TCD Technical Customer Documentation - SMI240

Combined angular rate and acceleration sensor for Safe Navigation

Product designation:	SMI240
Version:	1.2
Date:	2024-07-12

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1 Product identification

Product designation:	SMI240
Product part number:	0273142377
Type designation:	Inertial Sensor
Offer drawing number:	0 274 A01 835
Application:	Safe Navigation

Further applicable documents:

Offer Drawing

Safety Element out of Context

Validation report

1.1 Main Functions and Properties

The SMI240 is a combined three axis angular rate and three axis acceleration sensor module with a measurement range of +/-300°/s and up to 16g.

1.2 Key Features

Feature	Value
Gyroscope measurement axes	x / y/ z
Gyroscope measurement range	300 °/s
Accelerometer measurement axes	x / y/ z
Accelerometer measurement range	16g
Operating temperature range	-40...105 °C
Communication interfaces	SPI - 32 bit out of frame
Data width	16 bit
Output filters	Selectable low pass filters: 50Hz & 400Hz
Functional safety	Developed according to ASIL B (please also see below)

The SMI240 is developed according to ASIL B process (ISO26262:2018) and provides sensor signals with safety requirements up to ASIL B. The SMI240 is able to be used in systems up to and including ASIL D in accordance to ISO26262-9: 2018 i.e. fulfilling the decomposition rules and their necessary requirements and analysis.

2 General product description

The SMI240 inertial sensor is capable of measuring all 6 degrees of freedom (yaw/pitch/roll rate and acceleration in x/y/z directions).
The gyroscope channels are able to measure angular rates up to 300 °/s.
The acceleration sensor channels are able to measure accelerations up to 16g.

2.1 Technical Description

The SMI240 is a 6 DoF (Degrees of Freedom) sensor module providing acceleration and angular rate signals via a digital interface (SPI). The sensor consists of two Micro Electro Mechanical System (MEMS) elements and a sensor readout ASIC. The ASIC contains analogue front ends and a digital structure for signal processing and communication interface. The sensor module is available in a LGA (Land Grid Array) housing.

2.2 Intended use

The SMI240 sensor module is intended for use in earthbound automotive applications. It is only permitted to apply the SMI240 if the functional and safety relevant requirements on system level are tested and passed.
The sensor module is intended to be soldered on a printed circuit board (PCB) inside an Inertial Measurement Unit (IMU) or similar device. The IMU is typically applied inside the passenger compartment, e.g. the transmission tunnel, underneath the passenger seat or inside the luggage compartment. Excluded is any application with an environment containing harsh chemical elements (e.g. halides). The product has been developed, validated, and released exclusively for use in these applications.

2.3 Block Diagram

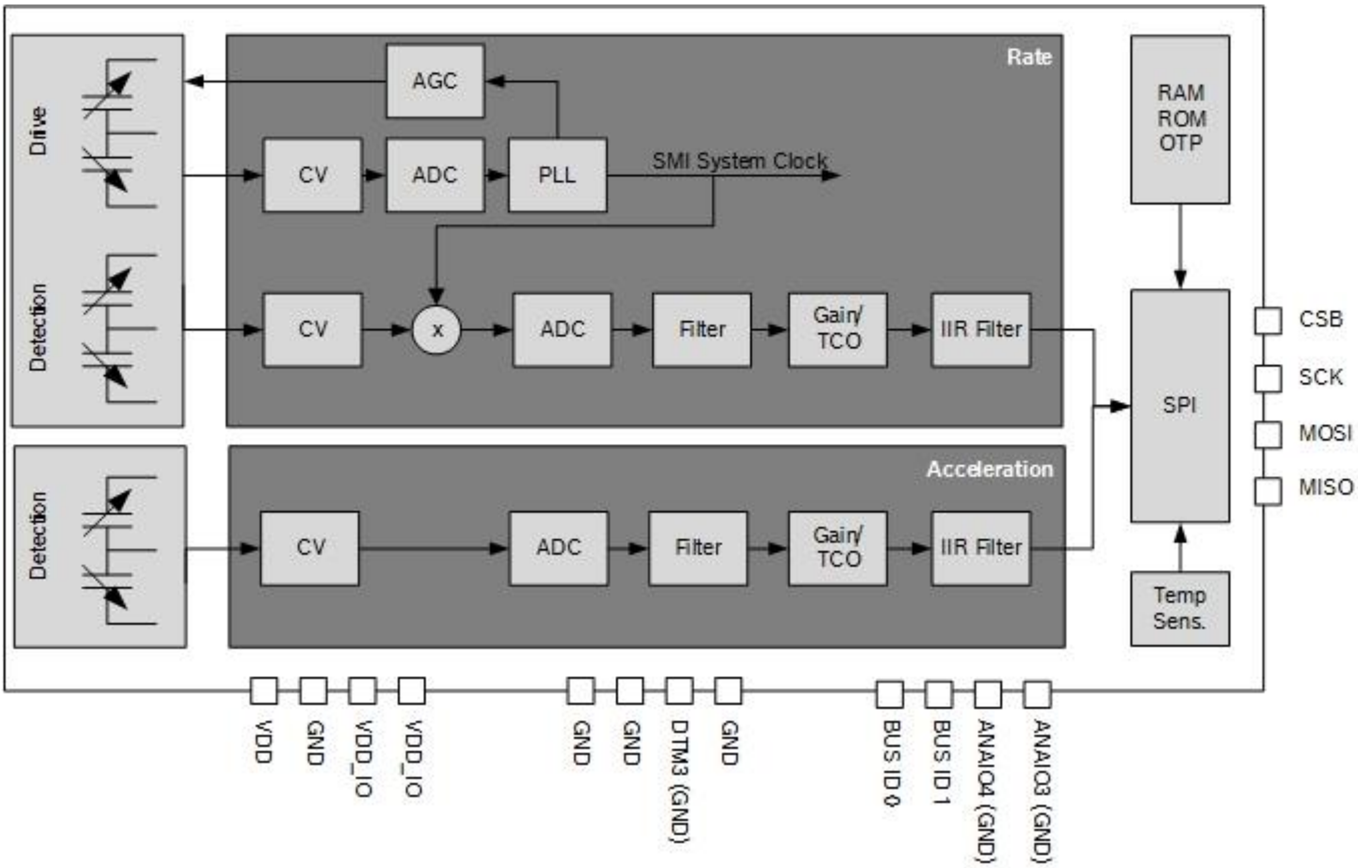


Figure 1 Block diagram of SMI240

2.4 Angular rate Sensing Element

The capacitive sensor element is fabricated in known IC production surface micromechanical processes. The detection path operates as an open loop system for the detection movement. The Coriolis mass resonates in the drive direction. When an angular rate is applied the appearing Coriolis force will excite the corresponding detection masses. The force is directed in detection direction and will lead to a deflection of the detection mass. This small movement of the detection mass is modulated with the detection frequency and can be detected via the associated fixed counter electrodes.
The mechanical structure is located on the upper surface of the wafer which is hermetically sealed by a second structured wafer. After dicing of the chips from the wafer, the realized sensor-element can be processed using standard semiconductor technologies.

2.5 Acceleration Sensing Element

The working principle of the sensor-element is based on a differential capacitor whose capacitances change inversely upon applied acceleration. The sensor-element is made through a surface micromechanical process. The mechanical structure is located on the upper surface of the wafer which is hermetically sealed by a second structured wafer. After dicing of the chips from the wafer, the realized sensor-element can be processed using standard semiconductor technologies.

2.6 Evaluation ASIC

The evaluation ASIC provides the frontends for the sensor signal channels as well as the processing and filtering of the sensor signal, a safety controller for monitoring of the correct sensor function, the power supply for the sensor and its functional blocks, and the communication interfaces to the system electronic control unit (ECU).

2.7 Filtering

The angular rate and accelerometer output signals of SMI240 are filtered by the digital signal processing unit of the evaluation ASIC. Two IIR low-pass filters are available that differ in terms of cut-off frequencies. The user can select between 50Hz and 400Hz.

2.8 Safety Concept

To check the physical functionality at start-up the ASIC performs internal tests, LBIST and BITE. During operation, important functional blocks are monitored. A malfunction of the device is indicated by the corresponding error flags.

2.9 Orientation of Sensing Axes

The coordinate system used within this specification uses three axes. The x-,y-, and z- axes are perpendicular to each other and form a right-hand coordinate system. The z-axis is perpendicular to the mounting plane. The angular rate axes Ωx, Ωy, Ωz are the rotations around the coordinate axes.

Sensor functions and functional parameters of the sensor refer to the coordinate system of the sensor.

The origin of the coordinate system is in the pin1 marked corner of the package.

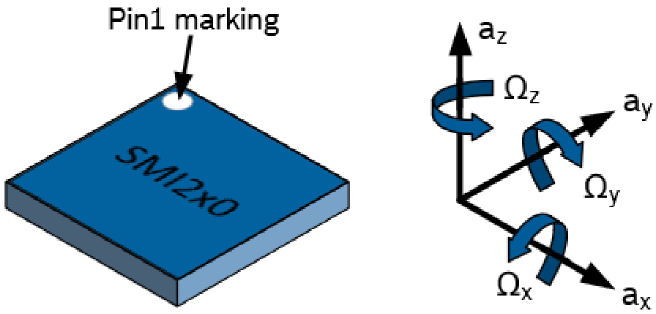


Figure 2 Axes Orientation

3 Hardware Interface Description and Packaging

3.1 Package Parameters

Parameter / Condition	Min	Typ	Max	Unit
Physical dimensions of sensor (length * width * height)		3.3x3.3x1.05		mm
Weight		27.48		mg
Thermal resistance		120		K/W

See offer drawing (separate document) for details on package and marking.
The package is a land grid array (LGA) package. The sensor module meets the current requirements of the EC restriction of hazardous substances (RoHS) directive. The development of the SMI240 complies with the requirements of the current edition of EU-RoHS. The use of the product SMI240 is not within the scope of EU-RoHS, therefore future changed requirements of EU-RoHS will not be considered.

3.2 Transport Package

The components will be delivered on tape and reel. Only one component is placed per cavity in tape and reel. Packaging is conform to the ESD requirements in EIA 541 (Version 01.June.1988) Packaging Material Standards for ESD Sensitive Items. These are package material / production auxiliaries. Bosch reserves the right to use alternative package material.

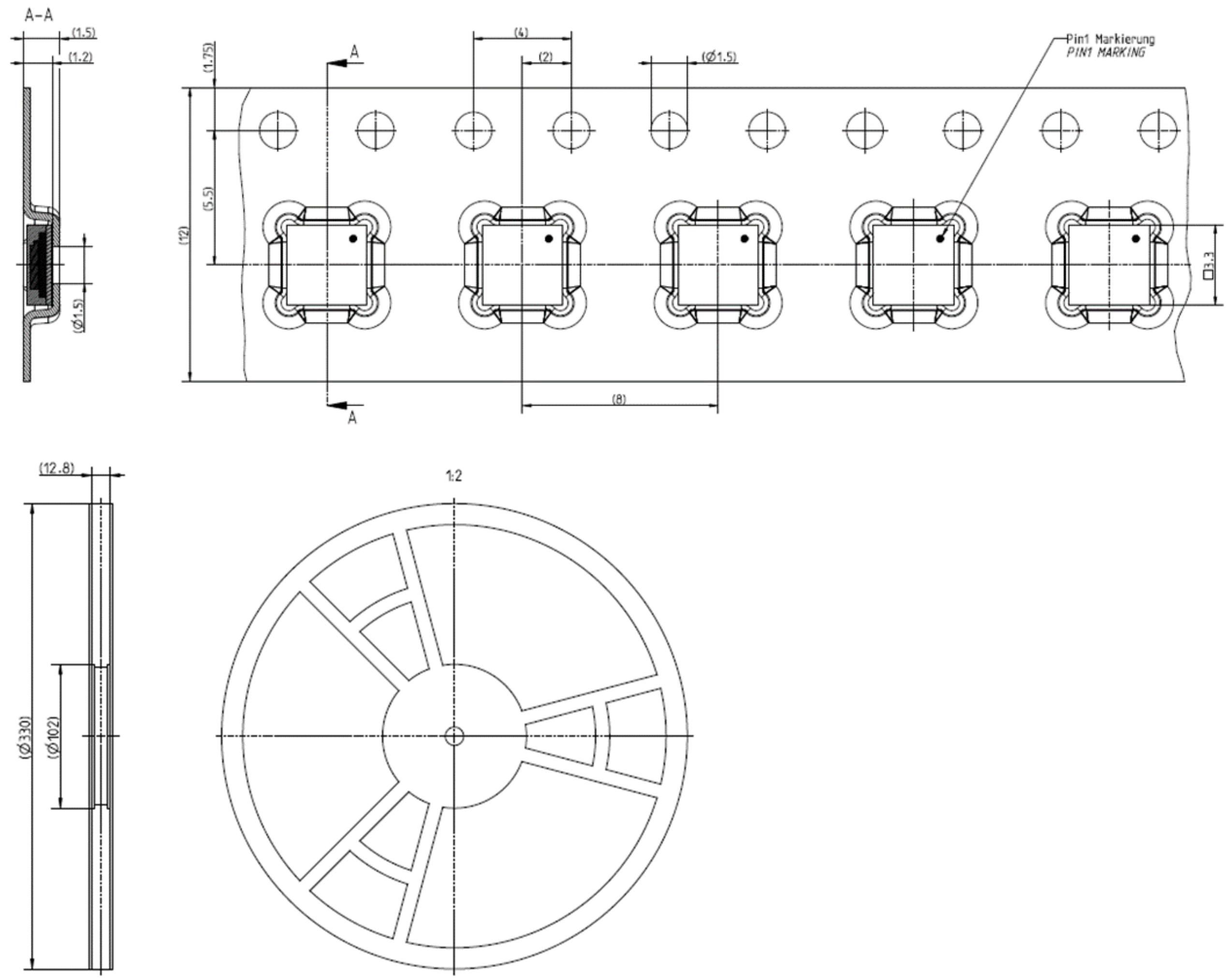
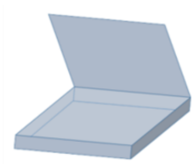


Figure 3 Tape and Reel Dimensions

3.3 Labelling of the Product

Carton:

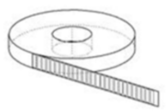


Customer label

+

Bosch label: part number - complete part number 0 273 142 xxx (ref. cover sheet)

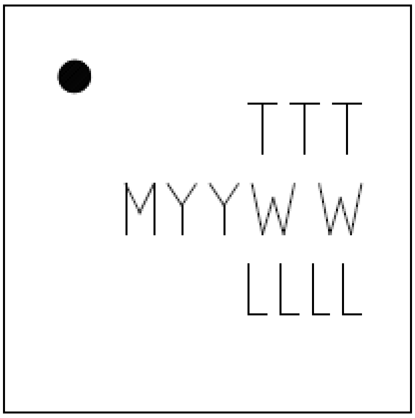
Reel :



Bosch label: part number - complete part number 0 273 142 xxx (ref. cover sheet)

Figure 4 Labelling of the Product

3.3.1 Laser Marking of the Product



Laser Marking	Value
TTT	Last 3 digits of part number
M	Assembly subcon ID
YY	Year of production
WW	Calendar week of production
LLLL	Assembly lot number

Figure 5 Laser Marking of the Sensor

3.4 Pinning

View from **underneath**

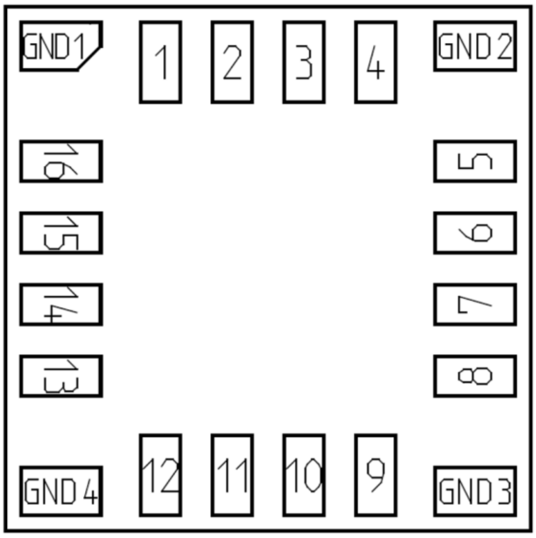


Figure 6 Pinning of sensor

All corner pins (GND1,2,3,4) **must** be connected to ground.

Pin number	Pin name	Connected to
1	CSB	Chip Select Bar
2	SCLK	SPI serial clock
3	MOSI	SPI serial data input
4	MISO	SPI serial data output
5	ANAIO3	Connect to GND
6	ANAIO4	Connect to GND
7	BUS ID 1	BUS ID 1 for sensor identification
8	BUS ID 0	BUS ID 0 for sensor identification
9	GND	Ground
10	DTM3	Connect to GND
11	GND	Ground
12	GND	Ground
13	VDDIO	Power supply
14	VDDIO	Power supply
15	GND	Ground
16	VDD	Power supply

3.5 Application Circuit

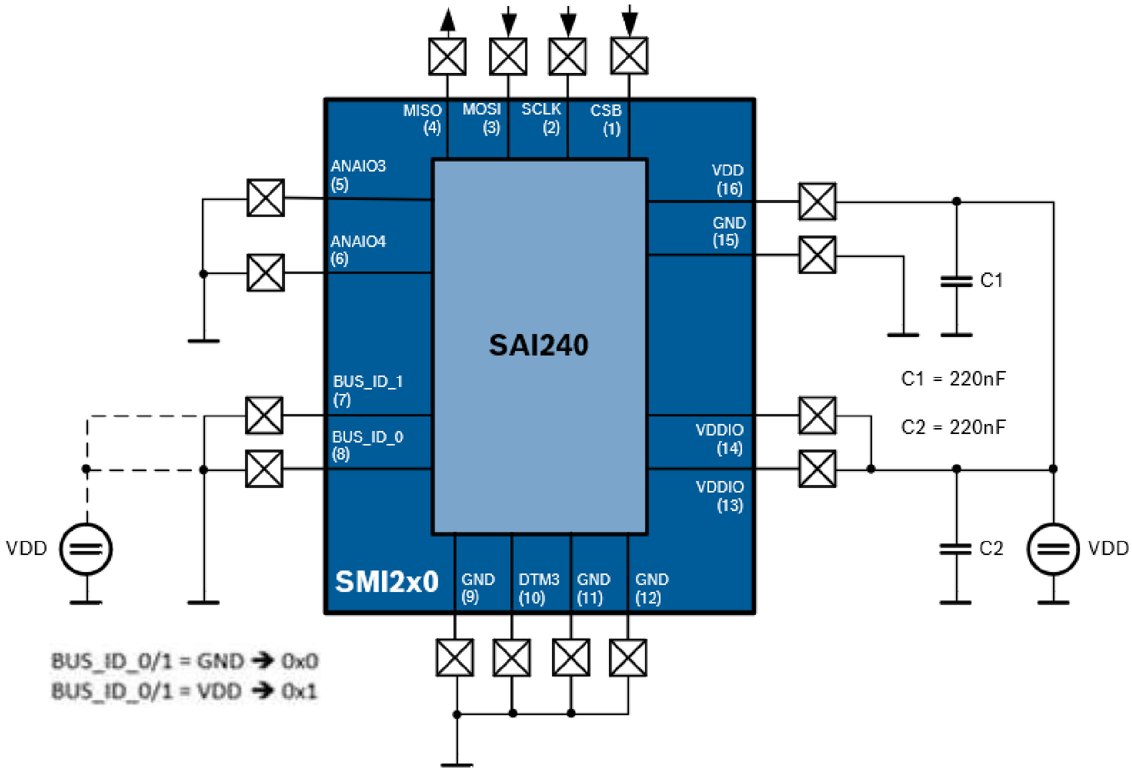


Figure 7 Application Circuit

VDD and VDDIO pins must be connected to the same supply and supplied simultaneously. *(SAI240 = ASIC name).*

3.6 Soldering

The sensor is designed for a Pb-free solder process. The sensor is suitable for double sided soldering. The moisture sensitivity level is MSL 1 according to IPC/JEDEC J-STD-020E.

The sensor is designed for mounting the device on a PCB using a lead-free reflow-soldering profile with a peak-temperature of up to 260°C. When soldering the sensor, the manufacturing temperature profile must stay below the peak temperature and may not exceed the specified limits (e. g. ramp up, ramp down, dwell times) of this qualification reflow profile.

The sensor module withstands up to 3 reflow solder cycles (2 for double sided soldering, 1 for analysis). Repair and manual soldering of the sensor is not permitted.

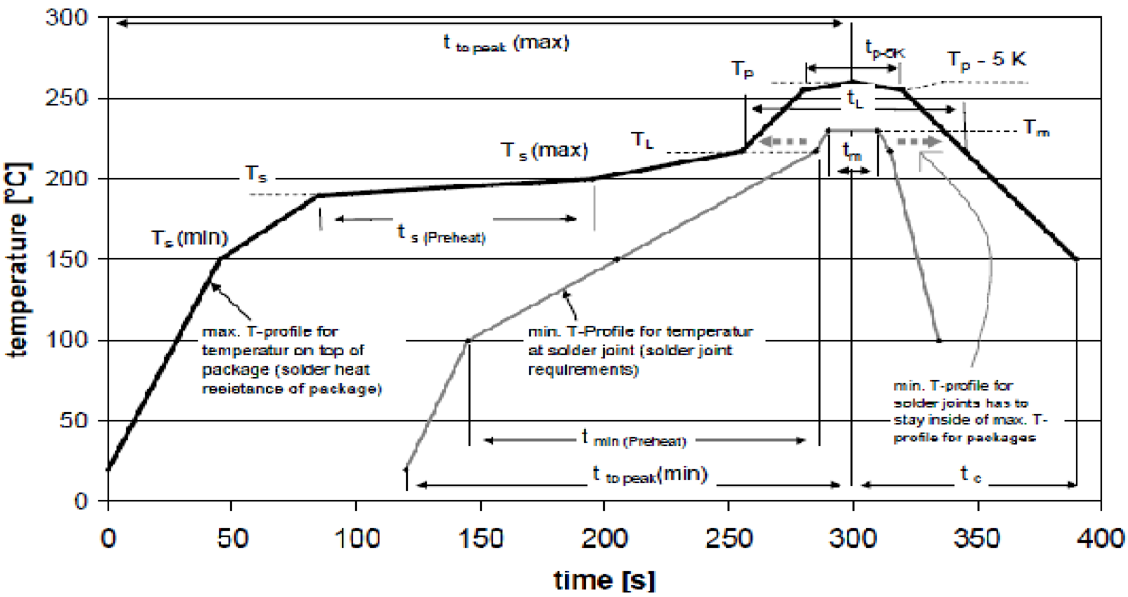


Figure 8 Solder Reflow Temperature Profile

Reflow soldering profile	
Preheating	
Ramp-up rate to 150°C	Max. 3 K/s
T_s (min)	Max. 150 °C
T_s (max)	Max. 200 °C
T_s (preheat)	Max. 110 s
Time between T_s (max) and T_L	Max. 85 s
Peak	
T_L	Max. 217 °C
t_L (time above TL)	Max. 90 s
T_p (peak temperature)	Max. 260 °C
t_p-5k (time within 5 °C of actual peak temperature)	Max. 40s
Ramp-up rate from 200 °C to T_p	Max. 3 K/s
t_{to} peak	Max. 300 s
Cooling	
Max ramp-down rate from peak temperature	Max. 4 K/s
t_c (Max. cooling time T_p to T_s (min))	Max. 90 s

3.7 Recommendations for PCB Layout

The edges of the LGA substrate of the sensor should be free of solder material. Avoid solder material forming a high meniscus covering the edge of the LGA substrate

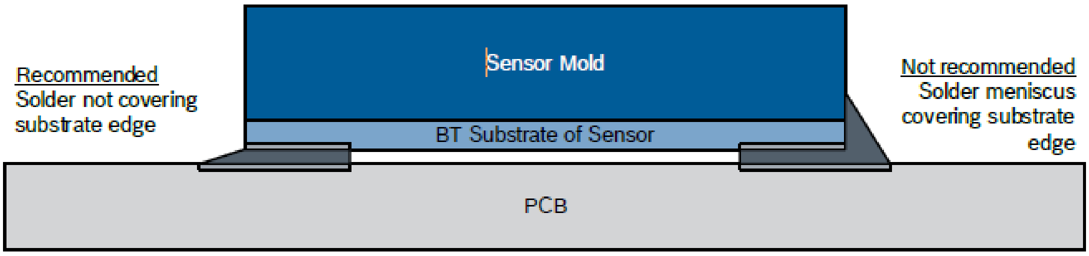


Figure 9 Solder Meniscus Recommendation

Several sensor modules can be mounted close to each other on one PCB.
Two sensor modules are mountable on opposite (top and bottom) sides of the PCB. However, the footprints of modules mounted on the opposite sides of the PCB may not overlap.
Placement of small components like capacitors or resistors on the opposite site of the PCB is possible.

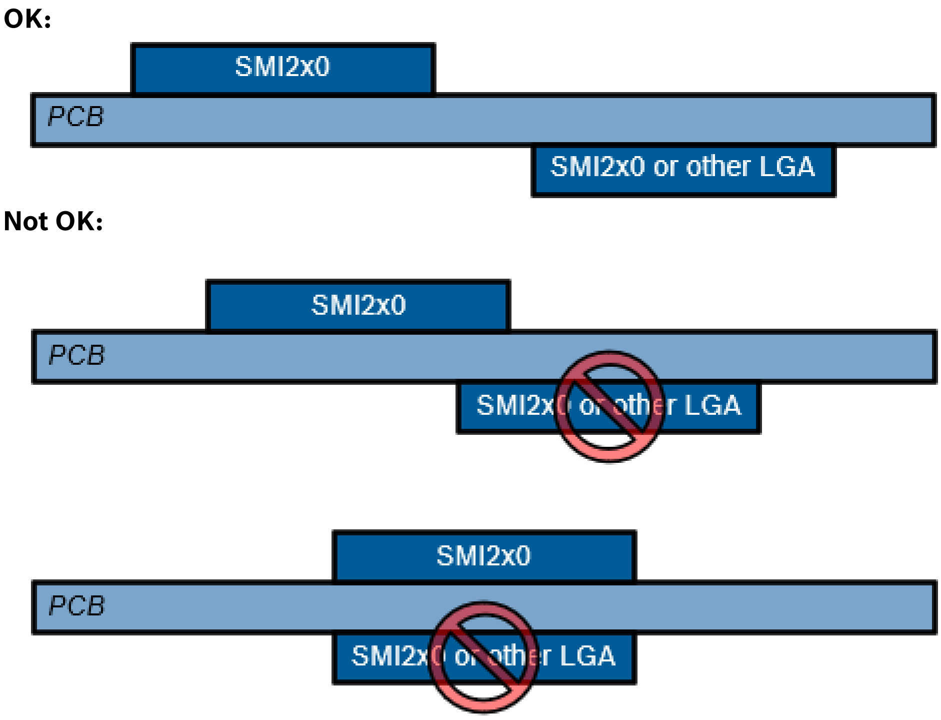


Figure 10 PCB Mounting Guidelines

The SMI240 in principle is suitable for conformal coating. MEMS sensors, however, are sensitive to mechanical stress. Please note that any measure on application level that influences the mechanical connection between the sensor and the PCB such as for example dip or spray or partial coating might potentially affect the sensor performance (e.g. shift of the package resonance frequencies) and board level reliability and therefore have to be chosen with care by and in responsibility of the PCB designer or manufacturer.

Generally:

- It is not recommended to place the sensor under or next to push-button contacts.
- It is not recommended to place the sensor in the direct vicinity of extremely high temperature spots.
- 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 X-ray inspection is used during production, the SMI240 must not be exposed to energy doses over 1.5 Gray

3.8 Land Pattern Recommendations

The Land pattern has the same footprint size as the SMI240 pins but with extended bond pad lengths to the outside edge of the package. The following recommendation only represents one possible solution for the layout of the PCB.
The PCB layout and its qualification lie in the responsibility of the customer and therefore, other suitable solutions can be implemented. The land pattern figure below is purely for the representation of the recommended dimensions.

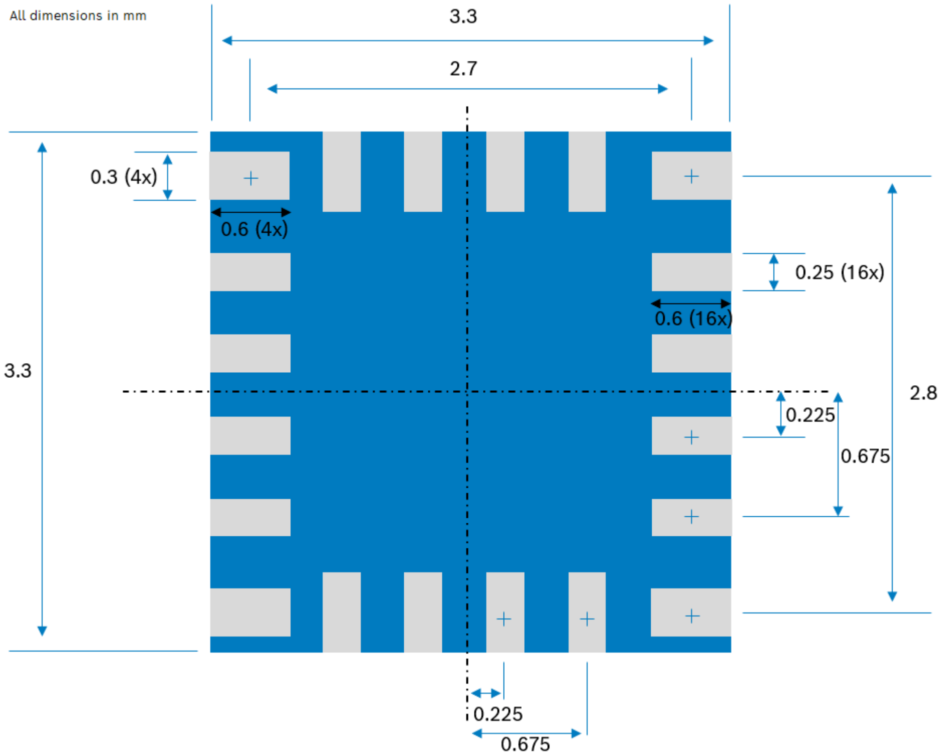


Figure 11 Land Pattern Recommendation

3.8.1 Solder Mask and Stencil Recommendations

Solder Mask: NSMD (non solder mask defined) pads are recommended
Stencil Thickness: A stencil thickness of 100µm is recommended. No more than 120µm should be used.
Solder Paste Opening: A solder paste opening of 0.22x0.6mm is recommended. The printing paste should be inside the land pattern pads (0.25 x 0.6mm).

4 Environment Specification

4.1 Maximum Ratings

Values within the specified maximum conditions will not damage the sensor. No specification value is guaranteed at or above these maximum conditions.

Any values beyond the given ratings may seriously damage the device. The sensor must be discarded when exceeding these limits. A proper ESD environment during handling and processing of the sensor has to be in place. Please pay special attention to the safety and warning notes in section 10.1.

Parameter / Condition	Min	Typ	Max	Unit
Non-destructive at VDD and VDDIO	-0.3	-	4.0	V
Non-destructive voltage range (MISO, MOSI, SCLK, CS, ID,)	-0.3	-	VDD +0.3 (always<4.0)	V
Temperature gradient without damage of component (passive)	-	-	20	K/min
Mechanical shock acceleration without damage to the sensor module. t < 0.5 ms, in x-, y-, z- direction		-	1500	g
Drop test to concrete surface, drop height Production directive: Damaged parts must not be used			1	m
Min./max. temperature passive without damage for short time <10h over life-time.	-50		150	°C
Electrostatic Discharge, HBM, for all pins 100pF/1.5K Ohm	2	-	-	kV

4.2 Operating Conditions

parameter / condition	min	typ	max	unit
Operating ambient temperature range	-40		105	°C
Operating temperature gradient	-5		5	K/min

4.3 Lifetime Conditions

With respect to the use and usage conditions described in this TCD, the life of the SMI240 is designed for the lifetime figures given in the tables below (whichever of the figures occurs first). The commercial warranty and liability is not affected by this and is governed separately by the delivery conditions.

parameter / condition	min	typ	max	unit
Maximum operating time.			41000	h
Life expectancy in years.			20	a
Power-ON/-OFF cycles over lifetime.			300000	

The sensor module is designed and qualified for the following mission profile. In case a different mission profile shall be applied, it needs to be verified whether this profile is still covered by the qualification.

Duration Charging [h]	Duration Driving [h]	at [°C]
764	57	-20
5702	423	10
18498	1600	45
4733	2640	60
2533	1440	70
503	720	80
67	240	85
55	160	90
50	254	95
41	237	100
34	229	105
Total: 33 000h	8000	

4.4 Storage Conditions

The sensor module is designed and qualified for the following storage profile. In case a different mission profile shall be applied, it needs to be verified whether this profile is still covered by the qualification.

Storage of SMI, soldered to PCB:

Duration [h]	at [°C]
50	70 ... 30
130800	30 ... 10
500	10 ... -40
50	-40 ... - 55
Total: 131 400h/15a	

Storage of SMI, unsoldered:

Duration [h]	at [°C]
14	140 ... 70
50	70 ... 40
8660	40 ... 10
50	10 ... -40
Total: 8 774h/1a	

4.5 Sensitivity to Mechanical Stress

Parameter / Condition	Min	Typ	Max	Unit
Maximum acceleration during milling process without mechanical damage or change in performance after relaxing the mechanical stress. f: 0-20 kHz	-	-	300	g
Maximum acceleration during milling process without mechanical damage or change in performance after relaxing the mechanical stress. f:20kHz…50kHz			20	g
Maximum acceleration during milling process without mechanical damage or change in performance after relaxing the mechanical stress. f:>50kHz			5	g
Maximum allowed PCB strain	-500		500	µm/m

4.6 Electrical Pins Specification

4.6.1 Electrical Specification for Input Pins

parameter / condition	min	typ	max	unit
V_{IO}- Supply voltage of SPI and other I/Os	3.13		3.47	V
V_{IL}- Input low voltage			0.8	V
V_{IH}- Input high voltage	2.4		V_{IO}	V
Input Low Leakage Current (no pull-R)			1	µA
Input High Leakage Current (no pull-R)			1	µA

4.6.2 Electrical Specification for Output Pins

parameter / condition	min	typ	max	unit
V_{OL}- Output low voltage (I Load = 1 mA)			0.4	V
V_{OH}- Output high voltage (I Load = 1 mA)	VIO -0.4		VIO	V

4.6.3 Electrical Specification for VDD

parameter / condition	min	typ	max	unit
Supply voltage at VDD pin:	3.13	3.3	3.47	V
Supply voltage at VDDIO pin:	3.13	3.3	3.47	V
VDD current consumption during normal operation.		2.5	5	mA
VDD current consumption during start up			15	mA
VDDIO current consumption during normal operation & start up		3	100	µA

The device only operates within specifications if the voltage at VDD and VDDIO pins are within the specified range.

5 Parameter Specification

The data in the following section, unless otherwise noted, apply for the valid operation conditions given in chapter 4. All following figures include voltage, temperature and lifetime effects if not noted otherwise. All figures except sensitivity are only valid without external stimulus applied. All operation conditions are only valid if no failure flags indicate any malfunction. All figures except the noise itself exclude noise effects.

5.1 Power Supply

parameter / condition	min	typ	max	unit
Supply voltage at VDD pin:	3.13	3.3	3.47	V
Supply voltage at VDDIO pin:	3.13	3.3	3.47	V
VDD current consumption during normal operation.		2.5	5	mA
VDD current consumption during start up			15	mA
VDDIO current consumption during normal operation & start up		3	100	µA
VDD under voltage detection		2.5		V
VDDIO under voltage detection		2.5		V

5.2 Technical Data

5.2.1 Performance Gyroscope

5.2.1.1 Parameter Specification

All parameters are valid at any time during lifetime and for parts soldered on PCB including bending on PCB as specified. All specified environmental conditions apply (e.g. operating temperature range, full voltage range, max. temperature gradient, …) if not constraint at some parameters individually. The offset error due to PSRR, EMC or vibration is not included.

All requirements regarding the angular rate sensor are valid for sensing axes x, y, z unless stated otherwise.

Sensor data are only valid if no failure flags indicate any malfunction. All values except the noise itself exclude noise effects.

The measurement range defines the absolute value of the most positive or most negative input angular rate which can be measured by the sensor. The required measurement range has to be considered based on the following calculation:

|required measurement range + total offset + sensitivity error at max. measurement range + nonlinearity error at max. measurement range| < configured measurement range.

parameter / condition	min	typ	max	unit
Measurement range		300		°/s
Digital output range 16 Bit	-32768		32767	LSB

When the signal exceeds the digital output range, the signal is clipped to the maximum/minimum digital value. As long as the signal is within the digital output range, the signal will not be clipped. Clipping of the digital output range will by itself not lead to an invalid signal status.

5.2.1.2 Offset

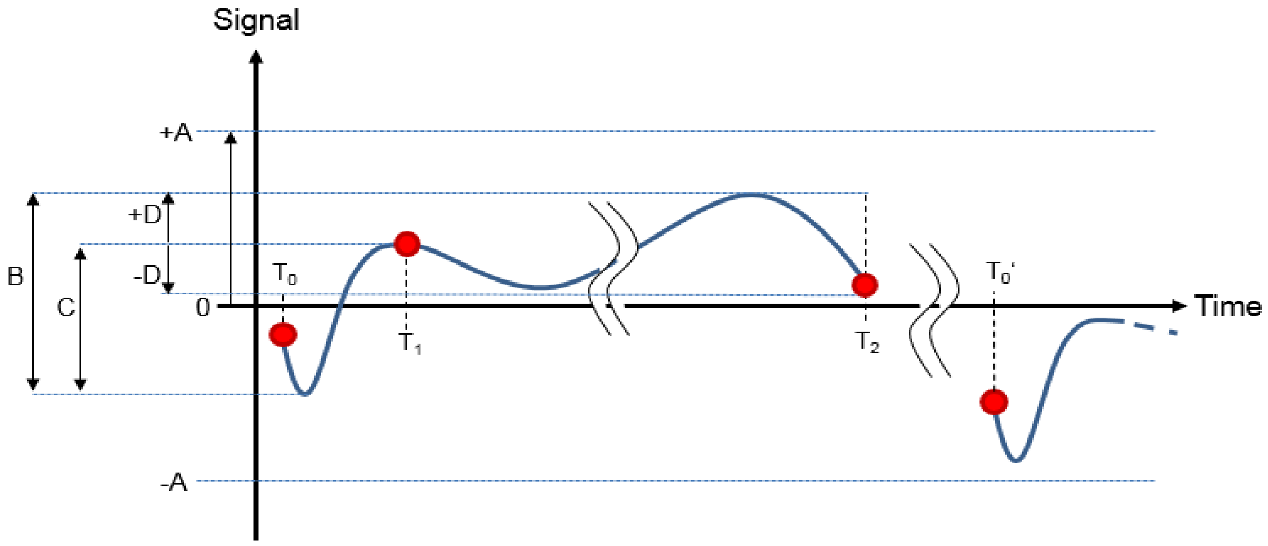


Figure 12 Offset w/o any Offset Compensation

T0: Power-on time (=0s).

T0': Power-on time of next ignition cycle.

T1: End of power-on drift duration.

T2: Power-off time.

A: Absolute total offset error relative to 0°/s stimulus, including power-on drift, full temperature range, full supply voltage range, lifetime, calibration effects and mechanical stress due to PCB bending as specified.

B: Offset short-term drift span during one ignition cycle, including power-on drift and temperature, |max-min|.

C: Offset power-on drift span from T0 to T1, |max-min| at constant environmental conditions.

D: Absolute offset error over time during 1 ignition cycle (max. 24h) at constant temperature, relative to offset value after power-on drift.

Offset values are measured by averaging for at least 1s with a sample rate larger or equal to the signal filter corner frequency.

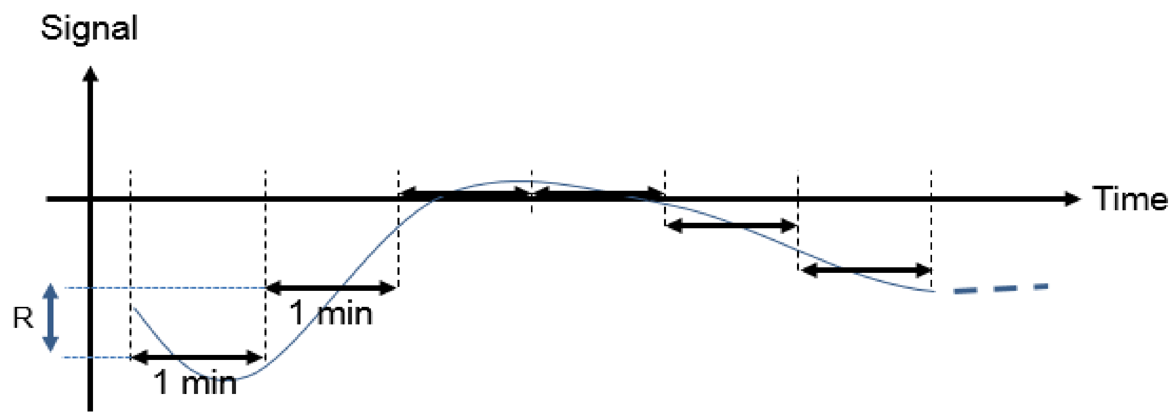


Figure 13 Offset Drift Rate Definition

Offset drift rate **R** is defined as the absolute difference between the average offset of two adjacent 1min sampling periods.

RT: Offset drift rate after power-on over temperature with a maximum temperature change rate of 0.5K/min.

parameter / condition	min	typ	max	unit
Absolute total offset error A:			5	°/s
Offset short-term drift span B:			4	°/s
Offset power-on drift span C:			1	°/s
Offset long-term gradient Determined by first order fit line over whole temperature range			0.03	°/s/K
Absolute offset error over time, relative to offset value after power-on drift, D:			0.5	°/s
End time of power-on drift T1:			20	s
Offset drift rate R_T in normal operation over temperature TGrad≤0.5K/min. Power-on drift excluded.			0.3	°/s/min
Bias instability (Minimum of Allan Deviation), 1 sigma (σ)			5	°/h
Angle random walk (N), 1 sigma (σ)			0.5	°/sqrt(h)
Additional Offset error due to EMC & PSRR (on VDD/ VDDIO acc BISS) Voltage ripple at supply voltage VDD / VDDIO of 50mV peak to peak 100Hz...2MHz.			5	°/s
Additional noise due to EMC & PSRR (on VDD/ VDDIO acc BISS) Voltage ripple at supply voltage VDD / VDDIO of 50mV peak to peak 100Hz...2MHz.			0.6	°/s rms

5.2.1.3 Overload and Mechanical Shock

parameter / condition	min	typ	max	unit
Internal headroom (sense frontend).	2000			°/s
Recovery time after overload w/o filter delay Additional delay to the time shift of the transfer characteristics of the output signal to return to 95 % of the final value of the output signal after ±2000°/s overload.			10	ms
Recovery time after overload Total recovery time of the output signal after ±2000°/s overload applied for min. 50ms. Valid for 50Hz filter setting.			60	ms
Recovery time after mechanical shock 50Hz filter ISO/CD 16750-3, 500 m/s^2 for a 6 ms half-sinusoidal pulse or equivalent			60	ms
Recovery time after mechanical shock 400Hz filter ISO/CD 16750-3, 500 m/s^2 for a 6 ms half-sinusoidal pulse or equivalent			10	ms

5.2.1.4 Vibration

The deviation of the angular rate signal is specified in terms of an applied quasi-static sinusoidal stimulus in any direction. The stimulus has specified peak amplitudes in certain frequency ranges. It is a linear acceleration and/or an angular rate. If the specified stimulus is not exceeded, the offset error stays within specified limits and no failure flags are set.

parameter / condition	min	typ	max	unit
Sensor initialization robustness against vibration w/o failure of start-up BITE sequence (with 100Hz filter). Broadband noise bandwidth 100Hz ... 1kHz and 1kHz ... 8kHz.			2.5	g rms
Deviation of angular rate due to specified stimulus X&Y axes: Linear acceleration 0Hz ≤ f < 20kHz (max 100m/s²) Linear acceleration 20kHz ≤ f < 22kHz (max 20m/s²) Linear acceleration 22kHz ≤ f < 28kHz (max 5m/s²) Linear acceleration 28kHz ≤ f < 34kHz (max 20m/s²) Linear acceleration 34kHz ≤ f < 41kHz (max 5m/s²) Linear acceleration 41kHz ≤ f < 50kHz (max 20m/s²) Z axis: Linear acceleration 0Hz ≤ f < 20kHz (max 100m/s²) Linear acceleration 20kHz ≤ f < 22kHz (max 20m/s²) Linear acceleration 22kHz ≤ f < 28kHz (max 13m/s²) Linear acceleration 28kHz ≤ f < 45kHz (max 20m/s²) Linear acceleration 45kHz ≤ f < 50kHz (max 3m/s²)	-5		5	°/s
Gyroscope resonance frequency XYZ	22.5	25	27.5	kHz

5.2.1.5 Sensitivity

If not stated otherwise the following specification is valid for the full measurement range.

parameter / condition	min	typ	max	unit
Sensitivity for 300°/s range configuration.		100		LSB/°/s
Sensitivity error	-3		3	%
Crossaxis-Sensitivity Intrinsic crossaxis sensitivity of MEMS and assembly misplacement (tilt/rotation)	-2.5		2.5	%
Physical resolution Smallest step of the output when raising the input stimulus			0.01	°/s
Nonlinearity up to 125°/s Least square fit over +/-125°/s range.	-0.5		0.5	°/s
Nonlinearity up to 300°/s Least square fit over +/-300°/s range.	-0.5		0.5	°/s
Differential nonlinearity up to 300 °/s Step size 5°/s.	-3		3	%
Hysteresis maximum difference between two output signal values at a certain input after changing the input and reapplying it at constant temperature (Room Temperature)	-0.15		0.15	°/s

5.2.1.6 Noise

The noise performance is specified as the standard deviation over a sampling period of min. 4000 statistically independent samples.

The specified values are valid over the full temperature and full measurement range but exclude vibration/EMC/PSRR.

parameter / condition	min	typ	max	unit
Noise 50Hz filter			0.1	°/s rms
Noise 400Hz filter			0.3	°/s rms

5.2.2 Performance Low-g Sensor

5.2.2.1 Parameter Specification

All parameters are valid at any time during lifetime and for parts soldered on PCB including bending on PCB as specified. All specified environmental conditions apply (e.g. operating temperature range, full voltage range, max. temperature gradient, ...) if not constraint at some parameters individually. The offset error due to PSRR, EMC or vibration is not included.

All requirements regarding the acceleration sensor are valid for sensing axes x, y, z unless stated otherwise.

Sensor data are only valid if no failure flags indicate any malfunction. All values except the noise itself exclude noise effects.

The measurement range defines the absolute value of the most positive or most negative input acceleration which can be measured by the sensor. The digital output range based on the chosen bit width meets the following calculation:

|measurement range + total offset + sensitivity error at max. measurement range|

parameter / condition	min	typ	max	unit
Measurement range		16		g
Digital output range of each channel 16 Bit	-32768		32767	LSB

When the signal exceeds the digital output range, the signal is clipped to the maximum/minimum digital value. As long as the signal is within the digital output range, the signal will not be clipped. Clipping of the digital output range will not lead to an invalid channel status.

5.2.2.2 Offset

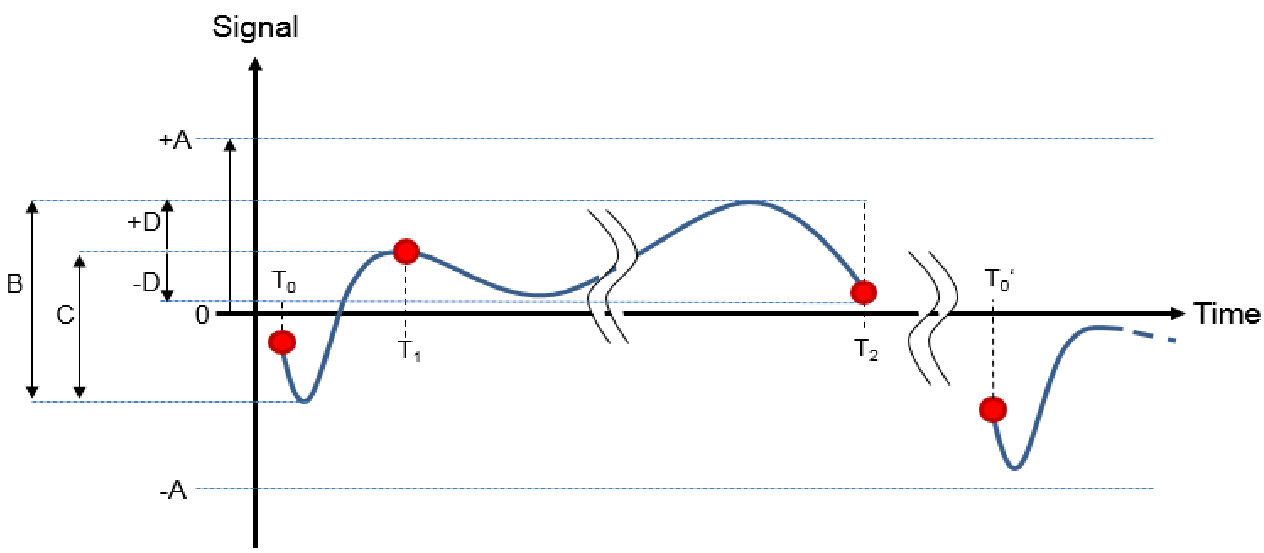


Figure 14 Offset w/o any Offset Cancellation

T0: Power-on time (=0s).

T0': Power-on time of next ignition cycle.

T1: End of power-on drift duration.

T2: Power-off time.

A: Absolute total offset error relative to 0g stimulus, including power-on drift, full temperature range, full supply voltage range, lifetime, calibration effects and mechanical stress due to PCB bending as specified.

B: Offset short-term drift span during one ignition cycle, including power-on drift and temperature, |max-min|.

C: Offset power-on drift span from T0 to T1, |max-min| at constant environmental conditions.

D: Absolute offset error over time during 1 ignition cycle (max. 24h) at constant temperature, relative to offset value after power-on drift.

Offset values are measured by averaging for at least 1s with a sample rate larger or equal to the signal filter corner frequency.

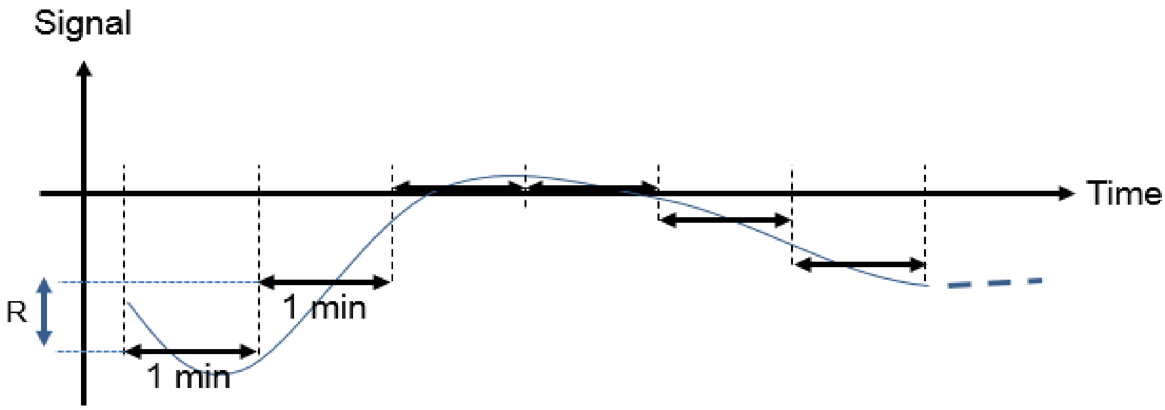


Figure 15 Offset Drift Rate Definition

Offset drift rate **R** is defined as the absolute difference between the average offset of two adjacent 1min sampling periods.

R_T: Offset drift rate after power-on over temperature with a maximum temperature change rate of 0.5K/min.

parameter / condition	min	typ	max	unit
Absolute total offset error A			100	mg
Offset short-term drift span B for X,Y axes			40	mg
Offset short-term drift span B for Z axis			60	mg
Offset power-on drift span C			10	mg
Offset long-term gradient for X,Y axes Determined by first order fit line over whole temperature range			0.3	mg/K
Offset long-term gradient for Z axes Determined by first order fit line over whole temperature range			0.45	mg/K
Absolute offset error over time, relative to offset value after power-on drift, D:			5	mg
End time of power-on drift T1:			20	s
Offset drift rate R_T in normal operation over temperature TGrad≤0.5K/min: Power-on drift excluded.			10	mg/min
Bias instability (Minimum of Allan Deviation), 1 sigma (σ)			50	µg
Velocity random walk (N), 1 sigma (σ)			0.3	m/s/sqrt(h)
Additional Offset error due to EMC & PSRR (on VDD/ VDDIO acc BISS) Voltage ripple at supply voltage VDD / VDDIO of 50mV peak to peak 100Hz...2MHz.			100	mg
Additional noise due to EMC & PSRR (on VDD/ VDDIO acc BISS) Voltage ripple at supply voltage VDD / VDDIO of 50mV peak to peak 100Hz...2MHz.			10	mg rms

5.2.2.3 Overload and Mechanical Shock

parameter / condition	min	typ	max	unit
Internal headroom			18	g
Internal headroom (static clipping) x, y axes	+/-33			g
Internal headroom (static clipping) z axis	+/-26			g
Recovery time after overload without filter delay Additional delay to the time shift of the transfer characteristics of the output signal to return to 95 % of the final value of the output signal after overload.			10	ms
Recovery time after shock 50Hz filter ISO/CD 16750-3, 500 m/s^2 for a 6 ms half-sinusoidal pulse or equivalent			60	ms
Recovery time after shock 400Hz filter ISO/CD 16750-3, 500 m/s^2 for a 6 ms half-sinusoidal pulse or equivalent			10	ms

5.2.2.4 Vibration

The deviation of the acceleration signal is specified in terms of an applied quasi-static sinusoidal stimulus in any direction. The stimulus has specified peak amplitudes in certain frequency ranges. It is a linear acceleration and/or an angular rate. If the specified stimulus is not exceeded, the offset error stays within specified limits and no failure flags are set.

parameter / condition	min	typ	max	unit
Sensor initialization robustness against vibration w/o failure of start-up BITE sequence. (with 100Hz filter) Broadband noise bandwidth 100Hz ... 1kHz and 1kHz ... 8kHz			2.5	g rms
Deviation of acceleration signal due to specified stimulus (Only specified until 20kHz due to acceleration MEMS damping) XYZ: Linear acceleration 0Hz ≤ f < 20kHz (max 100m/s²)	-5		5	mg

5.2.2.5 Sensitivity

If not stated otherwise the following specification is valid for the full measurement range.

parameter / condition	min	typ	max	unit
Sensitivity for 16g range		2000		LSB/g
Sensitivity error Calculated by extrapolating the line of best fit of the output data measured over an applied stimulus of +/-1g; for the complete measurement range.	-3		3	%
Cross axis-Sensitivity Intrinsic cross axis sensitivity of MEMS and assembly misplacement (tilt/rotation)	-2.5		2.5	%
Physical resolution Smallest step of the output signal when continuously raising the input stimulus. Specified for input stimulus -1…+1g			1	mg
Nonlinearity reduced range Input acceleration range +/-2g.	-30		30	mg
Differential nonlinearity X, Y 2g range, step size of input acceleration 100mg.	-5		5	%
Differential nonlinearity Z 2g range, step size of input acceleration 100mg.	-6		6	%
Hysteresis maximum difference between two output signal values at a certain input after changing the input and reapplying it at constant temperature (Room Temperature), over -1g...+1g range	-2		2	mg

5.2.2.6 Noise

The noise performance is specified as the standard deviation over a sampling period of min. 4000 statistically independent samples.

The specified values are valid over the full temperature and full measurement range, but exclude vibrations, EMC/PSRR.

parameter / condition	min	typ	max	unit
Noise 50Hz filter			4	mg rms
Noise 400Hz filter			12	mg rms

5.2.3 Performance Temperature Sensor

5.2.3.1 Parameter Specification

The parameter specification is valid only for the on-chip temperature of the ASIC. All parameters refer to on-chip condition.

The temperature offset and a deviant dynamic behavior caused by the sensor package, PCB or/and ECU environment must be considered additionally.

parameter / condition	min	typ	max	unit
Temperature signal bit width		16		bit
On chip Measurement range	-40		+105	°C
Temperature offset at 0 LSB		25		°C
Sensitivity		256		LSB/K
Sensitivity error	-6		6	%
Nonlinearity	-2.5		2.5	K
Output sample rate	87	97.66	108	Hz
Bandwidth (-3dB cut-off frequency)	19.8	22	24.2	Hz

The offset and gain adjusted temperature signal is used internally to compensate linear offset and linear sensitivity errors of the angular rate and acceleration signals.

5.3 Signal Filtering and Digital Signal Processing

The SMI240 offers two filters which are configurable by the customer via SPI command.

5.3.1 Frequency Response

The following filter specification is valid for the complete sensor including mechanical, analogue, and digital filter elements.

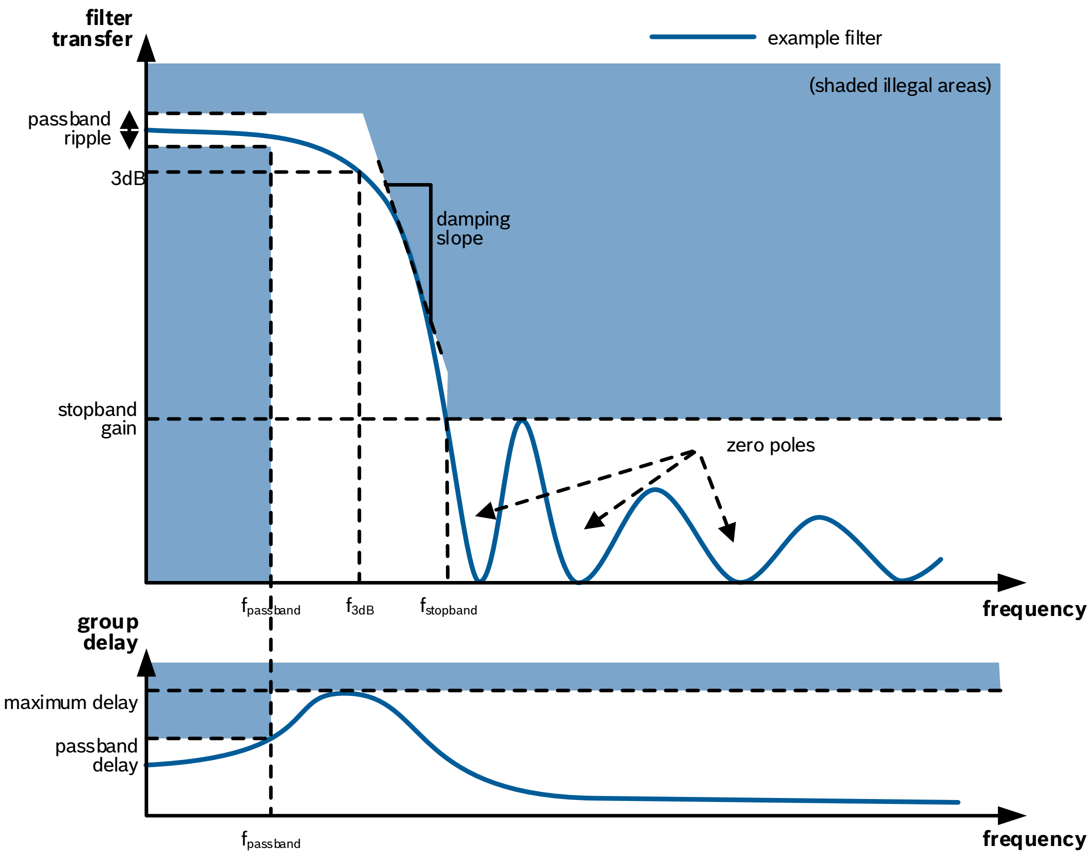


Figure 16 Signal Filtering Definition

Filter Specification (400Hz)

Parameter / Condition	Min	Typ	Max	Unit
Corner frequency (-3dB) Rate	328	400	472	Hz
Corner frequency (-3dB) ACC	344	400	456	Hz
Passband group delay (delay of whole signal path including MEMS)	2	2.45	3	ms
$f_{passband}$ (Damping <-0.2dB) Rate	114			Hz
$f_{Stopband}$ (Damping -40dB) Rate			2.2	kHz
$f_{passband}$ (Damping <-0.2dB) ACC	70			Hz
$f_{Stopband}$ (Damping -40dB) ACC			1.1	kHz
Output Data Rate	45	50	55	kHz

Filter Specification (50Hz)

Parameter / Condition	min	typ	max	unit
Corner frequency (-3dB) Rate	41	50	59	Hz
Corner frequency (-3dB) ACC	43	50	57	Hz
Passband group delay (delay of whole signal path including MEMS)	6	10	14	ms
$f_{passband}$ (Damping <-0.2dB) Rate	25			Hz
$f_{Stopband}$ (Damping -40dB) Rate			230	Hz
$f_{passband}$ (Damping <-0.2dB) ACC	24			Hz
$f_{Stopband}$ (Damping -40dB) ACC			230	Hz
Output Data Rate	22.5	25	27.5	kHz

5.4 Start-up Timing

The initialization sequence differs depending if automated or manual BITE repetitions are executed during start up (see 7.3 service functions).

Initialization sequence with automated BITE execution:

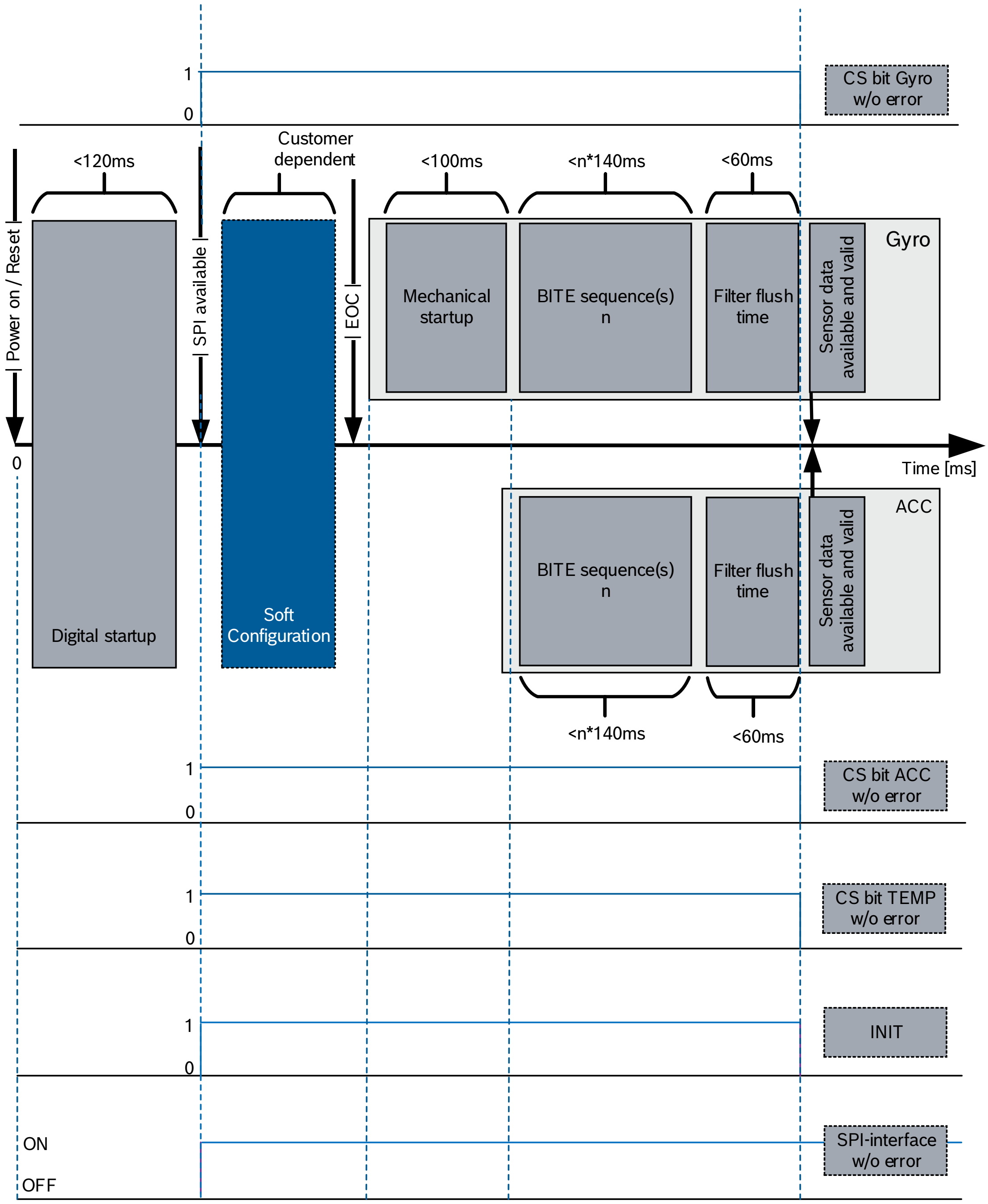


Figure 17 Init Sequence with Automated BITE

Start up timing table for gyro and accelerometer:

Step	Description	Time [ms]
1	Digital start, after this is the SPI is available	<120
2	Sensor module soft configuration	Customer dependent
3	Mechanical startup of gyroscope.	<100
4	Self-test (BITE) x1 (no. of BITEs configurable)	<140
5	Filter flush waiting time	<60
Valid sensor data available		**<420 + soft config time**

Initialization sequence with manual BITE execution:

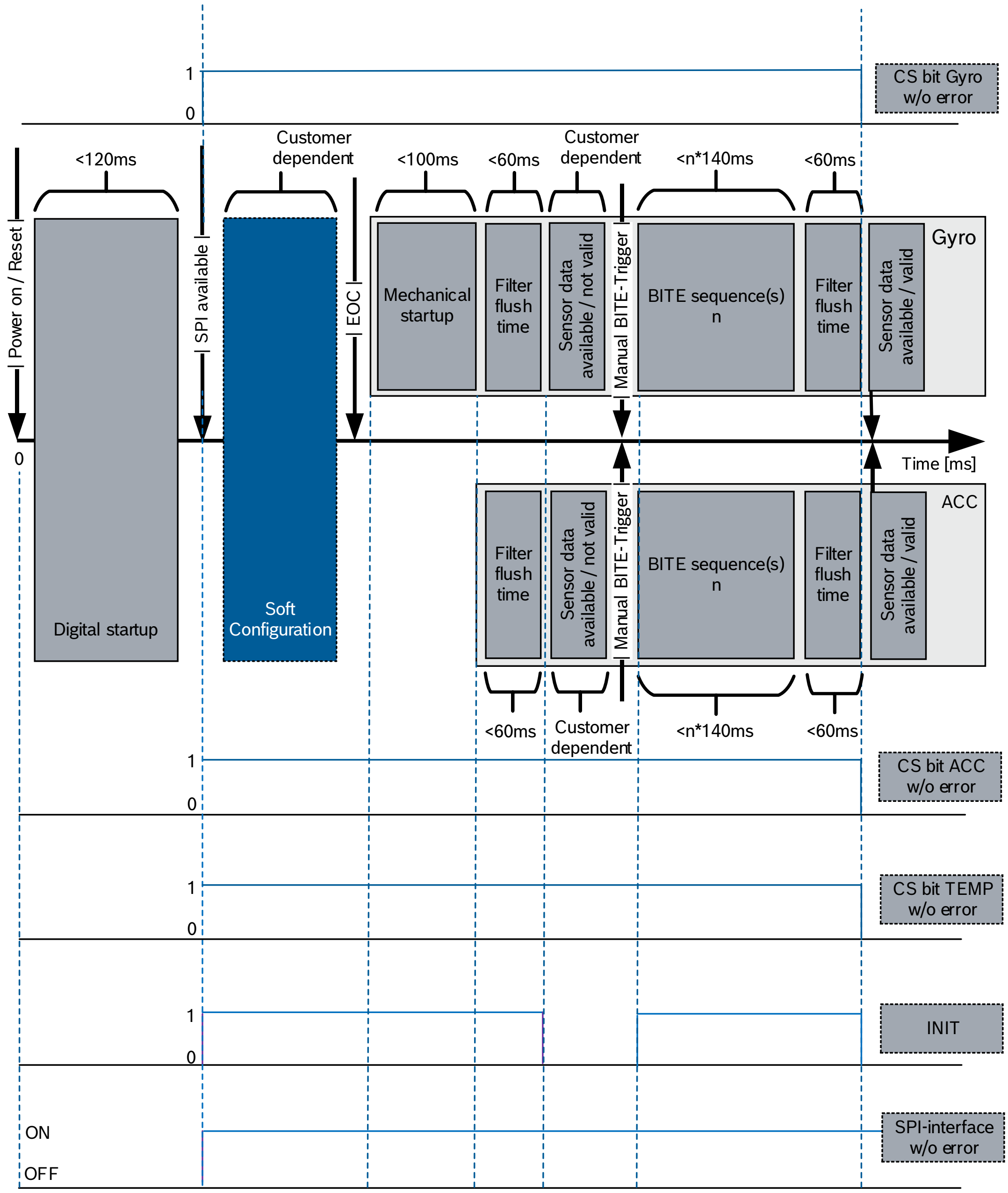


Figure 18 Init Sequence with Manual BITE

Start up timing table for gyro and accelerometer:

Step	Description	Time [ms]
1	Digital start, after this is the SPI is available	<120
2	Sensor module soft configuration	Customer dependent
3	Mechanical startup of gyroscope.	<100
4	Filter flush time	<60
5	Manual BITE trigger	Customer dependent
6	Self-test (BITE) x1 (no. of BITEs configurable)	<140
7	Filter flush waiting time	<60
Valid sensor data available		**<480 + soft config & manual BITE**

6 Software Interface Description

6.1 System Description

The SPI Interface of SMI240, as shown in the figure below, consists of 4 ports.

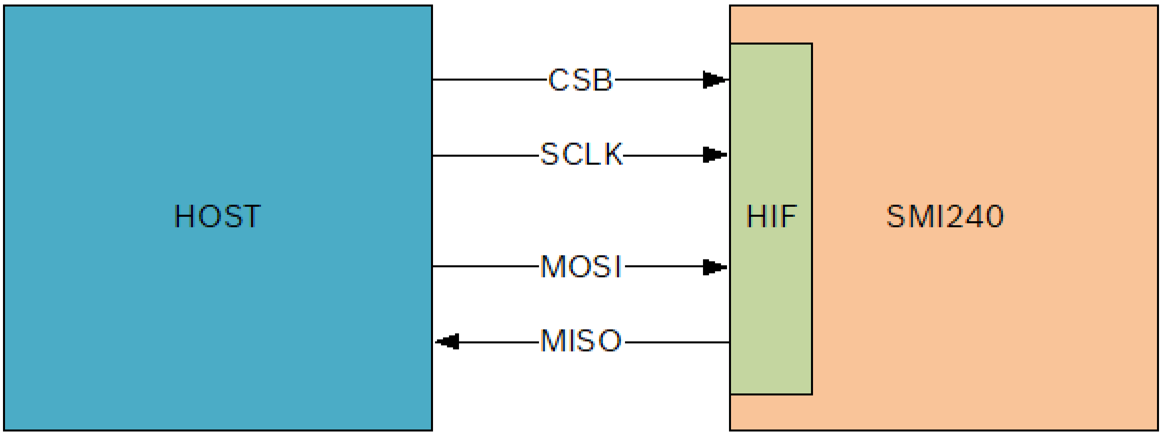


Figure 19 SPI Interface

The Serial clock **SCLK** input represents the master clock signal. This clock determines the speed of data transfer, all receiving and sending is done synchronously to this clock with a given phase and polarity.

Chip Select **CSB** activates the SPI interface. As long as **CSB** is **high**, the sensor will not accept the clock signal or data input.

The output **MISO** is in high impedance. Whenever **CSB** is in a low physical state, data can be transferred from the microcontroller and vice versa. Commands are transmitted through the Serial Input **MOSI** pin to the sensor and the sensor returns its response through the Serial Output **MISO** pin.

Up to four sensors can be connected to the same CS line. In order to identify one another a 2-bit BUS address is embedded in the protocol. Multiple SMI240 with the same BUS-address can be used if all SMI240 have their own CS line.

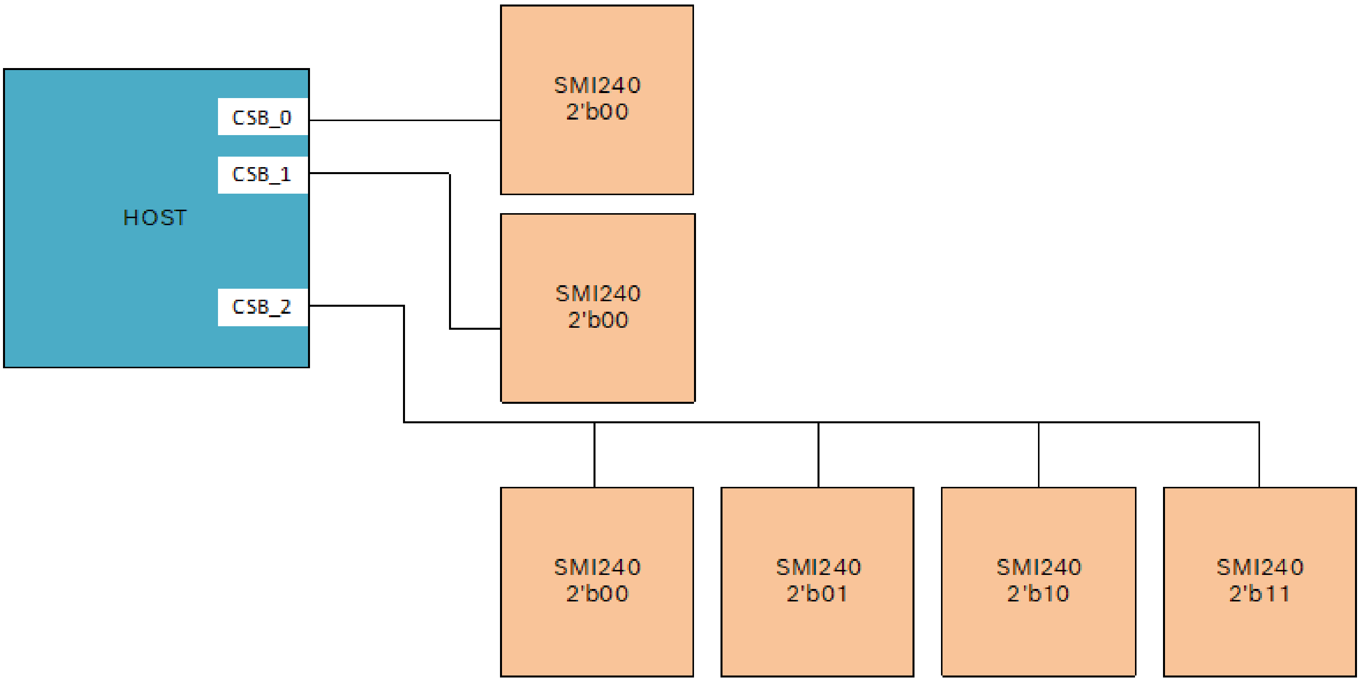


Figure 20 Multiple Sensors Over One Chip Select

6.2 SPI Levels and Timings

The SPI timings of SMI240 are specified to allow an operation of up to at least 10 MHz on the SPI. All timings are valid for the full range of specified voltage levels, input capacitances and current levels.

Definition of timing parameters for (CPOL=0) CPHA=0:

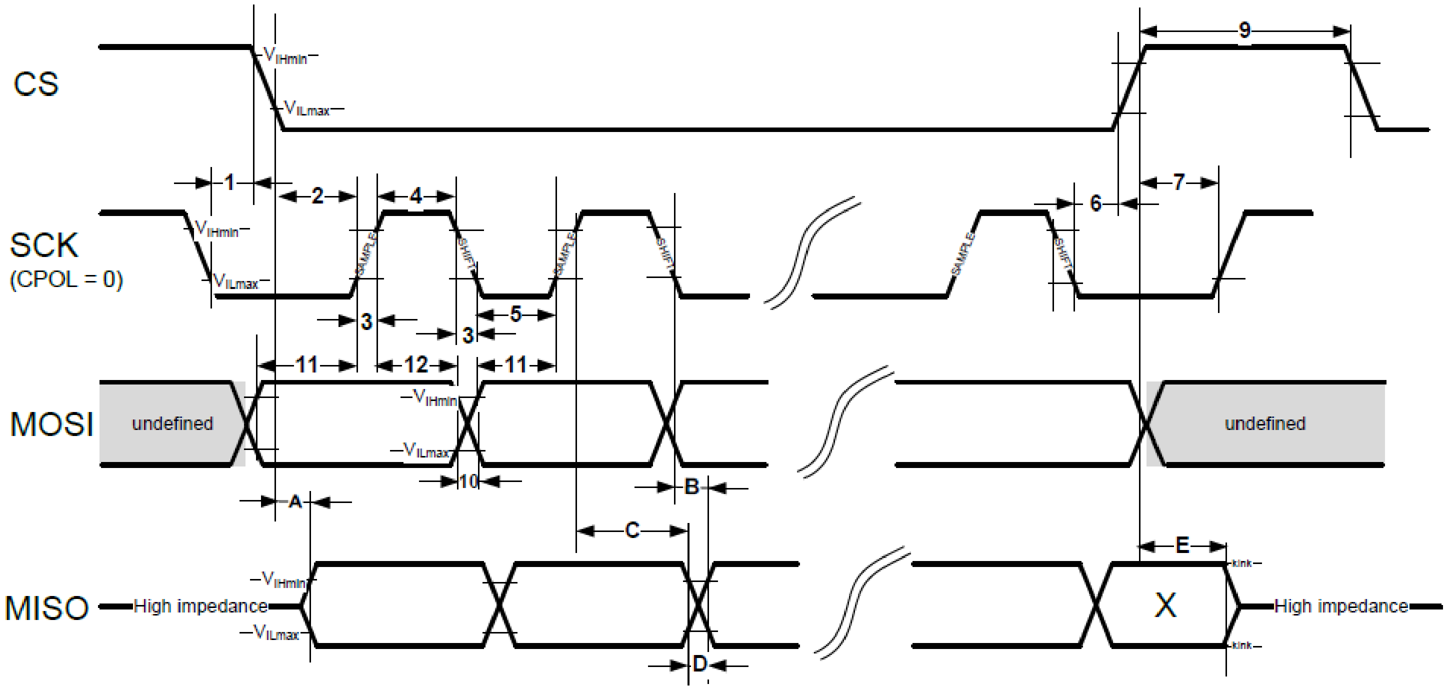


Figure 21 Definition of SPI Timing Parameters

6.2.1 SPI Timing: Master-point of view

The SMI240 is slave

Parameter / Condition	min	typ	max	unit
A- MISO data valid time (CSB)	-	-	40	ns
B- MISO data valid time (SCK)	-	-	30	ns
C- MISO data hold time – depending on Master MISO data is stable until the next SCK shift edge			-	ns
D- MISO rise/fall time	4		16	ns
E- MISO data disable lag time	-		50	ns

Parameter A, B do not include the rise/fall time of CSB and SCK.

The sensor can be operated with different load capacitances (from 60pF to 200pF), the corresponding pad drive strength must be programmed during soft configuration – see chapter 7.3.1

6.2.2 SPI Timing: Slave-point of view

Requirements to master from slave-point of view (SMI240 is slave, parameters to be guaranteed by external SPI master).

Parameter / Condition	min	typ	max	unit
1- SCK disable lead time	10	-	-	ns
2 - SCK enable lead time (CPHA = 0)	40	-	-	ns
3 - SCK rise and fall time – depending on master timings	5	-	15	ns
4 - SCK high time – depending on master timings	40			ns
5 - SCK low time – depending on master timings	40			ns
6 - SCK enable lag time	20	-	-	ns
7 - SCK disable lag time	10	-	-	ns
9 - Sequential transfer delay	700	-	-	ns
10 - MOSI rise / fall time	5	-	15	ns
11 - MOSI data setup time	10	-	-	ns
12 - MOSI data hold time	20	-	-	ns

The table assumes 10 MHz mode, max load.

6.3 SPI Protocol

The communication interface of the SMI240 module consists of a 32Bit Out Of Frame (OOF) SPI protocol, where the slave interface responds to the Master request in the next frame as shown in the figure below:

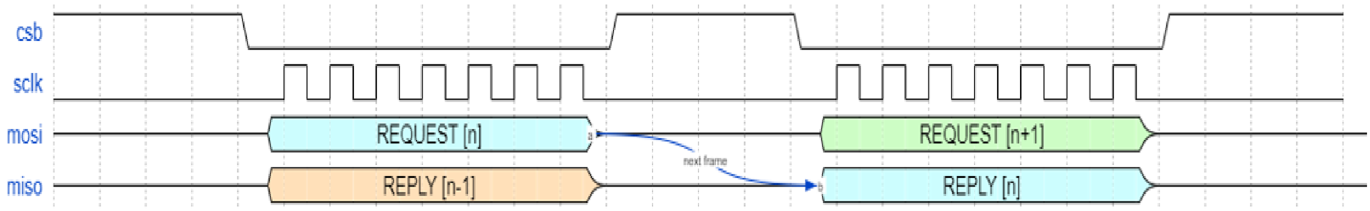


Figure 22 Out of Frame SPI

The SPI slave interface is locked after power on until the interface has been configured by the internal bootloader. While the interface is locked all requests are ignored and no response will be generated (MISO will stay at high impedance). The Interface will be available the frame after the boot procedure has been completed. From a request-response point of view, it means that the first request frame will stay in High-Z state. The second request frame will contain the response to the first request frame (no High-Z), as it can be seen below:

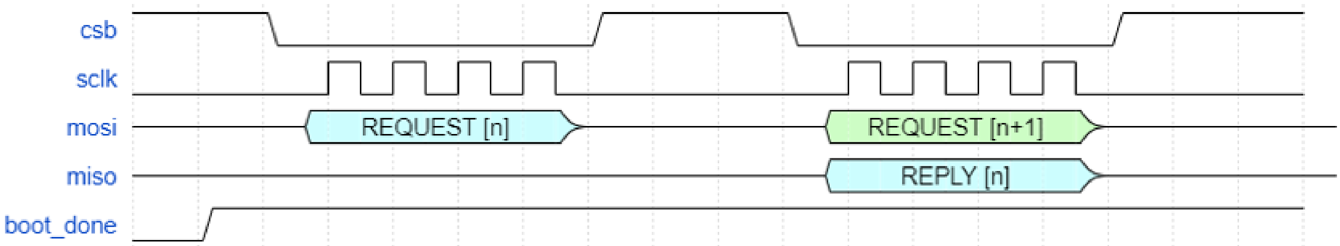


Figure 23 SPI Ready After Bootloader

6.3.1 Request Frame Structure

The MOSI (Request) frame consists of the following bits (bits marked with * are ignored by the slave):

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID(1:0)		ADR (7:0)								W	CAP	*	WDATA (15:0)																CRC(2:0)		

Figure 24 Request Frame Structure

ID(1:0): Identification code

Identification Code is required to address multiple SMI240 connected to the same CS line.

ID(1) is defined by the logic-level at the pin BUS_ID_1

ID(0) is defined by the logic-level at BUS_ID_0.

ID(x) = 1b if VDD connected to pin BUS_ID_x

ID(x) = 0b if GND connected to pin BUS_ID_x

BUS ID 1	BUS ID 0	ID (bits 31&30)
GND	GND	b00
GND	VDD	b01
VDD	GND	b10
VDD	VDD	b11

ADR(7:0): Represents the 8 bits address of the target request

W(1): write/read Bit

W = 1b write operation

W = 0b read operation

CAP(1): Capture Mode

CAP = 1b sensor channels of any module on the bus must capture data and channel status of all channels. The channel which is addressed with ADR feedbacks captured data of selected channel as response to capture command.

CAP = 0b the module won't capture data

WDATA(15:0): Write Data

Data to be written with current request (w=1b). When a read operation is performed (w=0b), the content of this field is ignored.

CRC(2:0): Cyclic Redundancy Check of the request

Cyclic Redundancy Check (CRC) of the request frame, checked by the slave to be consistent.

- CRC covers bits 31 to 3

- CRC polynomial: x^3+x+1

- Target value: 000b

- Start value: 101b

6.3.2 Response Frame Structure

The MISO (Response) frame consists of the following bits:

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
SD	ID(1:0)		SID(4:0)					PAGE	EXT(1:0)		INIT	RDATA (15:0)																CS	CRC(2:0)		

Figure 25 Response Frame Structure

SD(1): Sensor Data

The SD bit defines whether the response frame contains data of a sensor-channel or other (normal) data.

SD = 1b Sensor data

SD = 0b All data but sensor data (normal data)

ID(1:0): Identification code

Identification Code is required to address multiple SMI240 connected to the same CS line.

ID(1) is defined by the logic-level at the pin BUS_ID_1

ID(0) is defined by the logic-level at BUS_ID_0.

ID(x) = 1b if VDD connected to pin BUS_ID_x

ID(x) = 0b if GND connected to pin BUS_ID_x

BUS ID 1	BUS ID 0	ID (bits 31&30)
GND	GND	b00
GND	VDD	b01
VDD	GND	b10
VDD	VDD	b11

SID(4:0): Safety ID

The safety ID is configurable and identifies the data of the responding sensor. The default configuration is:

SID = 10000b Other data – non sensor data (e.g. read data from register)

SID = 10001b RATE_X channel

SID = 10010b RATE_Y channel

SID = 10011b RATE_Z channel

SID = 10100b Temperature channel

SID = 10101b ACC_X channel

SID = 10110b ACC_Y channel

SID = 10111b ACC_Z channel

PAGE(1): Page information

The PAGE bit defines which page is currently addressed. – Always 0 in user mode

EXT(1:0): Mode Identification

Indicates which mode is active – Always 0 (user mode)

INIT(1): Initialization phase identification

Identifies if the sensor is in the initialization phase.

INIT = 0b normal operation

INIT = 1b initialization phase

RDATA(15:0): Read Data

Register data requested by ADR(7:0) during previous request frame. If the request operation was a write (W=1), these bits represent the content of the register after WDATA was written to the register.

CS(1): Channel Status

The CS bit defines whether the data of the requested sensor-channel are valid or not. If no sensor-data are requested (SD=0), the CS bit is always 1.

CS = 1b Sensor data of the requested channel not valid

CS = 0b Sensor data of the requested channel fully valid

If captured data is read, then the CS-bit is the captured CS **OR** the current CS. It is mandatory to verify if the sensor data is valid or not by checking the CS bit to reach the specified safety targets.

CRC(2:0): Cyclic Redundancy Check of the response

Cyclic Redundancy Check (CRC) of the response frame. It is mandatory for each customer to verify if the CRC of the response is consistent to reach the specified safety targets.

- CRC covers bits 31 to 3
- CRC polynomial: x^3+x+1
- Target value: 000b
- Start value: 101b

6.4 Sensor Addressing

Current temperature, gyro and accelerometer data is accessed by reading from the appropriate address in the request frame during run mode. (The data is then sent in the response frame.)

All **request read data** Hex codes in this table are given as **examples** with the pins 'Bus ID 1' and 'Bus ID 0' connected to Ground, corresponding to **ID bits = 00b:**

Register Name	Address (Hex)	Shorthand	Description	RDATA Bit position	Request read data (Hex)
TEMP_DATA_CUR	10	temp_cur	Temperature sensor current data	15:0	04000004
ACCEL_DATA_X_CUR	11	acc_x_cur	Accel X axis current data	15:0	04400006
ACCEL_DATA_Y_CUR	12	acc_y_cur	Accel Y axis current data	15:0	04800000
ACCEL_DATA_Z_CUR	13	acc_z_cur	Accel Z axis current data	15:0	04C00002
GYRO_DATA_X_CUR	14	gyr_x_cur	Gyro X axis current data	15:0	05000007
GYRO_DATA_Y_CUR	15	gyr_y_cur	Gyro Y axis current data	15:0	05400005
GYRO_DATA_Z_CUR	16	gyr_z_cur	Gyro Z axis current data	15:0	05800003

6.4.1 Data Capture

Synchronization of sensor data is done by a capture mechanism. The protocol features data capturing on all sensor-channels of each sensor module connected to the same CS line. This means that sensor measurement data and channel status of all channels (temperature, and all gyro and accelerometer axes) on one chip select line can be captured (stored sensor internally) at one point in time and read out at a later point in time.

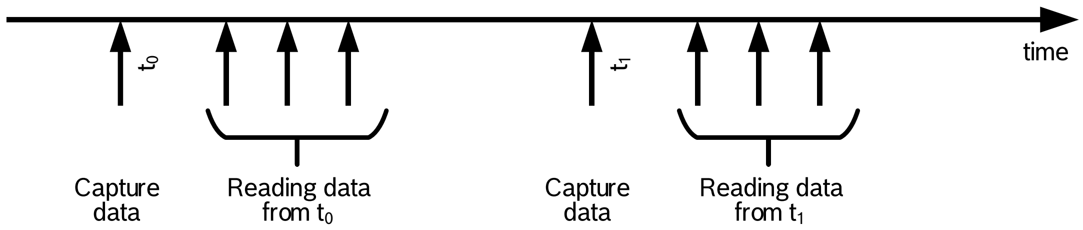


Figure 26 Capture Data

Captured temperature, gyro and accelerometer data is accessed by reading from the appropriate address in the request frame during run mode. The data is then sent in the response frame. To read captured data, the ‘Capture Mode’ bit in the request frame (chapter 6.3.1) has to have been previously set (to initiate a capture). The ‘Capture Mode’ bit must only be set once per time stamp.

The exact point when the data capture is performed, when the ‘Capture Mode’ bit =1, is the CSB rising edge of the request frame.

When reading captured data without capturing (‘Capture Mode’ bit =1) the Channel Status (CS) bit will be set to 1 – invalid data.

All **request read data** Hex codes in this table are given as **examples** with the pins 'Bus ID 1' and 'Bus ID 0' connected to Ground, corresponding to **ID bits = 00b:**

Register Name	Address (Hex)	Shorthand	Description	RDATA Bit position	Request read data (Hex)
TEMP_DATA_CAP	17	temp_cap	Temperature sensor captured data	15:0	05C00001
ACCEL_DATA_X_CAP	18	acc_x_cap	Accel X axis captured data	15:0	06000002
ACCEL_DATA_Y_CAP	19	acc_y_cap	Accel Y axis captured data	15:0	06400000
ACCEL_DATA_Z_CAP	1A	acc_z_cap	Accel Z axis captured data	15:0	06800006
GYRO_DATA_X_CAP	1B	gyr_x_cap	Gyro X axis captured data	15:0	06C00004
GYRO_DATA_Y_CAP	1C	gyr_y_cap	Gyro Y axis captured data	15:0	07000001
GYRO_DATA_Z_CAP	1D	gyr_z_cap	Gyro Z axis captured data	15:0	07400003

(The corresponding command to capture data for all axes is Hex 00100006, when ID = 00b):

7 Application Details

7.1 Traceability

The sensor module is traceable up to lot data and final test results. This is possible as each single sensor module has a unique serial number. This unique serial number is stored at final test and allows assignment of ASIC and sensor module test data. The sensor module is traceable to lot data and wafer level test results of a single ASIC by a unique ASIC serial number.

All **request read data** Hex codes in this table are given as **examples** with the pins 'Bus ID 1' and 'Bus ID 0' connected to Ground, corresponding to **ID bits = 00b.** The readable addresses for sensor traceability are as follows:

Register Name	Address (Hex)	Shorthand	Description	RDATA Bit Position	Request read data (Hex)
REV_CHIP_ID	0	chip_id	Chip Identification register	7:0	00000003
ASIC_ID1	5	-	48 bit number for traceability, XLSBs	15:0	01400002
ASIC_ID2	6	-	48 bit number for traceability, LSBs	15:0	01800004
ASIC_ID3	7	-	48 bit number for traceability, MSBs	15:0	01C00006
SERIAL_NUMBER	8	-	Serial number for traceability	15:0	02000005

7.2 Error flags

In order to detect sensor failures, the read-out of the channel status bit (CS bit) and the control of the CRC check sum is strongly recommended.

Sensor failures can be read-out via the following error flags. To read out the error flag registers send the corresponding address in the request frame.

The status from all flags (max 16) in the corresponding address will be sent in the RDATA of the response frame.

The error flags are latched until read, meaning that the corresponding failure bit stays active until it is read out by a SPI command. By reading, the flag is cleared so long as the failure is no longer present.

All **request read data** Hex codes in this table are given as **examples** with the pins 'Bus ID 1' and 'Bus ID 0' connected to Ground, corresponding to **ID bits = 00b:**

Register Name	Address (Hex)	Flag Name	RDATA Bit position
FLG_STATUS0 Flag status Register (Clear on Read) Request read data (Hex): 0DC00004 When ID= 00b	37	flg_pmu_vdda_vmon_sts	0
		flg_pmu_vddd_vmon_sts	1
		flg_pmu_vddg_vmon_sts	2
		flg_pmu_vddm_vmon_sts	3
		flg_gyro_bg_vmon_sts	4
		flg_pmu_vddm_uvlo_sts	5
		flg_pmu_vdd_uvlo_sts	6
		flg_pmu_vddio_uvlo_sts	7
		flg_gyro_cm_vmon_sts	8
		flg_gyro_curr_ref_vmon_sts	9
		flg_gyro_icmfb_drive_vmon_sts	10
		flg_gyro_vamp_dc_sts	11
		flg_gyro_vamp_noise_sts	12
		flg_gyro_vctrl_dc_sts	13

		flg_gyro_vctrl_noise_sts	14
		flg_gyro_icmfb_vmon_x_sts	15
FLG_STATUS1 Flag status Register (Clear on Read) Request read data (Hex): 0E000007 When ID= 00b	38	flg_gyro_icmfb_vmon_y_sts	0
		flg_gyro_icmfb_vmon_z_sts	1
		flg_gyro_adc_rate_lim_x_sts	2
		flg_gyro_adc_rate_lim_y_sts	3
		flg_gyro_adc_rate_lim_z_sts	4
		flg_gyro_adc_rate_stab_x_sts	5
		flg_gyro_adc_rate_stab_y_sts	6
		flg_gyro_adc_rate_stab_z_sts	7
		flg_gyro_quad_mon_x_sts	8
		flg_gyro_quad_mon_y_sts	9
		flg_gyro_quad_mon_z_sts	10
		flg_acc_cm_vmon_sts	11
		flg_acc_curr_ref_vmon_sts	12
		flg_acc_ref_cm_in_vmon_sts	13
		flg_acc_icmfb_vmon_x_sts	14
		flg_acc_icmfb_vmon_y_sts	15
FLG_STATUS2 Flag status Register (Clear on Read) Request read data (Hex): 0E400005 When ID= 00b	39	flg_acc_icmfb_vmon_z_sts	0
		flg_acc_adc_lim_x_sts	1
		flg_acc_adc_lim_y_sts	2
		flg_acc_adc_lim_z_sts	3
		flg_mon_temp_vmon_sts	4
		flg_temp_lim_sts	5
		flg_dig_acc_cic_decim_x_fail_sts	6
		flg_dig_acc_cic_decim_y_fail_sts	7
		flg_dig_acc_cic_decim_z_fail_sts	8
		flg_dig_acc_x_parity_reg_fail_sts	9
		flg_dig_acc_y_parity_reg_fail_sts	10
		flg_dig_acc_z_parity_reg_fail_sts	11
		flg_dig_gyr_cic_decim_x_fail_sts	12
		flg_dig_gyr_cic_decim_y_fail_sts	13
		flg_dig_gyr_cic_decim_z_fail_sts	14
		flg_dig_gyr_x_parity_reg_fail_sts	15
FLG_STATUS3 Flag status Register (Clear on Read) Request read data (Hex): 0E800003 When ID= 00b	3A	flg_dig_gyr_y_parity_reg_fail_sts	0
		flg_dig_gyr_z_parity_reg_fail_sts	1
		flg_dig_temp_cic_decim_fail_sts	2
		flg_dig_temp_parity_reg_fail_sts	3
		flg_dig_acc_cic_interp_x_fail_sts	4
		flg_dig_acc_cic_interp_y_fail_sts	5
		flg_dig_acc_cic_interp_z_fail_sts	6
		flg_dig_gyr_cic_interp_x_fail_sts	7
		flg_dig_gyr_cic_interp_y_fail_sts	8
		flg_dig_gyr_cic_interp_z_fail_sts	9
		flg_dig_gyr_sm_signature_sts	10
		flg_dig_acc_sm_signature_sts	11

		flg_dig_temp_sm_signature_sts	12
		flg_dig_dp_cc_signature_sts	13
		flg_dig_alu_st_signature_sts	14
		flg_dig_test_crc_fail_sts	15
FLG_STATUS4 Flag status Register (Clear on Read) Request read data (Hex): 0EC00001 When ID= 00b	3B	flg_dig_trim_crc_fail_sts	0
		flg_dig_bus_parity_fail_sts	1
		flg_dig_user_config_parity_fail_sts	2
		flg_dig_shdw_parity_fail_sts	3
		flg_dig_gyr_drv_ok_error_sts	4
		flg_dig_gyr_vco_ok_error_sts	5
		flg_acc_bite_x_delta_sts	6
		flg_acc_bite_x_symmetry_sts	7
		flg_acc_bite_y_delta_sts	8
		flg_acc_bite_y_symmetry_sts	9
		flg_acc_bite_z_delta_sts	10
		flg_acc_bite_z_symmetry_sts	11
		flg_acc_short_x_sts	12
		flg_acc_short_y_sts	13
		flg_acc_short_z_sts	14
		flg_gyro_quad_bite_x_delta_sts	15
FLG_STATUS5 Flag status Register (Clear on Read) Request read data (Hex): 0F000004 When ID= 00b	3C	flg_gyro_quad_bite_x_symmetry_sts	0
		flg_gyro_quad_bite_y_delta_sts	1
		flg_gyro_quad_bite_y_symmetry_sts	2
		flg_gyro_quad_bite_z_delta_sts	3
		flg_gyro_quad_bite_z_symmetry_sts	4
		flg_gyro_no_demod_x_sts	5
		flg_gyro_no_demod_y_sts	6
		flg_gyro_no_demod_z_sts	7
		flg_temp_bite_dummy_sts	8

7.2.1 Error Counters

The flags generated above are used as input to the error counters that filter out spurious temporary errors, avoiding to flag the sensor signal as invalid if it is not the case.

Each sensor channel has its own error counter, therefore there are 7 error counters in total (3 gyro, 3 accelerometer and 1 temperature channel). The error counter is hard wired with all the input error flags related to its own channel.

In case a defined limit is reached, the error counter value is immediately set to limit + hold and the channel status bit (CS bit in SPI frame) is set to logical 1, meaning "channel sensor data not valid". Once this status is reached an additional error will not increase the value of the error counter any further.
This status will be held for a defined hold time, after the error condition is no longer present.

If the failure condition is no more present the error counter starts to decrement. Once the limit is reached the SPI message is set to “valid”, i.e. CS bit is set to ‘0’.

Fatal errors will set error counters permanently to the maximum value deactivating the decrementation. Such errors will only vanish after a restart of the sensor.

7.2.2 BITE

The sensor module provides an electro-mechanical self-test (BITE) which checks the correct functionality and sensitivity of the sensor channels by applying an electrostatic force and checking the output change due to the induced deflection.

The BITE verifies the functionality of the MEMS elements and ASIC signal path. The sensor automatically evaluates the BITE sequence by comparing the current result to sensor specific BITE new part values (i.e. as measured in RB end of line testing). If a sequence is finished without a positive result, it will be repeated by up to the maximum number of counts set during soft configuration minus the initial count (0 to 7 repetitions). If the BITE fails in all BITE counts, the corresponding failure flags and "CS" bits are set (permanently and immediately).

After the BITE is switched off, the sensor waits for the filters to be flushed and will not provide valid data earlier than after the filter flush time.

7.2.3 Logic self-test (LBIST)

The LBIST is executed at power-on and after soft-reset. In case of fail, the device will stay in a frozen state without response to serial communication. Therefore, the reaction at MISO will be high-Z.

7.2.4 Voltage Checks

After start-up (when SPI is functional) the external voltage supply is monitored in terms of undervoltage. If an undervoltage is detected, a flag is raised. If the voltage drops further, the sensor is reset until the voltage returns to the operating range. The undervoltage reset threshold has a hysteresis to ensure that the sensor cannot be trapped in a reset loop.

Regardless of external voltage monitor limits and availability, the sensor signal specification is only guaranteed if the external voltage supply is inside of the electrical pin specification parameters defined in chapter 4.6

7.2.5 SPI Error Handling

The module features an internal error handling mechanism of the SPI interface that responds to certain events.

Error: MOSI CRC incorrect.

Reaction: High MISO impedance and no OCP read transaction on next frame. Neither Write nor Capture commands are executed internally.

Error: CPOL incorrect.

Reaction: High MISO impedance and no OCP read transaction on next frame. Neither Write nor Capture commands are executed internally.

Error: SCK cycles not equal to frame size (32).

Reaction: High MISO impedance and no OCP read transaction on next frame. Neither Write nor Capture commands are executed internally.

Error: Internal bus access not finished in time.

Reaction: MISO CRC inverted.

Error: Internal read/write bus error (e.g. write access in user mode to register which is only accessible in extended mode).

Reaction: MISO CRC inverted.

Error: Overlap of certain operations due to an insufficient interframe distance (interframe delay time too short).

Reaction: MISO CRC inverted.

Error: CSB glitch or a frame without any SPI clock cycles has been detected.

Reaction: In the case of an empty CSB, no write/read operation will be performed and the MISO will be put in High-Z.

Error: Wrong BUS_ID

Reaction: High MISO impedance and no OCP read transaction on next frame. Write command not executed internally.

It is important to note that the even if the read operation will be unsuccessful, the read data value in the SPI frame will contain the content of the register but the CRC value will be inverted.

7.2.6 Host Interface Flags

Host Interface (SPI) failures are contained in a register that keeps track of errors that would result in a MISO CRC inversion. The register contains the error flags tabulated below.

To read out the error flag registers send the corresponding address in the request frame. The status from all flags in the corresponding address will be sent in the RDATA of the response frame.

The error flags are latched until read, meaning that the corresponding failure bit stays active until it is read out by a SPI command. By reading, the flag is cleared so long as the failure is no longer present.

The register is not coupled to the CS bit of the response frame, meaning the CS bit is not active when a Host Interface Flag is raised. Therefore, the CRC must always be checked.

It is important to note that if the status register is not read each time a CRC inversion occurs there may be inconsistency in the reported status, due to a possible overlap of errors due to two or more wrong transactions.

The **request read data** Hex code in this table is given as an **example** with the pins 'Bus ID 1' and 'Bus ID 0' connected to Ground, corresponding to **ID bits = 00b:**

Register Name	Address (Hex)	Flag Name	Description	RDATA Bit Position
HIF_STATUS	21	wrong_access_read	Attempt to read a non-existent register	0
		wrong_access_write	Attempt to write a non-existent or read only register	1
Request read		wrong_parity_read	Internal read operation error	2
data (Hex):		wrong_parity_write	Internal write operation error	3
08400004		write_aborted	Internal write overlap timing error	4
When ID= 00b		capture_inconsistent	A capture overlaps with a capture read operation	5

7.3 Service Functions

7.3.1 Soft Configuration

Soft configuration is available as soon as the SPI interface is available. By writing to the appropriate address during the soft configuration phase of start up, several sensor parameters can be configured. Soft configuration is locked after the end of configuration bit (EoC) is set to 1, i.e. EoC=1 is written to the corresponding register address. The following parameters can be configured:

- Bandwidth (accel and gyro separately, but same setting for x,y,z-channels).
- Configurable SIDs
- Sign of sensor channels
- SPI pad-driver strength for the following loads:
  - Weak ~60pF MISO Load
  - Medium ~100pF MISO Load
  - Strong ~200pF MISO Load
- Number of automated bite-repetitions if BITE fails
- Configuration if BITE is executed automatically (default setting) or by manual trigger
- EoC (end of configuration, locks all register for write access) – must be written to 1 to end soft config phase.

The correct address along the with corresponding bit position of WDATA, and write bit have to be used when configuring the sensor. See example ‘write request frame’ figure below the table.

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ID(1:0)		ADR (7:0)								W	CAP	*	WDATA (15:0)																CRC(2:0)		

Figure 27 Request Frame

Register Name	Address (Hex)	Short hand	Description	WDATA Bit Position	Input/ write	Input/ write description
SOFT_CONFIG Soft Configuration Register	A	EoC	End of Soft Config - locks the write access to soft config registers until hard/soft reset (must be written by customer)	0	0b 1b	Disable Enable
		gyr_bw	Gyro bandwidth select	1	0b 1b	400Hz 50Hz
		acc_bw	Accel bandwidth select	2	0b 1b	400Hz 50hz
		bite_auto	BITE executed automatically	3	0b 1b	False True
		bite_rep	number of automated BITE counts (min is 1)	6:4	000b 001b 111b	1 Count 2 Counts ...... 8 Counts
		pad_drive	Pad drive strength	10:7	0011b 0101b 0111b	Weak Medium Strong
		acc_fs	Accel full g scale select	12:11	00b	16 g
SIGN_SFT_CFG Soft Configuration Register - writable during soft configuration	B	gyr_invert x	Inversion of x axis gyroscope	0	0b 1b	positive sign (no inversion) negative sign (inversion)
		gyr_invert y	Inversion of y axis gyroscope	1	0b 1b	positive sign (no inversion) negative sign (inversion)
		gyr_invert z	Inversion of z axis gyroscope	2	0b	positive sign (no inversion)

					1b	negative sign (inversion)
		acc_invert x	Inversion of x axis acceleration	3	0b	positive sign (no inversion)
					1b	negative sign (inversion)
		acc_invert y	Inversion of y axis acceleration	4	0b	positive sign (no inversion)
					1b	negative sign (inversion)
		acc_invert z	Inversion of z axis acceleration	5	0b	positive sign (no inversion)
					1b	negative sign (inversion)
SID_GYR_SFT_CFG SID for Gyroscrope - writable during soft configuration	C	sid_gyr x	SID Gyroscope x axis	4:0		
		sid_gyr y	SID Gyroscope y axis	9:5		
		sid_gyr z	SID Gyroscope z axis	14:10		
SID_TEMP_NORM_SFT_CFG SID for Temperature sensor (not sensor data) - writable during soft configuration	D	sid_temp	SID value for temperature	4:0		
		sid_norm	SID value for Not-Sensor data	9:5		
SID_ACC_SFT_CFG SID for Accelerometer - writable during soft configuration	E	sid_acc x	SID Accelerometer x axis	4:0		
		sid_acc y	SID Accelerometer y axis	9:5		
		sid_acc z	SID Accelerometer z axis	14:10		

Below is an example of a partially filled write request frame. Here the **ID = 00b** and the **Address = A** (in Hex) for the SOFT_CONFIG register. The write bit is set and the WDATA (write data) bit positions are labelled corresponding to the WDATA Bit Position in the table above. All WDATA bits are yet to be filled out. The CRC is blank as this must be calculated based on the previous 29 bits in the frame.

													WDATA bit positions																		
ID		Address								W	CAP	*	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	CRC		
0	0	0	0	0	0	1	0	1	0	1	0	0																			

Figure 28 Write Request Frame Example

The default settings for the soft configuration parameters are shown in the table below. Please note, there are no default settings for address ‘A’ as the EoC bit must be set to 1 to end to soft configuration phase and therefore, the whole register (all WDATA bits 15:0) must be written at every soft configuration. The register address ‘A’ can no longer be written when the EoC bit has been previously set to 1.

Register Name	Address (Hex)	Short hand	Description	WDATA Bit Position	Input/ write	Input/ write description
SIGN_SFT_CFG Soft Configuration Register - writable during soft configuration	B	gyr_invert x	Inversion of x axis gyroscope	0	0b	positive sign (no inversion)
		gyr_invert y	Inversion of y axis gyroscope	1	0b	positive sign (no inversion)
		gyr_invert z	Inversion of z axis gyroscope	2	0b	positive sign (no inversion)
		acc_invert x	Inversion of x axis acceleration	3	0b	positive sign (no inversion)
		acc_invert y	Inversion of y axis acceleration	4	0b	positive sign (no inversion)
		acc_invert z	Inversion of z axis acceleration	5	0b	positive sign (no inversion)
SID_GYR_SFT_CFG SID for Gyroscrope - writable during soft configuration	C	sid_gyr x	SID Gyroscope x axis	4:0	10001b	
		sid_gyr y	SID Gyroscope y axis	9:5	10010b	
		sid_gyr z	SID Gyroscope z axis	14:10	10011b	
SID_TEMP_NORM_SFT_CFG SID for Temperature sensor (not sensor data) - writable during soft configuration	D	sid_temp	SID value for temperature	4:0	10100b	
		sid_norm	SID value for Not-Sensor data	9:5	10000b	
SID_ACC_SFT_CFG SID for Accelerometer - writable during soft configuration	E	sid_acc x	SID Accelerometer x axis	4:0	10101b	
		sid_acc y	SID Accelerometer y axis	9:5	10110b	
		sid_acc z	SID Accelerometer z axis	14:10	10111b	

7.3.2 Built in Self-Test (BITE) and Soft Reset

The sensor contains a build in test (BITE) for the gyroscope and the accelerometer. A BITE can be triggered automatically during the initialization sequence(power-up) or over a SPI command. The BITE can also be triggered at any time after the initialization sequence is finished (over a SPI command).

When a BITE is triggered, the accelerometer and the gyroscope will start an automatic test sequence to verify the proper functionality of the entire signal path (including MEMS). The sequence runs in parallel on the accelerometer and gyroscope.

The Delta values of the BITE for the accelerometer and gyro are as follows:

parameter / condition	min	typ	max	unit
BITE Delta of one accelerometer BITE signal (corresponding to internal range setting)	8			g
BITE Delta of one Gyro BITE signal (corresponding to internal range setting)	200			°/s

In the case that no axes pass the initial BITE during the initialization sequence, the BITE will be repeated up to the configured number of times. The BITE can also be repeated manually if an initialization sequence with manual BITE was configured during soft configuration (before setting the EoC bit)

An individual axis is considered as 'pass' if it passes at least one of the BITE sequences (e.g. if only the gyro_x is failing in the first BITE and only the acc_z is failing on the second BITE repetition, the BITE is concluded with all axes passing). An axis is considered 'fail' if it is fails in each BITE repetition. If a BITE sequence fails all repetitions, the channel status bit (CS) of the affected channel is set to "1".

After finishing the sequences, the device will run the "BITE final settling" to flush the test signal response. After that, the BITE is completed.

A manual BITE can be triggered after the EoC bit has been set, by writing to the corresponding address as below. The same process is used for a soft reset.

Register Name	Address (Hex)	Short hand	Description	WDATA Bit Position	Input/ write (Hex)
CMD - Command Register	2F	cmd	SOFT RESET Triggers a soft reset	15:0	B6
BITE_CMD	36	bite_cmd	BITE command for issuing a manual BITE execution	15:0	B17E

When using the BITE or soft reset command, the 'write' bit has to be set to 1

When the soft rest has been executed, the soft configuration has to be performed again. Until the start up sequence is complete the CS bit and Init bit will be active (see chapter 6.3.2)

7.3.3 Start-up Recommendations

After start-up, error flags could arise from the BITE that are not real failures and produce **no** CS bit status. Therefore, it is recommended to read out all error flag registers to clear any false flags (clear on read). Otherwise, traceability of any real error flags that may arise would be compromised.

8 Product Safety

8.1 Functional Safety

8.1.1 Safety Concept

The SMI240 is developed according to ASIL B process (ISO26262:2018) and provides sensor signals with safety requirements up to ASIL B. The SMI240 is able to be used in systems up to and including ASIL D in accordance to ISO26262-9: 2018 i.e. fulfilling the decomposition rules and their necessary requirements and analysis. The safety critical functions of the sensor are to provide rate and acceleration signals at the communication interface (SPI). The temperature signal is not an ASIL qualified signal.

After the occurrence of a fault (causing a malfunctioning), the sensor will detect this fault within the Fault Detection Time. After this time the sensor sets a status flag (CS Bit) to indicate a detected fault. The following Fault Reaction Time Interval is relevant on system level.

8.1.1.1 Safe State

The safe state is the state the sensor may go to, if any safety criterion is violated. There are three states possible. If technical possible, criterion a) should be used:

a) status flag set for corresponding channel

b) wrong checksum for response

c) no response

8.1.1.2 FDT - Fault Detection Time

The fault detection time is measured from the time when any safety criterion is violated until the sensor is brought into any of its safe states.

8.1.1.3 Summary of Safety Targets

The requirements are valid for all interfaces if not noted otherwise. The requirements given in this document are valid for the sensor module, not the system in which the sensor is applied.

8.1.1.4 Safety targets for Rate

The safety requirement "Angular rate signal" defines that one rate channel is out of the safety thresholds and the behavior of other channels is not relevant.

parameter / condition	min	typ	max	unit
PMHF – λ Residual	-	-	1E-8	1/h
SPFM – FMC Residual	90	-	-	%
LFM – FMC Latent	60	-	-	%
FDT	-	-	20	ms

8.1.1.5 Safety targets for ACC

The safety requirement "Acceleration signal" defines that one acc channel is out of safety thresholds and the behavior of other channels is not relevant

parameter / condition	min	typ	max	unit
PMHF – λ Residual	-	-	1E-8	1/h
SPFM – FMC Residual	90	-	-	%
LFM – FMC Latent	60	-	-	%
FDT	-	-	20	ms

8.1.2 Dedicated Measures

The safety analysis/ safety development shows no dedicated measures are required.

8.2 Data Protection, Cyber Security and Over the Air Aspects

8.2.1 Data Protection

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.

8.2.2 General Information and Limits about Cybersecurity

Not applicable.

9 Functional and Lifetime Qualification Test Plan

The SMI240 is tested with a qualification plan in accordance to AEC-Q100 – Grade 2

9.1 EMC / ESD

Test plan development based on BISS (Generic IC EMC Test Specification_v2.1_May2017)
Failure criteria:

Rate offset-change > 5°/s
Acceleration offset change > 100mg
Upcoming status-flags
Function class A filter setting LF 50Hz rate and acceleration
Frequency steps according to BISS

parameter / condition	min	typ	max	unit
Electrostatic Discharge, HBM, for all pins 100pF/1.5kOhm	2			kV
Electrostatic discharge, CDM	500			V

10 Disclaimer

10.1 Safety and Warning Notes

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

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.
- Exceeding the X-ray energy dose recommendation.
- 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.

The product is released based on the regulatory requirements directly applicable to the product at the time of TCD creation in the following target market(s):
AR,AT,AU,BE,BG,BR,CA,CH,CN,CY,CZ,DE,DK,EE,ES,FI,FR,GB,GR,HK,HR,HU,IE,ID,IN,IL,IT,IS,JP,KR,LT,LU,LV,MT,MX,MY,NL,PH,NZ,PL,PT,RO,SE,SG,SI,SK,TR,TW,TH,US,VN,ZA (nomenclature according ISO 3166-1)

The product can be used in a released target market in the aforementioned applications, subject to the limits, conditions and other specifications described in this TCD ("Intended use").

Deliveries and services (fulfilment of contract) shall be subject to the provision that there are no obstacles to performance due to national or international (re-) export control regulation, in particular embargoes or other sanctions.

Repair and manual soldering of the sensor is not permitted.

The sensors must not be handled as bulk good.

Sensors with visible damages (housing, connectors, pins, etc.) and sensors which might have exceeded the absolute maximum ratings must not be mounted in the vehicle. These sensors must be scrapped.

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

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.

10.2 ISO26262: 2018

Bosch points out that the ASIL-classified requirements as per ISO 26262: 2018, their implementation and the assumptions made for this purpose are documented in the following documents: SEooC (safety element out of context).

The customer has to ensure that the SMI240 is suitable to be used within the overall system regarding any functional safety requirements assigned to the SMI240 in the overall system.

10.3 Considerations regarding electrical and mechanical robustness

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 following sections describe the different influences that might be relevant in the 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. 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.

As a consequence of the drive oscillation of the rate sensing element, the SMI240 may induce oscillation energy into the PCB. Therefore, if more than one SMI240 are mounted on the same PCB it is important, that any mechanical interference between the two sensors is suppressed by the design of the PCB itself and the mechanical connection between the sensors and the PCB. Failing to do this, the sensors can exhibit an increased noise level of the rate signal.

Due to the sensing principle, the SMI240 is sensitive to disturbances at its resonance frequencies. Therefore, any resonances of the PCB in the critical frequency range must be avoided. In addition to that the mechanical connection of the sensor to the PCB should be designed in a way that the sensor package does not amplify any disturbances induced by the PCB at critical frequencies. If this is not done carefully, the sensor may show rate offset variations over temperature, which might result in an offset out of specification.

The SMI240 in principle is suitable for conformal coating. MEMS sensors, however, are sensitive to mechanical stress. Please note that any measure on application level that alters the mechanical connection between the sensor and the PCB such as for example dip or spray or partial coating might potentially affect the sensor performance (e.g. shift of the resonance frequencies) and board level reliability and therefore, have to be chosen with care by and in responsibility of the customer. It is the responsibility of the customer to ensure the proper application of the product in the vehicle.

10.4 Vibrational Sensitivity

Note that any measures to alter the mechanical connection between the sensor and the PCB are application specific and therefore have to be evaluated and qualified by the customer. Robert Bosch does not take any responsibility for the implementation of any of those options in the customer specific application.

In any case, the mechanical stability of each system design including the SMI240 must be evaluated by the customer in advance to guarantee proper functionality during operation.

10.5 Electrical Considerations

The sensors are sensitive to electrical disturbances. Any disturbances on the supply voltage must be avoided. Especially frequency contents in the power supply at the resonance frequency of the sensing element can be critical. A decent filter strategy must be applied if a stable power supply cannot be guaranteed.

In any case, the electrical stability (power supply and EMC) of each system design, including the SMI240, must be evaluated by the customer in advance to guarantee proper functionality during operation.

10.6 Linux driver

Bosch provides a Linux driver for the SMI240 upon request. The Software was not designed for use in ASIL-classified use cases and no Safety concept was considered during development. The Software shall only be used for the intended use and within the target markets as defined in this TCD, but only for non-Safety use, including but not limited to ISO26262:2018 use. Please consider the disclaimer of the driver Software before its use.

11 Changes

Revision	Responsible	Chapter	Change description
0.1	AE/PAS1.1 Wilkins	-	First version
0.2	AE/PAS1.1 Wilkins	1	Gyro range changed to 300°/s
		1.4	Gyro range changed to 300°/s
		2	Gyro range changed to 300°/s
		2.1	Block diagram added
		2.7	Axis orientation diagram updated
		3.1	Dimensions changed
		3.1	Drawing added
		3.4.1	Pinning changed
		3.4.2	Application circuit changed
		3.4.3	Electrical pin specifications updated
		4.1	Maximum ratings changed and updated
		4.3	Lifetime conditions changed
		4.3	Mission profile added
		5.1	Supply current parameters reduced
		5.2.1.1	Gyro range changed to 300°/s
		5.2.1.2	Several parameters added
		5.2.1.3	Several parameters added
		5.2.1.4	Deviation of angular rate removed
		5.2.1.5	Gyro sensitivity changed to 100LSB/°/s
		5.2.1.5	Several parameters added
		5.2.2.2	Several parameters added
		5.2.2.3	Several parameters added
		5.2.2.4	Linear acceleration parameters removed
		5.2.2.5	Several parameters added
		5.2.3.1	Temperature sensor parameters added
		5.3	Chapter - signal filtering and digital signal processing added
		5.4	Chapter - start-up timing added
		6.2.	SPI levels and timings added
		6.3.1.2	SID description changed
		6.3.1.2	Page bit information added
		6.3.1.2	INIT bit information added
		6.4.1	Sensor addressing information added
		6.4.2	Data capture information added
		6.4.3	SPI data handling moved to chapter 8
		7.1	Service functions added
		7.1	Traceability information added and moved to chapter 7.2
		8.1.2	FTTI changed to FDT
		8.1.2.1	FTTI changed to FDT
		8.2	Safety Architecture chapter deleted (empty)
		8.2	Outline of monitoring concept information added.
		9.1	Corner pin CDM removed

0.3	AE/PAS1.1 Wilkins	3.4.1	Comment corner Pins connect to GND added
		3.4.1	VDDIO power supply changed
		3.4.2	Comment VDD and VDDIO common supply added
		3.4.2	Application diagram changed (common power supply for VDD and VDDIO)
		3.4.3	VDD and VDDIO arbitrary voltages comments deleted
		3.6	Figure format updated
		4.1	Wording changed
		4.1	VDDIO changed to VDD for max non-destructive voltage range
		4.3	Wording changed
		5.1	VDDIO power supply deleted (and added to VDD)
		5.2.1.2	Parameter description offset rate updated
		5.2.2.2	Parameter definition A – unit corrected
		5.2.2.2	Parameter description offset rate updated
		5.2.2.5	Parameter value for acceleration sensitivity changed
		5.3.1	Corner frequency (-3dB) Rate min value corrected
		6.3.1.1	VDDIO changed to VDD
		6.3.1.1	ID code table added
		6.3.1.1	CRC Start value added
		6.3.1.2	VDDIO changed to VDD
		6.3.1.2	ID code table added
		6.3.1.2	CS bit default value corrected
		6.4.1.1	Comment added regarding capture mode
		6.4.1.2	Sub chapter 'Sensor Time' added
		7.1.1	Default values for soft config address A deleted and comment added
		7.1.2	Comment for BITE and Soft Reset added
		10.1	Target markets and disclaimer changed
		10.1	'Bulk good' disclaimer added
		10.2	Wording changed
		N/A	Release signature table deleted at end of document
		N/A	Footnote 'rights reserved' text changed
1.0	AE/PAS1.1 Wilkins	N/A	New Bosch TCD layout used
		1	Product identification chapter now includes designation, part number, customer info, etc
		1.1	Main functions and properties deleted
		1.2	Intended use moved to chapter 2.2
		1.3	Preliminary disclaimer deleted
		2.1	Chapter 2 now includes subchapter 2.1 Technical description
		3.1	Height, weight and thermal resistance values added
		3.1	Offer drawing reference added
		3.1	EC RoHS statement added
		3.1	Preliminary package drawing deleted
		3.2	EIA 541 version added
		3.2	Alternative packaging material statement added
		3.2	Tape and Reel dimensions added
		3.3	Labelling of the product added

	3.3.1	Laser marking of the product added
	3.4.3	Electrical pins specification moved to Chapter 4
	3.6	MSL3 changed to MSL1
	3.7	Meniscus recommendations added
	3.7	Conformal coating statement added
	3.7	General recommendations added
	3.8	Land pattern recommendations added
	3.8.1	Solder mask and stencil recommendations added
	4.1	Mechanical shock value changed to 1500g (acc. AEC-Q100)
	4.1	Min Max active temperature deleted
	4.1	ESD HBM added
	4.5	Sensitivity to mechanical stress added
	4.6	Electrical pin distribution table split
	4.6.3	VDD current consumption during normal operation typ value added
	4.6.3	VDD current consumption during start up added
	4.6.3	VDDIO current consumption during normal operation & start up typ value added
	5.1	Power supply table updated also includes under voltage detection
	5.2.1.2	Short term humidity effects deleted from Absolute offset error
	5.2.1.2	Offset long-term gradient added
	5.2.1.2	Absolute offset error over time D added
	5.2.1.2	Additional noise due to EMC & PSRR changed from 0.5 to 0.6°/s rms
	5.2.1.4	Sensitivity to acceleration impacts replaced by deviation of angular rate
	5.2.1.4	Deviation of angular rate due to specified stimulus added
	5.2.1.4	Gyro resonance frequency updated
	5.2.1.5	Physical resolution added
	5.2.1.5	Nonlinearity up to 300/°s value updated
	5.2.1.5	Hysteresis value added for RT
	5.2.1.6	Value for noise with 400Hz filter added
	5.2.2.2	Short term humidity effects deleted from Absolute offset error
	5.2.2.2	Offset values averaging time reduced
	5.2.2.2	Offset short-term drift span B split for XY and Z channels
	5.2.2.2	Offset long-term gradient added
	5.2.2.2	Absolute offset error over time D added
	5.2.2.3	MEMS Internal headroom deleted
	5.2.2.3	Internal headroom added
	5.2.2.3	Internal headroom - Static clipping added
	5.2.2.4	Deviation of angular rate due to specified stimulus added
	5.2.2.5	Physical resolution added
	5.2.2.5	Nonlinearity for 16g range deleted
	5.2.2.5	Differential nonlinearity split between XY and Z axes
	5.2.2.5	Hysteresis value added for RT up to +/-1g
	5.2.3.1	Sensitivity error added
	5.2.3.1	Nonlinearity added
	5.2.3.1	Bandwidth min and max values added
	5.3.1	Passband and Stopband frequencies added

		6.3.2	Page info modified
		6.3.2	Mode identification modified
		6.4.1	Information added to data capture
		6.4.2	Sensor Time deleted
		7.1	Service functions - Soft configuration moved to 7.3
		7.1	Rev chip ID info changed
		7.2.6	Host Interface Flags added
		7.3.1	Pad drive strength descriptions and settings added
		7.3.2	BITE amplitudes added
		7.3.3	Start-up Recommendations added
		8.2	Outline of monitoring concept - monitors mode to 7.2
		8.2	Error counters moved to 7.2
		8.2	BITE moved to 7.2
		8.2	LBIST moved to 7.2
		8.2	Voltage Checks moved to 7.2
		8.2	SPI Error handling moved to 7.2
		10	Disclaimer updated
1.1	AE/PAS1.1 Wilkins	1.2	ASIL safety information updated for a more complete description
		4.6.1	VIO- Supply voltage of SPI and other I/Os changed
		5.2.1.2	Additional offset error due to EMC & PSRR, 1Hz corrected to 100Hz
		5.2.1.2	Additional noise due to EMC & PSRR, 1Hz corrected to 100Hz
		5.2.1.2	Additional noise due to EMC & PSRR corrected to 0.6°/s rms
		5.2.2.2	Additional offset error due to EMC & PSRR, 1Hz corrected to 100Hz
		5.2.2.2	Additional noise due to EMC & PSRR, 1Hz corrected to 100Hz
		5.2.2.4	Deviation of angular rate corrected to acceleration signal
		5.2.2.4	Comment added to Deviation of acceleration signal due to specified stimulus
		5.2.3.1	Min and Max values added to Output sample rate
		5.3.1	Frequency response tables updated for stopband and passband frequencies for both filter settings
		5.4	Initialization sequence diagrams in correct order
		5.4	BITE number (3) in initialization diagrams removed
		5.4	BITE number (1) added to start up timing tables
		7.2.2	BITE description updated
		7.2.4	Voltage checks description changed
		7.2.6	CS bit information added
		7.3.2	BITE amplitude table values updated
		7.3.2	BITE Description updated
		8.1.1	ASIL safety information updated for a more complete description
1.2	ME-SE/PAE-A1 Wilkins	3.8	Land pattern text added
		3.8	Land pattern figure adjusted
		5.2.1.2	Bias instability changed to max value
		5.2.1.2	Angle random walk changed to max value
		5.2.2.2	Velocity random walk (N) max value added
		5.2.2.5	Sensitivity error information added
		5.2.3.1	Non-linearity changed to absolute value in K

	6.4	Request read data examples added to table
	6.4.1	Request read data examples added to table
	7.1	Request read data examples added to table
	7.2	Request read data examples added to table
	7.2.6	Request read data examples added to table
	7.3.1	Figure 28 – 'Write Request Frame Example' added with description
	10	AR added to list of target markets

12 Table of Figures

13 Contact Person

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ME-SE/PAE-A1