Technical Product Description
SMG130

Triaxial Gyroscope for Non-Safety Automotive Applications

- Document revision 4.0
- Release date September-2020
- Part number 0273 142 062 (SMG130)
- Issued by AE/PAS1.3

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Please refer to the Technical Customer Documentation for specified values.

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1 Product identification

- Product Designation: SMG130
- Type Designation: Gyroscope
- Product Part Number: 0273 142 062
- This Product is intended for use in: Non-Safety Automotive Applications

1.1 Main Functions and Properties

The SMG130 is a triaxial gyroscope i.e. it measures angular velocity respectively (yaw) rate in all three spatial dimensions. This product is intended for use in non-safety related automotive applications, e.g. for in-dash navigation in the passenger compartment. The digital standard serial peripheral interface (SPI) of the SMG130 allows for bidirectional data transmission.

1.2 Key Features

Key Feature	Description
Gyroscope sensor	Advanced triaxial 16 bit gyroscope 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)
Consumer electronics suite	MSL1, RoHS compliant, halogen-free
Operating temperature	-40 ... +85 °C
Extended operating temperature	-40 ... +105 °C
Programmable functionality	Rate range selectable Low-pass filter bandwidths selectable
On-chip temperature sensor	Factory trimmed, 8 bit, typical

2 General product description

2.1 Mechanical Design

The gyroscope SMG130 is based upon a two-chip stacked concept. It consist of sensitive micro-electro-mechanical sensing element (MEMS) and its readout ASIC. The sensing element has the ASIC stacked on top of the MEMS and all elements are packed in one single LGA package.

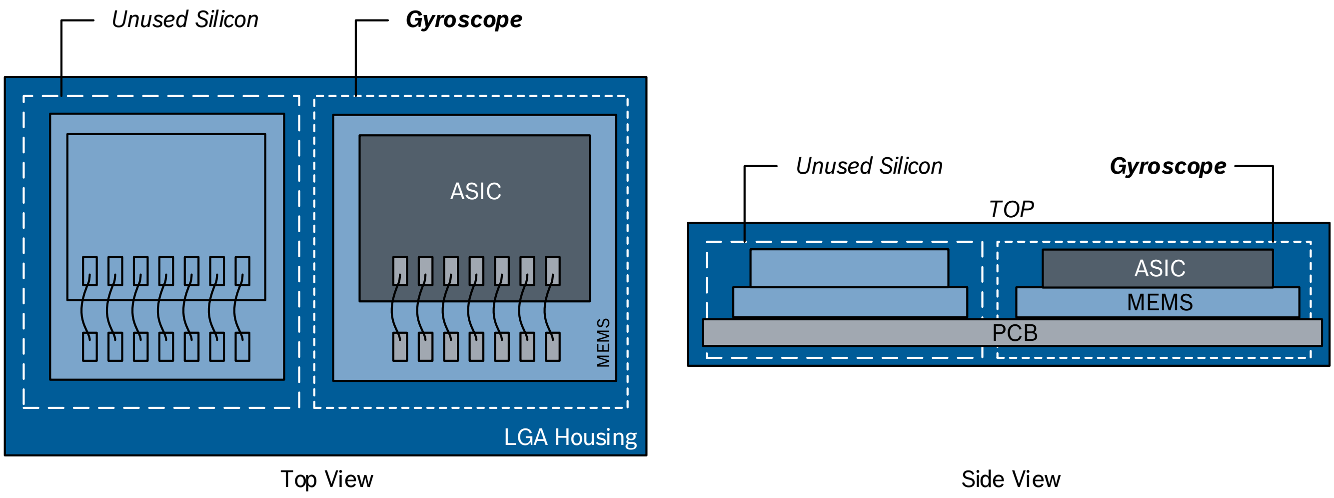

Figure 1 Schematics of the SMG130 mechanical design

2.2 Sensor Data

The sensor data, i.e. the yaw rate sensed by the MEMS and readout by the AISC can be accessed via a digital interface (SPI or TWI). Reading and evaluating the sensor data is described in section 7.4.

It is recommended to actively set appropriate, application specific **bandwidth** (BW) and measurement **range**. Both can be selected by specific register settings (see section 7.1 for details). The BW can be chosen between 32 Hz and 523 Hz, and the measurement range can be selected from ±125 °/s to ±2000 °/s.
Two different streams of 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 BW. Based on a specific register setting, either the filtered or the unfiltered data is stored in the registers. The data representation of the SMG130 follows two´s complement representation. For each axis, the gyroscope data is split into a MSB upper part and a LSB lower part.
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.
For all gyroscope sensor data readout details please see section 7.4.1

The ASIC additionally has a built-in temperature sensor with a data width of 8 bits, covering a temperature range of 128 K. The corresponding data can be read from registers 0x08 (TEMP) (details see section 7.4.2).

2.3 Block Diagram

Figure 2 shows the basic building blocks of the SMG130. A rate signal along the sensitive axis of the MEMS element causes a change of the capacitances of the MEMS element. This change is converted into a digital serial bit stream, which is further processed and can be accessed via SPI.

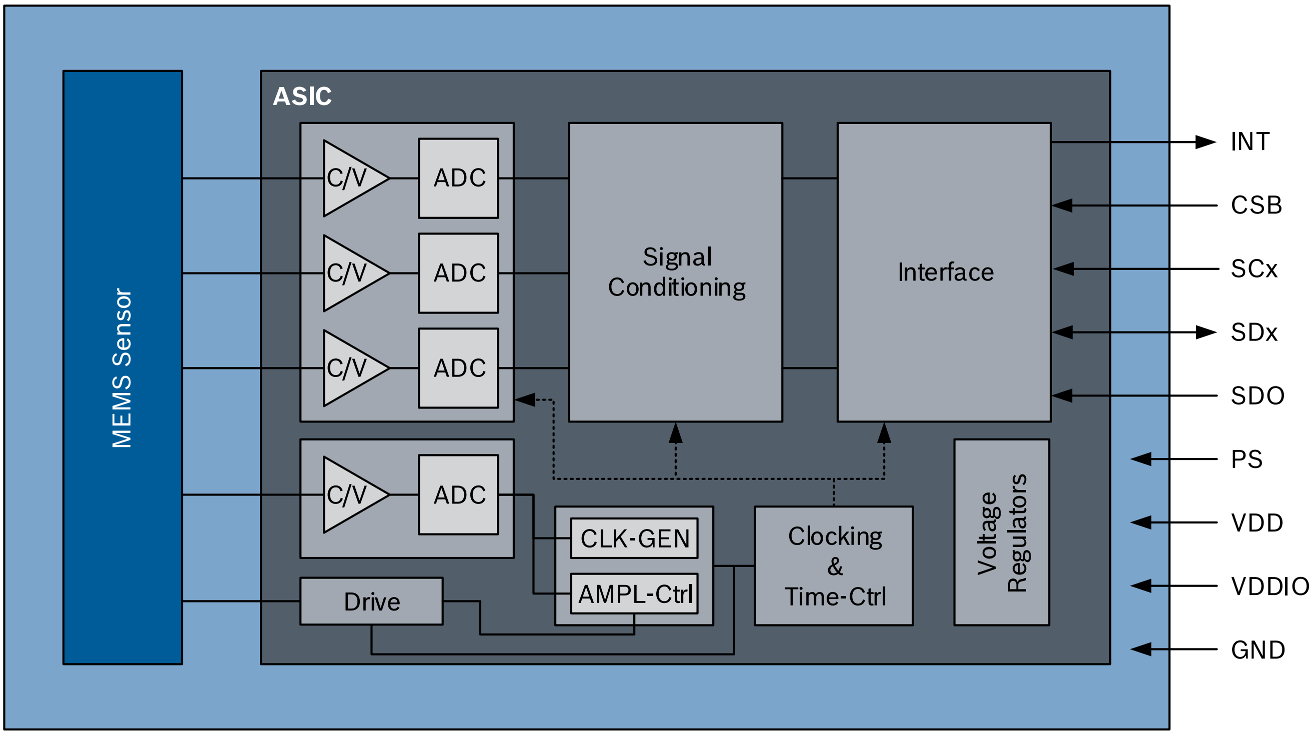

Figure 2 Simplified block diagram of the SMG130

2.4 Signal Path

The signal path of the gyroscope is sketched in Figure 3. 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.

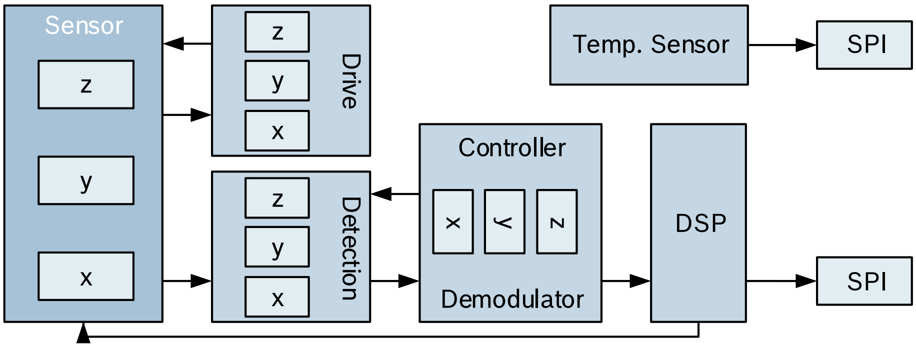

Figure 3 Simplified signal path of the gyroscope

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 4.

The block ‘Detection’ corresponds to the analog part of the SMG130. 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 conform 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 through a fine gain block and a low pass filter before being accessible via e.g. SPI.

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

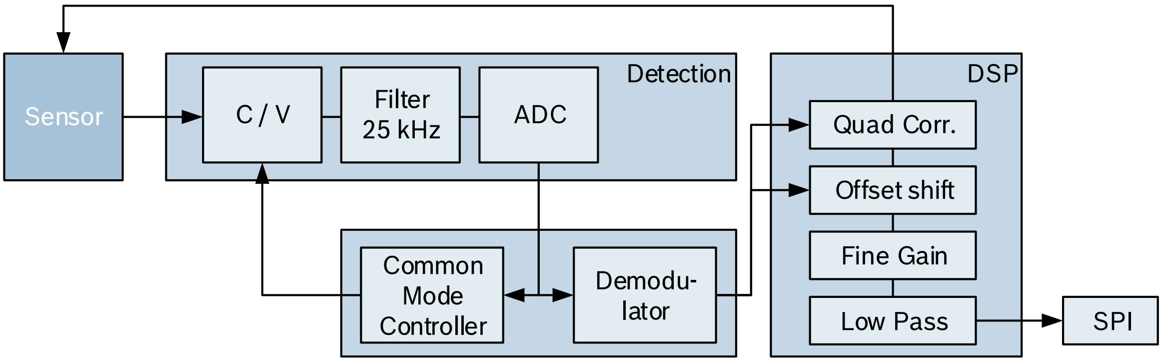

Figure 4 Path of the detection signal for one axis (gyroscope)

2.5 Orientation of the Sensing Axes

If the sensor is rotated in the indicated directions, the corresponding channels of the device will deliver a positive rate signal. If the sensor is at rest without any rotation, the output of the corresponding gyroscope channel will be 'zero'.

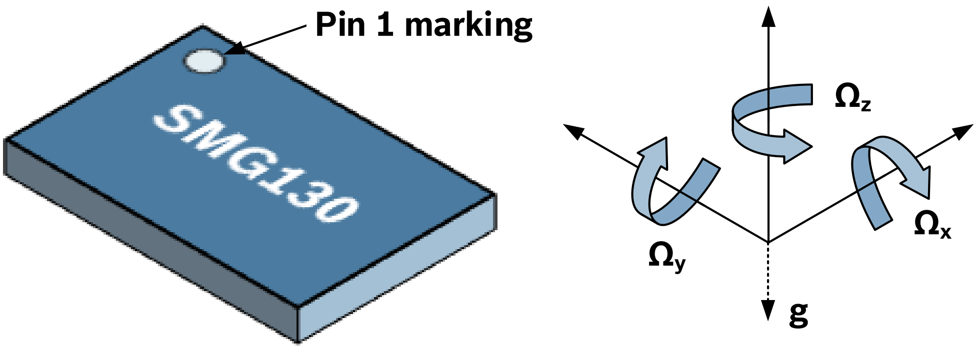

Figure 5 Sensing axis orientation

Example:

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

- ± 0 for the Ω_X-channel
- ± 0 for the Ω_Y-channel
- ± 0 for the Ω_Z -channel

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

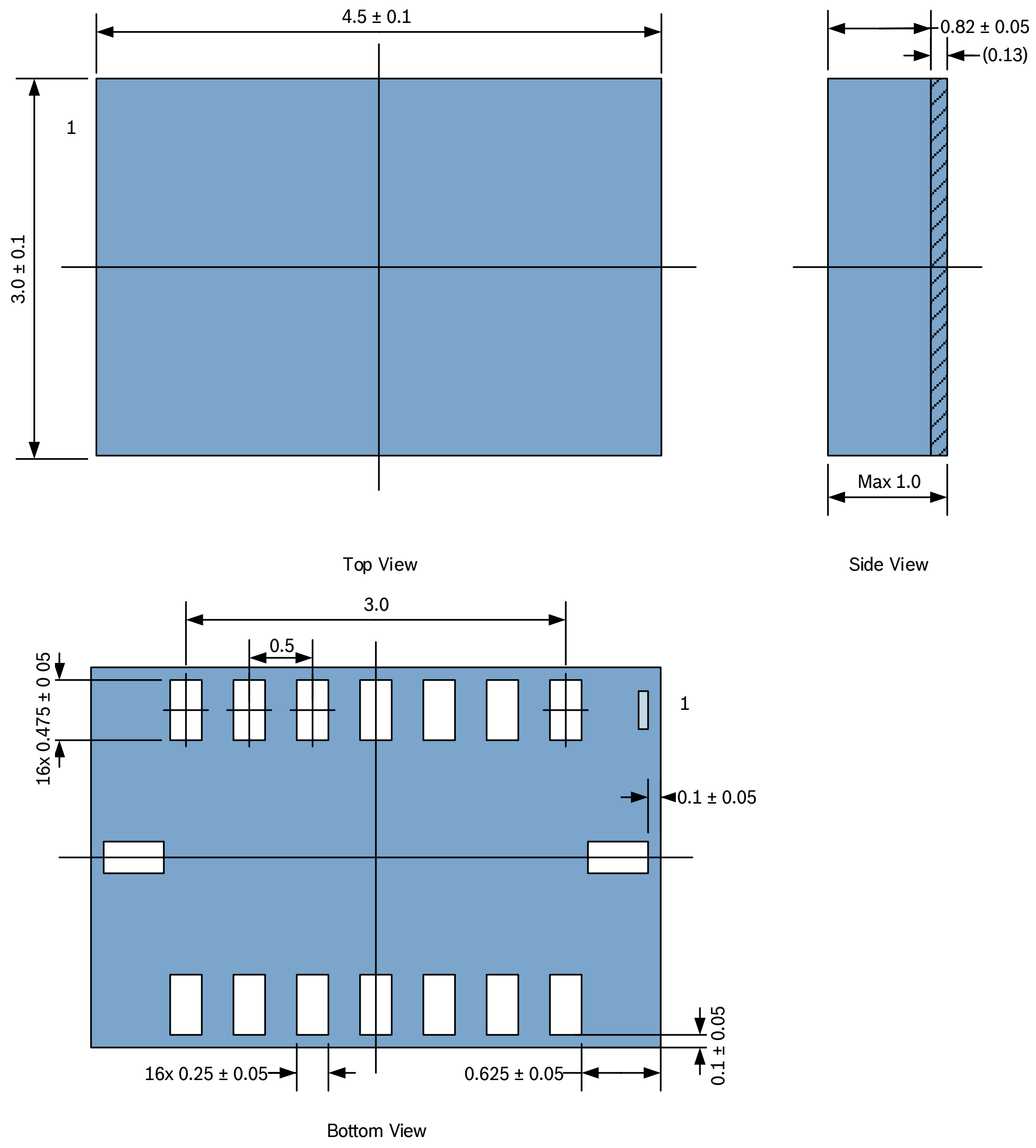

Figure 6 SMG130 package outline drawing

The sensor housing is a standard LGA package. The dimensions are given in mm.
Note: Unless otherwise specified, the tolerance is ± 0.05 mm.

3.2 Transport Package

3.2.1 Tape on Reel Specification

The SMG130 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.
SMG130 quantity: 5000 pcs per reel.
Please handle with care.

3.2.2 Tape Dimensions

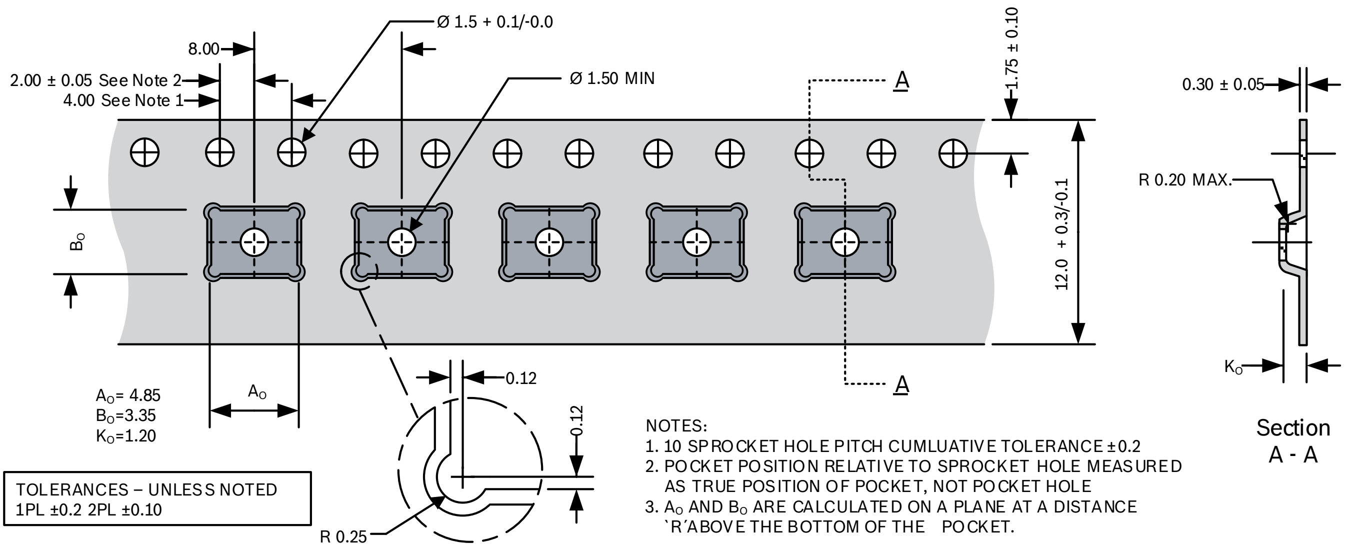

Figure 7 Tape dimensions in mm

3.2.3 Reel Dimensions

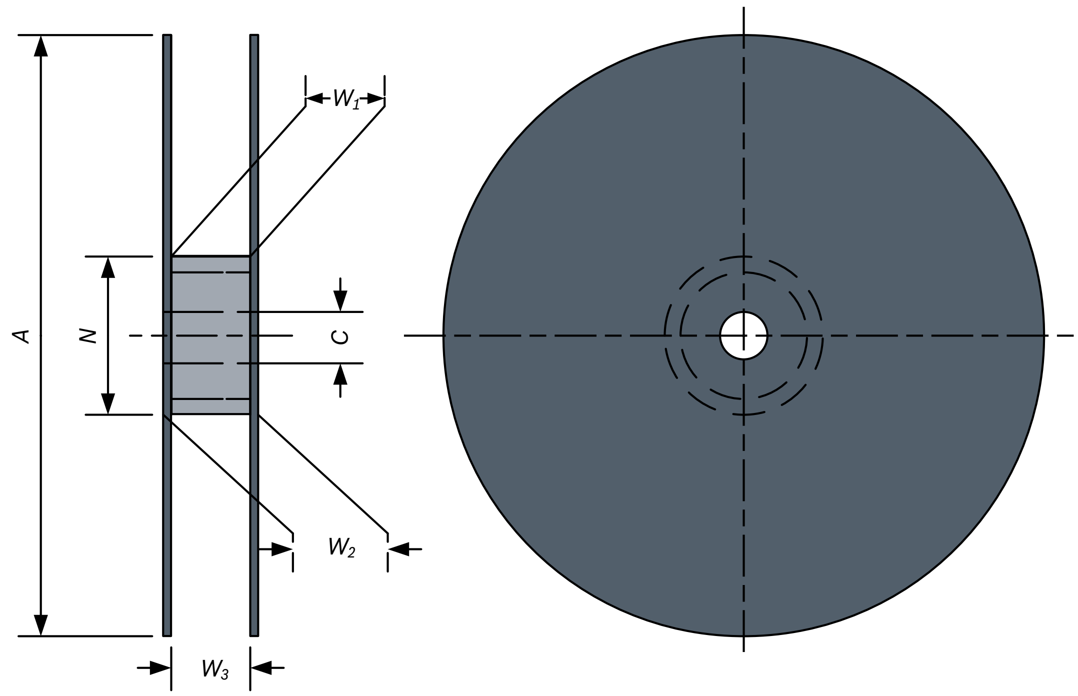

Figure 8 Reel dimensions

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

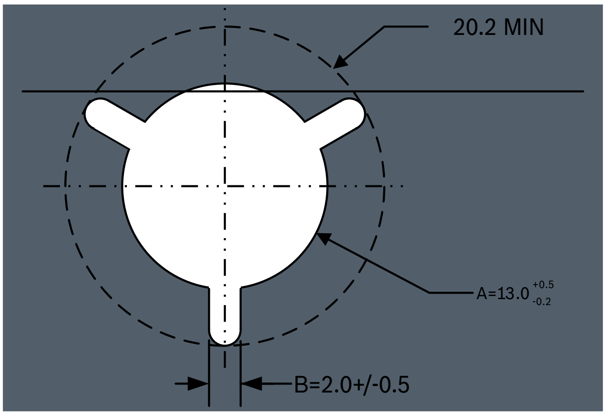

Figure 9 Details on hub hole dimension C in mm

3.2.4 Orientation within Reel

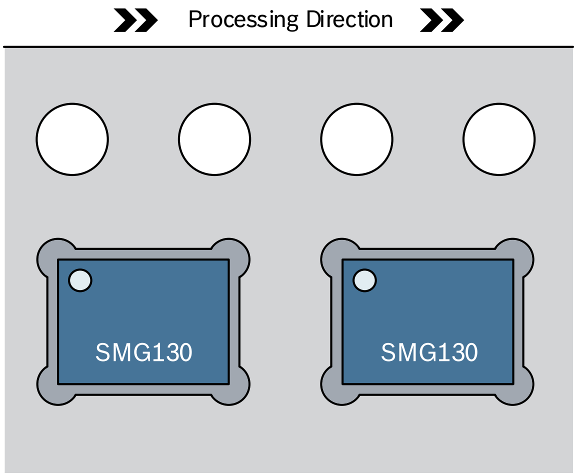

Figure 10 Orientation of the SMG130 devices relative to the tape

3.3 Labelling of the product

Labeling	Name	Symbol	Remark
xxx AYYWW CCC	Product number	xxx	3 numeric digits, fixed to identify product type (“062”)
	Sub-con 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

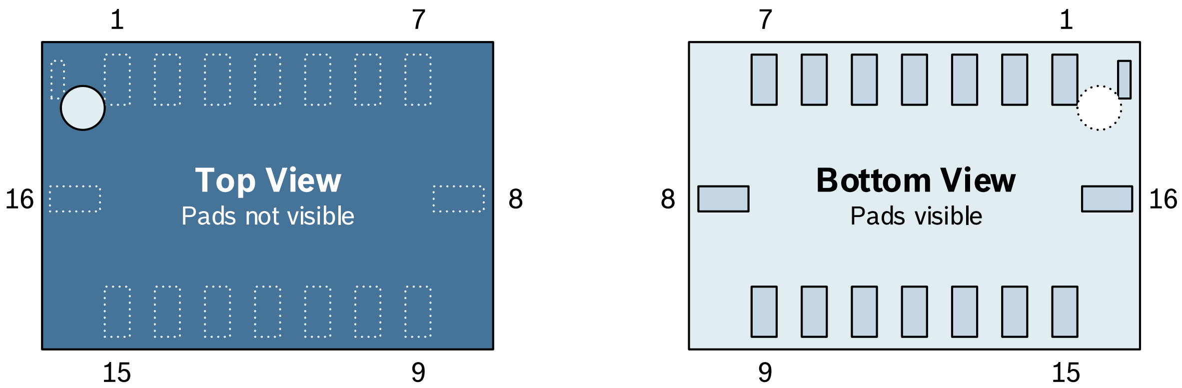

Figure 11 Pin-out top (left) and bottom (right) view

Pin	Name	I/O Type	Description	Connect to - SPI -	Connect to - TWI -
1	NF	--	--	DNC	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	CSB	Digital in	SPI chip select	CSB	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	SDO	Digital out	SPI: serial data out	SDO	SDO
11	VDDIO	Supply	Digital I/O supply voltage	VDDIO	VDDIO
12	INT	Digital out	Interrupt pin	INT / DNC	INT / DNC
13	NF	--	--	DNC	DNC
14	NF	--	--	DNC	DNC
15	NF	--	--	DNC	DNC
16	NF	--	--	DNC	DNC

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

3.5 Soldering

The moisture sensitivity level (MSL) of BOSCH SMG130 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.

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 12).

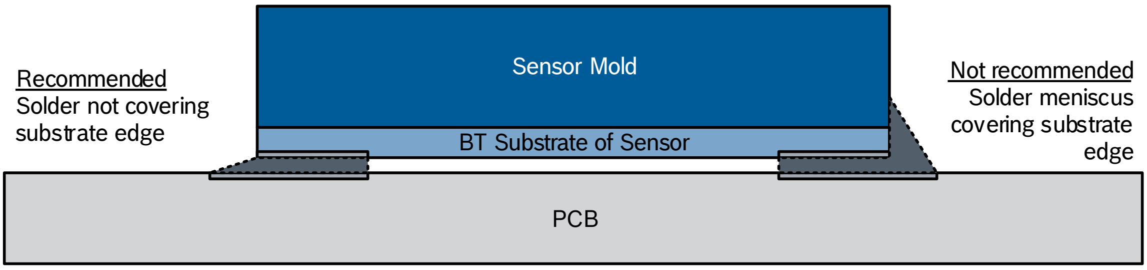

Figure 12 Reflow soldering recommendation

3.5.2 Classification Reflow Profile

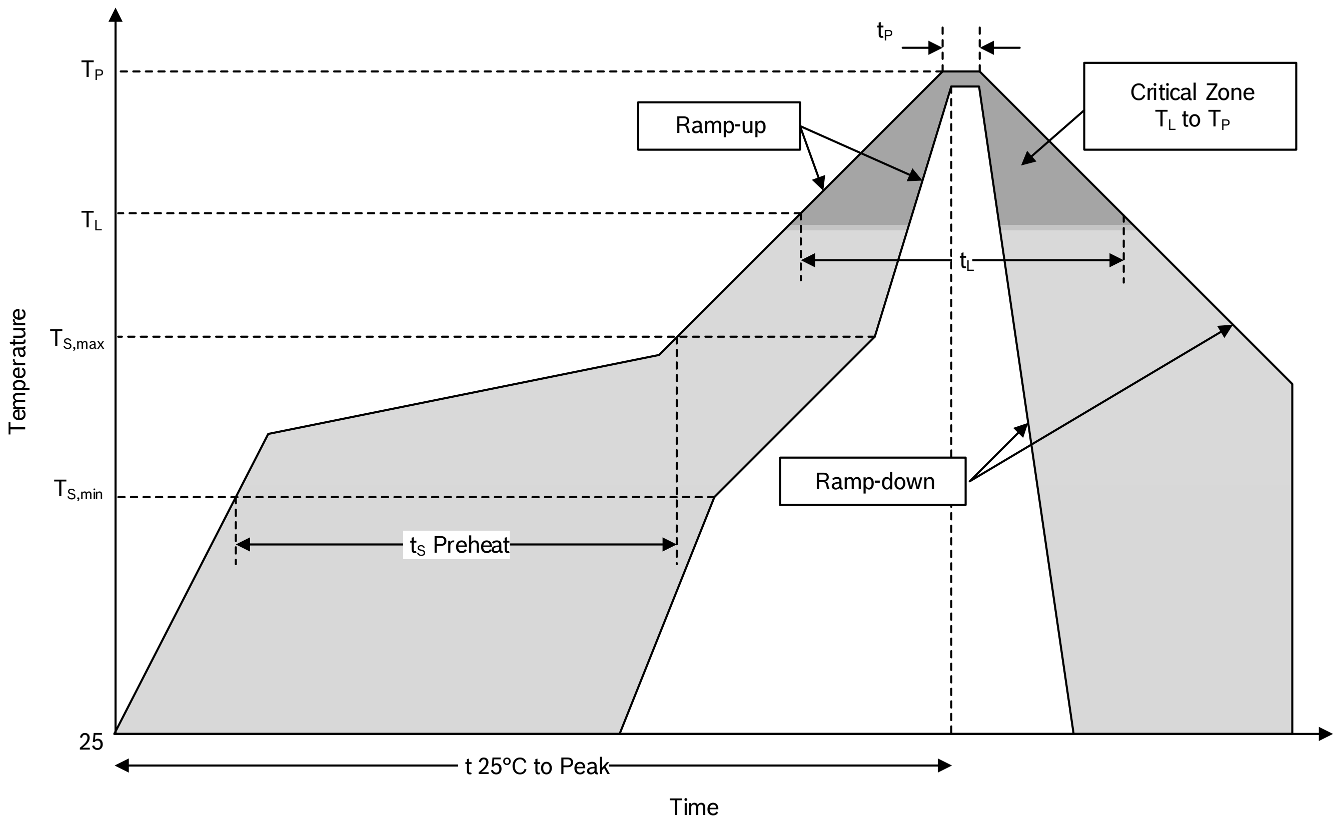

Figure 13 Soldering profile

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 °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 which 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, e.g. regarding:

- Thermal aspects: infrared camera
- Mechanical stress: warpage measurements and/or FEM-simulations
- Shock robustness: drop test after soldering on the target application PCB

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 must therefore be determined case by case.

- It is generally recommended to minimize the PCB thickness, since a thin PCB shows less intrinsic stress, e.g. during bending. (Recommendation ≤ 0.8 mm)
- 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 direct vicinity of extremely hot spots regarding temperature (e.g. a µController or a graphic chip) as this can result in heating up the PCB and consequently also of the sensor.
- It is *not* recommended to place the sensor in 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 to be expected.

- Please avoid partial coverage of the sensor by any kind of (epoxy) resin, as this can possibly result in mechanical stress.
- Avoid mounting (and operating) the sensor in the vicinity of strong magnetic, strong electric, and/or strong infrared (IR) radiation fields.
- Avoid electrostatic charging of the sensor and of the device in which the sensor is mounted.

In case you have any questions regarding the mounting of the sensor on your PCB or the evaluation and/or optimization of the considered placement position of the sensor on your PCB, please contact your Bosch representative.

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

The SMG130 is designed to sense angular rates 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.

We strongly recommend to avoid any g-forces beyond the limits specified in the data sheet during transport, handling, and mounting of the sensors in a defined and qualified installation process.

This device has built-in protections against high electrostatic discharges and electric fields (2 kV HBM); however, anti-static precautions should be taken as for 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 as shown in Figure 14Figure 14 SMG130 footprint is recommended. The dimensions are given in mm.

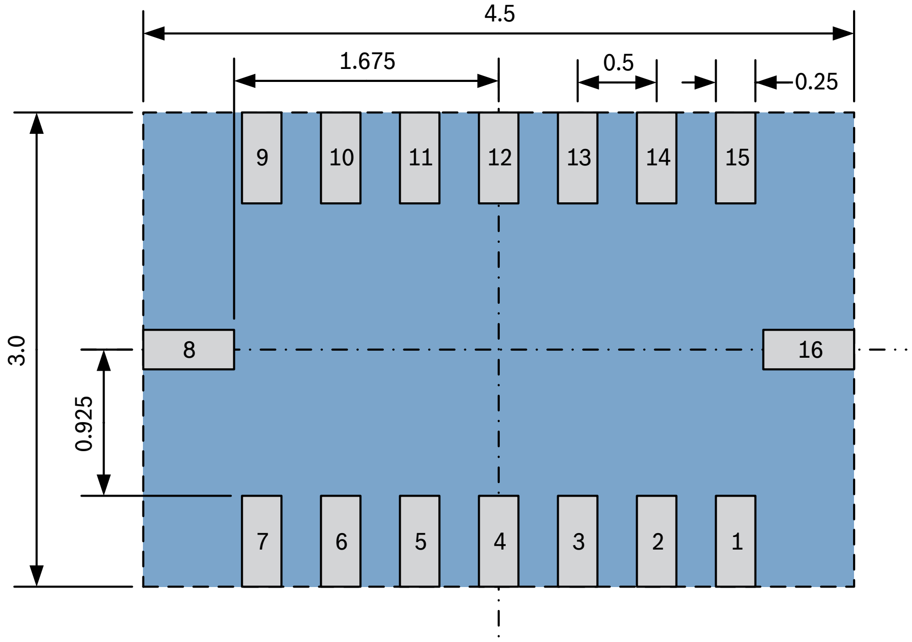

Figure 14 SMG130 footprint

4 Environment Specification

4.1 Absolute 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	4.27	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 (see section 5.2)	$T_{extended}$	-40	-	105	°C

4.3 Lifetime Conditions

Lifetime conditions are according to AEC-Q100 grade 3 requirements.

4.4 Environmental Safety

RoHS

The SMG130 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)*.

Halogen content

The SMG130 is halogen-free. For more details on the analysis results, please contact your Bosch representative.

5 Parameter Specification

5.1 Power Supply

The SMG130 has two distinct power supply pins:

- VDD is the main power supply for the internal blocks.
- VDDIO is a separate power supply pin 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. VDDIO			-

Switching sequence of power supply VDD and VDDIO

⚠ If VDD and VDDIO are not powered on simultaneously (via directly connecting both pins), VDD must 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 SMG130 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 stay 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 stay below for ≥ 2 µs while keeping VDD ≥ 1.8 V. Ramp up VDD and VDDIO to operating range.

SPI protocol requirement: 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 TCD section 5.2.1.

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 5.2.2. It is the customers' responsibility to assess the impact on system level.

The SMG130 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

5.2.1 Values in the Temperature Range up to 85°C

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

Parameter	Symbol	Condition / Comment	Typical	Max[1]	Unit
Supply current	I_{DD}	w/o SPI communication	5.5		mA
Start-up time	$t_{s,up}$	POR	0.1		s
Sensitivity tolerance		including temperature and lifetime effects	±4		%
Sensitivity tolerance		T = 25 °C over lifetime	±1		%
Temperature Coefficient Sensitivity	TCS	nominal VDD supply, over temperature range [-40;85] °C	±0.03		% / K
Zero-rate Offset* - reset to zero at end of customer line -		lifetime and temperature effects	±0.5		°/s
Zero-rate Offset		T = 25 °C over lifetime	±0.5		°/s
Temperature Coefficient Offset (zero-rate)	TCO	nominal VDD supply, over full temperature range	±0.015		°/s / K
Nonlinearity	NLIN	best fit straight line; range: ±125 °/s; no lifetime	0.1		°/s
Noise rms		T = 25 °C, nominal VDD supply; no lifetime	0.1		°/s
Cross axis sensitivity		including temperature and lifetime effects	±2		%
Temperature sensor measurement range				+85	°C
Temperature sensor slope			0.5		K / LSB
Temperature sensor offset		T = 25°C	±5		K

*Assumption: the gyroscope is offset corrected at end of customer production line on system level.

5.2.2 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

[1]For specified maximum values, please refer to the Technical Customer Documentation.

Zero-rate Offset		over full temperature range, w/o lifetime effects; with assumption: offset correction at end of customer production line on system level	±0.5	°/s
Temperature Coefficient Offset (zero-rate)	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 full temperature range, w/o lifetime effects	0.16	°/s

6 Software Interface Description

6.1 Serial Peripheral Interface (SPI)

6.1.1 SPI Connection

For communication, the SMG130 supports the SPI 4-wire protocol as a slave with a host device. The connection diagram is shown in Figure 15. The mapping for the interface of the gyroscope is given in the table below:

Pin	Name	Description
10	SDO	GYR data output
9	SDx	SDI serial data in
5	CSB	GYR chip select (enable)
8	SCx	SCK serial clock

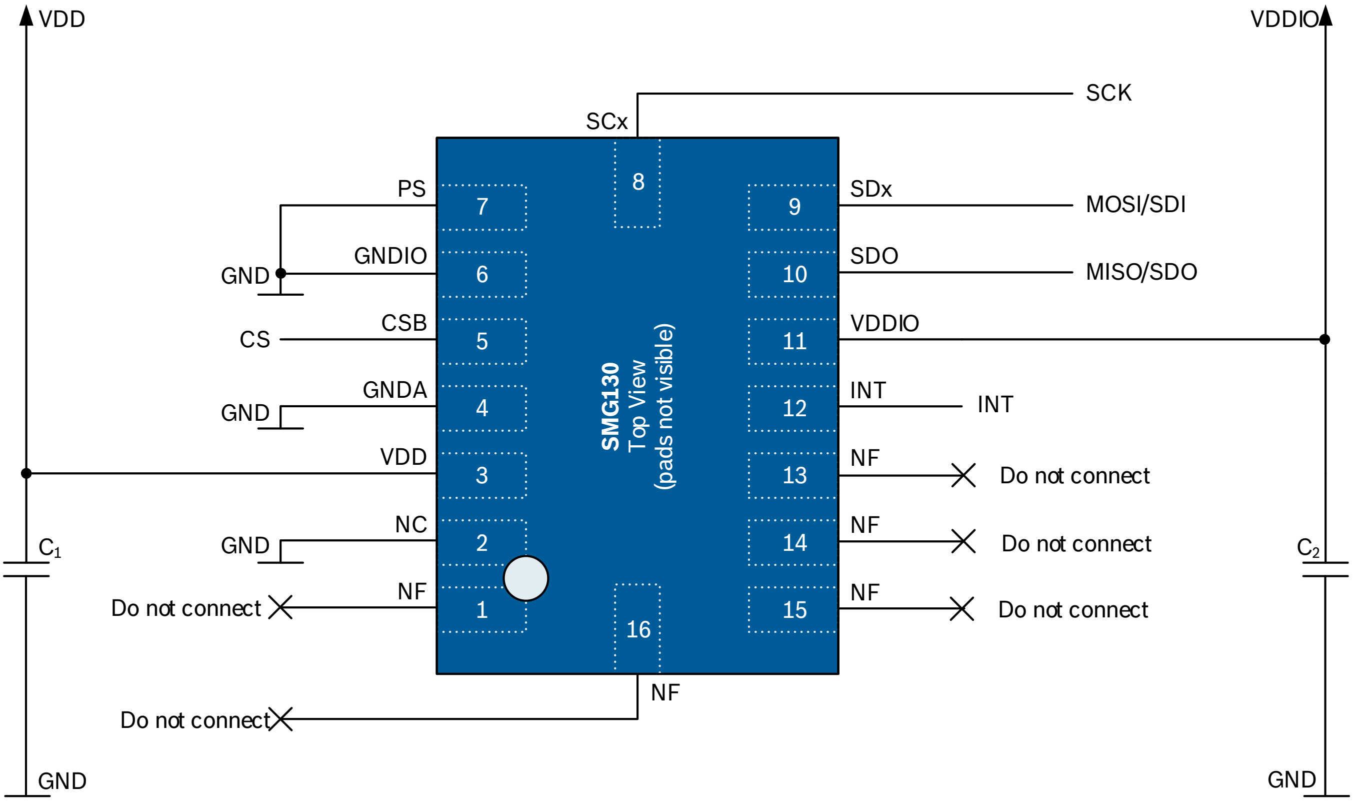

Figure 15 SPI connection diagram

C_1, C_2: 100 nF
INT: see registers 0x18, 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.

6.1.2 SPI Timing

The SPI timing specification of the SMG130 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 16 shows the definition of the SPI timing.

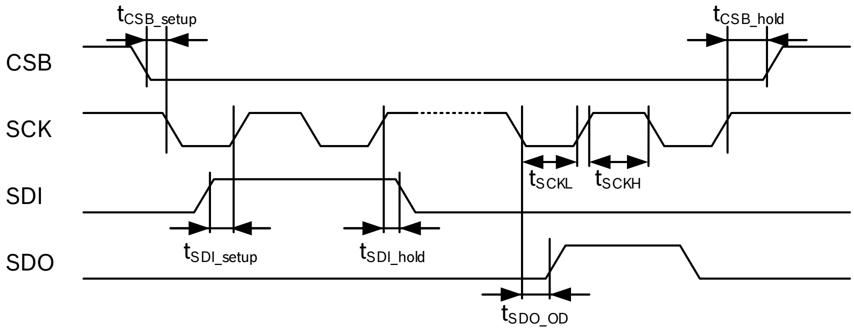

Figure 16 SPI timing diagram

The SPI interface of the SMG130 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. For single byte read and write operations, 16-bit protocols are used. The SMG130 also supports multiple-byte read operations.

For standard SPI configuration, CSB (chip select low active), SCK (serial clock), SDI (serial data input), and SDO (serial data output) pins are used. The communication starts when CSB is pulled low by the SPI master and stops when CSB is pulled high. SCK is also controlled by the SPI master. SDI and SDO 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 17. During the full write cycle, SDO remains in high-impedance state.

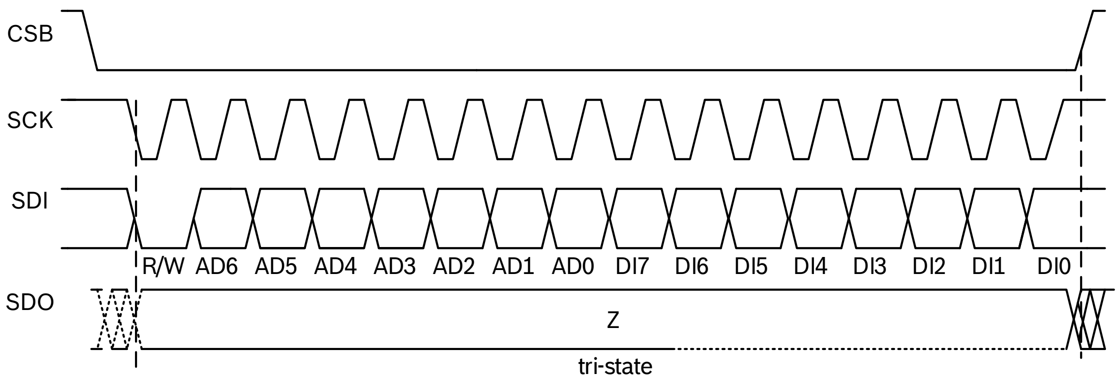

Figure 17 4-wire basic SPI write sequence (mode 11)

The basic read operation waveform for the 4-wire configuration is depicted in Figure 18.

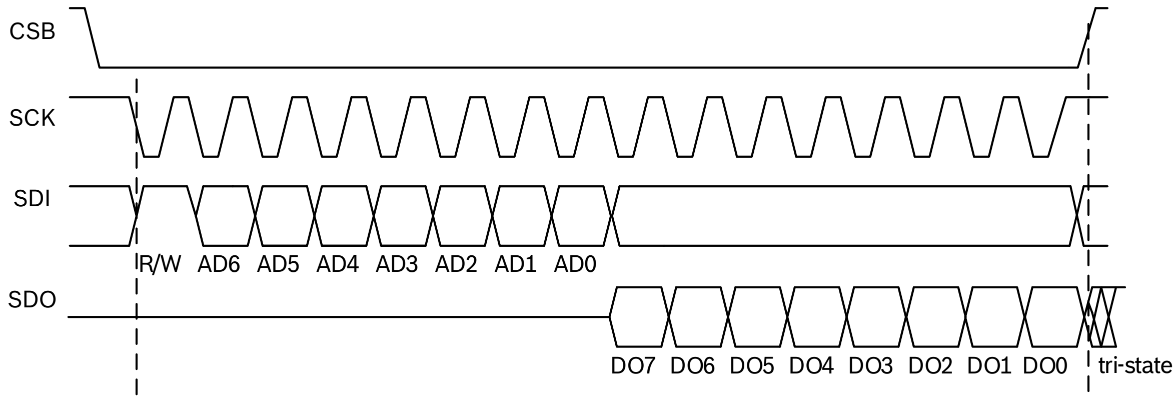

Figure 18 4-wire basic SPI read sequence (mode 11)

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 are the data SDI which will be written into the address. When in read mode, these 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 19.

	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 19 SPI multiple read

6.2 Two-wire Interface (TWI)

With some exceptions, the TWI interface of the SMG130 is compatible to the I²C specification UM10204 Rev. 03 (19 June 2007), available at http://www.nxp.com:

- The SMG130 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.

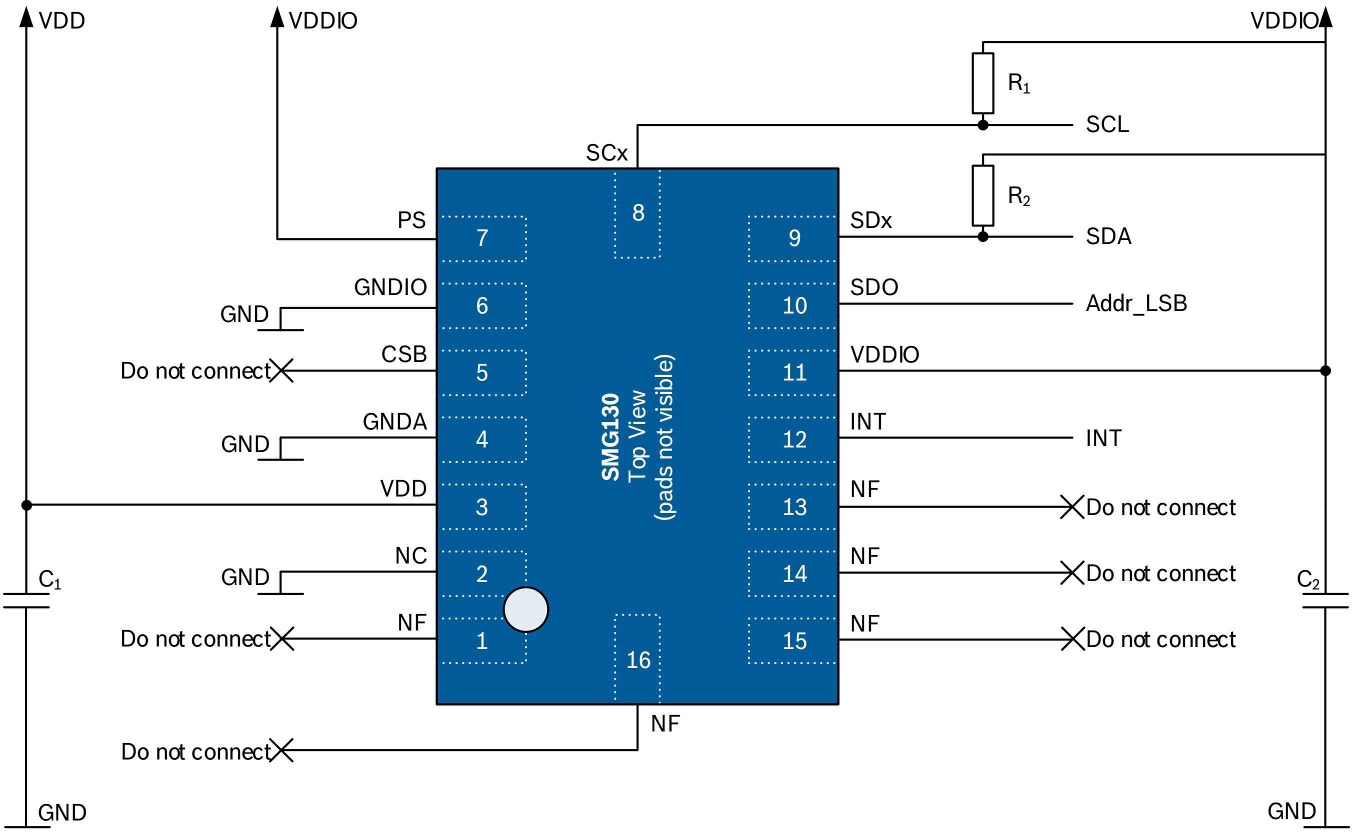

Figure 20 TWI connection diagram

C_1, C_2:	100 nF
R_1, R_2:	pull-up resistors
INT:	see registers 0x18, 0x16

SDO is used to define the TWI address of the gyroscope. The default TWI address is 0x68. It is used if SDO pin is pulled to GND. The alternative address is selected by pulling the SDO pin to VDDIO:

	Gyroscope address
SDO to GND	0x68 (GYR: 1101000)
SDO to VDDIO	0x69 (GYR: 1101001)

6.2.2 TWI Timing

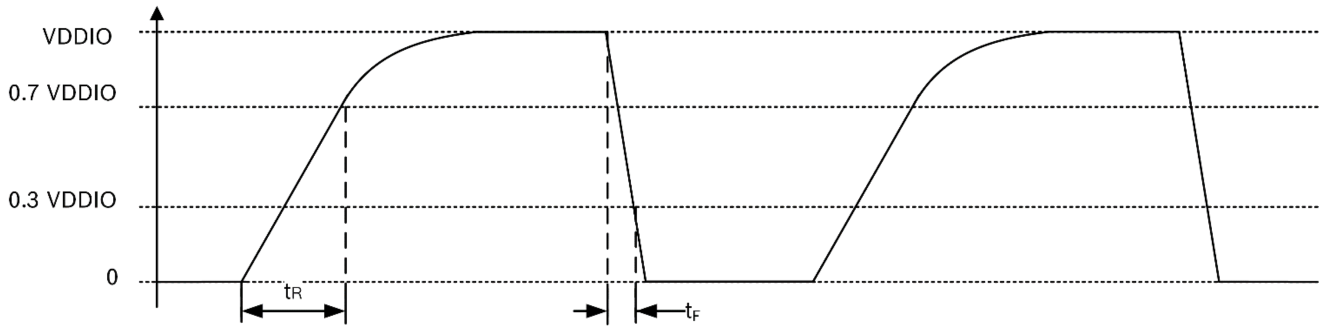

Figure 21 Definition of rise and fall time of TWI signals

The TWI timing specification of the SMG130 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

The definitions of the specified TWI timing given in the table above is illustrated in Figure 21 and Figure 22.

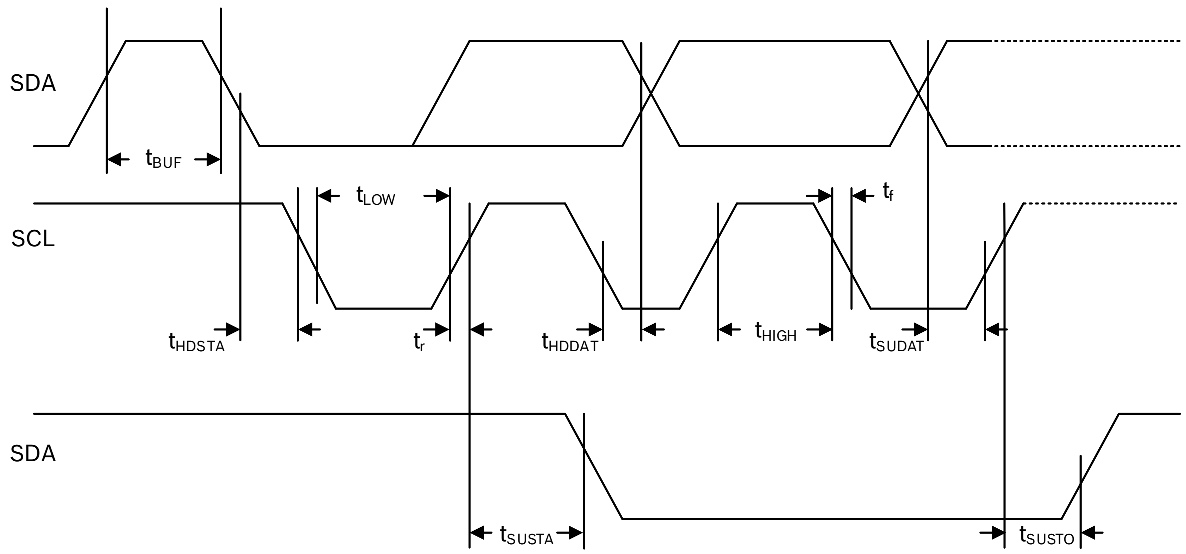

Figure 22 SMG130 TWI timing specification

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 SMG130.

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 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 will 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 23 shows an example of a TWI write access to the gyroscope.

<table>
<tr><td colspan="10"></td><td colspan="8">Control Byte</td><td></td><td colspan="8">Data Byte</td><td colspan="2"></td></tr>
<tr><td>Start</td><td colspan="7">Slave Address</td><td>RW</td><td>ACKS</td><td colspan="8">Register Address (0x10)</td><td>ACKS</td><td colspan="8">Data (0x09)</td><td>ACKS</td><td>Stop</td></tr>
<tr><td>S</td><td>1</td><td>1</td><td>0</td><td>1</td><td>0</td><td>0</td><td>0</td><td>0</td><td></td><td>0</td><td>0</td><td>0</td><td>1</td><td>0</td><td>0</td><td>0</td><td>0</td><td></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></td><td>P</td></tr>
</table>

Figure 23 Example of a TWI write access

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. Activity and timer period of the WDT can be configured via bits 2 (*i2c_wdt_en*) and 1 (*i2c_wdt_sel*) in register 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 24 shows an example of a TWI read access to the gyroscope.

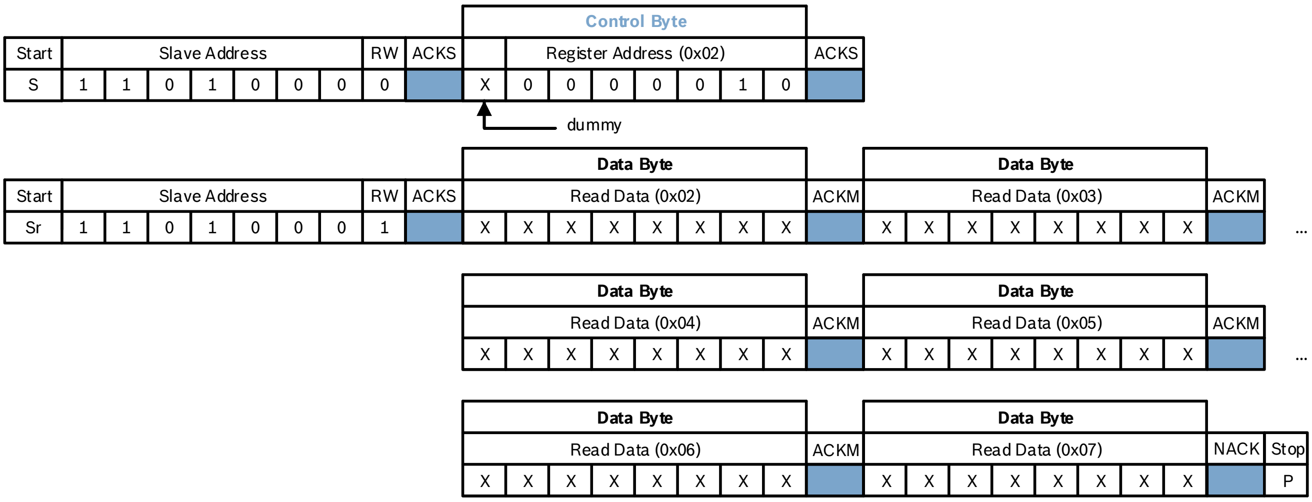

Figure 24 Example of a TWI read access

Note (Gyroscope Soft Reset):

The SMG130 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 SMG130, certain access restrictions apply for consecutive write accesses or a write/read sequence through the SPI and TWI interface.

As illustrated in Figure 25 an interface idle time of at least 2 µs is required following a write operation when the device operates.

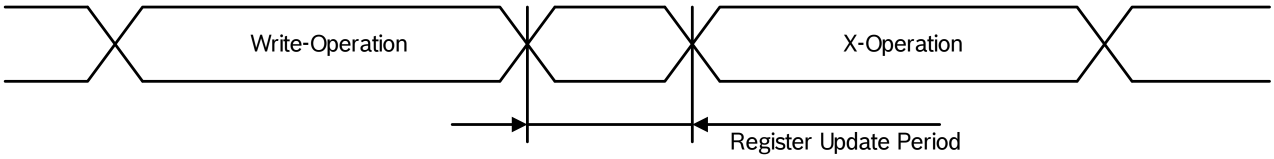

Figure 25 Post-write access timing constraints

7 Application Details

In Figure 26 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 allows further setup 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.

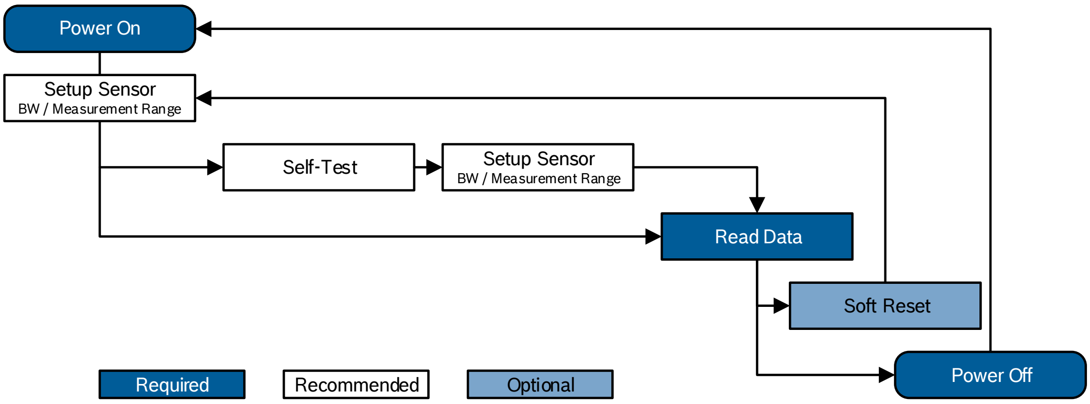

Figure 26 Basic flow chart for SMG130 application with key functional elements

7.1 Sensor Settings

The basic sensor setting includes selection of the bandwidth and measurement range.

The **bandwidth** of filtered rate data is determined by setting bits <3:0> (*bw*) in register 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 0x0F (*RANGE*) according to the table below.

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

7.2 Self-test

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

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

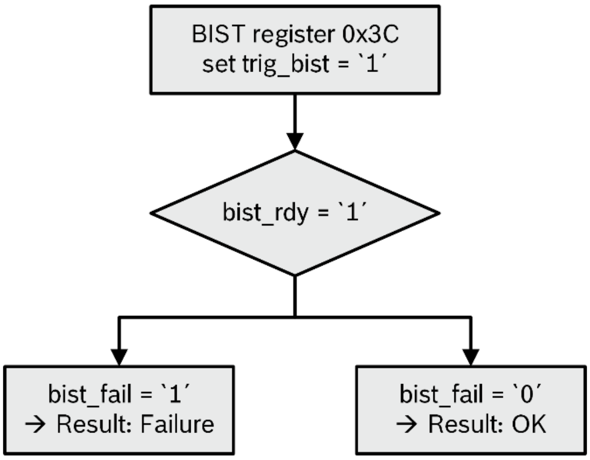

Figure 27 SMG130 BIST sequence

To trigger the BIST, set bit 0 (*trig_bist*) in register 0x3C (*BIST*) to 1. Two bits (read-only) have to be checked in BIST register 0x3C:

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

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

Note: 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

The SMG130 provide 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 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 0x15 (*INT_EN_0*) to 1 (0).

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

7.4 Reading Data

7.4.1 Gyroscope Sensor

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 0x02 (*RATE_X_LSB*) and 0x03 (*RATE_X_MSB*) contain the rate data for the x-channel, registers 0x04 (*RATE_Y_LSB*) and 0x05 (*RATE_Y_MSB*) for the y-channel and 0x06 (*RATE_Z_LSB*) and 0x07 (*RATE_Z_MSB*) for the z-channel. It is recommended to always 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 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 SMG130 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). Which kind of data is stored in the rate data registers depends on bit 7 (*data_high_bw*) in register 0x13 (*RATE_HBW*). If bit 7 is 0 (1), filtered (unfiltered) data is stored in the registers.

7.4.2 Temperature Sensor

The temperature sensor data of the SMG130 have a width of 8 bits, which cover a temperature range of 128 K. Temperature data can be read from register 0x08 (*TEMP*). The slope is typically 0.5 K/LSB. The typical, 3 σ, and worst case temperature behavior of the SMG130 is shown in Figure 28.

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

***temp* <7:0>**	**Temperature [°C]**
01111111	87.5
...	...
00000010	25
...	...
10000000	-40

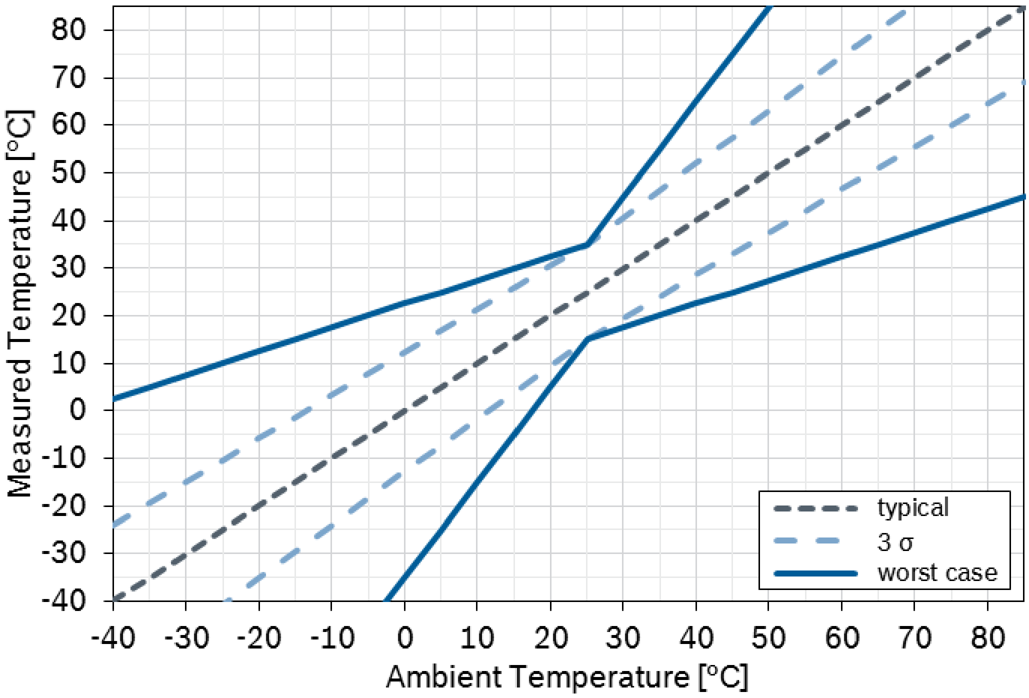

Figure 28 Temperature behavior of the SMG130

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 SMG130 is recommended.

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

7.6 Register Map

The entire communication with the device is performed by reading from and writing to registers. Registers have a width of 8 bits. They are mapped to a common space of 64 addresses from register 0x00 up to 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 that are completely marked as ‘reserved’. Furthermore, it is recommended to mask out (logical and with zero) reserved bits of registers that are partially marked as ‘reserved’.

Registers with addresses from register 0x00 up to 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 0x14 (*BGW_SOFTRESET*).

The following table shows the register map of the SMG130 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

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 its designated values after POR, soft-reset
and wake up from deep suspend.

7.6.1 Register 0x00 (*CHIP_ID*)

This register contains the chip identification code, having a fixed value of 00001111 = 0x0F.

0x00	*CHIP_ID*							
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	1	1	1	1
Content	*chip_id* <7:0>							

7.6.2 Register 0x02 (*RATE_X_LSB*)

This register contains the least significant 8 bits of x-channel angular rate readout value (two's complement format) (see section 7.4.1).

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>							

7.6.3 Register 0x03 (*RATE_X_MSB*)

This register contains the most significant 8 bits of x-channel angular rate readout value (two's complement format) (see section 7.4.1).

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>							

7.6.4 Register 0x04 (*RATE_Y_LSB*)

This register contains the least significant 8 bits of y-channel angular rate readout value (two's complement format) (see section 7.4.1).

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>							

7.6.5 Register 0x05 (*RATE_Y_MSB*)

This register contains the most significant 8 bits of y-channel angular rate readout value (two's complement format) (see section 7.4.1).

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>							

7.6.6 Register 0x06 (*RATE_Z_LSB*)

This register contains the least significant 8 bits of z-channel angular rate readout value (two's complement format) (see section 7.4.1).

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>							

7.6.7 Register 0x07 (*RATE_Z_MSB*)

This register contains the most significant 8 bits of z-channel angular rate readout value (two's complement format) (see section 7.4.1).

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>							

7.6.8 Register 0x08 (*TEMP*)

This register contains the current chip temperature value (two's complement format) (see section 7.4.2)

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>							

00000010 corresponds to 25°C

7.6.9 Register 0x0A (*INT_STATUS_1*)

This register contains the interrupt status flag *data_int* of the new data interrupt (see section 7.3)

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

7.6.10 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

Selection table for *range <2:0>*:

range <2:0>	rate range	Resolution [LSB / °/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)

7.6.11 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

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)

Register	Description
reserved	Write 0

7.6.12 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	The shadowing mechanism for the rate data output registers. 1: disable 0: enable
reserved	Write 0

7.6.13 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 10110110 = 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.

7.6.14 Register 0x15 (*INT_EN_0*)

This register enables the new data interrupt. See bit *data_int* in register 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

7.6.15 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

7.6.16 Register 0x18 (*INT_MAP_1*)

This register controls if interrupt signals are mapped to the INT 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 INT pin 0: disabled 1: enabled
reserved	Write 0

7.6.17 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

7.6.18 Register 0x3C (*BIST*)

This register contains the build-in self-test (BIST) options (see section 7.2).

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 finished, sensor ok
1	1	BIST finished, sensor not ok (details see 7.2)

8 Safety Concept

Not applicable.

9 Functional and Lifetime Qualification Test Plan

The SMG130 passed the 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 SMG130 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 SMG130 does not provide a CRC to check communication errors within a SPI/I2C frame.
- The SMG130 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 SMG130 Technical Customer Documentation (TCD) 1 279 929 694 Rev. 4.0.

12 Table of Figures