

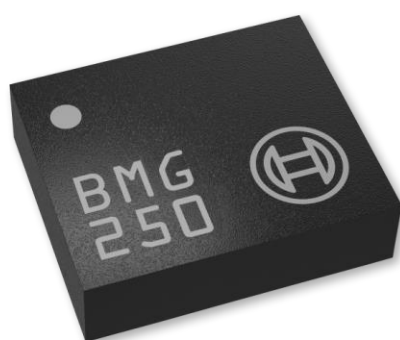
# BMG250

## Low noise, low power triaxial gyroscope

Bosch Sensortec



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### 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  $\mu$ A (gyroscope in full operation)
- Very small 2.5 x 3.0 mm<sup>2</sup> 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  $\rightarrow$  Primary Interface (I<sup>2</sup>C)
  - OIS  $\rightarrow$  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<sup>2</sup>C or SPI
- Extended I<sup>2</sup>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  $2.5 \times 3.0 \times 0.83 \text{ mm}^3$  LGA package. When the gyroscope is in full operation mode, power consumption is typically  $850 \mu\text{A}$ , enabling always-on applications in battery driven devices. The BMG250 offers a wide  $V_{\text{DD}}$  voltage range from 1.71V to 3.6V and a  $V_{\text{DDIO}}$  range from 1.2V to 3.6V, allowing the BMG250 to be powered at 1.8V for both  $V_{\text{DD}}$  and  $V_{\text{DDIO}}$ .

The BMG250 provides high precision sensor data together with the accurate timing of the corresponding data. The timestamps have a resolution of up to  $39 \mu\text{s}$ .

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<sup>2</sup>C 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.

## Index of Contents

### 1. Contents

---

|  |           |
|--|-----------|
| <b>2. SPECIFICATION .....</b>  | <b>7</b>  |
| 2.1 ELECTRICAL SPECIFICATION .....   | 7         |
| 2.2 ELECTRICAL AND PHYSICAL CHARACTERISTICS, MEASUREMENT PERFORMANCE ..... | 8         |
| 2.3 ABSOLUTE MAXIMUM RATINGS .....   | 10        |
| <b>3. FUNCTIONAL DESCRIPTION .....</b>                                     | <b>11</b> |
| 3.1 BLOCK DIAGRAM .....  | 11        |
| 3.2 POWER MODES .....  | 12        |
| 3.2.1 SUSPEND MODE .....   | 12        |
| 3.2.2 FAST START-UP MODE .....   | 12        |
| 3.2.3 TRANSITIONS BETWEEN POWER MODES .....                                | 13        |
| 3.2.4 PMU (POWER MANAGEMENT UNIT) .....                                    | 13        |
| 3.3 SENSOR TIMING AND DATA SYNCHRONIZATION .....                           | 14        |
| 3.3.1 SENSOR TIME .....  | 14        |
| 3.4 DATA PROCESSING .....  | 15        |
| 3.4.1 DATA PROCESSING .....  | 15        |
| 3.5 FIFO .....   | 16        |
| 3.5.1 FIFO FRAMES .....  | 16        |
| 3.5.2 FIFO CONDITIONS AND DETAILS .....                                    | 19        |
| 3.6 INTERRUPT CONTROLLER .....   | 21        |
| 3.6.1 DATA READY DETECTION .....   | 21        |
| 3.6.2 PMU TRIGGER (GYRO) .....   | 21        |
| 3.6.3 FIFO INTERRUPTS .....  | 21        |
| 3.7 DEVICE SELF TEST .....   | 22        |
| 3.8 OFFSET COMPENSATION .....  | 23        |
| 3.8.1 FAST OFFSET COMPENSATION .....                                       | 23        |
| 3.8.2 MANUAL OFFSET COMPENSATION .....                                     | 23        |
| 3.8.3 INLINE CALIBRATION .....   | 23        |
| 3.9 NON-VOLATILE MEMORY .....  | 24        |
| 3.10 REGISTER MAP .....  | 25        |
| 3.10.1 REGISTER (0x00) CHIPID .....  | 26        |
| 3.10.2 REGISTER (0x02) ERR_REG .....                                       | 27        |
| 3.10.3 REGISTER (0x03) PMU_STATUS .....                                    | 28        |
| 3.10.4 REGISTER (0x12-0x17) DATA .....                                     | 29        |
| 3.10.5 REGISTER (0x18-0x1A) SENSORTIME .....                               | 30        |
| 3.10.6 REGISTER (0x1B) STATUS .....  | 31        |
| 3.10.7 REGISTER (0x1D) INT_STATUS_1 .....                                  | 31        |

|  |           |
|--|-----------|
| 3.10.8 REGISTER (0x20-0x21) TEMPERATURE .....                | 32        |
| 3.10.9 REGISTER (0x22-0x23) FIFO_LENGTH .....                | 33        |
| 3.10.10 REGISTER (0x24) FIFO_DATA.....                       | 34        |
| 3.10.11 REGISTER (0x42) GYR_CONF.....                        | 35        |
| 3.10.12 REGISTER (0x43) GYR_RANGE .....                      | 36        |
| 3.10.13 REGISTER (0x45) FIFO_DOWNS .....                     | 37        |
| 3.10.14 REGISTER (0x46-0x47) FIFO_CONFIG .....               | 38        |
| 3.10.15 REGISTER (0x51) INT_EN.....                          | 39        |
| 3.10.16 REGISTER (0x53) INT_OUT_CTRL.....                    | 40        |
| 3.10.17 REGISTER (0x54) INT_IN_CTRL.....                     | 41        |
| 3.10.18 REGISTER (0x56) INT_MAP.....                         | 41        |
| 3.10.19 REGISTER (0x6A) CONF .....                           | 42        |
| 3.10.20 REGISTER (0x6B) IF_CONF.....                         | 42        |
| 3.10.21 REGISTER (0x6C) PMU_TRIGGER .....                    | 44        |
| 3.10.22 REGISTER (0x6D) SELF_TEST.....                       | 45        |
| 3.10.23 REGISTER (0x70) NV_CONF .....                        | 46        |
| 3.10.24 REGISTER (0x74-0x77) OFFSET .....                    | 47        |
| 3.10.25 REGISTER (0x7E) CMD .....                            | 48        |
| <b>4. DIGITAL INTERFACES.....</b>                            | <b>50</b> |
| 4.1 INTERFACE .....  | 50        |
| 4.1.1 INTERFACE I <sup>2</sup> C/SPI PROTOCOL SELECTION..... | 51        |
| 4.1.2 SPI INTERFACE.....                                     | 52        |
| 4.1.3 I <sup>2</sup> C INTERFACE.....                        | 55        |
| 4.1.4 SPI AND I <sup>2</sup> C ACCESS RESTRICTIONS .....     | 59        |
| <b>5. PIN-OUT AND CONNECTION DIAGRAMS .....</b>              | <b>61</b> |
| 5.1 PIN-OUT BMG250 .....                                     | 61        |
| 5.2 CONNECTION DIAGRAMS .....                                | 62        |
| 5.2.1 I <sup>2</sup> C INTERFACE.....                        | 62        |
| 5.2.2 SPI 3-WIRE INTERFACE .....                             | 62        |
| 5.2.3 SPI 4-WIRE INTERFACE .....                             | 63        |
| <b>6. PACKAGE .....</b>                                      | <b>65</b> |
| 6.1 OUTLINE DIMENSIONS .....                                 | 65        |
| 6.2 SENSING AXES ORIENTATION .....                           | 66        |
| 6.3 LANDING PATTERN RECOMMENDATION .....                     | 67        |
| 6.4 MARKING.....   | 68        |
| 6.4.1 MASS PRODUCTION MARKING.....                           | 68        |
| 6.4.2 ENGINEERING SAMPLES.....                               | 68        |
| 6.5 SOLDERING GUIDELINES.....                                | 69        |
| 6.6 HANDLING INSTRUCTIONS.....                               | 70        |
| 6.7 TAPE AND REEL SPECIFICATION .....                        | 71        |
| 6.7.1 ORIENTATION WITHIN THE REEL.....                       | 71        |
| 6.8 ENVIRONMENTAL SAFETY .....                               | 72        |
| 6.8.1 HALOGEN CONTENT .....                                  | 72        |

|  |           |
|--|-----------|
| 6.8.2 MULTIPLE SOURCING.....                       | 72        |
| <b>7. LEGAL DISCLAIMER.....</b>                    | <b>73</b> |
| 7.1 ENGINEERING SAMPLES .....                      | 73        |
| 7.2 PRODUCT USE .....                              | 73        |
| 7.3 APPLICATION EXAMPLES AND HINTS .....           | 73        |
| <b>8. DOCUMENT HISTORY AND MODIFICATIONS .....</b> | <b>74</b> |

## 2. Specification

If not stated otherwise, the given values are over lifetime and full performance temperature and voltage ranges, minimum/maximum values are  $\pm 3\sigma$ .

### 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 <sub>DD</sub>   |   | 1.71                  | 3.0 | 3.6                   | V      |
| Supply Voltage I/O Domain       | V <sub>DDIO</sub> |   | 1.2                   | 2.4 | 3.6                   | V      |
| Voltage Input Low Level         | V <sub>IL,a</sub> | SPI   |                       |     | 0.3V <sub>DDIO</sub>  | -      |
| Voltage Input High Level        | V <sub>IH,a</sub> | SPI   | 0.7V <sub>DDIO</sub>  |     |                       | -      |
| Voltage Output Low Level        | V <sub>OL,a</sub> | V <sub>DDIO</sub> =1.62V, I <sub>OL</sub> =3mA, SPI |                       |     | 0.2V <sub>DDIO</sub>  | -      |
|                                 |                   | V <sub>DDIO</sub> =1.2V, I <sub>OL</sub> =3mA, SPI  |                       |     | 0.23V <sub>DDIO</sub> | -      |
| Voltage Output High Level       | V <sub>OH,a</sub> | V <sub>DDIO</sub> =1.62V, I <sub>OH</sub> =3mA, SPI | 0.8V <sub>DDIO</sub>  |     |                       | -      |
|                                 |                   | V <sub>DDIO</sub> =1.2V, I <sub>OH</sub> =3mA, SPI  | 0.62V <sub>DDIO</sub> |     |                       | -      |
| Operating Temperature           | T <sub>A</sub>    |   | -40                   |     | +85                   | °C     |
| NVM write-cycles                | n <sub>NVM</sub>  | Non-volatile memory                                 | 14                    |     |                       | Cycles |
| Current consumption             | I <sub>DD</sub>   | Gyro in fast start-up, T <sub>A</sub> =25°C         |                       | 500 |                       | µA     |
|                                 |                   | Gyro full operation mode T <sub>A</sub> =25°C       |                       | 850 |                       |        |
|                                 |                   | Gyro in suspend mode, T <sub>A</sub> =25°C          |                       | 3   |                       |        |

## 2.2 Electrical and physical characteristics, measurement performance

Table 3: Electrical characteristics gyroscope

| OPERATING CONDITIONS GYROSCOPE                 |  |   |       |       |       |         |
|--|--|---|-------|-------|-------|---------|
| Parameter                                      | Symbol   | Condition   | Min   | Typ   | Max   | Unit    |
| Range  | R <sub>FS125</sub>   | Selectable<br>via serial digital interface  |       | 125   |       | °/s     |
|  | R <sub>FS250</sub>   |   |       | 250   |       | °/s     |
|  | R <sub>FS500</sub>   |   |       | 500   |       | °/s     |
|  | R <sub>FS1000</sub>  |   |       | 1,000 |       | °/s     |
|  | R <sub>FS2000</sub>  |   |       | 2,000 |       | °/s     |
| Range<br>(Secondary<br>interface)              | R <sub>FSOIS</sub>   | Fixed range setting   |       | 2,000 |       | °/s     |
| Start-up time                                  | t <sub>G,su</sub>  | Suspend to normal mode<br>ODR <sub>G</sub> =1600Hz                                  |       | 55    | 80    | ms      |
|  | t <sub>G,FS</sub>  | Fast start-up to normal<br>mode   |       | 10    | 15    | ms      |
| OUTPUT SIGNAL GYROSCOPE                        |  |   |       |       |       |         |
| Sensitivity                                    | R <sub>FSOIS</sub>   | T <sub>A</sub> =25°C  | 15.9  | 16.4  | 16.9  | LSB/°/s |
|  | R <sub>FS2000</sub>  | T <sub>A</sub> =25°C  | 15.9  | 16.4  | 16.9  | LSB/°/s |
|  | R <sub>FS1000</sub>  | T <sub>A</sub> =25°C  | 31.8  | 32.8  | 33.8  | LSB/°/s |
|  | R <sub>FS500</sub>   | T <sub>A</sub> =25°C  | 63.6  | 65.6  | 67.6  | LSB/°/s |
|  | R <sub>FS250</sub>   | T <sub>A</sub> =25°C  | 127.2 | 131.2 | 135.2 | LSB/°/s |
|  | R <sub>FS125</sub>   | T <sub>A</sub> =25°C  | 254.5 | 262.4 | 270.3 | LSB/°/s |
| Sensitivity change<br>over temperature         | TCS <sub>G</sub>   | R <sub>FS2000</sub> ,<br>Nominal V <sub>DD</sub> supplies<br>best fit straight line |       | ±0.02 |       | %/K     |
| Nonlinearity                                   | NL <sub>G</sub>  | Best fit straight line<br>R <sub>FS1000</sub> , R <sub>FS2000</sub>                 |       | 0.1   |       | %FS     |
| g- Sensitivity                                 |  | Sensitivity to acceleration<br>stimuli in all three axis<br>(frequency <20kHz)      |       |       | 0.1   | °/s/g   |
| Zero-rate offset                               | Off Ω <sub>x</sub><br>Ω <sub>y</sub> and Ω <sub>z</sub>                | T <sub>A</sub> =25°C,<br>fast offset compensation<br>off                            |       | ±3    |       | °/s     |
| Zero-Rate offset<br>Over temperature           | Off Ω <sub>x, oT</sub><br>Ω <sub>y, oT</sub> and<br>Ω <sub>z, oT</sub> | -40°C ≤ T <sub>A</sub> ≤ +85°C  |       | ±3    |       | °/s     |
| Zero-rate offset<br>change over<br>temperature | TCO <sub>G</sub>   | -40°C ≤ T <sub>A</sub> ≤ +85°C,<br>best fit straight line                           |       | 0.05  |       | °/s/K   |



|   |             |   |    |         |      |                        |
|---|-------------|---|----|---------|------|------------------------|
| Output Noise                                  | $n_{G,nD}$  | @10 Hz  |    | 0.007   |      | $^{\circ}/s/\sqrt{Hz}$ |
|   | $n_{G,rms}$ | Filter setting 74.6Hz, ODR 200 Hz             |    | 0.07    |      | $^{\circ}/s\ rms$      |
| Bias stability                                | $BS_G$      |   |    | 10      |      | $^{\circ}/h$           |
| 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        |    | $\pm 1$ |      | %                      |
| 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  | $^{\circ}C$ |
| Temperature Sensor Slope                                     | $dT_S$  |                       |     | 0.002   |     | K/LSB       |
| Temperature Sensor Offset                                    | $OT_S$  |                       |     | $\pm 2$ |     | 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 <sub>DD</sub> Pin          | -0.3 | 4.25                   | V     |
|  | V <sub>DDIO</sub> Pin        | -0.3 | 4.25                   | V     |
| Voltage at any Logic Pin                     | Non-Supply Pin               | -0.3 | V <sub>DDIO</sub> +0.3 | V     |
| Passive Storage Temp. Range                  | ≤65% rel. H.                 | -50  | +150                   | °C    |
| None-volatile memory (NVM)<br>Data Retention | T = 85°C,<br>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:

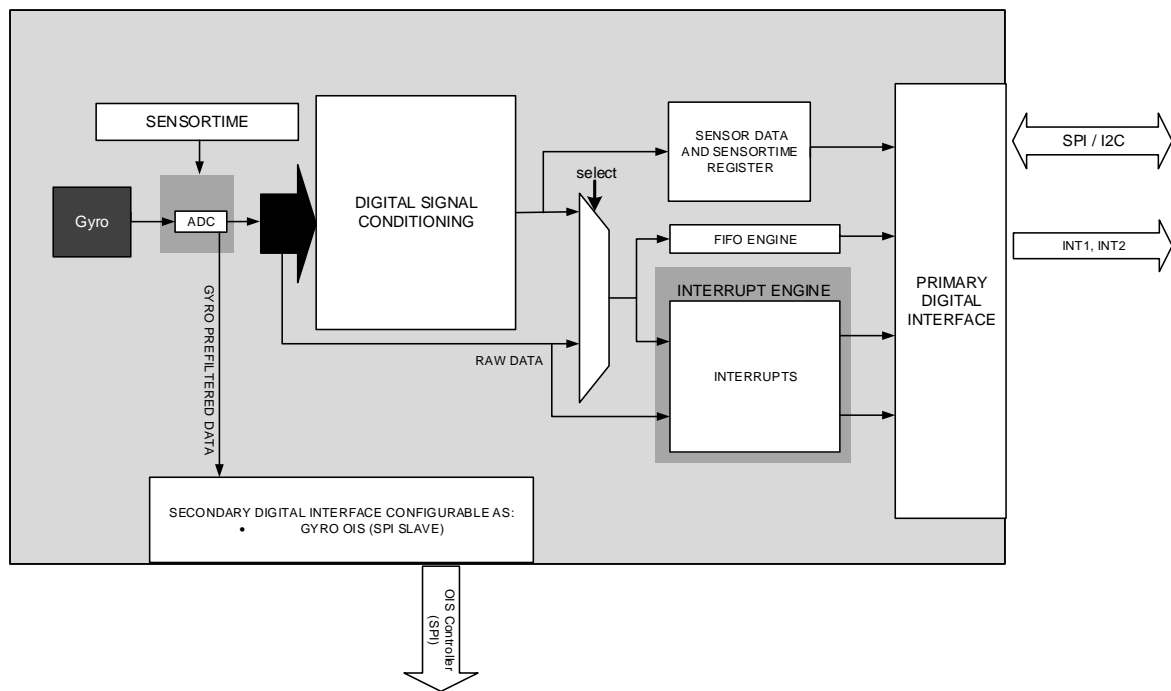


Figure 1: Block diagram of data flow

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<sup>2</sup>C operations are allowed. FIFO data readout is not supported in suspend mode.
- **Fast start-up mode:** start-up delay time to normal mode  $\leq 10$  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 ( $\sim 400 \mu\text{s}$ ), 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 ( $\leq 10$  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  $\mu\text{A}$  according to the gyroscope's modes

|                |               | Current consumption in $\mu\text{A}$ |
|----------------|---------------|--------------------------------------|
| 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  $\mu$ s. 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.

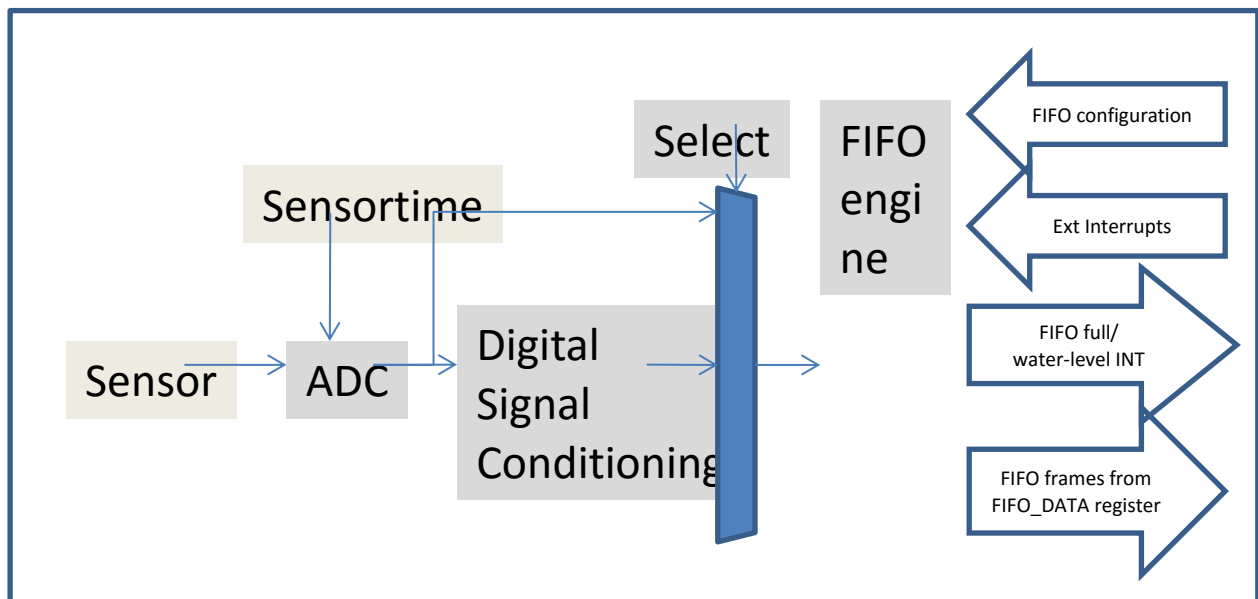


Figure 3: Block diagram of FIFO data path

#### 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.

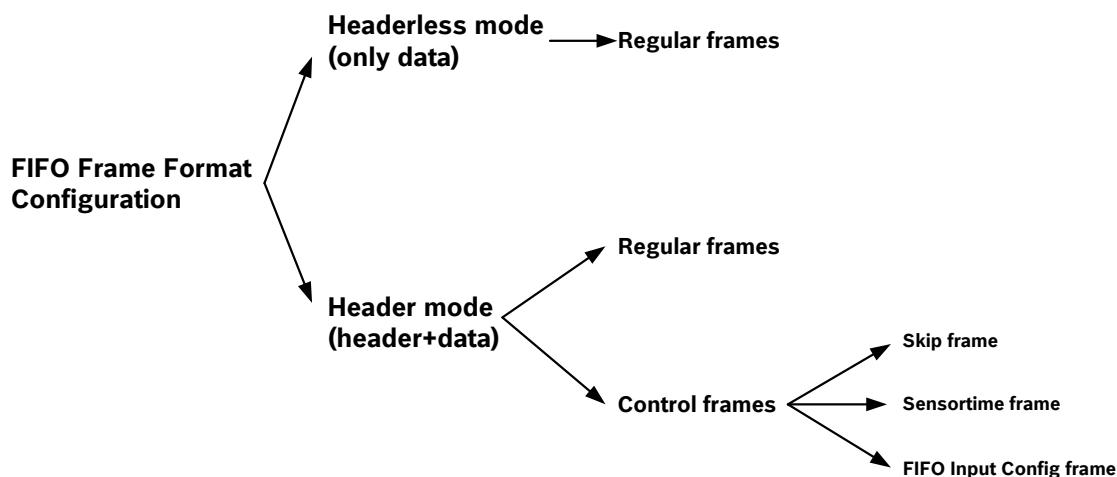


Figure 4: FIFO frame configurations

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

| <b>fh_mode&lt;1:0&gt;</b> | <b>Definition</b> | <b>fh_parm &lt;3:0&gt;</b> | <b>fh_ext&lt;1:0&gt;</b> |
|---------------------------|-------------------|----------------------------|--------------------------|
| 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\_parm* 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\_parm* = 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 sent 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_full       | reserved            | int2_drdy         | int2_fwm      | int2_full              | 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_full_en     | int_drdy_en         | reserved          |               |                        |                   |          |
| 0x0050           | -             | -             | reserved              |            |                 |                     |                   |               |                        |                   |          |
| 0x0048           | -             | -             | reserved              |            |                 |                     |                   |               |                        |                   |          |
| 0x0047           | FIFO_CONFIG_1 | 0x10          | fifo_gyr_en           | reserved   |                 | fifo_header_en      | fifo_tag_int1_e   | 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    | full_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_e | reserved        | err_code            |                   |               |                        | fatal_err         |          |
| 0x0001           | -             | -             | reserved              |            |                 |                     |                   |               |                        |                   |          |
| 0x0000           | CHIP_ID       | 0xD5          | chip_id               |            |                 |                     |                   |               |                        |                   |          |

**3.10.1 Register (0x00) CHIPID**

ADDRESS 0x00

RESET 0xD5

MODE R

DESCRIPTION The register contains the chip identification code.

DEFINITION

| Name        | Register (0x00) CHIPID |   |   |   |
|-------------|------------------------|---|---|---|
| Bit         | 7                      | 6 | 5 | 4 |
| Read/Write  | R                      | R | R | R |
| Reset Value | 1                      | 1 | 0 | 1 |
| Content     | chip_id<7:4>           |   |   |   |
| Bit         | 3                      | 2 | 1 | 0 |
| Read/Write  | R                      | R | R | R |
| Reset Value | 0                      | 1 | 0 | 1 |
| Content     | chip_id<3:0>           |   |   |   |

**3.10.2 Register (0x02) ERR\_REG**

ADDRESS 0x02

RESET 0b00000000

MODE RW

DESCRIPTION Reports sensor error flags. Flags are reset when read.

## DEFINITION

| Bit | Acronym      | Definition   |
|-----|--------------|--|
| 7   | Reserved     |  |
| 6   | drop_cmd_err | Dropped command to Register  |
| 5   | Reserved     |  |
| 4:1 | error_code   | 0000: no error<br>0001: reserved<br>0010: gyr conf error<br>0010-1111: reserved<br><br>The first reported error will be shown in the error code. |
| 0   | fatal_err    | Chip not operable. The only way to clear the flag is a POR or soft-reset.  |

The register is meant for debug purposes, not for regular verification if an operation completed successfully.

Error flags (bits 4:1) store error event until they are reset by reading the register.

**3.10.3 Register (0x03) PMU\_STATUS**

ADDRESS 0x03

RESET 0b0000-0000

MODE R

DESCRIPTION Shows the current power mode of the sensor.

DEFINITION

| Register (0x03) PMU_STATUS |                |   |          |   |
|----------------------------|----------------|---|----------|---|
| Bit                        | 7              | 6 | 5        | 4 |
| Read/Write                 | R              | R | R        | R |
| Reset Value                | 0              | 0 | 0        | 0 |
| Content                    | reserved       |   |          |   |
| Bit                        | 3              | 2 | 1        | 0 |
| Read/Write                 | R              | R | R        | R |
| Reset Value                | 0              | 0 | 0        | 0 |
| Content                    | gyr_pmu_status |   | reserved |   |

| gyr_pmu_status | Gyro Mode     |
|----------------|---------------|
| 0b00           | Suspend       |
| 0b01           | Normal        |
| 0b10           | Reserved      |
| 0b11           | Fast Start-Up |

The register reflects the current power modes of all sensor configured as soon as they are effective. If a sensor is enabled, the new sensor mode is reported as soon as the MEMS is up and before digital filters have settled. The settling time depends on filter settings. The power modes may be changed through the Register (0x7E) CMD. In addition, for the gyroscope through register events may be defined, which change the gyro power mode.

In suspend mode the FIFO is not accessible. For read outs of the FIFO the sensor has to be set to normal mode, after read-out the sensor can be set back suspend or fast start-up mode.

### 3.10.4 Register (0x12-0x17) DATA

ADDRESS 0x12 (6 bytes)

RESET (BYTEWISE) 0b0000-0000

MODE R

DESCRIPTION Register for gyroscope data. DATA[0-5] are treated as atomic update unit with respect to an I<sup>2</sup>C/SPI operation. A read operation on the Register (0x12-0x17) DATA resets the appropriate \*\_drdy bits in

Register (0x1B) STATUS. E.g. when only [0] is read, only *drdy\_gyr* is reset.

DEFINITION

DATA[0-5] contains the latest data for the gyroscope GYR\_[X-Z].

If the secondary interface (OIS interface, working in SPI protocol) is connected, the OIS data are accessible through Register (0x012-0x17) for OIS\_DATA\_[X/Y/Z]\_[0/1].

| DATA[X] | Acronym           |
|---------|-------------------|
| X=0     | GYR_X<7:0> (LSB)  |
| X=1     | GYR_X<15:8> (MSB) |
| X=2     | GYR_Y<7:0> (LSB)  |
| X=3     | GYR_Y<15:8> (MSB) |
| X=4     | GYR_Z<7:0> (LSB)  |
| X=5     | GYR_Z<15:8> (MSB) |

| OIS_DATA[AXIS]_[MSB] | Acronym                |
|----------------------|------------------------|
| AXIS = X, MSB = 0    | OIS_DATA_X<7:0> (LSB)  |
| AXIS = X, MSB = 1    | OIS_DATA_X<15:8> (MSB) |
| AXIS = Y, MSB = 0    | OIS_DATA_Y<7:0> (LSB)  |
| AXIS = Y, MSB = 1    | OIS_DATA_Y<15:8> (MSB) |
| AXIS = Z, MSB = 0    | OIS_DATA_Z<7:0> (LSB)  |
| AXIS = Z, MSB = 1    | OIS_DATA_Z<15:8> (MSB) |

### 3.10.5 Register (0x18-0x1A) SENSORTIME

ADDRESS 0x18 (3 byte)

RESET 0x00\_0000

MODE R

**DESCRIPTION** Sensortime is a 24 bit counter available in suspend, low power, and normal mode. The value of the register is shadowed when it is read in a burst read with the data register at the beginning of the operation and the shadowed value is returned. When the FIFO is read the register is shadowed whenever a new frame is read.

**DEFINITION** The sensortime increments with 39  $\mu$ s. The accuracy of the counter is the same as for the output data rate as described in section 2.2. The sensortime is unique for approx. 10 min and 54 seconds. I.e. the register value starts at 0x000000 and wraps after 0xFFFFF has been reached.

| Name        |                  | Register (0x18-0x1A) SENSORTIME [0] |          |          |  |
|-------------|------------------|-------------------------------------|----------|----------|--|
| Bit         | 7                | 6                                   | 5        | 4        |  |
| Read/Write  | W                | R/W                                 | R/W      | R/W      |  |
| Reset Value | 0                | 0                                   | 0        | 0        |  |
| Content     | sensor_time<7:4> |                                     |          |          |  |
| <b>Bit</b>  | <b>3</b>         | <b>2</b>                            | <b>1</b> | <b>0</b> |  |
| Read/Write  | R/W              | R/W                                 | R/W      | R/W      |  |
| Reset Value | 0                | 0                                   | 0        | 0        |  |
| Content     | sensor_time<3:0> |                                     |          |          |  |

| Name        |                    | Register (0x18-0x1A) SENSORTIME [1] |          |          |  |
|-------------|--------------------|-------------------------------------|----------|----------|--|
| Bit         | 7                  | 6                                   | 5        | 4        |  |
| Read/Write  | W                  | R/W                                 | R/W      | R/W      |  |
| Reset Value | 0                  | 0                                   | 0        | 0        |  |
| Content     | sensor_time<15:11> |                                     |          |          |  |
| <b>Bit</b>  | <b>3</b>           | <b>2</b>                            | <b>1</b> | <b>0</b> |  |
| Read/Write  | R/W                | R/W                                 | R/W      | R/W      |  |
| Reset Value | 0                  | 0                                   | 0        | 0        |  |
| Content     | sensor_time<10:8>  |                                     |          |          |  |

| Name        |                    | Register (0x18-0x1A) SENSORTIME [2] |          |          |  |
|-------------|--------------------|-------------------------------------|----------|----------|--|
| Bit         | 7                  | 6                                   | 5        | 4        |  |
| Read/Write  | W                  | R/W                                 | R/W      | R/W      |  |
| Reset Value | 0                  | 0                                   | 0        | 0        |  |
| Content     | sensor_time<23:19> |                                     |          |          |  |
| <b>Bit</b>  | <b>3</b>           | <b>2</b>                            | <b>1</b> | <b>0</b> |  |
| Read/Write  | R/W                | R/W                                 | R/W      | R/W      |  |
| Reset Value | 0                  | 0                                   | 0        | 0        |  |
| Content     | sensor_time<19:16> |                                     |          |          |  |

### 3.10.6 Register (0x1B) STATUS

ADDRESS 0x1B

RESET 0b00000000

MODE RW

DESCRIPTION Reports sensor status flags.

DEFINITION

| Bit | Acronym          | Definition   |
|-----|------------------|--|
| 7   | reserved         |  |
| 6   | drdy_gyr         | Data ready (DRDY) for gyroscope in register  |
| 5   | reserved         |  |
| 4   | nvm_rdy          | NVM controller status  |
| 3   | foc_rdy          | FOC completed  |
| 2   | reserved         |  |
| 1   | gyr_self_test_ok | '0' when gyroscope self-test is running or failed.<br>'1' when gyroscope self-test completed successfully. |
| 0   | por_detected     | '0' after read, '1' after software reset or power on   |

drdy\_\*: gets reset when one byte of the register for sensor \* is read.

nvm\_rdy: status of NVM controller: '0' → NVM write operation is in progress; '1' → NVM is ready to accept a new write trigger

foc\_rdy: Fast offset compensation completed

### 3.10.7 Register (0x1D) INT\_STATUS\_1

ADDRESS 0x1D (1 byte)

RESET

MODE RW

DESCRIPTION The register contains interrupt status flags.

DEFINITION

Each flag is associated with a specific interrupt function. It is set when the associated interrupt triggers. The interrupt function associated with a specific status flag must be enabled.

| Register (0x1D) INT_STATUS_1 |           | definition     |
|------------------------------|-----------|----------------|
| 6                            | fwm_int   | Fifo watermark |
| 5                            | ffull_int | Fifo full      |
| 4                            | drdy_int  | Data ready     |

'0' interrupt inactive, '1' interrupt active.

**3.10.8 Register (0x20-0x21) TEMPERATURE**

ADDRESS 0x20 (2 byte)

RESET 0x8000 (-128°C)

MODE R

DESCRIPTION Contains the temperature of the sensor

DEFINITION

The output word of the 16-bit temperature sensor is only valid if the gyroscope is in normal mode, i.e. *gyr\_pmu\_status*=0b01. The resolution is typically  $1/2^9$  K/LSB.

| Value  | Temperature      |
|--------|------------------|
| 0x7FFF | $87 - 1/2^9$ °C  |
| ...    | ...              |
| 0x0000 | 23 °C            |
| ...    | ...              |
| 0x8001 | $-41 + 1/2^9$ °C |
| 0x8000 | Invalid          |

If the gyroscope is in normal mode (see Register (0x03) PMU\_STATUS), the temperature is updated every 10 ms (+12%).

Otherwise, when the gyroscope is in suspend mode and TMP power state is in normal mode, the temperature is updated every 1.28s aligned with bit 15 of the Register (0x20-0x21) TEMPERATURE.

Another configuration is that, when the gyroscope is in fast-power up mode, but TMP power state is set to suspend mode, the temperature measurement will also be executed every 1.28s and Register (0x20-0x21) TEMPERATURE will be updated accordingly.

Comparatively, when both the gyroscope and TMP power states are set to suspend mode, the temperature measurement will be disabled and will not be executed.



### 3.10.9 Register (0x22-0x23) FIFO\_LENGTH

ADDRESS 0x22 (2 byte)

RESET 0x0000

MODE R

DESCRIPTION FIFO data readout register.

DEFINITION

The register contains FIFO status flags.

| Name        |                        | Register (0x22-0x23) FIFO_LENGTH [0] |   |   |  |
|-------------|------------------------|--------------------------------------|---|---|--|
| Bit         | 7                      | 6                                    | 5 | 4 |  |
| Read/Write  | R                      | R                                    | R | R |  |
| Reset Value | 0                      | 0                                    | 0 | 0 |  |
| Content     | fifo_byte_counter<7:4> |                                      |   |   |  |
| Bit         | 3                      | 2                                    | 1 | 0 |  |
| Read/Write  | R                      | R                                    | R | R |  |
| Reset Value | 0                      | 0                                    | 0 | 0 |  |
| Content     | fifo_byte_counter<3:0> |                                      |   |   |  |
| Name        |                        | Register (0x22-0x23) FIFO_LENGTH [1] |   |   |  |
| Bit         | 7                      | 6                                    | 5 | 4 |  |
| Read/Write  | R                      | R                                    | R | R |  |
| Reset Value | 0                      | 0                                    | 0 | 0 |  |
| Content     | Reserved               |                                      |   |   |  |
| Bit         | 3                      | 2                                    | 1 | 0 |  |
| Read/Write  | R                      | R                                    | R | R |  |
| Reset Value | 0                      | 0                                    | 0 | 0 |  |
| Content     | reserved               | fifo_byte_counter<10:8>              |   |   |  |

fifo\_byte\_counter: Current fill level of FIFO buffer. This includes the skip frame for a full FIFO. The FIFO counter also includes the number of skipped frames. E.g. after the FIFO is full, the counter may also reach values larger than what can actually be stored in the FIFO. An empty FIFO corresponds to 0x000. The byte counter may be reset by reading out all frames from the FIFO buffer or when the FIFO is reset through the Register (0x7E) CMD. The byte counter is updated, when a complete frame is read or written.

**3.10.10 Register (0x24) FIFO\_DATA**

ADDRESS 0x24

RESET 0x00

MODE R

DESCRIPTION FIFO data readout register.

DEFINITION

The FIFO data are organized in frames as described in chapter 3.5.1. 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 will be retransmitted (including the header in header mode) at the next readout. New data will only be present after the complete frame has been read.

| Name        | Register (0x24) FIFO_DATA |   |   |   |
|-------------|---------------------------|---|---|---|
| Bit         | 7                         | 6 | 5 | 4 |
| Read/Write  | R                         | R | R | R |
| Reset Value | 0                         | 0 | 0 | 0 |
| Content     | fifo_data<7:4>            |   |   |   |
| Bit         | 3                         | 2 | 1 | 0 |
| Read/Write  | R                         | R | R | R |
| Reset Value | 0                         | 0 | 0 | 0 |
| Content     | fifo_data<3:0>            |   |   |   |

fifo\_data<7:0>: FIFO data readout; data format depends on the setting of Register (0x46-0x47) FIFO\_CONFIG.

### 3.10.11 Register (0x42) GYR\_CONF

ADDRESS 0x42

RESET 0b00101000

MODE RW

DESCRIPTION Sets the output data rate, the bandwidth, and the read mode of the gyroscope in the sensor. DEFINITION

| Name        |          | Register (0x42) GYR_CONF |         |     |  |
|-------------|----------|--------------------------|---------|-----|--|
| Bit         | 7        | 6                        | 5       | 4   |  |
| Read/Write  | R/W      | R/W                      | R/W     | R/W |  |
| Reset Value | 0        | 0                        | 1       | 0   |  |
| Content     | reserved |                          | gyr_bwp |     |  |
| Bit         | 3        | 2                        | 1       | 0   |  |
| Read/Write  | R/W      | R/W                      | R/W     | R/W |  |
| Reset Value | 1        | 0                        | 0       | 0   |  |
| Content     | gyr_odr  |                          |         |     |  |

gyr\_odr: defines the output data rate of the gyro in the sensor. This is independent of the power mode setting for the sensor. Settings below = ODR 25 Hz are illegal. The output data rate in Hz is given by  $100/2^{8-\text{val}(\text{gyr\_odr})}$ .

| gyr_odr | Output data rate in Hz |
|---------|------------------------|
| 0b0000  | Reserved               |
| 0b0001  | Reserved               |
| 0b0010  | Reserved               |
| ...     | (all reserved)         |
| 0b0101  | Reserved               |
| 0b0110  | 25                     |
| ...     |                        |
| 0b1000  | 100                    |
| ...     |                        |
| 0b1100  | 1600                   |
| 0b1101  | 3200                   |
| 0b111x  | Reserved               |

gyr\_bwp: the gyroscope bandwidth coefficient defines the 3 dB cutoff frequency of the low pass filter for the sensor data. For details see Section 3.4.1.

Configurations without a bandwidth number are illegal settings and will result in an error code in the Register (0x02) ERR\_REG.

### 3.10.12 Register (0x43) GYR\_RANGE

ADDRESS 0x43

RESET 0b00000000

MODE RW

DESCRIPTION Defines the BMG250 angular rate measurement range

DEFINITION

A measurement range is selected by setting the range bits as follows:

| Register (0x43) GYR_RANGE |          |                |     |     |
|---------------------------|----------|----------------|-----|-----|
| Bit                       | 7        | 6              | 5   | 4   |
| Read/Write                | R/W      | R/W            | R/W | R/W |
| Reset Value               | 0        | 0              | 0   | 0   |
| Content                   | Reserved |                |     |     |
| 0                         |          |                |     |     |
| Bit                       | 3        | 2              | 1   | 0   |
| Read/Write                | R/W      | R/W            | R/W | R/W |
| Reset Value               | 0        | 0              | 0   | 0   |
| Content                   | reserved | gyr_range<2:0> |     |     |

| range[2:0]          | Full Scale | Resolution                     |
|---------------------|------------|--------------------------------|
| '000'               | ±2000°/s   | 16.4 LSB/°/s ⇔ 61.0 m°/s / LSB |
| '001'               | ±1000°/s   | 32.8 LSB/°/s ⇔ 30.5 m°/s / LSB |
| '010'               | ±500°/s    | 65.6 LSB/°/s ⇔ 15.3 m°/s / LSB |
| '011'               | ±250°/s    | 131.2 LSB/°/s ⇔ 7.6 m°/s / LSB |
| '100'               | ±125°/s    | 262.4 LSB/°/s ⇔ 3.8m°/s / LSB  |
| '101', '110', '111' | reserved   |                                |

gyr\_range<2:0>: Angular Rate Range and Resolution.

reserved:            write '0'

Changing the range of the gyroscope does not clear the data ready bit in the Register (0x1B) STATUS. It is recommended to read the Register (0x12-0x17) DATA after the range change to remove a stall data ready bit from before the range change.

**3.10.13 Register (0x45) FIFO\_DOWNS**

ADDRESS 0x45 (1 byte)

RESET 0b0000-0000

MODE RW

DESCRIPTION Used to configure the down sampling ratios of the data for FIFO.

DEFINITION The downsampling ratio for the data are given by  $2^{\text{Val}(\text{gyr\_fifo\_downs})}$ .  
[gyr]\_fifo\_filt\_data=0 (1) selects pre-filtered (filtered) data for the FIFO, respectively.

| Name        |                    | Register (0x45) FIFO_DOWNS |     |     |  |
|-------------|--------------------|----------------------------|-----|-----|--|
| Bit         | 7                  | 6                          | 5   | 4   |  |
| Read/Write  | n/a                | n/a                        | n/a | n/a |  |
| Reset Value | 0                  | 0                          | 0   | 0   |  |
| Content     | reserved           |                            |     |     |  |
| Bit         | 3                  | 2                          | 1   | 0   |  |
| Read/Write  | R/W                | R/W                        | R/W | R/W |  |
| Reset Value | 1                  | 0                          | 0   | 0   |  |
| Content     | gyr_fifo_filt_data | gyr_fifo_downs             |     |     |  |

### 3.10.14 Register (0x46-0x47) FIFO\_CONFIG

ADDRESS 0x46 (2 bytes)

RESET 0x80 (FIFO\_CONFIG[0]), 0x10 (FIFO\_CONFIG[1])

MODE RW

DESCRIPTION The Register (0x46-0x47) FIFO\_CONFIG is a read/write register and can be used for reading or setting the current FIFO watermark level. This register can also be used for setting the different modes of operation of the FIFO, e.g. which data is going to be stored in it and which format is going to be used (header or headerless mode).

DEFINITION

| Register (0x46-0x47) FIFO_CONFIG [0] |                       |     |     |     |
|--------------------------------------|-----------------------|-----|-----|-----|
| Bit                                  | 7                     | 6   | 5   | 4   |
| Read/Write                           | R/W                   | R/W | R/W | R/W |
| Reset Value                          | 1                     | 0   | 0   | 0   |
| Content                              | fifo_water_mark <7:4> |     |     |     |

|             |                       |     |     |     |
|-------------|-----------------------|-----|-----|-----|
| Bit         | 3                     | 2   | 1   | 0   |
| Read/Write  | R/W                   | R/W | R/W | R/W |
| Reset Value | 0                     | 0   | 0   | 0   |
| Content     | fifo_water_mark <3:0> |     |     |     |

*fifo\_water\_mark* <7:0>: *fifo\_water\_mark* defines the FIFO watermark level. An interrupt will be generated, when the number of entries in the FIFO exceeds *fifo\_water\_mark*. The unit of *fifo\_water\_mark* are 4 bytes.

| Register (0x46-0x47) FIFO_CONFIG [1] |             |                |                  |                  |              |                   |
|--------------------------------------|-------------|----------------|------------------|------------------|--------------|-------------------|
| Bit                                  | 7           | 4              | 3                | 2                | 1            | 0                 |
| Read/Write                           | R/W         | R/W            | R/W              | R/W              | R/W          | R/W               |
| Reset Value                          | 0           | 1              | 0                | 0                | 0            | 0                 |
| Content                              | fifo_gyr_en | fifo_header_en | fifo_tag_int1_en | fifo_tag_int2_en | fifo_time_en | fifo_stop_on_full |

When all the sensors are disabled, the FIFO is disabled and no headers are written. The sensors can be disabled via *fifo\_gyr\_en* respectively.

*fifo\_gyr\_en*: '0' no gyro data are stored in FIFO, '1' gyro data are stored in FIFO (all 3 axes)

*fifo\_header\_en*: If '1' each frame contains a header as defined in section 3.5.1. If '0' the frame format will be headerless.

*fifo\_tag\_int1\_en*: 1 ('0') enables (disables) FIFO tag (interrupt)

*fifo\_tag\_int2\_en*: 1 ('0') enables (disables) FIFO tag (interrupt)

*fifo\_time\_en*: '1'('0') returns (does not return) a sensortime frame after the last valid frame when more data are read than valid frames are in the FIFO.

*fifo\_stop\_on\_full*: stop writing samples into FIFO when FIFO is full.

**3.10.15 Register (0x51) INT\_EN**

ADDRESS 0x51 (1 byte)

RESET

0b0000-0000

MODE RW

DESCRIPTION Controls which interrupt engines are enabled.

DEFINITION

| Register (0x51) INT_EN [1] | acronym      | definition     |
|----------------------------|--------------|----------------|
| 7                          |              | Reserved       |
| 6                          | int_fwm_en   | FIFO watermark |
| 5                          | int_ffull_en | FIFO full      |
| 4                          | int_drdy_en  | Data ready     |

**3.10.16 Register (0x53) INT\_OUT\_CTRL**

ADDRESS 0x53

RESET 0b0000-0000

MODE RW

DESCRIPTION Contains the behavioral configuration (electrical definition of the interrupt pins.  
DEFINITION

| Register (0x53)<br>INT_OUT_CTRL | Acronym        | definition   |
|---------------------------------|----------------|--|
| 7                               | int2_output_en | Output enable for INT2 pin, select '0'→output disabled, or '1' →output enabled   |
| 6                               | int2_od        | select '0'→push-pull, or '1' →open drain behavior for INT2 pin. Only valid if int2_output_en=1.  |
| 5                               | int2_lvl       | '0'→active low, or '1'→active high level for INT2 pin. If int2_output_en=1 this applies for interrupt outputs, if int2_output_en=0 this applies to trigger PMU configured in Register (0x6C) PMU_TRIGGER. For tagging a frame in FIFO through fifo_tag_int2_en in Register (0x46-0x47) FIFO_CONFIG the setting of int2_lvl is not relevant.  |
| 4                               | int2_edge_ctrl | '1' ('0') is edge (level) triggered for INT2 pin   |
| 3                               | int1_output_en | Output enable for INT1 pin, select '0'→output disabled, or '1' →output enabled   |
| 2                               | int1_od        | select '0'→push-pull, or '1' →open drain behavior for INT1 pin. Only valid if int1_output_en=1   |
| 1                               | int1_lvl       | select '0'→active low, or '1'→active high level for INT1 pin. If int1_output_en=1 this applies for interrupt outputs, if int1_output_en=0 this applies to trigger PMU configured in Register (0x6C) PMU_TRIGGER.<br>For tagging in FIFO through fifo_tag_int2_en in Register (0x46-0x47) FIFO_CONFIG the setting of int2_lvl is not relevant.<br>For tagging a frame in FIFO through fifo_tag_int1_en in Register (0x46-0x47) FIFO_CONFIG the setting of int1_lvl is not relevant. |
| 0                               | int1_edge_ctrl | '1' ('0') is edge (level) triggered for INT1 pin   |

int<x>\_edge\_ctrl is only relevant for *int<x>\_output\_en = '1'*



**3.10.17 Register (0x54) INT\_IN\_CTRL**

ADDRESS 0x54

RESET 0b0000-0000

MODE RW

DESCRIPTION Contains the interrupt input mode selection.

DEFINITION

Not applied to new data

| Register (0x54) INT_IN_CTRL | MODE | Definition   |
|-----------------------------|------|--|
| <7:6>                       | n/a  | Reserved   |
| 5                           | RW   | Input enable for INT2 pin, select '0' → input disabled, or '1' → input enabled |
| 4                           | RW   | Input enable for INT1 pin, select '0' → input disabled, or '1' → input enabled |
| <3:0>                       | RW   | Reserved   |

**3.10.18 Register (0x56) INT\_MAP**

ADDRESS 0x56 (1 byte)

RESET

0b0000-0000

MODE RW

DESCRIPTION Controls which interrupt signals are mapped to the INT1 and INT2 pin.

DEFINITION

The tables show bit number of a register and meaning of the interrupt pin.

| Register (0x56) INT_MAP [1]<7:4> | Interrupt mapped to pin INT1 |
|----------------------------------|------------------------------|
| 7                                | Data ready                   |
| 6                                | FIFO watermark               |
| 5                                | FIFO full                    |
| 4                                | reserved                     |

| Register (0x56) INT_MAP [1]<3:0> | Interrupt mapped to pin INT2 |
|----------------------------------|------------------------------|
| 3                                | Data ready                   |
| 2                                | FIFO watermark               |
| 1                                | FIFO full                    |
| 0                                | reserved                     |

'1' means mapping is active, '0' means mapping is inactive.

When the external interrupt is mapped to an interrupt pin, all other interrupt mappings are disabled for this interrupt. When an external interrupt is mapped to an interrupt pin, no other interrupts may be enabled.

### 3.10.19 Register (0x6A) CONF

ADDRESS 0x6A

RESET 0b00000000

MODE RW

DESCRIPTION Configuration of the sensor

DEFINITION

| Register (0x6A) CONF Bit | Acronym     | Definition             |
|--------------------------|-------------|------------------------|
| 7                        | Reserved    |                        |
| 6                        | Reserved    |                        |
| 5                        | Reserved    |                        |
| 4                        | Reserved    |                        |
| 3                        | Reserved    |                        |
| 2                        | Reserved    |                        |
| 1                        | nvm_prog_en | Enable NVM programming |
| 0                        | Reserved    |                        |

nvm\_prog\_en: '1'('0') enables (disables) that the NVM may be programmed

### 3.10.20 Register (0x6B) IF\_CONF

ADDRESS 0x6B

RESET 0x00

MODE RW

DESCRIPTION Contains settings for the digital interface.

DEFINITION

| Name        | Register (0x6B) IF_CONF |     |         |      |
|-------------|-------------------------|-----|---------|------|
| Bit         | 7                       | 6   | 5       | 4    |
| Read/Write  | R/W                     | R/W | R/W     | R/W  |
| Reset Value | 0                       | 0   | 0       | 0    |
| Content     | Reserved                |     | if_mode |      |
| Bit         | 3                       | 2   | 1       | 0    |
| Read/Write  | R/W                     | R/W | R/W     | R/W  |
| Reset Value | 0                       | 0   | 0       | 0    |
| Content     | Reserved                |     |         | spi3 |

reserved: write '0'

spi3: select '0' → 4-wire SPI, or '1' → 3-wire SPI mode

if\_mode: 00: primary interface: autoconfig / secondary interface: off

01: Primary interface: I2C / secondary interface: OIS

10: reserved

11: reserved



**BOSCH**

**BMG250**  
Data sheet

Page 43

### 3.10.21 Register (0x6C) PMU\_TRIGGER

ADDRESS 0x6C

RESET 0b0001-0000

MODE RW

DESCRIPTION Used to set the trigger conditions to change the gyro power modes

DEFINITION

The *pmu\_gyr\_mode* in Register (0x03) PMU\_STATUS is updated with each transition triggered.

| Register (0x6C) PMU_TRIGGER |          |            |                 |          |
|-----------------------------|----------|------------|-----------------|----------|
| <b>Name</b>                 |          |            |                 |          |
| Bit                         | 7        | 6          | 5               | 4        |
| Read/Write                  | RW       | RW         | RW              | RW       |
| Reset Value                 | 0        | 0          | 0               | 0        |
| Content                     | Reserved | wakeup_int | gyr_sleep_state | Reserved |

|             |                       |          |                   |          |
|-------------|-----------------------|----------|-------------------|----------|
| <b>Bit</b>  | <b>3</b>              | <b>2</b> | <b>1</b>          | <b>0</b> |
| Read/Write  | RW                    | RW       | RW                | RW       |
| Reset Value | 0                     | 0        | 0                 | 0        |
| Content     | gyr_wakeup_trigger<0> | Reserved | gyr_sleep_trigger |          |

**gyr\_wakeup\_trigger:** when both trigger conditions are enabled, both conditions must be active to trigger the transition.

| gyr_wakeup_trigger | INT1 pin |
|--------------------|----------|
| 0b0                | no       |
| 0b1                | yes      |

**gyr\_sleep\_trigger:** when more than one trigger condition is enabled, one is sufficient to trigger the transition.

| gyr_sleep_trigger | Not INT1 pin | INT2 pin |
|-------------------|--------------|----------|
| 0b00              | no           | no       |
| 0b01              | no           | yes      |
| 0b10              | yes          | no       |
| 0b11              | yes          | yes      |

If **gyr\_sleep\_trigger** and **gyr\_wakeup\_trigger** are active at the same time, the **gyr\_wakeup\_trigger** wins.

The INTx pin takes into account the edge/level triggered setting in the Register (0x53) INT\_OUT\_CTRL.

**gyr\_sleep\_state:** '1'('0') transitions to suspend (fast start-up) state  
**wakeup\_int:** '1'('0') triggers an interrupt, when a gyro wakeup is triggered

**3.10.22 Register (0x6D) SELF\_TEST**

ADDRESS 0x6D

RESET 0b0000-0000

MODE RW

DESCRIPTION Contains the settings for the sensor self-test configuration and trigger.

DEFINITION

| Register (0x6D) SELF_TEST |          |          |          |                      |
|---------------------------|----------|----------|----------|----------------------|
| Bit                       | 7        | 6        | 5        | 4                    |
| Read/Write                | R/W      | R/W      | R/W      | R/W                  |
| Reset Value               | 0        | 0        | 0        | 0                    |
| Content                   | Reserved |          |          | gyr_self_test_enable |
| Bit                       | 3        | 2        | 1        | 0                    |
| Read/Write                | R/W      | R/W      | R/W      | R/W                  |
| Reset Value               | 0        | 0        | 0        | 0                    |
| Content                   | Reserved | Reserved | Reserved | Reserved             |

reserved: write '0x0'

gyr\_self\_test\_enable: starts self-test of the gyroscope. The result can be obtained from Register (0x1B) STATUS.

**3.10.23 Register (0x70) NV\_CONF**

ADDRESS 0x70

RESET 0x00

MODE RW

DESCRIPTION Contains settings for the digital interface.

DEFINITION

This register is backed by NVM and loaded from NVM during boot-up.

| Name        |          | Register (0x70) NV_CONF |             |        |  |
|-------------|----------|-------------------------|-------------|--------|--|
| Bit         | 7        | 6                       | 5           | 4      |  |
| Read/Write  | R/W      | R/W                     | R/W         | R/W    |  |
| Reset Value | 0        | 0                       | 0           | 0      |  |
| Content     | Reserved |                         |             |        |  |
| Bit         | 3        | 2                       | 1           | 0      |  |
| Read/Write  | R/W      | R/W                     | R/W         | R/W    |  |
| Reset Value | 0        | 0                       | 0           | 0      |  |
| Content     | reserved | i2c_wdt_en              | i2c_wdt_sel | spi_en |  |

reserved: write '0'

i2c\_wdt\_en: if I<sup>2</sup>C interface mode is selected then '1' → enable, or '0' → disables the watchdog at the SDI pin (= SDA for I<sup>2</sup>C)i2c\_wdt\_sel: select an I<sup>2</sup>C watchdog timer period of '0' → 1 ms, or '1' → 50 msspi\_en: disable the I<sup>2</sup>C and only enable SPI for the interface, when it is in autoconfig if\_mode.

### 3.10.24 Register (0x74-0x77) OFFSET

ADDRESS 0x74 (4 byte)

RESET Reads from NVM

MODE RW

DESCRIPTION Contains the offset compensation values for the gyroscope

DEFINITION

Offset values, which are added to the internal filtered and pre-filtered data for the sensor if the function is enabled with `gyr_off_en` in the register; the offset values are represented with two's complement notation; the content of the register may be written to the NVM; it is automatically restored from the NVM after each power-on or soft reset; offset values may be written directly by the user; it is generated automatically after triggering the fast offset compensation procedure.

|     |                             |
|-----|-----------------------------|
| [3] | <b>off_gyr_x&lt;7:0&gt;</b> |
| [4] | <b>off_gyr_y&lt;7:0&gt;</b> |
| [5] | <b>off_gyr_z&lt;7:0&gt;</b> |

| Name        |                         | Register (0x77) OFFSET [6] |                             |     |
|-------------|-------------------------|----------------------------|-----------------------------|-----|
| Bit         | 7                       |                            | 5                           | 4   |
| Read/Write  | R/W                     |                            | R/W                         | R/W |
| Reset Value | 0                       |                            | 0                           | 0   |
| Content     | <code>gyr_off_en</code> |                            | <b>off_gyr_z&lt;9:8&gt;</b> |     |

| Bit         | 3                           | 2   | 1                           | 0   |
|-------------|-----------------------------|-----|-----------------------------|-----|
| Read/Write  | R/W                         | R/W | R/W                         | R/W |
| Reset Value | 0                           | 0   | 0                           | 0   |
| Content     | <b>off_gyr_y&lt;9:8&gt;</b> |     | <b>off_gyr_x&lt;9:8&gt;</b> |     |

The offset of the gyroscope `off_gyr_[xyz]` is a two-complement number in units of  $0.12 \text{ deg/s} \cdot 2^{\text{Val}(\text{gyr\_range\_off})}$ , i.e. the resolution may be configured from 0.12 to 0.98 deg/s and the range from 31.25 to 250 deg/s. The configuration is done in the Register (0x70) `NV_CONF`.

The MSBs for the gyro offset setting are also contained in `OFFSET[6]`. Aside from this, the register also contains the two bits `gyr_off_en`, which can be set to 1 in order to enable gyro offset compensation.

### 3.10.25 Register (0x7E) CMD

Register (0x7E) CMD

ADDRESS 0x7E

RESET 0x00

MODE W

DESCRIPTION Command register triggers operations like *softreset*, NVM programming, etc.

DEFINITION

| Name        |          |   |   |   |
|-------------|----------|---|---|---|
| Bit         | 7        | 6 | 5 | 4 |
| Read/Write  | W        | W | W | W |
| Reset Value | 0        | 0 | 0 | 0 |
| Content     | cmd<7:4> |   |   |   |
| Bit         | 3        | 2 | 1 | 0 |
| Read/Write  | W        | W | W | W |
| Reset Value | 0        | 0 | 0 | 0 |
| Content     | cmd<3:0> |   |   |   |

During the time a command is executed, it occupies the Register (0x7E) CMD. All new writes to this register are dropped during this time with the exception of the *softreset* command. If a write to the Register (0x7E) CMD is dropped, *drop\_cmd\_err* in Register (0x02) ERR\_REG is set.

Table 24: Typical and max. execution times for which the CMD register is occupied

| Description  | Command code | Typ. time in ms | Max. time in ms |
|--|--------------|-----------------|-----------------|
| Set PMU mode of gyroscope to normal or fast start-up from suspend mode | 0x15; 0x17   | 55              | 80              |

The time it takes to perform a soft reset in conjunction with re-starting a sensor is essentially given by the corresponding PMU command execution time in Table 24 (to be more exact, a system start-up time of 300 µs has to be added to the times given for PMU switching).

cmd:

start\_foc: 0x03

Starts Fast Offset Calibration as configured in Register (0x69) FOC\_CONF and stores the result into the Register (0x74-0x77) OFFSET register.

gyr\_set\_pmu\_mode: 0b0001 01nn

Sets the PMU mode for the gyroscope. The encoding for 'nn' is identical to *gyr\_pmu\_status* in Register (0x03) PMU\_STATUS

|                      |          |  |
|----------------------|----------|--|
| <a href="#">0x10</a> | tmp_susp | Sets the PMU mode to suspend.  |
| <a href="#">0x11</a> | tmp_norm | Sets the PMU mode to normal.<br>This command is necessary if user want to program NVM. |





|                      |          |   |
|----------------------|----------|---|
| <a href="#">0x14</a> | gyr_susp | Sets the PMU mode for the Gyroscope to suspend.       |
| <a href="#">0x15</a> | gyr_norm | Sets the PMU mode for the Gyroscope to normal.        |
| <a href="#">0x16</a> | gyr_res  | Reserved  |
| <a href="#">0x17</a> | gyr_fsyp | Sets the PMU mode for the Gyroscope to fast start-up. |

prog\_nvm: 0xA0

Writes the NVM backed registers into NVM.

fifo\_flush: 0xB0

clears all data in the FIFO, does not change the Register (0x46-0x47) FIFO\_CONFIG and Register (0x45) FIFO\_DOWNS registers.

softreset: 0xB6

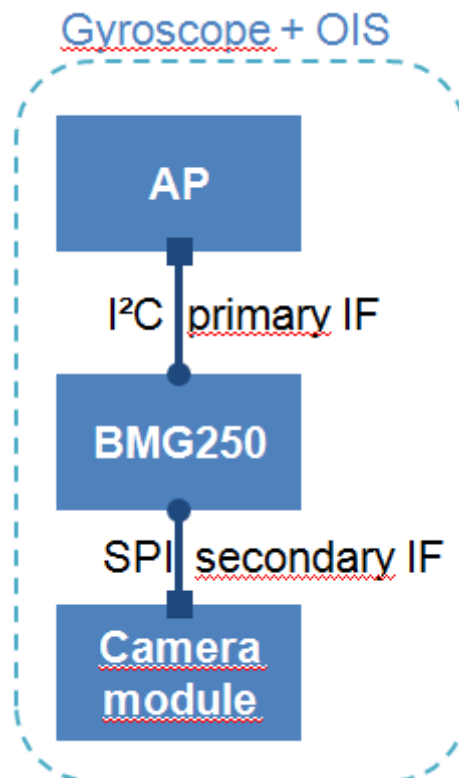
triggers a reset including a reboot. Other values are ignored. Following a delay, all user configuration settings are overwritten with their default state or the setting stored in the NVM, wherever applicable. This register is functional in all operation modes.

## 4. Digital interfaces

### 4.1 Interface

Beside the standard primary interface (I<sup>2</sup>C and SPI configurable), where the sensor acts as a slave to the application processor, BMG250 supports a secondary OIS-Interface (SPI).

In this mode, the secondary interface can be used as an OIS-Interface to be connected to an external OIS-Control unit, where the OIS controller will act as a master and the BMG250 as a slave.



By default, the BMG250 operates in I<sup>2</sup>C mode. The BMG250 interface can also be configured to operate in a SPI 4-wire configuration. It can be re-configured by software to work in 3-wire mode instead of 4-wire mode.

The mapping for the interface of the BMG250 is given in the following table:

Table 25: Mapping of the interface pins

| Pin# | Name | I/O Type    | Description   | Connect to |             |                             |
|------|------|-------------|---|------------|-------------|-----------------------------|
|      |      |             |   | in SPI4W   | in SPI3W    | in I <sup>2</sup> C         |
| 1    | SDO  | Digital I/O | Serial data output in SPI<br>Address select in I <sup>2</sup> C mode  | MISO       | DNC (float) | SA0 (GND for default addr.) |
| 4    | INT1 | Digital I/O | Interrupt pin 1 *)  | INT1       | INT1        | INT1                        |
| 9    | INT2 | Digital I/O | Interrupt pin 2 *)  | INT2       | INT2        | INT2                        |
| 12   | CSB  | Digital in  | Chip select for SPI mode / Protocol selection pin   | CSB        | CSB         | VDDIO                       |
| 13   | SCx  | Digital in  | SCK for SPI serial clock<br>SCL for I <sup>2</sup> C serial clock   | SCK        | SCK         | SCL                         |
| 14   | SDx  | Digital I/O | SDA serial data I/O in I <sup>2</sup> C<br>SDI serial data input in SPI 4W<br>SDA serial data I/O in SPI 3W | MOSI       | SISO        | SDA                         |

The following table shows the electrical specifications of the interface pins:

Table 26: Electrical specification of the interface pins

| Parameter   | Symbol                | Condition                            | Min | Typ | Max | Units |
|---|-----------------------|--------------------------------------|-----|-----|-----|-------|
| Pull-up Resistance, CSB pin                                   | R <sub>up</sub>       | Internal Pull-up Resistance to VDDIO | 75  | 100 | 150 | kΩ    |
| Input Capacitance   | C <sub>in</sub>       |                                      |     |     | 5   | pF    |
| I <sup>2</sup> C Bus Load Capacitance (max. drive capability) | C <sub>I2C_Load</sub> |                                      |     |     | 400 | pF    |

#### 4.1.1 Interface I<sup>2</sup>C/SPI Protocol Selection

The protocol is automatically selected based on the chip select CSB pin behavior after power-up. At reset / power-up, BMG250 is in I<sup>2</sup>C mode. If CSB is connected to V<sub>DDIO</sub> during power-up and not changed the sensor interface works in I<sup>2</sup>C mode. For using I<sup>2</sup>C, it is recommended to hard-wire the CSB line to V<sub>DDIO</sub>. Since power-on-reset is only executed when, both V<sub>DD</sub> and V<sub>DDIO</sub> are established, there is no risk of incorrect protocol detection due to power-up sequence.

If CSB sees a rising edge after power-up, the BMG250 interface switches to SPI until a reset or the next power-up occurs. Therefore, a CSB rising edge is needed before starting the SPI

communication. Hence, it is recommended to perform a SPI single read access to the ADDRESS 0x7F before the actual communication is started in order to use the SPI interface.

If toggling of the CSB bit is not possible without data communication, there is in addition the *spi\_en* bit in Register (0x70) NV\_CONF, which can be used to permanently set the interface to SPI without the need to toggle the CSB pin at every power-up or reset.

#### 4.1.2 SPI Interface

The timing specification for SPI of the BMG250 is given in the following table:

Table 27: SPI timing, valid at  $V_{DDIO} \geq 1.71V$ , if not stated otherwise

| Parameter                                      | Symbol                | Condition   | Min | Max | Units   |
|--|-----------------------|---|-----|-----|---------|
| Clock Frequency                                | $f_{SPI}$             | Max. Load on SDI or SDO = 25pF, $V_{DDIO} \geq 1.71V$ |     | 10  | MHz     |
|  |                       | $V_{DDIO} < 1.71V$                                    |     | 7.5 | MHz     |
| SCK Low Pulse                                  | $t_{SCKL}$            |   | 48  |     | ns      |
| SCK High Pulse                                 | $t_{SCKH}$            |   | 48  |     | ns      |
| SDI Setup Time                                 | $t_{SDI\_setup}$      |   | 20  |     | ns      |
| SDI Hold Time                                  | $t_{SDI\_hold}$       |   | 20  |     | ns      |
| SDO Output Delay                               | $t_{SDO\_OD}$         | Load = 30pF, $V_{DDIO} \geq 1.62V$                    | 45  |     | ns      |
|  |                       | Load = 25pF, $V_{DDIO} < 1.62V$                       | 52  |     | ns      |
|  |                       | Load = 250pF, $V_{DDIO} > 2.4V$                       | 45  |     | ns      |
| CSB Setup Time                                 | $t_{CSB\_setup}$      |   | 20  |     | ns      |
| CSB Hold Time                                  | $t_{CSB\_hold}$       |   | 40  |     | ns      |
| Idle time between write accesses, normal mode  | $t_{IDLE\_wacc\_nm}$  |   | 2   |     | $\mu s$ |
| Idle time between write accesses, suspend mode | $t_{IDLE\_wacc\_sum}$ |   | 450 |     | $\mu s$ |

The following figure shows the definition of the SPI timings:

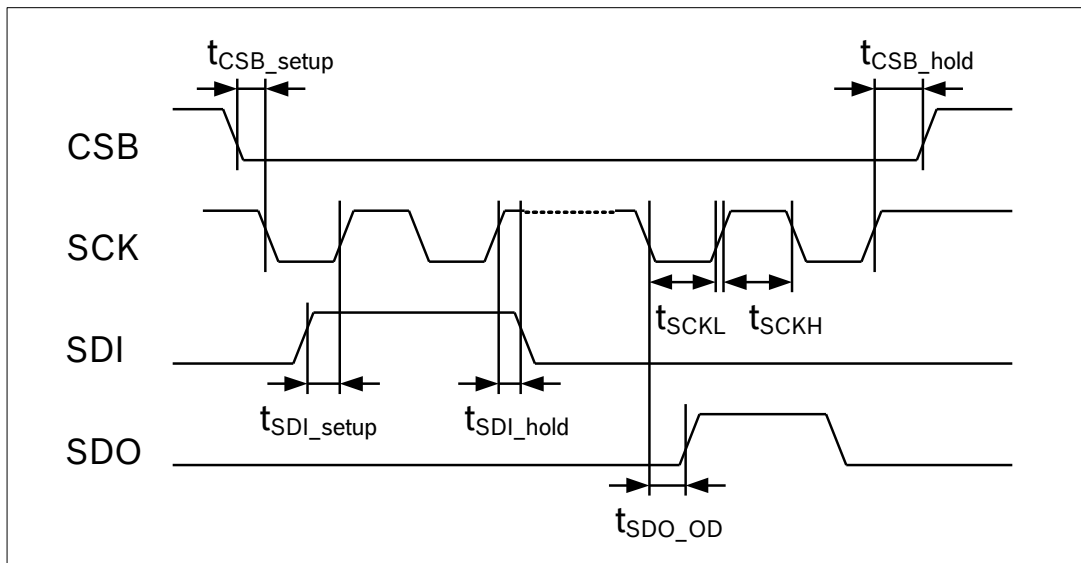


Figure 22: SPI timing diagram

The SPI interface of the BMG250 is compatible with two modes, '00' [CPOL = '0' and CPHA = '0'] and '11' [CPOL = '1' and CPHA = '1']. The automatic selection between '00' and '11' is controlled based on the value of SCK after a falling edge of CSB.

Two configurations of the SPI interface are supported by the BMG250: 4-wire and 3-wire. The same protocol is used by both configurations. The device operates in 4-wire configuration by default. It can be switched to 3-wire configuration by writing '1' to Register (0x6B) IF\_CONF *spi3*. Pin SDI is used as the common data pin in 3-wire configuration.

For single byte read as well as write operations, 16-bit protocols are used. The BMG250 also supports multiple-byte read and write operations.

**In SPI 4-wire configuration** CSB (chip select low active), SCK (serial clock), SDI (serial data input), and SDO (serial data output) pins are used. The communication starts when the CSB is pulled low by the SPI master and stops when CSB is pulled high. 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.

The basic write operation waveform for 4-wire configuration is depicted in the following figure. During the entire write cycle SDO remains in high-impedance state.

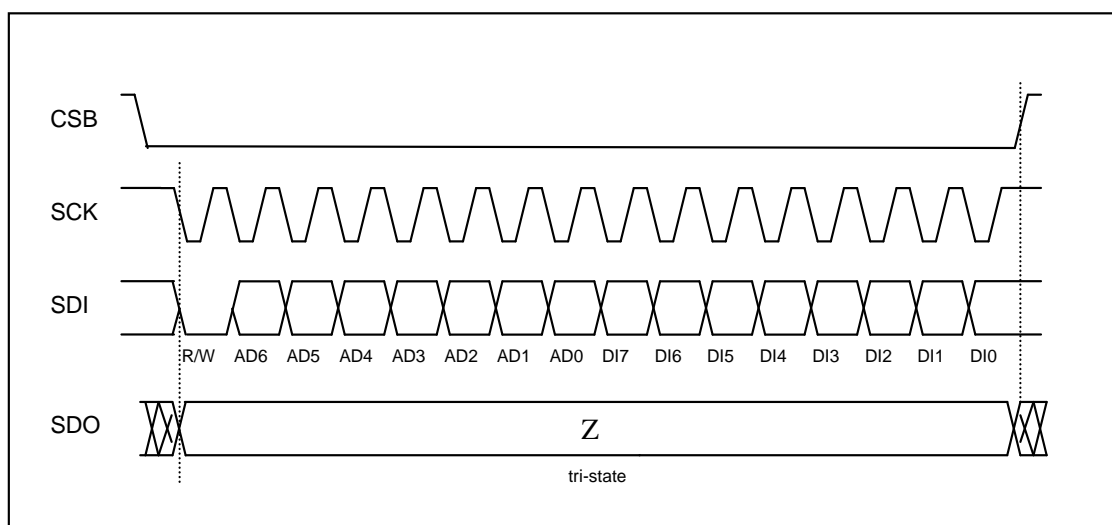


Figure 23: 4-wire basic SPI write sequence (mode '11')

The basic read operation waveform for 4-wire configuration is depicted in the figure below:

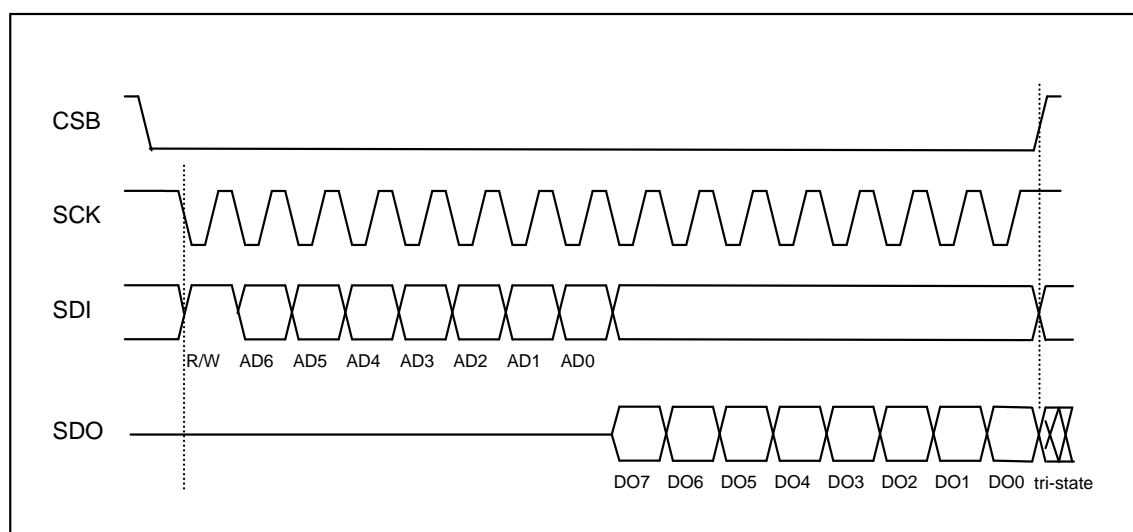


Figure 24: 4-wire basic SPI read sequence (mode '11')

The data bits are used as follows:

**Bit0:** Read/Write bit. When 0, the data SDI is written into the chip. When 1, the data SDO from the chip is read.

**Bit1-7:** Address AD(6:0).

Bit8-15: when in write mode, these are the data SDI, which will be written into the address. When in read mode, these are the data SDO, which are read from the address.

Multiple read operations are possible by keeping CSB low and continuing the data transfer. Only the first register address has to be written. Addresses are automatically incremented after each read access as long as CSB stays active low.

The principle of multiple read is shown in figure below:

[illegible]

Figure 25: SPI multiple read

**In SPI 3-wire configuration** CSB (chip select low active), SCK (serial clock), and SDI (serial data input and output) pins are used. While SCK is high, the communication starts when the CSB is pulled low by the SPI master and stops when CSB is pulled high. SCK is also controlled by SPI master. SDI 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.

The protocol as such is the same in 3-wire configuration as it is in 4-wire configuration. The basic operation wave-form (read or write access) for 3-wire configuration is depicted in the figure below:

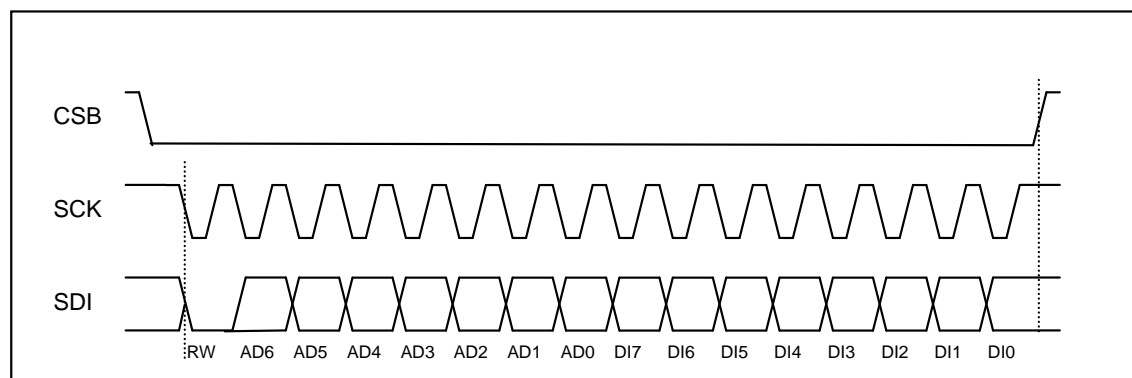


Figure 26: 3-wire basic SPI read or write sequence (mode '11')

### 4.1.3 I<sup>2</sup>C Interface

The I<sup>2</sup>C bus uses SCL (= SCx pin, serial clock) and SDA (= SDx pin, serial data input and output) signal lines. Both lines are connected to V<sub>DDIO</sub> externally via pull-up resistors so that they are pulled high when the bus is free.

The I<sup>2</sup>C addresses are identical to BMG160. The default I<sup>2</sup>C address of the device is 0b1101000 (0x68). It is used if the SDO pin is pulled to 'GND'. The alternative address 0b1101001 (0x69) is selected by pulling the SDO pin to 'VDDIO'.

The I<sup>2</sup>C interface of the BMG250 is compatible with the I<sup>2</sup>C Specification UM10204 Rev. 03 (19 June 2007), available at <http://www.nxp.com>. The BMG250 supports **I<sup>2</sup>C standard mode and fast mode**, only 7-bit address mode is supported. For  $V_{DDIO} = 1.2V$  to  $1.62 V$  the guaranteed voltage output levels are slightly relaxed as described in Table 1 of the electrical specification section.

BMG250 also supports an **extended I<sup>2</sup>C mode** that allows using clock frequencies up to 1 MHz. In this mode all timings of the fast mode apply and it additionally supports clock frequencies up to 1MHz.

The timing specification for I<sup>2</sup>C of the BMG250 is given in the following table:

Table 28: I<sup>2</sup>C timings

| Parameter  | Symbol                | Condition    | Min | Max  | Units   |
|--|-----------------------|--------------|-----|------|---------|
| Clock Frequency  | $f_{SCL}$             |              |     | 1000 | kHz     |
| SCL Low Period   | $t_{LOW}$             |              | 1.3 |      | $\mu s$ |
| SCL High Period  | $t_{HIGH}$            |              | 0.6 |      |         |
| SDA Setup Time   | $t_{SUDAT}$           |              | 0.1 |      |         |
| SDA Hold Time  | $t_{HDDAT}$           |              | 0.0 |      |         |
| Setup Time for a repeated Start Condition                    | $t_{SUSTA}$           |              | 0.6 |      |         |
| Hold Time for a Start Condition                              | $t_{HDSTA}$           |              | 0.6 |      |         |
| Setup Time for a Stop Condition                              | $t_{SUSTO}$           |              | 0.6 |      |         |
| Time before a new Transmission can start                     | $t_{BUF}$             | suspend mode | 400 |      |         |
|  |                       | normal mode  | 1.3 |      |         |
| Idle time between write accesses, normal mode, suspend mode  | $t_{IDLE\_wacc\_nm}$  | suspend mode | 400 |      |         |
|  |                       | normal mode  | 1.3 |      |         |
| Idle time between write accesses, suspend mode, suspend mode | $t_{IDLE\_wacc\_sum}$ |              | 400 |      |         |



The figure below shows the definition of the I<sup>2</sup>C timings given in Table 28:

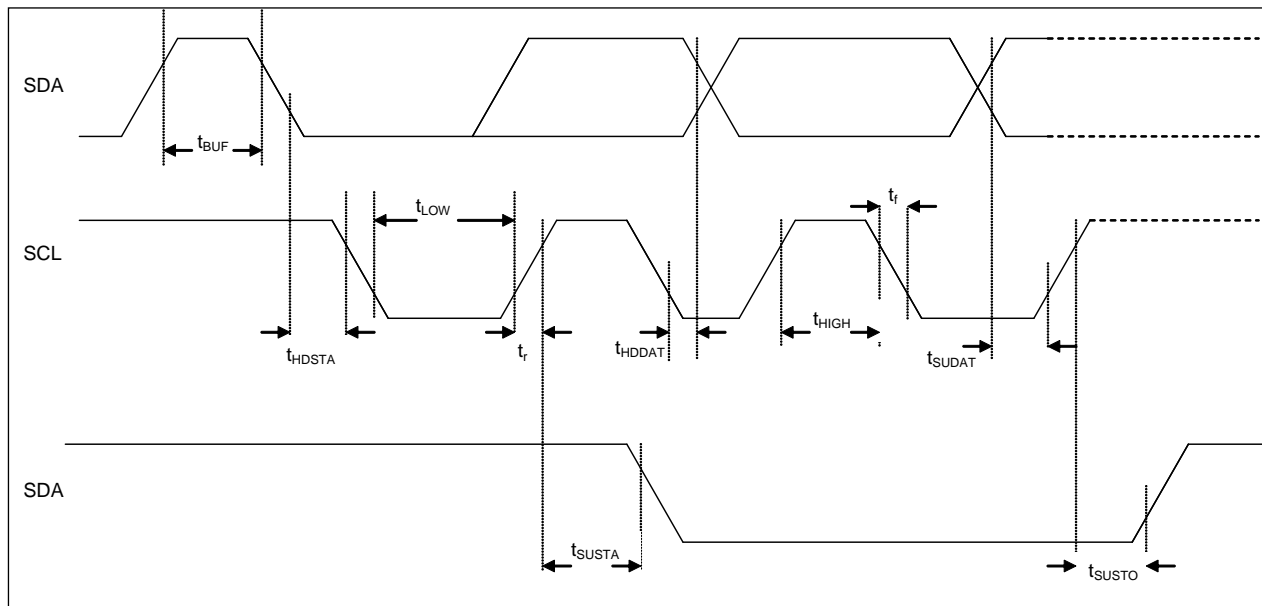


Figure 27: I<sup>2</sup>C timing diagram

The I<sup>2</sup>C 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 I<sup>2</sup>C 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.

In the following diagrams these abbreviations are used:

|       |                           |
|-------|---------------------------|
| S     | Start                     |
| P     | Stop                      |
| ACKS  | Acknowledge by slave      |
| ACKM  | Acknowledge by master     |
| NACKM | Not acknowledge by master |
| RW    | Read / Write              |

A START 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.

### I<sup>2</sup>C write access:

I<sup>2</sup>C write access can be used to write a data byte 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 (ACKS = 0) and releases the bus. Then the master sends the one byte register address. The slave again acknowledges the transmission and waits for the 8 bits of data which shall be written to the specified register address. After the slave acknowledges the data byte, the master generates a stop signal and terminates the writing protocol.

Example of an I<sup>2</sup>C write access:

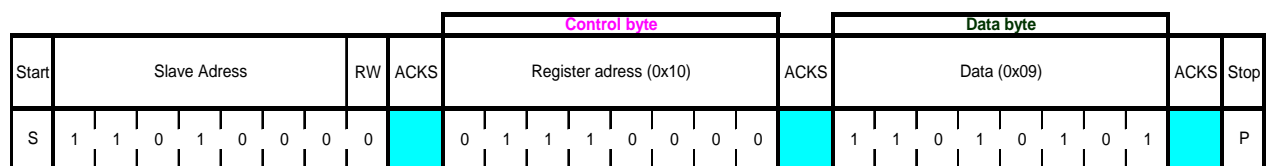


Figure 28: I<sup>2</sup>C write

### I<sup>2</sup>C read access:

I<sup>2</sup>C read access also can be used to read one or multiple data bytes in one sequence.

A read sequence consists of a one-byte I<sup>2</sup>C write phase followed by the I<sup>2</sup>C read phase. The two parts of the transmission must be separated by a repeated start condition (S). The I<sup>2</sup>C 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 (ACKS = 0) to enable further data transfer. A NACKM (ACKS = 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 byte 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 I<sup>2</sup>C write command. By default the start address is set at 0x00. In this way repetitive multi-bytes reads from the same starting address are possible.

In order to prevent the I<sup>2</sup>C slave of the device to lock-up the I<sup>2</sup>C bus, a watchdog timer (WDT) is implemented. The WDT observes internal I<sup>2</sup>C signals and resets the I<sup>2</sup>C interface if the bus is locked-up by the BMG250. The activity and the timer period of the WDT can be configured through the bits *i2c\_wdt\_en* and *i2c\_wdt\_sel* at Register (0x70) NV\_CONF.

Writing '1' ('0') to Register (0x70) NV\_CONF *i2c\_wdt\_en* activates (de-activates) the WDT. Writing '0' ('1') to Register (0x70) NV\_CONF *i2c\_wdt\_en* selects a timer period of 1 ms (50 ms).

Example of an I<sup>2</sup>C read access (reading gyro data):

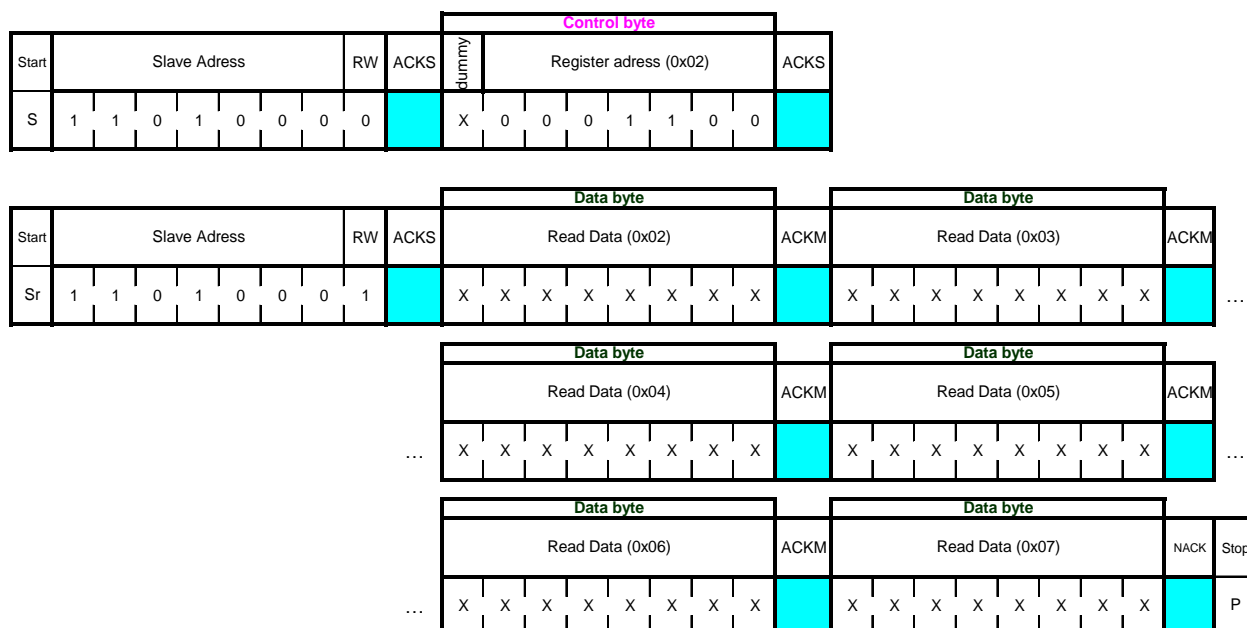


Figure 29: I<sup>2</sup>C multiple read

#### 4.1.4 SPI and I<sup>2</sup>C Access Restrictions

In order to allow for the correct internal synchronization of data written to the BMG250, certain access restrictions apply for consecutive write accesses or a write/read sequence through the SPI as well as I<sup>2</sup>C interface. The required waiting period depends on whether the device is operating in normal mode or other modes.

As illustrated in the figure below, an interface idle time of at least 2  $\mu$ s is required following a write operation when the device operates in normal mode. In suspend mode an interface idle time of at least 450  $\mu$ s is required<sup>1</sup>.

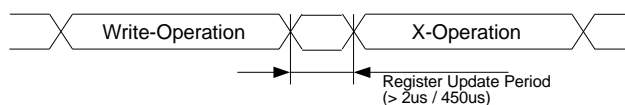


Figure 30: Post-Write Access Timing Constraints

<sup>1</sup> The times are preliminary and need to be verified.

## 4.2 Secondary Interface

OIS Interface (SPI) for connecting to a OIS control unit:

Secondary interface for OIS application can be enabled by writing '01' to Register (0x6B) IF\_CONF if\_mode.

In this case the secondary interface is used as a SPI interface where an external control unit is connected as a master to BMG250. The external control unit can be e.g. an OIS controller.

If secondary interface is used, primary interface is limited to I<sup>2</sup>C mode.

The mapping for the secondary interface of the BMG250 is given in the following table:

Table 29: Mapping of the secondary interface pins

| Pin# | Name | I/O Type    | Description             | Connect to (secondary IF) |          |                     |
|------|------|-------------|-------------------------|---------------------------|----------|---------------------|
|      |      |             |                         | in SPI4W                  | in SPI3W | in I <sup>2</sup> C |
| 10   | OSCB | Digital I/O | Secondary OIS interface | CSB                       | CSB      | DNC                 |
| 11   | OSDO | Digital I/O | Secondary OIS interface | MISO                      | DNC      | DNC                 |

### 4.2.1 Camera module connected to secondary interface for OIS

BMG250 supports specific optical image stabilization (OIS) applications with a dedicated interface. This interface is used for direct access to pre-filtered gyroscope data with minimum latency. Pre-filtered gyroscope data is available at output data rate (ODR) of 6.4 kHz and can be read out via OIS SPI interface at 10MHz maximum speed.

The OIS SPI interface supports 3-wire SPI as well as 4-wire SPI.

The timings of the secondary SPI interface are the same as for the primary SPI interface, see chapter 4.1.2. The connection diagrams are depicted in chapter.

## 5. Pin-out and Connection diagrams

### 5.1 Pin-out BMG250

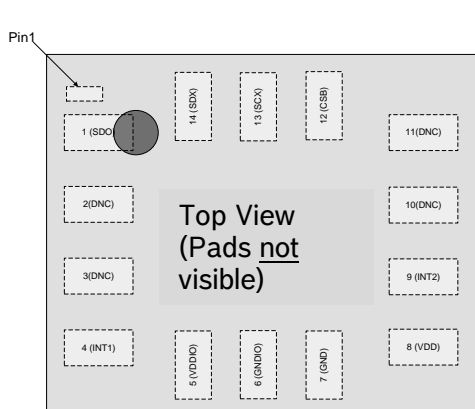


Figure 31: Pin-out top view

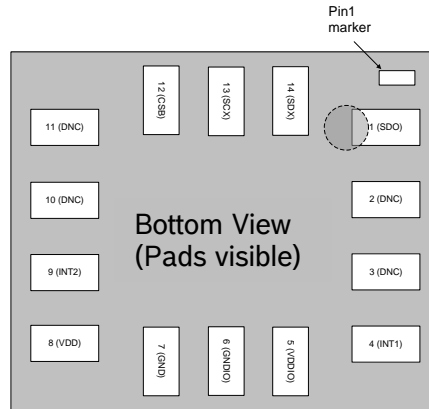


Figure 32: Pin-out bottom view

Table 30: BMG250 Pin-out and pin connections are described in the table below

| Pin# | Name             | I/O Type    | Description   |
|------|------------------|-------------|---|
| 1    | SDO              | Digital I/O | Serial data output in SPI<br>Address select in I <sup>2</sup> C mode  |
| 2    | ASD <sub>x</sub> | Digital I/O | MOSI serial data input in SPI 4W 2 <sup>ndary</sup> Interface<br>SISO serial data I/O in SPI 3W 2 <sup>ndary</sup> Interface<br>Other configuration: Do not connect (or GND)                |
| 3    | ASC <sub>x</sub> | Digital in  | SPI serial clock for 2 <sup>ndary</sup> Interface<br>Other configuration: Do not connect (or GND)   |
| 4    | INT1             | Digital I/O | Interrupt pin 1 *)  |
| 5    | VDDIO            | Supply      | Digital I/O supply voltage<br>(1.2 ... 3.6V)  |
| 6    | GNDIO            | Ground      | Ground for I/O  |
| 7    | GND              | Ground      | Ground for digital & analog   |
| 8    | VDD              | Supply      | Power supply analog & digital domain (1.62V – 3.6V)   |
| 9    | INT2             | Digital I/O | Interrupt pin 2 *)  |
| 10   | OSCB             | Digital I/O | CSB in SPI as 2 <sup>ndary</sup> Interface<br>Other configuration: Do not connect (or GND)  |
| 11   | OSCO             | Digital I/O | MISO in SPI 4W 2 <sup>ndary</sup> Interface<br>Other configuration: Do not connect (or GND)   |
| 12   | CSB              | Digital in  | Chip select for SPI mode / Protocol selection pin   |
| 13   | SC <sub>x</sub>  | Digital in  | SCK for SPI serial clock<br>SCL for I <sup>2</sup> C serial clock   |
| 14   | SD <sub>x</sub>  | Digital I/O | SDA serial data I/O in I <sup>2</sup> C<br>MOSI serial data input in SPI 4W (without 2 <sup>ndary</sup> Interface)<br>SISO serial data I/O in SPI 3W (without 2 <sup>ndary</sup> Interface) |

\*) If INT1 and/or INT2 are not used, please do not connect them (DNC)

NOTE: all pins must be soldered to the PCB even if they are electrically not connected

## 5.2 Connection diagrams

### 5.2.1 I<sup>2</sup>C interface without using secondary OIS interface

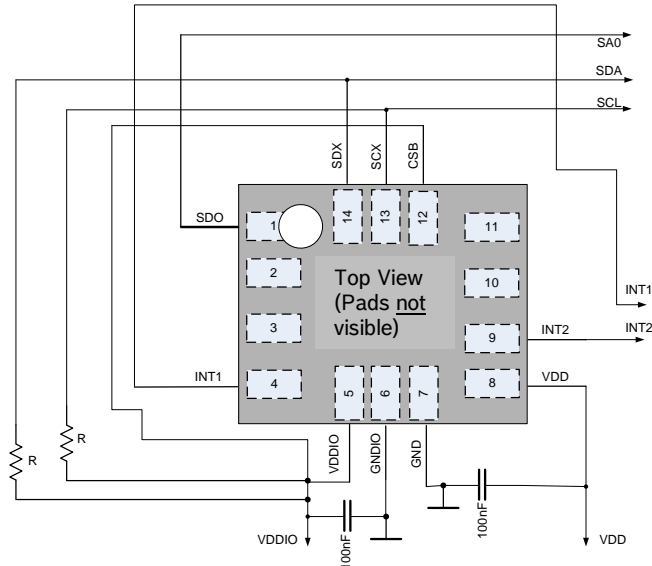


Figure 33: I<sup>2</sup>C as interface

### 5.2.2 SPI 3-wire interface without using secondary OIS interface

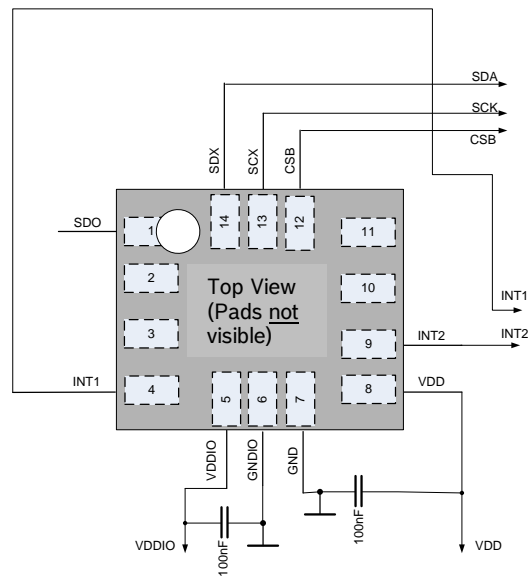


Figure 34: Only SPI 3-wire as interface

### 5.2.3 SPI 4-wire interface without using secondary OIS interface

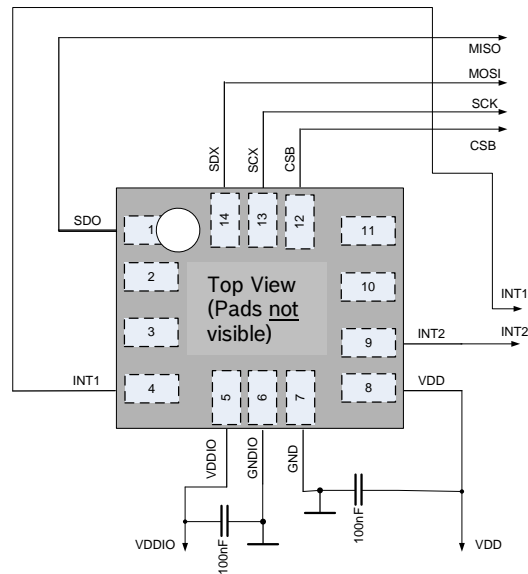
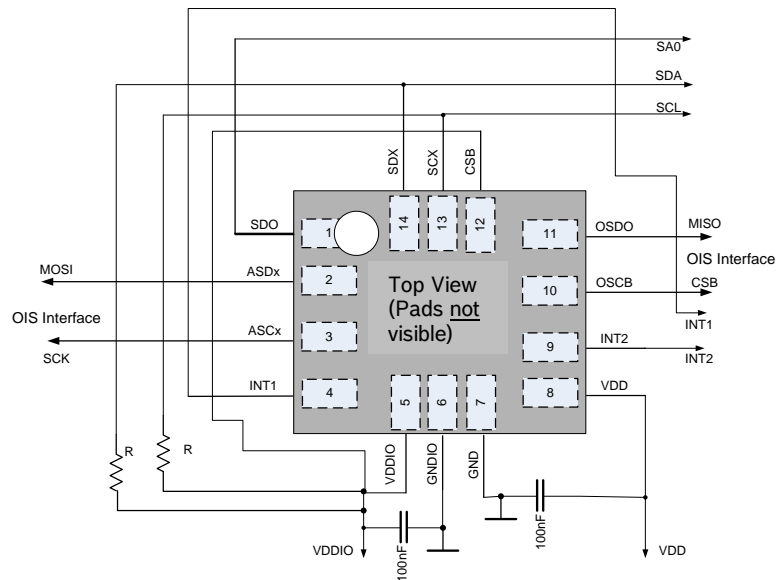


Figure 35: Only SPI 4-wire as interface

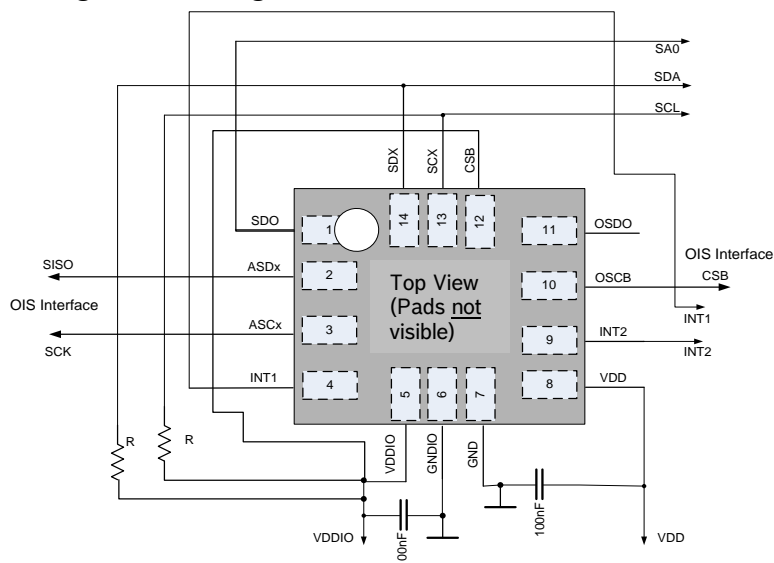
### 5.2.4 Primary I<sup>2</sup>C and secondary 4-wire SPI as OIS interface

Figure 36: Using I<sup>2</sup>C and 4-wire SPI as OIS interface



### 5.2.5 Primary I<sup>2</sup>C and secondary 3-wire SPI as OIS interface

Figure 37: Using I<sup>2</sup>C and 3-wire SPI as OIS interface





## 6. Package

### 6.1 Outline Dimensions

The package dimension is LGA 2.5mm x 3.0mm x 0.83mm.

Unit of the following drawing is mm. Note: Unless otherwise specified tolerance = decimal  $\pm 0.05$  mm.

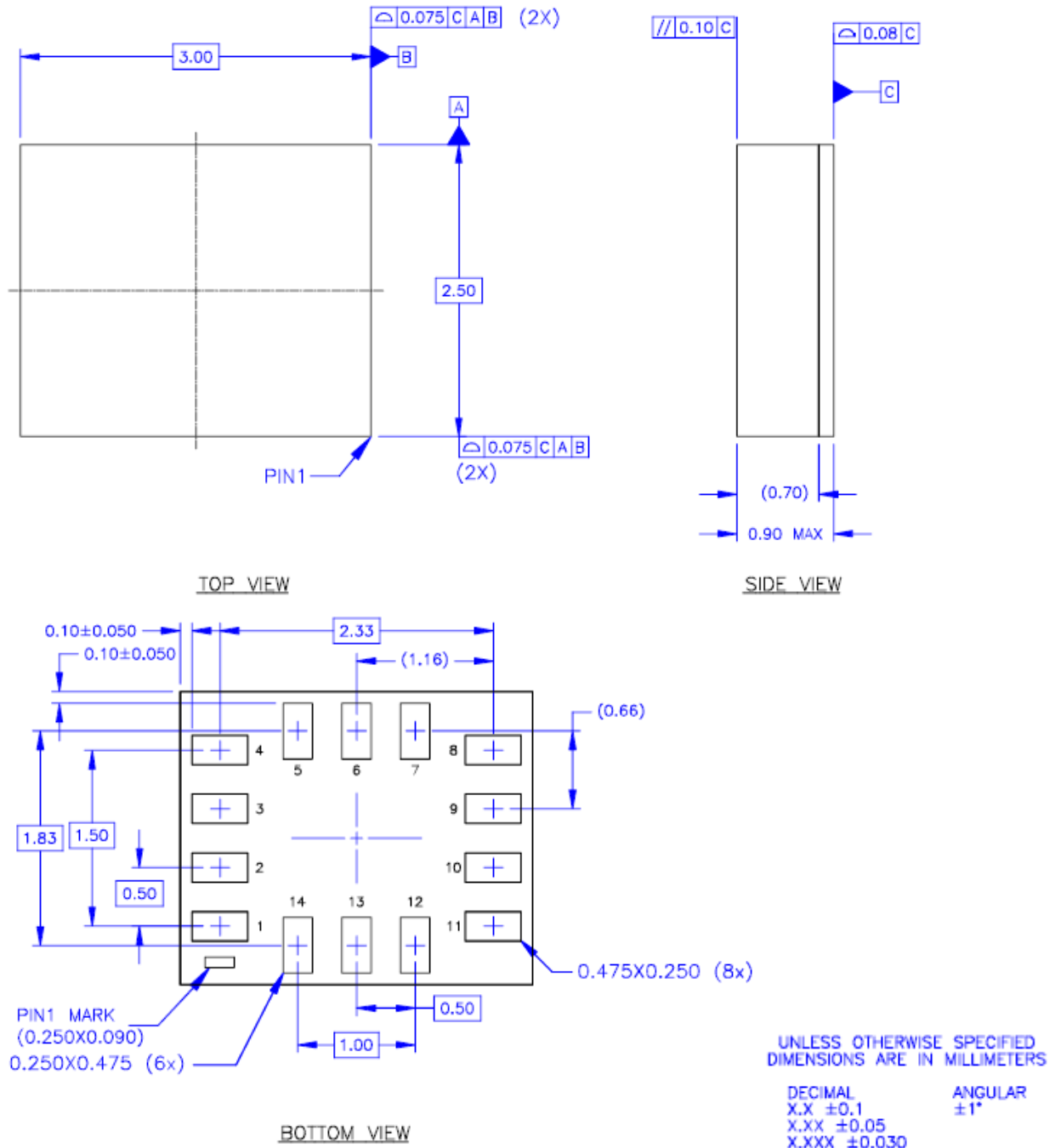


Figure 38: Packaging outline dimensions

Note: Pin1 marker is internally connected to Pin1. It must not be connected to a different signal than Pin1.

## 6.2 Sensing axes orientation

If the sensor is rotated in the indicated directions, the corresponding channels of the device will deliver a positive yaw rate signal. If the sensor is at rest without any rotation the output of the corresponding gyroscope channel will be “zero” (static acceleration).

Example: If the sensor would be placed on a seconds hand of a watch with the arrows of the following Fig. pointing towards the watch’s dial, the output signals are:

- + 6°/sec for the  $\Omega_x$  GYR channel
- + 6°/sec for the  $\Omega_y$  GYR channel
- + 6°/sec for the  $\Omega_z$  GYR channel

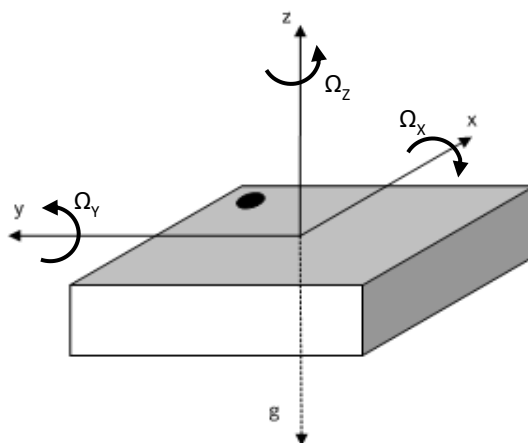


Figure 39: definition of sensing axes orientation

For reference the figure below shows the Android device orientation with an integrated BMG250.

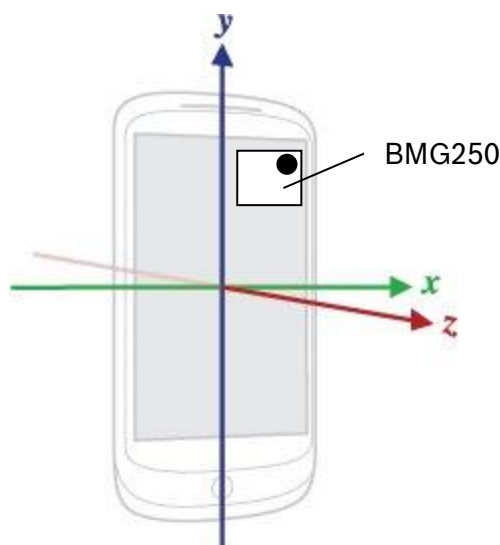


Figure 40: Android axis definition with BMG250



### 6.3 Landing pattern recommendation

The following landing pad recommendation is given for maximum stability of the solder connections.

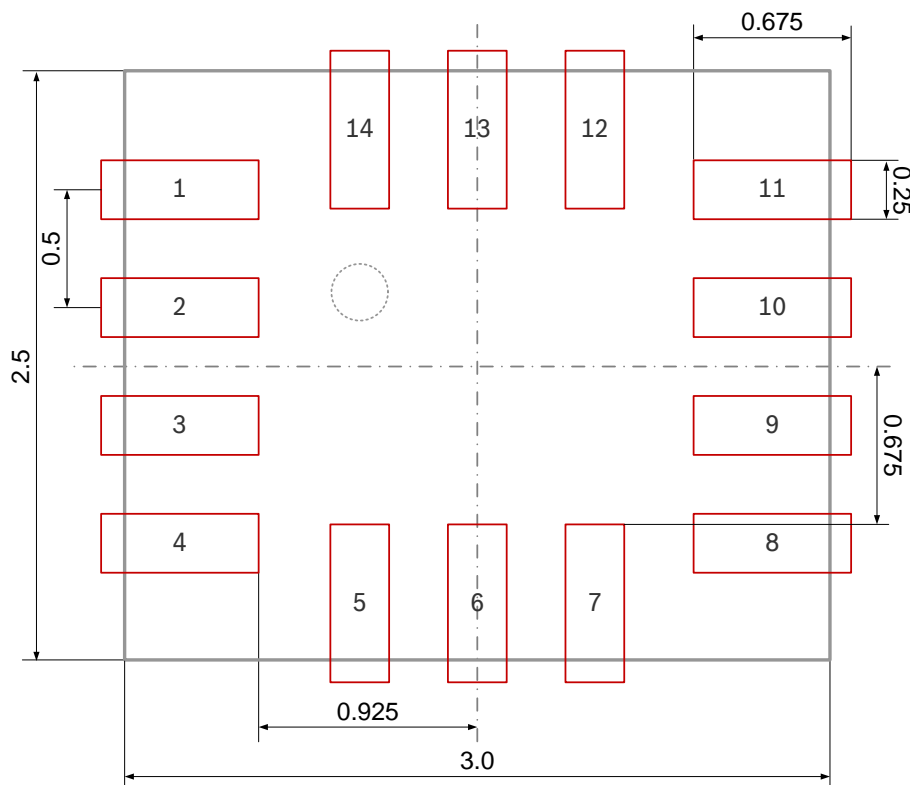


Figure 41: Landing pattern recommendation for BMG250

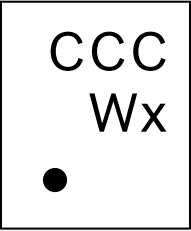
Note: Pin1 marker is internally connected to Pin1. It must not be connected to a different signal than Pin1.

The size of the landing pads may be further reduced in order to minimize solder-stress induced effects if sufficient control over the soldering process is given. Please contact your sales representative for further details.

## 6.4 Marking

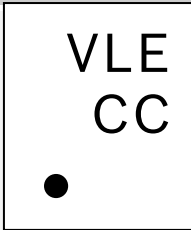
### 6.4.1 Mass production marking

Table 31: Marking of mass samples

| Labeling  | Name                        | Symbol | Remark   |
|---|-----------------------------|--------|--|
|  | Counter ID                  | CCC    | 3 alphanumeric digits, variable to generate trace-code |
|   | First letter of second row  | W      | Product identifier W, denoting BMG250                  |
|   | Second letter of second row | x      | Internal use – various digits possible                 |
|   | Pin 1 identifier            | ●      | --   |

### 6.4.2 Engineering samples

Table 32: Marking of engineering samples

| Labeling  | Name             | Symbol | Remark   |
|---|------------------|--------|--|
|  | Internal ID      | VLE    | Various digits – internal “E” denotes engineering status |
|   | Second row       | CC     | CC - internal revision ID                                |
|   | Pin 1 identifier | ●      | --   |

## 6.5 Soldering guidelines

The moisture sensitivity level of the BMG250 sensors corresponds to JEDEC Level 1, see also

- IPC/JEDEC J-STD-020C “Joint Industry Standard: Moisture/Reflow Sensitivity Classification for non-hermetic Solid State Surface Mount Devices”
- IPC/JEDEC J-STD-033A “Joint Industry Standard: Handling, Packing, Shipping and Use of Moisture/Reflow Sensitive Surface Mount Devices”

The sensor fulfils the lead-free soldering requirements of the above-mentioned IPC/JEDEC standard, i.e. reflow soldering with a peak temperature up to 260°C.

| Profile Feature  |  | Pb-Free Assembly                   |
|--|--|------------------------------------|
| Average Ramp-Up Rate<br>( $T_{s_{max}}$ to $T_p$ )   |  | 3° C/second max.                   |
| <b>Preheat</b> <ul style="list-style-type: none"> <li>– Temperature Min (<math>T_{s_{min}}</math>)</li> <li>– Temperature Max (<math>T_{s_{max}}</math>)</li> <li>– Time (<math>t_{s_{min}}</math> to <math>t_{s_{max}}</math>)</li> </ul> |  | 150 °C<br>200 °C<br>60-180 seconds |
| Time maintained above: <ul style="list-style-type: none"> <li>– Temperature (<math>T_L</math>)</li> <li>– Time (<math>t_L</math>)</li> </ul>   |  | 217 °C<br>60-150 seconds           |
| Peak/Classification Temperature ( $T_p$ )  |  | 260 °C                             |
| Time within 5 °C of actual Peak Temperature ( $t_p$ )  |  | 20-40 seconds                      |
| Ramp-Down Rate   |  | 6 °C/second max.                   |
| Time 25 °C to Peak Temperature   |  | 8 minutes max.                     |

**Note 1:** All temperatures refer to topside of the package, measured on the package body surface.

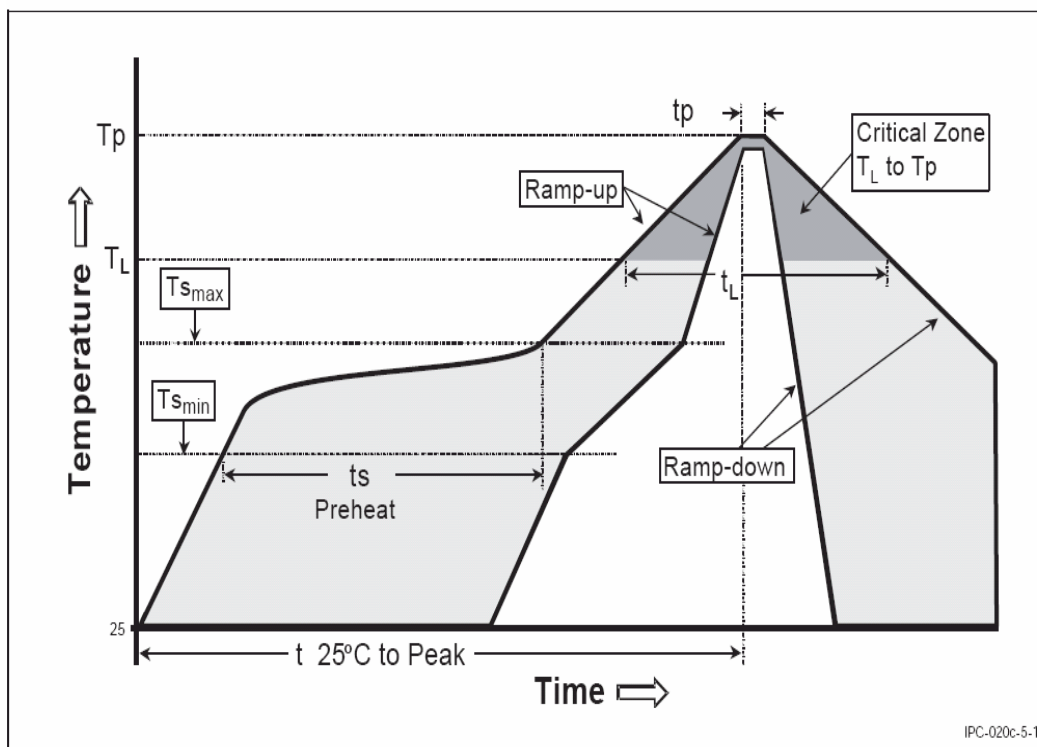


Figure 42: Soldering profile



## 6.6 Handling instructions

Micromechanical sensors are designed to sense rotations with high accuracy even at low turn rates and contain highly sensitive structures inside the sensor element. The MEMS sensor can tolerate mechanical shocks up to several thousand g's. However, these limits might be exceeded in conditions with extreme shock loads such as e.g. hammer blow on or next to the sensor, dropping of the sensor onto hard surfaces etc.

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

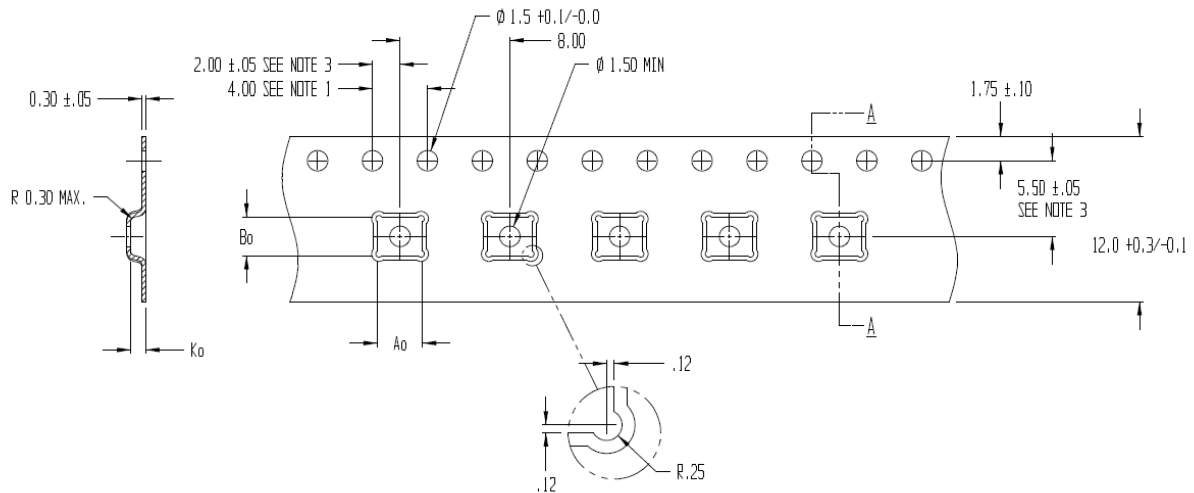
This device has built-in protections against high electrostatic discharges or electric fields (e.g. 2kV HBM); however, anti-static precautions should be taken as for any other CMOS component. Unless otherwise specified, proper operation can only occur when all terminal voltages are kept within the supply voltage range. Unused inputs must always be tied to a defined logic voltage level.

## 6.7 Tape and reel specification

The BMG250 is shipped in a standard cardboard box.

The box dimension for 1 reel is:  $L \times W \times H = 35 \text{ cm} \times 35 \text{ cm} \times 6 \text{ cm}$ .

BMG250 quantity: 5,000pcs per reel, please handle with care.



$$A_0 = 3.30, B_0 = 2.80, K_0 = 1.10$$

Note:

- Tolerances unless noted:  $\pm 0.1$
- Sprocket hole pitch cumulative tolerance  $\pm 0.1$
- 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

Figure 43: Tape and reel dimensions in mm

### 6.7.1 Orientation within the reel

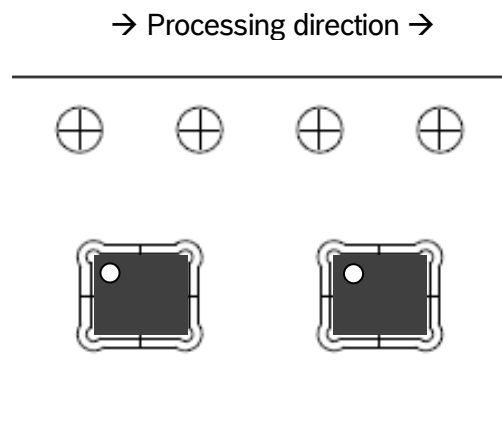


Figure 44: Orientation of the BMG250 devices relative to the tape

## 6.8 Environmental safety

The BMG250 sensor meets the requirements of the EC restriction of hazardous substances (RoHS) directive, see also:

*Directive 2002/95/EC of the European Parliament and of the Council of 27 January 2003 on the restriction of the use of certain hazardous substances in electrical and electronic equipment.*

### 6.8.1 Halogen content

The BMG250 is halogen-free. For more details on the analysis results please contact your Bosch Sensortec representative.

### 6.8.2 Multiple sourcing

Within the scope of Bosch Sensortec's ambition to improve its products and secure the mass product supply, Bosch Sensortec employs multiple sources in the supply chain.

While Bosch Sensortec takes care that all of technical parameters are described above are 100% identical for all sources, there can be differences in device marking and bar code labeling.

However, as secured by the extensive product qualification process of Bosch Sensortec, this has no impact to the usage or to the quality of the product.



## 7. Legal disclaimer

### 7.1 Engineering samples

Engineering Samples are marked with an asterisk (\*) or (e). Samples may vary from the valid technical specifications of the product series contained in this data sheet. They are therefore 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 product series. Bosch Sensortec assumes no liability for the use of engineering samples. The Purchaser shall indemnify Bosch Sensortec from all claims arising from the use of engineering samples.

### 7.2 Product use

Bosch Sensortec products are developed for the consumer goods industry. They may only be used within the parameters of this product data sheet. They are not fit for use in life-sustaining or safety-critical systems. Safety-critical systems are those for which a malfunction is expected to lead to bodily harm, death or severe property damage. In addition, they shall not be used directly or indirectly for military purposes (including but not limited to nuclear, chemical or biological proliferation of weapons or development of missile technology), nuclear power, deep sea or space applications (including but not limited to satellite technology).

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The purchaser accepts the responsibility to monitor the market for the purchased products, particularly with regard to product safety, and to inform Bosch Sensortec without delay of all safety-critical incidents.

### 7.3 Application examples and hints

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## 8. Document history and modifications

| Rev. No | Chapter | Description of modification/changes | Date      |
|---------|---------|-------------------------------------|-----------|
| 1.0     |         | Initial release                     | Sept 2015 |
| 1.1     |         | Update secondary Interface          | May 2016  |
| 1.2     |         | Final Release                       | July 2016 |
| 1.3     | 7       | Update of legal disclaimer          | Oct 2019  |

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