Technical Product Description
SMI130

Inertial Sensor (6DoF) for Non-Safety Automotive Applications

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1 Product Identification

- Product Designation: SMI130
- Type Designation: Inertial sensor
- Product Part Number: 0273 141 181
- This Product is intended for use in: Non-Safety Automotive Applications

1.1 Main Functions and Properties

The SMI130 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 SMI130 offers the detection of acceleration and angular rate for the x-, y-, and z-axis. The digital standard serial peripheral interface (SPI) of the SMI130 allows for bi-directional data transmission.

Sensor	Bosch Part Nr.	Type	Range	Resolution
SMI130	0273 141 181	Accelerometer	±2, ±4, ±8, ±16 g	12 bit
		Gyroscope	±125 ... ±2000 °/s	16 bit

1.2 Key Features

Key Feature	Description
Inertial sensor	Advanced triaxial 16 bit gyroscope and a versatile, leading edge triaxial 12 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
Consumer electronics suite	MSL1, RoHS compliant, halogen-free
Operating temperature	-40 ... +85 °C
Extended operating temperature	-40 ... +105 °C (details see chapter 4)
Programmable functionality	Acceleration and rate ranges selectable Low-pass filter bandwidths selectable
On-chip temperature sensor	Factory trimmed, 8 bit, typical

2 General Product Description

2.1 Mechanical Design

The inertial sensor SMI130 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.

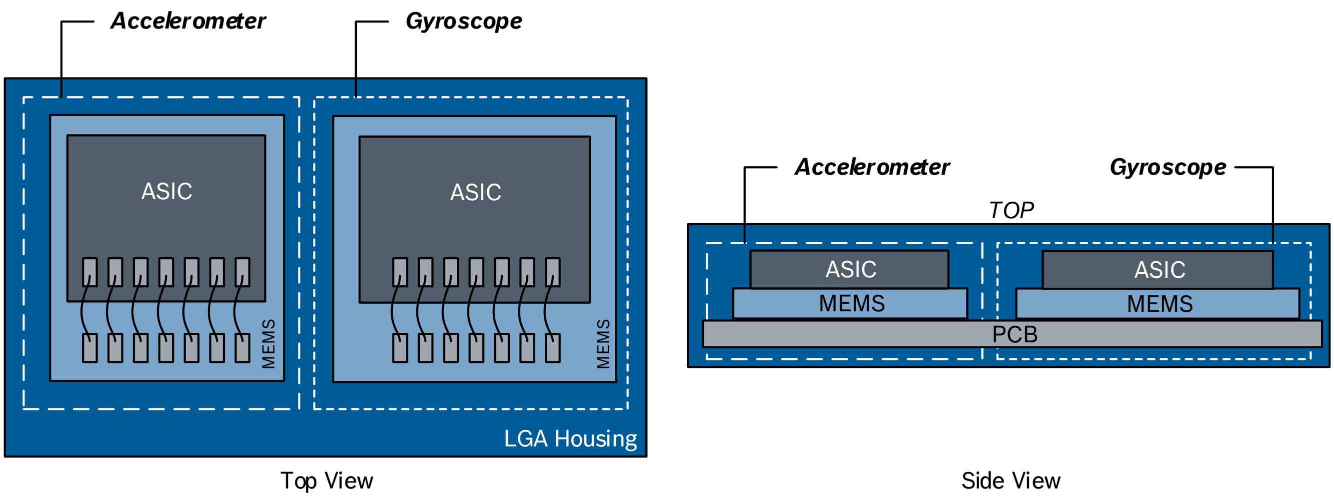


Figure 1 Schematics of the SMI130 mechanical design (left: top view; right: side view)

2.2 Sensor Data

The settings for the accelerometer and gyroscope can be set individually. The detailed description can be found in section 7.1. How to read and evaluate the sensor data is described in section 7.4

For both sensing elements it is recommended to actively set an appropriate, application specific bandwidth. For the accelerometer, the bandwidth can be set between 7.81 Hz and 1000 Hz. For the gyroscope, the bandwidth can be set between 32 Hz and 523 Hz.

Similar to the bandwidth, the measurement range can be selected by a specific register setting. The measurement range for the accelerometer is from ±2 g to ±16 g. For the gyroscope, the measurement range can be selected from ±125 °/s to ±2000 °/s.

The data representation of the SMI130 follows two´s complement representation. For each axis, the acceleration and gyroscope data is split into a MSB upper part and a LSB lower part. It is recommended to always start with reading the LSB register.

In order to ensure data integrity, a **shadowing procedure** can be enabled. When this is enabled, the content of the MSB register is locked when reading the corresponding LSB register, until the MSB register is read. This means that the MSB register always has to be read in order to remove the data lock. Shadowing can be disabled or enabled for each sensing part separately. For disabled shadowing, the content of both MSB and LSB registers is updated immediately.

Two different streams of acceleration and gyroscope data are available, **unfiltered** and **filtered** data. The unfiltered data is sampled with 2 kHz. The sampling rate (output data rate ODR) of the filtered data depends on the selected filter bandwidth (*BW*). Based on the specific register settings (*data_high_bw*), either the filtered or unfiltered data is stored in the registers.

The ASICs for accelerometer and gyroscope have a built-in temperature sensor. The corresponding data can be read from registers ACC 0x08 (*TEMP*) and GYR 0x08 (*TEMP*). The temperature sensor data of the SMI130 has a width of 8 bits, which covers a temperature range of 128 K. The slope is typically 0.5 K/LSB.

2.3 Block Diagram

Figure 2 shows the basic building blocks of the SMI130. As stated in section 2.1, 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.

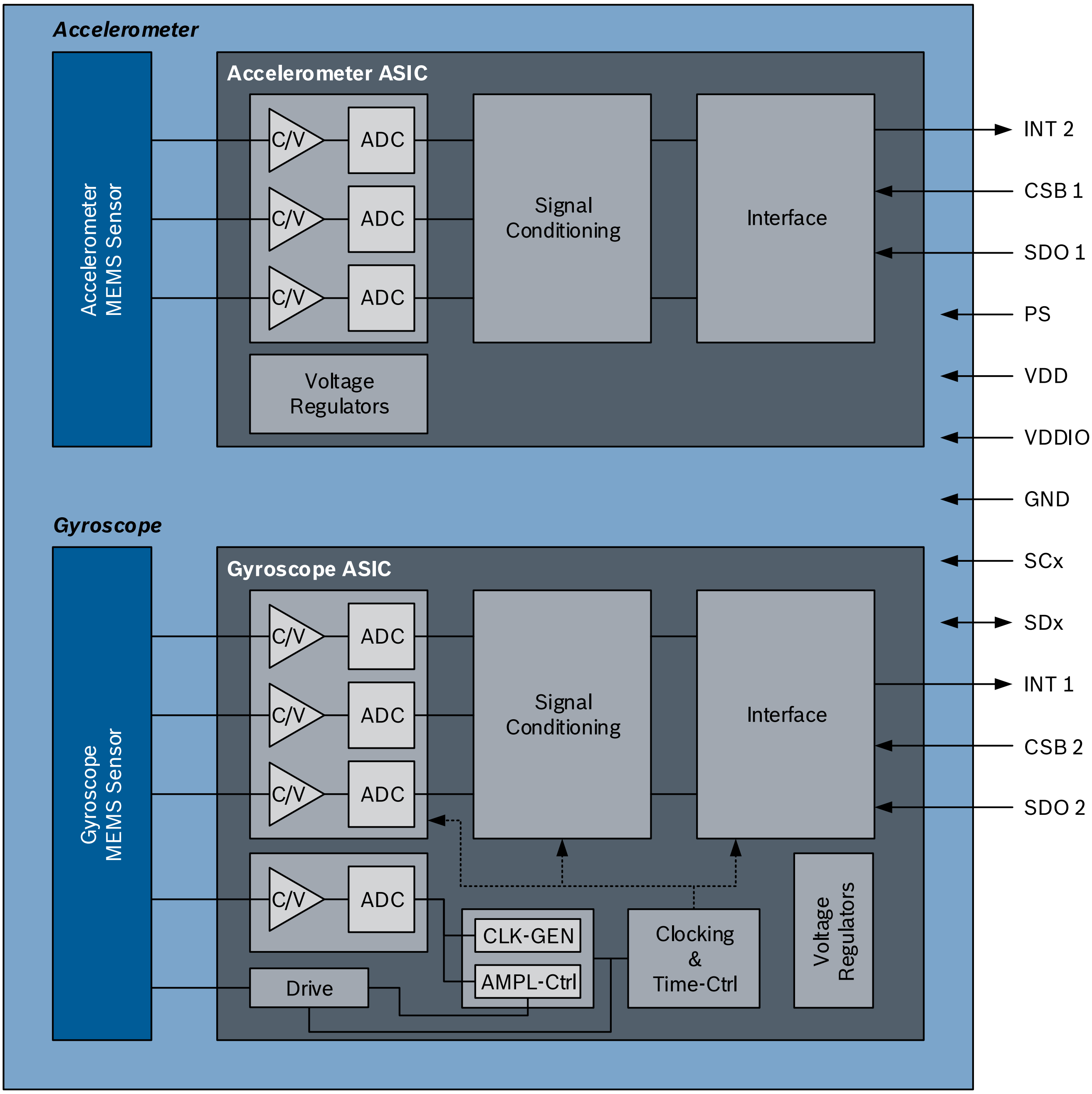


Figure 2 Simplified block diagram of the SMI130

2.4 Signal Path

2.4.1 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).

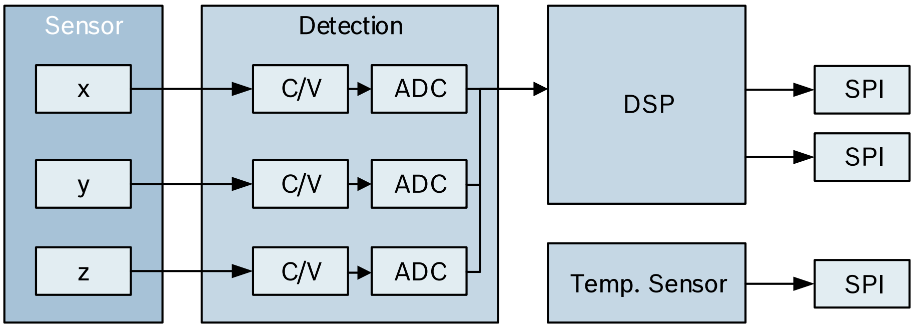


Figure 3 Simplified signal path of the accelerometer

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.

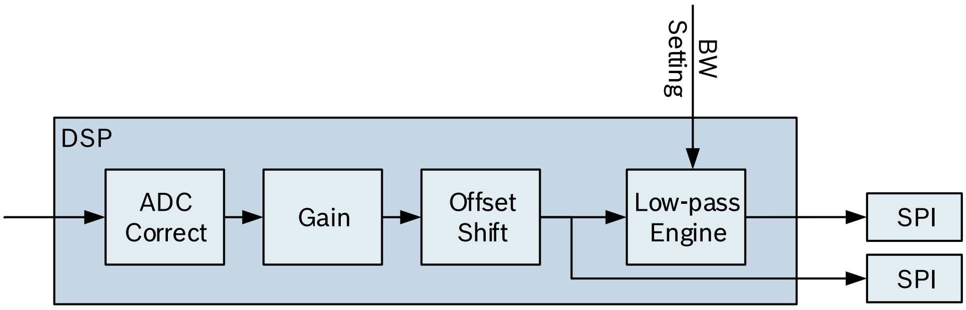


Figure 4 Simplified DSP element (accelerometer)

2.4.2 Gyroscope

The signal path of the gyroscope is sketched in Figure 5. 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.

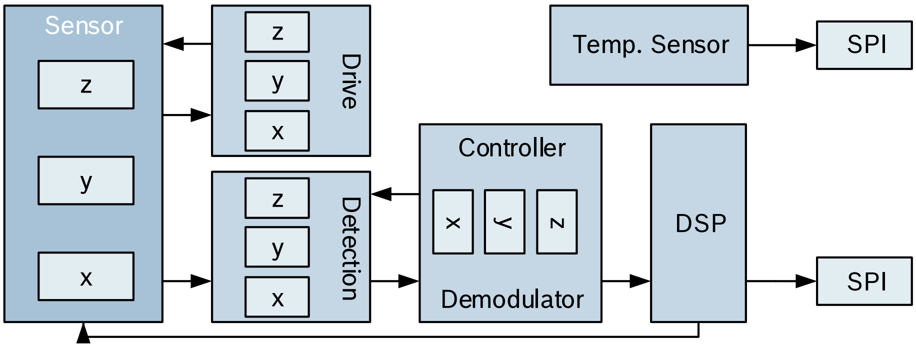


Figure 5 Simplified signal path of the gyroscope

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 SMI130. 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.

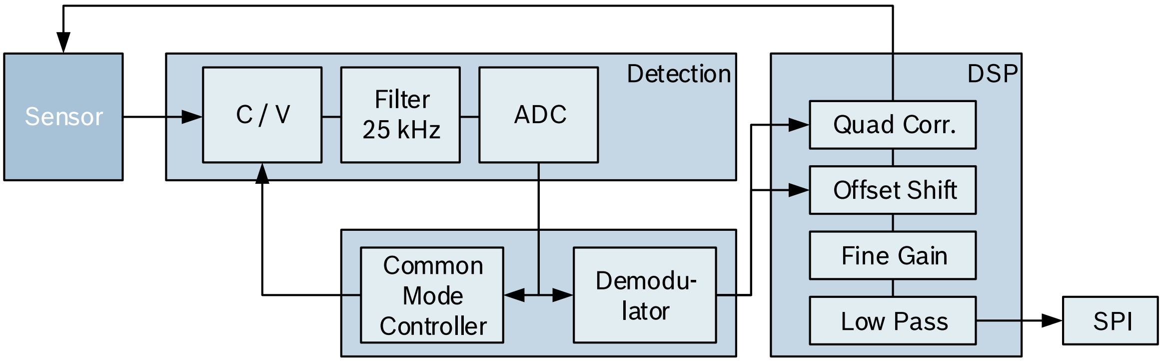


Figure 6 Path of the detection signal for one axis (gyroscope)

2.5 Orientation of the Sensing Axes

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).

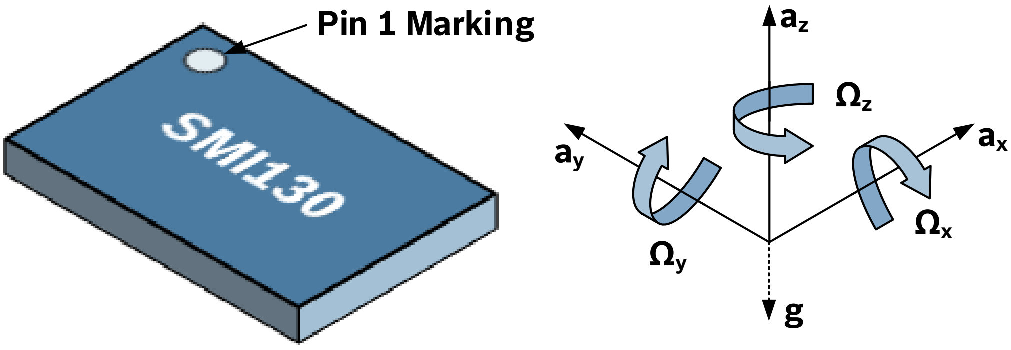


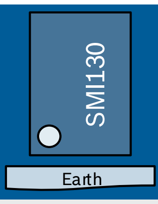
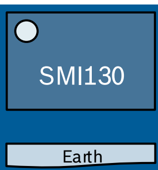
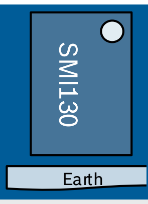
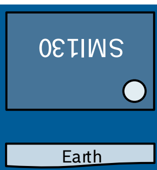
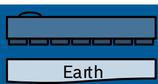
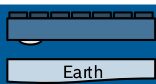
Figure 7 Sensing axis orientation

Example:

According to Figure 7, 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						
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

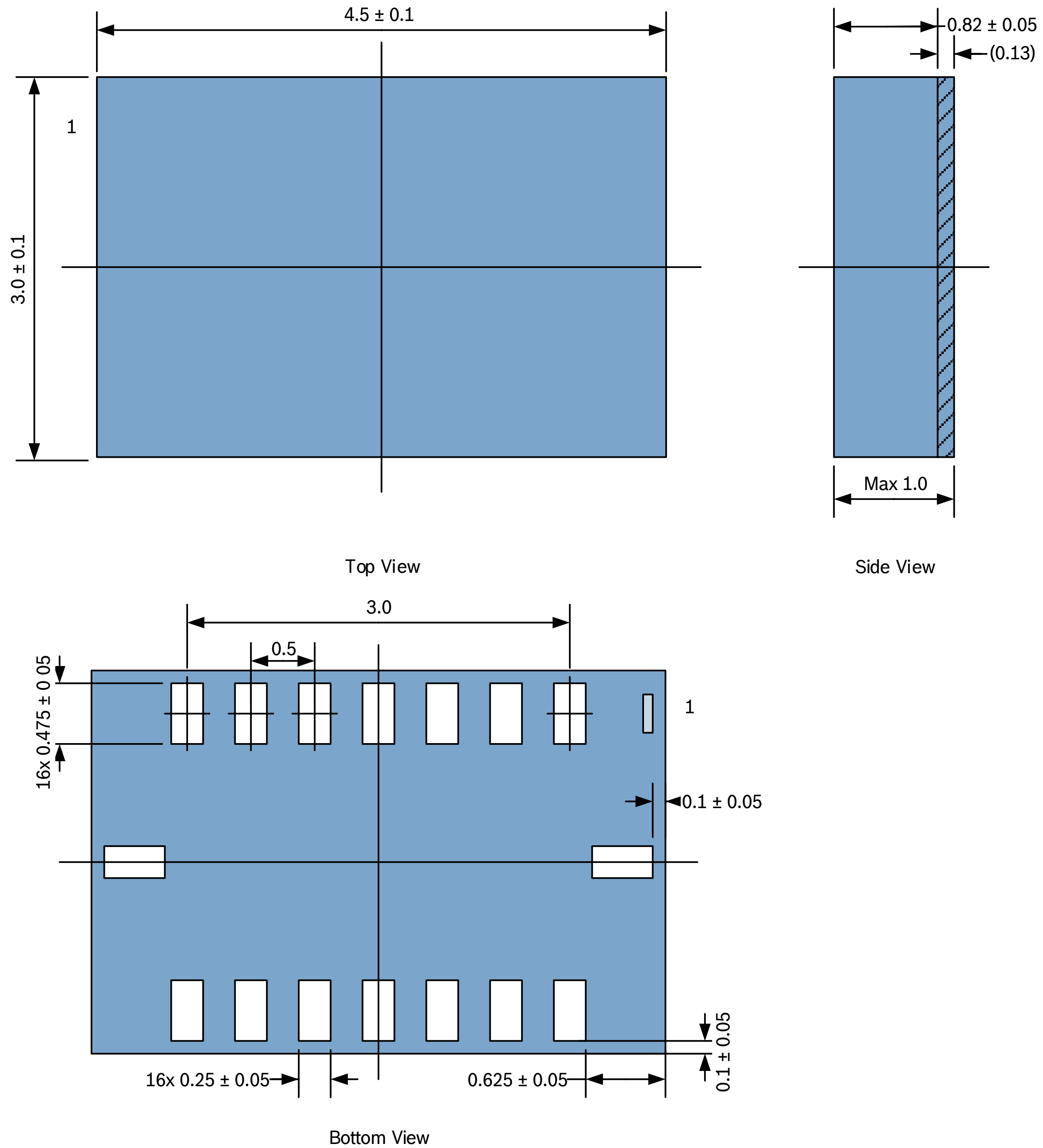


Figure 8 SMI130 package outline drawing

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

The sensor housing is a standard LGA package.

3.2 Transport Package

3.2.1 Tape on Reel Specification

The SMI130 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.

SMI130 quantity: 5000 pcs per reel. Please handle with care.

3.2.2 Tape Dimensions

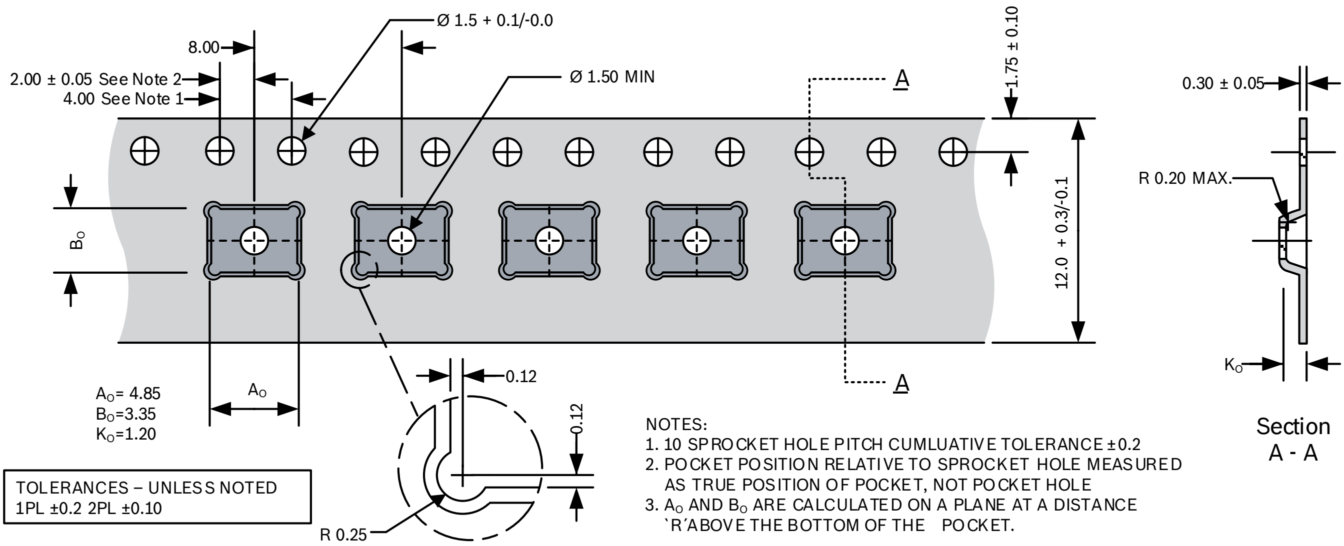


Figure 9 Tape dimensions in mm

3.2.3 Reel Dimensions

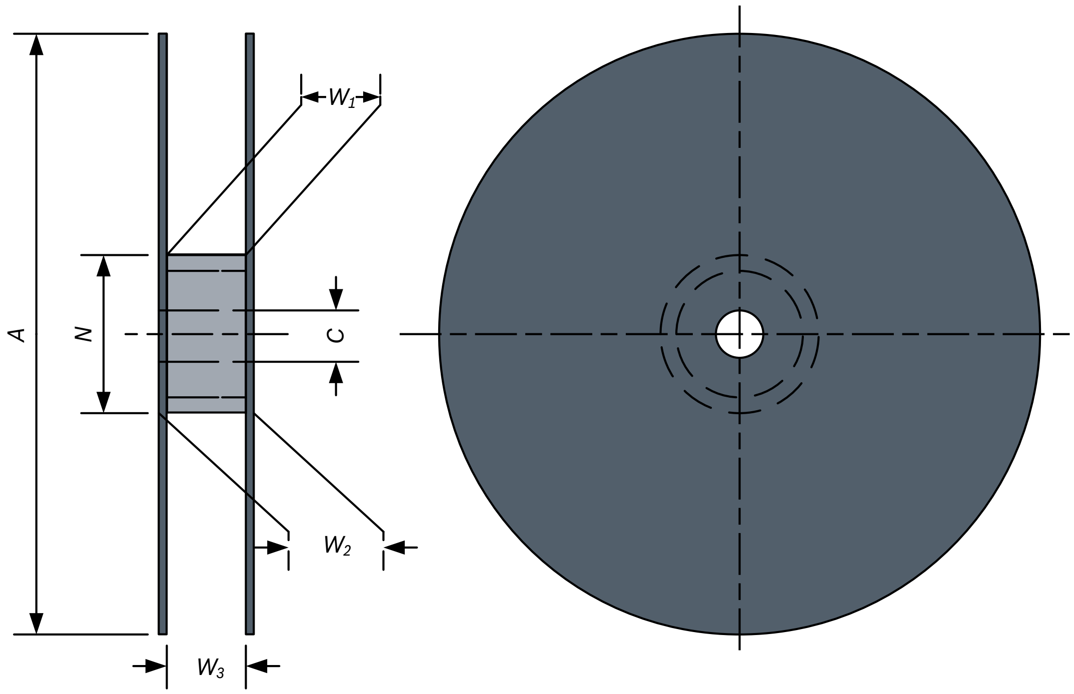


Figure 10 Reel dimensions

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

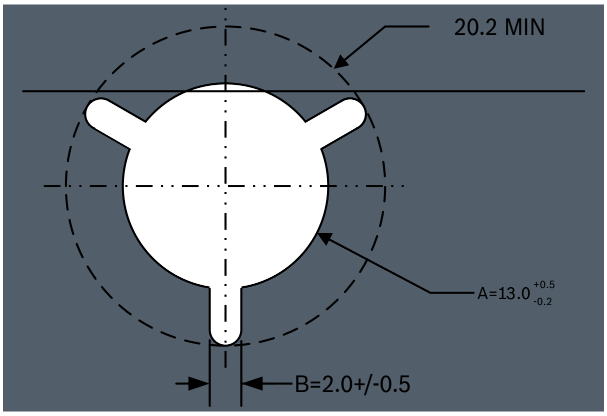


Figure 11 Details on hub hole dimension C in mm

3.2.4 Orientation within the Reel

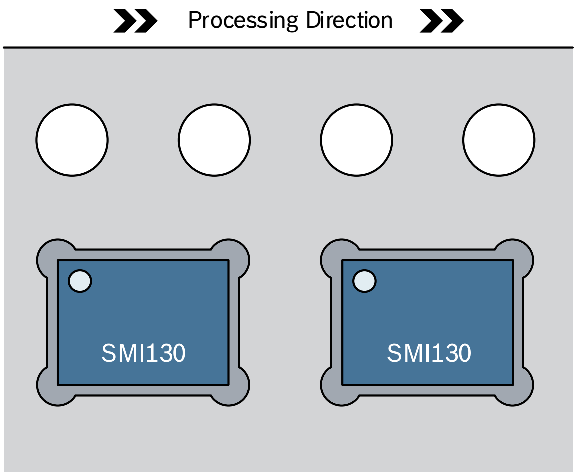
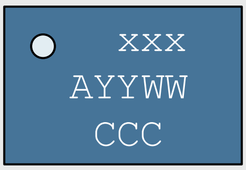


Figure 12 Orientation of the SMI130 devices relative to the tape

3.3 Labeling of the Product

Labeling	Name	Symbol	Remark
	Product number	xxx	3 numeric digits, 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

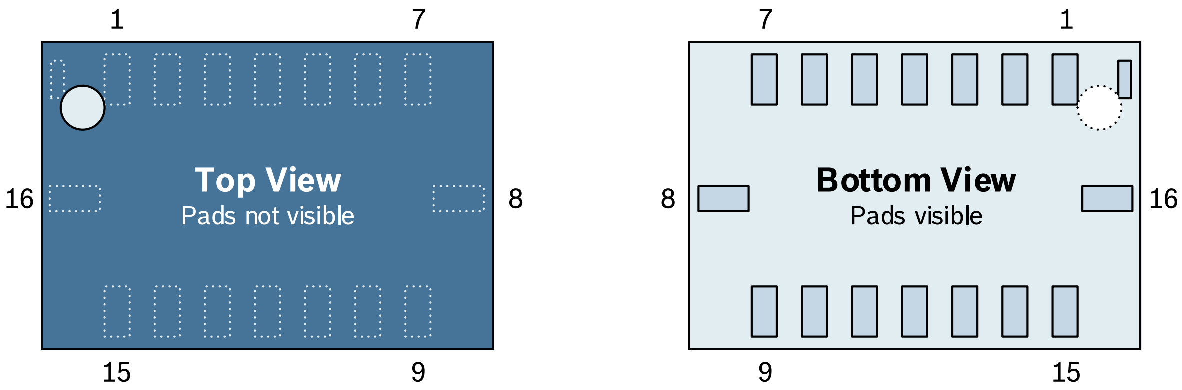


Figure 13 Pin-out top (left) and bottom (right) view

Pin	Name	I/O Type	Description	Connect to - SPI -	Connect to - TWI -
1	INT2	Digital out	Interrupt pin (ACC)	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	INT1	Digital out	Interrupt pin (GYR)	INT1 / DNC	INT1 / DNC
13	NF	--	--	DNC	DNC
14	CSB1	Digital in	SPI chip select ACC	CSB1	DNC (float)
15	SDO1	Digital out	SPI: serial data out ACC	SDO1	SDO1
16	NF	--	--	DNC	DNC

DNC: Do not connect
INTx: If not needed, DNC

3.5 Soldering

The moisture sensitivity level (MSL) of BOSCH SMI130 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 fulfills the lead-free soldering requirements of the above-mentioned IPC/JEDEC standard, i.e. reflow soldering with a peak temperature up to 260°C.

Repair and manual soldering of the sensor is not permitted.

3.5.1 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 14).

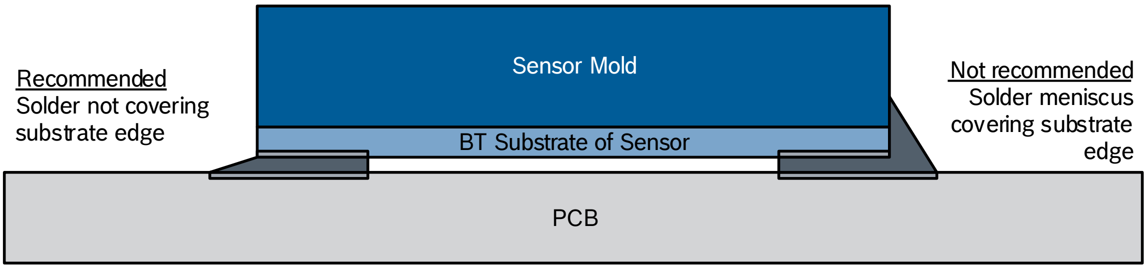


Figure 14 Reflow soldering recommendation

3.5.2 Classification Reflow Profile

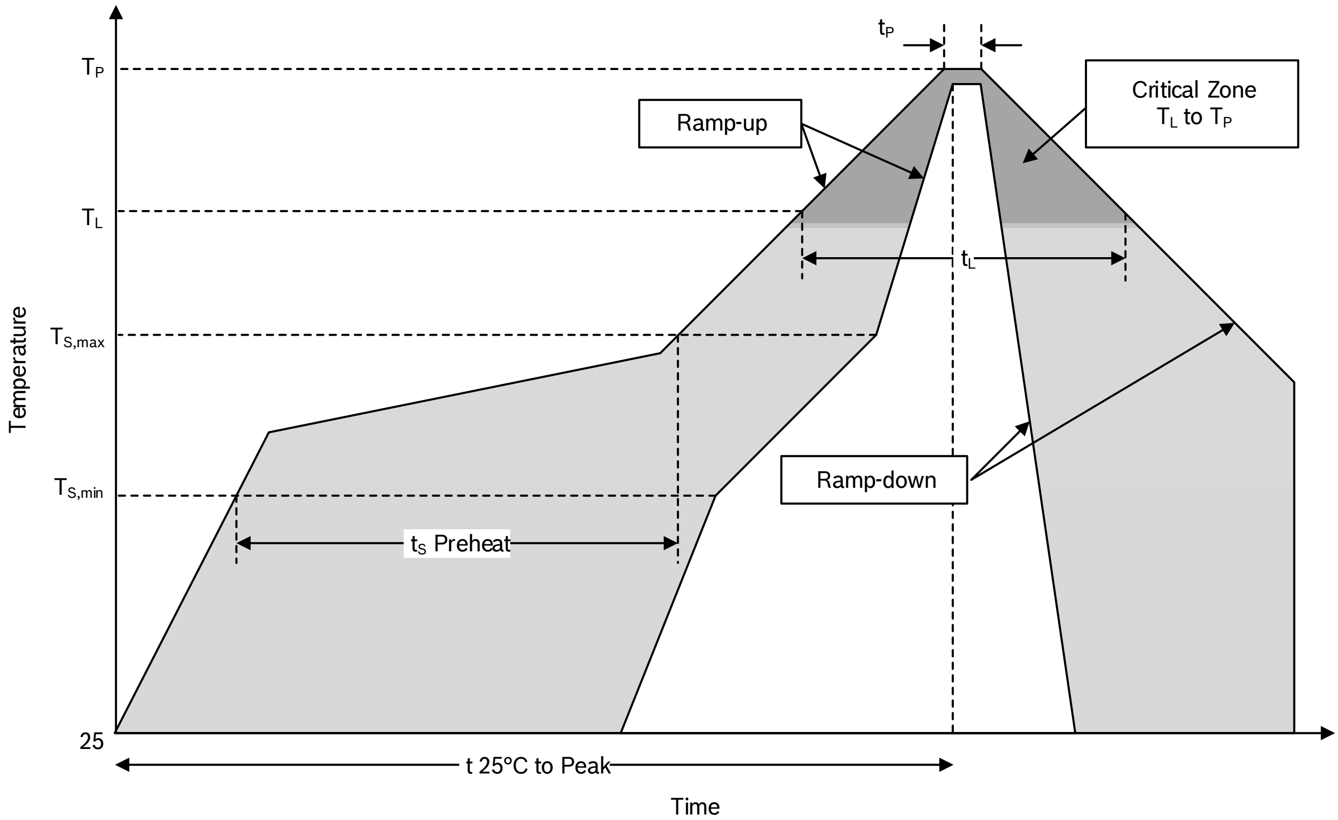


Figure 15 Soldering profile

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.

3.5.3 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) or where, in the next step, an additional re-work cycle could be required (1 reflow).

3.6 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.

The SMI130 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.

3.7 Recommendations for PCB Layout

For the design of the landing patterns, the dimensioning shown in Figure 16 is recommended.

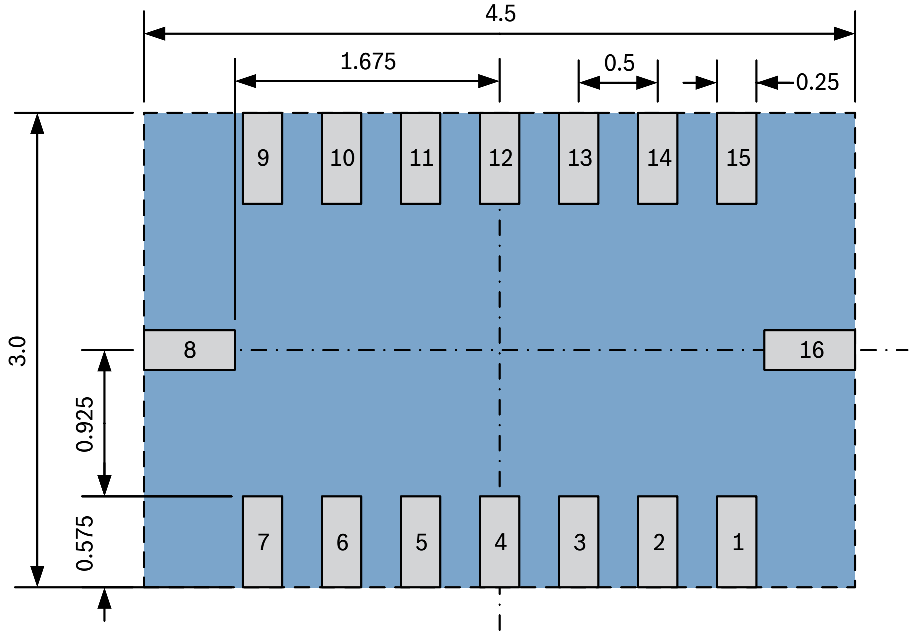


Figure 16 SMI130 footprint. Dimensions given in mm.

4 Environment Specification

4.1 Absolut Maximum Ratings

Any values outside of the given ratings may seriously damage the device. The sensor must be discarded after exceeding these limits.

Parameter	Condition	Min	Max	Unit
Voltage at supply pin	VDD pin	-0.3	4.27	V
Voltage at supply pin	VDDIO pin	-0.3	3.6	V
Voltage at any logic pin	non-supply pin	-0.3	VDDIO +0.3	V
Mechanical shock	free fall onto hard surfaces		1.2	m
Mechanical shock	duration <1 ms		2000	g
ESD	HBM, any pin		2	kV
ESD	CDM		500	V
ESD	MM		200	V

4.2 Operating Conditions

Parameter	Symbol	Min	Typical	Max	Unit
Operating temperature	T	-40	-	85	°C
Extended operating temperature (details see section 5.2)	$T_{extended}$	-40	-	105	°C

4.3 Lifetime Conditions

Parameter	Condition
Lifetime	according to AEC-Q100 grade 3 requirements

4.4 Environmental Safety

RoHS
The SMI130 sensor meets the requirements of the *Restriction of Hazardous Substances* (RoHS) 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.

Halogen content
The SMI130 is halogen-free. For more details on the analysis results, please contact your Bosch representative.

5 Parameter Specification

5.1 Power Supply

The SMI130 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.

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		1.2	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} = 3 mA			0.23 VDDIO	-
Voltage output high level	V_{OH}	I_{OH} = 3 mA	0.8 VDDIO			-

Switching sequence of power supply VDD and VDDIO

⚠ If VDD and VDDIO are not powered on simultaneously (via directly connecting both pins), VDD has to be powered on first and set to a specified level.
Thereafter, VDDIO can be powered on.

Not following this sequence might result in voltage levels of both pins which are not limited. This also applies if both are operated within their corresponding operating range.

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

The SMI130 provides a **power-on reset (POR)** generator. It resets the logic part and the register values after powering on VDD and VDDIO.

⚠ After POR, all settings are reset to the default values.
In the case that VDD < 1.8 V or VDDIO < 1V for longer than 1 ms, a safe POR (see below) is required.
Else, the device may end up in an undefined state.

Safe POR options:

A. Ramp down VDD to a level ≤ 0.35 V monotonically and keep it below this level for ≥ 2 µs. There is no constraint on the VDDIO level. Ramp up VDD and VDDIO to operating range.
B. Ramp down VDDIO to a level ≤ 0.35 V monotonically and keep it below for ≥ 2 µs while keeping VDD ≥ 1.8 V. Ramp up VDD and VDDIO to operating range.

SPI protocol requirements:

The PS pin must be directly connected to GNDIO.

5.2 Technical data

The data in the following section, unless otherwise noted, apply for the valid operation conditions given in section 4.2 and 5.1. All 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.

The sensor was validated and qualified in the temperature range from -40 °C to 85 °C according to Bosch standard release process. The specified values within this temperature range are given in the TPD section 5.2.1.1 and 5.2.2.1.

For elevated temperatures between 85 °C and 105 °C a characterization over the full range [-40 °C; 105 °C] was performed without consideration of lifetime effects. However the sensor will not be destroyed through thermal event in this temperature range. Within this temperature range, the typical values are given in section 5.2.1.2 and 5.2.2.2. It is the customers’ responsibility to assess the impact on system level.

5.2.1 Accelerometer

The SMI130 allows for selection of range and bandwidth:

Parameter	Symbol	Comment	Range (typical)	Unit	Resolution (typ.)	Unit
Measurement Range | Resolution	g_{FS}	selectable	±2 ±4 ±8 ±16	g	1024 512 256 128	LSB/g
Bandwidth	BW	selectable	8, 16, 31, 63, 125, 250, 500, 1000			Hz

5.2.1.1 Values in the Temperature Range -40 °C to 85 °C

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 1000 Hz.

Parameter	Symbol	Condition / Comment	Typical	Max	Unit
Supply current	I_{DD}	w/o SPI communication	0.15		mA
Start-up time	$t_{s,up}$	POR		0.2	s
Sensitivity tolerance		including temperature and lifetime effects		±5	%
Sensitivity tolerance		T = 25 °C, over lifetime		±4	%
Temperature Coefficient Sensitivity	TCS	nominal VDD supply, temperature range -40 °C to 85 °C	±0.025		% / K
Zero-g offset* - reset to zero at end of customer line -		Including lifetime and temperature effects	x ±35 y ±40 z ±90		mg
Zero-g offset		T = 25 °C, over lifetime	±70		mg
Temperature Coefficient Offset (zero-g)	TCO	nominal VDD supply, temperature range -40 °C to 85 °C	±1		mg / K
Nonlinearity BW: 62.5 Hz, range: ± 2g	NLIN	best fit straight line, no life-time	±25		mg
Noise rms		T = 25 °C, nominal VDD supply, no lifetime	6		mg
Temperature sensor slope			0.5		K / LSB
Temperature sensor offset		T = 25 °C	±5		K
Cross axis sensitivity		including temperature and lifetime effects	±3		%

* Assumption: ACC is offset corrected at end of customer production line on system level

5.2.1.2 Values in the Temperature Range 85 °C to 105 °C

Parameter	Symbol	Condition / Comment	Typical		Unit
Supply current	I_{DD}	w/o SPI communication	0.2		mA
Start-up time	$t_{s,up}$	POR	0.2		s
Sensitivity tolerance		over full temperature range, w/o lifetime effects	±1.4		%
Temperature Coefficient Sensitivity	TCS	nominal VDD supply, over full temperature range, w/o lifetime effects	±0.025		% / K
Zero-g offset* - reset to zero at end of customer line		over full temperature range, w/o lifetime effects	x	±35	mg
			y	±65	
			z	±90	
Temperature Coefficient Offset (zero-g)	TCO	nominal VDD supply, over full temperature range, w/o lifetime effects	±1		mg / K
Nonlinearity	NLIN	over full temperature range, w/o lifetime effects	±25		mg
Noise rms		nominal VDD supply, over full temperature range w/o lifetime effects	8		mg

* Assumption: ACC is offset corrected at end of customer production line on system level

5.2.2 Gyroscope

The SMI130 allows for selection of range and bandwidth:

Parameter	Symbol	Comment	Range (typical)	Unit	Resolution (typ.)	Unit
Measurement Range | Resolution	R_{FS}	selectable	±125 ±250 ±500 ±1000 ±2000	°/s	262.14 131.07 65.54 32.77 16.38	LSB/°/s
Bandwidth	BW	selectable	12, 23, 32, 47, 64, 116, 230, 523 (unfiltered)			Hz

5.2.2.1 Values in the Temperature Range -40 °C to 85 °C

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
Supply current	I_{DD}	w/o SPI communication		6.5	mA
Start-up time	$t_{s,up}$	POR		0.2	s
Sensitivity tolerance		including temperature and lifetime effects		±5.5	%
Sensitivity tolerance		T = 25 °C, over lifetime	±1		%
Temperature Coefficient Sensitivity	TCS	nominal VDD supply, temperature range -40 °C to 85 °C	±0.03		% / K
Zero-rate offset* - reset to zero at end of customer line -		Including lifetime and temperature effects	±0.5		°/s
Zero-rate offset		T = 25 °C, over lifetime		±1	°/s
Temperature Coefficient Offset (zero-g)	TCO	nominal VDD supply, temperature range -40 °C to 85 °C	±0.015		°/s / K
Nonlinearity BW: 23 Hz; range: ±125 °/s	NLIN	best fit straight line, no life-time		±1	°/s
Noise rms		T = 25 °C, nominal VDD supply, no lifetime	0.1		°/s
Temperature sensor measurement range				85	°C
Temperature sensor slope			0.5		K / LSB
Temperature sensor offset		T = 25 °C	±5		K
Cross axis sensitivity		including temperature and lifetime effects	±2		%

* Assumption: GYR is offset corrected at end of customer production line on system level

5.2.2.2 Values in the Temperature Range 85 °C to 105 °C

Parameter	Symbol	Condition / Comment	Typical	Unit
Supply current	I_{DD}	w/o SPI communication	5.4	mA
Start-up time	$t_{s,up}$	POR	0.2	s
Sensitivity tolerance		over full temperature range, w/o lifetime effects	±1.5	%
Temperature Coefficient Sensitivity	TCS	nominal VDD supply, over full temperature range, w/o lifetime effects	±0.03	% / K
Zero-rate offset* - reset to zero at end of customer line		over full temperature range, w/o lifetime effects	±0.5	°/s
	TCO	nominal VDD supply, over full temperature range, w/o lifetime effects	±0.015	°/s / K
Nonlinearity	NLIN	over full temperature range, w/o lifetime effects	0.1	°/s
Noise rms		nominal VDD supply, over temperature range, w/o lifetime effects	0.16	°/s

* Assumption: GYR is offset corrected at end of customer production line on system level

6 Software Interface Description

6.1 Serial Peripheral Interface (SPI)

6.1.1 SPI Connection

For communication, the SMI130 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

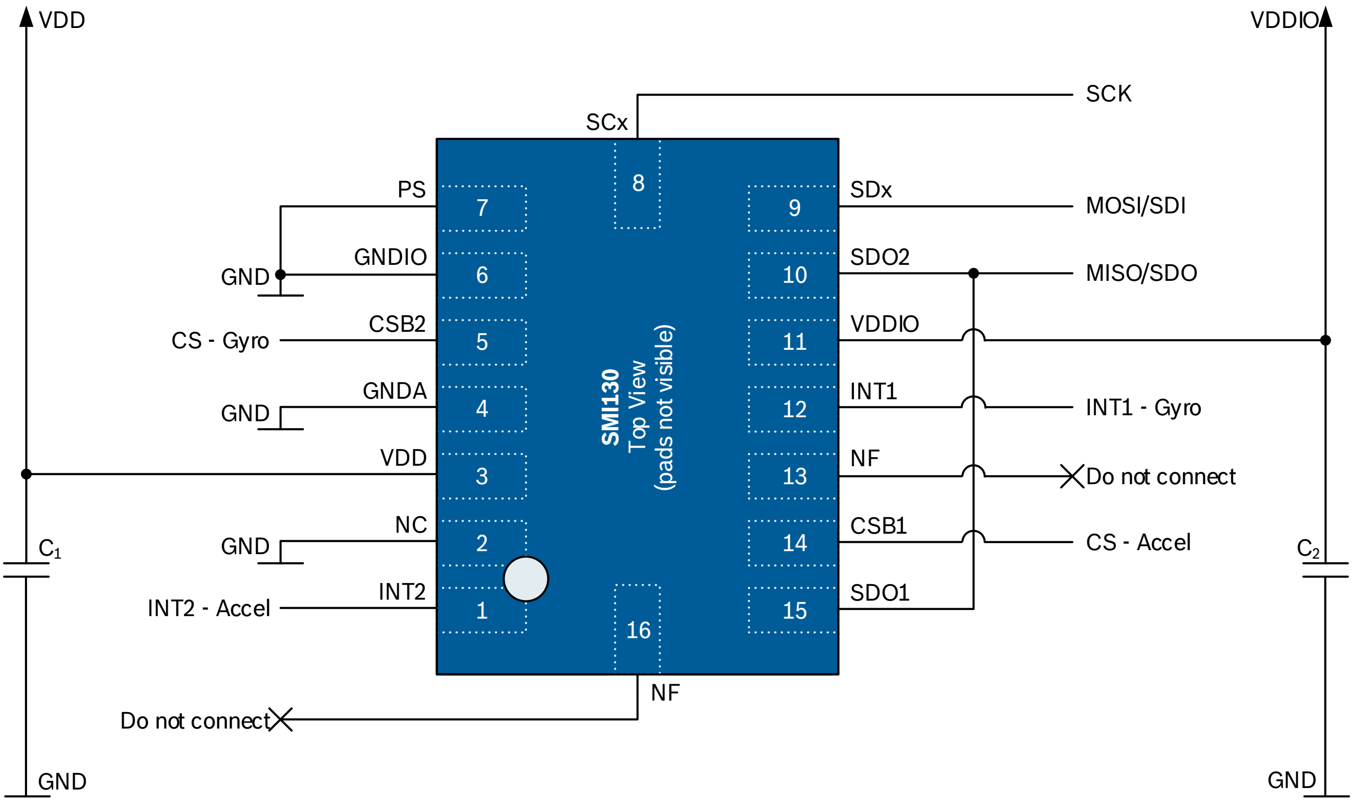


Figure 17 SPI connection diagram

C_1, C_2: 100 nF
INT1: see registers GYR 0x18, GYR 0x16
INT2: see registers ACC 0x1A, ACC 0x20

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.

6.1.2 SPI Timing

The SPI timing specification of the SMI130 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.

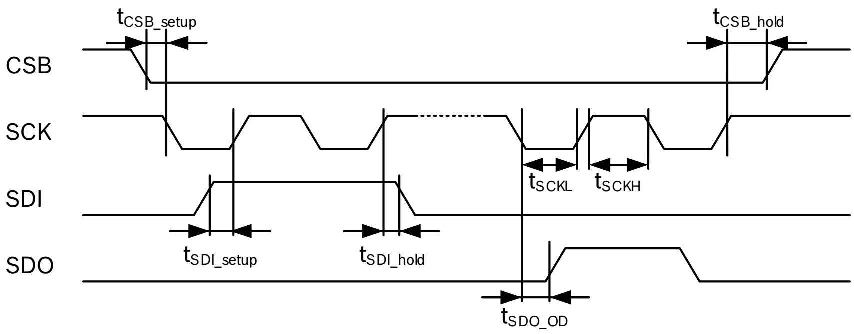


Figure 18 SPI timing diagram

The SPI interface of the SMI130 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 SMI130 also supports multiple-byte read operations.

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.

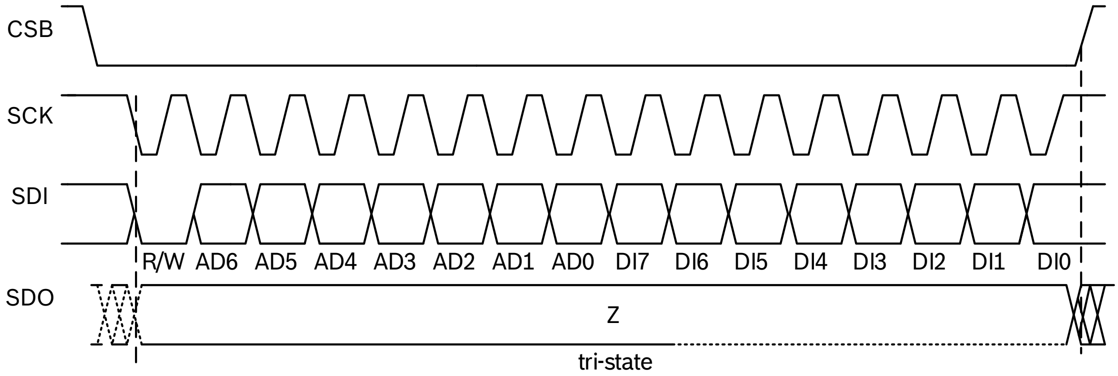


Figure 19 4-wire basic SPI write sequence (mode 11)

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

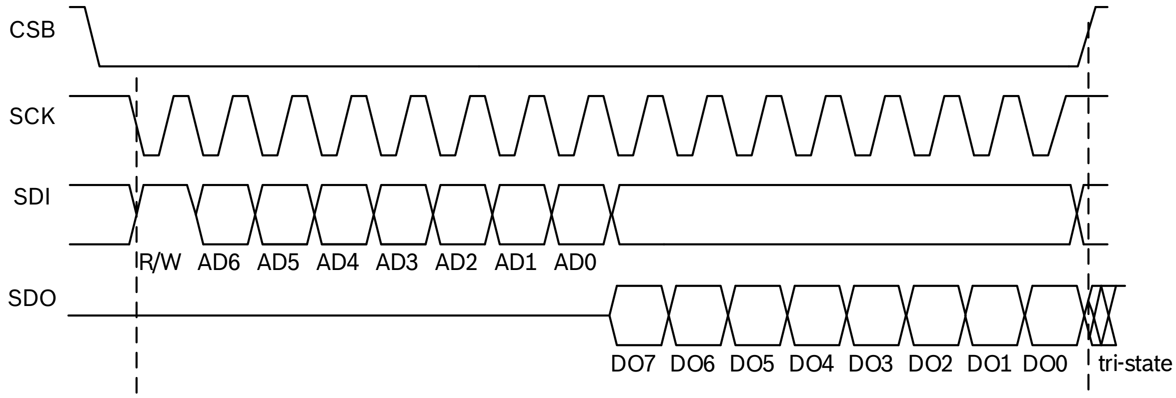


Figure 20 4-wire basic SPI read sequence (mode 11)

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 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.

	Control Byte								Data Byte								Data Byte								Data Byte								
Start	RW	Register address (02h)							Data register – address 02h								Data register – address 03h								Data register – address 04h								Stop
CSB = 0	1	0	0	0	0	0	1	0	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	CSB = 1

Figure 21 SPI multiple read

6.2 Two-wire Interface (TWI)

With some exceptions, the TWI interface of the SMI130 is compatible to the I²C specification UM10204 Rev. 03 (19 June 2007), available at http://www.nxp.com.

- The SMI130 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 6.2.2) have to be ensured by the bus master.

6.2.1 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.

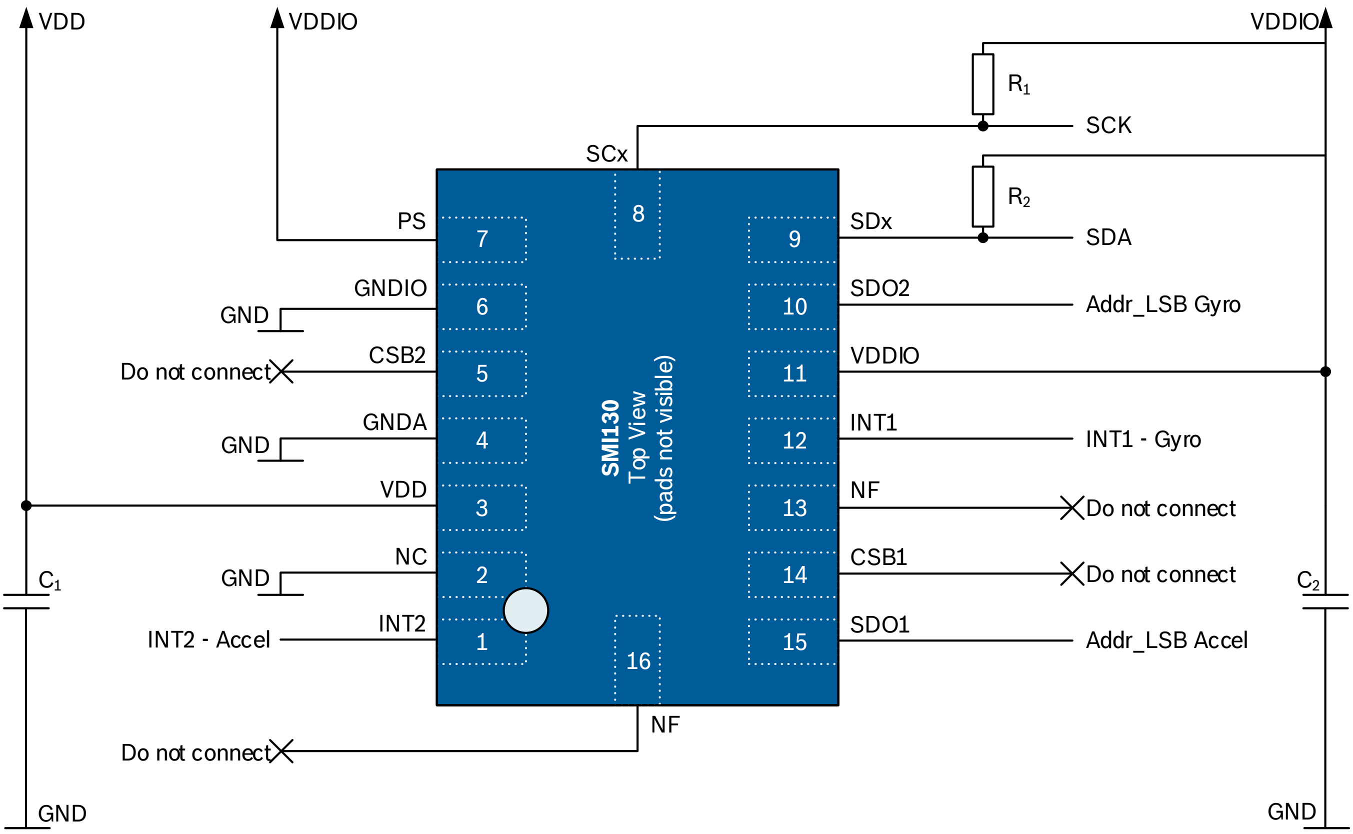


Figure 22 TWI connection diagram

C_1, C_2:	100 nF	R_1, R_2:	pull-up resistors
INT1:	see registers GYR 0x18, GYR 0x16	INT2:	see registers ACC 0x1A, ACC 0x20

SDO1 and SDO2 are used to define the TWI address of accelerometer and gyroscope. The default TWI address of the SMI130 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)

6.2.2 TWI Timing

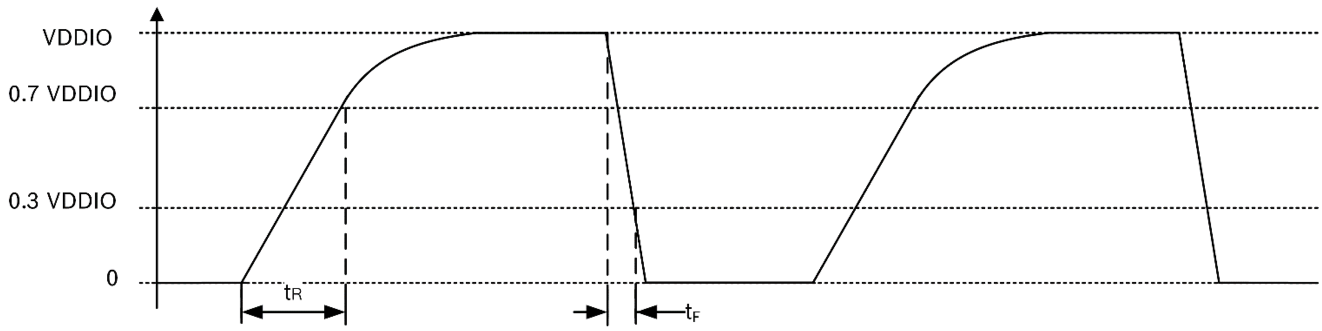


Figure 23 Definition of the rise and fall time of TWI signals

The TWI timing specification of the SMI130 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}	0.12		
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.

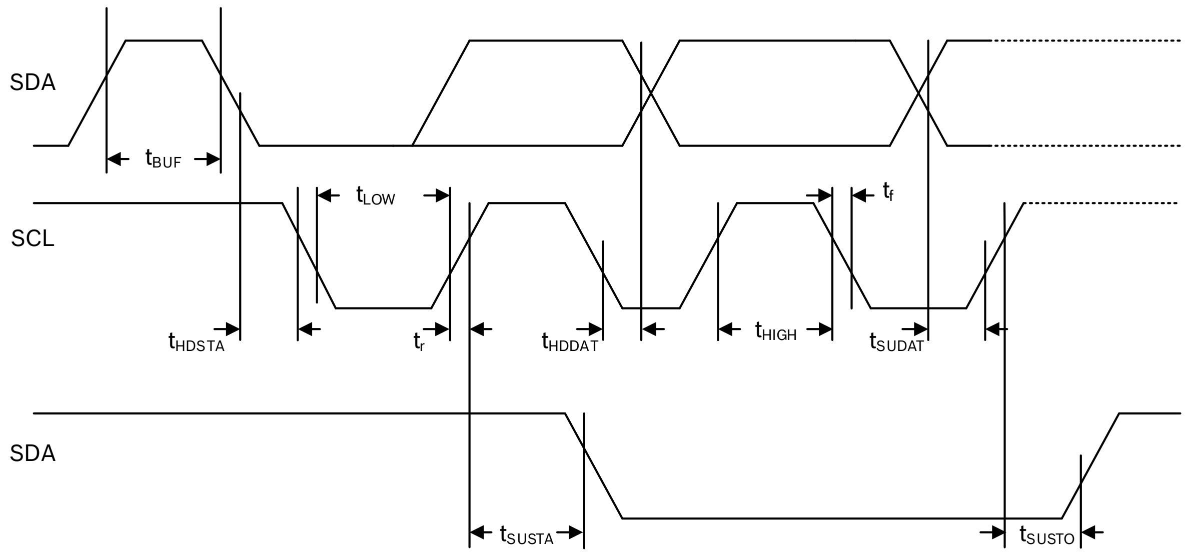


Figure 24 SMI130 TWI timing specification

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 SMI130.

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 registers ACC 0x34 (*BGW_SPI3_WDT*) and 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.

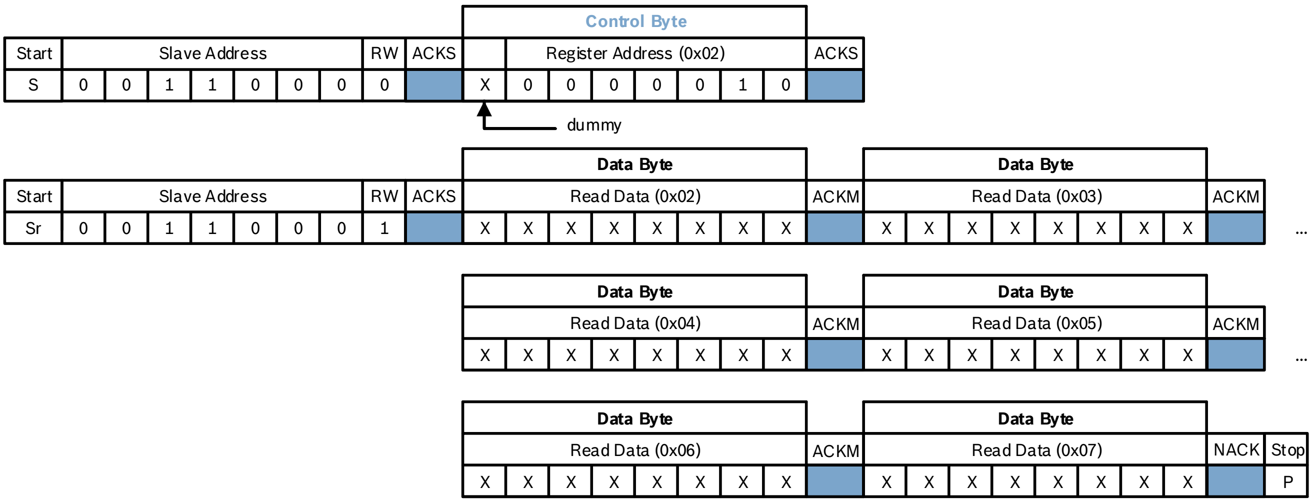


Figure 26 Example of a TWI read access to the accelerometer

Note (Gyroscope Soft Reset):

The SMI130 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.

6.3 Access Restrictions (SPI and TWI)

In order to allow for the correct internal synchronization of data written to the SMI130, 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.

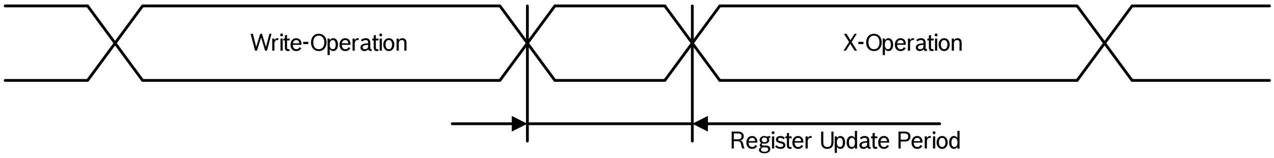


Figure 27 Post-write access timing constraints

7 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.

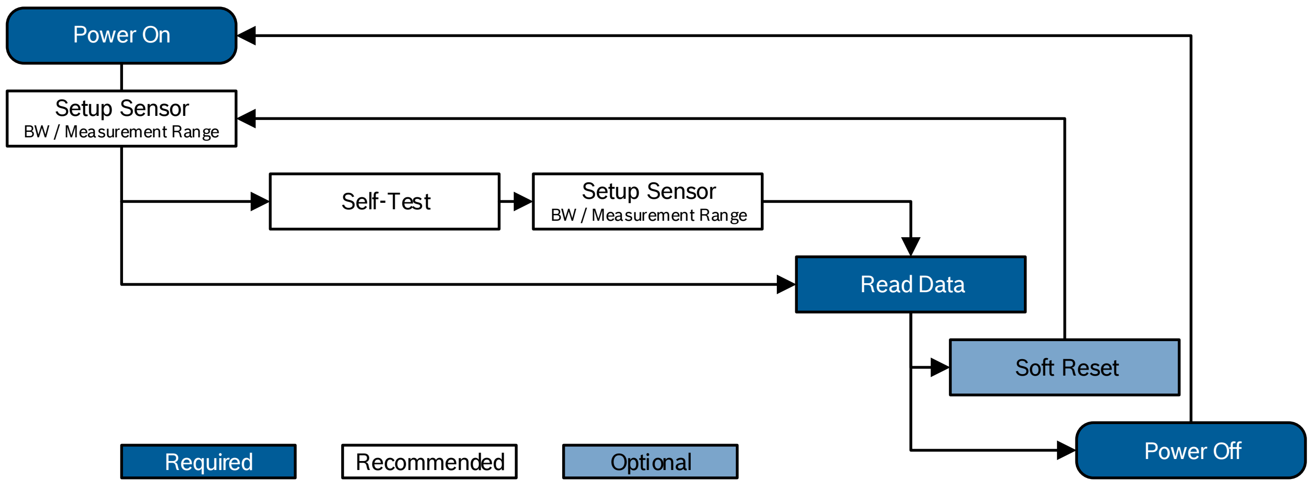


Figure 28 Basic flow chart for SMI130 application with key functional elements

7.1 Sensor Setup

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

7.1.1 Accelerometer

The **bandwidth** of filtered acceleration data is determined by setting bits <4:0> (*bw*) in register ACC 0x10 (*PMU_BW*) as shown in the following table. It is recommended to actively set an appropriate, application specific bandwidth and to use the *bw* range from 01000 to 01111.

bw <4:0>	Bandwidth	Update Time
00xxx	reserved	-
01000	7.81 Hz	64 ms
01001	15.63 Hz	32 ms
01010	31.25 Hz	16 ms
01011	62.5 Hz	8 ms
01100	125 Hz	4 ms
01101	250 Hz	2 ms
01110	500 Hz	1 ms
01111	1000 Hz	0.5 ms
1xxxx	reserved	-

The acceleration measurement **range** can be selected via bits <3:0> (*range*) in register ACC 0x0F (*PMU_RANGE*) according to the table below.

range <3:0>	Measurement Range	Resolution
0011	±2 g	1024 LSB/g
0101	±4 g	512 LSB/g
1000	±8 g	256 LSB/g
1100	±16 g	128 LSB/g
others	reserved	-

7.1.2 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	-

7.2 Self-Test

7.2.1 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.

Before enabling the self-test, the acceleration measurement range should be set to **8 g**. The bandwidth should be set to **1000 Hz**.

The self-test is activated with the register ACC 0x32 (*PMU_SELF_TEST*). For details please refer to section 0. All three axes are tested for a complete self-test. For a proper interpretation of the self-test signals, it is recommended to perform the self-test for both the positive and the negative direction and to then calculate the difference of the resulting acceleration values.

The self-test of **each axis** is triggered **separately** by setting bits <1:0> (*self_test_axis*) according to the following table.

self_test_axis <1:0>	**00**	**01**	**10**	**11**
self-test	deactivate self-test	x-axis	y-axis	z-axis

The **direction of the deflection** is controlled via bit 2 (*self_test_sign*). The deflection is negative (positive) when setting *self_test_sign* to 0 (1). The amplitude of the deflection has to be set high by setting bit 4 (*self_test_amp*) to 1. When a self-test is performed, only the acceleration data readout value of the selected axis is valid.

For each axis and direction, a waiting time of 50 ms is mandatory after enabling the self-test.

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	800 mg	800 mg	400 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.

7.2.2 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

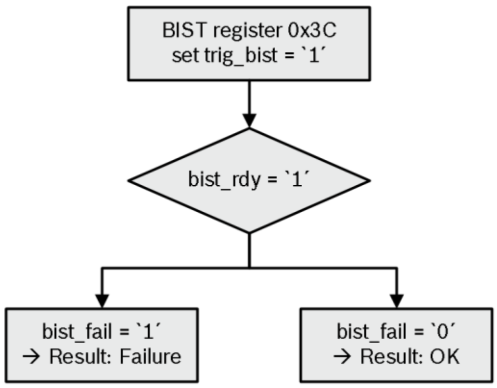


Figure 29 SMI130 BIST sequence

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.

7.3 Interrupt Engine

7.3.1 New Data Interrupt

7.3.1.1 Acceleration

The new_data flag of each LSB register indicates whether the data for this specific channel has been updated. In addition, the acceleration part of SMI130 provides a new data interrupt. The new data interrupt allows for synchronous reading of acceleration data. It is generated after a new value of z-axis acceleration data has been stored in the data register.

The interrupt status flag *data_int* of the new data interrupt is stored in register ACC 0x0A (*INT_STATUS_1*). It is active (inactive) if the bit is set to 1 (0). The interrupt is cleared automatically when the next data acquisition cycle starts. The interrupt status is 0 for a minimum of 50 µs. It is fixed to the non-latched mode.

The interrupt function associated with a specific status flag can be enabled (disabled) via setting bit 4 (*data_en*) in register ACC 0x17 (*INT_EN_1*) to 1 (0).

In addition, the new data interrupt can be mapped to an external INT2 pin. This feature can be enabled (disabled) via setting bit 7 (*int2_data*) in register ACC 0x1A (*INT_MAP_1*) to 1 (0).

7.3.1.2 Gyroscope

Comparable to the acceleration part, the SMI130 provides a new data interrupt for the gyroscope. The new data interrupt allows for synchronous reading of angular rate data. It is generated after storing a new z-axis angular rate value in the data register.

The interrupt status flag *data_int* of the new data interrupt is stored in register GYR 0x0A (*INT_STATUS_1*). It is active (inactive) if the bit is set to 1 (0). The interrupt clears automatically after 280 – 400 µs depending on settings. The interrupt mode of the new data interrupt is non-latched.

The interrupt function associated with the status flag can be enabled (disabled) via setting bit 7 (*data_en*) in register GYR 0x15 (*INT_EN_0*) to 1 (0).

In addition, the new data interrupt can be mapped to an external INT1 pin. This feature can be enabled (disabled) via setting bit 0 (*int1_data*) in register GYR 0x18 (*INT_MAP_1*) to 1 (0).

7.4 Reading Data

7.4.1 Accelerometer

For each axis, the 12 bits of acceleration data are split into a MSB upper part (bits <11:4> of acceleration data) and a LSB lower part (bits <3:0> of acceleration data). Registers ACC 0x02 (*ACCD_X_LSB*) and ACC 0x03 (*ACCD_X_MSB*) contain the acceleration data for the x-channel, ACC 0x04 (*ACCD_Y_LSB*) and ACC 0x05 (*ACCD_Y_MSB)* for the y-channel, and ACC 0x06 (ACCD_Z_LSB) and ACC 0x07 (*ACCD_Z_MSB*) for the z-channel. The LSB part (all axes) also contains the *new_data* flag. It 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.

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

LSB	1111 xxxx		0000 xxxx		0000 xxxx
MSB	0111 1111		0000 0000		1000 0000
LSB + MSB [bin]	0111 1111 1111		0000 0000 0000		1000 0000 0000
LSB + MSB [dec]	+2047	...	0	...	-2048
Acceleration value	+2 g	...	0 g	...	-2 g

In order to ensure data integrity, a **shadowing procedure** can be enabled. In this case, the content of the MSB register is locked by reading the corresponding LSB register until the MSB register is read. This means that the LSB register should be read first, followed by the MSB, register in order to remove the data lock. This condition is inherently fulfilled if a burst-mode read access is performed. Shadowing can be disabled (enabled) by writing 1 (0) to bit 6 (*shadow_dis*) in the register ACC 0x13 (*ACCD_HBW*). For disabled shadowing, the content of both MSB and LSB registers is updated immediately. Unused bits of the LSB registers may have any value and should be ignored.

New data can be identified by bit 0 (*new_data* flag) of each LSB register. It is set after the data registers have been updated and reset if either the corresponding MSB or LSB part is read. In addition there is the opportunity to use the new data interrupt, which is described in section 7.3.1.1.

Two different streams of acceleration data are available, **unfiltered** and **filtered** data. The unfiltered data is sampled with 2 kHz. The sampling rate (output data rate ODR) of the filtered data depends on the selected filter bandwidth (*BW*) and is always twice the selected bandwidth (BW = ODR/2). The type of data is stored in the data registers depends on bit 7 (*data_high_bw*) in register ACC 0x13 (*ACCD_HBW*). If bit 7 is 0 (1), filtered (unfiltered) data is stored in the registers. Both data streams are offset-compensated.

7.4.2 Gyroscope

For each axis, the 16 bits of rate data are split into a MSB upper part (bits <15:8> of rate data) and a LSB lower part (bits <7:0> of rate data). Registers GYR 0x02 (*RATE_X_LSB*) and GYR 0x03 (*RATE_X_MSB*) contain the rate data for the x-channel, GYR 0x04 (*RATE_ Y_LSB*) and GYR 0x05 (*RATE_ Y_MSB*) for the y-channel, and GYR 0x06 (*RATE_Z_LSB*) and GYR 0x07 (*RATE_Z_MSB*) for the z-channel. It is recommended to start reading the rate data registers with the LSB part followed by the corresponding MSB register. Angular rate data may be read from register LSB and/or MSB at any time except during power-up.

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

In order to ensure data integrity, a **shadowing procedure** can be enabled. In this case, the content of the MSB register is locked by reading the corresponding LSB register until the MSB register is read. This means that LSB register should be read first, followed by the MSB register in order to remove the data lock. This condition is inherently fulfilled if a burst-mode read access is performed. Shadowing can be disabled (enabled) by writing 1 (0) to bit 6 (*shadow_dis*) in the register GYR 0x13 (*RATE_HBW*). When shadowing is disabled, the content of both the MSB and the LSB register is updated immediately.

Two different streams of rate data are available, **unfiltered** and **filtered** data. The SMI130 processes the 2 kHz data of the analog frontend with a CIC/decimation filter, followed by an IIR filter, before sending it to the interrupt handler. The possible decimation factors are 2, 5, 10 and 20. It is also possible to bypass these filters and use the unfiltered 2 kHz data. The sampling rate (output data rate ODR) of the filtered data depends on the selected filter bandwidth (BW). The type of data is stored in the rate data registers depends on bit 7 (*data_high_bw*) in register GYR 0x13 (*RATE_HBW*). If bit 7 is 0 (1), filtered (unfiltered) data is stored in the registers.

7.4.3 Temperature Sensor

The temperature sensor data of the SMI130 have a width of 8 bits which covers a temperature range of 128 K. Temperature data can be read from registers ACC 0x08 (*TEMP*) and GYR 0x08 (*TEMP*). The update rate of the temperature register is 1 Hz. The slope is typically 0.5 K/LSB. The typical, 3 σ, and worst case temperature behavior of the SMI130 is shown in Figure 30.

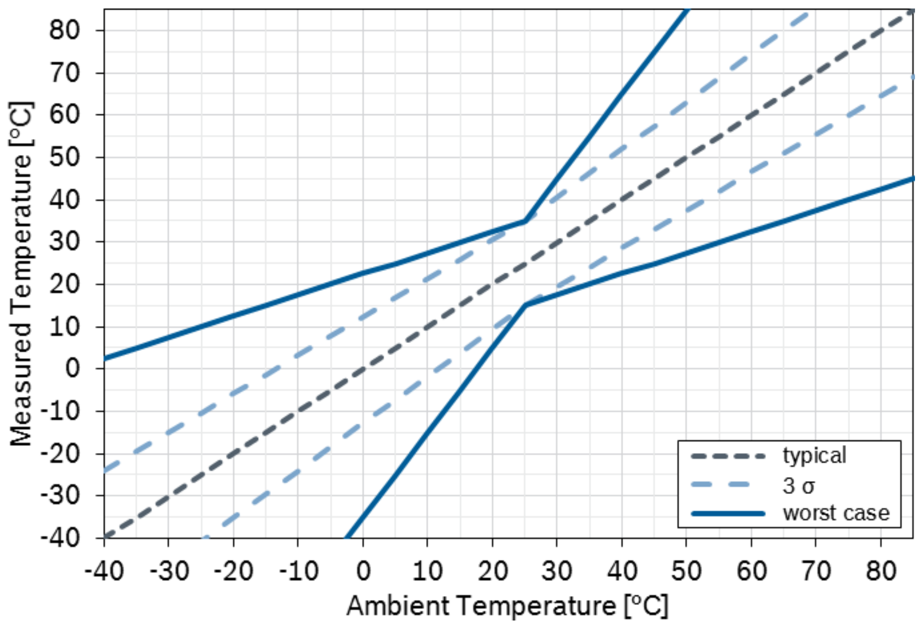


Figure 30 Temperature behavior of the SMI130

An example for the sensor reading and conversion to temperature is shown in the table below.

temp <7:0>	Accelerometer Temperature [°C]	Gyroscope Temperature [°C]
01111111	86.5	87.5
...	...	...
00000010	24	25
...	...	...
10000000	-41	-40

7.5 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 200 ms after a soft reset of the SMI130 accelerometer and gyroscope is recommended.

7.5.1 Accelerometer

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

7.5.2 Gyroscope

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

7.6 Register Map

7.6.1 Register Map Accelerometer

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 ACC 0x00 up to ACC 0x3F. 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 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 ACC 0x14 (*BGW_SOFTRESET*).

The following table shows the register map of the SMI130 accelerometer.

Register	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0	Default
0x34						*i2c_wdt_en*	*i2c_wdt_sel*		0x00
0x32				*self_test_amp*		*self_test_sign*	*self_test_axis<1:0>*		0x00
0x20					*int2_od*	*int2_lvl*			0x05
0x1E			*int_src_data*						0x00
0x1A	*int2_data*								0x00
0x17				*data_en*					0x00
0x14	*softreset*								0x00
0x13	*data_high_bw*	*shadow_dis*							0x00
0x10				*bw* <4:0>					0x0F
0x0F					*range* <3:0>				0x03
0x0A	*data_int*								0x00
0x08	*temp* <7:0>								0x00
0x07	*acc_z_msb* <11:4>								0x00
0x06	*acc_z_lsb* <3:0>							*new_data_z*	0x00
0x05	*acc_y_msb* <11:4>								0x00
0x04	*acc_y_lsb* <3:0>							*new_data_y*	0x00
0x03	*acc_x_msb* <11:4>								0x00
0x02	*acc_x_lsb* <3:0>							*new_data_x*	0x00
0x00	*chip_id* <7:0>								0xFA

(light grey)	w/r
(dark grey)	write only
(blue)	ready 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.

7.6.1.1 ACC Register 0x00 (*BGW_CHIPID*)

This register contains the chip identification code.

0x00	*BGW_CHIPID*							
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 11111010 = 0xFA

7.6.1.2 ACC Register 0x02 (*ACCD_X_LSB*)

This register contains the least significant bits of x-channel acceleration readout value (see section 7.4.1).

0x02	*ACCD_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* <3:0>				*undefined*			*new_data_x*

Register	Description
acc_x_lsb <3:0>	Least significant 4 bits of acceleration x-channel read-back value (two's complement format)
new_data_x	0: acceleration value has not been updated since it has been read out last 1: acceleration value has been updated since it has been read out last
undefined	Random data, to be ignored

7.6.1.3 ACC Register 0x03 (*ACCD_X_MSB*)

This register contains the most significant bits of x-channel acceleration readout value (see section 7.4.1).

0x03	*ACCD_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* <11:4>							

Register	Description
acc_x_msb <11:4>	Most significant 8 bits of acceleration x-channel read-back value (two's complement format)

7.6.1.4 ACC Register 0x04 (*ACCD_Y_LSB*)

This register contains the least significant bits of y-channel acceleration readout value (see section 7.4.1).

0x04	*ACCD_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* <3:0>				*undefined*			*new_data_y*

Register	Description
acc_y_lsb <3:0>	Least significant 4 bits of acceleration y-channel read-back value (two's complement format)
new_data_y	0: acceleration value has not been updated since it has been read out last 1: acceleration value has been updated since it has been read out last
undefined	Random data, to be ignored

7.6.1.5 ACC Register 0x05 (*ACCD_Y_MSB*)

This register contains the most significant bits of y-channel acceleration readout value (see section 7.4.1).

0x05	*ACCD_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* <11:4>							

Register	Description
acc_y_msb <11:4>	Most significant 8 bits of acceleration y-channel read-back value (two's complement format)

7.6.1.6 ACC Register 0x06 (*ACCD_Z_LSB*)

This register contains the least significant bits of z-channel acceleration readout value (see section 7.4.1).

0x06	*ACCD_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* <3:0>				*undefined*			*new_data_z*

Register	Description
acc_z_lsb <3:0>	Least significant 4 bits of acceleration z-channel read-back value (two's complement format)
new_data_z	0: acceleration value has not been updated since it has been read out last 1: acceleration value has been updated since it has been read out last
undefined	Random data, to be ignored

7.6.1.7 ACC Register 0x07 (*ACCD_Z_MSB*)

This register contains the most significant bits of z-channel acceleration readout value (see section 7.4.1)

0x07	*ACCD_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* <11:4>							

Register	Description
acc_z_msb <11:4>	Most significant 8 bits of acceleration z-channel read-back value (two's complement format)

7.6.1.8 ACC Register 0x08 (*TEMP*)

This register contains the current chip temperature (see section 7.4.3)

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 24 °C

7.6.1.9 ACC Register 0x0A (*INT_STATUS_1*)

This register contains the interrupt status flag *data_int* of the new data interrupt (see section 7.3.1.1)

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

7.6.1.10 ACC Register 0x0F (*PMU_RANGE*)

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

0x0F	***PMU_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	1	1
Content	*reserved*				*range* <3:0>			

Register	**Description**
range <3:0>	Selection of the accelerometer g-range
reserved	Write 0

range <3:0>	**g-range**	**Resolution [LSG / g]**
0011	±2 g	1024
0101	±4 g	512
100	±8 g	256
1100	±16 g	128

All other settings are reserved (do not use)

7.6.1.11 ACC Register 0x10 (*PMU_BW*)

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

0x10	***PMU_BW***							
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*			*bw* <4:0>				

Register	**Description**
bw <4:0>	Selection of the data filter bandwidth:
reserved	Write 0

***bw* <4:0>**	**Bandwidth**	***bw* <4:0>**	**Bandwidth**
01000	7.81 Hz	01100	125 Hz
01001	15.63 Hz	01101	250 Hz
01010	31.25 Hz	01110	500 Hz
01011	62.50 Hz	01111	1000 Hz

All other settings are reserved (do not use)

7.6.1.12 ACC Register 0x13 (*ACCD_HBW*)

This register controls the acceleration data acquisition and data output format.

0x13	ACCD_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 acceleration data registers 1: unfiltered 0: filtered
shadow_dis	Shadowing mechanism for the acceleration data output registers 1: disable 0: enable
reserved	Write 0

7.6.1.13 ACC 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*							

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.

7.6.1.14 ACC Register 0x17 (*INT_EN_1*)

This register enables the new data interrupt (see section 7.3.1.1).

0x17	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	0	0	0	0
Content	*reserved*			*data_en*	*reserved*			

Register	Description
data_en	Data ready interrupt 0: disabled 1: enabled
reserved	Write 0

7.6.1.15 ACC Register 0x1A (*INT_MAP_1*)

This register controls the interrupt signals to be mapped to the INT2 pin (see section 7.3.1.1).

0x1A	*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	*int2_data*	*reserved*						

Register	Description
int2_data	Map data ready interrupt to INT2 pin 0: disabled 1: enabled
reserved	Write 0

7.6.1.16 ACC Register 0x1E (*INT_SRC*)

This register controls the data source definition for interrupts with selectable data source.

0x1E	*INT_SRC*							
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*		*int_src_data*	*reserved*				

Register	Description
int_src_data	Data for new data interrupt 0: filtered 1: unfiltered
reserved	Write 0

7.6.1.17 ACC Register 0x20 (*INT_OUT_CTRL*)

This register controls the electrical behavior and configuration of the interrupt pins.

0x20	*INT_OUT_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	n/a	n/a	0	0	0	1	0	1
Content	*reserved*				*int2_od*	*int2_lvl*	*reserved*	

Register	Description
int2_od	Behavior for the INT2 pin 0: push-pull 1: open drain
int2_lvl	Level for the INT2 pin: 0: active low 1: active high
reserved	Write 0

7.6.1.18 ACC Register 0x32 (*PMU_SELF_TEST*)

This register contains the settings for the sensor self-test configuration and trigger (see section 7.2.1)

0x32	*PMU_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	*reserved*			*self_test_amp*	*reserved*	*self_test_sign*	*self_test_axis* <1:0>	

Register	Description
self_test_amp	Select the amplitude of the self-test deflection 1: high 0: low (default)
self_test_sign	Select the sign of self-test excitation 1: positive 0: negative
self_test_axis <1:0>	Select the axis to be self-tested 00: self-test disabled 01: x-axis 10: y-axis 11: z-axis
reserved	Write 0

7.6.1.19 ACC 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

7.6.2 Register Map Gyroscope

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*).

The following table shows the register map of the SMI130 gyroscope.

Register	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0	Default
0x3C				*rate_ok*		*bist_fail*	*bist_rdy*	*trig_bist*	0x00
0x34						*i2c_wdt_en*	*i2c_wdt_sel*		0x00
0x18								*int1_data*	0x00
0x16							*int1_od*	*int1_lvl*	0x0F
0x15	*data_en*								0x00
0x14	*softreset*								0x00
0x13	*data_high_bw*	*shadow_dis*							0x00
0x10					*bw* <3:0>				0x80
0x0F						*range* <2:0>			0x00
0x0A	*data_int*								0x00
0x08	*temp* <7:0>								0x00
0x07	*rate_z_msb* <15:8>								0x00
0x06	*rate_z_lsb* <7:0>								0x00
0x05	*rate_y_msb* <15:8>								0x00
0x04	*rate_y_lsb* <7:0>								0x00
0x03	*rate_x_msb* <15:8>								0x00
0x02	*rate_x_lsb* <7:0>								0x00
0x00	*chip_id* <7:0>								0x0F

(grey)	w/r
(dark grey)	write only
(blue)	ready 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.

7.6.2.1 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

7.6.2.2 GYR Register 0x02 (*RATE_X_LSB*)

This register contains the least significant bits of x-channel angular rate readout value (see section 7.4.2).

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)

7.6.2.3 GYR Register 0x03 (*RATE_X_MSB*)

This register contains the most significant bits of x-channel angular rate readout value (see section 7.4.2).

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)

7.6.2.4 GYR Register 0x04 (*RATE_Y_LSB*)

This register contains the least significant bits of y-channel angular rate readout value (see section 7.4.2).

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)

7.6.2.5 GYR Register 0x05 (*RATE_Y_MSB*)

This register contains the most significant bits of y-channel angular rate readout value (see section 7.4.2).

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)

7.6.2.6 GYR Register 0x06 (*RATE_Z_LSB*)

This register contains the least significant bits of z-channel angular rate readout value (see section 7.4.2).

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)

7.6.2.7 GYR Register 0x07 (*RATE_Z_MSB*)

This register contains the most significant bits of z-channel angular rate readout value (see section 7.4.2).

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)

7.6.2.8 GYR Register 0x08 (*TEMP*)

This register contains the current chip temperature (see section 7.4.3)

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

7.6.2.9 GYR Register 0x0A (*INT_STATUS_1*)

This register contains the interrupt status flag *data_int* of the new data interrupt (see section 7.3.1.2)

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

7.6.2.10 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)

7.6.2.11 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)

7.6.2.12 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

7.6.2.13 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.

7.6.2.14 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

7.6.2.15 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*						*int1_od*	*int1_lvl*

Register	Description
int1_od	Behavior for INT1 pin 0: push-pull 1: open drain
int1_lvl	Active level for INT1 pin 0: active low 1: active high
reserved	Write 0

7.6.2.16 GYR Register 0x18 (*INT_MAP_1*)

This register controls if interrupt signals are mapped to the INT1 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	*reserved*							*int1_data*

Register	Description
int1_data	Map new data interrupt to the INT1 pin 0: disabled 1: enabled
reserved	Write 0

7.6.2.17 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

7.6.2.18 GYR Register 0x3C (*BIST*)

This register contains the built-in self-test (BIST) options (see section 7.1).

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*

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

Register	**Description**
trig_bist	Write 1: perform the BIST
reserved	Write 0

8 Safety Concept

Not applicable.

9 Functional and Lifetime Qualification Test Plan

The SMI130 passed the following qualification: AEC-Q100 grade 3.

10 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.

Safety and warning notes

Please note that the sensor may be seriously damaged or sensor performance might be influenced by:

- Exceeding the maximum operating conditions. The sensor must be discarded when exceeding these limits.
- Electrostatic discharge. A proper ESD environment during handling and processing of the sensor has to be in place.
- Exceeding the qualification reflow profile. The maximum soldering profile as well as the maximum number of reflow cycles must be observed.
- Exceeding the mission profile: In case a different mission profile than the referred one shall be applied, it needs to be verified whether this profile is still covered by the qualification.
- Improper mechanical connection between the sensor and the PCB and any measure that alters the mechanical stress imposed on the sensor (such as, e.g. soldering, potting, coating, overmolding, etc.). Any measure on application level is considered to be application specific and has to be chosen with care by and in responsibility of the customer

Target market: The product is described by Bosch for the intended application (cf. Chapter 1) and released on the basis of the legal and normative requirements relevant to the Bosch product for use in the following target markets as follows:

The sensor complies with all statutory regulations regarding restriction of hazardous substances and recyclability which are in the scope of IMDS, insofar as such restrictions of hazardous substances and recyclability are regarded, the target market of the sensor is worldwide.

Functional Safety: 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 SMI130 must not be used if it influences safety goals with ratings higher than ASIL QM. Safety goals are defined in the overall system.
- Bosch cannot provide any quantitative failure analysis (e.g. FTA or FMEDA) for the SMG130.
- The SMI130 does not provide a CRC to check communication errors within a SPI/I2C frame.
- The SMI130 does not provide error flags to detect malfunctions of the ASIC.

Repair of the product is not possible. Manual soldering of sensors is not permitted.
Sensors must not be handled as bulk goods.
Sensors with visible damages (housing, connectors, pins, etc.) and sensors which might have exceeded the absolute maximum ratings must not be mounted in the vehicle. 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 fulfil the requirements of the product.

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

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.

Engineering Samples: 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.

11 Changes

This TPD is on basis of SMI130 Technical Customer Documentation (TCD) 1 279 929 731 Rev. 3.0.

12 Table of Figures