0x00				rate_ok		bist_fail	bist_rdy	trig_bist
0x34	BGW_SPI3_WDT	0x00						I2c_wdt_en	I2c_wdt_sel	
0x18	INT_MAP_1	0x00	int4_data							int3_data
0x16	INT_EN_1	0x0F					Int4_od	Int4_lvl	int3_od	int3_lvl
0x15	INT_EN_0	0x00	data_en							
0x14	BGW_SOFTRESET	0x00	softreset_cmd (0xb6)							
0x13	RATE_HBW	0x00	data_high_bw	shadow_dis						
0x11	GYRO_LPM1	0x00	power_mode [7:4]							
0x10	BW	0x80					bw [3:0]			
0x0F	RANGE	0x00						range [2:0]		
0x0A	INT_STATUS_1	0x00	data_int							
0x08	TEMP	0x00	temp [7:0]							
0x07	RATE_Z_MSB	0x00	rate_z_msb [15:8]							
0x06	RATE_Z_LSB	0x00	rate_z_lsb [7:0]							
0x05	RATE_Y_MSB	0x00	rate_y_msb [15:8]							
0x04	RATE_Y_LSB	0x00	rate_y_lsb [7:0]							
0x03	RATE_X_MSB	0x00	rate_x_msb [15:8]							
0x02	RATE_X_LSB	0x00	rate_x_lsb [7:0]							
0x00	CHIP_ID	0x0F	chip_id [7:0]							

(light grey)	read / write
(dark grey)	write only
(blue)	read only
(white)	reserved

! **All shown registers are common w/r registers:**
Application specific settings which are not equal to the default settings must be re-set to their designated values after POR, soft-reset and wake up from deep suspend.

The entire communication with the device is performed by reading from and writing to registers. Registers have a width of 8 bits and are mapped to a common space of 64 addresses from GYR 0x00 up to GYR 0x3C. Within this range some registers are either completely or partially marked as ‘reserved’. Any reserved bit is ignored when it is written and no specific value is guaranteed when the bit is read. It is recommended not to use registers which are completely marked as 'reserved'. Furthermore, it is recommended to mask out (logical and with zero) reserved bits of registers which are partially marked as 'reserved'.

Registers with addresses from GYR 0x00 up to GYR 0x0E are read-only. Any attempt to write to these registers will be ignored. There are bits within some registers which trigger internal sequences. These bits are configured for write-only access and read as 0. An example for such a write-only access is the entire register GYR 0x14 (*BGW_SOFTRESET*).

6.8.1 GYR Register 0x00 (*CHIP_ID*)

This register contains the chip identification code.

0x00	*CHIP_ID*							
Bit	7	6	5	4	3	2	1	0
Read/Write	R	R	R	R	R	R	R	R
Reset Value	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Content	*chip_id* <7:0>							

Register	Description
chip_id <7:0>	Fixed value 00001111 = 0x0F

6.8.2 GYR Register 0x02 (*RATE_X_LSB*)

This register contains the least significant bits of x-channel angular rate readout value (see section 6.5.2).

0x02	*RATE_X_LSB*							
Bit	7	6	5	4	3	2	1	0
Read/Write	R	R	R	R	R	R	R	R
Reset Value	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Content	*rate_x_lsb* <7:0>							

Register	Description
rate_x_lsb <7:0>	Least significant 8 bits of rate x-channel read-back value (two's complement format)

6.8.3 GYR Register 0x03 (*RATE_X_MSB*)

This register contains the most significant bits of x-channel angular rate readout value (see section 6.5.2).

0x03	*RATE_X_MSB*							
Bit	7	6	5	4	3	2	1	0
Read/Write	R	R	R	R	R	R	R	R
Reset Value	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Content	*rate_x_msb* <15:8>							

Register	Description
rate_x_msb <15:8>	Most significant 8 bits of rate x-channel read-back value (two's complement format)

6.8.4 GYR Register 0x04 (*RATE_Y_LSB*)

This register contains the least significant bits of y-channel angular rate readout value (see section 6.5.2).

0x04	*RATE_Y_LSB*							
Bit	7	6	5	4	3	2	1	0
Read/Write	R	R	R	R	R	R	R	R
Reset Value	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Content	*rate_y_lsb* <7:0>							

Register	Description
rate_y_lsb <7:0>	Least significant 8 bits of rate y-channel read-back value (two's complement format)

6.8.5 GYR Register 0x05 (*RATE_Y_MSB*)

This register contains the most significant bits of y-channel angular rate readout value (see section 6.5.2).

0x05	*RATE_Y_MSB*							
Bit	7	6	5	4	3	2	1	0
Read/Write	R	R	R	R	R	R	R	R
Reset Value	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Content	*rate_y_msb* <15:8>							

Register	Description
rate_y_msb <15:8>	Most significant 8 bits of rate y-channel read-back value (two's complement format)

6.8.6 GYR Register 0x06 (*RATE_Z_LSB*)

This register contains the least significant bits of z-channel angular rate readout value (see section 6.5.2).

0x06	*RATE_Z_LSB*							
Bit	7	6	5	4	3	2	1	0
Read/Write	R	R	R	R	R	R	R	R
Reset Value	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Content	*rate_z_lsb* <7:0>							

Register	Description
rate_z_lsb <7:0>	Least significant 8 bits of rate z-channel read-back value (two's complement format)

6.8.7 GYR Register 0x07 (*RATE_Z_MSB*)

This register contains the most significant bits of z-channel angular rate readout value (see section 6.5.2).

0x07	*RATE_Z_MSB*							
Bit	7	6	5	4	3	2	1	0
Read/Write	R	R	R	R	R	R	R	R
Reset Value	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Content	*rate_z_msb* <15:8>							

Register	Description
rate_z_msb <15:8>	Most significant 8 bits of rate z-channel read-back value (two's complement format)

6.8.8 GYR Register 0x08 (*TEMP*)

This register contains the current chip temperature (see section 6.5.3)

0x08	*TEMP*							
Bit	7	6	5	4	3	2	1	0
Read/Write	R	R	R	R	R	R	R	R
Reset Value	0	0	0	0	0	0	0	0
Content	*temp* <7:0>							

Register	Description
temp <7:0>	Temperature value (two's complement format) 00000010 corresponds to 25 °C

6.8.9 GYR Register 0x0A (*INT_STATUS_1*)

This register contains the interrupt status flag *data_int* of the new data interrupt (see section 0)

0x0A	*INT_STATUS_1*							
Bit	7	6	5	4	3	2	1	0
Read/Write	R	R	R	R	R	R	R	R
Reset Value	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Content	*data_int*	*reserved*						

Register	Description
data_int	Data ready interrupt status 0: inactive 1: active
reserved	Random data, to be ignored

6.8.10 GYR Register 0x0F (*RANGE*)

This register allows for the selection of the gyroscope angular rate measurement range.

0x0F	*RANGE*							
Bit	7	6	5	4	3	2	1	0
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Reset Value	0	0	0	0	0	0	0	0
Content	*reserved*					*range* <2:0>		

Register	Description
range <2:0>	Selection of the gyroscope angular rate range Resolution
reserved	Write 0

range <2:0>	rate range	Resolution [LSG / °/s]
000	±2000 °/s	16.38
001	±1000 °/s	32.77
010	±500 °/s	65.54
011	±250 °/s	131.07
100	±125 °/s	262.14

All other settings are reserved (do not use)

6.8.11 GYR Register 0x10 (*BW*)

This register allows for the selection of the rate data filter bandwidth.

0x10	*BW*							
Bit	7	6	5	4	3	2	1	0
Read/Write	R	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Reset Value	1	0	0	0	0	0	0	0
Content	*reserved*				*bw* <3:0>			

Register	Description
bw <3:0>	Selection of the data filter bandwidth
reserved	Write 0

bw <3:0>	Bandwidth	*bw <3:0>*	Bandwidth
0111	32 Hz	0011	47 Hz
0110	64 Hz	0010	116 Hz
0101	12 Hz	0001	230 Hz
0100	23 Hz	0000	unfiltered (523 Hz)

All other settings are reserved (do not use)

6.8.12 GYR Register 0x11 (GYRO_LPM1)

This register allows for the selection of the power mode.

0x11	*GYRO_LPM1*							
Bit	7	6	5	4	3	2	1	0
Read/Write	R	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Reset Value	0	0	0	0	0	0	0	0
Content	*power mode*				*reserved*			

Register	Description
power mode <7:4>	Selection of power mode 0x00: normal mode 0x80: suspend mode 0x20: deep suspend mode
reserved	Write 0

6.8.13 GYR Register 0x13 (*RATE_HBW*)

This register controls the angular rate data acquisition and data output format.

0x13	*RATE_HBW*							
Bit	7	6	5	4	3	2	1	0
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Reset Value	0	0	0	0	0	0	0	0
Content	*data_high_bw*	*shadow_dis*	*reserved*					

Register	Description
data_high_bw	Data-read from the rate data registers 1: unfiltered 0: filtered
shadow_dis	Shadowing mechanism for the rate data output registers 1: disable 0: enable
reserved	Write 0

6.8.14 GYR Register 0x14 (*BGW_SOFTRESET*)

This register controls the user triggered reset of the sensor.

0x14	*BGW_SOFTRESET*							
Bit	7	6	5	4	3	2	1	0
Read/Write	W	W	W	W	W	W	W	W
Reset Value	0	0	0	0	0	0	0	0
Content	*softreset<7:0>*							

Register	Description
softreset<7:0>	Writing 0xB6 to the register triggers a reset. Other values are ignored. After a delay, all user configuration settings are overwritten with their default values. Please note that all application specific settings which are not equal to the default settings must be reconfigured to their designated values.

6.8.15 GYR Register 0x15 (*INT_EN_0*)

This register enables the new data interrupt. See bit *data_int* in register GYR 0x0A (*INT_STATUS_1*).

0x15	*INT_EN_0*							
Bit	7	6	5	4	3	2	1	0
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Reset Value	0	0	0	0	0	0	0	0
Content	*data_en*	*reserved*						

Register	Description
data_en	New data interrupt 0: disabled 1: enabled
reserved	Write 0

6.8.16 GYR Register 0x16 (*INT_EN_1*)

This register contains interrupt pin configurations.

0x16	*INT_EN_1*							
Bit	7	6	5	4	3	2	1	0
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Reset Value	0	0	0	0	1	1	1	1
Content	*reserved*				*int4_od*	*int4_lvl*	*int3_od*	*int3_lvl*

Register	Description
int4_od	Behavior for INT4 pin 0: push-pull 1: open drain
int4_lvl	Active level for INT4 pin 0: active low 1: active high
int3_od	Behavior for INT3 pin 0: push-pull 1: open drain
int3_lvl	Active level for INT3 pin 0: active low 1: active high
reserved	Write 0

6.8.17 GYR Register 0x18 (*INT_MAP_1*)

This register controls if interrupt signals are mapped to the INT3 / INT4 pin.

0x18	*INT_MAP_1*							
Bit	7	6	5	4	3	2	1	0
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Reset Value	0	0	0	0	0	0	0	0
Content	*int4_data*	*reserved*						*int3_data*

Register	Description
int4_data	Map new data interrupt to the INT4 pin 0: disabled 1: enabled
int3_data	Map new data interrupt to the INT3 pin 0: disabled 1: enabled
reserved	Write 0

6.8.18 GYR Register 0x34 (*BGW_SPI3_WDT*)

This register contains settings for the digital interfaces.

0x34	*BGW_SPI3_WDT*							
Bit	7	6	5	4	3	2	1	0
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Reset Value	0	0	0	0	0	0	0	0
Content	*reserved*					*i2c_wdt_en*	*i2c_wdt_sel*	*reserved*

Register	Description
i2c_wdt_en	Watchdog timer at the SDA pin in TWI mode 0: disable 1: enable
i2c_wdt_sel	Watchdog timer period 0: 1 ms 1: 50 ms
reserved	Write 0

6.8.19 GYR Register 0x3C (*BIST*)

This register contains the built-in self-test (BIST) options (see section 6.1).

0x3C	*BIST*							
Bit	7	6	5	4	3	2	1	0
Read/Write	R/W	R/W	R/W	R	R/W	R	R	W
Reset Value	0	0	0	0	0	0	0	0
Content	*reserved*			*rate_ok*	*reserved*	*bist_fail*	*bist_rdy*	*trig_bist*

Register	Description
rate_ok	1: indicates proper sensor function, no trigger is needed for this
bist_fail	Contains the fail flag, needs to be evaluated together with *bist_rdy*
bist_rdy	Status of BIST, needs to be evaluated together with *bist_fail*
trig_bist	Write 1: perform the BIST
reserved	Write 0

bist_rdy	*bist_fail*	Status
0	-	BIST not finished
1	0	BIST ok, sensor ok
1	1	BIST not ok, sensor values not in expected range

7 Legal Disclaimer

In order to ensure proper functionality during operation, it is the responsibility of the customer to evaluate:

- The proper function of the sensor in the overall system.
- The mechanical stability of each system design including the sensor.
- The electrical stability, e.g. power supply and EMC, of each system design including the sensor.

Bosch complied with the following regulations specific to the target market when developing the product: The sensor complies with all statutory regulations regarding restriction of hazardous substances and recyclability which are in the scope of IMDS (International Material Data System).

If other or additional regulations are required for marketing the product or marketing is effected outside the named target markets, the customer requests compliance with the specific regulations of the target market from Bosch, or ensures these by itself.

Bosch points out that the system/product does not implement any ASIL-classified requirements (in the sense of ISO 26262). Therefore, it has not been approved by Bosch for applications in which Bosch delivered system/product has an ASIL-related (above QM) role. This implies the following limitations:

- The SMI230 must not be used if it influences safety goals with ratings higher than ASIL QM. Safety goals are defined in the overall system (i.e. on item level).
- Bosch cannot provide any quantitative failure analysis (e.g. FTA or FMEDA) for the SMI230.
- The SMI230 does not provide a CRC to check communication errors within a SPI/I2C frame.
- The SMI230 does not provide error flags to detect malfunctions of the ASIC.

Repair and manual soldering of sensors is not permitted.

Sensors must not be handled as bulk good.

Sensors with visible damages (housing, connectors, pins, etc.) and sensors which might have exceeded the absolute maximum ratings (e.g. dropped down from a height of more than 120 cm onto a hard surface) must not be mounted in the device. These sensors must be scrapped.

Data security: The sensor only contains the explicitly stated characteristics for product, data and information security. It is the responsibility of the system integrator to verify and validate on system level, if the stated characteristics comply with and fulfill the requirements of the product.

Returned products are considered good if they fulfill the specifications / test data for 0-mileage and field listed in this document.

Engineering samples are marked with (e) or (E). Samples may vary from the valid technical specifications of the series product contained in this data sheet. Therefore, they are not intended or fit for resale to third parties or for use in end products. Their sole purpose is internal client testing. The testing of an engineering sample may in no way replace the testing of a series product. Bosch assumes no liability for the use of engineering samples. The purchaser shall indemnify Bosch from all claims arising from the use of engineering samples.

Due to the measurement principle, the sensor is sensitive to mechanical disturbances, such as shocks, vibrations or stress. Therefore, the printed circuit board (PCB) has to be designed in such a way, as to suppress any of these influences and ensure the proper functionality in each application.

The sensor elements have to be protected against extreme shock loads such as e.g. hammer blows on or next to the sensor elements, vibrations of a power wrench when fixing bolts, dropping of the sensor elements onto hard surfaces, etc. Sensor modules which have been dropped must not be used and have to be scrapped. We recommend the avoidance of g-forces beyond the maximum rating during transport, handling and mounting of the sensors resulting in a defined and qualified installation process. As the sensor is sensitive to mechanical stress, any bending or torsion of the PCB close to the sensor, e.g. during forcing in, has to be avoided.

8 Document History

Version	Section	Comment	Date
1.0	General	Initial Release	

9 Table of Figures

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