TCD Technical Customer Documentation – SMI330

Inertial sensor for non-safety applications

Product designation:	SMI330
Document Number:	1279 940 740
Version:	V1.2
Date:	[2025-05-05]

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1 Product identification

Product designation:	SMI330 [C-Sample PN]
Product part number:	0273142404 [0274B04622-02]
Type designation:	Inertial Sensor
RB TCD Number	1279 940 740
Offer drawing number:	0274A02027
Application:	Navigation

The SMI330 is a combined three axis angular rate and three axis acceleration sensor module with a measurement range of up to +/- 500°/s and 16g.

1.1 Main Functions and Properties

Table 1 - Key Features

Key Feature	Description
Small package	LGA, 14 pins 2.5 x 3 mm^2, height 0.83mm
Gyroscope	X / Y / Z (up to 500°/s range)
Accelerometer	X / Y / Z (up to 16g range)
Operating temperature	-40°C ... 125°C
Communication interfaces	SPI / I3C / I^2C
Sample rates (ODR)	Selectable from 0.78125Hz ... 6.4kHz
Output filters	Selectable low pass filters
Ultra low current consumption	Typ. 790µA
On-chip temperature sensor	-40°C – 125°C
Smart operation and integration	On-chip interrupt engine
Mobility electronics suite	MSL1, RoHS compliant, halogen and lead free

1.2 Preliminary Disclaimer

Provided that SMI330 is used within the conditions (environment, application, installation, loads) as described in this TCD and the corresponding agreed upon documents, Bosch ensures that the product complies with the agreed properties. Agreements beyond this require the written approval from Bosch. The product is considered fit for the intended use when the product successfully has passed the tests in accordance with the TCD and agreed upon documents.
It is the responsibility of the customer to ensure the proper application of the product in the overall system/vehicle.
Bosch does not assume any responsibility for changes to the environment of the product that deviate from the TCD and the agreed upon documents as well all applications not released by Bosch.

2 General product description

The SMI330 is a highly integrated, low power inertial measurement unit (IMU) that combines precise acceleration and angular rate (gyroscopic) measurement with intelligent on-chip motion-triggered interrupt features. SMI330 integrates

· a 16 bit digital, triaxial accelerometer with range configurable to 2 g, 4 g, 8 g, 16 g
· a 16 bit digital, triaxial gyroscope with range configurable to ±125 °/s, ±250 °/s, ±500 °/s
· a 16 bit digital temperature sensor for an operating temperature range -40 °/C ... +125 °/C

2.1 Technical Description

The device includes the two sensors accelerometer and gyroscope. The accelerometer measures the direction and magnitude of the force applied to the sensor. In a free fall scenario, an accelerometer will report a vector of zeros. The gyroscope measures the rotational rate and is reporting a vector of zeros when the device is at rest. In addition, the device includes as auxiliary sensor a temperature sensor. All samples are reported synchronously with a unique time value.

2.2 Intended Use

The SMI330 is a combined triaxial accelerometer (ACC) and triaxial gyroscope (GYR), intended for use in non-safety related applications, e.g. for in-dash navigation in the passenger compartment. The product has been developed, validated, and released exclusively for use in these applications.

2.3 Block Diagram

The figure 1 details the signal view of the device from analog sensing through analog digital conversion, compensation filtering and feature computation to the data and the protocol interfaces.

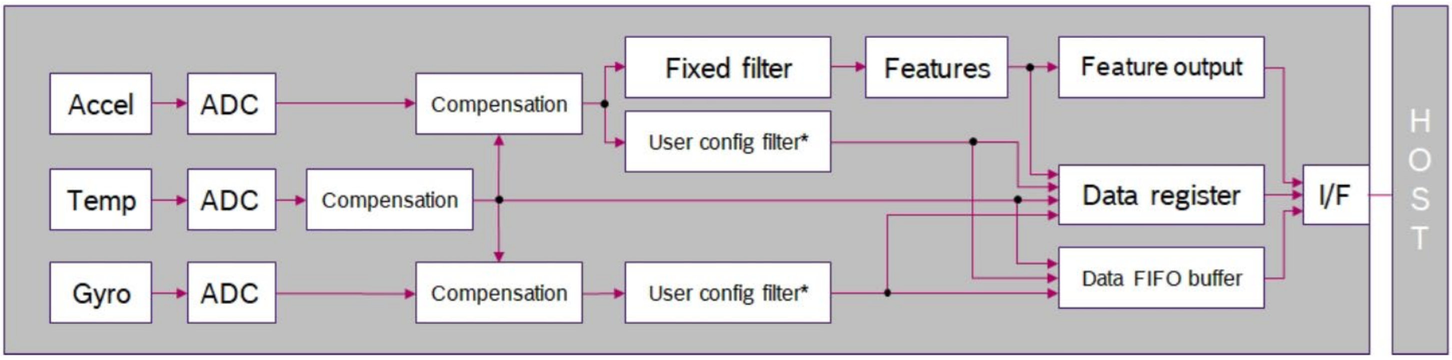


Figure 1 - Block Diagram

2.4 Orientation of Sensing Axes

If the sensor is accelerated and/or rotated in the indicated directions, the corresponding channels of the device will deliver a positive acceleration and/or yaw rate signal (dynamic acceleration). If the sensor is at rest without any rotation and the force of gravity is acting contrary to the indicated directions, the output of the corresponding acceleration channel will be positive and the corresponding gyroscope channel will be “zero” (static acceleration).
Example: if the sensor is at rest or at uniform motion in a gravity field according to the figure given below, the output signals are:

- ±0g for the ax accelerometer channel and 0°/s for the x gyroscope channel
- ±0g for the ay accelerometer channel and 0°/s for the y gyroscope channel
- +1g for the az accelerometer channel and 0°/s for the z gyroscope channel

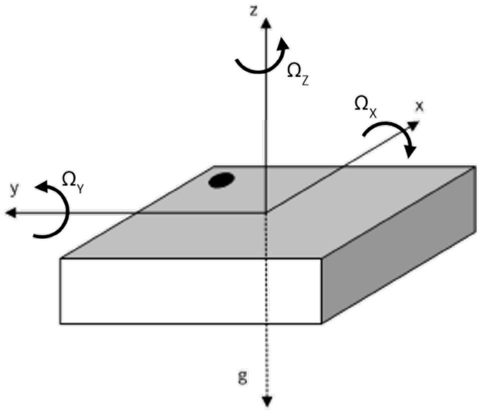


Figure 2 - Definition of the sensing axes

3 Hardware Interface Description and Packaging

3.1 Package Parameters

Table 2 - Package Parameters

Parameter	Typ	Unit
Physical dimensions of sensor (length x width x height)	2.5x3x0.83	mm
Weight	11.4	mg

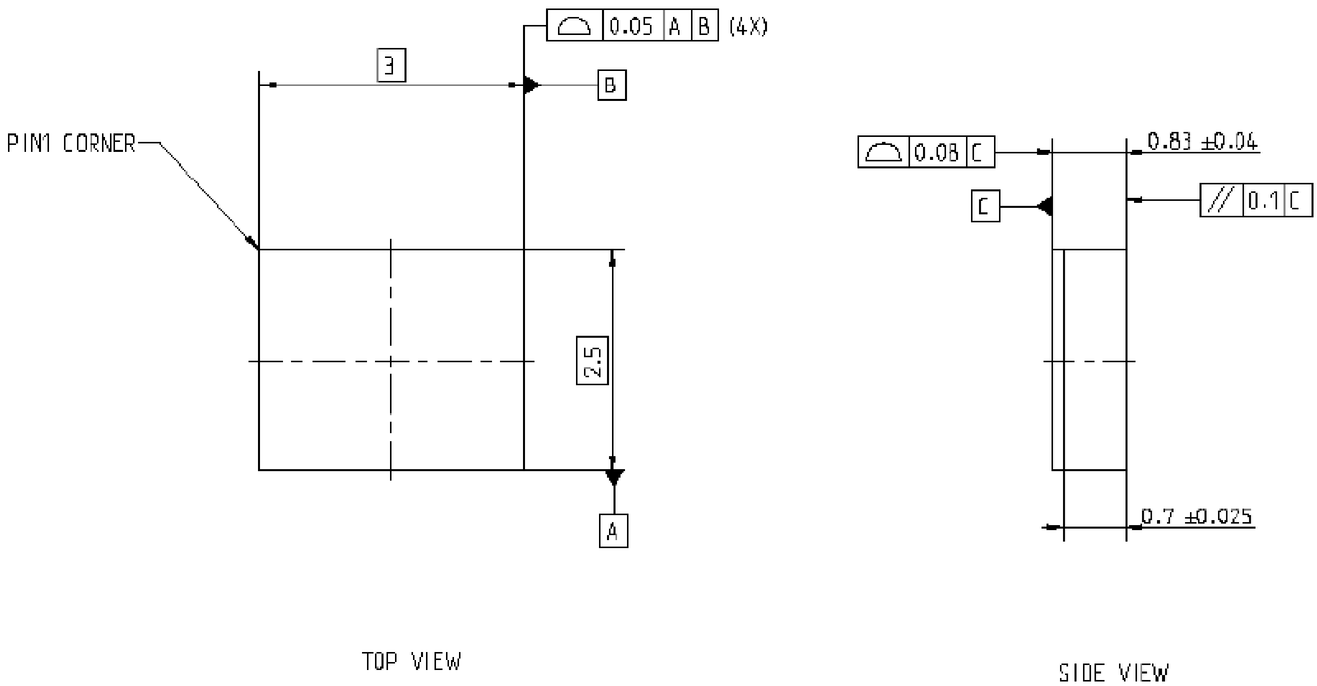


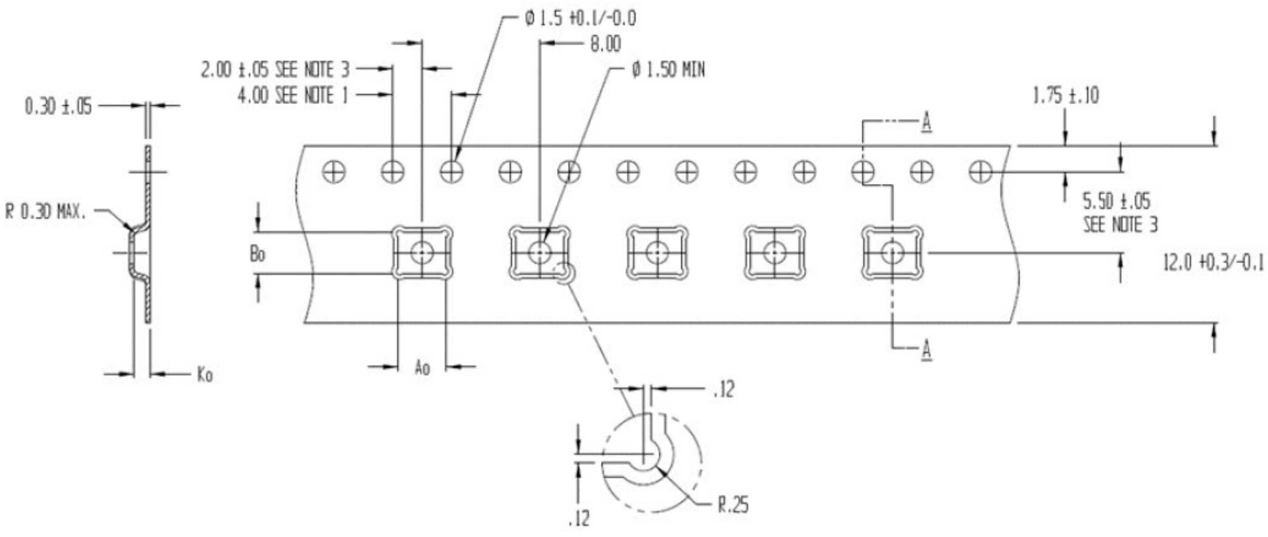
Figure 3 - Package Parameters

The development of the SMI330 complies with the requirements of the current edition of EU-RoHS. The use of the product SMI330 is not within the scope of EU-RoHS, therefore future changed requirements of EURoHS will not be considered.

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

3.2 Transport Package

The SMI330 is shipped in a standard cardboard box. The box dimensions for one reel are L x W x H 35 x 35 x 5 [cm]. SMI330 quantity: 5000 pcs per reel. Please handle with care.



A_0 = 3.30, B_0 = 2.80, K_0 = 1.10

Figure 4 - Tape & Reel dimension in mm

Note:

- Tolerances unless noted: ±0.1
- Sprocket hole pitch cumulative tolerance ±0.1
- Camber in compliance with EIA481
- Pocket position relative to sprocket hole measured as true position of pocket, not pocket hole.
- A_0 and B_0 are calculated on a plane at a distance “R” above the bottom of the pocket.

3.3 Labelling of the Product

Table 3 - Labelling Information

Labeling	Sample	Marking	Subcon-ID	Trace Code
● E T C C C	Engineering Sample	E	T	CCC (without letter O)
	C - Sample	C	T	CCC (without letter O)
	Series	N	T	CCC (without letter O)
	● Pin1 Marking	-	-	-

3.4 Pinning

The figures 5 +6 shows the pin-out of the device from top and bottom view, respectively.

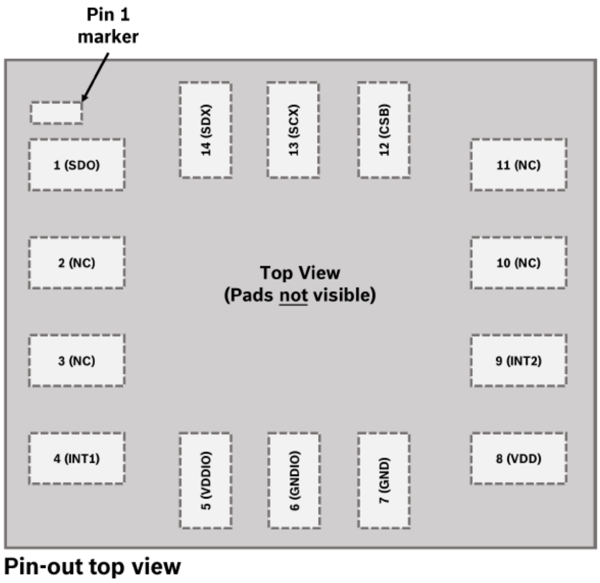


Figure 5 - Top View

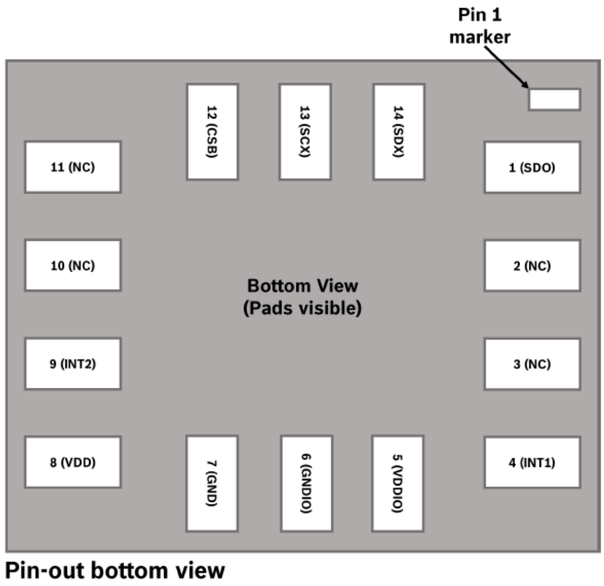


Figure 6 - Bottom View

Table 4 - SMI330 Pin description

Pin #	Name	I/O Type	Description	Connect to	
				in SPI	in I2C / I3C
1	SDO	Digital I/O	SDO Serial data output in SPI I2C address bit-0 select in I2C mode	SDO	GND for default i2C address
2	NC	Digital I/O		do not connect	
3	NC	Digital I/O		do not connect	
4	INT1	Digital I/O	Interrupt pin 1	INT1	INT1
5	VDDIO	Supply	Digital I/O supply voltage 1.08V … 3.63V	VDDIO	VDDIO
6	GNDIO	Ground	Ground for I/O	GNDIO	GNDIO
7	GND	Ground	Ground for digital & analog	GNDIO	GND
8	VDD	Supply	Power supply analog & digital domain 1.71V … 3.63V	VDD	VDD
9	INT2	Digital I/O	Interrupt pin 2	INT2	INT2
10	NC			do not connect	
11	NC			do not connect	
12	CSB	Digital in	Chip select for SPI mode	CSB	VDDIO
13	SCx	Digital in	SCK for SPI serial clock SCL for I2C serial clock	SCK	SCL
14	SDx	Digital I/O	SDA serial data I/O in I2C SDI serial data input in SPI	SDI	SDA

3.5 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.
Note: Ultrasonic cleaning and welding is not recommended.

3.6 Landing Pattern

Figure 7 provides the recommendation for the landing pads to ensure maximum stability of the solder connections. The Pin 1 marker must not be electrically connected. Vias underneath the package have to be avoided.

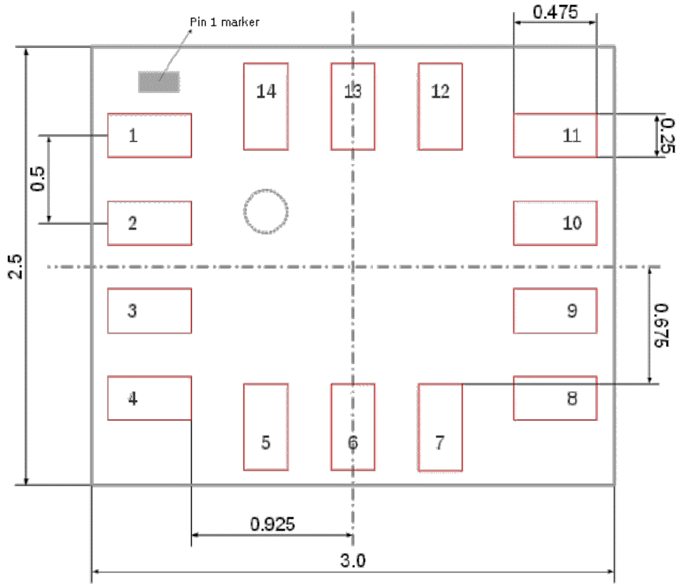


Figure 7 - Landing Pattern

3.7 Recommendation for PCB Layout

The following recommendations only represent one possible solution for the layout of the PCB based on Bosch experience and evaluation results. The PCB layout and its qualification lie in the responsibility of the customer and therefore other suitable solutions can be implemented.
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. It is known that some solder fluxes tend to mechanical cracking during temperature cycling. Since this may lead to short signal spikes in the angular rate signal, it is recommended to choose the solder flux carefully regarding cracking behaviour.

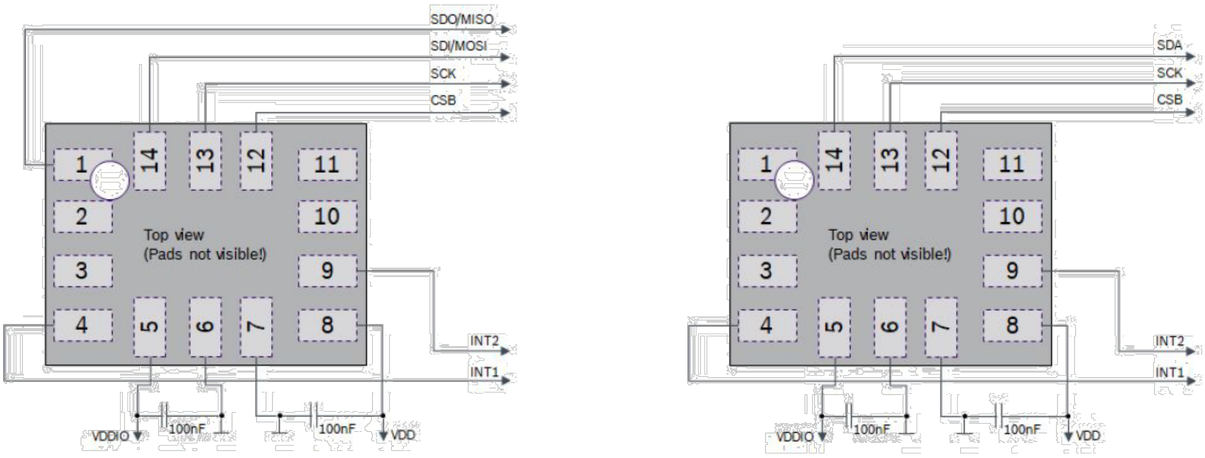


Figure 8 -SPI 4 wire and SPI 3 wire connection

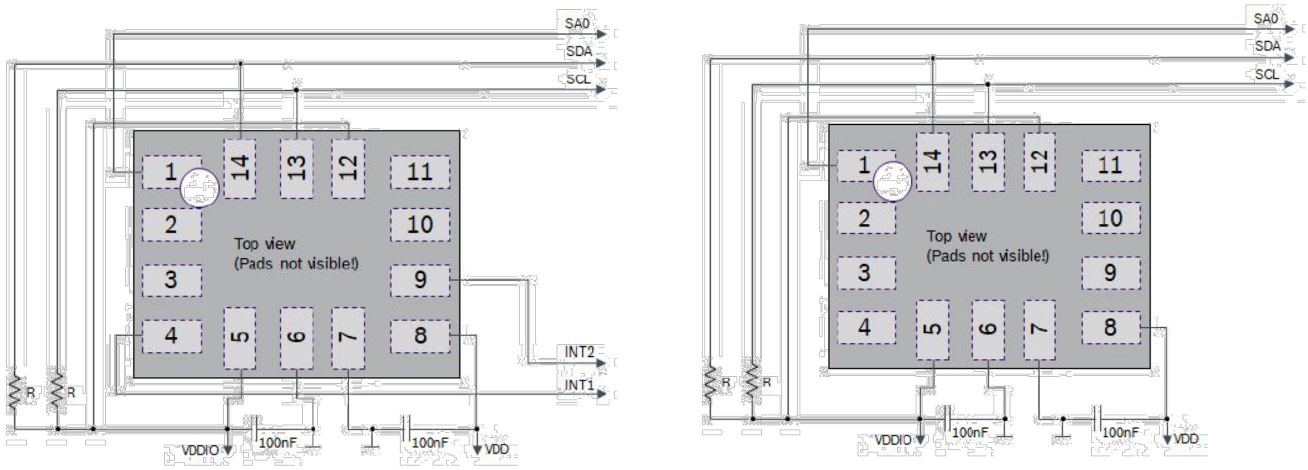


Figure 9 - I2C- and I3C- connection

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.

Table 5 - Maximum Ratings

Parameter	Condition	Min	Max	Unit
Voltage at Supply Pin	V_{DD} Pin	-0.3	4	V
Voltage at Supply Pin	V_{DDIO} Pin	-0.3	4	V
Voltage at any Logic Pin	Non-Supply Pin-out	-0.3	V_{DDIO}+0.3 and < 4	V
Passive Storage Temperature Range	≤65%rH	-50	150	°C
OTP Non-Volatile Memory Data Retention	T= 125°C	15	-	a
Mechanical Shock	-	-	1500	g
ESD	HBM at any Pin CDM MM	- - -	2000 500 200	V

4.2 Passive Storage Duration

Table 6 - Passive storage duration of SMI when soldered on PCB

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

Table 7 - Passive storage duration of unsoldered SMI

Duration[h]	At [°C]
24	150 ... 70
50	70 ... 40
8660	40 ... 10
50	10 ... -50
Total: 8784h / 1a	

4.3 Operating Conditions

Table 8 - Operating Conditions

Parameter	Min	Typ	Max	Unit
Operating temperature range	-40	-	125	°C

4.4 Lifetime Conditions

Lifetime conditions are checked according to AEC-Q100 grade 1 requirements, please see also chapter 9 “Functional and Lifetime Qualification Test Plan”.
The commercial warranty and liability is not affected by this and is governed separately by the delivery conditions.

4.5 Electrical Pins Specification

4.5.1 Electrical Specification for Input Pins

Table 9 - Specification for Input Pins

Parameter	Symbol	Condition	Min	Typ	Max	Unit
Voltage input low level	V_{IL}	SPI, I^2C, I3C			$0.3*V_{DDIO}$	V
Voltage input high level	V_{HL}	SPI, I^2C, I3C	$0.7*V_{DDIO}$			V

4.5.2 Electrical Specification for output Pins

Table 10 - Specification for Output Pins

Parameter	Symbol	Condition	Min	Typ	Max	Unit
Voltage output low level	V_{OL}	SPI			$0.2*V_{DDIO}$	V
Voltage output high level	V_{OH}	SPI	$0.8*V_{DDIO}$			V

4.5.3 Electrical Specification for VDD

Table 11 - Specification for Supply Pins

Parameter	Symbol	Condition	Min	Typ	Max	Unit
Supply voltage core domain	V_{DD}		1.71	1.8	3.63	V
Supply voltage I/O domain	V_{DDIO}		1.08	1.2	3.63	V

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 figures except the noise itself exclude noise effects.

5.1 Power Supply

Table 12 - Specification Sensor Supply

Parameter	Symbol	Condition	Min	Typ	Max	Unit
Supply voltage core domain	V_{DD}		1.71	1.8	3.63	V
Supply voltage I/O domain	V_{DDIO}		1.08	1.8	3.63	V
Voltage input low level	V_{IL}	SPI, I²C, I3C			0.3*V_{DDIO}	V
Voltage input high level	V_{HL}	SPI, I²C, I3C	0.7*V_{DDIO}			V
Voltage output low level	V_{OL}	SPI			0.2*V_{DDIO}	V
Voltage output high level	V_{OH}	SPI	0.8*V_{DDIO}			V
Current consumption	I_{DD}	A+G suspend mode A_{only} LPM, $f_{A,lp}$=25Hz A_{only} HPM, $f_{A,hp}$=max A+G HPM, $f_{A,hp}$= $f_{G,hp}$ = max A+G NM, $f_{A,nm}$= $f_{G,nm}$ = max A+G LPM, $f_{A,lp}$= $f_{G,lp}$ = 25Hz		100 130 230 870 780 530		µA

5.2 Technical Data

This chapter provides the specifications for the SMI330.
Unless stated otherwise, the specifications provide the characteristics for a nominal supply voltage of VDD = VDDIO = 1.8V, gyr 250 dps range, acc 8g range and an ODR = 800Hz. Either at an ambient temperature of T_A = 25°C or, if the characteristic is specified with respect to temperature and life time.

Table 13 - Technical Data

Parameter	Symbol	Condition	Min	Typ	Max	Unit
Power on time	Δt_{PO}	Time from supply on to serial I/F operational		1.5	2	ms
Accuracy of the output data rate	Δf_{ODR}	Any mode		2		%

5.2.1 Performance Gyroscope

Table 14 - Characteristic Gyroscope

Parameter	Symbol	Condition	Min	Typ	Max	Unit
Angular rate range	ω_{FS}	Selectable via serial digital interface		±125 ±250 ±500		°/s
Start up time	$t_{G,SU}$	Suspend to high performance mode $f_{A,hp}$=max including filter settling		30		ms
Resolution				16		Bit
Sensitivity	S_G	ω_{FS} = 125°/s ω_{FS} = 250°/s ω_{FS} = 500°/s		262.144 131.072 65.536		LSB/°/s
Sensitivity error	$S_{G,err}$ $S_{G,err(CRT)}$	Soldered, over temp and life time Soldered, over temp and life time w/ triggerd CRT @ RT		±4 ±3.5	±8 ±6.5	%
Zero-rate offset	$O_{G,(comp)}$ O_G	Soldered, over temp and life time w/ zeroing on pcb level Soldered over temp an life time		±1 ±1.2	±3.5 ±5	°/s
Zero-rate offset change over temperature	TCO_G	Best fit straight line		±0.01	±0.02	°/s/K
Noise density	$ND_{(oT)}$	Over temperature		0.015	0.03	°/s/rt(Hz)
Nonlinearity error	$S_{G,NL}$	Over temperature		±0.1	±0.3	°/s
Output data rate	$f_{G,hp}$, $fo_{G,n}$ $f_{G,lpm}$	High performance and normal mode Low power mode	12.5 0.78125		6400 400	Hz
Bandwidth (BW) in high performance and normal mode	B_{fG} = 12.5Hz B_{fG} = 25Hz B_{fG} = 50Hz B_{fG} = 100Hz B_{fG} = 200Hz B_{fG} = 400Hz B_{fG} = 800Hz B_{fG} = 1600Hz B_{fG} = 3200Hz B_{fG} = 6400Hz	0Hz ≤ f ≤ $f_{3dB\text{-}cutoff}$ of the gyroscope		6.2 12.4 24.9 49.7 99.5 198.9 397.6 689.1 1275.2 2012.4		Hz
Cross axis sensitivity:	$S_{G,YX}$ $S_{G,ZX}$ $S_{G,ZY}$	Over temperature (Non-orthogonality and alignment error incl)		±1	±2.2	%
Cross axis sensitivity: Non-orthogonality		Over temperature			±0.6	%
Angular random walk	ARW	@RT		0.32		deg/rt(h)
Bias istanbility	BI(X,Y,Z)	@RT for [X; Y; Z]		(3.7;4.5;3)		°/h

5.2.2 Performance Accelerometer

Table 15 - Characteristic Accelerometer

Parameter	Symbol	Condition	Min	Typ	Max	Unit
Range	a_{FS}	Selectable via serial digital interface		±2 ±4 ±8 ±16		g
Start up time	$t_{A,SU}$	Suspend to high performance mode f_A=max		2		ms
Resolution				16		Bit
Sensitivity	S_A	a_{FS} = 2g a_{FS} = 4g a_{FS} = 8g a_{FS} = 16g		16384 8192 4096 2048		LSB/g
Sensitivity error	$S_{A,err}$	Soldered over temperature and life time		±0.5	±1.2	%
Zero-g offset	O_A	Soldered over temperature and life time		±60	±150	mg
Zero-g offset change over temperature	TCO_A	Full T_P range, best fit straight line		±0.1	±0.3	mg/K
Noise density	$ND_{(oT)}$	HP mode, over temperature		190	300	µg/rt(Hz)
Nonlinearity error	$S_{A,NL}$	Over temperature		±5	±15	mg
Output data rate	$f_{A,hp}$, $f_{A,n}$ $f_{A,lpm}$	High performance and normal mode Low power mode	12.5 0.78125		6400 400	Hz
Bandwidth (BW) in high performance and normal mode	Axis	0Hz ≤ f ≤ $f_{3dB\text{-}cutoff}$ of the accelerometer		X / Y / Z		Hz
	$B_{fA = 12.5Hz}$			6 / 6 / 6		
	$B_{fA = 25Hz}$			12 / 12 / 12		
	$B_{fA = 50Hz}$			24 / 24 / 24		
	$B_{fA = 100Hz}$			49 / 49 / 49		
	$B_{fA = 200Hz}$			99 / 99 / 99		
	$B_{fA = 400Hz}$			197 / 197 / 195		
	$B_{fA= 800Hz}$			387 / 387 / 375		
	$B_{fA = 1600Hz}$			622 / 627 / 563		
	$B_{fA = 3200Hz}$			961 / 977 / 787		
	$B_{fA = 6400Hz}$			1192 / 1222 / 908		
Cross axis sensitivity:	$S_{A,YX}$ $S_{A,ZX}$ $S_{A,ZY}$	Over temperature (Non-orthogonality and alignment error incl)		±1	±2.2	%
Cross axis sensitivity: Non-orthogonality		Over temperature			±0.6	%
Velocity random walk	VRW	@RT		125		µg/rt(Hz)
Bias instability	BI	@RT		50		µg

5.2.3 Performance Temperature Sensor

Table 16 - Characteristic Temperature Sensor

Parameter	Symbol	Condition	Min	Typ	Max	Unit
Resolution				16		Bits
Measurement range	T_S	Theoretical range (released for -40 to 125 °C, see table 8)	-105		151	°C
Output at 23°C				0		LSB
Sensitivity	S_T			256		LSB/K
Temperature offset	O_T	After soldering		±3		K
Temperature sensitivity error		After soldering, T_P		2.2		%
Output data rate	$f_{T,G}$, $f_{T,combo}$	Any power operation mode with gyro in high performance mode or normal mode			50	Hz
	$f_{T,other}$	Any power operation mode with gyro either disabled, in low power mode or drive only enabled			12.5	
	$f_{T,A\text{-}only.lp}$	Accelerometer in low power mode, gyro disabled			6.25	

6 Software Interface Description

The device provides one serial interface to the host. It acts as a slave to the host. The serial interface is configurable to the interface protocols SPI, I3C and I2C. By default, the device operates in I²C mode. The interface of the device can be configured to operate in a SPI 4-wire configuration as well. It can also be re-configured by software to work in 3-wire mode.

Table 17 - Characteristic Sensor Interfaces

Parameter	Symbol	Condition	Min	Typ	Max	Unit
Pull-up resistance, CSB pin	R_{up}	Internal Pull-up resistance to VDDIO	75	100	140	kΩ
Input capacitance	C_{in}				5	pF
I²C bus load capacitance (max. drive capability)	$C_{load,I2C}$				400	pF
I3C bus load capacitance (max. drive capability)	$C_{load,I3C}$			10	50	pF

6.1 Protocol Selection

The protocol is automatically selected based on the behavior of the signal on the chip select pin CSB after power-up. After soft reset or power-up, the primary interface of the device is in I²C mode. If the CSB is connected to VDDIO during power-up and not changed, the primary interface works in I²C or I3C mode. The possible switches among the modes on the digital interface are summarized in table 18.
For using I²C and I3C, it is recommended to hard-wire the CSB line to VDDIO. Since power-on-reset is only executed when both VDD and VDDIO are stable, there is no risk of an incorrect protocol detection due to the power-up sequence.
If a rising edge is detected on CSB after power-up, the device interface switches after 200 μs to SPI until a soft reset or until the next power-up occurs. Therefore, a rising edge on CSB is needed before starting the SPI communication. It is recommended to perform a single read from a register, e.g. from CHIP_ID.chip_id, before the actual data exchange with the device. Note: the content of the retrieved data will be invalid.
The switch from I²C to I3C follows the MIPI I3CSM specification. Upon power up, the chip stays in I²C mode and once the dedicated Broadcast I3C Address (7'h7E) is seen on the bus, the chip will disable its I²C feature and the interface stays in the I3C mode until a soft reset or the next power-up occurs.

Table 18 - Protocol Switch

Protocol switch	To I²C	To I3C	To SPI
From I²C	n/a	Device ID 7E sent	Dummy SPI read
From I3C	Power-down or soft-reset	n/a	Dummy SPI read
From SPI	Power-down or soft-reset	Power-down or soft-reset	n/a

6.2 Common Specifications

The maximum ratings valid for all serial protocols supported by the device are given in the table below. For SPI, the additional specifications are given in the corresponding sub-section 6.2.1.

Table 19 - Common Specifications

Parameter	Symbol	Condition	Min	Typ	Max	Unit
Clock frequency	f_{I3C} f_{SPI} f_{I3C}, f_{SPI}	Max. load on SDI or SDO 30pF, V_{DDIO}≥1.62V V_{DDIO}≤1.62V			12.5 10 8	MHz
Idle time after any access in any mode	$t_{IDLE,rd}$		2			µs

6.2.1 SPI Protocol

The dedicated timing specifications for SPI of the device in addition to Table 19 are stated in Table 20. Figure 10 shows the definition of the SPI timings.

Table 20: SPI timings

Parameter	Symbol	Condition	Min	Max	Unit
SCK Low Pulse	t_{SCKL}	V_{DDIO} ≥ 1.62V	45		ns
SCK High Pulse	t_{SCKH}	V_{DDIO} ≥ 1.62V	45		ns
SCK Low Pulse	t_{SCKL}	V_{DDIO} ≤ 1.62V	66		ns
SCK High Pulse	t_{SCKH}	V_{DDIO} ≤ 1.62V	66		ns
SDI Setup Time	$t_{SDI,setup}$		20		ns
SDI Hold Time	$t_{SDI,hold}$		20		ns
SDO Output Delay	$t_{SDO,OD}$	Load = 30pF, V_{DDIO}≥ 1.62V		30	ns
CSB Setup Time	$T_{CSB,setup}$		40		ns
CSB Hold Time	$T_{CSB,hold}$		40		ns

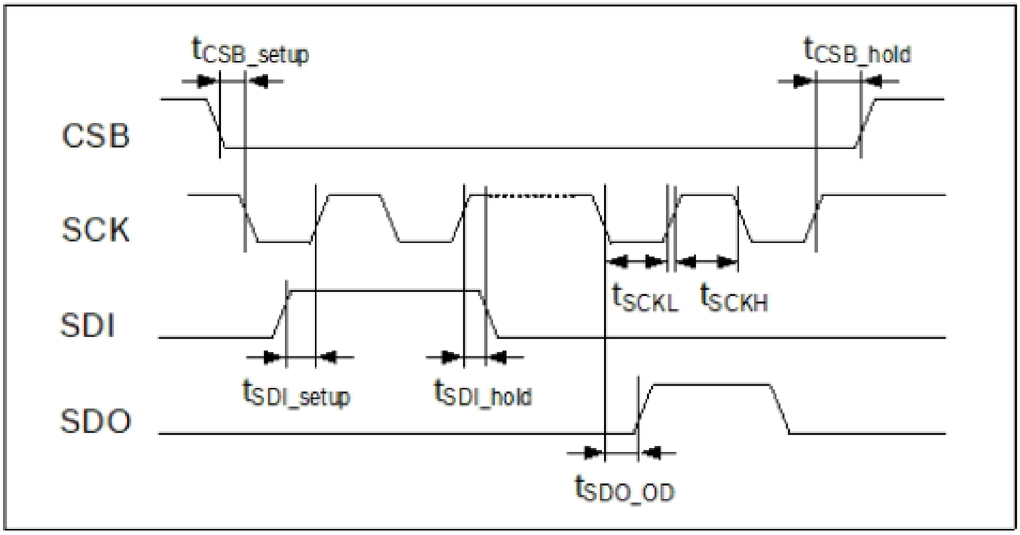


Figure 10 - SPI Timing Diagram

The SPI interface of the device is compatible with two modes:
'00' [CPOL = '0' and CPHA = '0']
'11' [CPOL = '1' and CPHA = '1'].

The automatic selection between '00' and '11' is controlled based on the value of the clock on the SCK pin after a falling edge is detected on the chip select pin CSB.
Two configurations of the SPI interface are supported by the device: 4-wire and 3-wire. The protocol used by both configurations is the same. The device operates in the 4-wire configuration by default. It can be switched to 3-wire configuration by writing 0b1 to IO_SPI_IF.spi3_en. In the 3-wire configuration, the pin SDX is used as the common data pin.

SPI 4-wire the pins CSB (chip select low active), SCX (as SCK for serial clock), SDX (as SDI for serial data input), and SDO (serial data output) are used. The communication starts when CSB is pulled low by the SPI master and stops when CSB is pulled high again. SCK is also controlled by SPI master. SDI and SDO are driven at the falling edge of SCK and should be captured at the rising edge of SCK.
Multiple and single write operations are possible by keeping CSB low and continuing the data transfer. Only the address of the first register has to be sent via SDX. Addresses are automatically incremented after each write access as long as CSB stays active low. The principle of multiple write is shown in the Figure below.

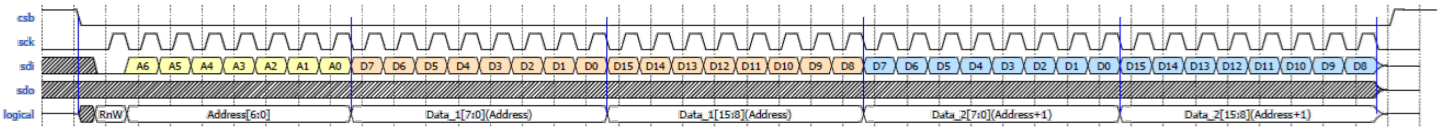


Figure 11 - Multiple write operation with SPI 4 wire protocol

The basic read operation waveform for 4-wire configuration is depicted in Figure 12. Please note, that the first byte received from the device via the SDO line corresponds to a dummy byte and the 2nd byte corresponds to the value read out of the specified register address. That means, for a basic read operation, at least two bytes have to be read and the first byte has to be dropped and all following bytes can be interpreted.

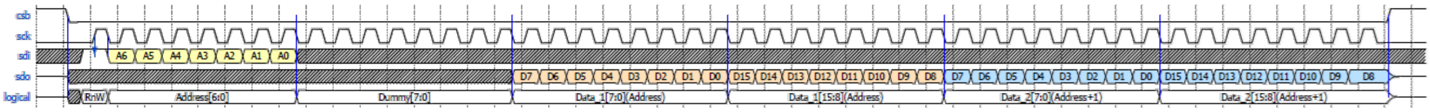


Figure 12 - Multiple read operation with SPI 4 wire protocol

Address [A6-A0]: Address of the first register
Data k [7:0], Data k [15:8]: In write mode, these are the data via the SDI, which will be written into the address.
Data k [7:0], Data k [15:8]: In read mode, these are the data on the 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. Please note that the first byte received from the device via the SDO line corresponds to a dummy byte and the 2nd byte corresponds to the value read out of the specified register address. The successive bytes read out correspond to values of incremented register addresses. That means, for a multiple read operation of n bytes, n+1 bytes have to be read, where the first byte has to be ignored and the successive bytes must be interpreted.

SPI 3-wire the pins CSB, SCX, and SDX are used. SCK is controlled by the SPI master. While SCK is pulled high, the communication starts when the CSB is pulled low by the SPI master and stops when CSB is pulled high again. SDX is driven (when used as input of the device) at the falling edge of SCK and should be captured, when used as the output of the device, at the rising edge of SCK.
In a 3-wire configuration, the protocol as such is the same as in a 4-wire configuration. The basic operation for read and write access for 3-wire configuration is depicted in Figures 13 and 14, respectively.

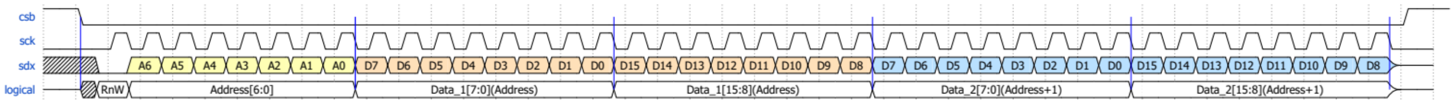


Figure 13 - Multiple word write with SPI3 wire protocol

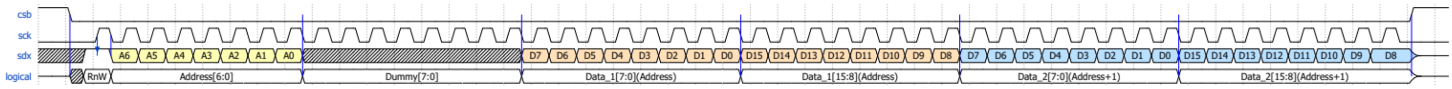


Figure 14 - Multiple word read with SPI3 wire protocol

6.2.2 I3C Protocol

- The device supports the I3C protocol with the features:
- I3C single data rate (SDR) mode with up to 12.5 MHz data rate
- I²C compatibility
- In-Band Interrupt (IBI)
- Timing control asynchronous 0 mode
- Timing control synchronous mode

The I3C bus uses the pin SCX as SCL for serial clock and SDX as SDA for serial data input and output for the signal lines. Both lines are connected to VDDIO externally via pull-up resistors so that they are pulled high when the bus is free.

The I3C interface of the device is compatible with the I3C^SM Improved Inter Integrated Circuit Version 1.0 from 23 December 2016, and the Frequently Asked Questions (FAQ) for MIPI I3C^SM Version 1.0 from 08 December 2017 available at http://www.mipi.org/specifications/i3c-sensor-specification.

The protocol used on the serial interface for writing data to the device consists of

- write the address byte, and
- then write instantly a sequence of words consisting of two bytes each.

The protocol used on the serial interface for reading data from the device consists of

- write the address byte, and then
- read:
    - two dummy bytes preceding the actual payload, and then instantly
    - the number of desired payload bytes/words.

6.2.2.1 I3C Mode^SM

Address Range The master can assign Dynamic Addresses from an allowed set of values to the device. In addition to the I3C Slave Address Restrictions defined in Table 9 in the section 5.1.2.2.5 of the I3C^SM specification “Improved Inter Integrated Circuit Version 1.0 – 23 December 2016”, the address 7’h7D is reserved for this device as well.

Bus Configuration The I3C protocol uses several identifiers and codes to handle communication between several masters and slaves. For communication with this device, there are defined

- The I3C provisional ID
- The Device Characteristics Register (DCR)
- The Bus Characteristics Register (BCR)
- The Mandatory Byte (MDB) for IBIs

The I3C provisional ID has the value defined in table 21

- Bit 12 is controlled by the level on the SDO pin, that is GND for 0b0 and VDDIO for 0b1
- Bit 13 to 15 are the so-called instance ID and defined as “000”

Table 21 : I3C provisional identifier

Byte	Byte 5								Byte 4								Byte 3								Byte 2								Byte 1								Byte 0							
Bit of byte	7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0
Bit of word	47	46	45	44	43	42	41	40	39	38	37	36	35	34	33	32	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
De-scrip-tion	MIPI member ID															IDT	Bosch group ID					Device ID											Instance ID				Reserved											
Bit value	0	0	0	0	0	1	1	1	0	1	1	1	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	SDO	0	0	0	0	0	0	0	0	0	0	0	0
Hex value	0				7				7				0				1				0				4				1				0 or 1				0				0				0			

The value of the Device Characteristics Register (DCR) is fixed to 0xEF. The value of the Bus Characteristics Register (BCR) is fixed to 0x26. This has the following meanings:

- Bit 5 of the BCR is set to 0b0, that is the device supports solely SDR.
- Bit 2 of the BCR is set to 0b1, that means that an accepted IBI is followed by the so-called mandatory byte. For details on the mandatory byte, please refer to the IBI description in this chapter.

The timing requirement is defined in table 74 “I3C Open Drain Timing Parameters” and table 75 “I3C Push-Pull Timing Parameters for SDR and HDR-DDR Modes” in the I3CSM specification “Improved Inter Integrated Circuit Version 1.0 – 23 December 2016”.

- **Read and Write Access** The SDR read and write access follows the I3C specification. In the following examples are given for write operations with figure 15 and 16 for single-word and multi-word writes, respectively, and for read operations with figure 17 and 18 for single-word and multi-word reads. For the diagrams/tables, the following colour coding is applied:
- transfer from the host to the device is indicated by green coloured normal text
- transfer from the device to the host is indicated by orange coloured text in italics
- acknowledgement from the device to the host:
  - with hand-off is indicated by orange coloured text in italics
  - without hand-off is indicated by brown coloured text in italics
- drives from either host or device are indicated by blue bold text.

In the diagrams, these abbreviations are used:

S Start
Sr Repeated start
P Stop
ACK Acknowledge
T Transition

For the examples of reading data from the device in figure 17 and 18, the stop (P) can be removed and replaced by a repeated start (Sr).

Broadcast Address			Specified Slave DAA			Register N Address		Register N Data [7:0]		Register N Data [15:8]		
S	7'h7E+'0'	ACK	Sr	7'hDAA+'0'	ACK	Address N	T	Data N low word	T	Data N high word	T	P/Sr

Figure 15 - I3C Single-Word Write Operation

Broadcast Address			Specified Slave DAA			Register M Address		Register M Data [7:0]		Register M Data [15:8]		...
S	7'h7E+'0'	ACK	Sr	7'hDAA+'0'	ACK	Address M	T	Data M low word	T	Data M high word	T	...

...	Register N-1 Data [7:0]			Register N-1 Data [15:8]		Register N Data [7:0]		Register N Data [15:8]		...
...	Sr	Data N-1 low word	T	Data N-1 high word	T	Data N low word	T	Data N high word	T	P/Sr

Figure 16 -I3C Multi-Word Wrie Operation

Broadcast Address			Specified Slave DAA			Register N Address		
S	7'h7E+'0'	ACK	Sr	7'hDAA+'0'	ACK	Address N	T	P

Broadcast Address			Specified Slave DAA			Dummy Byte		Dymmy Byte		...
S	7'h7E+'0'	ACK	Sr	7'hDAA+'1'	ACK	0x00	T	0x00	T	...

...	Register N Data [7:0]		Register N Data [15:8]		
...	Data N low word	T	Data N high word	T	P/Sr

Figure 17 - I3C Single-Word Read Operation (Non-Repeated)

Broadcast Address			Specified Slave DAA			Register M Address		
S	7'h7E+'0'	ACK	Sr	7'hDAA+'0'	ACK	Address M	T	P

Broadcast Address			Specified Slave DAA			Dummy Byte		Dymmy Byte		...
S	7'h7E+'0'	ACK	Sr	7'hDAA+'1'	ACK	0x00	T	0x00	T	...

...	Register M Data [7:0]		Register M Data [15:8]		...
...	Data M low word	T	Data M high word	T	...

...	Register N-1 Data [7:0]		Register N-1 Data [15:8]		...
...	Data N-1 low word	T	Data N-1 high word	T	...

...	Register N Data [7:0]		Register N Data [15:8]		
...	Data N low word	T	Data N high word	T	P/Sr

Figure 18 - I3C Multi-Word Read Operation (Non-Repeated)

In-Band Interrupt The device supports the IBI feature as defined in the section 5.1.6.2 of the I3CSM specification "Improved Inter Integrated Circuit Version 1.0 – 23 December 2016".
Upon power up, the feature is disabled by default. The IBI feature can be enabled by the Common Command Code (CCC) ENEC with the ENINT bit set to 0b1, and can be disabled by the CCC DISEC with the DISINT bit set to 0b1. Please note, that prior to sending the CCC RSTDAA, sending of an IBI by the device has to be disabled by sending the direct CCC DISEC to the device. If no START is forthcoming within the Bus Available Condition, then the chip will actively pull down the SDA line to issue a START. In case there is an IBI event, the device will emit its address into the arbitrated address header following a START (but not following a repeated START). The payload of the device specific IBI mandatory byte is defined in table 22.

Table 22 : I3C In-band Interrupt Mandatory Byte Payload

Bit	Purpose	Description
0	Specific Interrupt Identifier Field	FIFO Watermark IRQ or'ed with FIFO full IRQ
1		Sample ready IRQs (DRDY) of acceleration, angular rate and temperature or'ed
2		All feature IRQ´s or'ed
3+4		0b00
5+6	Interrupt Group Identifier Field	0b00
7		Defined by I3C

Table 23 : Supported I3C Common Command Codes

CCC Code	CCC Type	MIPI Requires	CCC name	Description	Supported
0x00	Broadcast	Y	ENEC	Enable events command	Y
0x01	Broadcast	Y	DISEC	Disable events command	Y
0x02	Broadcast	Y	ENTAS0	Enter activity state 0	Y
0x03	Broadcast	N	ENTAS1	Enter activity state 1	N
0x04	Broadcast	N	ENTAS2	Enter activity state 2	N
0x05	Broadcast	N	ENTAS3	Enter activity state 3	N
0x06	Broadcast	Y	RSTDAA	Reset dynamic address assignment	Y
0x07	Broadcast	Y	ENTDAA	Enter dynamic address assignment	Y
0x08	Broadcast	N	DEFSLVS	Define list of slaves	N
0x09	Broadcast	Y	SETMWL	Set max write length	N[7]
0x0A	Broadcast	Y	SETMRL	Set max read length	N[7]
0x0B	Broadcast	N	ENTTM	Enter test mode	N
0x20	Broadcast	N	ENTHDR0	Enter HDR mode 0	Y[8]
0x21	Broadcast	N	ENTHDR1	Enter HDR mode 1	N
0x22	Broadcast	N	ENTHDR2	Enter HDR mode 2	N
0x23	Broadcast	N	ENTHDR3	Enter HDR mode 3, reserved by MIPI	N
0x24	Broadcast	N	ENTHDR4	Enter HDR mode 4, reserved by MIPI	N
0x25	Broadcast	N	ENTHDR5	Enter HDR mode 5, reserved by MIPI	N
0x26	Broadcast	N	ENTHDR6	Enter HDR mode 6, reserved by MIPI	N
0x27	Broadcast	N	ENTHDR7	Enter HDR mode 7, reserved by MIPI	N
0x28	Broadcast	N	SETXTIME	Exchange timing information	Y
0x61…0x7F	Broadcast	N		Vendor extension – broadcast CCC's	N
0x80	Direct	Y	ENEC	Enable event command	Y
0x81	Direct	Y	DISEC	Disable event command	Y
0x82	Direct	Y	ENTAS0	Enter activity state 0	Y
0x83	Direct	N	ENTAS1	Enter activity state 1	N
0x84	Direct	N	ENTAS2	Enter activity state 2	N
0x85	Direct	N	ENTAS3	Enter activity state 3	N
0x86	Direct	Y	RSTDAA	Reset dynamic address assignment	Y[9]
0x87	Direct	N	SETDASA	Set dynamic address assignment from	Y
0x88	Direct	Y	SETNEWDA	Set new dynamic address	Y
0x89	Direct	Y	SETMWL	Set max write length	N[7]
0x8A	Direct	Y	SETMRL	Set max read length	N[7]
0x8B	Direct	Y	GETMWL	Get max write length	N[7]
0x8C	Direct	Y	GETMRL	Get max read length	N[7]
0x8D	Direct	Y	GETPID	Get provisional ID	Y
0x8E	Direct	Y	GETBCR	Get bus characteristics register	Y

0x8F	Direct	Y	GETDCR	Get device characteristics register	Y
0x90	Direct	Y	GETSTATUS	Get device status	Y
0x91	Direct	N	GETACCMST	Get accept mastership	N
0x93	Direct	N	SETBRGTGT	Set bridge targets	N
0x94	Direct	N	GETMXDS	Get max data speed	N
0x95	Direct	N	GETHDRCAP	Get HDR capability	N
0x98	Direct	N	SETXTIME	Exchange timing information	Y
0x99	Direct	N	GETXTIME	Get timing information	Y
0xE0…0xFE	Direct	N		Vendor extension – direct CCC's	N

Master Clock Stalling The I3C specification defines master clock stalling. This allows the master to stall the clock for at most 100 µs. After this stall time, the slave may release the bus. The device releases the bus after 100 µs if a sensor is enabled in the registers ACC_CONF or GYR_CONF. In all other cases, the device does not automatically release the bus. In these cases, the watchdog intended for the I²C protocol may be used to detect a master hang situation. If the device drives the SDA line for more than 1.25 or 40 ms, the device resets its interface, if the watchdog is enabled in IO_I2C_IF. watchdog_timer_en. For details on the watchdog, see section 6.2.2.2.

[7] These features are optional for the slave, see section 5.1.9.2.5 "Set/Get Max Write Length" in the MIPI I3C^{SM} specification Version 1.0

[8] ENTHDR0 is recognized, but the device does not support HDR operations.

[9] Prior to sending the CCC RSTDAA, sending of an IBI by the device has to be disabled by sending the direct CCC DISEC to the device.

[10] This material may not be disclosed or used for any other purpose than needed to support the use of the BOSCH products. MIPI provides such material on an AS IS basis, without warranty of any kind.

6.2.2.2 I²C Protocol in the I3C Compatibility Mode

The I²C interface of the device is compatible with the legacy support of the I²C of the standard "I3CSM Improved Inter Integrated Circuit Version 1.0" from 23 December 2016, and the "Frequently Asked Questions (FAQ) for MIPI I3CSM Version 1.0" from 08 December 2017 available at http://www.mipi.org/specifications/i3c-sensor-specificati on. The timing specification and diagrams for I²C can be retrieved from this specification. Following the compatible mode defined in the I3C specification, the device supports fast mode (400 kHz fm) and fast mode plus (1 MHz fm+).

Table 24 and figure 19 are copyright 2016 by MIPI Alliance, Inc and reprinted with their permission[10].

Table 24: I2C Timings

		Legacy Mode 400kHz / Fm		Legacy Mode 1MHz / Fm+		
Parameter	**Symbol**	**Min**	**Max**	**Min**	**Max**	**Units**
SCL clock frequency	f_{SCL}	0	0.4	0	1.0	MHz
Setup time for a repeated START	$t_{SU,STA}$	600	-	260	-	ns
Hold time for a (repeated) START	$t_{HD,STA}$	600	-	260	-	ns
SCL clock low period	t_{LOW}	1300	-	500	-	ns
	$t_{DIG,L}$	$t_{LOW} + t_{rCL}$	-	$t_{LOW} + t_{rCL}$	-	
SCL clock high period	t_{HIGH}	600	-	260	-	ns
	$t_{DIG,H}$	$t_{HIGH} + t_{rCL}$	-	$t_{HIGH} + t_{rCL}$	-	
Data setup time	$t_{SU,DAT}$	100	-	50	-	ns
Data hold time	$t_{HD,DAT}$	-	-	-	-	ns
SCL signal rise time	t_{rCL}	20	300	-	120	ns
SCL signal fall time	t_{fCL}	$20*(\frac{V_{DDIO}}{5.5V})$	300	$20*(\frac{V_{DDIO}}{5.5V})$	120	ns
SDA signal rise time	t_{rDA}	20	300	-	120	ns
SDA signal fall time	t_{fDA}	$20*(\frac{V_{DDIO}}{5.5V})$	300	$20*(\frac{V_{DDIO}}{5.5V})$	120	ns
Setup time for STOP	$t_{SU,STO}$	600	-	260	-	ns
Bus free time between a STOP condition and a START condition	t_{BUF}	1.3	-	0.5	-	µs
Pulse width of spikes that the spike filter must suppress	t_{SPIKE}	0	50	0	50	µs

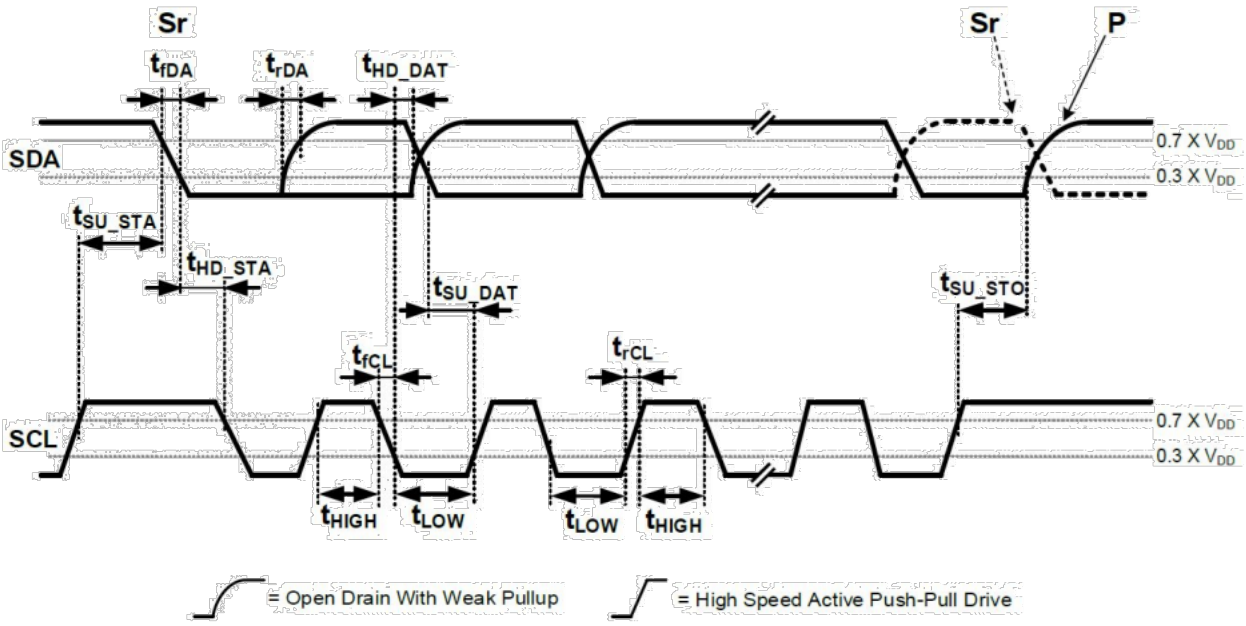


Figure 19 - I2C Timing Diagram

Only the 7-bit address mode is supported. The default I²C legacy address of the device is 0b01101000 (0x68). It is used if the SDO pin is pulled to 'GND'. The alternative address 0b01101001 (0x69) is selected by pulling the SDO pin to 'VDDIO'. The I²C legacy protocol works as follows:

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 I²C 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 master. The STOP condition is a low to high transition on SDA line while SCL is held high.
ACKS: 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.

A START immediately followed by a STOP (without SCL toggling from 'VDDIO' to 'GND') is not supported. If such a combination occurs, the STOP is not recognized by the device. In the following diagrams/tables, these abbreviations are used:

S Start
P Stop
ACK Acknowledge
RW Read / Write

In the diagrams/tables, a transfer from the host to the device is indicated by green coloured normal text while transfer from the device to the host is indicated by orange coloured text in italics.

I²C write access I²C write access can be used to write a data word in one sequence. The sequence begins with start condition generated by the master, followed by 7 bits 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 two times 8 bits of data which shall be written to the specified register address. After the slave has acknowledged the data bytes, the master generates a stop signal and terminates the writing protocol. An example of an I²C write access is stated in figure 20

Start	Slave Address	RW	ACK	Register M Address (0x38)	ACK	Register M Data [7:0]	ACK	Register M Data [15:8]	ACK	Stop
S	1 1 0 1 0 0 0	0	0	X 0 1 1 1 0 0 0	0	1 1 0 1 0 1 0 1	0	0 0 1 0 1 0 1 0	0	P

Figure 20 - I2C Single Word Write Operation

Start	Slave Address	RW	ACK	Register M Address (0x38)	ACK	Register M Data [7:0]	ACK	Register M Data [15:8]	ACK	
S	1 1 0 1 0 0 0	0	0	X 0 1 1 1 0 0 0	0	1 1 0 1 0 1 0 1	0	0 0 1 0 1 0 1 0	0	¬

	Register N Data [7:0]	ACK	Register N Data [15:8]	ACK	Stop
└	1 0 1 0 1 0 1 0	0	0 1 0 1 0 1 0 1	0	P

Figure 21 - I2C Multi Word Write Operation

Multi-word writes are supported without restriction on normal registers with auto-increment as well as on special registers with address trap. An example of an I²C multi-word write access is stated in figure 21.

I²C read access I²C read access can be used to read one or multiple data bytes or words in one sequence. A read sequence consists of a one-byte I²C write phase followed by the I²C read phase to read a single byte, a single 16bit word of two bytes or multiple 16bit words. The two parts of the transmission must be separated by a repeated start condition (S). The I²C write phase addresses the slave and sends the register address to be read. After slave acknowledges the transmission, the master generates again 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 slave. After each data byte the master has to generate an acknowledge bit (ACK = 0) to enable further data transfer. A non-ACK by the master (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 and, therefore, more than one word can be sequentially read out. Once a new data read transmission starts, the start address will be set to the register address specified since the latest I²C write command. By default the start address is set at 0x00. In this way repetitive reads of words from the same starting address are possible. An example of an I²C single-word read access with Repeated Start is provided in figure 22.

Start	Slave Address	RW	ACK	Register N Address (0x38)	ACK
S	1 1 0 1 0 0 0	0	0	X 0 1 1 1 0 0 0	0

Start	Slave Address	RW	ACK	dummy byte	ACK	dummy byte	ACK	
Sr	1 1 0 1 0 0 0	1	0	0 0 0 0 0 0 0 0	0	0 0 0 0 0 0 0 0	0	¬

	Register N Data [7:0]	ACK	Register N Data [15:8]	ACK	Stop
└	x x x x x x x x	0	x x x x x x x x	1	P

Figure 22 - I2C Single Word Read Operation

In order to prevent the I²C slave of the device to lock-up the I²C bus, a watchdog timer (WDT) is implemented. The WDT observes internal I²C signals and resets the I²C interface if the bus is locked-up by the SMI330. The activity and the timer period of the WDT can be configured through the bits IO_I2C_IF.watchdog_timer_en and IO_I2C_IF.watchdog_timer_sel. An example of an I²C read access for multiple words with Repeated Start is given in figure 23.

Start	Slave Address	RW	ACK	Register M Address (0x38)	ACK
S	1 1 0 1 0 0 0	0	0	X 0 1 1 1 0 0 0	0

Start	Slave Address	RW	ACK	dummy byte	ACK	dummy byte	ACK	¬
Sr	1 1 0 1 0 0 0	1	0	0 0 0 0 0 0 0 0	0	0 0 0 0 0 0 0 0	0	

└	Register M Data [7:0]	ACK	Register M Data [15:8]	ACK	...
	x x x x x x x x	0	x x x x x x x x	0	...

...	Register N Data [7:0]	ACK	Register N Data [15:8]	ACK	Stop
...	x x x x x x x x	0	x x x x x x x x	0	P

Figure 23 - I2C Multi Word Read Operation (With Repeated Start)

6.3 Digital communication

Communication Access Restriction In order to allow for the correct internal synchronization of data written to or read from the device, certain access restrictions apply for consecutive write accesses or a write/read sequence through the I3C and I²C interface as well as the SPI. The required waiting period depends on the operation mode of the device: In high-performance and normal mode an interface idle time of at least 2 µs, for suspend mode an idle time of 450 µs is required. As illustrated in figure 24, an interface idle time of at least 2 µs is required following an operation when the device operates in any mode.

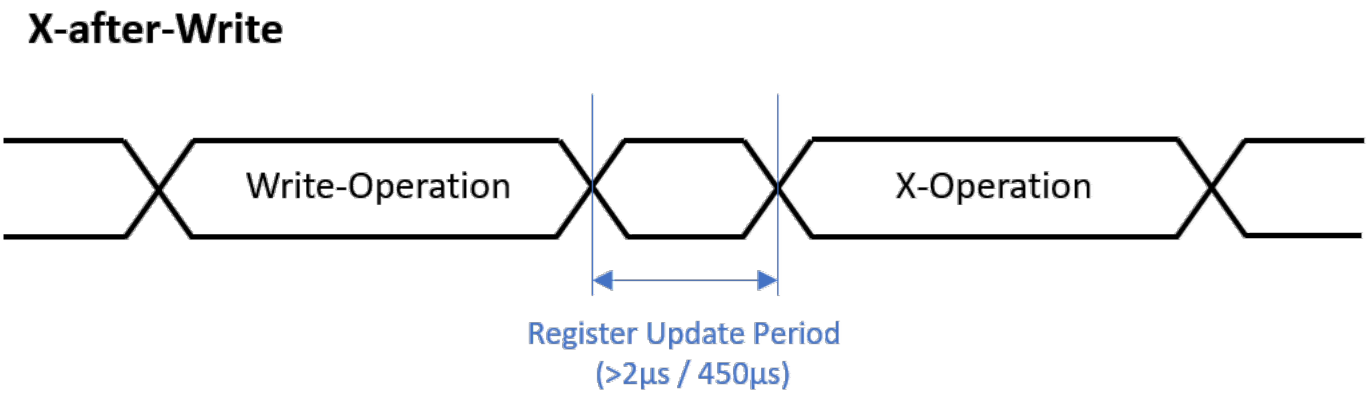


Figure 24 - Post-Write Access Timing Constraints

7 Application Details

7.1 Device Initialization

The communication between application processor and the device will happen over one of the interfaces I3C, I²C or SPI. Each register read operation includes the following number of inserted dummy bytes before the payload

SPI : **1**
I²C: **2**
I3C: **2**

The device is configured for suspend mode after Power On Reset (POR) or soft reset. In this device operation mode, reading and writing to the registers is possible without requiring to switch the operation mode of the device.
After proper power up by applying the stable supply voltage to the corresponding device pins, the device enters automatically into the POR sequence. The default serial interface configuration is I3C and I²C. One initial dummy read configures it to SPI.
During Power on Reset (POR), the voltages VDD and VDDIO are ramped to their respective target levels. After reaching the target level, all registers are accessible after a delay of 450 µs. After every power on reset or soft reset, the device is in the suspend mode. All registers of the device can be read and written without switching the device operation mode.

7.2 Power Modes

The main power operation modes of the sensor are

Suspend mode: Lowest possible power consumption, while the sensor still maintains its configuration. All device register are accessible at full digital interface speed.
Low power mode: Motion sensing at lowest possible power consumption
High performance mode: Motion sensing at maximum performance

Table 25 : Configuration to enter different power modes

	Component	ACC_CONF.acc_mode (0x20)	GYR_CONF.gyr_mode (0x21)	Typ. Current consumption [µA] RT	over T
Suspend mode		000	000	100	(430)
Low power mode	Accel only	011	000	130[3]	(460[3])
	Gyro only	000	011	520[4]	(870[4])
	IMU	011	011	530[3,4]	(880[3,4])
High performance mode[5]	Accel only	111	000	230[3]	(570[3])
	Gyro only	000	111	770[4]	(1100[4])
	IMU	111	111	870[3,4]	(1210[3,4])
Normal mode[5]	Accel only	100	000	200[3]	(530[3])
	Gyro only	000	100	720[4]	(1050[4])
	IMU	100	100	780[3,4]	(1130[3,4])

The power state of the device is controlled through the configuration of the accelerometer, the gyroscope and the feature engine. The registers ACC_CONF.acc_mode and GYR_CONF.gyr_mode control directly the power state of the sensors. When setting a new configuration, the start-up time of the sensor depends on the prior configuration of the sensor. The performance of the new device configuration does not depend on the prior device configuration.

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[3] Depends on the accelerometer configuration in ACC_CONF.

[4] Depends on the gyroscope configuration in GYR_CONF.

[5] The high performance power operation mode is the preferred continuous power operation mode

7.3 Sensor Output

The sensor outputs the three signals acceleration, angular rate and temperature along with the time of the device when the sensors captured the samples. A burst read on the register set of data output from the sensors always provides self contained and therefore consistent values for acceleration, angular rate, temperature and sensor time.

ACC_CONF.acc_mode and GYR_CONF.gyr_mode settings are used to enable and disable the accelerometer, gyroscope and temperature sensing of the device depending on the chosen power mode. After Power on Reset (POR) and soft reset, all sensors of the device are per default disabled. The temperature sensor is automatically enabled and disabled with the either accelerometer or the gyroscope being enabled or disabled. For operation of the device after enabling a sensor, please check before disabling a sensor for the availability of the corresponding sample ready (DRDY) event either by polling the corresponding register or configuring the corresponding interrupt(s). In case the sample ready event is not available after the start-up time for each sensor, the user should check the content of ERR_REG.fatal_err. For the gyroscope, the timeout until an error will be reported in this register is max 350 ms. Please note, that a user should check that no error is reported in ERR_REG.fatal_err before enabling a sensor.

7.4 Accelerometer

The three dimensional acceleration data is provided with 16 bits width in two's complement representation. The 16 bits of each axis are available within one 16 bit wide register from ACC_DATA_X to ACC_DATA_Z. Reading byte-wise the 16 bit acceleration data registers always returns first the least significant byte, then the most significant byte. The default value for each axis is invalid value with 0x8000.

The sensor characteristics and performance is controlled for the accelerometer via the registers ACC_CONF.acc_range, ACC_CONF.acc_bw and ACC_CONF.acc_avg_num. This means, that the selected filtering configuration for accelerometer influences the noise power and the latency of the acceleration respectively. In all configurations, register settings as well as FIFO data are retained.

Accelerometer Power Operation Modes ACC_CONF.acc_mode enables the accelerometer with desired power modes or disables the accelerometer. After power-on and soft-reset, the accelerometer is disabled with 0b000. The temperature sensor is automatically enabled and disabled in conjunction the accelerometer with characteristics depending on the accelerometer power mode and, if the gyroscope is enabled, also depending on the gyroscope power mode.

Accelerometer Range Settings The measurement range of the accelerometer can be configured to the ranges 2g, 4g, 8g and 16g. After power up and soft reset, the range is per default range 8g.

Accelerometer Data Processing in High Performance Mode and Normal Mode These two modes can be enabled by setting ACC_CONF.acc_mode to 0b and self-test 111 for high performance mode and 0b100 for normal mode. The data processing for this mode is configured using ACC_CONF.acc_bw. The rate of data available to the host (ODR) can be configured in one of ten different valid ODR configurations going from 12.5 Hz up to 6400 Hz through ACC_CONF.acc_odr. Sample rates less than 12.5 Hz are only supported in low power mode. Note: ACC_CONF.acc_avg_num has no effect in these modes. In this power mode, the accelerometer data is output continuously at equidistant points in the time defined by the accelerometer output data rate parameter ACC_CONF.acc_odr. The filtering of the acceleration in these modes is configurable through ACC_CONF.acc_bw to either 0b0 for ODR/2 or 0b1 for ODR/4. The filter modes influence the characteristics of the low pass filter applied to the signal, in particular the 3 dB cut-off frequency, the noise suppression, and the group delay. The group delay induced by a filter setting is provided in table 24. The cut-off frequencies corresponding to the sample rates and filtering are stated in Table 13. The default is 0b0 for ODR/2. Note: the filter settings have no effect when the synchronous timing control mode of I3C is enabled.

Table 26 - Accelerometer group delay in high performance mode

Sample rate [Hz]	12.5	25	50	100	200	400	800	1600	3200	6400
Group Delay (typ.) [ms]	45.9	23.2	11.8	6.09	3.24	1.82	0.95	0.63	0.47	0.39

Accelerometer Data Processing in Low Power Mode This mode can be enabled by setting ACC_CONF.acc_mode to 0b011 for low power mode. The data processing for this mode is configured using ACC_CONF.acc_avg_num. The rate of signal available to the host (ODR) can be configured as one of ten different valid sample rate configurations from 0.78 Hz up to 400 Hz through ACC_CONF.acc_odr. Sample rates greater than 400 Hz are only supported in normal and high performance mode . In this power mode, the accelerometer alternates between an idle phase, where no measurements are performed, and an active phase, where data is acquired. The data output to the host is the average of all samples acquired during the active phase. The number of averaged samples is configured through ACC_CONF.acc_avg_num. A larger number of averaged samples will result in a lower noise level of the signal. Since the active phase is increased, the power consumption will also rise. The period for changing between active and idle mode, also known as duty cycle period, is determined automatically by the value configured through ACC_CONF.acc_odr and ACC_CONF.acc_avg_num. Valid combinations for these two configurations stated in table 27. Note: these filter settings have no effect in the time control synchronous mode of I3C is enabled.

Table 27 - ASIC internal filter settings for low-power operation mode

ODR [Hz]	Internal specification of post-processing by averaging				
	64	32	16	8	4, 2, 1
400	N	N	N	Y	Y
200	N	N	Y	Y	Y
100	N	Y	Y	Y	Y
50	Y	Y	Y	Y	Y
25 … 0.78	Y	Y	Y	Y	Y

Accelerometer Data Ready Notification The host or another device can be notified about the availability of a new set of sampled data from the accelerometer is available in the registers ACC_DATA_X to ACC_DATA_Z either

- indirectly by polling the status of the accelerometer data ready in STATUS.drdy_acc, or
- directly by an interrupt raised on one of the two (physical) interrupt pins of the in-band-interrupt (IBI) feature of I3C.

Direct notification by an interrupt allows a low latency read of data. To enable the data ready interrupt, please map it via INT_MAP2.acc_drdy_int to the desired interrupt interface with 0b01 to the INT1 pin, 0b10 to the INT2 pin or 0b11 to the I3C-IBI. Latching of the interrupt status is configurable via INT_CONF.int_latch. In non-latched mode, the interrupt is cleared automatically after 1/6400 Hz. If this automatic clearance is not desired, please configure the latched mode for interrupts, see Section 7.12. In the latched mode, if acknowledgement of interrupts is desired, the flag INT_STATUS_INT1. int1_acc_drdy, INT_STATUS_INT2.int2_acc_drdy or INT_STATUS_IBI.ibi_acc_drdy has to be cleared by reading the status register depending on the mapping of the interrupt to an interrupt interface. The flag STATUS.drdy_acc is cleared when any of the registers ACC_DATA_X to ACC_DATA_Z is read. Note: a data ready interrupt raised through the INT1 or INT2 pin allows an estimation of the real sample rate when the interrupt data line is also linked to an automatically latched high frequency and high resolution timer on the receiver side of the interrupt.

7.5 Gyroscope

The three dimensional angular rate data is provided with 16 bits width in two's complement representation. The 16 bits of each axis are available within one 16 bit wide register from GYR_DATA_X to GYR_DATA_Z. Reading byte-wise the 16 bit gyroscope data registers always returns first the least significant byte, then the most significant byte. The default value for each axis is invalid value with 0x8000. If the device detects an overflow in the signal path, the saturation of angular rate values in the data registers and the FIFO data buffer is reported for each axis individually with SAT_FLAGS. satf_gyr_x, SAT_FLAGS.satf_gyr_y, and SAT_FLAGS.satf_gyr_z.

Gyroscope Power Operation Modes GYR_CONF.gyr_mode enables the gyroscope with desired power modes or disables the gyroscope. Per default, the gyroscope is disabled with 0b000. The temperature sensor is automatically enabled and disabled in conjunction with the gyroscope with characteristics depending only the gyroscope power mode. As long as the gyroscope is enabled, the temperature sensor power operation mode is not dependent on the accelerometer power mode, see sub-section 7.6.

Gyroscope Range Settings The measurement range of the gyroscope can be configured to the ranges 125 °/s, 250°/s and 500°/s . After power up and soft reset, the default range is 125 °/s.

Gyroscope Data Processing in High Performance Mode and Normal Mode These two modes can be enabled by setting GYR_CONF.gyr_mode to 0b111 for high performance mode and 0b100 for normal mode . The data processing for this mode is configured using GYR_CONF.gyr_bw. The rate of signal available to the host (ODR) can be configured in one of ten different valid sample rate configurations starting at 12.5 Hz up to 6400 Hz. Sample rates less than 12.5 Hz are only supported in low power mode. Note: GYR_CONF.gyr_avg_num has no effect in these modes. In this power mode, the gyroscope data is output continuously at equidistant points in the time defined by the gyroscope output data rate parameter GYR_CONF.gyr_odr. The filtering of the angular rate in these modes is configurable through GYR_CONF.gyr_bw to either 0b0 for ODR/2 or 0b1 for ODR/4. The filter modes influence the characteristics of the low pass filter applied to the signal, in particular the 3 dB cutoff frequency, the noise suppression, and the group delay. The group delay induced by a filter setting is provided in Table 28. The cut-off frequencies corresponding to the sample rates and filtering are stated in Table 12. The default is 0b0 for ODR/2. Note: the filter settings have no effect in the time control synchronous mode of I3C is enabled.

Table 28 - Gyroscope group delay in high performance mode

Sample rate [Hz]	12.5	25	50	100	200	400	800	1600	3200	6400
Group Delay (typ.) [ms]	46.4	23.7	12.3	6.57	3.72	2.30	1.43	1.11	0.95	0.88

Gyroscope Data Processing in Low Power Mode This modes can be enabled by setting GYR_CONF.gyr_mode to 0b011 for low power mode. The data processing for this mode is configured using GYR_CONF.gyr_avg_num. The rate of data available to the host (ODR) can be configured as one of ten different valid ODR configurations from 0.78 Hz up to 400 Hz. Sample rates greater than 400 Hz are only supported in normal and high performance mode . In this power mode, the gyroscope alternates between an idle phase, where no measurements are performed, and an active phase, where data is acquired. The data output to the host is the average of all samples acquired during the active phase. The number of averaged samples is configured through GYR_CONF.gyr_avg_num. A larger number of averaged samples will result in a lower noise level of the signal. Since the active phase is increased, the power consumption will also rise. The period for changing between active and idle mode, also known as duty cycle period, is determined automatically by the value configured through GYR_CONF.gyr_odr and GYR_CONF.gyr_avg_num. Valid combinations for these two configurations are the same as stated for the accelerometer in Table 27. **Note:** these filter settings have no effect in the time control synchronous mode of I3C is enabled.

Gyroscope Data Ready Notification The host or another device can be notified about the availability of a new set of sampled data from the gyroscope is available in the registers GYR_DATA_X to GYR_DATA_Z either · indirectly by polling the status of the gyroscope data ready in STATUS.drdy_gyr, or · directly by an interrupt raised on one of the two (physical) interrupt pins of the in-band-interrupt (IBI) feature of I3C. Direct notification by an interrupt allows a low latency read of data. To enable the data ready interrupt, please map it via INT_MAP2.gyr_drdy_int to the desired interrupt interface with 0b01 to the INT1 pin, 0b10 to the INT2 pin or 0b11 to the I3C-IBI. Latching of the interrupt status is configurable via INT_CONF.int_latch. In non-latched mode, the interrupt is cleared automatically after 1/6400 Hz. If this automatic clearance is not desired, please configure the latched mode for interrupts, see Section 7.12.. In the latched mode, if acknowledgement of interrupts is desired, the flag INT_STATUS_INT1. int1_gyr_drdy, INT_STATUS_INT2.int2_gyr_drdy or INT_STATUS_IBI.ibi_gyr_drdy has to be cleared by reading the status register depending on the mapping of the interrupt to an interrupt interface. The flag STATUS.drdy_gyr is cleared when any of the registers GYR_DATA_X to GYR_DATA_Z is read. **Note:** A data ready interrupt raised through the INT1 or INT2 pin allows an estimation of the real sample rate when the interrupt data line is also linked to an automatically latched high frequency and high resolution timer on the receiver side of the interrupt.

7.6 Further Sensor Data

Temperature Sensor The data from the temperature sensor is provided with 16 bits width in two’s complement representation in the 16 bit wide register TEMP_DATA. Reading byte-wise the 16 bit data registers always returns first the least significant byte, then the most significant byte. The range of the temperature sensor output is from −40°C to +125°C. The temperature sensor is automatically enabled with enabling either the accelerometer or the gyroscope. It is automatically disabled when both accelerometer and gyroscope are being disabled. The register contains the invalid value 0x8000 until the first temperature measurement is completed. The rate of data available to the host (ODR) depends on the hand on which sensors of the device are enabled and on the other hand to which power mode of a sensor is configured, see table 29.

Table 29 - Temperature sensor sample rate f_T

<table>
<tr><th>Operation mode combination</th><th>Min</th><th>Typ</th><th>Max</th><th>Unit</th></tr>
<tr><td>Accelerometer in high performance mode or normal mode and gyroscope disabled or in fast start-up mode</td><td>12.5</td><td></td><td>12.5</td><td rowspan="8">Hz</td></tr>
<tr><td>Accelerometer in low-power mode and gyroscope disabled or in fast start-up mode</td><td colspan="2">$f_{A,\ \text{low-power}}$</td><td>6.25</td></tr>
<tr><td>Gyroscope in high performance mode or normal mode and accelerometer disabled</td><td>50</td><td>...</td><td>50</td></tr>
<tr><td>Gyroscope in low-power mode and accelerometer disabled</td><td colspan="2">$f_{G,\ \text{low-power}}$</td><td>12.5</td></tr>
<tr><td>Accelerometer and gyroscope in any of high performance mode or normal mode</td><td>50</td><td>...</td><td>50</td></tr>
<tr><td>Accelerometer in low-power mode and gyroscope in high performance mode or normal mode</td><td>50</td><td>...</td><td>50</td></tr>
<tr><td>Gyroscope in low-power mode and accelerometer in high performance mode or normal mode</td><td>12.5</td><td></td><td>12.5</td></tr>
<tr><td>Accelerometer in low power mode and gyroscope in low-power mode</td><td colspan="2">max { $f_{A,\ \text{low-power}}$; $f_{G,\ \text{low-power}}$ }</td><td>12.5</td></tr>
</table>

Sensor Time The device provides the time of the sensors synchronized to any sample acquired from the accelerometer, gyroscope and temperature sensor. The value of the timer is provided with 32 bits width in the registers SENSOR_TIME_1 and SENSOR_TIME_0. The most significant word is stored in SENSOR_TIME_1 and the least significant word in SENSOR_TIME_0. The minimum increment of the timer is 9.765625 µs per LSB of SENSOR_TIME_0. A burst read on the registers always provides self contained and therefore consistent values. The sensor time will wrap around after approximately 11 hours and 39 minutes.

Table 30 - Resolution and update rate of the sensor time

Bit m in SENSOR_TIME_1	31	30	29	28	27	26	25	24
Resolution [s]	res.	res.	20971.52	10485.76	5242.88	2621.44	1310.72	655.36
Sample Rate [Hz]								
Bit m in SENSOR_TIME_1	**23**	**22**	**21**	**20**	**19**	**18**	**17**	**16**
Resolution [s]	327.68	163.84	81.92	40.96	20.48	10.24	5.12	2.56
Sample Rate [Hz]								
Bit m in SENSOR_TIME_0	**15**	**14**	**13**	**12**	**11**	**10**	**9**	**8**
Resolution [ms]	1280	640	320	160	80	40	20	10
Sample Rate [Hz]	0.78125	1.5625	3.125	6.25	12.5	25	50	100
Bit m in SENSOR_TIME_0	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
Resolution [µs]	5000	2500	1250	625	312.5	156.25	78.125	39.0625
Sample Rate [Hz]	200	400	800	1600	3200	6400		

7.7 Configuration Changes

If the configuration of the device in the registers ACC_CONF or GYR_CONF is altered while the sensors are enabled, the changes are not immediately applied to the sensors. The configuration becomes effective when a sampling event for the currently active ODR coincides with a sampling event for the newly requested ODR on the sensor time sampling grid. In the case where the currently active ODR equals the newly requested ODR, the configuration changes become effective at the next sampling event. This behaviour is detailed in the figure 25.

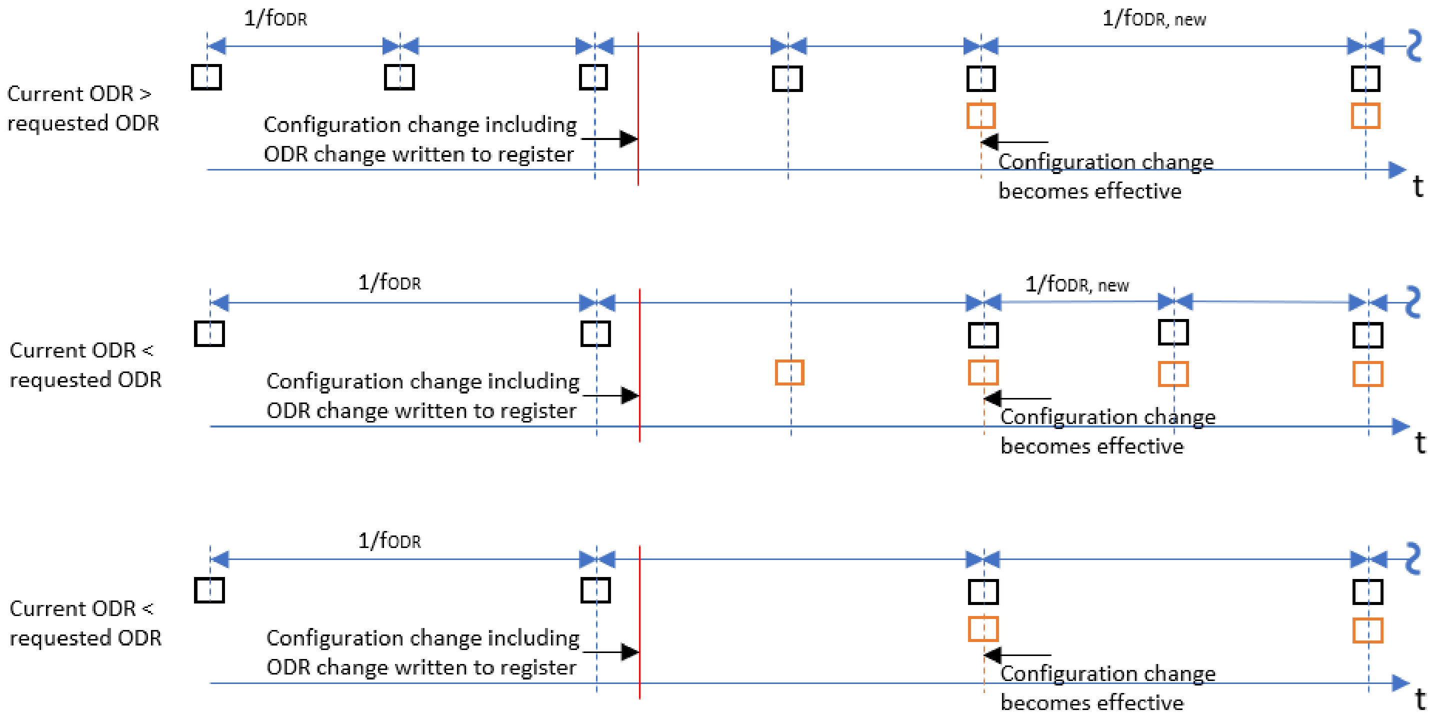

Figure 25 - Effectiveness of configuration changes related to the sample rate

7.8 FIFO Data Buffer

The FIFO data buffer collects and stores data from selected sensors to minimize transfers between device and host. The device supports the following FIFO operating modes for the FIFO data buffer:

- **Streaming mode:**
  - Overwrite oldest data on buffer full condition
  - Configuration: set FIFO_CONF.fifo_stop_on_full to 0b0
- **Stop-on-full mode:**
  - Discard newest data on buffer full condition
  - Configuration FIFO_CONF.fifo_stop_on_full to 0b1

The FIFO data buffer has a size of 2048 bytes. It can trigger the following interrupts to the host for the conditions of FIFO data buffer filled and FIFO data buffer watermark level reached, see details in section 7.8.3. The FIFO data buffer is enabled to store

- acceleration from the accelerometer with FIFO_CONF.fifo_acc_en=0b1
- angular rate from the gyroscope with FIFO_CONF.fifo_gyr_en=0b1
- temperature with FIFO_CONF.fifo_temp_en set to 0b1
- sensor time with FIFO_CONF.fifo_time_en set to 0b1

The FIFO data buffer may be used in all power modes of the device to record data. No restrictions for reading the FIFO data buffer from the host apply.

7.8.1 FIFO Frames

The data is stored in the FIFO data buffer with frames. The frames have no header. The total width of a buffer frame depends on the signal sources configured for storage in the buffer. When the sources to be stored in the FIFO data buffer are set, the width one frame is constant until the configuration for sources to be stored in the FIFO is changed. Each source adds its own specific width to the total width of a frame. The order of sources for any possible configuration of a buffer frame is fixed, see table 31. A lower ordering number of a source means that data appears prior in a buffer frame compared to a higher ordering number of a source. Disabled sources do not add any data to the buffer frame. Any change in configuration that have an impact on the width of a buffer frame or the order of sources within a frame causes an instant flush of the FIFO data buffer and a restart of storing signals with the new settings.

Table 31 - Order and size of sources to the FIFO data buffer

Order	Source	Size [words]	Description
1	Accelerometer	3	Acceleration with one 16 bit word for each axis x,y,z
2	Gyroscope	3	Angular rate with one 16 bit word for each axis x,y,z
3	Temperature Sensor	1	Temperature as one 16 bit word
4	Oscillator	1	Sensor time as one 16 bit word

Example: Gyroscope, time, and acceleration is enabled, then the order within the buffer frame is (accel:gyro:time) Changes to the configuration of the FIFO data buffer can cause a flush of the buffer, see details in subsection 7.8.4. A change of the configuration of the sensor, e.g. measurement range, ODR, etc, will restart the signal processing in the device causing invalid data until the data path is settled. The invalid data is not inserted into the buffer frames and skipped automatically. Instead, to keep the width of a frame constant, special dummy-data is inserted. This dummy-data can also be used to distinguish frames with old and new settings in place. The dummy data has a fixed signature for each signal source as shown in table 32.

Table 32 - Signature of dummy frames in the FIFO data buffer

Word	Accelerometer	Gyroscope	Temperature
1	0x7F01	0x7F02	0x8000
2	0x8000	0x8000	n/a

7.8.2 Conditions and Details

Enabling FIFO Data Buffering The FIFO data buffer has to be enabled before enabling any sensor, that is the accelerometer or the gyroscope. If the FIFO data buffering was not enabled before and is needed in any low power mode, the device must be switched to high performance mode or normal mode to activate then the FIFO data buffer and switch back to the low power mode.

Buffer Frame Reads A buffer frame is deleted from the FIFO data buffer after being fully read through the register FIFO_DATA. If a frame is read only partially, it will be repeated completely with the next read of the FIFO data buffer. In the case of a buffer overflow between the first partial read and the second read attempt, the frame is kept only if FIFO_CONF.fifo_stop_on_full is set to ‘1’.

Buffer Overreads When more data is read from the FIFO buffer than valid data is available, a value of 0x8000 is returned for each word read exceeding the valid data.

Frame Rates The sampling rate of buffer frames in the FIFO buffer is defined by the maximum output data rate of the sensors enabled for storage in the FIFO buffer.

Buffer Overflow In case of an overflow, the FIFO buffer can either stop recording data or overwrite the oldest data. This behavior is controlled by the register FIFO_CONF.fifo_stop_on_full. If FIFO_CONF.fifo_stop_on_full is set to ‘0’, the FIFO logic will delete the oldest frames. If FIFO_CONF.fifo_stop_on_full is set to 0b1, the newest frame may be discarded when the remaining free space in the FIFO buffer is less than the maximum size frame. During a read operation from the FIFO buffer by the host, no data at the FIFO buffer tail may be dropped. If the host reads the FIFO buffer with a slower rate than it is filled, it may happen that the sensor needs to drop new data, even if FIFO_CONF. fifo_stop_on_full is set to ‘0’.

7.8.3 FIFO Interrupts

The FIFO buffer supports two kinds of interrupts

- **Buffer full interrupt**

This interrupt is issued when the FIFO fill level is above the full threshold. The full threshold is reached just before the last two frames are stored in the data buffer. This interrupt is enabled by setting INT_MAP2.fifo_full_int to ‘1’.

- **Watermark level interrupt**

This interrupt is triggered when the fill level of the data buffer is equal or above a defined watermark level in the register FIFO_Watermark.fifo_watermark. Note: If the watermark level is set higher than the full level, the interrupt may be triggered more often than expected.
The interrupt is enabled by setting INT_MAP2.fifo_watermark_int to ‘1’. The watermark level is defined in number of words. 1 word = 2 bytes

7.8.4 FIFO Buffer Flush

A flush of the FIFO data buffer can be triggered by the user directly or indirectly by a re-configuration of the device. The user can directly trigger a flush of the FIFO buffer by writing 0b1 to FIFO_CTRL.fifo_flush. An indirect, automated flash of the FIFO data buffer is caused by:

- a signal source being enabled or disabled, and
- a signal source to be stored in the FIFO data buffer being added or removed.

Changes of the configuration, that do not cause a flush of the FIFO data buffer, are:

- Measurement range
- Sample rate of providing data to the host (ODR), and
- Filter configuration.

7.9 Sensor motion features

7.9.1 General Configuration

The advanced features of the device can be activated after enabling the feature engine. The feature engine has to be enabled following the steps also detailed in figure 26:

1. disable all sensors except enabling the feature engine directly after power on or soft reset, then
2. first writing 0x012C to FEATURE_IO2 followed by 0x0001 to FEATURE_IO_STATUS, then
3. setting FEATURE_CTRL.engine_en to 0b1, and then
4. waiting for the feature engine to be initialized by polling FEATURE_IO1.error_status for the value 0b001.

Note: the advanced features may be incorrectly interpreted if the accelerometer and/or gyroscope are enabled before feature engine.

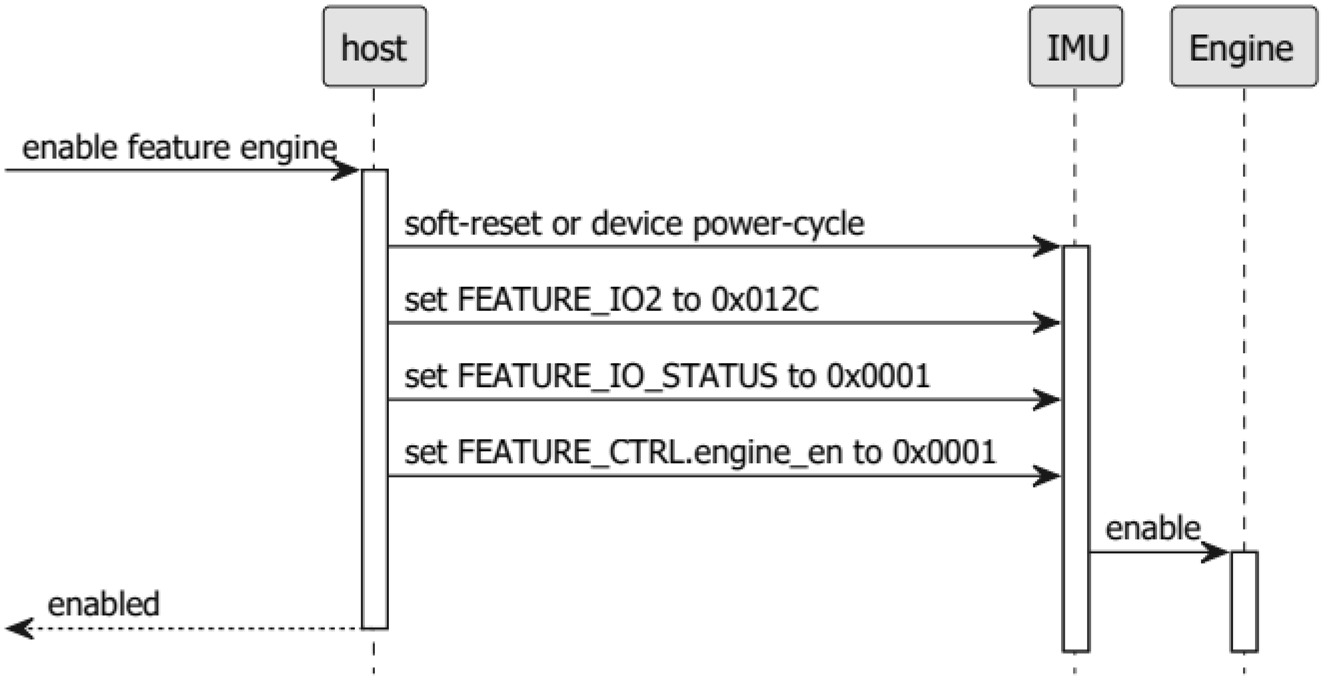

Figure 26 - Enable the feature engine

The feature engine may be disabled by setting FEATURE_CTRL.engine_en to 0b0, however, a soft reset or power cycle is required to re-enable the feature engine. Configuration, state toggling and the data input/output of the features is possible via

- the register interface through the registers FEATURE_IO0 to FEATURE_IO3 and the input/output synchronization register FEATURE_IO_STATUS for
  - enabling and disabling of features and
  - data and status output of advanced features, or
- the command interface via the register CMD for initiating non-continuously running features, and
- the configuration interface for features through the registers FEATURE_DATA_ADDR, FEATURE_DATA_TX and FEATURE_DATA_STATUS, see section 7.18.

The configuration of the sensor through FEATURE_IO0 must be executed following this procedure:

- write or modify the configuration to FEATURE_IO0, and subsequently
- activate the configuration by writing 0b1 to FEATURE_IO_STATUS.feature_io_status.

Note: Prior to enabling of any of the advanced features, the configuration and enabling of the accelerometer is required.

Table 33 provides the overview on supported sample rates per feature in the low power operation mode of the accelerometer. In the high performance power operation mode, features are supported independent of the configured sample rates of the accelerometer.

Table 33 - Overview of supported sample rates in low-power mode

Sample Rate	Any motion detection	No motion detection	Tilt detector
>200	✓	✓	✓
200	✓	✓	✓
100	✓	✓	✓
50	✓	✓	✓
25	✓	✓	✓
12.5	✓	✓	✓

The device adjusts the sample rate dependent parameters of the features to the configured reduced sample rate. Threshold values are not dependent on the sample rate and therefore not modified. All user configurations are retained and not modified until soft-reset or power down. Hence, you do not need to update the configuration when changing the sample rate (ODR) of the accelerometer.

7.9.2 Any-motion Detection

The feature any-motion detects changes in motion of one axis. It uses the slope between adjacent samples of the acceleration signal to trigger this event. With a different behaviour in interrupt frequency and interrupt hold time, this feature can be configured to the generate an interrupt for motion detect with GEN_SET_1.event_report_mode set to 0b1. The interrupt is enabled for each axis independently by writing 0b1 to FEATURE_IO0.any_motion_x_en, FEATURE_IO0. any_motion_y_en, and FEATURE_IO0.any_motion_z_en. The difference between the current acceleration sample and the reference sample gives the slope. The computation of the slope depends on the setting of ANYMO_1.acc_ref_up. In the default configuration of ANYMO_1.acc_ref_up being 0b1, the reference sample is the previous acceleration sample. When ANYMO_1.acc_ref_up is set to 0b0, the reference sample is set to the acceleration sample when the interrupt was generated.

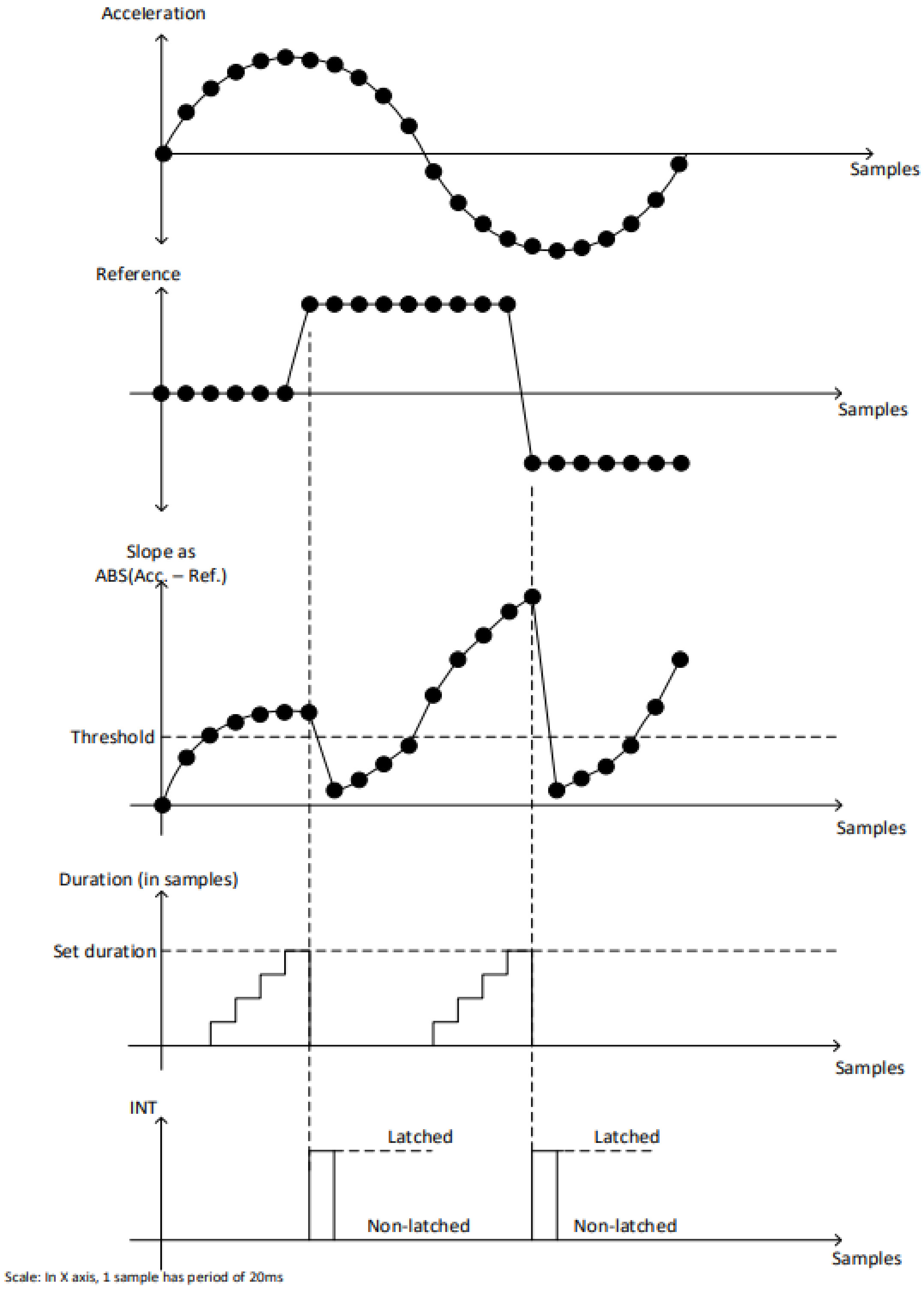

Figure 27 - Principle of any motion detection

The feature generates an interrupt when the absolute value of the slope exceeds the pre-set ANYMO_1.slope_thres for a certain number of consecutive samples defined by ANYMO_3.duration. The reference sample is updated when the condition is fulfilled. In other words, this means that the reference for the detection is the last state when sensor detected an any-motion event.

The generated interrupt will be cleared as soon as the slope value drops below the threshold and after the duration ANYMO_3.wait_time elapsed. The sensitivity of this interrupt to be rethrown when the slope increases again after dropping below the threshold is controlled with ANYMO_2.hysteresis. This feature is supported in the high performance power operation mode for all sample rates and in the low power operation mode for the sample rates from 12.5 Hz to the maximum supported sample rate, see table 37.

Configuration Settings:

1. FEATURE_IO0.any_motion_x_en – enable the feature for the x-axis
2. FEATURE_IO0.any_motion_y_en – enable the feature for the y-axis
3. FEATURE_IO0.any_motion_z_en – enable the feature for the z-axis
4. ANYMO_1.slope_thres – the threshold for the slope
5. ANYMO_1.acc_ref_up – update mode of the acceleration reference when an event was detected or always
6. ANYMO_2.hysteresis – hysteresis for the slope of the acceleration
7. ANYMO_3.duration – the number of consecutive samples for which the threshold condition must be respected for interrupt assertion
8. ANYMO_3.wait_time – wait time for clearing the event after the slope is below the configured threshold value ANYMO_1.slope_thres

7.9.3 No motion Detection

The feature no-motion detection evaluates the slope between adjacent samples of the acceleration signal in all selected axes to detect a stationary state. The interrupt is enabled for each axis independently by writing 0b1 to FEATURE_IO0. no_motion_x_en, FEATURE_IO0.no_motion_y_en, and FEATURE_IO0.no_motion_z_en. With a different behaviour in interrupt frequency and interrupt hold time, this feature can be configured to the generate an interrupt for stationary detect with GEN_SET_1.event_report_mode set to 0b1. The difference between the current acceleration sample and the reference sample gives the slope. An interrupt is generated when the slope for all selected axis remains smaller than the programmable threshold value NOMO_1. slope_thres for the configurable duration value in NOMO_3.duration. This feature is supported in the high performance power operation mode for all sample rates and in the low power operation mode for the sample rates from 12.5 Hz to the maximum supported sample rate, see table 33.

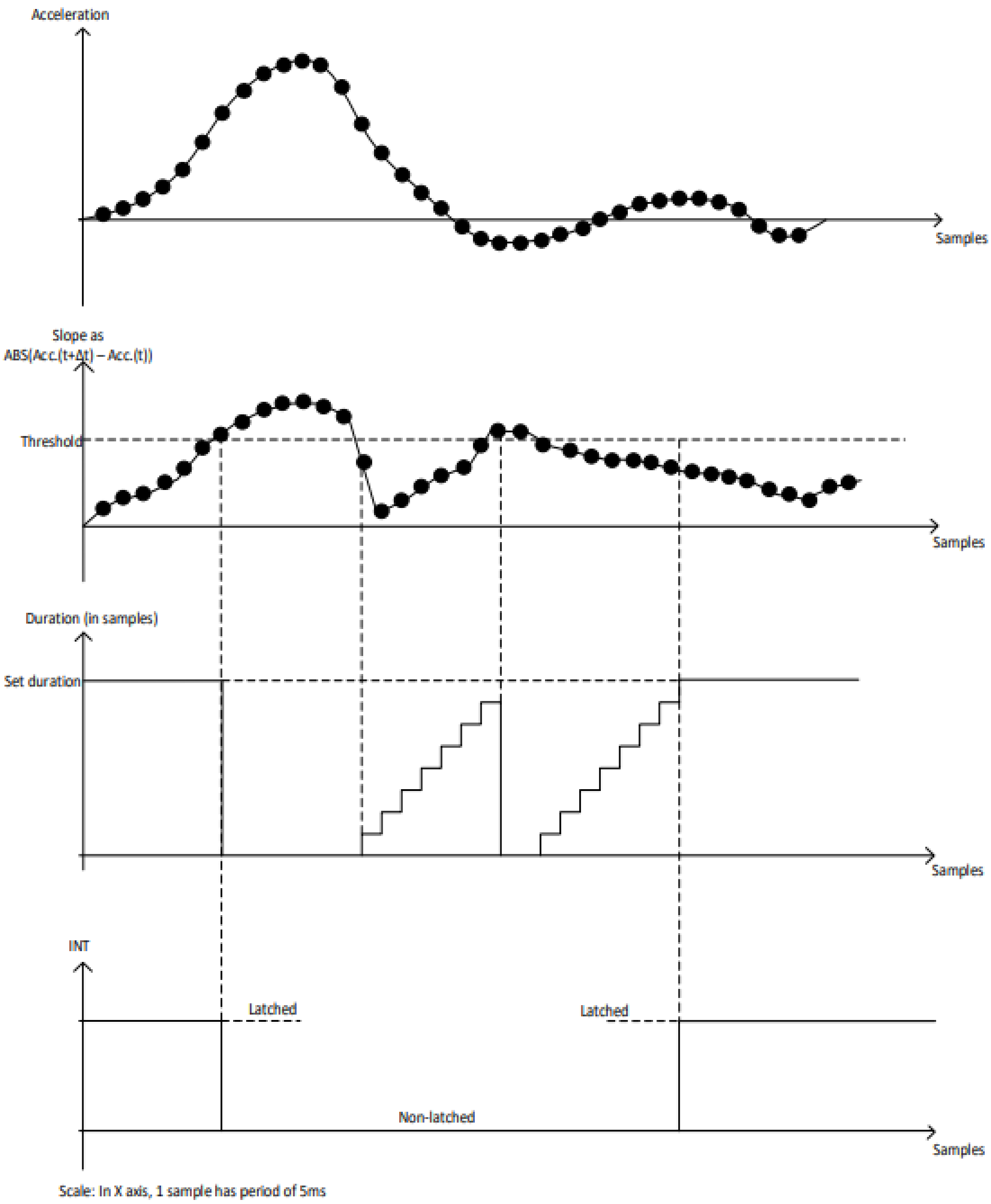

Figure 28 - Principle of no motion detection

Configuration Settings:

1. FEATURE_IO0.no_motion_x_en – enable the feature for the x-axis
2. FEATURE_IO0.no_motion_y_en – enable the feature for the y-axis
3. FEATURE_IO0.no_motion_z_en – enable the feature for the z-axis
4. NOMO_1.slope_thres – the threshold for the slope
5. NOMO_1.acc_ref_up – update mode of the acceleration reference when an event was detected or always
6. NOMO_2.hysteresis – hysteresis for the slope of the acceleration
7. NOMO_3.duration – the number of consecutive samples for which the threshold condition must be respected for interrupt assertion
8. NOMO_3.wait_time – wait time for clearing the event after the slope is below the configured threshold value NOMO_1.slope_thres

7.9.4 Tilt Detection

The function and behaviour of the tilt detector is derived from the Android specification. A tilt interrupt is reported when the attitude angle of the device changes by a value greater than configured angle threshold. The detection of a tilt of the device can be enabled by writing 0b1 to FEATURE_IO0.tilt_en, otherwise the feature is disabled. This feature is supported in the high performance power operation mode for all sample rates and in the low power operation mode for the sample rates from 50 Hz to the maximum supported sample rate, see Table 19. The minimum angle of tilt for event detection can be configured using EXT.TILT_1.min_tilt_angle. The value for the threshold for tilt angle set is computed as 256*cos θ. The time interval, in which the gravity acceleration signal vector has to be estimated, is configured via the parameter TILT_1.segment_size. The lowpass filtering for the continuous estimation of the gravity acceleration vector can be configured with parameter TILT_2.beta_acc_mean. The feature can be configured to output only the first detected event and ignoring the following events, also known as one-shot behaviour, by setting GEN_SET_1.event_report_mode as 0b1. When this configuration is enabled, the configuration values of TILT_1.min_tilt_angle are set to 35 degrees and the TILT_1.segment_size to 2 seconds. When GEN_SET_1.event_report_mode is set to 0b1, changes to the values of this user configuration have no impact on the behaviour this algorithm.

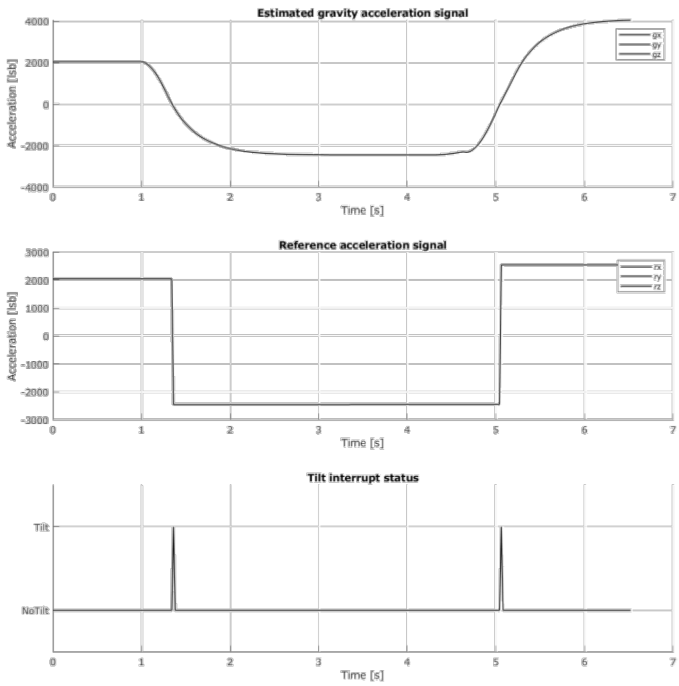

Figure 29 - Tilt Detection Principle

The tilt interrupt is triggered when the change of the angle is greater than set threshold independent of the direction of movement.
Configuration Settings Configuration parameters for enabling and disabling of feature as well as to adapt the behaviour to the application. The available parameters are described in table 34.

Table 34 - Parameters for tilt detector

Register	Description	Default Value	Range
FEATURE_IO0.tilt_en	Enable tilt detection	0	0/1 (disable/enable)
TILT_1.segment_size	Duration of averaging reference vector	100	0 ... 255
TILT_1.min_tilt_angle	Minimum angle for event detection	210	0 ... 255
TILT_2.beta_acc_mean	Decay coefficient for computation of acceleration vector mean	61545	0 ... 65535

7.10 Self Calibration (CRT)

The device offers self-calibration for the gyroscope sensitivity error and the gyroscope offset. Self-calibration to reduce the gyroscope sensitivity error is also known as component re-trim.

Before initiating the self-calibration, it should be checked for an on-going self-calibration or self-test by reading FEATURE_IO1.state. When the value is 0b00, a self-calibration can be initiated. As long as FEATURE_IO1.state is not 0b00, this bit shall be polled by re-reading until the value turns to 0b00. To start a self-calibration, the accelerometer is required to be enabled (already) in high performance mode with a sample rate preferred in the range of 25 Hz up to 200 Hz. The alternative sensor configurations for accelerometer and gyroscope must be disabled by setting ALT_ACC_CONF.alt_acc_mode and ALT_GYR_CONF.alt_gyr_mode to 0b0, respectively. Then, a self-calibration can be initiated.
Note: if the command for a self-calibration is sent once or multiple times while FEATURE_IO1.state has the value 0b01, 0b10 and 0b11, the command is ignored.

Configuration of the Self Calibration The self-calibration sequence can be configured with GYR_SC_SELECT. sens_en and GYR_SC_SELECT.offs_en to calibrate either both gyroscope sensitivity error and gyroscope offset or only one of them. If both gyroscope characteristics are desired to be calibrated, the device is calibrated first for the gyroscope sensitivity error followed by the gyroscope offset. The default configuration of calibrating both gyroscope characteristics can be changed by writing 0b0 to GYR_SC_SELECT.sens_en or GYR_SC_SELECT.offs_en. By default, the results of the self-calibration are written to data path registers GYR_DP_DGAIN_X, GYR_DP_DGAIN_Y and GYR_DP_DGAIN_Z for the sensitivity error and GYR_DP_OFF_X, GYR_DP_OFF_Y and GYR_DP_OFF_Z for the offset. By setting GYR_SC_SELECT.apply_corr to 0b0, the update of the data path registers can be suppressed. The device monitors the motion that is imposed by the context onto the device. The sensitivity of this motion detection can be configured through GYR_MOT_DET.slope. Note: this configuration of the detection of any motion is also used by the device self test.

Execution of the Self Calibration The device shall be kept in a still orientation while the self-calibration is running and shall not be exposed to noise and distortion. The self-calibration can be started by writing 0x0101 to the register CMD. After initiating the self-calibration, the device shall not be re-configured until the end of self-calibration procedure is reported.
The start of the self-calibration disables immediately the output of gyroscope sensor samples (data). During the execution of the self-calibration, the gyroscope sensor output in the data registers as well as in the FIFO data buffer is invalid, however, accelerometer output is still valid. The output of any previously enabled features of section 7.9 will still be provided during self-calibration. The duration of the self-calibration for standard settings is approximately 350 ms

for the measurement of the re-scaling for the angular rate and 80 ms for the gyroscope offset measurement.
The state of the self-calibration can be determined by checking FEATURE_IO1.sc_st_complete. An ongoing self-calibration is reflected by 0b0 while 0b1 is reported when it is completed. An ongoing self-calibration is also reflected in the register field FEATURE_IO1.state with the value 0b01. The completion of the self-calibration is also reported in FEATURE_IO1.error_status with the value 0x5. The success of the self-calibration is reported in the register field FEATURE_IO1.gyro_sc_result with 0b1, a failure with 0b0. Depending on the configuration GYR_SC_SELECT.apply_corr of the self-calibration, the data path registers are updated automatically.

Note: the results of the self-calibration in the data path registers should to be saved by the host to a non-volatile storage to allow restoring them after a power down or soft reset of the device.

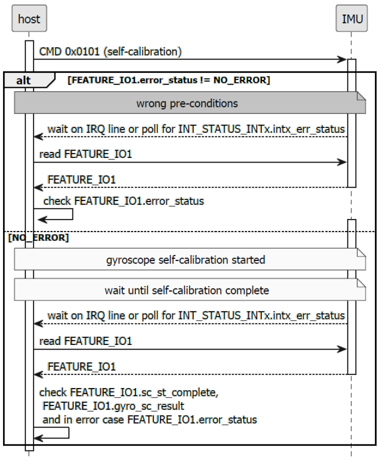

Figure 30 - Self Calibration Start Sequence

Abort the Self Calibration A running self-calibration can be aborted by sending the command 0x0200 to CMD. Then, FEATURE_IO1.state can be checked for any state different than 0b01 and the device reports in FEATURE_IO1.error_status the value 0x9.

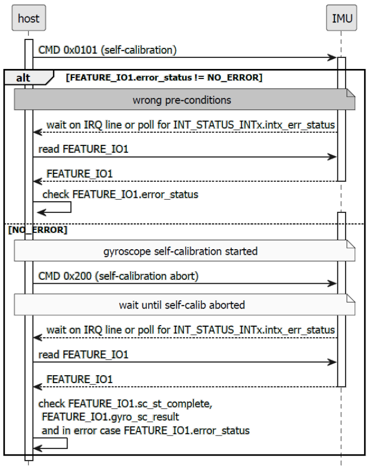

Figure 31 - Self-Calibration Abortion Sequence

7.11 Self Test

The self-test of the device checks for a correct function of the accelerometer as well as the gyroscope. The execution of the self-test expects the following prerequisites to be fulfilled:

- for the gyroscope self-test, the accelerometer must be configured to high performance mode at least, and
- the alternative sensor configurations for accelerometer and gyroscope must be disabled by setting ALT_ACC_CONF.alt_acc_mode and ALT_GYR_CONF.alt_gyr_mode to 0b0, respectively.
  Note: In case the gyroscope is enabled for self-test, set ACC ODR <= 200Hz!

The self-test for the accelerometer and the gyroscope is initiated by writing the command 0x0100 to the register CMD. It is possible to configure the self-test to check only the accelerometer or the gyroscope by disabling either the gyroscope with ST_SELECT.gyr_st_en to 0b0 or the accelerometer with ST_SELECT.acc_st_en to 0b0, respectively. Depending on the configuration, the self-test takes from 100ms for the only the accelerometer up to 350ms for both sensors.
Once a self-test is initiated, the output of data of the device to the registers and FIFO data buffer as well as all features are disabled. While the self-test is in progress, the host is not allowed to modify the configuration of the device. The device reports in the register field FEATURE_IO1.sc_st_complete with 0b1 when the self-test is completed. The result of the self-test can be determined by evaluating the register field FEATURE_IO1.st_result. In case the self-test failed, detailed information about the sensor and axis causing the failure can be obtained by reading from EXT.ST_RESULT. After a completed self-test, a soft reset or power cycle of the device is not required.
The device monitors the motion the device is exposed to while executing the self-test.
The sensitivity of this motion detection can be configured through GYR_MOT_DET.slope. Note: this configuration of the detection of any motion is also used by the device self-calibration.

7.12 General Interrupt Configuration

The signaling of interrupts to the host is possible via the I3C feature in-band interrupt (IBI) and two electrical pins. When the protocols SPI and I²C are used, signaling of interrupts to the host is only possible via the INT1 and INT2 pin. IBI can only be used when the device is connected to the host via I3C. When using the protocol I3C, the IBI feature as well as the two interrupt pins can be used at the same time to signal interrupts to the host.

Interrupt Mapping and Acknowledgement The mapping of a feature interrupt to a signaling channel can be configured through the registers INT_MAP1 and INT_MAP2. Each feature is mapped exclusively to one of these signaling channels using the scheme stated in table 35.

Table 35 - Interrupt mapping to HW channel

Map mode	Description
00	Signal of interrupt is disabled
01	Signal mapped to INT1 pin
10	Signal mapped to INT2 pin
11	Signal mapped to I3C IBI

Once an interrupt is notified to the host via a configured signaling channel, the host can determine the source of the interrupt through the status bits of the corresponding signaling interface. For each interrupt signaling channel, a dedicated interrupt status register is present in the register map of the device:

- INT1 pin has the corresponding status register INT_STATUS_INT1
- INT2 pin has the corresponding status register INT_STATUS_INT2
- The in-band interrupt (IBI) of the I3C bus has the corresponding status register INT_STATUS_IBI

It is recommended to separate the interrupts of the feature engine from the basic interrupts (data ready for signals and FIFO buffer interrupts), as the advanced features signaling pattern could be overruled by the basic interrupts.

Electrical Interrupt Pin Behaviour The interrupt pins can be enabled via IO_INT_CTRL.int1_output_en and IO_INT_CTRL.int2_output_en, respectively. Note: this is not applicable to the I3C IBI feature. Both interrupt pins INT1 and INT2 can be configured to have the desired

- Electrical drive characteristic
- Active level of interrupt
- Interrupt latching

The characteristic of the output driver of the interrupt pins may be configured with bits IO_INT_CTRL.int1_od and IO_INT_CTRL.int2_od. By setting these bits to 0b1, the output driver shows open-drain characteristic, by setting the configuration bits to 0b0, the output driver shows push-pull characteristic.
The interpretation of the active level controlled through the interrupt pin can be configured as either “active-high” or “active-low” via IO_INT_CTRL.int1_lvl and IO_INT_CTRL.int2_lvl, respectively.
The device supports non-latched and latched interrupts modes for data ready, FIFO watermark, FIFO full, error, and the advanced feature interrupts. The mode is selected by INT_CONF.int_latch. Non-latched interrupts are designed for systems using edge triggered interrupts while latched interrupts are designed for systems using level-triggered interrupts.
In the latched mode, an asserted interrupt status in INT_STATUS_INT1 and the INT1 pin are reset, if the status register INT_STATUS_INT1 is read. The same applies to an asserted interrupt status in INT_STATUS_INT2 and the INT2 pin, which are reset once the status register INT_STATUS_INT2 is read. If the interrupt activation condition still holds when the interrupt is reset, the interrupt status and pin are asserted again. In the non-latched mode, the configured INT1 or INT2 pin is reset as soon as the activation condition is not valid any more:

- for the feature engine based interrupts, the INT1 and INT2 pins are reset after the hold time selected by the host. In case of the features any-motion and no-motion, the INT1/2 pin will be reset and set again if the hold time is configured to a value less than 20ms even though the condition is true.

The interrupt status bits are active until read by the host.

7.13 Auto-operation Mode Change

The auto-operation mode change is a built-in feature to support the smart power management of the device. The function provides automatic switching among two sets of operation modes for its accelerometer and gyroscope. The switching is initiated by events of enabled advanced features or by commands sent from the host. In the following, the one set of configurations consists of ACC_CONF and GYR_CONF for the accelerometer and gyroscope and is called user configuration. The other set sensor of configurations consists of ALT_ACC_CONF and ALT_GYR_CONF, and is called alternative configuration.
Switching between the user and alternative configuration is enabled through ALT_CONF.alt_acc_en and ALT_CONF.alt_gyr_en for the accelerometer and gyroscope, respectively. The conditions to switch from the operation mode configured can be configured through ALT_CONFIG_CHG. By selecting one of the advanced features described in section 7.9, it can be configure independently
on the one hand through ALT_CONFIG_CHG.alt_conf_alt_switch_src_select to switch from the user configuration to the alternative configuration by selecting one of the advanced features with source IDs in table 36, and
on the other hand through .ALT_CONFIG_CHG.alt_conf_user_switch_src_select to switch from the alternative configuration to the user configuration by selecting one of the advanced features with source IDs in table 36.
Table 36 details the selectable advanced features with respect to the index letter. Please be aware, that if advanced features are configured for both transitions, that means for the switch from the user to the alternative configuration and for the switch from the alternative to the user configuration, not the same advanced feature is enabled. If ALT_CONF.alt_rst_conf_write_en is enabled, the configurations of the sensors can be instantly reset to the user configuration by directly writing from the host to either ACC_CONF or GYR_CONF.

Table 36 - Feature mapping indices

Index letter	Feature name
A (0001)	No motion detection
B (0010)	Any motion detection
H (1000)	Tilt detection

7.14 Soft Reset

A soft reset can be initiated at any time by writing the command soft reset 0xDEAF to the register CMD. The soft reset performs a fundamental reset to the device which is largely equivalent to a power cycle. Following a delay, all user configuration settings are overwritten with their default state wherever applicable. To access the serial interface with any of the protocols SPI, I3C or I²C after a soft reset, the same timing constraints apply as for power on, see chapter 4.1 for details.

7.15 Device Status

The device reports its status though several registers

- Register ERR_REG (0x01) for hardware errors:
  - Illegal configuration in the registers ACC_CONF and GYR_CONF will result in an error code in the fields ERR_REG.acc_conf_err and ERR_REG.gyr_conf_err. In this case, the content of the corresponding data register is undefined. For details, please refer to section 7.3.
  - I3C errors are reported to ERR_REG.i3c_error0 and ERR_REG.i3c_error3. For details, please see 6.2.2.
- The register STATUS for availability information: For details, please see section 7.3.
- The register FEATURE_IO_STATUS for motion feature information
- The register FEATURE_DATA_STATUS for the status of the configuration interface for the motion features
- The register FEATURE_ENGINE_STATUS for hardware errors of the feature engine

Reserved bits in these registers are for Bosch internal purposes only and can be ignored safely.

7.16 I3C Timing Control

The device supports time control modes as defined by the MIPI I3CSM standard. As defined by the I3C specification, the device supports timing control for both synchronous systems and events called synchronous mode as well as for asynchronous systems and events called asynchronous basic mode. The modes can be configured, entered, and left using I3C common command codes (CCCs).

Mode for Asynchronous Systems and Events The device supports the asynchronous basic mode of timing control (asynchronous mode 0) as defined in the MIPI I3CSM specification. For entering the asynchronous mode 0, the host sends the CCC SETXTIME with the defining byte 0xDF. For exiting the asynchronous mode 0, the host sends the CCC SETXTIME with sub-command 0xFF.

Mode for Synchronous System and Events The main idea of the synchronous mode is to configure the sensor for synchronization first and then issue periodically synchronization messages to keep the sensor device synchronized with the host device. The data ready interrupts of accelerometer, gyroscope and temperature sensor are aligned with respect to sample rate phase. The synchronization process is divided into the two phases configuration and run-time.
Note: this mode

- Cannot be used together with when the automatic operation mode switch is enabled
- Cannot be enabled while a self-test is ongoing, and
- Aborts an ongoing self-calibration when this mode is enabled

Note: if a self-test is in progress while this mode is requested to be enabled, the synchronous timing control will be enabled only after the self-test is finished.

The mode for synchronous systems and events has to be configured for the serial interface with the CCC SETXTIME, and the data processing control FEATURE_IO0.i3c_sync_en. To have the serial interface entering the synchronous mode, the host sends the CCC SETXTIME with any of the sub-command 0x3F, 0x9F, or 0x8F. The argument of the subcommand is ignored, if the device is not in the synchronous mode. To enter the timing control in synchronous mode and to set the time period and the phase value 0xABCD, the host needs to send the two CCCs SETXTIME 0x3F|0x9F|0x8F followed by two dummy bytes and then SETXTIME 0x3F 0xABCD.
Before sending I3C synchronization messages, the synchronous mode needs to be enabled for the data processing by setting FEATURE_IO0.i3c_sync_en to 0b1. For exiting the synchronous mode, the host sets FEATURE_IO0.i3c_sync_en to 0b0 to disable the I3C data processing and sends the CCC SETXTIME with sub-command 0xFF to control the serial interface of the device.

Configuration During the configuration phase the parameters sample rate (ODR), time period and phase (T_Ph) and time unit (TU) have to be configured by the host:

ODR The ODR command selects the enforced ODR. The payload of this command consists of one byte. The format of the ODR payload equals the ACC_CONF.acc_odr register. The minimum and maximum configurable sample rate for synchronous timing control is in the range of 6.25 Hz up to 800 Hz. If the configuration is selected beyond this range, the default sample rate of 100 Hz is configured. Example: ODR payload = 0x8 means 100 Hz.

T_ph The time period and phase (T_ph) command provides the number of samples that are included between two successive synchronization messages.

TU The TU command configures the resolution ratio of the delay, given by DT command.

During the configuration phase the command ODR, TPH and TU are updated by the CCC SETXTIME in I3C mode. However, the new values take effect only active after sending configuration change command 0x201 for synchronous timing control to the register CMD. With a ST or DT message, any change of the configuration will become effective for this device.
Before entering the Runtime phase, the sync for sensor feature must be enabled by FEATURE_IO0.i3c_sync_en.
Note: while timing control synchronous is enabled, the configuration of the sample rate of the accelerometer and gyroscope must not be modified through ACC_CONF.acc_odr and GYR_CONF.gyr_odr, respectively. Any change to these values is ignored and will be overwritten by the device, and this is reported in FEATURE_IO1.error_status with a value of 0xF. The configuration of the sample rate has to be done through the corresponding CCC.

Run Time Operation In the run-time phase, the host issues periodically synchronization messages to the sensor. These messages consist of two inter-related commands. First, the ST command selects a START event as reference for calculating the next synchronization period. Afterwards the DT command is sent by the host validating the ST and providing a delay time information to adjust the START event. If both commands are received, the sensor can update its clock parameters.

ST The sync tick command identifies the transaction START event. It has no payload.

DT The DT command delivers the delay time between the ST message and the correct START moment. It has one byte of payload. The MSB of the payload indicates that the delay time is valid (0) or that this sync procedure is aborted (1). If the delay is valid, the remaining 7 bits indicate the number of resolution steps between ST and the correct START event, see the description of TU.

For a more detailed description of the synchronization protocol see the MIPI I3C℠ specification.

ODR Configuration Error The synchronous mode feature will operate in the correct manner only when the user follows the constraints on the supported sample rates. The device checks continuously for matching values of sample rates. If the value for one of the signals acceleration, angular rate or temperature is not within the limits, the i3c_error bit is set. The conditions for return an I3C error for an invalid sample rate (ODR) is detailed in figure 32.

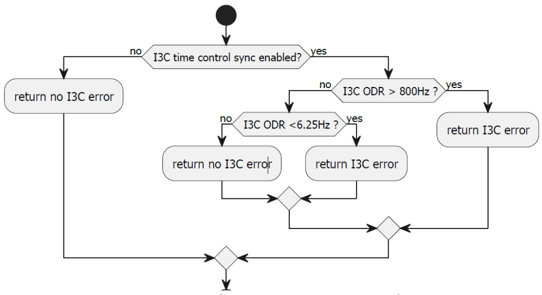

Figure 32 - Conditions for I3C ODR configuration errors

Output Details After enabling the synchronous timing control feature for I3C, the sensor data is available in the FIFO data buffer. Furthermore, the current valid sample set can be obtained via the extended register map from EXT.SYNC_ACC_X to EXT.SYNC_TIME. No valid data will be available in data registers ACC_DATA_X to TEMP_DATA. The format of the data in the FIFO data buffer is the same as in any other mode. That means, sensors that are not enabled will not appear in the FIFO data frame, see Section 7.8.

7.17 Memory Map

The device can be operated for all standard features directly through registers. The registers are described in the register map in section 7.17.2. The configuration and extended outputs of the advanced features provided by the feature engine can be accessed through the extended register map. The layout of the extended registers is described in section 7.18.2.
For all data read from registers, content marked as reserved must be ignored. If only the first byte of a register contains non-reserved data, the upper byte is not required to be read.
When performing an update of a register with fields marked as reserved (partial update), a read-modify-write approach has to be followed to write the content of a register. That means, for a write access to a register with reserved content, the whole register must be read, then the desired content must be updated and the content written (back) to the register to avoid overwriting the reserved part with undefined content. This is especially important for the extended register map where many configurations are located.

7.17.1 Register Map Overview

<table>
<tr><th colspan="3">Legend</th><th colspan="4">Read-only</th><th colspan="4">Read/Write</th><th colspan="4">Write-only</th><th colspan="4">Reserved</th></tr>
<tr><th>Addr</th><th>Name</th><th>Reset Value</th><th>Bit15</th><th>Bit14</th><th>Bit13</th><th>Bit12</th><th>Bit11</th><th>Bit10</th><th>Bit9</th><th>Bit8</th><th>Bit7</th><th>Bit6</th><th>Bit5</th><th>Bit4</th><th>Bit3</th><th>Bit2</th><th>Bit1</th><th>Bit0</th></tr>
<tr><td>0x00</td><td>CHIP_ID</td><td>0x1242</td><td colspan="8">reserved</td><td colspan="8">chip_id</td></tr>
<tr><td>0x01</td><td>ERR_REG</td><td>0x0000</td><td colspan="4">reserved</td><td>i3c_error3</td><td colspan="2">reserved</td><td>i3c_error0</td><td>reserved</td><td>gyr_conf_err</td><td>acc_conf_err</td><td>uc_wd</td><td>reserved</td><td>uc_irq_ovrn</td><td>reserved</td><td>fatal_err</td></tr>
<tr><td>0x02</td><td>STATUS</td><td>0x0001</td><td colspan="8">reserved</td><td>drdy_acc</td><td>drdy_gyr</td><td>drdy_temp</td><td colspan="4">reserved</td><td>por_detect</td></tr>
<tr><td>0x03</td><td>ACC_DATA_X</td><td>0x8000</td><td colspan="16">acc_x</td></tr>
<tr><td>0x04</td><td>ACC_DATA_Y</td><td>0x8000</td><td colspan="16">acc_y</td></tr>
<tr><td>0x05</td><td>ACC_DATA_Z</td><td>0x8000</td><td colspan="16">acc_z</td></tr>
<tr><td>0x06</td><td>GYR_DATA_X</td><td>0x8000</td><td colspan="16">gyr_x</td></tr>
<tr><td>0x07</td><td>GYR_DATA_Y</td><td>0x8000</td><td colspan="16">gyr_y</td></tr>
<tr><td>0x08</td><td>GYR_DATA_Z</td><td>0x8000</td><td colspan="16">gyr_z</td></tr>
<tr><td>0x09</td><td>TEMP_DATA</td><td>0x8000</td><td colspan="16">temp_data</td></tr>
<tr><td>0x0A</td><td>SENSOR_TIME_0</td><td>0x0000</td><td colspan="16">sensor_time_15_0</td></tr>
<tr><td>0x0B</td><td>SENSOR_TIME_1</td><td>0x0000</td><td colspan="16">sensor_time_31_16</td></tr>
<tr><td>0x0C</td><td>SAT_FLAGS</td><td>0x0000</td><td colspan="10">reserved</td><td>satf_gyr_z</td><td>satf_gyr_y</td><td>satf_gyr_x</td><td>satf_acc_z</td><td>satf_acc_y</td><td>satf_acc_x</td></tr>
<tr><td>0x0D</td><td>INT_STATUS_INT1</td><td>0x0000</td><td>int1_ffull</td><td>int1_fwm</td><td>int1_acc_drdy</td><td>int1_gyr_drdy</td><td>int1_temp_drdy</td><td>int1_err_status</td><td>int1_i3c</td><td>reserved</td><td>int1_tilt</td><td colspan="5">reserved</td><td>int1_any_motion</td><td>int1_no_motion</td></tr>
<tr><td>0x0E</td><td>INT_STATUS_INT2</td><td>0x0000</td><td>int2_ffull</td><td>int2_fwm</td><td>int2_acc_drdy</td><td>int2_gyr_drdy</td><td>int2_temp_drdy</td><td>int2_err_status</td><td>int2_i3c</td><td>reserved</td><td>int2_tilt</td><td colspan="5">reserved</td><td>int2_any_motion</td><td>int2_no_motion</td></tr>
<tr><td>0x0F</td><td>INT_STATUS_IBI</td><td>0x0000</td><td>ibi_ffull</td><td>ibi_fwm</td><td>ibi_acc_drdy</td><td>ibi_gyr_drdy</td><td>ibi_temp_drdy</td><td>ibi_err_status</td><td>ibi_i3c</td><td>reserved</td><td>ibi_tilt</td><td colspan="5">reserved</td><td>ibi_any_motion</td><td>ibi_no_motion</td></tr>
<tr><td>0x10</td><td>FEATURE_IO0</td><td>0x0000</td><td>i3c_sync_en</td><td colspan="3">reserved</td><td>tilt_en</td><td colspan="5">reserved</td><td>any_motion_z_en</td><td>any_motion_y_en</td><td>any_motion_x_en</td><td>no_motion_z_en</td><td>no_motion_y_en</td><td>no_motion_x_en</td></tr>
<tr><td>0x11</td><td>FEATURE_IO1</td><td>0x0000</td><td colspan="3">reserved</td><td colspan="2">state</td><td>axis_map_complete</td><td colspan="2">reserved</td><td>sample_rate_error</td><td>st_result</td><td>gyro_sc_result</td><td>sc_st_complete</td><td colspan="4">error_status</td></tr>
<tr><td>0x12</td><td>FEATURE_IO2</td><td>0x0000</td><td colspan="16">reserved</td></tr>
</table>

<table>
<tr><td>0x14</td><td>FEATURE_IO_STATUS</td><td>0x0018</td><td colspan="15">reserved</td><td>status</td></tr>
<tr><td>0x15</td><td>FIFO_FILL_LVL</td><td>0x0000</td><td colspan="5">reserved</td><td colspan="11">fifo_fill_level</td></tr>
<tr><td>0x16</td><td>FIFO_DATA</td><td>0x0000</td><td colspan="16">fifo_data</td></tr>
<tr><td>0x20</td><td>ACC_CONF</td><td>0x0028</td><td>reserved</td><td colspan="3">acc_mode</td><td>reserved</td><td colspan="3">acc_avg_num</td><td>acc_bw</td><td colspan="3">acc_range</td><td colspan="4">acc_odr</td></tr>
<tr><td>0x21</td><td>GYR_CONF</td><td>0x0008</td><td>reserved</td><td colspan="3">gyr_mode</td><td>reserved</td><td colspan="3">gyr_avg_num</td><td>gyr_bw</td><td colspan="2">reserved</td><td>gyr_range</td><td colspan="4">gyr_odr</td></tr>
<tr><td>0x28</td><td>ALT_ACC_CONF</td><td>0x3206</td><td>reserved</td><td colspan="3">alt_acc_mode</td><td>reserved</td><td colspan="3">alt_acc_avg_num</td><td colspan="4">reserved</td><td colspan="4">alt_acc_odr</td></tr>
<tr><td>0x29</td><td>ALT_GYR_CONF</td><td>0x1206</td><td>reserved</td><td colspan="3">alt_gyr_mode</td><td>reserved</td><td colspan="3">alt_gyr_avg_num</td><td colspan="4">reserved</td><td colspan="4">alt_gyr_odr</td></tr>
<tr><td>0x2A</td><td>ALT_CONF</td><td>0x0000</td><td colspan="7">reserved</td><td>alt_rst_conf_write_en</td><td colspan="3">reserved</td><td>alt_gyr_en</td><td colspan="3">reserved</td><td>alt_acc_en</td></tr>
<tr><td>0x2B</td><td>ALT_STATUS</td><td>0x0000</td><td colspan="11">reserved</td><td>alt_acc_active</td><td colspan="3">reserved</td><td>alt_acc_active</td></tr>
<tr><td>0x35</td><td>FIFO_WATERMARK</td><td>0x0000</td><td colspan="6">reserved</td><td colspan="10">fifo_watermark</td></tr>
<tr><td>0x36</td><td>FIFO_CONF</td><td>0x0000</td><td colspan="4">reserved</td><td>fifo_temp_en</td><td>fifo_gyr_en</td><td>fifo_acc_en</td><td>fifo_time_en</td><td colspan="7">reserved</td><td>fito_stop_on_full</td></tr>
<tr><td>0x37</td><td>FIFO_CTRL</td><td>0x0000</td><td colspan="15">reserved</td><td>fifo_flush</td></tr>
<tr><td>0x38</td><td>IO_INT_CTRL</td><td>0x0000</td><td colspan="4">reserved</td><td>int2_input_en</td><td>int2_output_en</td><td>int2_od</td><td>int2_lvl</td><td colspan="4">reserved</td><td>int1_input_en</td><td>int1_output_en</td><td>int1_od</td><td>int1_lvl</td></tr>
<tr><td>0x39</td><td>INT_CONF</td><td>0x0000</td><td colspan="15">reserved</td><td>int_latch</td></tr>
<tr><td>0x3A</td><td>INT_MAP1</td><td>0x0000</td><td colspan="2">tilt_out</td><td colspan="10">reserved</td><td colspan="2">any_motion_out</td><td colspan="2">no_motion_out</td></tr>
<tr><td>0x3B</td><td>INT_MAP2</td><td>0x0000</td><td colspan="2">fifo_full_int</td><td colspan="2">fifo_watermark_int</td><td colspan="2">acc_drdy_int</td><td colspan="2">gyr_drdy_int</td><td colspan="2">temp_drdy_int</td><td colspan="2">error_status</td><td colspan="2">i3c_out</td><td colspan="2">reserved</td></tr>
<tr><td>0x40</td><td>FEATURE_CTRL</td><td>0x0000</td><td colspan="15">reserved</td><td>engine_en</td></tr>
<tr><td>0x41</td><td>FEATURE_DATA_ADDR</td><td>0x0000</td><td colspan="5">reserved</td><td colspan="11">data_address</td></tr>
<tr><td>0x42</td><td>FEATURE_DATA_TX</td><td>0x0000</td><td colspan="16">data_tx_value</td></tr>
<tr><td>0x43</td><td>FEATURE_DATA_STATUS</td><td>0x0000</td><td colspan="14">reserved</td><td>data_tx_ready</td><td>data_outofbound_err</td></tr>
<tr><td>0x45</td><td>Feature_ENGINE_STATUS</td><td>0x0000</td><td colspan="10">reserved</td><td>watchdog_not_ack</td><td>disabled_by_host</td><td>data_tx_active</td><td>reserved</td><td>irq_ovrn</td><td>sleep</td></tr>
<tr><td>0x4F</td><td>IO_PDN_CTRL</td><td>0x0000</td><td colspan="15">reserved</td><td>anaio_pdn_dis</td></tr>
</table>

0x50	IO_SPI_IF	0x0000	reserved		spi3_en
0x51	IO_PAD_STRENGTH	0x000A	reserved	if_i2c_boost	if_drv
0x52	IO_I2C_IF	0x0000	reserved	i2c_wdt_en	i2c_wdt_sel
0x53	IO_ODR_DEVIATION	0x0000	reserved	odr_deviation	
0x66	GYR_DP_OFF__X	0x0000	reserved	gyr_dp_off_x	
0x67	GYR_DP_GAIN_X	0x0000	reserved	gyr_dp_dgain_x	
0x68	GYR_DP_OFF__Y	0x0000	reserved	gyr_dp_off_y	
0x69	GYR_DP_GAIN_Y	0x0000	reserved	gyr_dp_dgain_y	
0x6A	GYR_DP_OFF__Z	0x0000	reserved	gyr_dp_off_y	
0x6B	GYR_DP_GAIN_Z	0x0000	reserved	gyr_dp_dgain_y	
0x7E	CMD	0x0000	cmd		

7.17.2 Registers Memory Map

7.17.2.1 Register (0x00) CHIP_ID

Description: Device identification code. Only bits 0 to 7 contain valid information, the contents of bits 8 to 15 must be ignored.

Bit	15	14	13	12	11	10	9	8
Read/Write	R	R	R	R	R	R	R	R
Reset Value	0	0	0	0	0	0	0	0
Content	reserved							

Bit	7	6	5	4	3	2	1	0
Read/Write	R	R	R	R	R	R	R	R
Reset Value	0	1	0	0	0	0	1	0
Content	chip_id							

- Reserved: write 0x00
- Bit **[7:0]** CHIP_ID.chip_id : Chip identifier – For C-Sample ChipID = 0x42

7.17.2.2 Register (0x01) ERR_REG

Description: Reports sensor error conditions

Bit	15	14	13	12	11	10	9	8
Read/Write	R	R	R	R	R/W	R	R	R/W
Reset Value	0	0	0	0	0	0	0	0
Content	reserved				i3c_error3	reserved		i3c_error0

Bit	7	6	5	4	3	2	1	0
Read/Write	R	R	R	R/W	R	R/W	R	R
Reset Value	0	0	0	0	0	0	0	0
Content	reserved	gyr_conf_err	acc_conf_err	feat_eng_wd	reserved	feat_eng_overload	reserved	fatal_err

- Reserved: write 0x00
- Bit **[0]** ERR_REG.fatal_err : Fatal error, chip is not in operational state (Boot-, power-system) This flag will be reset only by power-on-reset or softreset.
- Bit **[2]** ERR_REG.feat_eng_overload : Overload of the feature engine detected. This flag is clear-on-read.
- Bit **[4]** ERR_REG.feat_eng_wd : Watchdog timer of the feature engine triggered. This flag is clear_on_read.
- Bit **[5]** ERR_REG.acc_conf_err : Unsupported accelerometer configuration set by user. This flag will be reset when configuration has been corrected.
- Bit **[6]** ERR_REG.gyr_conf_err : Unsupported gyroscope configuration set by user. This flag will be reset when configuration has been corrected.
- Bit **[8]** ERR_REG.i3c_error0 : SDR parity error or read abort condition (maximum clock stall time for I3C Read Trasfer) occurred. This flag is a clear-on-read type. It is cleared automatically once read. Refer to the MIPI I3C specification chapter 'Master Clock Stalling' for detail info regarding the read abort condition.
- Bit **[11]** ERR_REG.i3c_error3 : S0/S1 error occurred. When S0/S1 error occurs, the slave will recover automatically after 60 us as if we see a HDR-exit pattern on the bus while the flag will persist for notification purpose. This flag is clear-on-read type. It is cleared automatically once read.

7.17.2.3 Register (0x02) STATUS

Description: Sensor status flags

Bit	15	14	13	12	11	10	9	8
Read/Write	R	R	R	R	R	R	R	R
Reset Value	0	0	0	0	0	0	0	0
Content	reserved							

Bit	7	6	5	4	3	2	1	0
Read/Write	R/W	R/W	R	R	R	R	R	R
Reset Value	0	0	0	0	0	0	0	1
Content	drdy_acc	drdy_gyr	drdy_temp	reserved				por_ detected

- Reserved: write 0x00
- Bit **[0]** STATUS.por_detected : ‘1’ after sensor power up or soft-reset. This flag is clear-on-read.
- Bit **[5]** STATUS.drdy_temp : Data ready for temperature sensor. This flag is clear-on-read.
- Bit **[6]** STATUS.drdy_gyr : Data ready for gyroscope. This flag is clear-on-read.
- Bit **[7]** STATUS.drdy_acc : Data ready for accelerometer. This flag is clear-on-read.

7.17.2.4 Register (0x03) ACC_DATA_X

Description: Acceleration sample, X-channel

Bit	15	14	13	12	11	10	9	8
Read/Write	R	R	R	R	R	R	R	R
Reset Value	1	0	0	0	0	0	0	0
Content	acc_x							

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	acc_x							

- Bit **[15:0]** ACC_DATA_X.acc_x

7.17.2.5 Register (0x04) ACC_DATA_Y

Description: Acceleration sample, Y-channel

Bit	15	14	13	12	11	10	9	8
Read/Write	R	R	R	R	R	R	R	R
Reset Value	1	0	0	0	0	0	0	0
Content	acc_y							

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	acc_y							

- Bit **[15:0]** ACC_DATA_Y.acc_y

7.17.2.6 Register (0x05) ACC_DATA_Z

Description: Acceleration sample, Z-channel

Bit	15	14	13	12	11	10	9	8
Read/Write	R	R	R	R	R	R	R	R
Reset Value	1	0	0	0	0	0	0	0
Content	acc_z							

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	acc_z							

- Bit **[15:0]** ACC_DATA_Z.acc_z

7.17.2.7 Register (0x06) GYR_DATA_X

Description: Angular rate sample, X-channel

Bit	15	14	13	12	11	10	9	8
Read/Write	R	R	R	R	R	R	R	R
Reset Value	1	0	0	0	0	0	0	0
Content	gyr_x							

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	gyr_x							

- Bit **[15:0]** GYR_DATA_X.gyr_x

7.17.2.8 Register (0x07) GYR_DATA_Y

Description: Angular rate sample, Y-channel

Bit	15	14	13	12	11	10	9	8
Read/Write	R	R	R	R	R	R	R	R
Reset Value	1	0	0	0	0	0	0	0
Content	gyr_y							

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	gyr_y							

- Bit **[15:0]** GYR_DATA_Y.gyr_y

7.17.2.9 Register (0x08) GYR_DATA_Z

Description: Angular rate sample, Z-channel

Bit	15	14	13	12	11	10	9	8
Read/Write	R	R	R	R	R	R	R	R
Reset Value	1	0	0	0	0	0	0	0
Content	gyr_z							

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	gyr_z							

- Bit **[15:0]** GYR_DATA_Z.gyr_z

7.17.2.10 Register (0x09) TEMP_DATA

Description: Temperature data. The resolution is 256 LSB/K. 0x0000 -> 23°C

Bit	15	14	13	12	11	10	9	8
Read/Write	R	R	R	R	R	R	R	R
Reset Value	1	0	0	0	0	0	0	0
Content	temp_data							

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_data							

- Bit **[15:0]** TEMP_DATA.temp_data : Temperature value. Return value in 2´s complement.
    - T[°C] = $\frac{temp\_data}{256} + 23$
    - 0x8000 is invalid

Example:

Bit[15:0]	**Register value (hex)**	**Temp (°C) | Comment**
0000 0000 0000 0000	0x0000	23
1111 1111 1110 1010$_{(2)}$	0xFFEA	22
0111 1111 1111 1111$_{(2)}$	0x7FFF	150
1000 0000 0000 0001$_{(2)}$	0x8001	-105

7.17.2.11 Register (0x0A) SENSOR_TIME_0

Description: Sensor time, least significant word [15:0]

Bit	**15**	**14**	**13**	**12**	**11**	**10**	**9**	**8**
Read/Write	R	R	R	R	R	R	R	R
Reset Value	0	0	0	0	0	0	0	0
Content	sensor_time_15_0							

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	sensor_time_15_0							

- Bit **[15:0]** SENSOR_TIME_0.sensor_time_15_0 : LSW of the sensor time stamp.

7.17.2.12 Register (0x0B) SENSOR_TIME_1

Description: Sensor time, most significant word [31:16]

Bit	**15**	**14**	**13**	**12**	**11**	**10**	**9**	**8**
Read/Write	R	R	R	R	R	R	R	R
Reset Value	0	0	0	0	0	0	0	0
Content	sensor_time_31_16							

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	sensor_time_31_16							

- Bit **[15:0]** SENSOR_TIME_1.sensor_time_31_16 : MSW of the sensor time stamp.

7.17.2.13 Register (0x0C) SAT_FLAGS

Description: Saturation flags for each sensor and axis

Bit	15	14	13	12	11	10	9	8
Read/Write	R	R	R	R	R	R	R	R
Reset Value	0	0	0	0	0	0	0	0
Content	reserved							

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	reserved		satf_gyr_z	satf_gyr_y	satf_gyr_x	satf_acc_z	satf_acc_y	satf_acc_x

- Bit **[0]** SAT_FLAGS.satf_acc_x : Saturation flag for the accelerometer X-axis.
- Bit **[1]** SAT_FLAGS.satf_acc_y : Saturation flag for the accelerometer Y-axis.
- Bit **[2]** SAT_FLAGS.satf_acc_z : Saturation flag for the accelerometer Z-axis.
- Bit **[3]** SAT_FLAGS.satf_gyr_x : Saturation flag for the gyroscope X-axis.
- Bit **[4]** SAT_FLAGS.satf_gyr_y : Saturation flag for the gyroscope Y-axis.
- Bit **[5]** SAT_FLAGS.satf_gyr_z : Saturation flag for the gyroscope Z-axis.

7.17.2.14 Register (0x0D) INT_STATUS_INT1

Description: INT1 status register. This register is cleard_on_read.

Bit	15	14	13	12	11	10	9	8
Read/Write	R	R	R	R	R	R	R	R
Reset Value	0	0	0	0	0	0	0	0
Content	int1_ffull	int1_fwm	int1_acc _drdy	int1_gyr _drdy	int1_temp _drdy	int1_err_ status	int1_i3c	reserved

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	int1_tilt	reserved					int1_any_ motion	int1_no_ motion

- Bit **[0]** INT_STATUS_INT1.int1_no_motion : No motion detection output
- Bit **[1]** INT_STATUS_INT1.int1_any_motion : Any motion detection output
- Bit **[7]** INT_STATUS_INT1.int1_tilt : Tilt detection output
- Bit **[9]** INT_STATUS_INT1.int1_i3c : I3C tc sync data ready interrupt
- Bit **[10]** INT_STATUS_INT1.int1_err_status : Feature engine error or status change
- Bit **[11]** INT_STATUS_INT1.int1_temp_drdy : Temperature data ready interrupt
- Bit **[12]** INT_STATUS_INT1.int1_gyr_drdy : Gyroscope data ready interrupt
- Bit **[13]** INT_STATUS_INT1.int1_acc_drdy : Accelerometer data ready interrupt
- Bit **[14]** INT_STATUS_INT1.int1_fwm : FIFO watermark interrupt
- Bit **[15]** INT_STATUS_INT1.int1_ffull : FIFO full interrupt

7.17.2.15 Register (0x0E) INT_STATUS_INT2

Description: INT2 status register. This register is clear-on-read.

Bit	15	14	13	12	11	10	9	8
Read/Write	R	R	R	R	R	R	R	R
Reset Value	0	0	0	0	0	0	0	0
Content	int2_ffull	int2_fwm	int2_acc_drdy	int2_gyr_drdy	int2_temp_drdy	int2_err_status	int2_i3c	reserved

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	int2_tilt	reserved					int2_any_motion	int2_no_motion

- Bit **[0]** INT_STATUS_INT2.int2_no_motion : No motion detection output
- Bit **[1]** INT_STATUS_INT2.int2_any_motion : Any motion detection output
- Bit **[7]** INT_STATUS_INT2.int2_tilt : Tilt detection output
- Bit **[9]** INT_STATUS_INT2.int2_i3c : I3C tc sync data ready interrupt
- Bit **[10]** INT_STATUS_INT2.int2_err_status : Feature engine error or status change
- Bit **[11]** INT_STATUS_INT2.int2_temp_drdy : Temperature data ready interrupt
- Bit **[12]** INT_STATUS_INT2.int2_gyr_drdy : Gyroscope data ready interrupt
- Bit **[13]** INT_STATUS_INT2.int2_acc_drdy : Accelerometer data ready interrupt
- Bit **[14]** INT_STATUS_INT2.int2_fwm : FIFO watermark interrupt
- Bit **[15]** INT_STATUS_INT2.int2_ffull : FIFO full interrupt

7.17.2.16 Register (0x0F) INT_STATUS_IBI

Description: I3C IBI status register. This register is clear-on-read.

Bit	15	14	13	12	11	10	9	8
Read/Write	R	R	R	R	R	R	R	R
Reset Value	0	0	0	0	0	0	0	0
Content	ibi_ffull	ibi_fwm	ibi_acc_drdy	ibi_gyr_drdy	ibi_temp_drdy	ibi_err_status	reserved	reserved

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	ibi_tilt	reserved					ibi_any_motion	ibi_no_motion

- Bit **[0]** INT_STATUS_IBI.ibi_no_motion : No motion detection output
- Bit **[1]** INT_STATUS_ IBI.ibi_any_motion : Any motion detection output
- Bit **[7]** INT_STATUS_IN IBI.ibi_tilt : Tilt detection output
- Bit **[10]** INT_STATUS_ IBI.ibi_err_status : Feature engine error or status change
- Bit **[11]** INT_STATUS_ IBI.ibi_temp_drdy : Temperature data ready interrupt
- Bit **[12]** INT_STATUS_ IBI.ibi_gyr_drdy : Gyroscope data ready interrupt
- Bit **[13]** INT_STATUS_ IBI.ibi_acc_drdy : Accelerometer data ready interrupt
- Bit **[14]** INT_STATUS_ IBI.ibi_fwm : FIFO watermark interrupt
- Bit **[15]** INT_STATUS_ IBI.ibi_ffull : FIFO full interrupt

7.17.2.17 Register (0x10) FEATURE_IO0

Description: Feature engine configuration, before setting/changing an active configuration the register must be cleared (set to 0).

Bit	15	14	13	12	11	10	9	8
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	i3c_sync_en	reserved			tilt_en	reserved		

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	reserved	any_motion_z_en	any_motion_y_en	any_motion_x_en	no_motion_z_en	no_motion_y_en	no_motion_x_en

- Reserved write '0'
- Bit **[0]** FEATURE_IO0.no_motion_x_en : Enables no motion feature for X-axis
- Bit **[1]** FEATURE_IO0.no_motion_y_en : Enables no motion feature for Y-axis
- Bit **[2]** FEATURE_IO0.no_motion_z_en : Enables no motion feature for Z-axis
- Bit **[3]** FEATURE_IO0.any_motion_x_en : Enables any motion feature for X-axis
- Bit **[4]** FEATURE_IO0.any_motion_y_en : Enables any motion feature for Y-axis
- Bit **[5]** FEATURE_IO0.any_motion_z_en : Enables any motion feature for Z-axis
- Bit **[11]** FEATURE_IO0.tilt_en : Enables tilt detection
- Bit **[15]** FEATURE_IO0.i3c_sync_en : Enables I3C TC-sync-feature

7.17.2.18 Register (0x11) FEATURE_IO1

Description: Feature engine I/O register.

Bit	15	14	13	12	11	10	9	8
Read/Write	R	R	R	R	R	R	R	R
Reset Value	0	0	0	0	0	0	0	0
Content	reserved			state		reserved	reserved	

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	sample_rate_err	st_result	gyro_sc_result	sc_st_complete	error_status			

Value	Description
0x0 [0000]	Feature engine still inactive
0x1 [0001]	Feature engine activated
0x3 [0011]	Configuration string download failed
0x5 [0101]	No error
0x8 [1000]	I3C TC-sync error because either I3C TC-sync enable request was sent while auto-low-power feature was active or I3C TC-sync configuration command was sent with invalid TPH, TU and ODR values. For later case, invalid configuration parameters TPH, TU and ODR will not be used.
0x9 [1001]	Ongoing self-calibration (gyroscope only) or self-test (gyroscope only) was aborted. The command was aborted either due to device movements or due to the abort command (self-calibration only) or due to a request to enable I3C TC-sync feature (self-calibration only)
0xA [1001]	Self-calibration (gyroscope only) command ignored because either self-calibration or self-test or I3C TC-sync was ongoing
0xB [1011]	Self-test (accelerometer and/or gyroscope) command ignored because either self-calibration or self-test or I3C TC-sync was ongoing
0xC [1100]	Self-calibration (gyroscope only) or self-test (accelerometer and/or gyroscope) command was not processed because pre-conditions were not met. Either accelerometer was not configured correctly (self-test and self-calibration gyroscope only) or auto-low-power feature was active.
0xD [1101]	Auto-mode change feature was enabled or illegal sensor configuration change detected in ACC_CONF/GYR_CONF while self-calibration or self-test was ongoing. Self-calibration and self-test results may be inaccurate.
0xE [1110]	I3C TC-sync enable request was sent while self-test (accelerometer and/or gyroscope) was ongoing. I3C TC-sync will be enabled at the end of self-test.
0xF [1111]	Illegal sensor configuration change detected in ACC_CONF/GYR_CONF while I3C TC-sync was active. Sensors are re-configured is to be requested I3C TC-sync ODR.

Definition of status information:

- Reserved write ‘0’
- Bit **[3:0]** FEATURE_IO1.error_status : Error and status information

- Bit **[4]** FEATURE_IO1.sc_st_complete : Self-calibration (gyroscope only) or self-test (accelerometer and / or gyroscope) execution status. “0” (1) indicates procedure is ongoing (completed).
- Bit **[5]** FEATURE_IO1.gyr_sc_result : Gyroscope self-calibration result (1= OK, 0= Not Ok)
- Bit **[6]** FEATURE_IO1.st_result : Accelerometer and/or gyroscope self-test result (1= Ok, 0= Not Ok). Bit sc_st_complete should be “1” prior to reading this bit.
- Bit **[7]** FEATURE_IO1.sample_rate_err: Insufficient sample rate for either 50Hz or 200Hz
- Bit **[12:11]** FEATURE_IO1.state: Current state of the system

Definition of different states:

Value	Description
0x0 [00]	System in feature mode
0x1 [01]	System is executing self-calibration of gyroscope in feature mode
0x2 [10]	System in self-test mode
0x3 [11]	System in error mode

7.17.2.19 Register (0x12) FEATURE_IO2

Description: Feature engine I/O register.

Bit	15	14	13	12	11	10	9	8
Read/Write	W	W	R	R	R	R	R	R
Reset Value	0	0	0	0	0	0	0	0
Content								

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								

- Reserved write ‘0’
- Bit **[15:0]** FEATURE_IO2: Value 0x012C deactivates MCU stop and enables access to motion features.

7.17.2.20 Register (0x14) FEATURE_IO_STATUS

Description: Feature engine I/O register.

Bit	15	14	13	12	11	10	9	8
Read/Write	W	W	R	R	R	R	R	R
Reset Value	0	0	0	0	0	0	0	0
Content	reserved							

Bit	7	6	5	4	3	2	1	0
Read/Write	R	R	R	R	R	R	R	R
Reset Value	0	0	0	1	1	0	0	0
Content	reserved							feature_io_status

- Reserved write ‘0’
- Bit **[0]** FEATURE_IO_STATUS.feature_io_status: Read: Data has been written by the feature engine
  Write: Data written by the host shall be sent to the feature engine

7.17.2.21 Register (0x15) FIFO_FILL_LEVEL

Description: This register represents the fill level state in words.

Bit	15	14	13	12	11	10	9	8
Read/Write	R	R	R	R	R	R	R	R
Reset Value	0	0	0	0	0	0	0	0
Content	reserved					fifo_fill_level		

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	fifo_fill_level							

- Bit **[10:0]** FIFO_FILL_LEVEL.fifo_fill_level : Current fill level of FIFO buffer. An empty FIFO corresponds to 0x000. The word counter may be reset by reading out all frames from the FIFO buffer or when the FIFO is reset through fifo_flush. The word counter is updated each time a complete frame was read or written.

7.17.2.22 Register (0x16) FIFO_DATA

Description: FIFO data output register

Bit	15	14	13	12	11	10	9	8
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	fifo_data							

Bit	7	6	5	4	3	2	1	0
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Reset Value	0	0	0	0	0	0	0	0
Content	fifo_data							

- Bit **[15:0]** FIFO_DATA.fifo_data : FIFO read data (16 bits) Data format depends on the setting of register FIFO_CONF. The FIFO data are organized in frames. The new data flag is preserved. Read burst access must be used, the address will not increment when the read burst reads at the address of FIFO_DATA. When a frame is only partially read out it is retransmitted including the header at the next readout.

7.17.2.23 Register (0x20) ACC_CONF

Description: This register sets the configuration of the accelerometer.

Bit	15	14	13	12	11	10	9	8
Read/Write	R	R/W	R/W	R/W	R	R/W	R/W	R/W
Reset Value	0	0	0	0	0	0	0	0
Content	reserved	acc_mode			reserved	acc_avg_num		

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	1	0	1	0	0	0
Content	acc_bw	acc_range			acc_odr			

- Reserved write ‘0’
- Bit **[3:0]** ACC_CONF.acc_odr : Sample rate (Output Data Rate) in Hz

Definition of different ODR settings:

Value	Description	Value	Description
0x1 [0001]	0.78125 Hz	0x8 [1000]	100Hz (default)
0x2 [0010]	1.5625 Hz	0x9 [1001]	200 Hz
0x3 [0011]	3.125 Hz	0xA [1010]	400 Hz
0x4 [0100]	6.25 Hz	0xB [1011]	800 Hz
0x5 [0101]	12.5 Hz	0xC [1100]	1.6 kHz
0x6 [0110]	25 Hz	0xD [1101]	3.2 kHz
0x7 [0111]	50Hz	0xE [1110]	6.4 kHz

- Bit **[6:4]** ACC_CONF.acc_range : Full scale, resolution

Definition of different range settings:

Value	Description
0x0 [000]	±2g, 16.38 LSB/mg
0x1 [001]	±4g, 8.19 LSB/mg
0x2 [010]	±8g, 4.10 LSB/mg
0x3 [011]	±16g, 2.05 LSB/mg

- Bit **[7]** ACC_CONF.acc_bw : Configure the -3dB cut-off frequency for the accelerometer

Definition of different bw settings:

Value	Description
0x0 [0]	BW = acc_odr/2
0x1 [1]	BW = acc_odr/4

- Bit **[10:8]** ACC_CONF.acc_avg_num : Numbers of samples to be averaged

Definition of different average sample settings:

Value	Description	Value	Description
0x0 [000]	No averaging: pass sample	0x4 [100]	Averaging of 16 samples
0x1 [001]	Averaging of 2 samples	0x5 [101]	Averaging of 32 samples
0x2 [010]	Averaging of 4 samples	0x6 [110]	Averaging of 64 samples
0x3 [011]	Averaging of 8 samples	-	-

- Bit **[14:12]** ACC_CONF.acc_mode : Operation modes for the accelerometer

Definition of different mode settings:

Value	Description
0x0 [000]	Disables the accelerometer
0x3 [011]	Enables the accelerometer with sensing operated in duty-cycling
0x4 [100]	Enables the accelerometer in a continuous operation mode with reduced current
0x7 [111]	Enables the accelerometer in high performance mode

7.17.2.24 Register (0x21) GYR_CONF

Description: This register sets the configuration of the gyroscope.

Bit	15	14	13	12	11	10	9	8
Read/Write	R	R/W	R/W	R/W	R	R/W	R/W	R/W
Reset Value	0	0	0	0	0	0	0	0
Content	reserved	gyr_mode			reserved	gyr_avg_num		

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	0	0	0
Content	gyr_bw	reserved	gyr_range		gyr_odr			

- Reserved write ‘0’
- Bit **[3:0]** GYR_CONF.gyr_odr : Sample rate (Output Data Rate) in Hz

Definition of different ODR settings:

Value	Description	Value	Description
0x1 [0001]	0.78125 Hz	0x8 [1000]	100Hz (default)
0x2 [0010]	1.5625 Hz	0x9 [1001]	200 Hz
0x3 [0011]	3.125 Hz	0xA [1010]	400 Hz
0x4 [0100]	6.25 Hz	0xB [1011]	800 Hz
0x5 [0101]	12.5 Hz	0xC [1100]	1.6 kHz
0x6 [0110]	25 Hz	0xD [1101]	3.2 kHz
0x7 [0111]	50Hz	0xE [1110]	6.4 kHz

- Bit **[5:4]** GYR_CONF.gyr_range : Full scale, resolution

Definition of different range settings:

Value	Description
0x0 [00]	±125°/s, 262.144 LSB/°/s
0x1 [01]	±250°/s, 131.072 LSB/°/s
0x2 [10]	±500°/s, 65.536 LSB/°/s

- Bit **[7]** GYR_CONF.gyr_bw : Configure the -3dB cut-off frequency for the gyroscope

Definition of different bw settings:

Value	Description
0x0 [0]	BW = gyr_odr/2
0x1 [1]	BW = gyr_odr/4

- Bit **[10:8]** GYR_CONF.gyr_avg_num : Numbers of samples to be averaged

Definition of different average sample settings:

Value	Description	Value	Description
0x0 [000]	No averaging: pass sample	0x4 [100]	Averaging of 16 samples
0x1 [001]	Averaging of 2 samples	0x5 [101]	Averaging of 32 samples
0x2 [010]	Averaging of 4 samples	0x6 [110]	Averaging of 64 samples
0x3 [011]	Averaging of 8 samples	-	-

- Bit **[14:12]** GYR_CONF.gyr_mode : Operation modes for the gyroscope

Definition of different mode settings:

Value	Description
0x0 [000]	Disables the gyroscope
0x1 [001]	Disables the gyroscope but keep the gyroscope drive enabled
0x3 [011]	Enables the gyroscope with sensing operated in duty-cycle
0x4 [100]	Enables the gyroscope in a continuous operating mode with reduced current
0x7 [111]	Enables the gyroscope in high performance mode

7.17.2.25 Register (0x28) ALT_ACC_CONF

Description: Sets the alternative output data rate, bandwidth, range and the mode of the accelerometer

Bit	15	14	13	12	11	10	9	8
Read/Write	R	R/W	R/W	R/W	R	R/W	R/W	R/W
Reset Value	0	0	1	1	0	0	0	0
Content	reserved	alt_acc_mode			reserved	alt_acc_avg_num		

Bit	7	6	5	4	3	2	1	0
Read/Write	R	R	R	R	R/W	R/W	R/W	R/W
Reset Value	0	0	0	0	0	1	1	0
Content	reserved				alt_acc_odr			

- Reserved write '0'
- Bit **[3:0]** ALT_ACC_CONF.alt_acc_odr : Sample rate (Output Data Rate) in Hz

Definition of different ODR settings:

Value	Description	Value	Description
0x1 [0001]	0.78125 Hz	0x8 [1000]	100Hz
0x2 [0010]	1.5625 Hz	0x9 [1001]	200 Hz
0x3 [0011]	3.125 Hz	0xA [1010]	400 Hz
0x4 [0100]	6.25 Hz	0xB [1011]	800 Hz
0x5 [0101]	12.5 Hz	0xC [1100]	1.6 kHz
0x6 [0110]	25 Hz (default)	0xD [1101]	3.2 kHz
0x7 [0111]	50Hz	0xE [1110]	6.4 kHz

- Bit **[10:8]** ALT_ACC_CONF.alt_acc_avg_num : Numbers of samples to be averaged

Definition of different average sample settings:

Value	Description	Value	Description
0x0 [000]	No averaging: pass sample	0x4 [100]	Averaging of 16 samples
0x1 [001]	Averaging of 2 samples	0x5 [101]	Averaging of 32 samples
0x2 [010]	Averaging of 4 samples	0x6 [110]	Averaging of 64 samples
0x3 [011]	Averaging of 8 samples	-	-

- Bit **[14:12]** ALT_ACC_CONF.alt_acc_mode : Operation modes for the accelerometer

Definition of different mode settings:

Value	Description
0x0 [000]	Disables the accelerometer
0x3 [011]	Enables the accelerometer with sensing operated in duty-cycling
0x4 [100]	Enables the accelerometer in a continuous operation mode with reduced current
0x7 [111]	Enables the accelerometer in high performance mode

7.17.2.26 Register (0x29) ALT_GYR_CONF

Description: This register sets the configuration of the gyroscope.

Bit	15	14	13	12	11	10	9	8
Read/Write	R	R/W	R/W	R/W	R	R/W	R/W	R/W
Reset Value	0	0	0	1	0	0	1	0
Content	reserved	alt_gyr_mode			reserved	alt_gyr_avg_num		

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	1	1	0
Content	reserved				alt_gyr_odr			

- Reserved write '0'
- Bit **[3:0]** ALT_GYR_CONF.alt_gyr_odr : Sample rate (Output Data Rate) in Hz

Definition of different ODR settings:

Value	Description	Value	Description
0x1 [0001]	0.78125 Hz	0x8 [1000]	100Hz
0x2 [0010]	1.5625 Hz	0x9 [1001]	200 Hz
0x3 [0011]	3.125 Hz	0xA [1010]	400 Hz
0x4 [0100]	6.25 Hz	0xB [1011]	800 Hz
0x5 [0101]	12.5 Hz	0xC [1100]	1.6 kHz
0x6 [0110]	25 Hz (default)	0xD [1101]	3.2 kHz
0x7 [0111]	50Hz	0xE [1110]	6.4 kHz

- Bit **[10:8]** ALT_GYR_CONF.alt_gyr_avg_num : Numbers of samples to be averaged

Definition of different average sample settings:

Value	Description	Value	Description
0x0 [000]	No averaging: pass sample	0x4 [100]	Averaging of 16 samples
0x1 [001]	Averaging of 2 samples	0x5 [101]	Averaging of 32 samples
0x2 [010]	Averaging of 4 samples	0x6 [110]	Averaging of 64 samples
0x3 [011]	Averaging of 8 samples	-	-

- Bit **[14:12]** ALT_GYR_CONF.gyr_mode : Operation modes for the gyroscope

Definition of different mode settings:

Value	Description
0x0 [000]	Disables the gyroscope
0x1 [001]	Disables the gyroscope but keep the gyroscope drive enabled
0x3 [011]	Enables the gyroscope with sensing operated in duty-cycle
0x4 [100]	Enables the gyroscope in a continuous operating mode with reduced current
0x7 [111]	Enables the gyroscope in high performance mode

7.17.2.27 Register (0x2A) ALT_CONF

Description: Alternate configuration control

Bit	15	14	13	12	11	10	9	8
Read/Write	R	R	R	R	R	R	R	R/W
Reset Value	0	0	0	0	0	0	0	0
Content	reserved							alt_rst_conf_write_en

Bit	7	6	5	4	3	2	1	0
Read/Write	R	R	R	R/W	R	R	R	R/W
Reset Value	0	0	0	0	0	0	0	0
Content	reserved			alt_gyr_en	reserved			alt_acc_en

- Reserved write ‘0’
- Bit **[0]** ALT_CONF.alt_acc_en : Enables switching possibility to alternate configuration for accelerometer.
- Bit **[4]** ALT_CONF.alt_gyr_en : Enables switching possibility to alternate configuration for gyroscope.
- Bit **[8]** ALT_CONF.alt_rst_conf_write_en : If ‘1’, any write to ACC_CONF or GYR_CONF will instantly switch back to associated user configuration.

7.17.2.28 Register (0x2B) ALT_STATUS

Description: Reports the active configuration for the accelerometer and gyroscope

Bit	15	14	13	12	11	10	9	8
Read/Write	R	R	R	R	R	R	R	R
Reset Value	0	0	0	0	0	0	0	0
Content	reserved							

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	reserved			alt_gyr_active	reserved			alt_acc_active

- Reserved write ‘0’
- Bit **[0]** ALT_STATUS.alt_acc_active : Accelerometer is using ALT_ACC_CONF if set; otherwise ACC_CONF
- Bit **[4]** ALT_STATUS.alt_gyr_active : Gyroscope using ALT_GYR_CONF if set; otherwise GYR_CONF

7.17.2.29 Register (0x35) FIFO_WATERMARK

Description: FIFO watermark level

Bit	15	14	13	12	11	10	9	8
Read/Write	R	R	R	R	R	R	R/W	R/W
Reset Value	0	0	0	0	0	0	0	0
Content	reserved						fifo_watermark	

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	fifo_watermark							

- Reserved write ‘0’
- Bit **[9:0]** FIFO_WATERMARK.fifo_watermark : Triggers an interrupt when FIFO buffer contains here defined words. (1 word = 2 bytes)

7.17.2.30 Register (0x36) FIFO_CONF

Description: Configuration of the FIFO data buffer.

Bit	15	14	13	12	11	10	9	8
Read/Write	R	R	R	R	R/W	R/W	R/W	R/W
Reset Value	0	0	0	0	0	0	0	0
Content	reserved				fifo_temp_en	fifo_gyr_en	fifo_acc_en	fifo_time_en

Bit	7	6	5	4	3	2	1	0
Read/Write	R	R	R	R	R	R	R	R/W
Reset Value	0	0	0	0	0	0	0	0
Content	reserved							fifo_stop_On_full

- Reserved write ‘0’
- Bit **[0]** FIFO_CONF.fifo_stop_on_full : Configure whether to overwrite oldest samples when the FIFO data buffer is full

Definition of different FIFO settings:

Value	Description
0x0 [0]	Continue writing to the data buffer by overwriting oldest samples
0x1 [1]	Stop writing into the FIFO data buffer when full

- Bit **[8]** FIFO_CONF.fifo_time_en : Write the sensor time into the FIFO data buffer.

Definition of different data settings:

Value	Description
0x0 [0]	No sensortime is written
0x1 [1]	Sensortime is written

- Bit **[9]** FIFO_CONF.fifo_acc_en : Write 3-axis samples from the accelerometer into the FIFO data buffer

Definition of different data settings:

Value	Description
0x0 [0]	No accelerometer data is written
0x1 [1]	Accelerometer data is written

- Bit **[10]** FIFO_CONF.fifo_gyr_en : Write 3-axis samples from the gyroscope into the FIFO data buffer

Definition of different data settings:

Value	Description
0x0 [0]	No gyroscope data is written
0x1 [1]	Gyroscope data is written

- Bit **[11]** FIFO_CONF.fifo_temp_en : Write temperature samples into the FIFO data buffer

Definition of different data settings:

Value	Description
0x0 [0]	No temperature data is written
0x1 [1]	Temperature data is written

7.17.2.31 Register (0x37) FIFO_CTRL

Description: Control of the FIFO data buffer.

Bit	15	14	13	12	11	10	9	8
Read/Write	R	R	R	R	R	R	R	R
Reset Value	0	0	0	0	0	0	0	0
Content	reserved							

Bit	7	6	5	4	3	2	1	0
Read/Write	R	R	R	R	R	R	R	W
Reset Value	0	0	0	0	0	0	0	0
Content	reserved							fifo_flush

- Reserved write ‘0’
- Bit **[0]** FIFO_CTRL.fifo_flush : Write ‘1’ to clear the FIFO data buffer

7.17.2.32 Register (0x38) IO_INT_CTRL

Description: Configures the electrical behaviour of the interrupt pins

Bit	15	14	13	12	11	10	9	8
Read/Write	R	R	R	R	R	R/W	R/W	R/W
Reset Value	0	0	0	0	0	0	0	0
Content	reserved					Int2_output_en	Int2_od	Int2_lvl

Bit	7	6	5	4	3	2	1	0
Read/Write	R	R	R	R	R	R/W	R/W	R/W
Reset Value	0	0	0	0	0	0	0	0
Content	reserved					int1_output_en	int1_od	int1_lvl

- Reserved write '0'
- Bit **[0]** IO_INT_CTRL.int1_lvl : Configure output level of INT1 pin

Definition of different pin settings:

Value	Description
0x0 [0]	Active low
0x1 [1]	Active high

- Bit **[1]** IO_INT_CTRL.int1_od : Configure output level of INT1 pin

Definition of different pin settings:

Value	Description
0x0 [0]	Push-pull
0x1 [1]	Open drain

- Bit **[2]** IO_INT_CTRL.int1_output_en : Output enable for INT1 pin
- Bit **[8]** IO_INT_CTRL.int2_lvl : Configure output level of INT2 pin

Definition of different pin settings:

Value	Description
0x0 [0]	Active low
0x1 [1]	Active high

- Bit **[9]** IO_INT_CTRL.int2_od : Configure behaviour of INT2 pin

Definition of different pin settings:

Value	Description
0x0 [0]	Push pull
0x1 [1]	Open drain

- Bit **[10]** IO_INT_CTRL.int1_output_en : Output enable for INT2 pin

7.17.2.33 Register (0x39) INT_CONF

Description: Interrupt configuration register

Bit	15	14	13	12	11	10	9	8
Read/Write	R	R	R	R	R	R	R	R
Reset Value	0	0	0	0	0	0	0	0
Content	reserved							

Bit	7	6	5	4	3	2	1	0
Read/Write	R	R	R	R	R	R	R	R/W
Reset Value	0	0	0	0	0	0	0	0
Content	reserved							int1_latch

- Reserved write ‘0’
- Bit **[0]** INT_CONF.int_latch : Configuration of the interrupt clear behaviour as not latched or permanently latched.

Definition of different interrupt configuration:

Value	Description
0x0 [0]	Non latched
0x1 [1]	Permanent latched

7.17.2.34 Register (0x3A) INT_MAP1

Description: Mapping feature engine interrupts to output

Bit	15	14	13	12	11	10	9	8
Read/Write	R/W	R/W	R	R	R	R	R	R
Reset Value	0	0	0	0	0	0	0	0
Content	tilt_out		reserved					

Bit	7	6	5	4	3	2	1	0
Read/Write	R	R	R	R	R/W	R/W	R/W	R/W
Reset Value	0	0	0	0	0	0	0	0
Content	reserved				any_motion_out		no_motion_out	

- Reserved write '0'
- Bit **[1:0]** INT_MAP1.no_motion_out : Map no motion output to either INT1, INT2 or IBI

Definition of different pin mapping:

Value	Description
0x0 [00]	Interrupt disabled
0x1 [01]	Mapped to INT1
0x2 [10]	Mapped to INT2
0x3 [11]	Mapped to I2C IBI

- Bit **[3:2]** INT_MAP1.any_motion_out : Map any motion output to either INT1, INT2 or IBI

Definition of different pin mapping:

Value	Description
0x0 [00]	Interrupt disabled
0x1 [01]	Mapped to INT1
0x2 [10]	Mapped to INT2
0x3 [11]	Mapped to I2C IBI

- Bit **[15:14]** INT_MAP1.tilt_out : Map tilt output to either INT1, INT2 or IBI

Definition of different pin mapping:

Value	Description
0x0 [00]	Interrupt disabled
0x1 [01]	Mapped to INT1
0x2 [10]	Mapped to INT2
0x3 [11]	Mapped to I2C IBI

7.17.2.35 Register (0x3B) INT_MAP2

Description: Mapping feature engine interrupts, data ready signal and FIFO interrupts to output

Bit	15	14	13	12	11	10	9	8
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	fifo_full_int		fifo_watermark_int		acc_drdy_int		gyr_drdy_int	

Bit	7	6	5	4	3	2	1	0
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R	R
Reset Value	0	0	0	0	0	0	0	0
Content	temp_drdy_int		err_status		i3c_out		reserved	

- Reserved write ‘0’
- Bit **[3:2]** INT_MAP2.i3c_out : Map i3c output to either INT1, INT2 or IBI

Definition of different pin mapping:

Value	Description
0x0 [00]	Interrupt disabled
0x1 [01]	Mapped to INT1
0x2 [10]	Mapped to INT2
0x3 [11]	Mapped to I2C IBI

- Bit **[5:4]** INT_MAP2.error_status : Map feature engines error or status change to either INT1, INT2 or IBI

Definition of different pin mapping:

Value	Description
0x0 [00]	Interrupt disabled
0x1 [01]	Mapped to INT1
0x2 [10]	Mapped to INT2
0x3 [11]	Mapped to I2C IBI

- Bit **[7:6]** INT_MAP2.temp_drdy_int : Map temperature data ready interrupt to either INT1, INT1 or IBI

Definition of different pin mapping:

Value	Description
0x0 [00]	Interrupt disabled
0x1 [01]	Mapped to INT1
0x2 [10]	Mapped to INT2
0x3 [11]	Mapped to I2C IBI

- Bit **[9:8]** INT_MAP2.gyr_drdy_int : Map gyroscope data ready interrupt to either INT1, INT1 or IBI

Definition of different pin mapping:

Value	Description
0x0 [00]	Interrupt disabled
0x1 [01]	Mapped to INT1
0x2 [10]	Mapped to INT2
0x3 [11]	Mapped to I2C IBI

- Bit **[11:10]** INT_MAP2.acc_drdy_int : Map accelerometer data ready interrupt to either INT1, INT1 or IBI

Definition of different pin mapping:

Value	Description
0x0 [00]	Interrupt disabled
0x1 [01]	Mapped to INT1
0x2 [10]	Mapped to INT2
0x3 [11]	Mapped to I2C IBI

- Bit **[13:12]** INT_MAP2.fifo_watermark_int : Map FIFO watermark interrupt to either INT1, INT1 or IBI

Definition of different pin mapping:

Value	Description
0x0 [00]	Interrupt disabled
0x1 [01]	Mapped to INT1
0x2 [10]	Mapped to INT2
0x3 [11]	Mapped to I2C IBI

- Bit **[15:14]** INT_MAP2.fifo_full_int : Map FIFO full interrupt to either INT1, INT1 or IBI

Definition of different pin mapping:

Value	Description
0x0 [00]	Interrupt disabled
0x1 [01]	Mapped to INT1
0x2 [10]	Mapped to INT2
0x3 [11]	Mapped to I2C IBI

7.17.2.36 Register (0x40) FEATURE_CTRL

Description: Feature engine control register

Bit	15	14	13	12	11	10	9	8
Read/Write	R	R	R	R	R	R	R	R
Reset Value	0	0	0	0	0	0	0	0
Content	reserved							

Bit	7	6	5	4	3	2	1	0
Read/Write	R	R	R	R	R	R	R	R/W
Reset Value	0	0	0	0	0	0	0	0
Content	reserved							engine_en

- Reserved write ‘0’
- Bit **[0]** FEATURE_CTRL.engine_en : Enable or disable the feature engine. Note: a soft-reset is required to re-enable the feature engine.

7.17.2.37 Register (0x41) FEATURE_DATA_ADDR

Description: Address register for feature data: configurations and extended output

Bit	15	14	13	12	11	10	9	8
Read/Write	R	R	R	R	R	R/W	R/W	R/W
Reset Value	0	0	0	0	0	0	0	0
Content	reserved					data_address		

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_address							

- Reserved write ‘0’
- Bit **[10:0]** FEATURE_DATA_ADDR.data_address: Start address for the feature data, that is feature configuration and extended feature output.

7.17.2.38 Register (0x42) FEATURE_DATA_TX

Description: I/O port for the data values of the feature engine

Bit	15	14	13	12	11	10	9	8
Read/Write	R	R	R	R	R	R/W	R/W	R/W
Reset Value	0	0	0	0	0	0	0	0
Content	data_tx_value							

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_tx_value							

- Bit **[15:0]** FEATURE_DATA_TX.data_tx_value: Data port for DMA transfers

7.17.2.39 Register (0x43) FEATURE_DATA_STATUS

Description: Status of the data access to the feature engine

Bit	15	14	13	12	11	10	9	8
Read/Write	R	R	R	R	R	R	R	R
Reset Value	0	0	0	0	0	0	0	0
Content	reserved							

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	reserved						data_tx_ready	data_outofbound_err

- Reserved write ‘0’
- Bit **[0]** FEATURE_DATA_STATUS.data_outofbound_err: Too much data read or written to the feature engine. Bit will be reset upon next data transfer to or from the feature engine.
- Bit **[1]** FEATURE_DATA_STATUS.data_tx_ready: Data is writeable to the feature engine or readable from the feature engine.

7.17.2.40 Register (0x45) FEATURE_ENGINE_STATUS

Description: Status of the feature engine

Bit	15	14	13	12	11	10	9	8
Read/Write	R	R	R	R	R	R	R	R
Reset Value	0	0	0	0	0	0	0	0
Content	reserved							

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	reserved		watchdog_not_ack	disabled_by_host	data_tx_active	reserved	overload	sleep

- Reserved write '0'
- Bit **[0]** FEATURE_ENGINE_STATUS.sleep : Feature engine halted or sleeping
- Bit **[1]** FEATURE_ENGINE_STATUS.overload : Transfer of data to or from the feature engine is ongoing
- Bit **[3]** FEATURE_ENGINE_STATUS.data_tx_active : DMA controller has started DMA and DMA transactions are ongoing
- Bit **[4]** FEATURE_ENGINE_STATUS.disabled_by_host : Feature engine was disabled by the host. Perform a soft-reset to re-enable the feature engine.
- Bit **[5]** FEATURE_ENGINE_STATUS.watchdog_not_ack : The feature engine did not acknowledge its internal watchdog in time. Perform a soft-reset to re-enable the feature engine.

7.17.2.41 Register (0x4F) IO_PDN_CTRL

Description: Pull down behaviour control

Bit	15	14	13	12	11	10	9	8
Read/Write	R	R	R	R	R	R	R	R
Reset Value	0	0	0	0	0	0	0	0
Content	reserved							

Bit	7	6	5	4	3	2	1	0
Read/Write	R	R	R	R	R	R	R	R/W
Reset Value	0	0	0	0	0	0	0	0
Content	reserved							anaio_pdn_dis

- Reserved write '0'
- Bit **[0]** IO_PDN_CTRL.anaio_pdn_dis : Disable the pull down on Pin2 and Pin3

7.17.2.42 Register (0x50) IO_SPI_IF

Description: Configuration register of the SPI interface

Bit	15	14	13	12	11	10	9	8
Read/Write	R	R	R	R	R	R	R	R
Reset Value	0	0	0	0	0	0	0	0
Content	reserved							

Bit	7	6	5	4	3	2	1	0
Read/Write	R	R	R	R	R	R	R	R/W
Reset Value	0	0	0	0	0	0	0	0
Content	reserved							spi3_en

- Reserved write ‘0’
- Bit **[0]** IO_SPI_IF.spi3_en : Enable or disable the 3-wire SPI interface. ‘0’ enables the default 4-wire configuration, ’1’ enables the 3-wire configuration.

7.17.2.43 Register (0x51) IO_PAD_STRENGTH

Description: Configuration register for the electrical characteristics of the pads

Bit	15	14	13	12	11	10	9	8
Read/Write	R	R	R	R	R	R	R	R
Reset Value	0	0	0	0	0	0	0	0
Content	reserved							

Bit	7	6	5	4	3	2	1	0
Read/Write	R	R	R	R	R/W	R/W	R/W	R/W
Reset Value	0	0	0	0	1	0	1	0
Content	reserved				if_i2c_boost	if_drv		

- Reserved write ‘0’
- Bit **[2:0]** IO_PAD_STRENGTH.if_drv : Generic drive strength control for the output pads: 0:=weakest; 7:=strongest
- Bit **[3]** IO_PAD_STRENGTH.if_i2c_boost : Enable or disable the drive strength for SDX when interfacing via I2C. ‘1’ enables the default increased drive strength, ‘0’ does not increase the drive strength.

7.17.2.44 Register (0x52) IO_I2C_IF

Description: Configuration register for the I2C interface

Bit	15	14	13	12	11	10	9	8
Read/Write	R	R	R	R	R	R	R	R
Reset Value	0	0	0	0	0	0	0	0
Content	reserved							

Bit	7	6	5	4	3	2	1	0
Read/Write	R	R	R	R	R	R	R/W	R/W
Reset Value	0	0	0	0	0	0	0	0
Content	reserved						watchdog_timer_en	watchdog_timer_sel

- Reserved write ‘0’
- Bit **[0]** IO_I2C_IF.watchdog_timer_sel : Select the timer period of the I2C watchdog

Definition of different watchdog configuration:

Value	Description
0x0 [0]	I2C watchdog timeout after 1.25ms
0x1 [1]	2C watchdog timeout after 40ms

- Bit **[1]** IO_I2C_IF.watchdog_timer_en : Enable or disable the watchdog for the I2C interface. Disable this feature when using I3C or SPI.

7.17.2.45 Register (0x53) IO_ODR_DEVIATION

Description: ODR Deviation Trim Register (OTP backed) - User mirror register

Bit	15	14	13	12	11	10	9	8
Read/Write	R	R	R	R	R	R	R	R
Reset Value	0	0	0	0	0	0	0	0
Content	reserved							

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	reserved			odr_deviation				

- Reserved write ‘0’
- Bit **[4:0]** IO_ODR_DEVIATION.odr_deviation : ODR clock deviation

7.17.2.46 Register (0x66) GYR_DP_OFF_X

Description: Data path register for the gyroscope offset of axis X

Bit	15	14	13	12	11	10	9	8
Read/Write	R	R	R	R	R	R	R/W	R/W
Reset Value	0	0	0	0	0	0	0	0
Content							gyr_dp_off_x	

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	gyr_dp_off_x							

- Reserved write ‘0’
- Bit **[9:0]** GYR_DP_OFF_X.gyr_dp_off_x : Data path register for the temperature independent gyroscope offset of axis x: 1 LSB = 0.061°/s; 0x200 -> invalid!

7.17.2.47 Register (0x67) GYR_DP_DGAIN_X

Description: Data path register for the gyroscope re-scale of axis X

Bit	15	14	13	12	11	10	9	8
Read/Write	R	R	R	R	R	R	R	R
Reset Value	0	0	0	0	0	0	0	0
Content	reserved							

Bit	7	6	5	4	3	2	1	0
Read/Write	R	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Reset Value	0	0	0	0	0	0	0	0
Content	reserved	gyr_dp_dgain_x						

- Reserved write ‘0’
- Bit **[6:0]** GYR_DP_DGAIN_X.gyr_dp_dgain_x : Data path register for the temperature independent gyroscope re-scale of axis x: covers ±12.5% of sensitivity.

7.17.2.48 Register (0x68) GYR_DP_OFF_Y

Description: Data path register for the gyroscope offset of axis Y

Bit	15	14	13	12	11	10	9	8
Read/Write	R	R	R	R	R	R	R/W	R/W
Reset Value	0	0	0	0	0	0	0	0
Content							gyr_dp_off_y	

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	gyr_dp_off_y							

- Reserved write ‘0’
- Bit **[9:0]** GYR_DP_OFF_Y.gyr_dp_off_y : Data path register for the temperature independent gyroscope offset of axis y: 1 LSB = 0.061°/s; 0x200 -> invalid!

7.17.2.49 Register (0x69) GYR_DP_DGAIN_Y

Description: Data path register for the gyroscope re-scale of axis Y

Bit	15	14	13	12	11	10	9	8
Read/Write	R	R	R	R	R	R	R	R
Reset Value	0	0	0	0	0	0	0	0
Content	reserved							

Bit	7	6	5	4	3	2	1	0
Read/Write	R	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Reset Value	0	0	0	0	0	0	0	0
Content	reserved	gyr_dp_dgain_y						

- Reserved write ‘0’
- Bit **[6:0]** GYR_DP_DGAIN_Y.gyr_dp_dgain_y : Data path register for the temperature independent gyroscope re-scale of axis y: covers ±12.5% of sensitivity.

7.17.2.50 Register (0x6A) GYR_DP_OFF_Z

Description: Data path register for the gyroscope offset of axis Z

Bit	15	14	13	12	11	10	9	8
Read/Write	R	R	R	R	R	R	R/W	R/W
Reset Value	0	0	0	0	0	0	0	0
Content							gyr_dp_off_z	

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	gyr_dp_off_z							

- Reserved write ‘0’
- Bit **[9:0]** GYR_DP_OFF_Z.gyr_dp_off_z : Data path register for the temperature independent gyroscope offset of axis z: 1 LSB = 0.061°/s; 0x200 -> invalid!

7.17.2.51 Register (0x6B) GYR_DP_DGAIN_Z

Description: Data path register for the gyroscope re-scale of axis Z

Bit	15	14	13	12	11	10	9	8
Read/Write	R	R	R	R	R	R	R	R
Reset Value	0	0	0	0	0	0	0	0
Content	reserved							

Bit	7	6	5	4	3	2	1	0
Read/Write	R	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Reset Value	0	0	0	0	0	0	0	0
Content	reserved	gyr_dp_dgain_z						

- Reserved write '0'
- Bit **[6:0]** GYR_DP_DGAIN_Z.gyr_dp_dgain_z : Data path register for the temperature independent gyroscope re-scale of axis z: covers ±12.5% of sensitivity.

7.17.2.52 Register (0x7E) CMD

Description: Command register

Bit	15	14	13	12	11	10	9	8
Read/Write	W	W	W	W	W	W	W	W
Reset Value	0	0	0	0	0	0	0	0
Content	cmd							

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	cmd							

- Bit **[15:0]** CMD.cmd : Available commands (Note: Register will always return 0x00 as read result) Following values can be sent to or read from the field cmd:

Definition of different commands:

Value	Description
0x100	Trigger the self-test of the device. Default scope of the self-test is a test of the accelerometer and gyroscope. Notes: an enabled feature engine is required; further settings are possible via the feature engine data interface.
0x101	Trigger the self-calibration of the gyroscope. Notes: an enabled feature engine is required; further settings are possible via the feature engine data interface

0x200	Abort a running self-calibration of the gyroscope
0x201	reserved
0x300	Axis mapping gets updated
0x301	User gain/offset gets updated
0xDEAF	Triggers a soft reset, that is all user configurations data registers are overwritten with their default state and the feature engine is reset

7.18 Extended Memory Map

The extended configuration and input/output of the feature engine has to be done through the feature engine data interface. The data can be read from or written through FEATURE_DATA_TX to an address in the extended register map configured in FEATURE_DATA_ADDR by a data exchange transaction. A transaction consists of writing the address to FEATURE_DATA_ADDR and then continuously reading all data from or writing all data to FEATURE_DATA_TX, see figure 33 When reading and writing data via this interface, there must be no communication to any other register before the read or write transaction is complete.

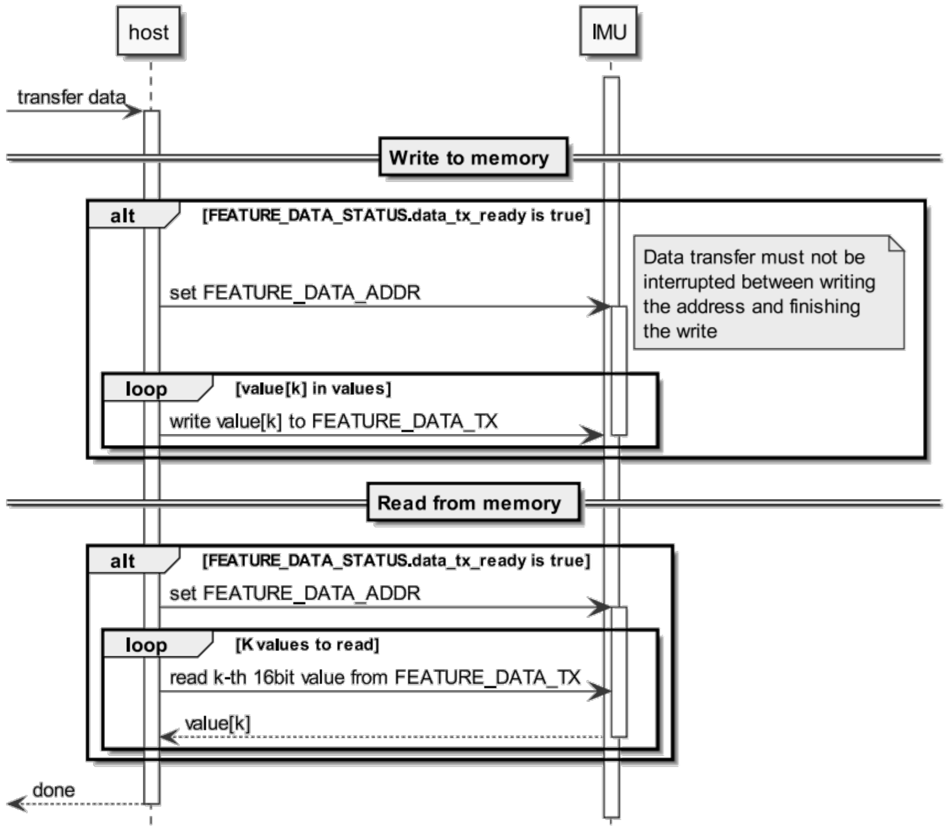

Figure 33 - Data transfer to and from the extended memory map

Otherwise, the written or received data is invalid. The status of the data transfer is reported in the register FEATURE_DATA_STATUS: · FEATURE_DATA_STATUS.data_tx_ready is set by the device to 0b1, if data can be read from or written to the device · FEATURE_DATA_STATUS.data_outofbound_err is set by the device to 0b1, if data is tried to be read from or written to outside the specified register address range.

7.18.1 Extended Register Map Overview

<table>
<tr><th colspan="3">Legend</th><th colspan="4">Read-only</th><th colspan="4">Read/Write</th><th colspan="4">Write-only</th><th colspan="4">Reserved</th></tr>
<tr><th>Addr</th><th>Name</th><th>Reset Value</th><th>Bit15</th><th>Bit14</th><th>Bit13</th><th>Bit12</th><th>Bit11</th><th>Bit10</th><th>Bit9</th><th>Bit8</th><th>Bit7</th><th>Bit6</th><th>Bit5</th><th>Bit4</th><th>Bit3</th><th>Bit2</th><th>Bit1</th><th>Bit0</th></tr>
<tr><td>0x02</td><td>GEN_SET_1</td><td>0x0006</td><td colspan="10">reserved</td><td>sw_lock</td><td colspan="4">int_hold_dur</td><td>event_report_mode</td></tr>
<tr><td>0x05</td><td>ANYMO_1</td><td>0x100A</td><td colspan="3">reserved</td><td>acc_ref_up</td><td colspan="12">slope_thres</td></tr>
<tr><td>0x06</td><td>ANYMO_2</td><td>0x0002</td><td colspan="6">reserved</td><td colspan="10">hysteresis</td></tr>
<tr><td>0x07</td><td>ANYMO_3</td><td>0x600A</td><td colspan="3">wait_time</td><td colspan="13">duration</td></tr>
<tr><td>0x08</td><td>NOMO_1</td><td>0x100A</td><td colspan="3">reserved</td><td>acc_ref_up</td><td colspan="12">slope_thres</td></tr>
<tr><td>0x09</td><td>NOMO_2</td><td>0x0002</td><td colspan="6">reserved</td><td colspan="10">hysteresis</td></tr>
<tr><td>0x0A</td><td>NOMO_3</td><td>0x600A</td><td colspan="3">wait_time</td><td colspan="13">duration</td></tr>
<tr><td>0x21</td><td>TILT_1</td><td>0xD264</td><td colspan="8">min_tilt_angle</td><td colspan="8">segment_size</td></tr>
<tr><td>0x22</td><td>TILT_2</td><td>0xF069</td><td colspan="16">beta_acc_mean</td></tr>
<tr><td>0x23</td><td>ALT_CONFIG_CHG</td><td>0x0000</td><td colspan="8">reserved</td><td colspan="4">alt_conf_user_switch_src_select</td><td colspan="4">alt_conf_alt_switch_src_select</td></tr>
<tr><td>0x24</td><td>ST_RESULT</td><td>0x0000</td><td colspan="9">reserved</td><td>gyr_drive_ok</td><td>gyr_sens_z_ok</td><td>gyr_sens_y_ok</td><td>gyr_sens_x_ok</td><td>acc_sens_z_ok</td><td>acc_sens_y_ok</td><td>acc_sens_x_ok</td></tr>
<tr><td>0x25</td><td>ST_SELECT</td><td>0x0003</td><td colspan="14">reserved</td><td>gyr_st_en</td><td>acc_st_en</td></tr>
<tr><td>0x26</td><td>GYR_SC_SELECT</td><td>0x0007</td><td colspan="13">reserved</td><td>apply_corr</td><td>offs_en</td><td>sens_en</td></tr>
<tr><td>0x27</td><td>GYR_SC_ST_CONF</td><td>0x0B76</td><td>reserved</td><td colspan="2">gyr_sc_st_conf_res</td><td colspan="5">offs_filtercoeff</td><td colspan="2">sens_filtercoeff</td><td colspan="6">reserved</td></tr>
<tr><td>0x35</td><td>GYR_MOT_DET</td><td>0x0000</td><td colspan="11">reserved</td><td colspan="5">slope</td></tr>
<tr><td>0x3F</td><td>UGAIN_OFF_SEL</td><td>0x0000</td><td colspan="14">reserved</td><td>gyr_off_gain_reset</td><td>acc_off_gain_reset</td></tr>
</table>

7.18.2 Registers Extended Memory Map

7.18.2.1 Register (0x02) GEN_SET_1

Description: Common register settings

Bit	15	14	13	12	11	10	9	8
Read/Write	R	R	R	R	R	R	R	R
Reset Value	0	0	0	0	0	0	0	0
Content	reserved							

Bit	7	6	5	4	3	2	1	0
Read/Write	R	R	R/W	R/W	R/W	R/W	R/W	RW
Reset Value	0	0	0	0	0	1	1	0
Content	reserved		sw_lock	int_hold_dur				event_report_mode

- Reserved: write ‘0’
- Bit **[0]** GEN_SET_1.event_report_mode : Configuration of the reporting mode

Definition of parameter properties:

Value	Description
0x0 [00]	All detected events are reported
0x1 [01]	Report first detected event, then keep silent

- Bit **[4:1]** GEN_SET_1.int_hold_dur : Interrupt hold time duration. Range 0 to 13. Hold time = 0.625ms * (2 ^interrupt_hold_duration) i.e 0.625ms to 5120ms. If set above 13, then hold time input is considered as 13. Default is 5ms. The hold time is only applicable for the auto operation mode interrupts in non-latched mode. Deviation up to +/- 1.25ms + ODR accuracy deviation.
- Bit **[5]** GEN_SET_1.sw_lock : Reserved

7.18.2.2 Register (0x05) ANYMO_1

Description: Configuration of acceleration slope threshold and reference update mode

Bit	15	14	13	12	11	10	9	8
Read/Write	R	R	R	R/W	R/W	R/W	R/W	R/W
Reset Value	0	0	0	1	0	0	0	0
Content	reserved			acc_ref_up	slope_thres			

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	RW
Reset Value	0	0	0	0	1	0	1	0
Content	slope_thres							

- Reserved: write ‘0’
- Bit **[11:0]** ANYMO_1.slope_thres : Minimum slope of acceleration signal for motion detection.

Definition of parameter properties:

Property	Value
Bitwidth	12
Sign	unsigned
Unit	[g]
Scaling (Default value)	512 (10/512)
Range	Min=0.0 | Max=7.998046875

- Bit **[12]** ANYMO_1.acc_ref_up : Mode of the acceleration reference update.

Definition of register information:

Value	Description
0x0 [00]	On detection of the event
0x1 [01]	On update of acceleration signal

7.18.2.3 Register (0x06) ANYMO_2

Description: Configuration for hysteresis of acceleration slope

Bit	15	14	13	12	11	10	9	8
Read/Write	R	R	R	R	R	R	R/W	R/W
Reset Value	0	0	0	0	0	0	0	0
Content	reserved						hysteresis	

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	RW
Reset Value	0	0	0	0	0	0	1	0
Content	hysteresis							

- Reserved: write ‘0’
- Bit **[9:0]** ANYMO_2.hysteresis :Hysteresis for the slope of acceleration signal for motion detection.

Definition of parameter properties:

Property	Value
Bitwidth	10
Sign	unsigned
Unit	[g]
Scaling (Default value)	512 (2/512)
Range	Min=0.0 | Max=1.998046875

7.18.2.4 Register (0x07) ANYMO_3

Description: Configuration of timing related parameters for any motion detection

Bit	15	14	13	12	11	10	9	8
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Reset Value	0	1	1	0	0	0	0	0
Content	wait_time			duration				

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	RW
Reset Value	0	0	0	0	1	0	1	0
Content	duration							

- Bit **[12:0]** ANYMO_3.duration : Minimum duration for which the slope shall be greater than threshold for motion detection

Definition of parameter properties:

Property	Value
Bitwidth	13
Sign	unsigned
Unit	[s]
Scaling (Default value)	50 (0.2)
Range	Min=0.0 | Max=163.82

- Bit **[15:13]** ANYMO_3.wait_time : Wait time for clearing the event after slope is below threshold

Definition of parameter properties:

Property	Value
Bitwidth	3
Sign	unsigned
Unit	[s]
Scaling (Default value)	50 (0.06)
Range	Min=0.0 | Max=0.14

7.18.2.5 Register (0x08) NOMO_1

Description: Configuration of acceleration slope threshold and reference update mode

Bit	15	14	13	12	11	10	9	8
Read/Write	R	R	R	R/W	R/W	R/W	R/W	R/W
Reset Value	0	0	0	1	0	0	0	0
Content	reserved			acc_ref_up	slope_thres			

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	RW
Reset Value	0	0	0	0	1	0	1	0
Content	slope_thres							

- Reserved: write ‘0’
- Bit **[11:0]** NOMO_1.slope_thres : Minimum slope of acceleration signal for no motion detection.

Definition of parameter properties:

Property	Value
Bitwidth	12
Sign	unsigned
Unit	[g]
Scaling (Default value)	512 (10/512)
Range	Min=0.0 | Max=7.998046875

- Bit **[12]** NOMO_1.acc_ref_up : Mode of the acceleration reference update.

Definition of register information:

Value	Description
0x0 [00]	On detection of the event
0x1 [01]	On update of acceleration signal

7.18.2.6 Register (0x09) NOMO_2

Description: Configuration for hysteresis of acceleration slope

Bit	15	14	13	12	11	10	9	8
Read/Write	R	R	R	R	R	R	R/W	R/W
Reset Value	0	0	0	0	0	0	0	0
Content	reserved						hysteresis	

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	RW
Reset Value	0	0	0	0	0	0	1	0
Content	hysteresis							

- Reserved: write ‘0’
- Bit **[9:0]** NOMO_2.hysteresis :Hysteresis for the slope of acceleration signal.

Definition of parameter properties:

Property	Value
Bitwidth	10
Sign	unsigned
Unit	[g]
Scaling (Default value)	512 (2/512)
Range	Min=0.0 | Max=1.998046875

7.18.2.7 Register (0x0A) NOMO_3

Description: Configuration of timing related parameters for any motion detection

Bit	15	14	13	12	11	10	9	8
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Reset Value	0	1	1	0	0	0	0	0
Content	wait_time			duration				

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	RW
Reset Value	0	0	0	0	1	0	1	0
Content	duration							

- Bit **[12:0]** NOMO_3.duration : Minimum duration for which the slope shall be greater than threshold for no motion detection

Definition of parameter properties:

Property	Value
Bitwidth	13
Sign	unsigned
Unit	[s]
Scaling (Default value)	50 (0.2)
Range	Min=0.0 | Max=163.82

- Bit **[15:13]** NOMO_3.wait_time : Wait time for clearing the event after slope is below threshold

Definition of parameter properties:

Property	Value
Bitwidth	3
Sign	unsigned
Unit	[s]
Scaling (Default value)	50 (0.06)
Range	Min=0.0 | Max=0.14

7.18.2.8 Register (0x21) TILT_1

Description: Configuration for averaging duration of reference vector and minimum tilt angle

Bit	15	14	13	12	11	10	9	8
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Reset Value	1	1	0	1	0	0	1	0
Content	min_tilt_angle							

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	RW
Reset Value	0	1	1	0	0	1	0	0
Content	segment_size							

- Bit **[7:0]** TILT_1.segment_size : Duration for which the acceleration vector is averaged to be reference vector

Definition of parameter properties:

Property	Value
Bitwidth	8
Sign	unsigned
Unit	[s]
Scaling (Default value)	50 (2.0s)
Range	Min=0.0 | Max=5.10

Bit width of duration, 8 bits with value range [0, 255] -> 255/50 = 5.1sec

- Bit **[15:8]** TILT_1.min_tilt_angle : Minimum tilt angle for event detection

Definition of parameter properties:

Property	Value
Bitwidth	8
Sign	unsigned
Unit	[°] deg
Scaling (Default value)	256 (210 ≙ 35°)
Range	Min=0.0 | Max=90
Interpretation	val[LSB] = 256*cos([deg]*π/180)

7.18.2.9 Register (0x22) TILT_2

Description: Configuration for averaging of acceleration vector

Bit	**15**	**14**	**13**	**12**	**11**	**10**	**9**	**8**
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Reset Value	1	1	1	1	0	0	0	0
Content	beta_acc_mean							

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	RW
Reset Value	0	1	1	0	1	0	0	1
Content	beta_acc_mean							

- Bit **[15:0]** TILT_2.beta_acc_mean : Exponential smoothing coefficient for computing low-pass mean of acceleration vector

Definition of parameter properties:

Property	**Value**
Bitwidth	16
Sign	unsigned
Scaling (Default value)	65536 (61545)
Interpretation	val[LSB] =exp(-2*π/(50*x))*65536

This parameter directly correlates with the duration configuration TILT_1.segment_size where x = duration in seconds.

7.18.2.10 Register (0x23) ALT_CONFIG_CHG

Description: Conditions to switch to alternate or user config of the sensors

Bit	15	14	13	12	11	10	9	8
Read/Write	R	R	R	R	R	R	R	R
Reset Value	0	0	0	0	0	0	0	0
Content	reserved							

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	alt_conf_user_switch_src_select				alt_conf_alt_switch_src_select			

- Reserved write ‘0’
- Bit **[3:0]** ALT_CONFIG_CHG.alt_conf_user_switch_src_select : Selection of int (none = 0, A,B,H) for switch to alternate configuration mode for both accel and gyro. Invalid values will be ignored and the last valid configuration will remain. Note: Based on the selection in ’alt_conf_alt_switch_src_select’ and ’alt_conf_user_switch_src_select’ the state transition may happen immediately into the selected mode according to the events detected by the feature engine.

Value	Description
0b0000(0x0)	None selected
0b0001(0x1)	A = No motion detection
0b0010(0x2)	B = Any motion detection
0b1000(0x8)	H = Tilt detection

- Bit **[7:4]** ALT_CONFIG_CHG.alt_conf_alt_switch_src_select : Selection of interrupt (none = 0, A; B; H) for switch to user configuration mode for both accel and gyro. Invalid values will be ignored and the last valid configuration will remain. Note: Based on the selection in ’alt_conf_alt_switch_src_select’ and ’alt_conf_user_switch_src_select’ the state transition may happen immediately into the selected mode according to the events detected by the feature engine.

Value	Description
0b0000(0x0)	None selected
0b0001(0x1)	A = No motion detection
0b0010(0x2)	B = Any motion detection
0b1000(0x8)	H = Tilt detection

7.18.2.11 Register (0x24) ST_RESULT

Description: Self-test (Accelerometer and Gyroscope) results

Bit	15	14	13	12	11	10	9	8
Read/Write	R	R	R	R	R	R	R	R
Reset Value	0	0	0	0	0	0	0	0
Content	reserved							

Bit	7	6	5	4	3	2	1	0
Read/Write	R	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Reset Value	0	0	0	0	0	0	0	0
Content	reserved	gyr_drive_ok	gyr_sens_z_ok	gyr_sens_y_ok	gyr_sens_x_ok	acc_sens_z_ok	acc_sens_y_ok	acc_sens_x_ok

- Reserved: write ‘0’
- Bit **[0]** ST_RESULT.acc_sens_x_ok : Self-test of accelerometer X-axis
- Bit **[1]** ST_RESULT.acc_sens_y_ok : Self-test of accelerometer Y-axis
- Bit **[2]** ST_RESULT.acc_sens_z_ok : Self-test of accelerometer Z-axis
- Bit **[3]** ST_RESULT.gyr_sens_x_ok : Self-test of gyroscope X-axis
- Bit **[4]** ST_RESULT.gyr_sens_y_ok : Self-test of gyroscope Y-axis
- Bit **[5]** ST_RESULT.gyr_sens_z_ok : Self-test of gyroscope Z-axis
- Bit **[6]** ST_RESULT.gyr_drive_ok : Self-test of gyroscope drive

7.18.2.12 Register (0x25) ST_SELECT

Description: Self-test (Accelerometer and Gyroscope) type selection

Bit	15	14	13	12	11	10	9	8
Read/Write	R	R	R	R	R	R	R	R
Reset Value	0	0	0	0	0	0	0	0
Content	reserved							

Bit	7	6	5	4	3	2	1	0
Read/Write	R	R	R	R	R	R	R/W	R/W
Reset Value	0	0	0	0	0	0	1	1
Content	reserved						gyr_st_en	acc_st_en

- Reserved: write ‘0’
- Bit **[0]** ST_SELECT.acc_st_en : Enable self-test of accelerometer
- Bit **[1]** ST_SELECT.gyr_st_en : Enable self-test of gyroscope

7.18.2.13 Register (0x26) GYR_SC_SELECT

Description: Type selection for gyroscope self-calibration

Bit	15	14	13	12	11	10	9	8
Read/Write	R	R	R	R	R	R	R	R
Reset Value	0	0	0	0	0	0	0	0
Content	reserved							

Bit	7	6	5	4	3	2	1	0
Read/Write	R	R	R	R	R	R	R/W	R/W
Reset Value	0	0	0	0	0	1	1	1
Content	reserved					apply_corr	offs_en	sens_en

- Reserved: write '0'
- Bit **[0]** GYR_SC_SELECT.sens_en : Enable self-calibration for gyroscope sensitivity
- Bit **[1]** GYR_SC_SELECT.offs_en : Enable self-calibration for gyroscope offset
- Bit **[2]** GYR_SC_SELECT.apply_corr : Apply correction of offset and/or sensitivity error calculated by gyroscope self-calibration feature

7.18.2.14 Register (0x27) GYR_SC_ST_CONF

Description: Gyroscope self-calibration and self-test configuration and result register

Bit	15	14	13	12	11	10	9	8
Read/Write	R	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Reset Value	0	0	0	0	1	0	1	1
Content	reserved	gyr_sc_st_conf_res		offs_filtercoeff				sens_filtercoeff

Bit	7	6	5	4	3	2	1	0
Read/Write	R/W	R/W	R	R	R	R	R	R
Reset Value	0	1	0	0	0	0	0	0
Content	sens_filtercoeff		reserved					

- Reserved: write '0'
- Bit **[8:6]** GYR_SC_ST_CONF.sens_filtercoeff : Filter coefficient of low pass filter used during gyroscope sensitivity self-calibration and self-test. Range = 3 to 6. Number of gyroscope samples (@1600Hz) averaged = 2*(2^(sens_filtercoeff+2)).
- Bit **[12:9]** GYR_SC_ST_CONF.offs_filtercoeff : Filter coefficient of low pass filter used during gyroscope offset self-calibration. Range = 3 to 11. Number of gyroscope samples (@1600Hz) averaged = 2^(offs_filtercoeff+2).
- Bit **[2]** GYR_SC_ST_CONF.gyr_sc_st_conf_res : res

7.18.2.15 Register (0x35) GYR_MOT_DET

Description: Motion detection threshold common for both gyroscope self-calibration and gyroscope self-test

Bit	15	14	13	12	11	10	9	8
Read/Write	R	R	R	R	R	R	R	R
Reset Value	0	0	0	0	0	0	0	0
Content	reserved							

Bit	7	6	5	4	3	2	1	0
Read/Write	R	R	R	R/W	R/W	R/W	R/W	R/W
Reset Value	0	0	0	0	0	0	0	0
Content	reserved			slope				

- Reserved: write '0'
- Bit **[4:0]** GYR_MOT_DET.slope : Maximum acceptable acceleration change between two samples. Range= 0 to 31. Value = 10mg + slope*5mg.

7.18.2.16 Register (0x3F) UGAIN_OFF_SEL

Description: Reset bits for user gain / offset update

Bit	15	14	13	12	11	10	9	8
Read/Write	R	R	R	R	R	R	R	R
Reset Value	0	0	0	0	0	0	0	0
Content	reserved							

Bit	7	6	5	4	3	2	1	0
Read/Write	R	R	R	R	R	R	R/W	R/W
Reset Value	0	0	0	0	0	0	0	0
Content	reserved						gyr_off_gain_reset	acc_off_gain_reset

- Reserved: write '0'
- Bit **[0]** UGAIN_OFF_SEL.acc_off_gain_reset : Accelerometer offset and gain reset
- Bit **[1]** UGAIN_OFF_SEL.gyr_off_gain_reset : Gyroscope offset and gain reset

8 Product Safety

8.1 Functional Safety

N.A.

8.1.1 Saftey Concept

N.A.

8.1.2 Dedicated Measures

N.A.

8.2 Data Protection, Cyber Security and Over-the-Air Aspects

N.A.

9 Functional and Lifetime Qualification Text Plan

The SMI330 is tested according to the qualification plan AEC-Q100 rev H grade 1.

Any mission profile applied to the sensor must be verified if it is covered by the qualification.

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

Target market: 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 to ISO-3166-1, ALPHA-2 Code).

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.

Functional Safety: Bosch points out that the SMI330 has been developed according to QM and does not implement any ASIL-classified requirements (in the sense of ISO 26262). It is therefore not approved by Bosch for applications in which one or more requirements with an ASIL classification (above QM) are assigned to the Bosch scope of supply.

The customer has to ensure that the SMI330 is suitable to be used within the overall system regarding any functional safety requirements assigned to the SMI330 in the overall system.
This implies the following limitations:

- The SMI330 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 SMI330.
- The SMI330 does not provide a CRC to check communication errors within a SPI/I2C/I3C frame.
- The SMI330 does not provide error flags to detect malfunctions of the ASIC.

Repair of the product is not permitted. 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.
Products are considered good if they fulfill the specifications / test data for 0-mileage and field listed in the TCD.

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.

10.1 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.

11 Changes

Release	Date	Edited by	Release description
V0.1	7-dec-2023	Anstett PAS1.3	Initial preliminary version
V1.0	8-oct-2024	Anstett PAE-A3	V1 preliminary datasheet
V1.1	8-nov-2024	Anstett PAE-A3	Added chapter 4.2 passive storage duration
V1.2	5-mar-2025	Anstett PAE-A3	Official release datasheet incl life time tolerances

12 Terms and Definitions

13 Table of Figures

14 Contact Person

- Contact person: [ME-SE/PAE-A3 - Anstett]

Robert Bosch GmbH

ME-SE/PAE-A3

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