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Data sheet

BMG250
Low noise, low power triaxial gyroscope

Bosch Sensortec

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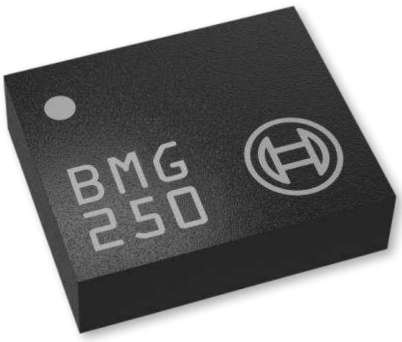
Invented for life



BMG250 – Data sheet

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BMG250
Low noise, low power triaxial gyroscope

The BMG250 is a low noise, low power three axial gyroscope that provides a precise angular rate (gyroscopic) measurement at market leading low power consumption.

The BMG250 is a 16 bit digital, triaxial gyroscope sensor.

Key features
- High performance low noise and low offset gyroscope
- Very low power consumption: typ. 850 µA (gyroscope in full operation)
- Very small 2.5 x 3.0 mm^2 footprint, height 0.83 mm
- Secondary high speed interface for OIS application
  - Optimized for low latency and high Output Data Rate
- Parallel use for OIS and standard UI applications
  - UI → Primary Interface (I^{2}C)
  - OIS → Secondary Interface (SPI)
- Built-in power management unit (PMU) for advanced power management
- Power saving with fast start-up mode of gyroscope
- Wide power supply range: 1.71V ... 3.6V
- Allocatable FIFO buffer of 1024 bytes
- Hardware sensor time-stamps for accurate sensor data fusion
- Flexible digital interface to connect to host over I^{2}C or SPI
- Extended I^{2}C mode with clock frequencies up to 1 MHz

Typical applications
- Optical Image Stabilization
- Electronic Image Stabilization
- Optical/Electronic Video Stabilization
- Augmented Reality
- Indoor navigation
- 3D scanning / indoor mapping
- Advanced gesture recognition
- Immersive gaming
- 3-axis motion detection, e.g. Air mouse applications and pointers
- Advanced system power management for mobile applications
- warranty logging

Target Devices
- Smart phones, tablet and transformer PCs
- Camera modules for Smartphones
- Digital Still Cameras / Digital Video Cameras
- Game controllers, remote controls and pointing devices
- Head tracking devices
- Wearable devices, e.g. smart watches or augmented reality glasses
- Sport and fitness devices
- Toys, e.g. toy helicopters

General Description

The BMG250 is a three axial gyroscope consisting of a state-of-the-art low power 3-axis gyroscope. It has been designed for low power, high precision multi-axis applications in mobile phones, tablets, wearable devices, remote controls, game controllers, head-mounted devices and toys. The BMG250 is available in a compact 2.5 × 3.0 × 0.83 mm^3 LGA package. When the gyroscope is in full operation mode, power consumption is typically 850 µA, enabling always-on applications in battery driven devices. The BMG250 offers a wide V_{DD} voltage range from 1.71V to 3.6V and a V_{DDIO} range from 1.2V to 3.6V, allowing the BMG250 to be powered at 1.8V for both V_{DD} and V_{DDIO}.

The BMG250 provides high precision sensor data together with the accurate timing of the corresponding data. The timestamps have a resolution of up to 39 µs.

The integrated 1024 byte FIFO buffer supports low power applications and prevents data loss in non-real-time systems. The intelligent FIFO architecture allows dynamic reallocation of FIFO space. For typical applications, this is sufficient for approx. 1.4s of data capture at an output data rate of 100Hz in FIFO mode with data header.

The smart built-in power management unit (PMU) can be configured, for example, to further lower the power consumption by automatically sending the gyroscope temporarily into fast start-up mode and waking it up again by externally triggering this function from the host device's logical unit.

Besides the flexible primary interface (I^2C or SPI) that is used to connect to the host, BMG250 provides an additional secondary interface. This secondary interface can be used in SPI mode for OIS (optical image stabilization) applications in conjunction with camera modules, or in advanced gaming use cases.

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1. Contents

2. Specification

If not stated otherwise, the given values are over lifetime and full performance temperature and voltage ranges, minimum/maximum values are ±3σ.

2.1 Electrical specification

VDD and VDDIO can be ramped in arbitrary order without causing the device to consume significant currents. The values of the voltage at VDD and the VDDIO pins can be chosen arbitrarily within their respective limits. The device only operates within specifications if the both voltages at VDD and VDDIO pins are within the specified range. The voltage levels at the digital input pins must not fall below GNDIO-0.3V or go above VDDIO+0.3V to prevent excessive current flowing into the respective input pin. BMG250 contains a brownout detector, which ensures integrity of data in the non-volatile memory under all operating conditions.

Table 1: Electrical parameter specification

OPERATING CONDITIONS BMG250						
Parameter	**Symbol**	**Condition**	**Min**	**Typ**	**Max**	**Unit**
Supply Voltage Internal Domains	V_{DD}		1.71	3.0	3.6	V
Supply Voltage I/O Domain	V_{DDIO}		1.2	2.4	3.6	V
Voltage Input Low Level	$V_{IL,a}$	SPI			$0.3V_{DDIO}$	-
Voltage Input High Level	$V_{IH,a}$	SPI	$0.7V_{DDIO}$			-
Voltage Output Low Level	$V_{OL,a}$	V_{DDIO}=1.62V, I_{OL}=3mA, SPI			$0.2V_{DDIO}$	-
		V_{DDIO}=1.2V, I_{OL}=3mA, SPI			$0.23V_{DDIO}$	-
Voltage Output High Level	$V_{OH,a}$	V_{DDIO}=1.62V, I_{OH}=3mA, SPI	$0.8V_{DDIO}$			-
		V_{DDIO}=1.2V, I_{OH}=3mA, SPI	$0.62V_{DDIO}$			-
Operating Temperature	T_A		-40		+85	°C
NVM write-cycles	n_{NVM}	Non-volatile memory	14			Cycles
Current consumption	I_{DD}	Gyro in fast start-up, T_A=25°C		500		µA
		Gyro full operation mode T_A=25°C		850		
		Gyro in suspend mode, T_A=25°C		3		

2.2 Electrical and physical characteristics, measurement performance

Table 3: Electrical characteristics gyroscope

Parameter	Symbol	Condition	Min	Typ	Max	Unit
OPERATING CONDITIONS GYROSCOPE						
Range	R_{FS125}	Selectable via serial digital interface		125		°/s
	R_{FS250}			250		°/s
	R_{FS500}			500		°/s
	R_{FS1000}			1,000		°/s
	R_{FS2000}			2,000		°/s
Range (Secondary interface)	R_{FSOIS}	Fixed range setting		2,000		°/s
Start-up time	$t_{G,su}$	Suspend to normal mode ODR_G=1600Hz		55	80	ms
	$t_{G,FS}$	Fast start-up to normal mode		10	15	ms
OUTPUT SIGNAL GYROSCOPE						
Sensitivity	R_{FSOIS}	Ta=25°C		16.4		LSB/°/s
	R_{FS2000}	Ta=25°C		16.4		LSB/°/s
	R_{FS1000}	Ta=25°C		32.8		LSB/°/s
	R_{FS500}	Ta=25°C		65.6		LSB/°/s
	R_{FS250}	Ta=25°C		131.2		LSB/°/s
	R_{FS125}	Ta=25°C		262.4		LSB/°/s
Sensitivity change over temperature	TCS_G	R_{FS2000}, Nominal V_{DD} supplies best fit straight line		±0.02		%/K
Nonlinearity	NL_G	Best fit straight line R_{FS1000}, R_{FS2000}		0.1		%FS
g- Sensitivity		Sensitivity to acceleration stimuli in all three axis (frequency <20kHz)			0.1	°/s/g
Zero-rate offset	Off Ω_x Ω_y and Ω_z	T_A=25°C, fast offset compensation off		±3		°/s
Zero-Rate offset Over temperature	Off $\Omega_{x,oT}$ $\Omega_{y,oT}$ and $\Omega_{z,oT}$	-40°C ≤ T_A ≤+85°C		±3		°/s
Zero-rate offset change over temperature	TCO_G	-40°C ≤ T_A ≤+85°C, best fit straight line		0.05		°/s/K

Output Noise	$n_{G,nD}$	@10 Hz		0.007		°/s/√Hz
	$n_{G,rms}$	Filter setting 74.6Hz, ODR 200 Hz		0.07		°/s rms
Bias stability	BS_G			10		°/h
Output Data Rate (set of x,y,z rate)	ODR_G		25		3200	Hz
Output Data Rate (set of x,y,z rate)	ODR_{OIS}	Fixed setting		6400		Hz
Output Data rate accuracy (set of x,y,z rate)	$AODR_G$	Over whole operating temperature range		±1		%
Cross Axis Sensitivity	$X_{G,S}$	Sensitivity to stimuli in non-sense-direction			2	%

Table 4: Electrical characteristics temperature sensor

OPERATING CONDITIONS AND OUTPUT SIGNAL OF TEMPERATURE SENSOR						
Parameter	**Symbol**	**Condition**	**Min**	**Typ**	**Max**	**Unit**
Temperature Sensor Measurement Range	T_S		-40		85	°C
Temperature Sensor Slope	dT_S			0.002		K/LSB
Temperature Sensor Offset	OT_S			±2		K
Output Data Rate	ODR_T	gyro in fast start-up		0.8		Hz
		Gyro active		100		Hz
Resolution	n_T	gyro in fast start-up		8		bit
		Gyro active		16		Bit

2.3 Absolute maximum ratings

Table 5: Absolute maximum ratings

Parameter	Condition	Min	Max	Units
Voltage at Supply Pin	V_{DD} Pin	-0.3	4.25	V
	V_{DDIO} Pin	-0.3	4.25	V
Voltage at any Logic Pin	Non-Supply Pin	-0.3	V_{DDIO}+0.3	V
Passive Storage Temp. Range	≤65% rel. H.	-50	+150	°C
None-volatile memory (NVM) Data Retention	T = 85°C, after 15 cycles	10		y
Mechanical Shock	Duration 200 µs, half sine		10,000	g
	Duration 1.0 ms, half sine		2,000	g
	Free fall onto hard surfaces		1.8	m
ESD	HBM, at any Pin		2	kV
	CDM		500	V
	MM		200	V

Note: Stress above these limits may cause damage to the device. Exceeding the specified electrical limits may affect the device reliability or cause malfunction.

3. Functional Description

3.1 Block diagram

The figure below depicts the dataflow in BMG250:

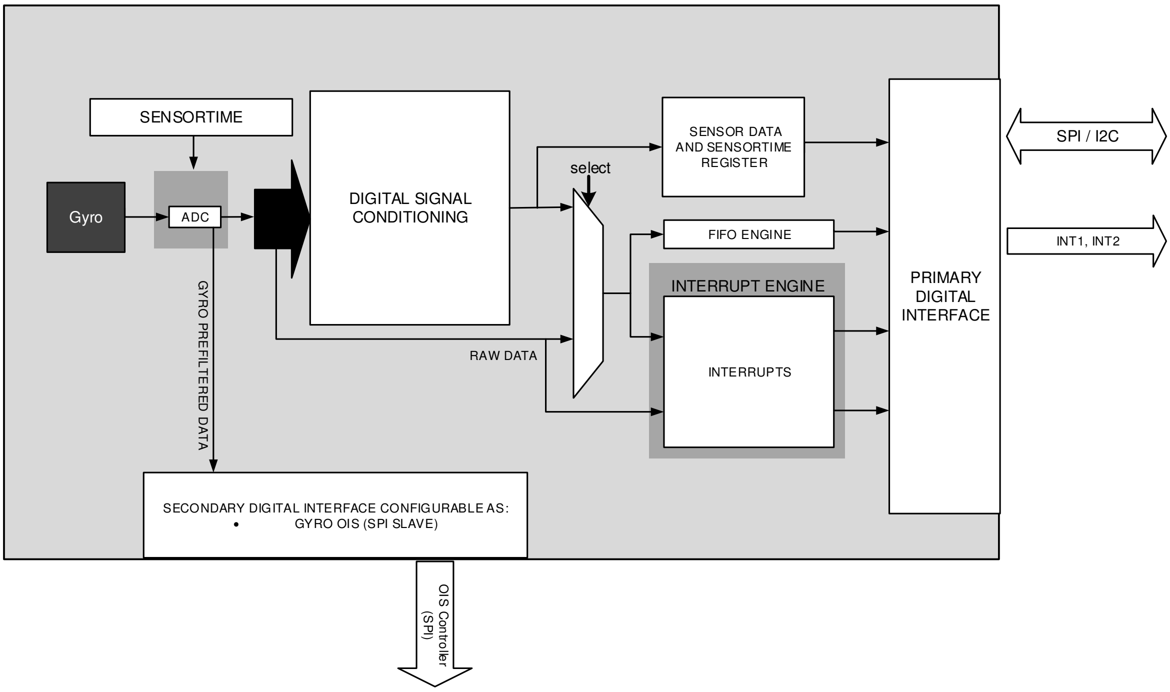

Figure 1: Block diagram of data flow

The pre-filtered input data may be already temperature compensated or other low level correction operations may be applied to them.
The data from the sensor are always sampled with a data rate of 6400 Hz. The data are low pass filtered at an output data rate as configured in the Register (0x42) GYR_CONF. In addition further down sampling for the interrupt engines and the FIFO is possible and configured in the Register (0x45) FIFO_DOWNS. This down sampling discards data frames.
The sensor time is synchronized with the update of the data register.

3.2 Power modes

By default the BMG250 is in suspend mode after powering up the device. From there, the device will start-up to normal mode within 50ms typically. Alternatively, the device may be also held in Fast Start-up mode. The device is powering up from Fast Start-up mode in less than 10ms.

Three power modes are supported:

Gyroscope

- **Normal mode:** full chip operation
- **Suspend mode**: No sampling takes place, all data is retained, and delays between subsequent I^2C operations are allowed. FIFO data readout is not supported in suspend mode.
- **Fast start-up mode:** start-up delay time to normal mode ≤10 ms. FIFO data readout is supported in fast start-up mode, although the data will only be generated during normal mode. This means data generated in normal mode can be read after the BMG250 has been switched to fast start-up mode. After the end of valid data is reached only values of 0x8000 can be read, which should be interpreted as “FIFO empty”. If the measured rate would be 0x8000 in reality, a 0x8001 is generated.

Table 6: Power modes of BMG250

full operation mode	Normal mode
Sleep modes	Fast Start-up mode
	Suspend mode

Suspend and fast start-up modes are *sleep modes*. Switching between normal and fast start-up mode will stop sampling of data. No valid data can be sampled in fast start-up mode. However, previously collected data in normal mode can still be read. The system can be switched from fast start-up mode to normal mode within 10ms to again sample data.

3.2.1 Suspend mode

In suspend mode, the MEMS sensor is powered off but the digital circuitry is still active.

Note:
When the sensor is in suspend or fast start-up mode, burst writes are not supported, normal writes need wait times after the write command is issued (~400 μs), and burst reads are not supported on Register (0x24) FIFO_DATA.

3.2.2 Fast start-up mode

In **fast start-up mode** the sensing analog part is powered down, while the drive and the digital part remains largely operational. No data acquisition is performed. The latest rate data and the content of all configuration registers are kept. The fast start-up mode allows a fast transition (≤10 ms) into normal mode while keeping power consumption significantly lower than in normal mode.

3.2.3 Transitions between power modes

With regard to the below diagram, transitions are allowed between any power mode.

Table 7: Typical total current consumption in µA according to the gyroscope's modes

		Current consumption in µA
Gyroscope Mode	Suspend	3
	Fast Start-up	500
	Normal	850

The power mode setting can be configured independently from the output data rate set. The main difference between normal and Fast Start-up mode is the power consumption which is in the Fast Start-up mode determined by the drive circuitry and the IO communication.

3.2.4 PMU (Power Management Unit)

The integrated PMU (Power Management Unit) allows advanced power management features by combining power management features of the sensor and externally available wake-up devices. See chapter 3.6.2 PMU Trigger (Gyro).

3.2.4.1 Automatic gyroscope power mode changes

To further lower the power consumption, the gyroscope may be configured to be temporarily put into sleep mode, which is in BMG250 configurable as suspend or fast-start-up mode. To configure this feature Register (0x6C) PMU_TRIGGER is used.

3.3 Sensor Timing and Data synchronization

3.3.1 Sensor Time

The Register (0x18-0x1A) SENSORTIME is a free running counter, which increments with a resolution of 39 µs. All sensor events e.g. updates of data registers are synchronous to this register as defined in the table below. With every update of the data register or the FIFO, a bit *m* in the Register (0x18-0x1A) SENSORTIME toggles where *m* depends on the output data rate for the data register and the output data rate and the FIFO down sampling rate for the FIFO. The table below shows which bit toggles for which update rate of data register and FIFO. The time stamps in Register (0x18-0x1A) SENSORTIME are available independent of the power mode the device is in.

Table 11: Sensor time

Bit *m* in sensor_time	Resolution [ms]	Update rate [Hz]
0	0.039	25641
1	0.078	12820
2	0.156	6400
3	0.3125	3200
4	0.625	1600
5	1.25	800
6	2.5	400
7	5	200
8	10	100
9	20	50
10	40	25
11	80	12.5
12	160	6.25
13	320	3.125
14	640	1.56
15	1280	0.78
16	2560	0.39
17	5120	0.20
18	10240	0.10
19	20480	0.049
20	40960	0.024
21	81920	0.012
22	163840	0.0061
23	327680	0.0031

3.4 Data Processing

The digital filter can be configured through the parameters: *gyr_bwp* and *gyr_odr.* There is no undersampling parameter for the gyroscope.

Note:
Illegal settings in configuration registers will result in an error code in the Register (0x02) ERR_REG. The content of the data register is undefined, and if the FIFO is used, it may contain no value.

3.4.1 Data Processing

The gyroscope data can only be processed in normal power mode.
There are three data processing modes defined by gyr_bwp. Normal mode, OSR2, OSR4. For details see chapter 3.4.1.1.

3.4.1.1 Gyroscope data processing for normal power mode

When the filter mode is set to normal (gyr_bwp=0b010), the gyroscope data is sampled at equidistant points in the time, defined by the gyroscope output data rate parameter (gyr_odr). The output data rate can be configured in one of eight different valid ODR configurations going from 25Hz up to 3200Hz.

Note: Lower ODR values than 25Hz are not allowed. If they are used they result in an error code in Register (0x02) ERR_REG.

The filter bandwidth as configured by gyr-odr shows a 3db cutoff frequency shown in the following table:

Gyroscope ODR [Hz]	**25**	**50**	**100**	**200**	**400**	**800**	**1600**	**3200**
3dB Cutoff frequency [Hz]	10.7	20.8	39.9	74.6	136.6	254.6	523.9	890

When the filter mode is set to **OSR2** (gyr_bwp=0b001), both stages of the digital filter are used and the data is oversampled with an oversampling rate of 2. That means that for a certain filter configuration, the ODR has to be 2 times higher than in the normal filter mode. Conversely, for a certain filter configuration, the filter bandwidth will be the approximately half of the bandwidth achieved for the same ODR in the normal filter mode. For example, for ODR=50Hz we will have a 3dB cutoff frequency of 10.7Hz.

When the filter mode is set to **OSR4** (gyr_bwp=0b000), both stages of the digital filter are used and the data is oversampled with an oversampling rate of 4. That means that for a certain filter configuration, the ODR has to be 4 times higher than in the normal filter mode. Conversely, for a certain filter configuration, the filter bandwidth will be approximately 4 times smaller than the bandwidth achieved for the same ODR in the normal filter mode. For example, for ODR=100Hz we will have a 3dB cutoff frequency of 10.7Hz.
There is no undersampling mode for the gyroscope data processing.

3.5 FIFO

A FIFO is integrated in BMG250 to support low power applications and prevent data loss in non-real-time systems. The FIFO has a size of 1024 bytes. The FIFO architecture supports to dynamically allocate FIFO space. For typical applications, this is sufficient for approx. 1.4s of data capture (ODR=100Hz). If a lower ODR is used, the FIFO size will be sufficient for capturing data longer, increasing ODR will reduce available capturing time. The FIFO features a FIFO full and watermark interrupt. Details can be found in chapter 3.6.3.

A schematic of the data path when the FIFO is used is shown in the figure below.

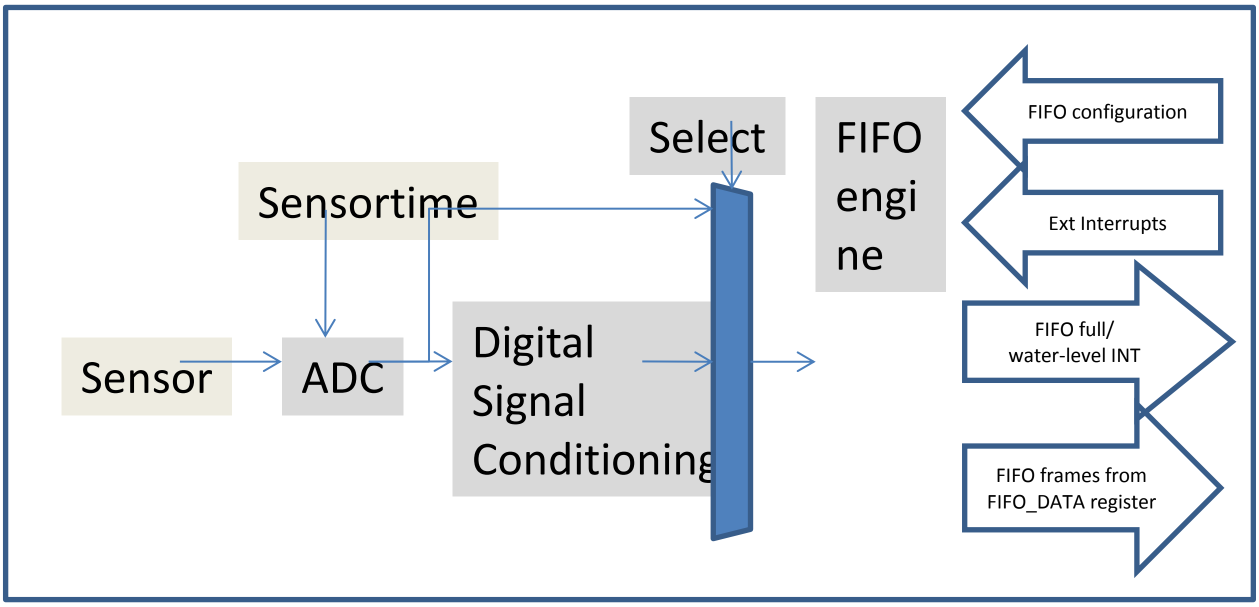

Figure 3: Block diagram of FIFO data path

3.5.1 FIFO Frames

When using the FIFO, the stored data can be read out by performing a burst read on the register (0x24) FIFO_DATA. The data is stored in units called frames.

3.5.1.1 Frame rates

The frame rate for the FIFO is defined by the maximum output data rate of the sensor via the Register (0x46-0x47) FIFO_CONFIG. If pre-filtered data are selected in Register (0x45) FIFO_DOWNS, a data rate of 6400 Hz is used.

The frame rate can be reduced further via downsampling (Register (0x45) FIFO_DOWNS). This can be done independently for each sensor. Downsampling just drops sensor data; no data processing or filtering is performed.

3.5.1.2 Frame format

When using the FIFO, the stored data can be read out by performing a burst read on the register (0x24) FIFO_DATA. The data will be stored in frames. The frame format is configurable.

The FIFO can be configured to store data in either header mode or in headerless mode (see figure below). The headerless mode is usually used when the structure of data does not change during data acquisition. In this case, the number of storable frames can be maximized. In contrast, the header mode is intended for situations where flexibility in the data structure is required, e.g. when the sensor runs at different ODRs or when switching the sensor on or off during operation.

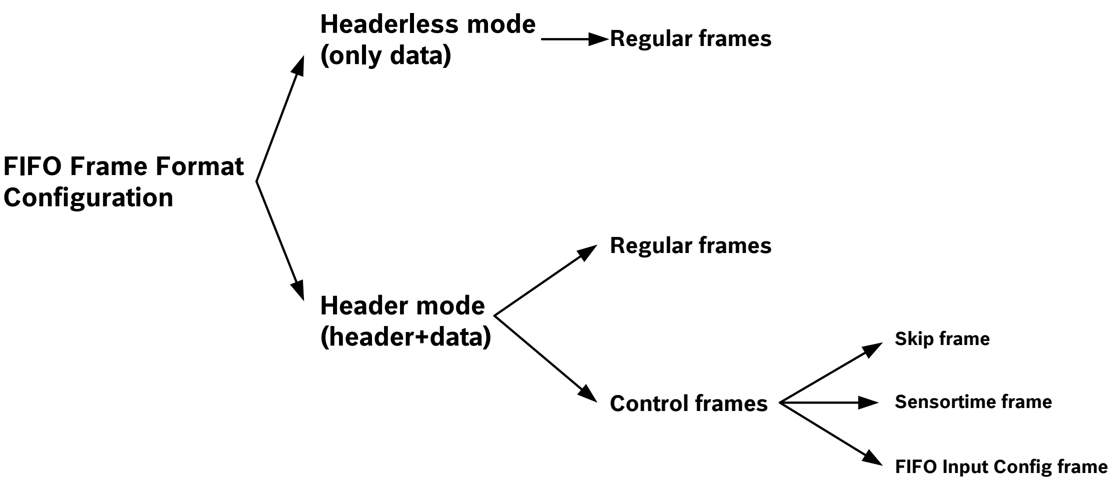

Figure 4: FIFO frame configurations

In **headerless mode** no header byte is used and the frames consist only of data bytes. The data bytes will always be sensor data. This mode has the advantage of an easy frame format and an optimized usage of the 1024 bytes of FIFO storage. It can be selected by disabling fifo_header in Register (0x46-0x47) FIFO_CONFIG. In case of overreading the FIFO, non-valid frames always contain the fixed expression (magic number) 0x80 in the data frame.

In **header mode** every frame consists of a header byte followed by one or more data bytes. The header defines the frame type and contains parameters for the frame. The data bytes may be sensor data or control data. Header mode supports different ODRs for the gyroscope data and external interrupt flags. It is activated by enabling fifo_header in Register (0x46-0x47) FIFO_CONFIG.

3.5.1.3 Header byte format

The header format is shown below:

Bit	**7**	**6**	**5**	**4**
Content	fh_mode		fh_parm<3:2>	

Bit	**3**	**2**	**1**	**0**
Read/Write	fh_parm<1:0>		fh_ext	

The *fh_mode, fh_opt* and *fh_ext* fields are defined as

fh_mode<1:0>	Definition	fh_parm <3:0>	fh_ext<1:0>
0b10	Regular	Frame content	Tag of INT2 and INT1
0b01	Control	Control Opcode	
0b00	Reserved	Na	
0b11	Reserved	Na	

f_parm=0b0000 is invalid for regular mode, a header of 0x80 indicates an uninitialized frame.

3.5.1.4 Data bytes Format

When the FIFO is set to “headerless mode“, only sensor data will be saved into the FIFO (in the same order as in the data register). External interrupt tags are not supported in headerless mode.

When the FIFO is set to “header mode“, the data byte format is different depending on the type of frame. There are two basic frame types, control frames and regular data frames. Each different type of control frame has its own data byte format. It can contain skipped frames, sensortime data or FIFO configuration information as explained in the following chapters. If the frame type is a regular frame (sensor data), the data byte section of the frame depend on how the data is being transmitted in this frame (as specified in the header byte section).

The **data byte** part for regular data frames is identical to the format defined for the Register (0x12-0x17) DATA.

Control frame (fh_mode=0b01):

Control frames, which are only available in header mode, are used for special or exceptional information. All control frames contribute to the *fifo_byte _counter* in Register (0x22-0x23) FIFO_LENGTH. In detail, there are three types of control frame, which can be distinguished by the *fh_parm* field:

Skip frame (fh_parm=0b000):
In case of a FIFO overflow, a skip frame is prepended to the FIFO content when the next readout is performed. A skip frame indicates the number of skipped frames since the last readout.
In the header byte of a skip frame, fh_mode equals 0b01 (since it is a control frame) and the fh_param equals 0b000 (indicating skip frame). The data byte part of a skip frame consists of one byte and contains the number of skipped frames. When more than 0xFF frames have been skipped, 0xFF is returned.

Sensortime frame (fh_parm=0b001):
If the sensortime frame functionality is activated (see description of Register (0x46-0x47) FIFO_CONFIG) and the FIFO is overread, the last data frame is followed by a sensortime frame. This frame contains the BMG250 timestamp content corresponding to the time at which the last data frame was read.
In the header byte of a sensortime frame, fh_mode = 0b01 (since is a control frame) and fh_param = 0b001 (indicating sensortime frame). The data byte part of a sensortime frame

consists of 3 bytes and contains the 24-bit sensortime. A sensortime frame does not consume memory in the FIFO.

FIFO_input_config frame (fh_parm=0b010):
Whenever the configuration of the FIFO input data sources changes, a FIFO input config frame is inserted into the FIFO in front of the data to which the configuration change is applied.
In the header byte of a config frame, fh_mode = 0b01 (since it is a control frame) and fh_param = 0b010 (indicating FIFO_input_config frame). The data byte part of a FIFO_Input_Config Frame consists of one byte and contains data corresponding to the following table:

Bit	7	6	5	4
Content	reserved			

Bit	3	2	1	0
Read/Write	gyr_range_ch	gyr_conf_ch	reserved	

gyr_range_ch: A change in Register (0x43) GYR_RANGE becomes active.
gyr_conf_ch: A change in Register (0x42) GYR_CONF or gyr_fifo_filt_data or gyr_fifo_downsampling in Register (0x45) FIFO_DOWNS becomes active.

3.5.2 FIFO conditions and details

3.5.2.1 Overflows

In the case of overflows the FIFO will overwrite the oldest data. A skip frame will be prepended at the next FIFO readout if the available FIFO space falls below the maximum size frame.

3.5.2.2 Overreads

If more data bytes are read from the FIFO than valid data bytes are available, ‘0x80’ is returned. Since a header ‘0x80’ indicates an invalid frame, the SW can recognize the end of valid data. After the invalid header the data is undefined. This is valid in both headerless and header mode. In addition, if header mode and the sensortime frame are enabled, the last data frame is followed by a sensortime frame. After this frame, a 0x80 header will be returned that indicates the end of valid data.

3.5.2.3 Partial frame reads

When a frame is only partially read through, it will be repeated within the next reading operation (including the header).

3.5.2.4 FIFO synchronization with external events

External events can be synchronized with the FIFO data by connecting the event source to one of the BMG250 interrupt pins (which needs to be configured as an input interrupt pin). External events can be generated e.g. by a camera module. Each frame contains the value of the interrupt input pin at the time of the external event.

The fh_ext<1:0> field is set when an external interrupt is triggered. External interrupt tags are configured using *int<x>_output_en* in Register (0x53) INT_OUT_CTRL.

3.5.2.5 FIFO Reset

A reset of the BMG250 is triggered by writing the opcode 0xB0 "fifo_flush" to the Register (0x7E) CMD. This will clear all data in the FIFO while keeping the FIFO settings unchanged.
Automatic resets are only done in two exceptional cases where the data would not be usable without a reset:

- a sensor is enabled or disabled in headerless mode, or
- a transition between headerless and header mode occurred.

3.5.2.6 Error Handling

In case of a configuration error in Register (0x46-0x47) FIFO_CONFIG, no data will be written into the FIFO and the error is reported in Register (0x02) ERR_REG.

3.6 Interrupt Controller

There are 2 interrupt output pins, to which 3 different interrupt signals can be mapped independently via user programmable parameters.

Available interrupts in normal mode are:

- **Data ready ("new-data")** for synchronizing sensor data read-out with the MCU / host controller
- **FIFO full / FIFO watermark** allows FIFO fill level and overflow handling.

All Interrupts are available only in normal (low-noise) mode, but not in suspend mode.

Input Interrupt Pins: For special applications (e.g. PMU Trigger, FIFO Tag) interrupt pins can be configured as input pins. For all other cases (standard interrupts), the pin must be configured as an output.

Note: The direction of the interrupt pins is controlled with *int<x>_output_en* and *int_x_input_en* in Register (0x53) INT_OUT_CTRL and Register (0x54) INT_IN_CTRL. If both are enabled, the input (e.g. marking fifo) is driven by the interrupt output.

3.6.1 Data Ready Detection

This interrupt is enabled whenever a new data sample is complete. This allows a low latency data readout.
The data update detection monitors the *data_update* signals for all axes. It generates an interrupt as soon as the values for all axes which are required for the configured output data rates have been updated.
The interrupt is cleared automatically when the update for the next sample starts or the data is read out from the data register.

3.6.2 PMU Trigger (Gyro)

Whenever a PMU (power management unit) trigger (either wakeup or sleep) is issued, *wakeup_int* in Register (0x6C) PMU_TRIGGER configures if an interrupt is send to the application processor. If the AP wants to trigger sleeps itself for the gyro, the *gyr_wakeup_trigger* is configured accordingly and no wakeup triggers are issued.

3.6.3 FIFO Interrupts

The FIFO supports two interrupts, a FIFO full interrupt and a watermark interrupt. The FIFO full interrupt is issued when the FIFO is full and the next full data sample would cause a FIFO overflow, which may lead to samples being deleted. Technically, that means that a FIFO full interrupt is issued, whenever less space than two maximum size frames is left in the FIFO. The FIFO watermark interrupt is fired, when the FIFO fill level in *fifo_byte_counter* in Register (0x22-0x23) FIFO_LENGTH is above a pre-configured watermark, defined in *fifo_watermark* in Register (0x46-0x47) FIFO_CONFIG.

Note: The unit of *fifo_watermark* is 4 bytes whereas the unit of *fifo_byte_counter* is single bytes.

3.7 Device self test

This feature permits to check the sensor functionality via a built-in self-test (BIST).
The BIST can be triggered during normal operation mode. It checks the sensors drive amplitude, its frequency and the stability of the drive control loop. Hence, disturbances of the movement by particles, mechanical damage or pressure loss can be detected.
The self-test for the gyroscope will be started by writing a '1' to *gyr_self_test_enable* in Register (0x6D) SELF_TEST. The result will be in *gyr_self_test_ok* in Register (0x1B) STATUS.

In addition, any particles or damages can be easily identified in a „Manual Performance Check". Due to the outstanding offset and noise performance the measured values at zero-rate fit the specified performance.

3.8 Offset Compensation

BMG250 offers fast and manual compensation as well as inline calibration.
Fast offset compensation is performed with pre-filtered data, and the offset is then applied to both, pre-filtered and filtered data. If necessary the result of this computation is saturated to prevent any overflow errors (the smallest or biggest possible value is set, depending on the sign).
The public offset compensation Register (0x74-0x77) OFFSET are images of the corresponding registers in the NVM. With each image update the contents of the NVM registers are written to the public registers. The public registers can be overwritten by the user at any time. Offset compensation needs to be enabled through *gyr_off_en* (Register 0x77).

3.8.1 Fast offset compensation

Fast offset compensation (FOC) is a one-shot process that compensates offset errors by setting the offset compensation registers to the negated offset error. This is best suited for "end-of-line trimming" with the customers device positioned in a well-defined orientation.
The Gyroscope target value is always 0 dps at rest.

FOC is triggered by issuing a *start_foc* command to Register (0x7E) CMD. Once triggered, the status of the fast correction process is reflected in the status bit *foc_rdy* in
Register (0x1B) STATUS. *foc_rdy* is '0' while the measurement is in progress. Preset filter settings apply. This will take a maximum time of 250 ms.
The negated measured values are written to Register (0x74-0x77) OFFSET automatically (overwriting previous offset register values), cancelling out offset errors.
Fast compensation can only be used in normal mode.
The fast offset compensation does not automatically clear the data ready bit in Register (0x1B) STATUS. It is recommended to read the Register (0x12-0x17) DATA after FOC completes, to remove a stall data ready bit from before the FOC. In this way the data ready bit can be made functional again to indicate that the next sample is available for reading, while using data from the FOC mechanism.

3.8.2 Manual offset compensation

The contents of the public compensation Register (0x74-0x77) OFFSET may be set manually via the digital interface. After modifying the Register (0x74-0x77) OFFSET the next data sample is not valid.
Writing to the offset compensation registers is not allowed while the fast compensation procedure is running.

3.8.3 Inline calibration

For certain applications, it is often desirable to calibrate the offset once and to store the compensation values permanently. This can be achieved by using fast or manual offset compensation to determine the proper compensation values and then storing these values permanently in the NVM.

Each time the device is reset, the compensation values are loaded from the non-volatile memory into the image registers and used for offset compensation.

3.9 Non-Volatile Memory

The memory of the BMG250 consists of volatile and non-volatile registers. Part of it can be both read and written by the user. Access to non-volatile memory is only possible through (volatile) image registers.

A maximum number of write cycles to non-volatile memory of equal or less than 14 is supported.

The Register (0x70) NV_CONF and Register (0x74-0x77) OFFSET have NVM backups which are accessible by the user.
The content of the NVM is loaded to the image registers after a reset (either POR or softreset). As long as the image update is in progress, bit *nvm_rdy* in
Register (0x1B) STATUS is ´0´, otherwise it is ´1´.

The image registers can be read and written like any other register.

Writing to the NVM is a four-step procedure:
Write "0x11" into CMD (0x7E) register to make sensor enter NORMAL power state.
Write the new contents to the image registers.
Write ´1´ to bit *nvm_prog_en in the* Register (0x6A) CONF register in order to unlock the NVM.
Write prog_nvm (0xA0) to the Register (0x7E) CMD to trigger the write process.

Writing to the NVM always renews the entire NVM contents. It is possible to check the write status by reading bit *nvm_rdy*. While *nvm_rdy* = ´0´, the write process is still in progress; if *nvm_rdy* = ´1´, then writing is completed. As long as the write process is ongoing, no change of power mode and image registers is allowed.

After *nvm_rdy* turns to be ´1´, user can optionally write "0x10" into CMD (0x7E) register to switch power status back into suspend mode, if needed.

3.10 Register Map

This chapter contains register definitions. REG[x]<y> denotes bit y in byte x in register REG. Val(Name) is the value contained in the register interpreted as non-negative binary number. When writing to reserved bits, '0' should be written when not stated different.

read/write	read only	write only	reserved

Register Address	Register Name	Default Value	bit7	bit6	bit5	bit4	bit3	bit2	bit1	bit0
0x007D	-	-	reserved							
0x0078	-	-	reserved							
0x0077	OFFSET_6	0x00	gyr_off_en	reserved	off_gyr_z_9_8		off_gyr_y_9_8		off_gyr_x_9_8	
0x0076	OFFSET_5	0x00	off_gyr_z_7_0							
0x0075	OFFSET_4	0x00	off_gyr_y_7_0							
0x0074	OFFSET_3	0x00	off_gyr_x_7_0							
0x0073	-	-	reserved							
0x0071	-	-	reserved							
0x0070	NV_CONF	0x00	reserved					i2c_wdt_en	i2c_wdt_sel	spi_en
0x006F	-	-	reserved							
0x006E	-	-	reserved							
0x006D	SELF_TEST	0x00	reserved			gyr_self_test_start	reserved			
0x006C	PMU_TRIGGER	0x10	reserved		gyr_sleep_state	reserved	gyr_wakeup_trigg	reserved	gyr_sleep_trigger	
0x006B	IF_CONF	0x00	reserved		reserved	if_mode	reserved			spi3
0x006A	CONF	0x00	reserved						nvm_prog_en	reserved
0x0069	-	-	reserved							
0x0057	-	-	reserved							
0x0056	INT_MAP_1	0x00	int1_drdy	int1_fwm	int1_ffull	reserved	int2_drdy	int2_fwm	int2_ffull	reserved
0x0055	-	-	reserved							
0x0054	INT_LATCH	0x00	reserved		int2_input_en	int1_input_en	reserved			
0x0053	INT_OUT_CTRL	0x00	int2_output_en	int2_od	int2_lvl	int2_edge_ctrl	int1_output_en	int1_od	int1_lvl	int1_edge_ctrl
0x0052	-	-	reserved							
0x0051	INT_EN_1	0x00	reserved	int_fwm_en	int_ffull_en	int_drdy_en	reserved			
0x0050	-	-	reserved							
0x0048	-	-	reserved							
0x0047	FIFO_CONFIG_1	0x10	fifo_gyr_en	reserved		fifo_header_en	fifo_tag_int1_en	fifo_tag_int2	fifo_time_en	fifo_stop_on_full
0x0046	FIFO_CONFIG_0	0x80	fifo_water_mark							
0x0045	FIFO_DOWNS	0x88	reserved				gyr_fifo_filt_dat	gyr_fifo_downs		
0x0044	-	-	reserved							
0x0043	GYR_RANGE	0x00	reserved					gyr_range		
0x0042	GYR_CONF	0x28	reserved		gyr_bwp		gyr_odr			
0x0041	-	-	reserved							
0x0025	-	-	reserved							
0x0024	FIFO_DATA	0x00	fifo_data							
0x0023	FIFO_LENGTH_1	0x00	reserved					fifo_byte_counter_10_8		
0x0022	FIFO_LENGTH_0	0x00	fifo_byte_counter_7_0							
0x0021	TEMPERATURE_1	0x80	temperature_15_8							
0x0020	TEMPERATURE_0	0x00	temperature_7_0							
0x001F	-	-	reserved							
0x001E	-	-	reserved							
0x001D	INT_STATUS_1	0x00	reserved	fwm_int	ffull_int	drdy_int	reserved			
0x001C	-	-	reserved							
0x001B	STATUS	0x01	reserved	drdy_gyr	reserved	nvm_rdy	foc_rdy	reserved	gyr_self_test_ok	reserved
0x001A	SENSORTIME_2	0x00	sensor_time_23_16							
0x0019	SENSORTIME_1	0x00	sensor_time_15_8							
0x0018	SENSORTIME_0	0x00	sensor_time_7_0							
0x0017	DATA_19	0x00	gyr_z_15_8							
0x0016	DATA_18	0x00	gyr_z_7_0							
0x0015	DATA_17	0x00	gyr_y_15_8							
0x0014	DATA_16	0x00	gyr_y_7_0							
0x0013	DATA_15	0x00	gyr_x_15_8							
0x0012	DATA_14	0x00	gyr_x_7_0							
0x0011	-	-	reserved							
0x0004	-	-	reserved							
0x0003	PMU_STATUS	0x00	reserved		tmp_pmu_status		gyr_pmu_status		reserved	
0x0002	ERR_REG	0x00	reserved	drop_cmd_err	reserved	err_code				fatal_err
0x0001	-	-	reserved							
0x0000	CHIP_ID	0xD5	chip_id							