BMI090L

High-performance longevity Inertial Measurement Unit

BMI090L: Datasheet

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Basic description

BMI090L is a high-performance longevity Inertial Measurement Unit (IMU) with extended availability up to 10 years[1]. BMI090L is designed to cater the industrial applications such as robots and white goods, which require long lifecycles. The 6-axis IMU combines a 16-bit triaxial gyroscope and a 16-bit triaxial accelerometer in a miniature 3 x 4.5 x 0.95 mm3 (16-pin) LGA package. BMI090L features a closed-loop gyro and a robust accelerometer with a built-in mechanical filter to suppress high-frequency vibrations, thus enabling precise orientation and motion tracking in harsh and demanding industrial environments.

BMI090L offers wide acceleration measurement range (from ±3 g to ±24 g), vibration robustness as well as high temperature stability. The automotive-proven gyroscope of the BMI090L has an unmatched bias instability of less than 2 °/h (consumer electronics industry-best) and a low temperature coefficient of offset (TCO) below 15 mdps/K. The accelerometer features a low TCO of 0.2 mg/K and low spectral noise of less than 200 µg/sqrt (Hz). BMI090L provides accurate and reliable inertial sensor data even under demanding conditions, including environments where those conditions change, such as thermal effects like heating, mechanical impacts and stresses such as high shocks, vibrations and PCB bending.

The BMI090L is designed for best possible fit into modern embedded consumer electronics devices. The sensor has very wide ranges for VDD and VDDIO supply voltages. The performance and the current consumption are stable over the whole voltage supply range. BMI090L provides two digital serial interfaces: I2C and SPI. The sensor has an extended measurement range of up to ±24g to avoid signal clipping under strong signal exposure.

The high robustness of the sensor gives the user more freedom in placing the sensor on a PCB and can help to reduce the design effort and costs on system level, for example by omitting additional damping structures or freeing up space when considering heat sources or thermal distributions across the PCB. Depending on the application needs, the sensor may also allow to reduce calibration effort at end-of-line tests.

BMI090L features a 1 kB FIFO for accelerometer data and a 0.6 kB FIFO for gyroscope data. Both FIFOs support synchronization with external events. BMI090L supports the following industry-relevant features:

- Axis remapping
- Any motion/no motion
- High g/low g
- Orientation

Together with the barometric pressure sensor BMP388 and the magnetometer BMM150, the BMI090L is part of a comprehensive 7-DoF/10-DoF solution from Bosch Sensortec, allowing for additional features like precise altitude measurement and accurate heading calculation.

10 YEARS LONGEVITY

[1] See longevity disclaimer on the last page of this document.

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1. Specification

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

1.1 Electrical specifications

Table 1: Electrical parameter specification

Parameter	Symbol	Condition	Min	Max	Unit
Supply Voltage Internal Domains	VDD		2.4	3.6	V
Supply Voltage I/O Domain	VDDIO		1.2	3.6	V
Voltage Input Low Level	$V_{IL,a}$	SPI & I²C		0.3VDDIO	-
Voltage Input High Level	$V_{IH,a}$	SPI & I²C	0.7VDDIO		-
Voltage Output Low Level	$V_{OL,a}$	I_{OL}<= 2mA, SPI		0.23VDDIO	-
Voltage Output High Level	V_{OH}	I_{OH} <= 2mA, SPI	0.8VDDIO		-
Operating Temperature	T_A		-40	+85	°C

1.1.1 Electrical specifications: accelerometer/gyroscope

Table 2: Electrical parameter specification accelerometer

Parameter	Symbol	Condition	Min	Typ	Max	Units
Total Supply Current in Normal mode	I_{DD}	VDD = VDDIO =3.0V, 25°C, g_{FS4g}		150		µA
Total Supply Current in Suspend Mode	I_{DDsum}	VDD = VDDIO =3.0V, 25°C		3		µA
Power-up time	t_{s_up}	Time to first valid sample from suspend mode			1	ms

Table 3: Electrical parameter specification gyroscope

Parameter	Symbol	Condition	Min	Typ	Max	Unit
Supply Current in Normal Mode	I_{DD}	VDD = VDDIO = 3.0V, 25°C, ODR =1kHz		5		mA
Supply Current in Suspend Mode	I_{DDsum}	VDD = VDDIO = 3.0V, 25°C		25		µA
Supply Current in Deep Suspend Mode	I_{DDdsum}	VDD = VDDIO = 3.0V, 25°C		<5		µA
Start-up time	t_{su}	to ±1°/s of final value; from power-off		30		ms
Wake-up time	t_{wusm}	From suspend- and deep suspend-modes		30		ms
Wake-up time	t_{wufpm}	From fast power-up mode		10		ms

1.2 Accelerometer specifications

Table 4: Accelerometer specifications

Parameter	Symbol	Condition	Min	Typ	Max	Units
Acceleration Range	g_{FS3g}	Selectable via serial digital interface		±3		g
	g_{FS6g}			±6		g
	g_{FS12g}			±12		g
	g_{FS24g}			±24		g
Sensitivity	S_{3g}	g_{FS3g}, T_A=25°C		10920		LSB/g
	S_{6g}	g_{FS6g}, T_A=25°C		5460		LSB/g
	S_{12g}	g_{FS12g}, T_A=25°C		2730		LSB/g
	S_{24g}	g_{FS24g}, T_A=25°C		1365		LSB/g
Sensitivity Temperature Drift	TCS			0.002		%/K
Zero-g Offset	Off	Nominal VDD and VDDIO, 25°C, g_{FS6g}		20		mg
Zero-g Offset Temperature Drift	TCO			<0.2		mg/K
Output Data Rate	ODR		12.5		1600	Hz
Bandwidth range	BW	3dB cut-off frequency of the accelerometer depends on ODR and OSR	5		280 (245 for Z axis)	Hz
Nonlinearity	NL	best fit straight line, g_{FS3g}		0.5		%FS
Output Noise Density	n_{rms}	g_{FS3g}, T_A=25°C Nominal VDD supplies Normal mode		190 (Z-axis) 160 (X- & Y-axis)		µg/√Hz
Cross Axis Sensitivity	S	relative contribution between any two of the three axes		0.5		%
Alignment Error	E_A	relative to package outline		0.5		°

1.3 Gyroscope specifications

Table 5: Gyroscope specifications

Parameter	Symbol	Condition	Min	Typ	Max	Unit
Range	R_{FS125}	Selectable via serial digital interface		125		°/s
	R_{FS250}			250		°/s
	R_{FS500}			500		°/s
	R_{FS1000}			1000		°/s
	R_{FS2000}			2000		°/s
Sensitivity		Ta=25°C, R_{FS125}		262.144		LSB/°/s
		Ta=25°C, R_{FS250}		131.072		LSB/°/s
		Ta=25°C, R_{FS500}		65.536		LSB/°/s
		Ta=25°C, R_{FS1000}		32.768		LSB/°/s
		Ta=25°C, R_{FS2000}		16.384		LSB/°/s
Sensitivity tolerance		Ta=25°C, R_{FS2000}		±1		%
Sensitivity Change over Temperature	TCS	Nominal VDD supplies -40°C ≤ T_A ≤ +85°C R_{FS2000}		±0.03		%/K
Sensitivity Supply Volt. Drift	S_{VDD}	T_A=25°C, VDD_{min} ≤ VDD ≤ VDD_{max}		<0.4		%/V
Nonlinearity	NL	best fit straight line R_{FS1000}, R_{FS2000}		±0.05		%FS
g-Sensitivity		Sensitivity to acceleration stimuli in all three axis (frequency <20kHz)			0.1	°/s/g
Zero-rate Offset	Off Ω_x Ω_y and Ω_z	Nominal VDD supplies T_A=25°C, slow and fast offset cancellation off		±1		°/s
Zero-rate Offset Change over Temperature	TCO	Nominal VDD supplies -40°C ≤ T_A ≤ +85°C R_{FS2000}		±0.015		°/s per K
Zero-rate Offset Supply Volt. Drift	$Off\Omega_{VDD}$	T_A=25°C, VDD_{min} ≤ VDD ≤ VDD_{max}		<0.1		°/s /V
Output Noise	n_{rms}	rms, BW=47Hz (@ 0.014°/s/√Hz)		0.1		°/s
Bandwidth BW	f_{-3dB}			523 230 116 64		Hz

				47 32 23 12		
Data rate (set of x,y,z rate)				2000 1000 400 200 100		Hz
Data rate tolerance (set of x,y,z rate)				±0.3		%
Cross Axis Sensitivity		Sensitivity to stimuli in non-sense-direction		±1		%

1.4 Temperature sensor specifications

Table 6: Temperature sensor specifications

Parameter	Symbol	Condition	Min	Typ	Max	Units
Temperature Sensor Measurement Range	T_S		-104		150	°C
Temperature Sensor Slope	dT_S			0.125		K/LSB
Temperature Sensor Offset error	OT_S	at 25°C		±1		K

1.5 Absolute maximum ratings

Table 7: Absolute maximum ratings

Parameter	Condition	Min	Max	Units
Voltage at Supply Pin	VDD Pin	-0.3	4	V
	VDDIO Pin	-0.3	4	V
Voltage at any Logic Pin	Non-Supply Pin	-0.3	VDDIO+0.3	V
Passive Storage Temp. Range	≤ 65% rel. H.	-50	+150	°C
Mechanical Shock	Duration ≤ 200µs		10,000	g
	Duration ≤ 1.0ms		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.

2. Block diagram

Figure 1 shows the basic building blocks of the BMI090L:

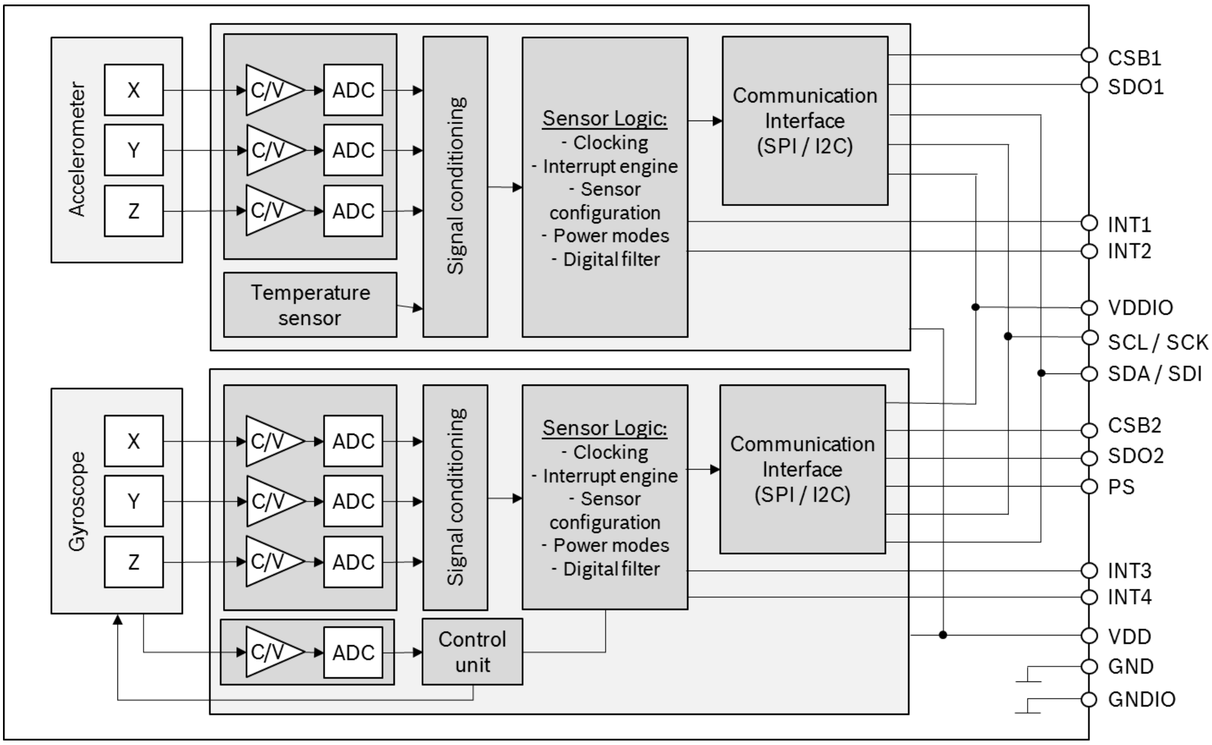


Figure 1: Block diagram of BMI090L

3. Quick start guide – device initialization

For a proper device initialization, the following steps should be considered:

- The user must decide on the interface (I2C or SPI) already during HW design: with the PS pin the user determines which interface the sensor should listen to (see chapter 6).
- The gyroscope sensor of the BMI090L initializes its I/O pins according to the selection given by the PS pin.
- The acceleration sensor starts in I2C mode. It will stay in I2C mode until it detects a rising edge on the CSB1 pin (chip select of the accelerometer), on which the acceleration sensor switches to SPI mode and stays in this mode until the next power-up-reset.
- To change the accelerometer to SPI mode in the initialization phase, the user must perform a dummy SPI read operation, e.g. of register ACC_CHIP_ID (the obtained value will be invalid).

After the POR the gyroscope is in normal mode, while the accelerometer is in suspend mode. To switch the accelerometer into normal mode, the user must perform the following steps:

- Power up the sensor
- Wait 1 ms
- Enter normal mode by setting the bit ACC_PWR_CTRL.acc_en
- Wait for 50 ms

4. Functional description

4.1 Power management and power modes

The BMI090L has two distinct power supply pins:

- VDD is the main power supply for the internal blocks
- VDDIO is a separate power supply pin mainly used for the supply of the interface

There are no limitations on the voltage levels of both pins relative to each other, as long as each of them lies within its operating range. Furthermore, the device can be completely switched off (VDD = 0V) while keeping the VDDIO supply on (VDDIO > 0V) or vice versa.

When the VDDIO supply is switched off, all interface pins (CSB, SDI, SCK, PS) must be kept close to GND_{IO} potential.

The device contains a power-on reset (POR) generator. It resets the logic part and the register values after powering-on VDD and VDDIO. This means that all application specific settings which are not equal to the default settings (refer to 6.2 register map accelerometer and to 8.2 register map gyroscope), must be changed back to their designated values after POR.

Please note: the POR resets also the interface. For the gyroscope sensor, the interface is defined by the voltage level on the PS pin. The interface of the accelerometer is defined by the voltage level of the CSB1 pin, the moment when the POR is initiated (see chapter 3).

4.1.1 Power modes: accelerometer

The power state of the BMI090L accelerometer is controlled through the register ACC_PWR_CTRL. The register ACC_PWR_CTRL enables and disables the accelerometer and the temperature sensor.

To enter **normal mode**, set the bit ACC_PWR_CTRL.acc_en

To enter **suspend mode**, clear the bit ACC_PWR_CTRL.acc_en

Note: the sensor is in suspend mode after reset (POR or soft-reset), thus the user actively needs to enter normal mode in order to obtain acceleration values.

Note: after POR or soft-reset, the acceleration sensor needs up to 1ms boot time. When changing power modes, the sensor needs up to 5ms to settle. Any communication with the sensor during this time should be avoided.

4.1.2 Power modes: gyroscope

The gyroscope has 3 different power modes. Besides normal mode, which represents the fully operational state of the device, there are 2 energy saving modes: suspend mode and deep-suspend mode.

After power-up gyro is in normal mode so that all parts of the device are held powered-up and data acquisition is performed continuously.

In **suspend mode** the whole analog part is powered down. No data acquisition is performed. While in suspend mode the latest rate data and the content of all configuration registers are kept. The registers can still be read (though they are not updated).

Suspend mode is entered by writing 0x80 to the GYRO_LPM1 register. It can be left by writing 0x00 to GYRO_LPM1 or by a soft reset (see 4.9).

Although write access to registers is supported at the full interface clock speed (SCL or SCK), a waiting period must be inserted between two consecutive write cycles (please refer also to section 9.2.1).

In **deep suspend mode** the device reaches the lowest possible power consumption. Only the interface section is kept alive. No data acquisition is performed and the content of the configuration registers is lost.

Deep suspend mode is entered by writing 0x20 to the GYRO_LPM1 register. It can be left by writing 0x00 to GYRO_LPM1 to or by a soft reset (see 4.9).

Please note, that all application specific settings, which are not equal to the default settings, must be re-set to its designated values after leaving deep-suspend mode.

Note: after POR or soft-reset, or when switching between the different power modes, the gyroscope sensor needs up to 30ms time to reach the new state. Any communication with the sensor during this time should be avoided.

4.2 Device Initialization

After power up sequence the accelerometer is in suspend mode, device must initialized through the following procedure. Initialization has to be performed as well after every POR or soft reset.

- Disable advanced power save mode: ACC_PWR_CONF.pwr_save_mode = 0b0
- *Wait for 450 us. The* SENSORTIME_0 register *increments every 39.25 μsec and may be used for* accurate timing.
- Write INIT_CTRL.init_ctrl = 0x00
    - Burst write initialization data to FEATURES_IN Register. The configuration file is included in the driver available on the Bosch Sensortec website (www.bosch-sensortec.com) or from your regional support team. Optionally the configuration file can be written to the Register FEATURES_IN in several consecutive burst write access. Every burst write must contain an even number of bytes.
    - Optionally:
      Burst read configuration file from Register FEATURES_IN and check correctness. Check sensor API for details of timing & length.
- Enable sensor features– write 0x01 into register INIT_CTRL.init_ctrl. This operation must not be performed more than once after POR or softreset.

- Wait until Register INTERNAL_STATUS.message contains the value 0b1. *This will happen after at most 140-150 msec.*

After initialization sequence has been completed, the device is in configuration mode (power mode). Now it is possible to switch to the required power mode and all features are ready to use as described in chapter Integrated feature set.

4.3 Sensor data

The width of the gyroscope and accelerometer sensor data is 16 bits (11 bits for the temperature sensor) given in two's complement representation.
The bits for each axis are split into an MSB upper part and an LSB lower part. Reading the sensor data registers shall always start with the LSB part. In order to ensure the integrity of the sensor data, the content of an MSB register is locked by reading the corresponding LSB register (shadowing procedure).

For details regarding the registers and the interpretation of the data found in these registers see:
- Chapter 5.5 for the gyroscope part
- Chapter 5.3 for the accelerometer part
- Chapter 5.3.24 for the temperature sensor

The burst-access mechanism provides an efficient way to read out the angular rate data in I2C or SPI mode. During a burst-access, the sensor automatically increments the starting read address after each byte. The burst-access allows data to be transferred over the I2C bus with up to 50% reduced data density. The sensor data (angular rate or acceleration data) in all read-out registers is locked as long as the burst read access is active. Reading the sensor data registers of each gyroscope and accelerometer part in burst read access mode ensures that the sensor values in all readout registers belong to the same sample.

4.4 Sensor time

The accelerometer part of BMI090L has a built-in counter with a width of 24 bits. It increments periodically with a resolution of 39.0625µs. Details can be found in chapter 5.3.18 to 5.3.20.

4.5 Output data rate and low-pass filter

The sensor signals from the acceleration sensor and gyroscope analog front-end are each routed through a low-pass filter.

4.5.1 Accelerometer

The 3db cut-off frequency of the digital low-pass filter depends on the chosen ODR as well as on the over-sampling-ratio (OSR). Both can be configured in register. The following table lists the possible options:

Table 8: 3dB cutoff frequency of the accelerometer according to ODR and OSR settings in register

Accelerometer ODR [Hz]	Normal (acc_bwp = 0xA)	OSR2 (acc_bwp = 0x9)	OSR4 (acc_bwp = 0x8)
12.5	5 Hz	2 Hz	1 Hz
25	10 Hz	5 Hz	3 Hz
50	20 Hz	9 Hz	5 Hz
100	40 Hz	19 Hz	10 Hz
200	80 Hz	38 Hz	20 Hz

400	145 Hz	75 Hz	40 Hz
800	230 Hz (200 Hz for z channel)	140 Hz	80 Hz
1600	280 Hz (245 Hz for z channel)	234 Hz (215 Hz for z channel)	145 Hz

4.5.2 Gyroscope

The user can choose between 8 different ODR and low pass filter bandwidth settings (see GYRO_BANDWIDTH).

4.6 Range settings

The measurement range can be set through the registers described in section ACC_RANGE for the accelerometer and in section GYRO_RANGE for the gyroscope.

4.7 Self-test

The BMI090L incorporates a self-test feature for both the accelerometer and the gyroscope, indicating whether the sensor is still ok.

4.7.1 Accelerometer

The self-test feature allows for checking the sensor functionality by applying electrostatic forces to the sensor core instead of external accelerations. By physically deflecting the seismic mass, the entire signal path of the sensor is tested. Activation of the self-test results in a static offset in the acceleration data. Any external acceleration or gravitational force, which is applied to the sensor during a self-test, will be observed in the sensor output as a superposition of the acceleration and the self-test signal. This means that the self-test signal depends on the orientation of the sensor. To overcome this, the full self-test procedure should be performed under static circumstances, e.g. when the part is not excited to any acceleration except gravity.

The recommended self-test procedure is as follows:
1) Set ±24g range by writing 0x03 to register ACC_RANGE (0x41)
2) Set ODR=1.6kHz, continuous sampling mode, “normal mode” (norm_avg4) by writing 0xAC to register ACC_CONF (0x40)
   - Continuous filter function: set bit7 in ACC_CONF
   - “normal avg4 mode”: ACC_CONF |= 0x02<<4
   - ODR=1.6kHz: ACC_CONF |= 0x0C
3) Wait for > 2 ms
4) Enable the positive self-test polarity (i.e. write 0x0D to register ACC_SELF_TEST (0x6D))
5) Wait for > 50ms
6) Read the accelerometer offset values for each axis (positive self-test response)
7) Enable the negative self-test polarity (i.e. write 0x09 to register ACC_SELF_TEST (0x6D))
8) Wait for > 50ms
9) Read the accelerometer offset values for each axis (negative self-test response)
10) Disable the self-test (i.e. write 0x00 to register ACC_SELF_TEST (0x6D))
11) Calculate difference of positive and negative self-test response and compare with the expected values (see table below)
12) Wait for > 50ms to let the sensor settle to normal mode steady state operation

Table 9: Accelerometer self-test: resulting minimum difference signal between positive and negative self-test signal

x-axis signal	y-axis signal	z-axis signal
≥1000 mg	≥1000 mg	≥500 mg

It is recommended to perform a reset of the device after a self-test has been performed, since the self-test response also affects the interrupt generation. If the reset cannot be performed, the following sequence must be kept to prevent unwanted interrupt generation: disable interrupts, change parameters of interrupts, wait for at least 50ms, and enable desired interrupts.

4.7.2 Gyroscope

A built-in self-test facility of the gyro does not deflect the mechanical MEMS structure (as the accelerometer self-test does), but this test also provides a quick way to determine if the gyroscope is operational within the specified conditions.

To trigger the self-test, bit #0 (‘bite_trig’) in address GYRO_SELF_TEST must be set. When the test is finished, bit #1 (‘bist_rdy’) will be set by the gyro and the test result can then be found in bit #2 (‘bist_fail’). A ‘0’ indicates that the test was passed without issues. If a failure occurred, the bit ‘bist_fail’ will be set to ‘1’.

A further test which is running continuously in the background can be checked by reading bit #4 in address GYRO_SELF_TEST. Proper sensor function is indicated if the bit is set to '1'.

4.8 New data interrupt

Both accelerometer and gyroscope part offer a new data ready interrupt, which fires whenever a new data sample set is complete and made available in the corresponding sensor data registers. This allows a low latency data readout.

4.8.1 Accelerometer

The new data interrupt flag can be found in the register ACC_INT_STAT_1 (bit #7). It is set whenever new data is available in the data registers and cleared automatically.

The interrupt can be mapped to the interrupt pins INT1 and/or INT2 in register INT_MAP_DATA.

Both interrupt pins INT1 and INT2 can be configured regarding their electrical behavior (see INT1_IO_CTRL and INT2_IO_CTRL).

4.8.2 Gyroscope

The gyroscope provides a new data interrupt, which will generate an interrupt every time after storing a new value of z-axis angular rate data in the data register. The interrupt is cleared automatically after 280-400 µs.

In contrast to the accelerometer part, for the gyro the new data interrupt must be explicitly enabled by writing 0x80 to the register GYRO_INT_CTRL.

The interrupt can be mapped to the interrupt pins INT3 and/or INT4 in register INT3_INT4_IO_MAP.

Both interrupt pins INT3 and INT4 can be configured regarding their electrical behavior (see INT3_INT4_IO_CONF)

4.9 Soft-reset

A soft-reset can be initiated at any time

- for the accelerometer part by writing the command *soft-reset (0xB6)* to register ACC_SOFTRESET(see section 5.3.61)
- for the gyroscope part by writing the command *soft-reset (0xB6)* to register GYRO_SOFTRESET (see section 5.5.8)

The soft-reset performs a fundamental reset to the device, which is largely equivalent to a power cycle. Following a delay, all user configuration settings are overwritten with their default state wherever applicable.

4.10 FIFO

BMI090L offers two integrated FIFO (First In, First Out) buffers for accelerometer and gyroscope sensor signals, helping the user to reduce or even omit time critical read access to the sensor in order to obtain data with a high timing precision.

4.10.1 FIFO operating modes

The FIFO can be operated in different modes: FIFO (or stop-at-full) mode and STREAM mode.

- **FIFO or stop-at-full mode:** In FIFO or stop-at-full mode, the sensor values are stored in the FIFO buffer subsequently until it is full.

- **STREAM mode**: The STREAM mode works like the FIFO mode with the difference that once the buffer is full, the oldest data in the FIFO will be overwritten with the newest data from the sensor.

4.10.2 FIFO interrupts

The FIFO buffers support two different types of interrupts:

- **Watermark interrupt:** Triggered, when the fill level of the FIFO buffer reaches a user-defined level.
- **FIFO-full interrupt:** Triggered, when the FIFO is full.

4.10.3 Accelerometer sensor FIFO buffer

The accelerometer part of BMI090L has an integrated 1024 byte data FIFO. The FIFO captures data from the data registers in frames, and each frame contains only one sample of a sensor.

4.10.3.1 Enabling FIFO and selecting the mode

The FIFO for accelerometer sensor data is enabled by setting bit #6 in register 0x49 (see FIFO_CONFIG_1)

4.10.3.1.1 Mode selection

When STREAM mode is desired, then the bit #0 in register 0x48 has to be cleared (set to ‘0’) (default value on power up reset, see FIFO_CONFIG_0)

For FIFO or stop-at-full mode, bit #0 has to be set to ‘1’ in register 0x48.

4.10.3.1.2 FIFO data sampling rate

The input data rate to the FIFO is the same as the configured ODR of the sensor. However, it can be reduced selecting a down-sampling factor of 2^k with k=[0, 1, … 7]. The factor k must be written to bits #4-6 of register 0x45 (see FIFO_DOWNS)

4.10.3.1.3 FIFO synchronization with external interrupts (tag application) for the accel

If the INT1 and/or INT2 pin is configured as input pin (by setting int2_io in register INT2_IO_CTRL and/or setting int1_io in register INT1_IO_CTRL), signals on these pins can also be recorded in the FIFO, and the frames are “tagged” accordingly. Therefore the pins need to be activated for FIFO recording in register FIFO_CONFIG_1

4.10.3.2 Data format in FIFO

The FIFO captures data in frames. The first byte is a header byte, defining the type of frame. From this, the number of consecutive bytes and their content can be derived.
The header byte consists of the header signature (first 6 bits) and two bits indicating the status of the interrupt pins INT1 and INT2 if configured accordingly (see 4.10.3.1.3).

4.10.3.2.1 Acceleration sensor data frame

- Frame length: 7 bytes (1 byte header + 6 bytes payload)
- Header:

Bit	7	6	5	4	3	2	1	0
	1	0	0	0	0	1	[INT2 tag]	[INT1 tag]

- Payload: the next bytes contain the sensor data in the same order as defined in the register map (addresses 0x12 – 0x17).

4.10.3.2.2 Skip frame

In the case of FIFO overflows, in both FIFO and STREAM mode, a skip_frame is prepended to the FIFO content, when read out next time. A skip frame does not consume memory in the FIFO.

- Frame length: 2 bytes (1 byte header + 1 byte payload)
- Header:

Bit	7	6	5	4	3	2	1	0
	0	1	0	0	0	0	reserved	reserved

- Payload: one byte containing the number of skipped frames. When more than 0xFF frames have been skipped, 0xFF is returned.

4.10.3.2.3 Sensortime frame

A sensortime frame is only sent if the FIFO becomes empty during the burst read. A sensortime frame does not consume memory in the FIFO.

- Frame length: 4 bytes (1 byte header + 3 bytes payload)
- Header:

Bit	7	6	5	4	3	2	1	0
	0	1	0	0	0	1	reserved	reserved

- Payload: Sensortime (content of registers 0x18 – 0x1A), taken when the last byte of the last frame is read.

4.10.3.2.4 FIFO input config frame

Whenever the filter configuration or the range of the accelerometer sensor is changed, a FIFO input config frame is inserted into the FIFO, before the configuration change becomes active. E.g. when the bandwidth for the accelerometer filter is changed in Register ACC_CONF, a FIFO input config frame is inserted before the first frame with accelerometer data with the new bandwidth configuration.

- Frame length: 2 bytes (1 byte header + 1 byte payload)
- Header:

Bit	7	6	5	4	3	2	1	0
	0	1	0	0	1	0	reserved	reserved

- Payload: The FIFO input config frame contains one byte of data, of which the following bits have a meaning (the content of the other bits can safely be ignored):
  - Bit #1: indicates that a configuration change through register ACC_RANGE becomes active (means for example that the range of the accelerometer was changed).
  - Bit #0: indicates that a configuration change through the registers ACC_CONF or FIFO_DOWNS becomes active (means of example that the filter settings where changed or the FIFO sampling rate was modified).

4.10.3.2.5 Sample drop frame

After a reconfiguration, indicated by the fifo_Input_Config frame, the next sample may be dropped, until the sensor delivers valid data again. Instead, a drop frame is inserted at the ODR tick at which a sample was to be expected without reconfiguration.

- Frame length: 2 bytes (1 byte header + 1 byte payload)
- Header:

Bit	7	6	5	4	3	2	1	0
	0	1	0	1	0	0	reserved	reserved

- Payload: The sample drop frame contains one byte of data, whose content can be ignored.

4.10.3.2.6 FIFO partial frame reads and overreads

When a frame is only partially (uncompletely) read through the register FIFO_DATA it will be repeated completely with the next access. In the case of a FIFO overflow between the first partial read and the second read attempt, the frame may be deleted.

If the data read from the FIFO is more than the valid data that is present, then 0x8000 is returned.

4.10.3.3 FIFO interrupts

The FIFO supports two interrupts, a FIFO full interrupt and a watermark interrupt:

- The FIFO full interrupt is issued when the FIFO fill level is above the full threshold. The full threshold is reached just before the last two frames are stored in the FIFO.
- The FIFO watermark is issued when the FIFO fill level is superior or equal to the watermark level defined in register FIFO_WTM

In order to enable/use the FIFO full or watermark interrupts they need to be mapped on the desired interrupt pin via INT1_INT2_MAP_DATA

Both interrupts are suppressed when a read operation on the register FIFO_DATA is ongoing.

Latched FIFO interrupts will only get cleared, if the status register gets read and the fill level is below the corresponding FIFO interrupt (full or watermark).

4.10.3.4 FIFO reset

The user can trigger a FIFO reset by writing 0xB0 to ACC_SOFTRESET (register 0x7E).

4.10.4 Gyroscope sensor FIFO buffer

The gyroscope part of BMI090L features an integrated FIFO memory capable of storing up to 100 frames of data in FIFO mode. Each frame consists of three 16-bit rate_x,y,z data words, and 16 bits of interrupt data sampled at the same point in time.

4.10.4.1 Enabling FIFO and selecting the mode

The FIFO for gyroscope sensor data is enabled by setting the appropriate FIFO mode in GYR_FIFO_CONFIG_1

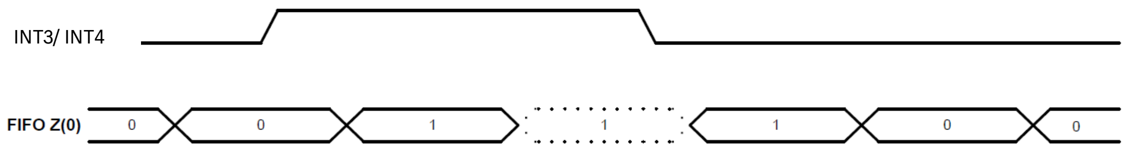
4.10.4.1.1 FIFO data sampling rate

The input data rate to the FIFO is the same as the configured ODR of the sensor.

4.10.4.1.2 FIFO sync with external interrupts (tag application) for the gyroscope

The FIFO of the gyroscope features a mode that allows the precise synchronization of external events with the gyroscope angular rate saved in the FIFO. This synchronization can be used for example for image and video stabilization applications.

Any of the gyroscope interrupt pins (INT3 or INT4) can be reconfigured to act as input pin, but not both. In addition, the tag mode has to be enabled. The so configured interrupt pin will then behave as an input pin and not as an interrupt pin. The working principle is shown in the figure below:



Timing diagram for external FIFO synchronization.

INT3/INT4 is the Interrupt pin configured to capture external events. FIFO z(0) is the least significant bit of the z-axis gyro data stored in the FIFO.
In order to enable the tag mode, bit 5 must be set in register 0x34 (see the respective register). The pin can be chosen in the same register, bit 4.
In this mode, the least significant bit of the z-axis is used as tag-bit, therefore losing its meaning as gyroscope data bit. The remaining 15 bits of the z-axis gyroscope data keep the same meaning as in standard mode.
Once the pin, which is configured for the tag mode, is set to high level, the next FIFO word will be marked with a tag (z-axis LSB = 1). While pin is kept at a high level, the corresponding FIFO words will continuously be tagged. After the pin is reset to low level, the immediate next FIFO word could still be tagged, and only after this word, the next tag will be reset (z-axis LSB=0). This is shown in the above diagram.
The tag synchronizes external events with the same time precision as the FIFO update rate. Therefore update rate of the tag is determined by the output data rate.

4.10.4.2 FIFO data readout

The FIFO stores the data that are also available at the read-out registers 0x02-0x07. Thus, all configuration settings apply to the FIFO data as well as the data readout registers. The FIFO read out is possible through register 0x3F (FIFO_DATA). The readout can be performed using burst mode. A single burst can read out one or more frames at a time. If a frame is not read completely due to an incomplete read operation, the remaining part of the frame is lost. In this case the FIFO aligns to the next frame during the next read operation. The data format is described in the respective chapter.

4.10.4.2.1 Interface speed requirements for gyroscope FIFO use

In order to use the FIFO effectively, larger blocks of data need to be read out quickly. Depending on the output data rate of the sensor, this can impose requirements on the interface.
The output data rate of the gyroscope is determined by the filter configuration (see the data sheet of the sensor). What interface speed is required depends on the selected rate.

- For an I²C speed of 400 kHz, every filter mode can be used.
- For an I²C speed of 200 kHz, only modes with an output data rate of 1 KHz and below are recommended.
- For an I²C speed of 100 kHz, only modes with an output data rate of 400 Hz and below are recommended.

4.10.4.3 FIFO frame counter and overrun flag

The frame counter at address 0x0E bits<6:0>, (see the respective register) indicates the current fill level of the buffer. If additional frames are written to the buffer although the FIFO is full, the overrun flag (register 0x0E bit 7) is set. If the FIFO is reset, the FIFO fill level indicated in the frame_counter<6:0> is set to '0' and the overrun flag is reset each time a write operation happens to the FIFO configuration registers.

Note: the overrun bit is not reset when the FIFO fill level frame_counter<6:0> has decremented to '0' due to reading from the FIFO_DATA register, but only when a write operation is performed on FIFO configuration registers.

4.10.4.4 FIFO interrupts

The FIFO supports two interrupts, a FIFO full interrupt and a watermark interrupt:

- The FIFO full interrupt is issued when the buffer has been fully filled with samples. In FIFO mode this occurs after 100 samples, and in STREAM mode after 99 samples, have been stored in a previously empty FIFO.
  The status of the FIFO-full interrupt may be read back through the status bit in INT_STATUS_1 register 0x0A.
- The watermark interrupt is issued when the fill level in the buffer has reached the frame number defined by the water mark level trigger in 0x3D. The status of the watermark may be read back through the address 0x0A bit 4 (fifo_int) status bit. Writing to water mark level trigger in register 0x3D clears the FIFO buffer.

4.11 Integrated feature set

Default threshold value for High G, Low G and any motion is sensitive. Host has the possibility to fine-tune the sensitivity, based on the target platform. Configuration parameters are available in Features-in register map.
Enable accelerometer and wait for 40ms before enabling integrated feature sets.

4.11.1 Axis remapping for interrupt features

If the coordinate system of the end device differs from the sensor coordinate system the sensor axis must be remapped to use the orientation dependent features (e.g. orientation interrupt, High_g interrupt) properly.
Axis remapping register allows the host to freely map individual axis to the coordinate system of the used platform. Individual axis can be mapped to any other defined axis. The sign value of the axis can also be configured depending on the use case. For example x axis can be mapped to –x axis, +y axis, - y axis, +z axis or –z axis. Similarly, other axes also have their own combinations.
Invalid remapping's are signaled through the register INTERNAL_STATUS.axes_remap_error if an advanced feature is enabled.

Note:
The axis remapping applies only to the data fetched into the features. The data registers and FIFO are not affected and should be remapped accordingly on the driver level.

Configuration settings:

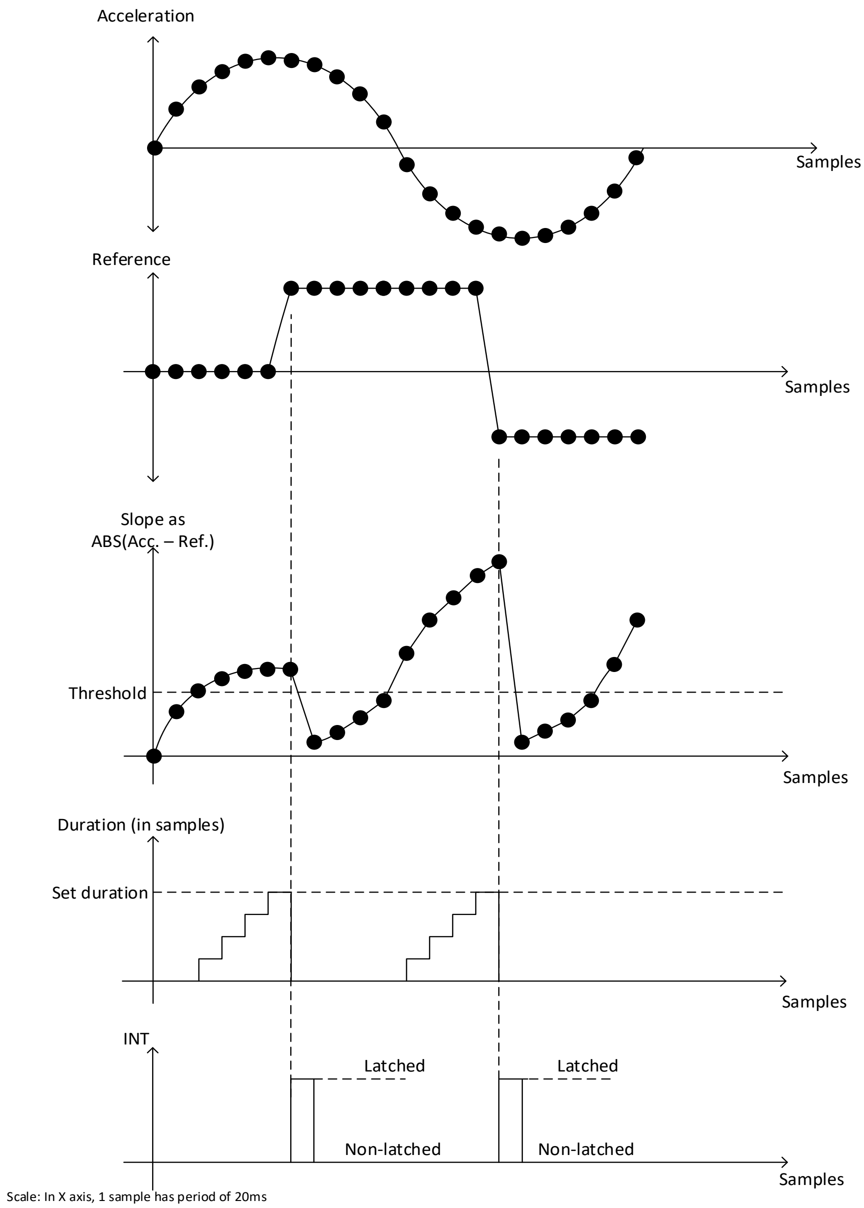
1. AXIS_REMAP_1.map_x_axis – describes which axis shall be mapped to x axis.
2. AXIS_REMAP_1.map_x_axis_sign – describes whether the mapped axis shall be inverted or not to be inverted.
3. AXIS_REMAP_1.map_y_axis – describes which axis shall be mapped to y axis.
4. AXIS_REMAP_1.map_y_axis_sign – describes whether the mapped axis shall be inverted or not to be inverted.
5. AXIS_REMAP_1.map_z_axis – describes which axis shall be mapped to z axis.
6. AXIS_REMAP_1.map_z_axis_sign – describes whether the mapped axis shall be inverted or not to be inverted.

4.11.2 Any motion/ no motion detection

When any motion interrupt is active, accelerometer is disabled and then re-enabled. Hence, a false positive interrupt might get triggered. In order to avoid the false-positive interrupt, disable the features before accelerometer enable.
Any-motion detection:
Any-motion detection uses the slope between current input and reference acceleration samples to detect the motion status of the device. The interrupt is configured by setting enable flag ANYMO_1.enable along with at least one of the following flags:
ANYMO_2.x_en, ANYMO_2.y_en and ANYMO_2.z_en, respectively for each axis.

Any-motion provides an interrupt when the absolute value of the slope exceeds the configurable ANYMO_1.threshold for consecutive ANYMO_2.duration samples for at-least one of the enabled sensing axis.

Reference acceleration sample is updated only when an any-motion interrupt is triggered. The interrupt status is reset as soon as the slope falls below the set ANYMO_1.threshold value. The signals and timings relevant to the any-motion interrupt functionality are depicted in the figure below:



Signal and timing diagram for any-motion interrupt detection

Configuration settings:

1. ANYMO_1.enable - Enable the feature.
2. ANYMO_1.threshold – the slope threshold.
3. ANYMO_2.duration the number of consecutive data points for which the threshold condition must be respected, for interrupt assertion.
4. ANYMO_2.x_en – indicates if this feature is enabled for x axis
5. ANYMO_2.y_en – indicates if this feature is enabled for y axis
6. ANYMO_2.z_en –indicates if this feature is enabled for z axis

Output details:

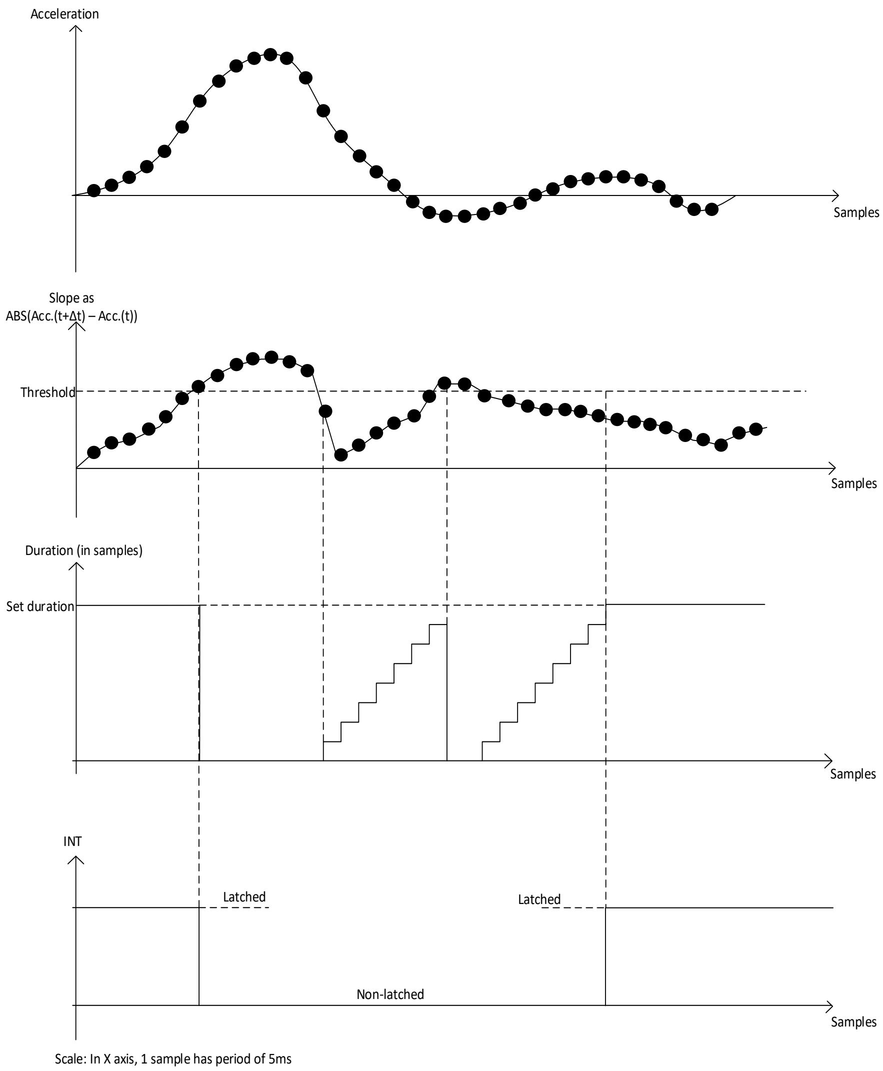
1. ACC_INT_STAT_0. any_motion_out – Set to 1 when any motion interrupt is generated by the device.

No motion detection:

No-motion detection uses the slope between two consecutive acceleration signal samples to detect static state of the device. The interrupt is configured by setting enable flag NOMO_1.enable along with at least one of the following flags: NOMO_2.x_en, FEATURES_IN.no_motion.NOMO_2.y_en and NOMO_2.z_en, respectively for each axis.

No-motion interrupt is triggered when the slope on all enabled sensing axis remains smaller than the configurable NOMO_1.threshold for the duration configured by NOMO_2.duration. No-motion interrupt is cleared as soon as the acceleration slope exceeds the set threshold. The signals and timings relevant to the no-motion interrupt functionality are depicted in the figure below.

Signal and timing diagram for no-motion interrupt detection



Register NOMO_2.duration defines the number of consecutive data points for which the slope of enabled axis must be smaller than the threshold for an interrupt to be asserted.

Configuration settings:

1. NOMO_1.enable – enable the feature.
2. NOMO_1.threshold – the slope threshold.
3. NOMO_2.duration – the number of consecutive data points for which the threshold condition must be respected, for interrupt assertion.
4. NOMO_2.x_en – indicates if this feature is enabled for x axis
5. NOMO_2.y_en – indicates if this feature is enabled for y axis
6. NOMO_2.z_en –indicates if this feature is enabled for z axis

Output details:

1. ACC_INT_STAT_0. no_motion_out – Set to 1 when no motion interrupt is generated by the device.

4.11.3 High_g/ low_g detection

High_g detection

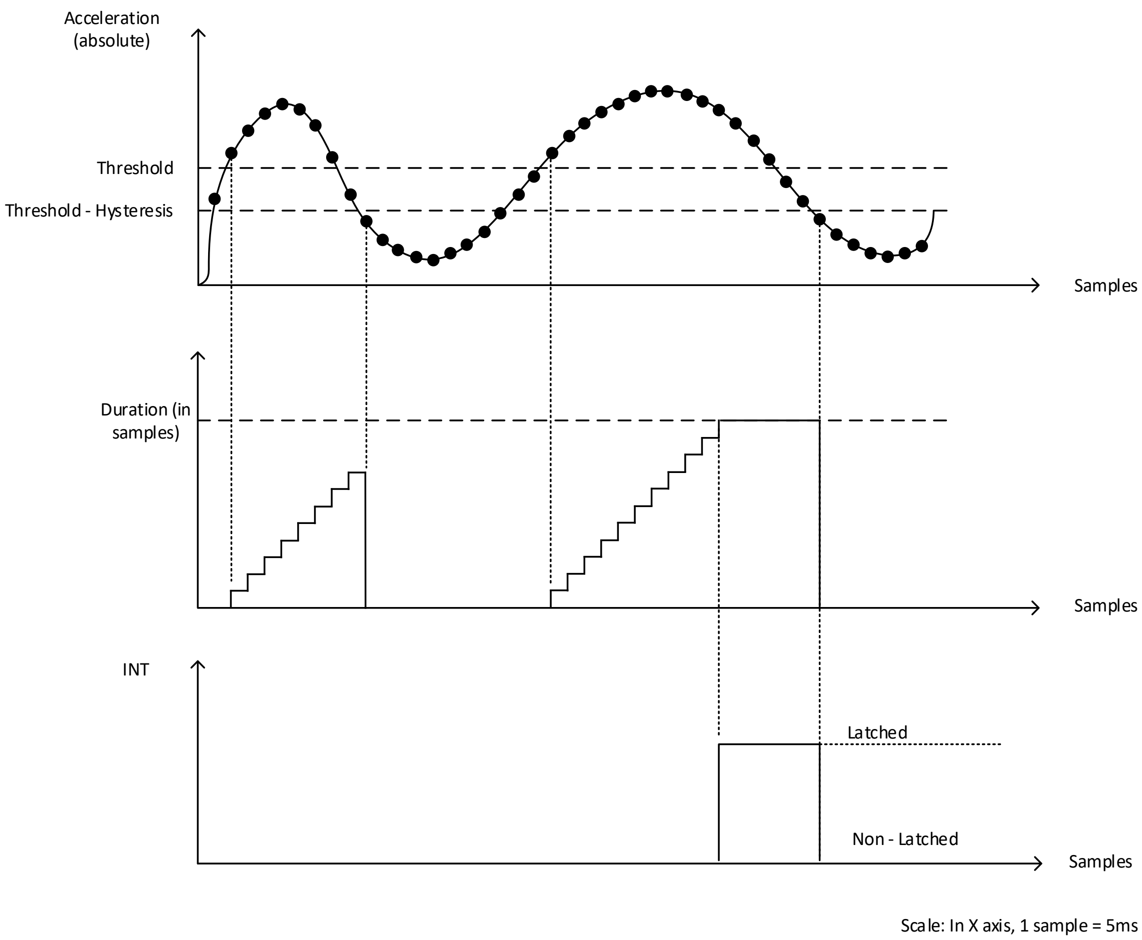
This interrupt is enabled by setting enable flag HI_G_2.enable along with at least one axis.

The interrupt is asserted if the absolute value of acceleration data of at least one enabled axis exceeds the programmed HI_G_1.threshold and the sign of the value does not change for a minimum HI_G_3.duration.

The interrupt condition is cleared when the absolute value of acceleration data of all selected axes falls below the HI_G_1.threshold minus HI_G_2.hysteresis or if the sign of the acceleration value changes.

If any device axis is parallel to the gravitational vector, then that axis will report ±1g as output. In this case, it is recommended to have (threshold - hysteresis) greater than 1g. If (threshold - hysteresis) is less than 1g then after high-g interrupt is triggered, the interrupt will not get cleared if anyone axis is parallel to the gravitational vector since that axis will already be at 1g.

The X, Y and Z axes are enabled with HI_G_2.en_x, HI_G_2.en_y, HI_G_2.en_z bits.



Signal and timing diagram for high-g detection

Configuration settings:

1. HI_G_3.duration – 12 bit unsigned integer (valid values 0...4095) holding the duration in 200 Hz samples (5 ms) for which the threshold has to be exceeded; default value 4 = 20 msec. Range is 0 to 20sec.
2. HI_G_2.hysteresis – 12 bit unsigned integer (valid values 0...4095) holding the hysteresis. Default value is 1000 = 0.49 g. Range is 0 to 2g.
3. HI_G_2.en_x – Selects the feature for x axis
4. HI_G_2.en_y – Selects the feature for y axis
5. HI_G_2.en_z – Selects the feature for z axis
6. HI_G_2.enable – Enables the feature
7. HI_G_1.threshold – The acceleration threshold above which the high_g motion is signaled. 15 bit un-signed integer (valid values 0...32767) holding the threshold. Default is 10000 = 4.9g. Range is 0 to 16g.

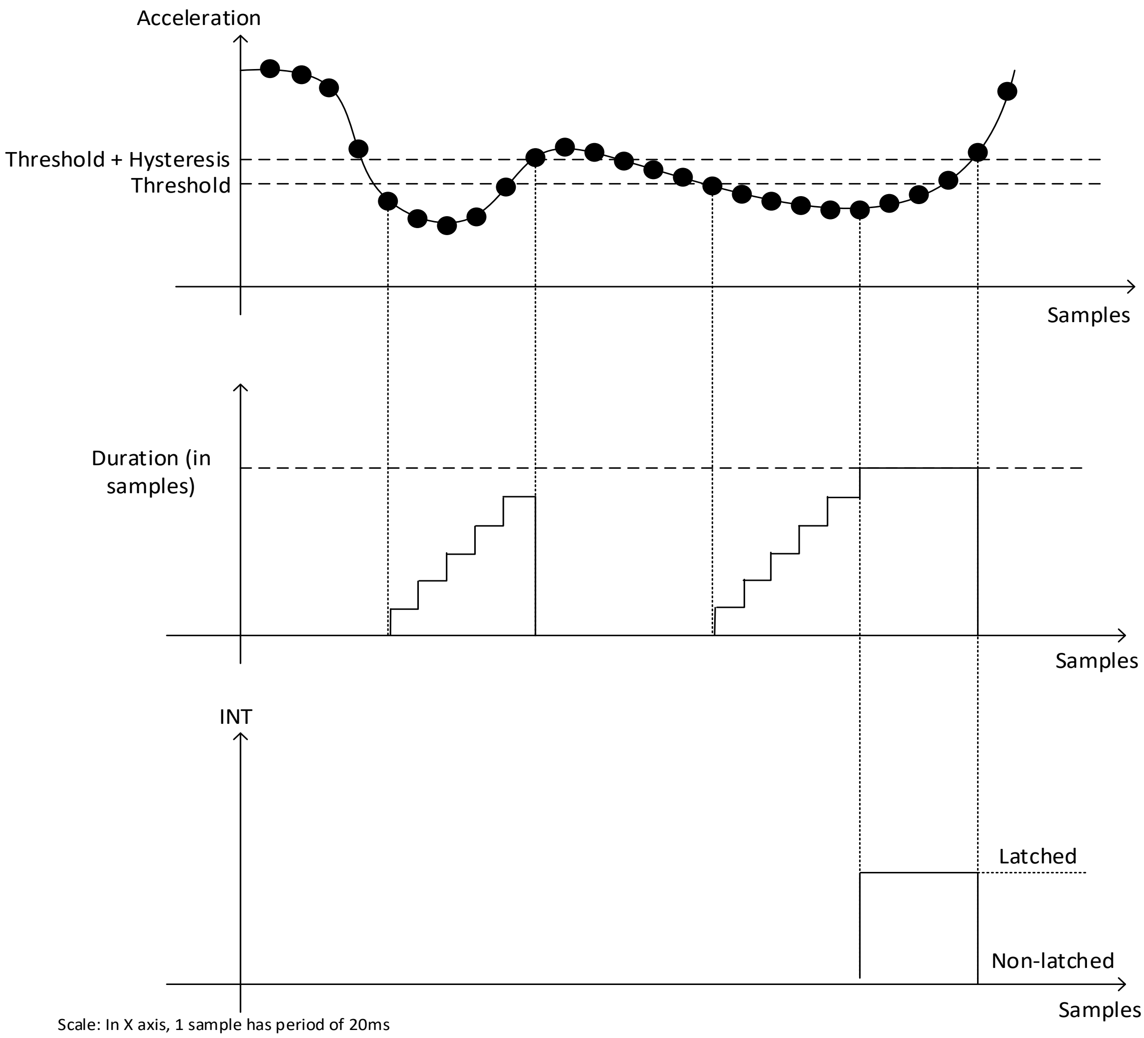
Output details:

1. Bit 3 (ORIENT_HIGHG_OUT.high_g_detect_x), this is set if high-g was detected on x axis.
2. Bit 4 (ORIENT_HIGHG_OUT.high_g_detect_y), this is set if high-g was detected on y axis.
3. Bit 5 (ORIENT_HIGHG_OUT.high_g_detect_z), this is set if high-g was detected on z axis.
4. Bit 6 (ORIENT_HIGHG_OUT.high_g_detect_sign), this reflects the sign of the acceleration for which the high-g was detected; 1 – negative, 0 – positive.
5. ACC_INT_STAT_0 . high_g_out – Set to 1 when high-g interrupt is generated by the device.

Low_g detection

For low-g detection, the absolute values of the acceleration data of all axes are observed. The vector length of all accelerations, sqrt(acc_x^2 + acc_y^2 + acc_z^2), is compared with the LO_G_1.threshold.

The interrupt will be generated when the acceleration is smaller than threshold for minimum number of samples (LO_G_3.duration). The interrupt is reset when the acceleration is above the Threshold + Hysteresis value.



Signal and timing diagram for low-g detection

Configuration settings:

1. LO_G_1.threshold – 15 bit unsigned integer (valid values 0...32767) holding the threshold value. Default is 512 = 0.25 g. Range is 0 to 16g. Recommended range for customer: 0…1g
2. LO_G_2.hysteresis – 12 bit unsigned integer (valid values 0...4095) holding the hysteresis value. Default value is 256 = 0.125 g. Range is 0 to 2g. Recommended range for customer: 0…0.5g
3. LO_G_3.duration – 12 bit unsigned integer (valid values 0...4095) holding the duration in 50 Hz samples (20 ms) for which the threshold has to be exceeded; default: 0 = 0 ms. Range is 0 to 82 sec.
4. LO_G_2.enable – Enables the feature

Output details:

1. ACC_INT_STAT_0__low_g_out – Set to 1 when low-g interrupt is generated by the device.

4.11.4 Orientation detection

The orientation recognition feature informs on an orientation change of the sensor with respect to the gravitational field vector g. There are the orientations face up/face down and orthogonal to that portrait upright, landscape left, portrait downside, and landscape right. The interrupt for face up/face down may be enabled separately through ORIENT_1.ud_en.

The sensor orientation is defined by the angles phi and theta (phi φ is rotation around the stationary z axis, theta θ is rotation around the stationary y axis).

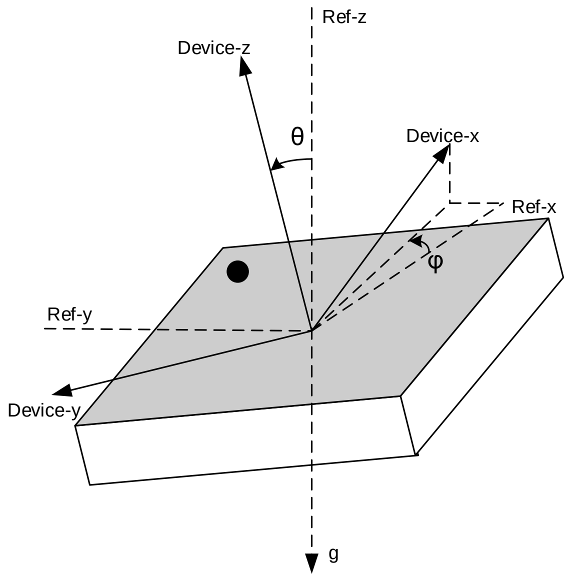


Figure: Definition of coordinate system with respect to pin 1 marker

This feature uses the earth's gravitational field for reference coordinates. The measured acceleration vector components look as follows:

$$acc\_x = 1g * \sin\theta * \cos\varphi \quad (1)$$
$$acc\_y = -1g * \sin\theta * \sin\varphi \quad (2)$$
$$acc\_z = 1g * \cos\theta \quad (3)$$
$$(2) / (1): acc\_y / acc\_x = -\tan\varphi$$

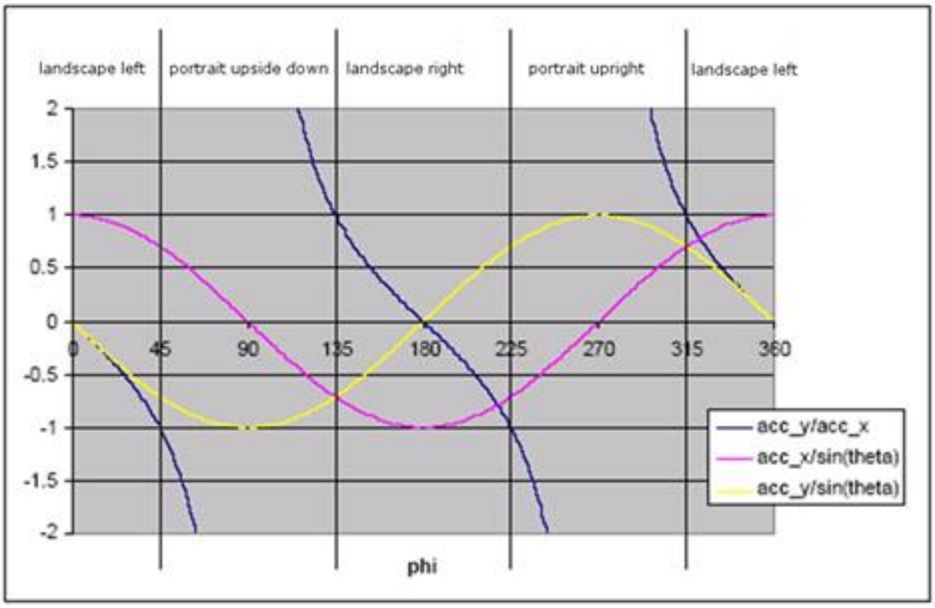


Figure: Angle-to-Orientation Mapping

Note that the sensor measures the direction of the force which needs to be applied to keep the sensor at rest (i.e. opposite direction than g itself).

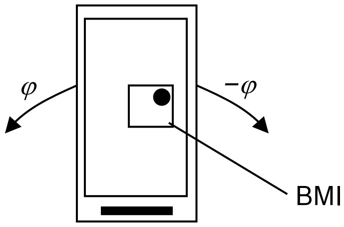


Figure: Looking at phone device from frontside/portrait upright (φ = 90°, θ =270°)

The orientation value is stored in the output register. There are three orientation calculation modes: symmetrical, high-asymmetrical and low-asymmetrical. The mode is selected by the register ORIENT_1.mode as follows:

ORIENT_1.mode	**Orientation mode**
00	Symmetrical
01	High asymmetrical
10	Low asymmetrical
11	Symmetrical

Orientation Mode: Symmetrical or Asymmetrical

The output has the following meanings depending on the switching mode:

Orient	Name	Angle	Condition
x01	landscape left	315°<phi<45°	|acc_y/acc_x|<1 && acc_x≥0
x11	landscape right	135°<phi<225°	|acc_y/acc_x|<1 && acc_x<0
x10	portrait upside down	45°<phi<135°	|acc_y/acc_x|≥1 && acc_y<0
x00	portrait upright	225°<phi<315°	|acc_y/acc_x|≥1 && acc_y≥0

Symmetrical mode

Orient	Name	Angle	Condition
x01	landscape left	297°<phi<63°	|acc_y/acc_x|<2 && acc_x≥0
x11	landscape right	117°<phi<243°	|acc_y/acc_x|<2 && acc_x<0
x10	portrait upside down	63°<phi<117°	|acc_y/acc_x|≥2 && acc_y<0
x00	portrait upright	243°<phi<297°	|acc_y/acc_x|≥2 && acc_y≥0

High asymmetrical mode

Orient	Name	Angle	Condition
x01	landscape left	333°<phi<27°	|acc_y/acc_x|<0.5 && acc_x≥0
x11	landscape right	153°<phi<207°	|acc_y/acc_x|<0.5 && acc_x<0
x10	portrait upside down	27°<phi<153°	|acc_y/acc_x|≥0.5 && acc_y<0
x00	portrait upright	207°<phi<333°	|acc_y/acc_x|≥0.5 && acc_y≥0

Low asymmetrical mode

For upside or downside orientation, the respective bit of output has the definition:

ORIENT_HIGHG_OUT.orientation_faceup_dow	acc_z
Value 0 = upside	(270° < θ < 90°) → *acc_z >= 0*
Value 1 = downside	(90° < θ < 270°) → *acc_z < 0*

Upside/Downside definition

Both portrait/landscape and upside/downside recognition use an ORIENT_2.hysteresis. The hysteresis for portrait/landscape detection is configurable and applies to all conditions as described in the tables below.

Orient	Name	Angle	Condition
x01	landscape left	315°+hy <phi< 45°-hy	|acc_y|<|acc_x|-hyst && acc_x≥0
x11	landscape right	135°+hy <phi< 225°-hy	|acc_y|<|acc_x|-hyst && acc_x<0
x10	portrait upside down	45°+hy <phi< 135°-hy	|acc_y|>|acc_x|+hyst && acc_y<0
x00	portrait upright	225°+hy <phi< 315°-hy	|acc_y|>|acc_x|+hyst && acc_y≥0

Symmetrical mode

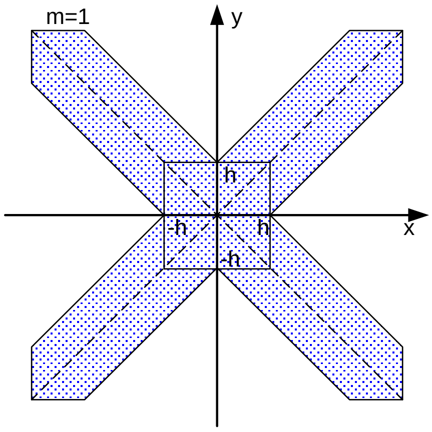


Figure: Hysteresis in symmetrical mode

orient	Name	Angle	Condition
x01	landscape left	297°+hy <phi<63°-hy	|acc_y|<2*(|acc_x|-hyst) && acc_x≥0
x11	landscape right	117°+hy <phi<243°-hy	|acc_y|<2*(|acc_x|-hyst) && acc_x<0
x10	portrait upside down	63°+hy <phi<117°-hy	|acc_y|>2*|acc_x|+hyst && acc_y<0
x00	portrait upright	243°+hy <phi<297°-hy	|acc_y|>2*|acc_x|+hyst && acc_y≥0

High asymmetrical mode

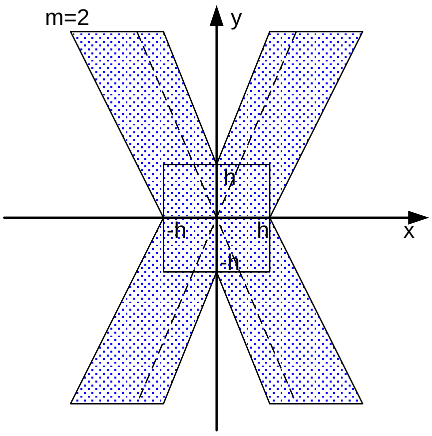


Figure: Hysteresis in high asymmetrical mode

orient	Name	Angle	Condition
x01	landscape left	333°+hy <phi<27°-hy	|acc_y|<(|acc_x|-hyst)/2 && acc_x≥0
x11	landscape right	153°+hy <phi<207°-hy	|acc_y|<(|acc_x|-hyst)/2 && acc_x<0
x10	portrait upside down	27°+hy <phi<153°-hy	|acc_y|>|acc_x|/2+hyst && acc_y<0
x00	portrait upright	207°+hy <phi<333°-hy	|acc_y|>|acc_x|/2+hyst && acc_y≥0

Low asymmetrical mode

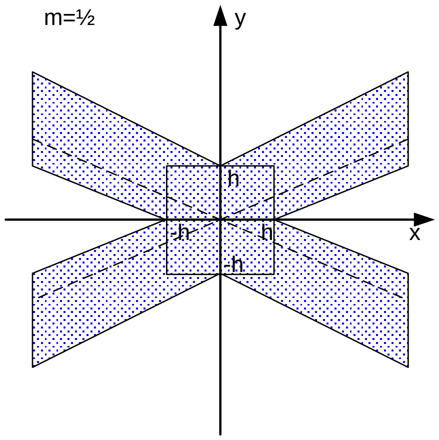


Figure: Hysteresis in low asymmetrical mode

The hysteresis for upside/downside detection is fixed to 11.5° which is ~200 mg.

Orient	Name	Angle	Condition
0xx	upside	281.5°<Theta<78.5°	acc_z>200mg (|acc_z|>200mg and acc_z≥0)
1xx	downside	101.5°<phi<258°	acc_z<−200mg (|acc_z|>200mg and acc_z<0)

Upside/downside hysteresis

Blocking mode

The orientation blocking mode feature may be used to avoid undesired orientation change detection e.g. if the device is nearly flat or in motion. The configuration of the blocking mode is done via the ORIENT_1.blocking parameter:

Blocking	Conditions
00	Interrupt blocking is disabled
01	Interrupt blocked if device close to the horizontal position (theta_flat) OR acceleration of any axis > 1.5g
10	Interrupt blocked if device close to the horizontal position (theta_flat) OR acceleration of any axis > 1.5g OR slope>0.2g
11	Interrupt blocked if device close to the horizontal position (theta_flat) OR acceleration of any axis > 1.5g OR slope > 0.4g OR another change within 100ms

Table: Orientation blocking

If the 100 msec interrupt blocking is enabled (blocking mode ‘11’), to trigger the interrupt, the detected orientation has to remain the same (stable) until the timer for 100 msec expires. The timer starts to count when orientation changes between two consecutive samples. If the orientation changes while timer is still counting, the timer is restarted.

Configuration settings:

1. ORIENT_1.mode – Sets the mode: symmetrical (values 0 or 3), high asymmetrical (value 1) or low asymmetrical (value 2).
2. ORIENT_1.blocking – Sets the blocking mode. If blocking is set, no orientation interrupt will be triggered. Default value is 3 – the most restrictive blocking mode.
3. ORIENT_1.theta – Coded value of the threshold angle with horizontal used in Blocking modes; theta = 64 * (tan(angle)^2); default value is 40, equivalent to 38 degrees angle.
4. ORIENT_2.hysteresis - Acceleration hysteresis for orientation detection. Resolution of field is 4.8mg (Value 2048 = 1g). Default value is 128 = 0.0625g. Range is 0 to 1g.
5. ORIENT_1.enable – Enables the feature.
6. ORIENT_1.ud_en – Enables the upside/downside detection, in addition to landscape/portrait detection.

Output details:

There are 3 bits:

1. Bit 2 (ORIENT_HIGHG_OUT.orientation_faceup_down) reflects the face-up (value 0), respectively face-down (value 1), only if ud_en is enabled. If host disables this feature with ud_en=0, then the output bit is not valid until ud_en is set to 1 again.
2. Bit 0-1 (ORIENT_HIGHG_OUT.orientation_portrait_landscape) have the value:
   - portrait_upright = 0
   - landscape_left = 1
   - portrait_upside_down = 2
   - landscape_right = 3
3. ACC_INT_STAT_0__orientation_out – Set to 1 when change of orientation is detected by the device. Change of orientation means:
   - Output bit 2 is modified i.e. Face-up to face-down or vice versa
   - Output bits 0-1 are modified i.e. change in portrait/landscape orientation

5. Register map

5.1 Communication with the sensor

The entire communication with the device is performed by reading from and writing to registers. Registers have a width of 8 bits; they are mapped to an 8-bit address space. Accelerometer and gyroscope have individual register maps. The selection of the appropriate register map is done on digital interface level by either selecting the corresponding chip select pin (SPI mode) or I^2C address (I^2C mode). For details regarding the digital interface, see chapter 6.

The functional registers and the register addresses containing functional bits are marked in the following register maps. All non-functional registers are marked as reserved and should be completely ignored by the user.

It is recommended to mask out (logical *and* with zero) non-functional bits (marked with '-') of registers which partially contain functional bits (i.e. read the register content first, changing bit by means of bit-wise operations, and write the modified byte back to the register).

5.2 Register map: accelerometer

read/write	read only	write only	reserved

Corresponding to BMI090L_main.tbin, version 1.5, register map version 1.2

<table>
<tr><th>Addr</th><th>Name</th><th>Reset value</th><th>bit7</th><th>bit6</th><th>bit5</th><th>bit4</th><th>bit3</th><th>bit2</th><th>bit1</th><th>bit0</th></tr>
<tr><td>0x7E</td><td>ACC_SOFTRESET</td><td>0x00</td><td colspan="8">softreset_cmd (0xb6)</td></tr>
<tr><td>0x7D</td><td>ACC_PWR_CTRL</td><td>0x00</td><td colspan="5">reserved</td><td>acc_en</td><td colspan="2">reserved</td></tr>
<tr><td>0x7C</td><td>ACC_PWR_CONF</td><td>0x03</td><td colspan="7">reserved</td><td>pwr_save_mode</td></tr>
<tr><td>0x7B</td><td>-</td><td>-</td><td colspan="8">reserved</td></tr>
<tr><td>...</td><td>-</td><td>-</td><td colspan="8">reserved</td></tr>
<tr><td>0x74</td><td>-</td><td>-</td><td colspan="8">reserved</td></tr>
<tr><td>0x73</td><td>OFFSET_2</td><td>0x00</td><td colspan="8">off_acc_z</td></tr>
<tr><td>0x72</td><td>OFFSET_1</td><td>0x00</td><td colspan="8">off_acc_y</td></tr>
<tr><td>0x71</td><td>OFFSET_0</td><td>0x00</td><td colspan="8">off_acc_x</td></tr>
<tr><td>0x70</td><td>NV_CONF</td><td>0x00</td><td colspan="4">reserved</td><td>acc_off_en</td><td>i2c_wdt_en</td><td>i2c_wdt_sel</td><td>spi_en</td></tr>
<tr><td>0x6F</td><td>-</td><td>-</td><td colspan="8">reserved</td></tr>
<tr><td>0x6E</td><td>-</td><td>-</td><td colspan="8">reserved</td></tr>
<tr><td>0x6D</td><td>ACC_SELF_TEST</td><td>0x00</td><td colspan="4">reserved</td><td>acc_self_test_amp</td><td>acc_self_test_sign</td><td>reserved</td><td>acc_self_test_en</td></tr>
<tr><td>0x6C</td><td>-</td><td>-</td><td colspan="8">reserved</td></tr>
<tr><td>0x6B</td><td>IF_CONF</td><td>0x00</td><td colspan="3">reserved</td><td>if_mode</td><td colspan="3">reserved</td><td>spi3</td></tr>
<tr><td>0x6A</td><td>NVM_CONF</td><td>0x00</td><td colspan="6">reserved</td><td>nvm_prog_en</td><td>reserved</td></tr>
<tr><td>0x69</td><td>-</td><td>-</td><td colspan="8">reserved</td></tr>
<tr><td>...</td><td>-</td><td>-</td><td colspan="8">reserved</td></tr>
<tr><td>0x60</td><td>-</td><td>-</td><td colspan="8">reserved</td></tr>
<tr><td>0x5F</td><td>INTERNAL_ERROR</td><td>0x00</td><td colspan="5">reserved</td><td>int_err_2</td><td>int_err_1</td><td>reserved</td></tr>
<tr><td>0x5E</td><td>FEATURES_IN</td><td>0x00</td><td colspan="8">features_in</td></tr>
<tr><td>0x5D</td><td>-</td><td>-</td><td colspan="8">reserved</td></tr>
<tr><td>...</td><td>-</td><td>-</td><td colspan="8">reserved</td></tr>
<tr><td>0x5A</td><td>-</td><td>-</td><td colspan="8">reserved</td></tr>
</table>

0x59	INIT_CTRL	0x90	init_ctrl							
0x58	INT_MAP_DATA	0x00	reserved	int2_drdy	int2_fwm	int2_ffull	reserved	int1_drdy	int1_fwm	int1_ffull
0x57	INT2_MAP	0x00	error_int_out	reserved	no_motion_out	orientation_out	low_g_out	high_g_out	any_motion_out	Data_sync_out
0x56	INT1_MAP	0x00	error_int_out	reserved	no_motion_out	orientation_out	low_g_out	high_g_out	any_motion_out	Data_sync_out
0x55	INT_LATCH	0x00	reserved							int_latch
0x54	INT2_IO_CTRL	0x00	reserved			input_en	output_en	od	lvl	edge_ctrl
0x53	INT1_IO_CTRL	0x00	reserved			input_en	output_en	od	lvl	edge_ctrl
0x52	-	-	reserved							
...	-	-	reserved							
0x50	-	-	reserved							
0x4F	AUX_WR_DATA	0x02	write_data							
0x4E	AUX_WR_ADDR	0x4C	write_addr							
0x4D	AUX_RD_ADDR	0x42	read_addr							
0x4C	AUX_IF_CONF	0x83	aux_manual_en	reserved					aux_rd_burst	
0x4B	AUX_DEV_ID	0x20	i2c_device_addr							reserved
0x4A	-	-	reserved							
0x49	FIFO_CONFIG_1	0x10	reserved	fifo_acc_en	fifo_aux_en	fifo_header_en	fifo_tag_int1_en	fifo_tag_int2_en	reserved	
0x48	FIFO_CONFIG_0	0x02	reserved						fifo_time_en	fifo_stop_on_full
0x47	FIFO_WTM_1	0x02	reserved			fifo_water_mark_12_8				
0x46	FIFO_WTM_0	0x00	fifo_water_mark_7_0							
0x45	FIFO_DOWNS	0x80	acc_fifo_filt_data	acc_fifo_downs			reserved			
0x44	AUX_CONF	0x46	aux_offset				aux_odr			
0x43	-	-	reserved							
0x42	-	-	reserved							
0x41	ACC_RANGE	0x01	reserved						acc_range	
0x40	ACC_CONF	0xA8	acc_perf_mode	acc_bwp			acc_odr			
0x3F	-	-	reserved							

...	-	-	reserved							
0x2B	-	-	reserved							
0x2A	INTERNAL_STATUS	0x00	reserved		axes_remap_error	message				
0x29	ORIENT_HIGHG_OUT	0x00	reserved	high_g_detect_sign	high_g_detect_z	high_g_detect_y	high_g_detect_x	orientation_faceup_down	orientation_portrait_landscape	
0x28	-	-	reserved							
0x27	-	-	reserved							
0x26	FIFO_DATA	0x00	fifo_data							
0x25	FIFO_LENGTH_1	0x00	reserved		fifo_byte_counter_13_8					
0x24	FIFO_LENGTH_0	0x00	fifo_byte_counter_7_0							
0x23	-	-	reserved							
0x22	TEMPERATURE	0x00	temperature							
0x21	-	-	reserved							
...	-	-	reserved							
0x1E	-	-	reserved							
0x1D	ACC_INT_STAT_1	0x00	acc_drdy_int	reserved					fwm_int	ffull_int
0x1C	ACC_INT_STAT_0	0x00	error_int_out	reserved	no_motion_out	orientation_out	low_g_out	high_g_out	any_motion_out	Data_sync_out
0x1B	EVENT	0x01	reserved							por_detected
0x1A	SENSORTIME_2	0x00	sensor_time_23_16							
0x19	SENSORTIME_1	0x00	sensor_time_15_8							
0x18	SENSORTIME_0	0x00	sensor_time_7_0							
0x17	ACC_Z_MSB	0x00	acc_z_11_4							
0x16	ACC_Z_LSB	0x00	acc_z_3_0				reserved			
0x15	ACC_Y_MSB	0x00	acc_y_11_4							
0x14	ACC_Y_LSB	0x00	acc_y_3_0				reserved			
0x13	ACC_X_MSB	0x00	acc_x_11_4							
0x12	ACC_X_LSB	0x00	acc_x_3_0				reserved			
0x11	DATA_7	0x00	aux_r_11_4							

0x10	DATA_6	0x00	aux_r_3_0				reserved			
0x0F	DATA_5	0x00	aux_z_11_4							
0x0E	DATA_4	0x00	aux_z_3_0				reserved			
0x0D	DATA_3	0x00	aux_y_11_4							
0x0C	DATA_2	0x00	aux_y_3_0				reserved			
0x0B	DATA_1	0x00	aux_x_11_4							
0x0A	DATA_0	0x00	aux_x_3_0				reserved			
0x09	-	-	reserved							
...	-	-	reserved							
0x04	-	-	reserved							
0x03	ACC_STATUS	0x10	drdy_acc	reserved	drdy_aux	cmd_rdy	reserved	aux_man_op	reserved	
0x02	ACC_ERR_REG	0x00	aux_err	fifo_err	reserved	error_code			cmd_err	fatal_err
0x01	-	-	reserved							
0x00	ACC_CHIP_ID	0x1A	chip_id							

FEATURES_IN

Register Address	Register Name	Default Value	7		6	5	4	3	2	1	0
0x5E: 0x1D	general_settings.AXIS_REMAP_1[1]	0x00		reserved							map_z_axis_sign
0x5E: 0x1C	general_settings.AXIS_REMAP_1[0]	0x88		map_z_axis		map_y_axis_sign	map_y_axis		map_x_axis_sign	map_x_axis	
0x5E: 0x1B	general_settings.Reserved[1]	0x00		Reserved							
0x5E: 0x1A	general_settings.Reserved[0]	0x00		Reserved							
0x5E: 0x19	no_motion.NOMO_2[1]	0xE0	z_en		y_en	x_en	duration				
0x5E: 0x18	no_motion.NOMO_2[0]	0x05		duration							
0x5E: 0x17	no_motion.NOMO_1[1]	0x00		reserved				enable	threshold		

0x5E: 0x16	no_motion.NOMO_1[0]	0xAA		threshold							
0x5E: 0x15	orientation.ORIENT_2[1]	0x00		reserved					hysteresis		
0x5E: 0x14	orientation.ORIENT_2[0]	0x80		hysteresis							
0x5E: 0x13	orientation.ORIENT_1[1]	0x0A		reserved				theta			
0x5E: 0x12	orientation.ORIENT_1[0]	0x30		theta		blocking		mode		ud_en	enable
0x5E: 0x11	low_g.LO_G_3[1]	0x00		reserved				duration			
0x5E: 0x10	low_g.LO_G_3[0]	0x00		duration							
0x5E: 0x0F	low_g.LO_G_2[1]	0x01		reserved			enable	hysteresis			
0x5E: 0x0E	low_g.LO_G_2[0]	0x00		hysteresis							
0x5E: 0x0D	low_g.LO_G_1[1]	0x02	reserved		threshold						
0x5E: 0x0C	low_g.LO_G_1[0]	0x00		threshold							
0x5E: 0x0B	high_g.HI_G_3[1]	0x00		reserved				duration			
0x5E: 0x0A	high_g.HI_G_3[0]	0x04		duration							
0x5E: 0x09	high_g.HI_G_2[1]	0x73	enable		en_z	en_y	en_x	hysteresis			
0x5E: 0x08	high_g.HI_G_2[0]	0xE8		hysteresis							

0x5E: 0x07	high_g.HI_G_1[1]	0x0C	reserved		threshold					
0x5E: 0x06	high_g.HI_G_1[0]	0x00		threshold						
0x5E: 0x05	-	-		reserved						
0x5E: 0x04	-	-		reserved						
0x5E: 0x03	any_motion.ANYMO_2[1]	0xE0	z_en		y_en	x_en	duration			
0x5E: 0x02	any_motion.ANYMO_2[0]	0x05		duration						
0x5E: 0x01	any_motion.ANYMO_1[1]	0x00		reserved				enable	threshold	
0x5E: 0x00	any_motion.ANYMO_1[0]	0xAA		threshold						

5.3 Register description: accelerometer

5.3.1 Register (0x00) ACC_CHIP_ID

DESCRIPTION: Chip identification code
RESET: 0x1E
DEFINITION (Go to register map):

Address	Bit	Name	Description	Reset	Access
0x00		ACC_CHIP_ID		0x1A	
	7…0	chip_id	Chip identification code for BMI090L	0x1A	R

5.3.2 Register (0x02) ACC_ERR_REG

DESCRIPTION: Reports sensor error conditions
RESET: 0x00
DEFINITION (Go to register map):

Address	Bit	Name	Description	Reset	Access
0x02		ACC_ERR_REG		0x00	
	0	fatal_err	Fatal Error, chip is not in operational state (Boot-, power-system). This flag will be reset only by power-on-reset or softreset.	0x0	R
	1	cmd_err	Command execution failed.	0x0	R
	4…2	error_code	Error codes for persistent errors **Value** **Name** **Description** 0x00 no_error no error is reported 0x01 acc_err error in Register ACC_CONF	0x0	R
	6	fifo_err	Error in FIFO detected: Input data was discarded in stream mode. This flag will be reset when read.	0x0	R
	7	aux_err	Error in I2C-Master detected. This flag will be reset when read.	0x0	R

5.3.3 Register (0x03) ACC_STATUS

DESCRIPTION: Sensor status flags
RESET: 0x10
DEFINITION (Go to register map):

Address	Bit	Name	Description	Reset	Access
0x03		ACC_STATUS		0x10	
	2	aux_man_op	‘1’(‘0’) indicate a (no) manual auxiliary interface operation is ongoing.	0x0	R
	4	cmd_rdy	CMD decoder status. `0´ -> Command in progress `1´ -> Command decoder is ready to accept a new command	0x1	R

	5	drdy_aux	Data ready for auxiliary sensor. It gets reset when one auxiliary DATA register is read out	0x0	R
	7	drdy_acc	Data ready for accelerometer. It gets reset when one accelerometer DATA register is read out	0x0	R

5.3.4 Register (0x0A) DATA_0

DESCRIPTION: AUX_X(LSB)
RESET: 0x00
DEFINITION (Go to register map):

Address	Bit	Name	Description	Reset	Access
0x0A		DATA_0		0x00	
	7...4	aux_x_3_0		0x0	R

5.3.5 Register (0x0B) DATA_1

DESCRIPTION: AUX_X(MSB)
RESET: 0x00
DEFINITION (Go to register map):

Address	Bit	Name	Description	Reset	Access
0x0B		DATA_1		0x00	
	7...0	aux_x_11_4		0x0	R

5.3.6 Register (0x0C) DATA_2

DESCRIPTION: AUX_Y(LSB)
RESET: 0x00
DEFINITION (Go to register map):

Address	Bit	Name	Description	Reset	Access
0x0C		DATA_2		0x00	
	7...4	aux_y_3_0		0x0	R

5.3.7 Register (0x0D) DATA_3

DESCRIPTION: AUX_Y(MSB)
RESET: 0x00
DEFINITION (Go to register map):

Address	Bit	Name	Description	Reset	Access
0x0D		DATA_3		0x00	
	7...0	aux_y_11_4		0x0	R

5.3.8 Register (0x0E) DATA_4

DESCRIPTION: AUX_Z(LSB)
RESET: 0x00
DEFINITION (Go to register map):

Address	Bit	Name	Description	Reset	Access
0x0E		DATA_4		0x00	
	7…4	aux_z_3_0		0x0	R

5.3.9 Register (0x0F) DATA_5

DESCRIPTION: AUX_Z(MSB)
RESET: 0x00
DEFINITION (Go to register map):

Address	Bit	Name	Description	Reset	Access
0x0F		DATA_5		0x00	
	7…0	aux_z_11_4		0x0	R

5.3.10 Register (0x10) DATA_6

DESCRIPTION: AUX_R(LSB)
RESET: 0x00
DEFINITION (Go to register map):

Address	Bit	Name	Description	Reset	Access
0x10		DATA_6		0x00	
	7…4	aux_r_3_0		0x0	R

5.3.11 Register (0x11) DATA_7

DESCRIPTION: AUX_R(MSB)
RESET: 0x00
DEFINITION (Go to register map):

Address	Bit	Name	Description	Reset	Access
0x11		DATA_7		0x00	
	7…0	aux_r_11_4		0x0	R

5.3.12 Register (0x12) ACC_X_LSB

DESCRIPTION: ACC_X(LSB)
RESET: 0x00
DEFINITION (Go to register map):

Address	Bit	Name	Description	Reset	Access
0x12		ACC_X_LSB		0x00	
	7…4	acc_x_3_0		0x0	R

5.3.13 Register (0x13) ACC_X_MSB

DESCRIPTION: ACC_X(MSB)
RESET: 0x00
DEFINITION (Go to register map):

Address	Bit	Name	Description	Reset	Access
0x13		ACC_X_MSB		0x00	
	7...0	acc_x_11_4		0x0	R

5.3.14 Register (0x14) ACC_Y_LSB

DESCRIPTION: ACC_Y(LSB)
RESET: 0x00
DEFINITION (Go to register map):

Address	Bit	Name	Description	Reset	Access
0x14		ACC_Y_LSB		0x00	
	7...4	acc_y_3_0		0x0	R

5.3.15 Register (0x15) ACC_Y_MSB

DESCRIPTION: ACC_Y(MSB)
RESET: 0x00
DEFINITION (Go to register map):

Address	Bit	Name	Description	Reset	Access
0x15		ACC_Y_MSB		0x00	
	7...0	acc_y_11_4		0x0	R

5.3.16 Register (0x16) ACC_Z_LSB

DESCRIPTION: ACC_Z(LSB)
RESET: 0x00
DEFINITION (Go to register map):

Address	Bit	Name	Description	Reset	Access
0x16		ACC_Z_LSB		0x00	
	7...4	acc_z_3_0		0x0	R

5.3.17 Register (0x17) ACC_Z_MSB

DESCRIPTION: ACC_Z(MSB)
RESET: 0x00
DEFINITION (Go to register map):

Address	Bit	Name	Description	Reset	Access
0x17		ACC_Z_MSB		0x00	
	7...0	acc_z_11_4		0x0	R

5.3.18 Register (0x18) SENSORTIME_0

DESCRIPTION: Sensor time <7:0>
RESET: 0x00
DEFINITION (Go to register map):

Address	Bit	Name	Description	Reset	Access
0x18		SENSORTIME_0		0x00	
	7...0	sensor_time_7_0	Sensor time <7:0> in units of 39.0625 us.	0x0	R

5.3.19 Register (0x19) SENSORTIME_1

DESCRIPTION: Sensor time <15:8>
RESET: 0x00
DEFINITION (Go to register map):

Address	Bit	Name	Description	Reset	Access
0x19		SENSORTIME_1		0x00	
	7...0	sensor_time_15_8	Sensor time <15:8> in units of 10 ms.	0x0	R

5.3.20 Register (0x1A) SENSORTIME_2

DESCRIPTION: Sensor time <23:16>
RESET: 0x00
DEFINITION (Go to register map):

Address	Bit	Name	Description	Reset	Access
0x1A		SENSORTIME_2		0x00	
	7...0	sensor_time_23_16	Sensor time <23:16> in units of 2.56 s.	0x0	R

5.3.21 Register (0x1B) EVENT

DESCRIPTION: Sensor status flags
RESET: 0x01
DEFINITION (Go to register map):

Address	Bit	Name	Description	Reset	Access
0x1B		EVENT		0x01	
	0	por_detected	'1' after device power up or softreset. Clear-on-read	0x1	R

5.3.22 Register (0x1C) ACC_INT_STAT_0

DESCRIPTION: Interrupt/Feature status.This register will be cleared on read.
RESET: 0x00
DEFINITION (Go to register map):

Address	Bit	Name	Description	Reset	Access
0x1C		ACC_INT_STAT_0		0x00	
	0	Data_sync_out	Data Synchronization out	0x0	R
	1	any_motion_out	Any-motion detection output	0x0	R

	2	high_g_out	High_g detection out	0x0	R
	3	low_g_out	Low_g detection out	0x0	R
	4	orientation_out	orientation detection out	0x0	R
	5	no_motion_out	No-motion detection out	0x0	R
	7	error_int_out	Error interrupt output	0x0	R

5.3.23 Register (0x1D) ACC_INT_STAT_1

DESCRIPTION: Interrupt Status. This register will be cleared on read.
RESET: 0x00
DEFINITION (Go to register map):

Address	Bit	Name	Description	Reset	Access
0x1D		ACC_INT_STAT_1		0x00	
	0	ffull_int	FIFO Full Interrupt	0x0	R
	1	fwm_int	FIFO Watermark Interrupt	0x0	R
	7	acc_drdy_int	Accelerometer data ready interrupt	0x0	R

5.3.24 Register (0x22) TEMPERATURE

DESCRIPTION: Contains the temperature value of the sensor
RESET: 0x00
DEFINITION (Go to register map):

Address	Bit	Name	Description	Reset	Access
0x22		TEMPERATURE		0x00	
	7...0	temperature	Temperature value in two's complement representation in units of 1 Kelvin: 0x00 corresponds to 23 degree Celsius.	0x0	R

5.3.25 Register (0x24) FIFO_LENGTH_0

DESCRIPTION: FIFO byte count register (LSB)
RESET: 0x00
DEFINITION (Go to register map):

Address	Bit	Name	Description	Reset	Access
0x24		FIFO_LENGTH_0		0x00	
	7...0	fifo_byte_counter_7_0	Current fill level of FIFO buffer.	0x0	R

5.3.26 Register (0x25) FIFO_LENGTH_1

DESCRIPTION: FIFO byte count register (MSB)
RESET: 0x00
DEFINITION (Go to register map):

Address	Bit	Name	Description	Reset	Access
0x25		FIFO_LENGTH_1		0x00	
	5...0	fifo_byte_counter_13_8	FIFO byte counter bits 13..8	0x0	R

5.3.27 Register (0x26) FIFO_DATA

DESCRIPTION: FIFO data output register
RESET: 0x00
DEFINITION (Go to register map):

Address	Bit	Name	Description	Reset	Access
0x26		FIFO_DATA		0x00	
	7...0	fifo_data	FIFO read data.	0x0	R

5.3.28 Register (0x29) ORIENT_HIGHG_OUT

DESCRIPTION: Describes orientation and highg output
RESET: 0x00
DEFINITION (Go to register map):

<table>
<tr><th>Address</th><th>Bit</th><th>Name</th><th>Description</th><th>Reset</th><th>Access</th></tr>
<tr><td rowspan="6">0x29</td><td></td><td>ORIENT_HIGHG_OUT</td><td></td><td>0x00</td><td></td></tr>
<tr><td>1...0</td><td>orientation_portrait_landscape</td><td>Output value of the orientation detection feature. Value after device initialization is 0b00 i.e. portrait upright
<table><tr><th>Value</th><th>Name</th><th>Description</th></tr><tr><td>0x00</td><td>portrait_upright</td><td>Portrait upright orientation</td></tr><tr><td>0x01</td><td>landscape_left</td><td>Landscape left orientation</td></tr><tr><td>0x02</td><td>portrait_upside_down</td><td>Portrait upside down orientation</td></tr><tr><td>0x03</td><td>landscape_right</td><td>Landscape right orientation</td></tr></table></td><td>0x0</td><td>R</td></tr>
<tr><td>2</td><td>orientation_faceup_down</td><td>Output value of face down face up orientation (only if ud_en is enabled). Value after device initialization is 0b0 i.e. face up
<table><tr><th>Value</th><th>Name</th><th>Description</th></tr><tr><td>0x00</td><td>face_up</td><td>Face up orientation</td></tr><tr><td>0x01</td><td>face_down</td><td>Face down orientation</td></tr></table></td><td>0x0</td><td>R</td></tr>
<tr><td>3</td><td>high_g_detect_x</td><td>High-g was detected on X-axis</td><td>0x0</td><td>R</td></tr>
<tr><td>4</td><td>high_g_detect_y</td><td>High-g was detected on Y-axis</td><td>0x0</td><td>R</td></tr>
<tr><td>5</td><td>high_g_detect_z</td><td>High-g was detected on Z-axis</td><td>0x0</td><td>R</td></tr>
</table>

	6	high_g_detect_sign	Axis direction for which the high-g was detected. 1 for negative axis, 0 for positive axis.	0x0	R

5.3.29 Register (0x2A) INTERNAL_STATUS

DESCRIPTION:
RESET: 0x00
DEFINITION (Go to register map):

Address	Bit	Name	Description	Reset	Access
0x2A		INTERNAL_STATUS		0x00	
	4...0	message	Internal Status Message **Value Name Description** 0x00 not_init ASIC is not initialized 0x01 init_ok ASIC initialized 0x02 init_err Initialization error 0x03 dvr_err Invalid driver 0x04 sns_stop Sensor stopped	0x0	R
	5	axes_remap_error	Axes remapped wrongly because a source axis is not assigned to more than one target axis.	0x0	R

5.3.30 Register (0x40) ACC_CONF

DESCRIPTION: Sets the output data rate, the bandwidth, and the read mode of the acceleration sensor
RESET: 0xA8
DEFINITION (Go to register map):

Address	Bit	Name	Description	Reset	Access
0x40		ACC_CONF		0xA8	
	3...0	acc_odr	ODR in Hz. The output data rate is independent of the power mode setting for the sensor, but not all settings are supported in all power modes. **Value Name Description** 0x00 reserved Reserved 0x01 odr_0p78 25/32 0x02 odr_1p5 25/16 0x03 odr_3p1 25/8 0x04 odr_6p25 25/4 0x05 odr_12p5 25/2 0x06 odr_25 25 0x07 odr_50 50 0x08 odr_100 100 0x09 odr_200 200 0x0a odr_400 400 0x0b odr_800 800	0x8	RW

			0x0c odr_1k6 1600 0x0d odr_3k2 Reserved 0x0e odr_6k4 Reserved 0x0f odr_12k8 Reserved		
	6…4	acc_bwp	Bandwidth parameter, determines filter configuration (acc_perf_mode=1) and averaging for undersampling mode (acc_perf_mode=0) **Value** **Name** **Description** 0x00 osr4_avg1 acc_perf_mode = 1 -> OSR4 mode; acc_perf_mode = 0 -> no averaging 0x01 osr2_avg2 acc_perf_mode = 1 -> OSR2 mode; acc_perf_mode = 0 -> average 2 samples 0x02 norm_avg4 acc_perf_mode = 1 -> normal mode; acc_perf_mode = 0 -> average 4 samples 0x03 cic_avg8 acc_perf_mode = 1 -> Reserved; acc_perf_mode = 0 -> average 8 samples 0x04 res_avg16 acc_perf_mode = 1 -> Reserved; acc_perf_mode = 0 -> average 16 samples 0x05 res_avg32 acc_perf_mode = 1 -> Reserved; acc_perf_mode = 0 -> average 32 samples 0x06 res_avg64 acc_perf_mode = 1 -> Reserved; acc_perf_mode = 0 -> average 64 samples 0x07 res_avg128 acc_perf_mode = 1 -> Reserved; acc_perf_mode = 0 -> average 128 samples	0x2	RW
	7	acc_perf_mode	Select accelerometer filter performance mode: **Value** **Name** **Description** 0x00 cic_avg averaging mode. 0x01 cont continuous filter function.	0x1	RW

5.3.31 Register (0x41) ACC_RANGE

DESCRIPTION: Selection of the Accelerometer g-range
RESET: 0x01
DEFINITION (Go to register map):

<table>
<tr><th>Address</th><th>Bit</th><th>Name</th><th>Description</th><th>Reset</th><th>Access</th></tr>
<tr><td rowspan="2">0x41</td><td></td><td>ACC_RANGE</td><td></td><td>0x01</td><td></td></tr>
<tr><td>1...0</td><td>acc_range</td><td>Accelerometer g-range
Value Name Description
0x00 range_3g +/-3g
0x01 range_6g +/-6g
0x02 range_12g +/-12g
0x03 range_24g +/-24g</td><td>0x1</td><td>RW</td></tr>
</table>

5.3.32 Register (0x44) AUX_CONF

DESCRIPTION: Sets the output data rate of the Auxiliary interface
RESET: 0x46
DEFINITION (Go to register map):

<table>
<tr><th>Address</th><th>Bit</th><th>Name</th><th>Description</th><th>Reset</th><th>Access</th></tr>
<tr><td rowspan="3">0x44</td><td></td><td>AUX_CONF</td><td></td><td>0x46</td><td></td></tr>
<tr><td>3...0</td><td>aux_odr</td><td>Select the poll rate for the sensor attached to the Auxiliary interface.
Value Name Description
0x00 reserved Reserved
0x01 odr_0p78 25/32
0x02 odr_1p5 25/16
0x03 odr_3p1 25/8
0x04 odr_6p25 25/4
0x05 odr_12p5 25/2
0x06 odr_25 25
0x07 odr_50 50
0x08 odr_100 100
0x09 odr_200 200
0x0a odr_400 400
0x0b odr_800 800
0x0c odr_1k6 Reserved
0x0d odr_3k2 Reserved
0x0e odr_6k4 Reserved
0x0f odr_12k8 Reserved</td><td>0x6</td><td>RW</td></tr>
<tr><td>7...4</td><td>aux_offset</td><td>trigger-readout offset in units of 2.5 ms. If set to zero, the offset is maximum, i.e. after readout a trigger is issued immediately.</td><td>0x4</td><td>RW</td></tr>
</table>

5.3.33 Register (0x45) FIFO_DOWNS

DESCRIPTION: Configure Accelerometer downsampling rates for FIFO
RESET: 0x80
DEFINITION (Go to register map):

Address	Bit	Name	Description	Reset	Access
0x45		FIFO_DOWNS		0x80	
	6...4	acc_fifo_downs	Downsampling for accelerometer data (2**acc_fifo_downs)	0x0	RW
	7	acc_fifo_filt_data	selects filtered or unfiltered Accelerometer data for fifo **Value** **Name** **Description** 0x00 unfiltered Unfiltered data 0x01 filtered Filtered data	0x1	RW

5.3.34 Register (0x46) FIFO_WTM_0

DESCRIPTION: FIFO Watermark level LSB
RESET: 0x00
DEFINITION (Go to register map):

Address	Bit	Name	Description	Reset	Access
0x46		FIFO_WTM_0		0x00	
	7...0	fifo_water_mark_7_0		0x0	RW

5.3.35 Register (0x47) FIFO_WTM_1

DESCRIPTION: FIFO Watermark level MSB
RESET: 0x02
DEFINITION (Go to register map):

Address	Bit	Name	Description	Reset	Access
0x47		FIFO_WTM_1		0x02	
	4...0	fifo_water_mark_12_8		0x2	RW

5.3.36 Register (0x48) FIFO_CONFIG_0

DESCRIPTION: FIFO frame content configuration
RESET: 0x02
DEFINITION (Go to register map):

Address	Bit	Name	Description	Reset	Access
0x48		FIFO_CONFIG_0		0x02	
	0	fifo_stop_on_full	Stop writing samples into FIFO when FIFO is full. **Value** **Name** **Description** 0x00 disable do not stop writing to FIFO when full	0x0	RW

			0x01 enable Stop writing into FIFO when full.		
	1	fifo_time_en	Return sensortime frame after the last valid data frame. **Value Name Description** 0x00 disable do not return sensortime frame 0x01 enable return sensortime frame	0x1	RW

5.3.37 Register (0x49) FIFO_CONFIG_1

DESCRIPTION: FIFO frame content configuration
RESET: 0x10
DEFINITION (Go to register map):

Address	Bit	Name	Description	Reset	Access
0x49		FIFO_CONFIG_1		0x10	
	2	fifo_tag_int2_en	FIFO interrupt 2 tag enable **Value Name Description** 0x00 disable disable tag 0x01 enable enable tag	0x0	RW
	3	fifo_tag_int1_en	FIFO interrupt 1 tag enable **Value Name Description** 0x00 disable disable tag 0x01 enable enable tag	0x0	RW
	4	fifo_header_en	FIFO frame header enable **Value Name Description** 0x00 disable no header is stored (output data rate of all enabled sensors need to be identical) 0x01 enable header is stored	0x1	RW
	5	fifo_aux_en	Store Auxiliary data in FIFO (all 3 axes) **Value Name Description** 0x00 disable no Auxiliary data is stored 0x01 enable Auxiliary data is stored	0x0	RW
	6	fifo_acc_en	Store Accelerometer data in FIFO (all 3 axes) **Value Name Description** 0x00 disable no Accelerometer data is stored 0x01 enable Accelerometer data is stored	0x0	RW

5.3.38 Register (0x4B) AUX_DEV_ID

DESCRIPTION: Auxiliary interface slave device id
RESET: 0x20
DEFINITION (Go to register map):

Address	Bit	Name	Description	Reset	Access
0x4B		AUX_DEV_ID		0x20	
	7…1	i2c_device_addr	I2C device address of Auxiliary slave	0x10	RW

5.3.39 Register (0x4C) AUX_IF_CONF

DESCRIPTION: Auxiliary interface configuration
RESET: 0x83
DEFINITION (Go to register map):

Address	Bit	Name	Description	Reset	Access
0x4C		AUX_IF_CONF		0x83	
	1…0	aux_rd_burst	Burst data length (1,2,6,8 byte) **Value Name Description** 0x00 BL1 Burst length 1 0x01 BL2 Burst length 2 0x02 BL6 Burst length 6 0x03 BL8 Burst length 8	0x3	RW
	7	aux_manual_en	Enable auxiliary interface manual mode. **Value Name Description** 0x00 disable Data mode 0x01 enable Setup mode	0x1	RW

5.3.40 Register (0x4D) AUX_RD_ADDR

DESCRIPTION: Auxiliary interface read register address
RESET: 0x42
DEFINITION (Go to register map):

Address	Bit	Name	Description	Reset	Access
0x4D		AUX_RD_ADDR		0x42	
	7…0	read_addr	Address to read	0x42	RW

5.3.41 Register (0x4E) AUX_WR_ADDR

DESCRIPTION: Auxiliary interface write register address
RESET: 0x4C
DEFINITION (Go to register map):

Address	Bit	Name	Description	Reset	Access
0x4E		AUX_WR_ADDR		0x4C	
	7…0	write_addr	Address to write	0x4C	RW

5.3.42 Register (0x4F) AUX_WR_DATA

DESCRIPTION: Auxiliary interface write data
RESET: 0x02
DEFINITION (Go to register map):

Address	Bit	Name	Description	Reset	Access
0x4F		AUX_WR_DATA		0x02	
	7...0	write_data	Data to write	0x2	RW

5.3.43 Register (0x53) INT1_IO_CTRL

DESCRIPTION: Configure the electrical behaviour of the interrupt pins
RESET: 0x00
DEFINITION (Go to register map):

Address	Bit	Name	Description	Reset	Access
0x53		INT1_IO_CTRL		0x00	
	0	edge_ctrl	Configure trigger condition of INT1 pin (input) **Value** **Name** **Description** 0x00 level_tr Level 0x01 edge_tr Edge	0x0	RW
	1	lvl	Configure level of INT1 pin **Value** **Name** **Description** 0x00 active_low active low 0x01 active_high active high	0x0	RW
	2	od	Configure behaviour of INT1 pin to open drain. **Value** **Name** **Description** 0x00 push_pull push-pull 0x01 open_drain open drain	0x0	RW
	3	output_en	Output enable for INT1 pin **Value** **Name** **Description** 0x00 off Output disabled 0x01 on Output enabled	0x0	RW
	4	input_en	Input enable for INT1 pin **Value** **Name** **Description** 0x00 off Input disabled 0x01 on Input enabled	0x0	RW

5.3.44 Register (0x54) INT2_IO_CTRL

DESCRIPTION: Configure the electrical behaviour of the interrupt pins
RESET: 0x00
DEFINITION (Go to register map):

Address	Bit	Name	Description	Reset	Access
0x54		INT2_IO_CTRL		0x00	
	0	edge_ctrl	Configure trigger condition of INT2 pin (input) **Value** **Name** **Description** 0x00 level_tr Level	0x0	RW

			0x01 edge_tr Edge		
	1	lvl	Configure level of INT2 pin **Value Name Description** 0x00 active_low active low 0x01 active_high active high	0x0	RW
	2	od	Configure behaviour of INT2 pin to open drain. **Value Name Description** 0x00 push_pull push-pull 0x01 open_drain open drain	0x0	RW
	3	output_en	Output enable for INT2 pin **Value Name Description** 0x00 off Output disabled 0x01 on Output enabled	0x0	RW
	4	input_en	Input enable for INT2 pin **Value Name Description** 0x00 off Input disabled 0x01 on Input enabled	0x0	RW

5.3.45 Register (0x55) INT_LATCH

DESCRIPTION: Configure interrupt modes
RESET: 0x00
DEFINITION (Go to register map):

Address	Bit	Name	Description	Reset	Access
0x55		INT_LATCH		0x00	
	0	int_latch	Latched/non-latched/temporary interrupt modes **Value Name Description** 0x00 none non latched 0x01 permanent latched	0x0	RW

5.3.46 Register (0x56) INT1_MAP

DESCRIPTION: Interrupt/Feature mapping on INT1
RESET: 0x00
DEFINITION (Go to register map):

Address	Bit	Name	Description	Reset	Access
0x56		INT1_MAP		0x00	
	0	Data_sync_out	Data Synchronization out	0x0	RW
	1	any_motion_out	Any-motion detection output	0x0	RW
	2	high_g_out	High_g detection out	0x0	RW
	3	low_g_out	Low_g detection out	0x0	RW
	4	orientation_out	orientation detection out	0x0	RW
	5	no_motion_out	No-motion detection out	0x0	RW
	7	error_int_out	Error interrupt output	0x0	RW

5.3.47 Register (0x57) INT2_MAP

DESCRIPTION: Interrupt/Feature mapping on INT2
RESET: 0x00
DEFINITION (Go to register map):

Address	Bit	Name	Description	Reset	Access
0x57		INT2_MAP		0x00	
	0	Data_sync_out	Data Synchronization out	0x0	RW
	1	any_motion_out	Any-motion detection output	0x0	RW
	2	high_g_out	High_g detection out	0x0	RW
	3	low_g_out	Low_g detection out	0x0	RW
	4	orientation_out	orientation detection out	0x0	RW
	5	no_motion_out	No-motion detection out	0x0	RW
	7	error_int_out	Error interrupt output	0x0	RW

5.3.48 Register (0x58) INT_MAP_DATA

DESCRIPTION: Interrupt mapping hardware interrupts
RESET: 0x00
DEFINITION (Go to register map):

Address	Bit	Name	Description	Reset	Access
0x58		INT_MAP_DATA		0x00	
	0	int1_ffull	FIFO Full interrupt mapped to INT1	0x0	RW
	1	int1_fwm	FIFO Watermark interrupt mapped to INT1	0x0	RW
	2	int1_drdy	Data Ready interrupt mapped to INT1	0x0	RW
	4	int2_ffull	FIFO Full interrupt mapped to INT2	0x0	RW
	5	int2_fwm	FIFO Watermark interrupt mapped to INT2	0x0	RW
	6	int2_drdy	Data Ready interrupt mapped to INT2	0x0	RW

5.3.49 Register (0x59) INIT_CTRL

DESCRIPTION: Start initialization
RESET: 0x90
DEFINITION (Go to register map):

Address	Bit	Name	Description	Reset	Access
0x59		INIT_CTRL		0x90	
	7...0	init_ctrl	Start initialization	0x90	RW

5.3.50 Register (0x5E) FEATURES_IN

DESCRIPTION: Feature configuration read/write port
RESET: 0x00
DEFINITION (Go to register map):

Address	Bit	Name	Description	Reset	Access
0x5E		FEATURES_IN		0x00	
	7...0	features_in	Feature configuration read/write data	0x0	RW

Address	Bit	Name	Description	Reset	Access
any_motion					
0x5E: 0x00		ANYMO_1	Any-motion detection general configuration flags - part 1	0x00AA	
	10...0	threshold	Slope threshold value for any-motion detection. Range is 0 to 1.5g. Default value is 0xAA = 124mg.	0xAA	RW
	11	enable	Enables the feature	0x0	RW
0x5E: 0x02		ANYMO_2	Any-motion detection general configuration flags - part 2	0xE005	
	12...0	duration	Defines the number of consecutive data points for which the threshold condition must be respected for interrupt assertion. It is expressed in 50 Hz samples (20 ms). Range is 0 to 163sec. Default value is 5=100ms.	0x5	RW
	13	x_en	Enables the feature on a per-axis basis	0x1	RW
	14	y_en	Enables the feature on a per-axis basis	0x1	RW
	15	z_en	Enables the feature on a per-axis basis	0x1	RW
high_g					
0x5E: 0x06		HI_G_1	The acceleration threshold above which the high_g motion is signaled.	0x0C00	
	14...0	threshold	The acceleration threshold above which the high_g motion is signaled15 bit, signed integer (valid values 0...32767) holding the threshold in 5.11 g format. Default is 3072 = 2.25 g. Range is 0 to 24g.	0xC00	RW
0x5E: 0x08		HI_G_2	Enable flags and hysteresis configuration	0x73E8	
	11...0	hysteresis	Hysteresis value for high_g feature. Range is 0 to 3g. Default value is 1000 = 0.74g.	0x3E8	RW
	12	en_x	Enables the feature on a per-axis basis	0x1	RW
	13	en_y	Enables the feature on a per-axis basis	0x1	RW
	14	en_z	Enables the feature on a per-axis basis	0x1	RW
	15	enable	Enables the feature	0x0	RW
0x5E: 0x0A		HI_G_3	Duration interval	0x0004	
	11...0	duration	12 bit signed character (valid values 0...4095) holding the duration in 200 Hz samples (5 ms) for which the threshold has to be exceeded; default value 4 = 20 msec. Range is 0 to 20sec.	0x4	RW
low_g					
0x5E: 0x0C		LO_G_1	The acceleration threshold below which the low_g motion is signaled.	0x0200	

	14...0	threshold	Threshold value for low-g feature. Range is 0 to 1.5g. Default value is 512 = 0.375g.	0x200	RW
0x5E: 0x0E		LO_G_2	Enable flag and hysteresis configuration	0x0100	
	11...0	hysteresis	Hysteresis value for low_g feature. Range is 0 to 0.75g. Default value is 256 = 0.187g.	0x100	RW
	12	enable	Enables the feature	0x0	RW
0x5E: 0x10		LO_G_3	Duration interval	0x0000	
	11...0	duration	Duration in 50 Hz samples (20 msec) for which the threshold has to be exceeded. Range is 0 to 82 sec. Default value is 0 = 0 ms.	0x0	RW
orientation					
0x5E: 0x12		ORIENT_1	Orientation general configuration flags	0x0A30	
	0	enable	Enables the feature	0x0	RW
	1	ud_en	Enables upside/down detection, if set to 1	0x0	RW
	3...2	mode	Sets the mode: symmetrical (values 0 or 3), high asymmetrical (value 1) or low asymmetrical (value 2).	0x0	RW
	5...4	blocking	Sets the blocking mode. If blocking is set, no Orientation interrupt will be triggered. Default value is 3 – the most restrictive blocking mode.	0x3	RW
	11...6	theta	Coded value of the threshold angle with horizontal used in Blocking modes; theta = 64 * (tan(angle)^2); default value is 40, equivalent to 38 degrees angle.	0x28	RW
0x5E: 0x14		ORIENT_2	Acceleration hysteresis	0x0080	
	10...0	hysteresis	Acceleration hysteresis for orientation detection. Default value is 128 = 0.09375g. Range is 0 to 1.5g.	0x80	RW
no_motion					
0x5E: 0x16		NOMO_1	No-motion detection general configuration flags - part 1	0x00AA	
	10...0	threshold	Slope threshold value for no-motion detection. Range is 0 to 1.5g. Default value is 0xAA = 124mg.	0xAA	RW
	11	enable	Enables the feature	0x0	RW
0x5E: 0x18		NOMO_2	No-motion detection general configuration flags - part 2	0xE005	
	12...0	duration	Defines the number of consecutive data points for which the threshold	0x5	RW

			condition must be respected for interrupt assertion. It is expressed in 50 Hz samples (20 ms). Range is 0 to 163sec. Default value is 5=100ms.		
	13	x_en	Enables the feature on a per-axis basis	0x1	RW
	14	y_en	Enables the feature on a per-axis basis	0x1	RW
	15	z_en	Enables the feature on a per-axis basis	0x1	RW
general_settings					
0x5E: 0x1A		Reserved	Reserved	0x0000	
	15...0	Reserved	Reserved	0x0	R
0x5E: 0x1C		AXIS_REMAP_1	Describes axes remapping	0x0088	
	1...0	map_x_axis	Map the x axis to desired axis **Value** **Name** **Description** 0x00 x_axis Map to x-axis 0x01 y_axis Map to y-axis 0x02 z_axis Map to z-axis 0x03 reserved Map to x-axis	0x0	RW
	2	map_x_axis_sign	Map the x axis sign to the desired one **Value** **Name** **Description** 0x00 not_invert Clear this bit to not invert the x axis 0x01 inverted Set this bit to invert the x axis	0x0	RW
	4...3	map_y_axis	Map the y axis to desired axis **Value** **Name** **Description** 0x00 x_axis Map to x-axis 0x01 y_axis Map to y-axis 0x02 z_axis Map to z-axis 0x03 reserved Map to y-axis	0x1	RW
	5	map_y_axis_sign	Map the y axis sign to the desired one **Value** **Name** **Description** 0x00 not_invert Clear this bit to not invert the y axis 0x01 inverted Set this bit to invert the y axis	0x0	RW
	7...6	map_z_axis	Map the z axis to desired axis **Value** **Name** **Description** 0x00 x_axis Map to x-axis 0x01 y_axis Map to y-axis 0x02 z_axis Map to z-axis 0x03 reserved Map to z-axis	0x2	RW
	8	map_z_axis_sign	Map the z axis sign to the desired one **Value** **Name** **Description** 0x00 not_invert Clear this bit to not invert the z axis	0x0	RW

			0x01 inverted Set this bit to invert the z axis		

5.3.51 Register (0x5F) INTERNAL_ERROR

DESCRIPTION: Internal error flags.
RESET: 0x00
DEFINITION (Go to register map):

Address	Bit	Name	Description	Reset	Access
0x5F		INTERNAL_ERROR		0x00	
	1	int_err_1	Internal error flag - long processing time, processing halted	0x0	R
	2	int_err_2	Internal error flag - fatal error, processing halted	0x0	R

5.3.52 Register (0x6A) NVM_CONF

DESCRIPTION: NVM controller mode (Prog/Erase or Read only)
RESET: 0x00
DEFINITION (Go to register map):

Address	Bit	Name	Description	Reset	Access
0x6A		NVM_CONF		0x00	
	1	nvm_prog_en	Enable NVM programming **Value** **Name** **Description** 0x00 disable disable 0x01 enable enable	0x0	RW

5.3.53 Register (0x6B) IF_CONF

DESCRIPTION: Serial interface settings
RESET: 0x00
DEFINITION (Go to register map):

Address	Bit	Name	Description	Reset	Access
0x6B		IF_CONF		0x00	
	0	spi3	Configure SPI Interface Mode for primary interface **Value** **Name** **Description** 0x00 spi4 SPI 4-wire mode 0x01 spi3 SPI 3-wire mode	0x0	RW
	4	if_mode	Auxiliary interface configuration **Value** **Name** **Description** 0x00 p_auto_s_off Auxiliary interface:off 0x01 p_auto_s_mag Auxilary interface:Magnetometer	0x0	RW

5.3.54 Register (0x6D) ACC_SELF_TEST

DESCRIPTION: Settings for the sensor self-test configuration and trigger
RESET: 0x00
DEFINITION (Go to register map):

Address	Bit	Name	Description	Reset	Access
0x6D		ACC_SELF_TEST		0x00	
	0	acc_self_test_en	Enable accelerometer self-test **Value** **Name** **Description** 0x00 disabled disabled 0x01 enabled enabled	0x0	RW
	2	acc_self_test_sign	select sign of self-test excitation as **Value** **Name** **Description** 0x00 negative negative 0x01 positive positive	0x0	RW
	3	acc_self_test_amp	select amplitude of the selftest deflection: **Value** **Name** **Description** 0x00 low low 0x01 high high	0x0	RW

5.3.55 Register (0x70) NV_CONF

DESCRIPTION: NVM backed configuration bits.
RESET: 0x00
DEFINITION (Go to register map):

Address	Bit	Name	Description	Reset	Access
0x70		NV_CONF		0x00	
	0	spi_en	disable the I2C and enable SPI for the primary interface, when it is in autoconfig mode **Value** **Name** **Description** 0x00 disabled I2C enabled 0x01 enabled I2C disabled	0x0	RW
	1	i2c_wdt_sel	Select timer period for I2C Watchdog **Value** **Name** **Description** 0x00 wdt_short I2C watchdog timeout after 1.25 ms 0x01 wdt_long I2C watchdog timeout after 40 ms	0x0	RW
	2	i2c_wdt_en	I2C Watchdog at the SDI pin in I2C interface mode **Value** **Name** **Description** 0x00 Disable Disable I2C watchdog 0x01 Enable Enable I2C watchdog	0x0	RW
	3	acc_off_en	Add the offset defined in the off_acc_[xyz] OFFSET register to filtered and unfiltered Accelerometer data **Value** **Name** **Description** 0x00 disabled Disabled 0x01 enabled Enabled	0x0	RW

5.3.56 Register (0x71) OFFSET_0

DESCRIPTION: Offset compensation for Accelerometer X-axis (NVM backed)
RESET: 0x00
DEFINITION (Go to register map):

Address	Bit	Name	Description	Reset	Access
0x71		OFFSET_0		0x00	
	7...0	off_acc_x	Accelerometer offset compensation (X-axis).	0x0	RW

5.3.57 Register (0x72) OFFSET_1

DESCRIPTION: Offset compensation for Accelerometer Y-axis (NVM backed)
RESET: 0x00
DEFINITION (Go to register map):

Address	Bit	Name	Description	Reset	Access
0x72		OFFSET_1		0x00	
	7...0	off_acc_y	Accelerometer offset compensation (Y-axis).	0x0	RW

5.3.58 Register (0x73) OFFSET_2

DESCRIPTION: Offset compensation for Accelerometer Z-axis (NVM backed)
RESET: 0x00
DEFINITION (Go to register map):

Address	Bit	Name	Description	Reset	Access
0x73		OFFSET_2		0x00	
	7...0	off_acc_z	Accelerometer offset compensation (Z-axis).	0x0	RW

5.3.59 Register (0x7C) ACC_PWR_CONF

DESCRIPTION: Power mode configuration register
RESET: 0x03
DEFINITION (Go to register map):

Address	Bit	Name	Description	Reset	Access
0x7C		ACC_PWR_CONF		0x03	
	0	pwr_save_mode	**Value** / **Name** / **Description** 0x00 / aps_off / advanced power save disabled (fast clk always enabled). 0x01 / aps_on / advanced power mode enabled (slow clk is active when no measurement is ongoing.)	0x1	RW

5.3.60 Register (0x7D) ACC_PWR_CTRL

DESCRIPTION: Sensor enable register
RESET: 0x00
DEFINITION (Go to register map):

<table>
<tr><th>Address</th><th>Bit</th><th>Name</th><th>Description</th><th>Reset</th><th>Access</th></tr>
<tr><td rowspan="2">0x7D</td><td></td><td>ACC_PWR_CTRL</td><td></td><td>0x00</td><td></td></tr>
<tr><td>2</td><td>acc_en</td><td>Value Name Description
0x00 acc_off Disables the Accelerometer.
0x01 acc_on Enables the Accelerometer.</td><td>0x0</td><td>RW</td></tr>
</table>

5.3.61 Register (0x7E) ACC_SOFTRESET

DESCRIPTION: Command Register
RESET: 0x00
DEFINITION (Go to register map):

<table>
<tr><th>Address</th><th>Bit</th><th>Name</th><th>Description</th><th>Reset</th><th>Access</th></tr>
<tr><td rowspan="2">0x7E</td><td></td><td>ACC_SOFTRESET</td><td></td><td>0x00</td><td></td></tr>
<tr><td>7...0</td><td>softreset_cmd
(0xb6)</td><td>Writing a value of 0xB6 to this register resets the sensor. Do not write any other content to this register. Following a delay of 1 ms, all configuration settings are overwritten with their reset value. The soft-reset can be triggered from any operation mode.</td><td>0x0</td><td>RW</td></tr>
</table>

5.4 Register map: gyroscope

read/write	read only	write only	reserved

Reg. Addr.	Register name	Reset value	bit7	bit6	bit5	bit4	bit3	bit2	bit1	bit0
0x3F	FIFO_DATA	N/A	fifo_data_output_register							
0x3E	FIFO_CONFIG_1	0x00	fifo_mode							
0x3D	FIFO_CONFIG_0	0x00		fifo_water_mark_level_trigger_retain						
0x3C	GYRO_SELF_TEST	N/A	-			rate_ok	-	bist_fail	bist_rdy	trig_bst
0x3B - 0x35: reserved										
0x34	FIFO_EXT_INT_S	0x00			ext_fifo_s_en	ext_fifo_s_sel				
0x33 - 0x1F: reserved										
0x1E	FIFO_WM_EN	0x00	fifo_watermark_enable							
0x1D - 0x19: reserved			-							
0x18	INT3_INT4_IO_MAP	0x00	Int4_data	-	Int4_fifo	-		Int3_fifo	-	Int3_data
0x17: reserved			-							
0x16	INT3_INT4_IO_CONF	0x0F	-				Int4_od	Int4_lvl	Int3_od	Int3_lvl
0x15	GYRO_INT_CTRL	0x00	data_en	fifo_en	-					
0x14	GYRO_SOFTRESET	N/A	softreset							
0x13 - 0x12: reserved			-							
0x11	GYRO_LPM1	0x00	gyro_pm							
0x10	GYRO_BANDWIDTH	0x80	gyro_bw							
0x0F	GYRO_RANGE	0x00	gyro_range							
0x0E	FIFO_STATUS	N/A	fifo_overrun	fifo_frame_counter						
0x0D - 0x0B: reserved			-							
0x0A	GYRO_INT_STAT_1	N/A	gyro_drdy	-		fifo_int	-			
0x09 - 0x08: reserved			-							
0x07	RATE_Z_MSB	N/A	rate_z[15:8]							
0x06	RATE_Z_LSB	N/A	rate_z[7:0]							
0x05	RATE_Y_MSB	N/A	rate_y[15:8]							
0x04	RATE_Y_LSB	N/A	rate_y[7:0]							
0x03	RATE_X_MSB	N/A	rate_x[15:8]							
0x02	RATE_X_LSB	N/A	rate_x[7:0]							
0x01	*Reserved*	N/A	-							
0x00	GYRO_CHIP_ID	0x0F	gyro_chip_id							

5.5 Register description: gyroscope

5.5.1 Register 0x00: GYRO_CHIP_ID

Bit	Access	Reset value	Description
[7:0]	RO	0x0F	Contains identifier code of gyroscope.

5.5.2 Register 0x02 – 0x07: Rate data

Registers containing the angular velocity sensor output. The sensor output is stored as signed 16-bit number in 2's complement format in each 2 registers. From the registers, the gyro values can be calculated as follows:

Rate_X: RATE_X_MSB * 256 + RATE_X_LSB
Rate_Y: RATE_Y_MSB * 256 + RATE_Y_LSB
Rate_Z: RATE_Z_MSB * 256 + RATE_Z_LSB

When a register is read containing the LSB value of a rate value, the corresponding MSB register is locked internally, until it is read. By this mechanism, it is ensured that both LSB and MSB values belong to the same rate range value and are not updated between the readouts of the individual registers.

The unit is in LSB. The conversion from LSB to angular velocity (degree per second) is based on the range settings (see 5.5.5). For example, for the default range setting of 0x00 in register 0x0F, the following conversion table applies:

Sensor output [LSB]	Angular rate (in 2000°/s range mode)
+32767	+ 2000°/s
...	...
0	0°/s
...	...
-32767	- 2000°/s

5.5.3 Register 0x0A: GYRO_INT_STAT_1

Bit	Name	Access	Reset value	Description
[7]	gyro_drdy	RO	N/A	Data ready interrupt status. The interrupt is cleared automatically after 280-400 µs.
[6:5]	*reserved*			
[4]	fifo_int	RO	N/A	FIFO interrupt status
[3:0]	*reserved*			

5.5.4 Register 0x0E: FIFO_STATUS

The register contains FIFO status information.

Bit	Name	Access	Reset value	Description
[7]	Fifo_overrun	RO	N/A	If set, FIFO overrun condition has occurred. Note: flag can only be cleared by writing to the FIFO configuration register FIFO_CONFIG_1
[6:0]	Fifo_frame_counter	RO	N/A	Current fill level of FIFO buffer. An empty FIFO corresponds to 0x00. The frame counter can be cleared by reading out all frames from the FIFO buffer or writing to the FIFO configuration register FIFO_CONFIG_1.

5.5.5 Register 0x0F: GYRO_RANGE

Bit	Access	Reset value	Description
[7:0]	RW	0x00	Angular rate range and resolution. Possible values:

gyro_range	Full scale [°/s]	Resolution
0x00	±2000	16.384 LSB/°/s ⇔ 61.0 m°/s / LSB
0x01	±1000	32.768 LSB/°/s ⇔ 30.5 m°/s / LSB
0x02	±500	65.536 LSB/°/s ⇔ 15.3 m°/s / LSB
0x03	±250	131.072 LSB/°/s ⇔ 7.6 m°/s / LSB
0x04	±125	262.144 LSB/°/s ⇔ 3.8m°/s / LSB

5.5.6 Register 0x10: GYRO_BANDWIDTH

Bit	Access	Reset value	Description
[7:0]	RW	0x80[2]	The register allows the selection of the rate data filter bandwidth and output data rate (ODR). Possible values:

gyro_bw	ODR [Hz]	Filter bandwidth [Hz]
0x00	2000	532
0x01	2000	230
0x02	1000	116
0x03	400	47
0x04	200	23
0x05	100	12
0x06	200	64
0x07	100	32

5.5.7 Register 0x11: GYRO_LPM1

Selection of the main power modes. Please note that only switching between normal mode and the suspend modes is allowed, it is not possible to switch between suspend and deep suspend and vice versa.

Bit	Access	Reset value	Description
[7:0]	RW	0x00	Switch to the main power modes.

gyro_pm	Power mode
0x00	normal
0x80	suspend
0x20	deep suspend

5.5.8 Register 0x14: GYRO_SOFTRESET

Bit	Access	Reset value	Description
[7:0]	W	N/A	Writing a value of **0xB6** to this register resets the sensor. (Other values are ignored.) Following a delay of 30 ms, all configuration settings are overwritten with their reset value. The soft reset can be triggered from any operation mode.

[2] Note: bit #7 is read-only and always ‚1‘, but has no function and can safely be ignored.

5.5.9 Register 0x15: GYRO_INT_CTRL

Bit	Access	Reset value	Description
[7]	RW	0x0	Enables the new data interrupt to be triggered on new data.
[6]	RW	0x0	Enables the FIFO interrupt.
[5:0]	*reserved*		

5.5.10 Register 0x16: INT3_INT4_IO_CONF

Sets electrical and logical properties of the interrupt pins.

<table>
<tr><th>Bit</th><th>Name</th><th>Access</th><th>Reset value</th><th>Description</th></tr>
<tr><td>[3]</td><td>Int4_od</td><td>RW</td><td>‘1’</td><td><table><tr><th>Int4_od</th><th>Pin INT4 output configuration</th></tr><tr><td>‘0’</td><td>Push-pull</td></tr><tr><td>‘1’</td><td>Open-drain</td></tr></table></td></tr>
<tr><td>[2]</td><td>Int4_lvl</td><td>RW</td><td>‘1’</td><td><table><tr><th>Int4_lvl</th><th>Pin INT4 active state</th></tr><tr><td>‘0’</td><td>Active low</td></tr><tr><td>‘1’</td><td>Active high</td></tr></table></td></tr>
<tr><td>[1]</td><td>Int3_od</td><td>RW</td><td>‘1’</td><td><table><tr><th>Int3_od</th><th>Pin INT3 output configuration</th></tr><tr><td>‘0’</td><td>Push-pull</td></tr><tr><td>‘1’</td><td>Open-drain</td></tr></table></td></tr>
<tr><td>[0]</td><td>Int3_lvl</td><td>RW</td><td>‘1’</td><td><table><tr><th>Int3_lvl</th><th>Pin INT3 active state</th></tr><tr><td>‘0’</td><td>Active low</td></tr><tr><td>‘1’</td><td>Active high</td></tr></table></td></tr>
</table>

5.5.11 Register 0x18: INT3_INT4_IO_MAP

Map the data ready interrupt pin to one of the interrupt pins INT3 and/or INT4.

Bit	Access	Reset value	Description
[7]	RW	0x0	Data ready interrupt is mapped to INT4 pin.
[6]	*reserved*		
[5]	RW	0x0	FIFO interrupt is mapped to INT4.
[4:3]	*reserved*		
[2]	RW	0x0	FIFO interrupt is mapped to INT3.
[1]	*reserved*		
[0]	RW	0x0	Data ready interrupt is mapped to INT3 pin.

5.5.12 Register 0x1E: FIFO_WM_ENABLE

Enables FIFO watermark level interrupt.

<table>
<tr><th>Bit</th><th>Access</th><th>Reset value</th><th>Description</th></tr>
<tr><td>[7:0]</td><td>RW</td><td>0x08</td><td><table><tr><th>Value</th><th>Description</th></tr><tr><td>0x08</td><td>FIFO watermark level interrupt disabled</td></tr><tr><td>0x88</td><td>FIFO watermark level interrupt enabled</td></tr></table></td></tr>
</table>

5.5.13 Register 0x34: FIFO_EXT_INT_S

<table>
<tr><th>Bit</th><th>Access</th><th>Reset value</th><th>Description</th></tr>
<tr><td>[7:6]</td><td colspan="3">reserved</td></tr>
<tr><td>[5]</td><td>RW</td><td>0x00</td><td>If set, enables external FIFO synchronization mode</td></tr>
<tr><td>[4]</td><td>RW</td><td>0x00</td><td>Selects source for external FIFO synchronization<table><tr><th>ext_fifo_s_sel</th><th>Behavior</th></tr><tr><td>0x0</td><td>Source is pin INT3</td></tr><tr><td>0x1</td><td>Source is pin INT4</td></tr></table></td></tr>
<tr><td>[3:0]</td><td colspan="3">reserved</td></tr>
</table>

5.5.14 Register 0x3C: GYRO_SELF_TEST

Built-in self-test of gyroscope.

Bit	Access	Name	Reset value	Description
[4]	R	rate_ok	‘0’	A value of ‘1’ indicates proper sensor function.
[2]	R	bist_fail	‘0’	If ‘0’ and bist_rdy = ‘1’: built-in self-test is ok, sensor is ok If ‘1’ and bist_rdy = ‘1’: built-in self-test is not ok, sensor values may not be in expected range
[1]	R	bist_rdy	‘0’	If bit is ‘1’, built-in self-test has been performed and finished
[0]	W	trig_bist	N/A	Setting this bit to ‘1’ (i.e. writing 0x01 to this register) starts the built-in self-test.

5.5.15 Register 0x3D: GYR_FIFO_CONFIG_0

Bit	Access	Reset value	Description
[7]	*Reserved*		
[6:0]	RW	0x00	fifo_water_mark_level_trigger_retain<6:0> defines the FIFO watermark level. An interrupt will be generated, when the number of entries in the FIFO exceeds fifo_water_mark_level_trigger_retain<6:0>. Writing to this register clears the FIFO buffer.

5.5.16 Register 0x3E: GYR_FIFO_CONFIG_1

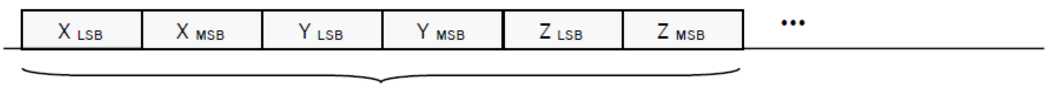
Contains FIFO configuration settings. The FIFO buffer memory is cleared and the fifo-full flag is cleared when writing to FIFO_CONFIG_1 register. In addition, the FIFO overrun flag (see the respective register) is cleared (it overrun occurred before).

<table>
<tr><th>Bit</th><th>Access</th><th>Reset value</th><th>Description</th></tr>
<tr><td>[7:0]</td><td>RW</td><td>0x08</td><td>
<table>
<tr><th>fifo_ mode</th><th>mode</th><th>description</th></tr>
<tr><td>0x40</td><td>FIFO</td><td>data collection stops once buffer is full (i.e. filled with 100 frames)</td></tr>
<tr><td>0x80</td><td>STREAM</td><td>sampling continues when buffer is full (i.e. filled with 99 frames); old is discarded</td></tr>
<tr><td>else</td><td colspan="2">reserved</td></tr>
</table>
</td></tr>
</table>

5.5.17 Register 0x3F: FIFO_DATA

FIFO data readout register. The format of the LSB and MSB components corresponds to that of the angular rate data readout registers. Read burst access may be used since the address counter will not increment when the read burst is started at the address of FIFO_DATA. The entire frame is discarded when a fame is only partially read out.

The format of the data read-out from register 0x3F is as follows:



Frame 1 (≡ 6 Bytes)

6. Digital interface

The BMI090L supports two serial digital interface protocols for communication as a slave with a host device: SPI and I²C. The active interface is selected by the state of the Pin#07 (PS) ‘protocol select’ pin:

- PS = ´VDDIO´ selects I²C
- PS = ´GND´ selects SPI

Important:

- Please note that in case of SPI protocol the initialization process for the accelerometer part of BMI090L requires some additional steps (see chapter 3).
- Please also note that as the pins of the package are shared between accelerometer and gyroscope part, it is not advisable to configure different interfaces for the two parts.

Both digital interfaces share partly the same pins. Additionally each inertial sensor (accelerometer and gyroscope) provides specific interface pins, which allow the user to operate the inertial sensors independently of each other. The mapping for each interface and each inertial sensor is given in the following table:

Table 10: Mapping of the interface pins

Pin#	Name	use w/ SPI	use w/ I²C	Description
15	SDO1	SDO1	address	SPI: Accel Data Output I²C: Used to set LSB of Accel I²C address
10	SDO2	SDO2	address	SPI: Gyro Data Output I²C: Used to set LSB of Gyro I²C address
9	SDA / SDI	SDI	SDA	SPI: Accel and Gyro Data In I²C: Serial Data
14	CSB1	CSB1	unused	SPI: Accel Chip Select (enable)
5	CSB2	CSB2	unused	SPI: Gyro Chip Select (enable)
8	SCL / SCK	SCK	SCL	SPI: Serial Clock SCK I²C: Serial Clock SCL

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

Table 11: Electrical specification of the interface pins

Parameter	Symbol	Condition	Min	Typ	Max	Units
Pull-up Resistance, CSB pin	R_{up}	Internal Pull-up Resistance to VDDIO	75	100	125	kΩ
Input Capacitance	C_{in}			5	10	pF
I²C Bus Load Capacitance (max. drive capability)	C_{I2C_Load}				400	pF

In order to allow for the correct internal synchronisation of data written to the BMI090L, a **wait time** of at least 2 µs (normal mode) or 1000 µs (suspend mode) must be followed.

6.1 Serial peripheral interface (SPI)

The behavior of the SPI interface is slightly different between gyroscope part and accelerometer part:

- Initialization phase: as described in chapter 3, the interface of the gyroscope part is selected by the level of the PS pin. In contrast to this, the accelerometer part starts always in I^2C mode (regardless of the level of the PS pin) and needs to be changed to SPI mode actively by sending a rising edge on the CSB1 pin (chip select of the accelerometer), on which the accelerometer part switches to SPI mode and stays in this mode until the next power-up-reset. To change the sensor to SPI mode in the initialization phase, the user could perfom a dummy SPI read operation, e.g. of register (the obtained value will be invalid).
- In case of read operations, the SPI interface of the accelerometer part does not send the requested information directly after the master has send the corresponding register address, but sends a dummy byte first, whose content is not predictable. Only after this dummy byte the desired content is sent. (This dummy byte procedure does not apply to the gyroscope part.) Please find more details below in section 6.1.2.

The timing specification for SPI of the BMI090L is given in the following table:

Table 12: SPI timing

Parameter	Symbol	Condition	Min	Max	Units
Clock Frequency	f_{SPI}	Max. Load on SDI or SDO = 25pF		10	MHz
SCK Low Pulse	t_{SCKL}		45		ns
SCK High Pulse	t_{SCKH}		45		ns
SDI Setup Time	t_{SDI_setup}		20		ns
SDI Hold Time	t_{SDI_hold}		20		ns
SDO Output Delay	t_{SDO_OD}	Load = 25pF		30	ns
		Load = 250pF, VDDIO > 2.4V		40	ns
CSB Setup Time	t_{CSB_setup}		40		ns
CSB Hold Time	t_{CSB_hold}		40		ns
Idle time between write accesses	t_{IDLE_wacc}	normal mode	2		µs

The following figure shows the definition of the SPI timings:

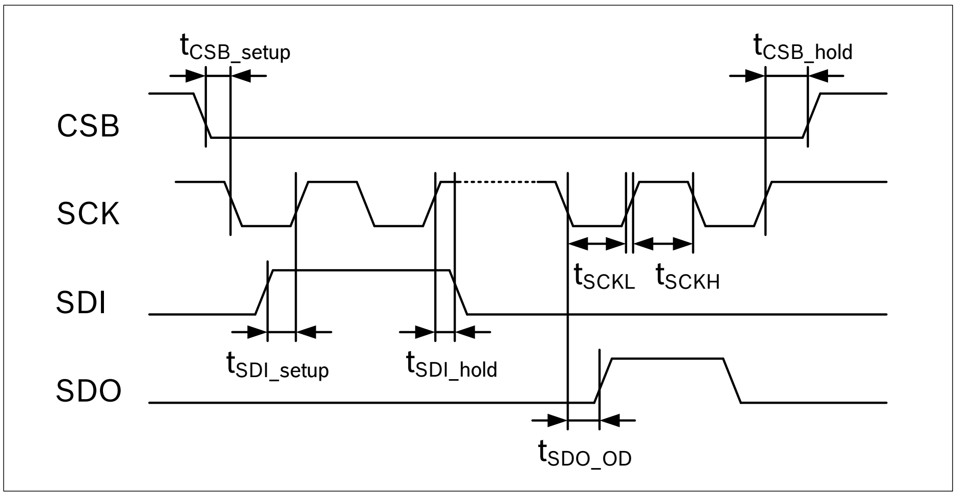


Figure 2: SPI timing diagram

The SPI interface of the BMI090L is compatible with two modes, ´00´ and ´11´. The automatic selection between [CPOL = ´0´ and CPHA = ´0´] and [CPOL = ´1´ and CPHA = ´1´] is controlled based on the value of SCK after a falling edge of CSB (1 or 2).

6.1.1 SPI interface of gyroscope part

For single byte read as well as write operations, 16-bit protocols are used. The SPI interface also supports multiple-byte read operations (burst-read).

The communication starts when the CSB (1 or 2) is pulled low by the SPI master and stops when CSB (1 or 2) is pulled high. SCK is also controlled by SPI master. SDI and SDO (1 or 2) are driven at the falling edge of SCK and should be captured at the rising edge of SCK.

The **data bits** are used as follows:

- Bit #0: Read/Write bit. When 0, the data SDI is written into the chip. When 1, the data SDO from the chip is read.
- Bit #1-7: Address AD(6:0).
- Bit #8-15: 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 (**burst-read**) are possible by keeping CSB low and continuing the data transfer (i.e. continuing to toggle SCK). Only the first register address has to be written. Addresses are automatically incremented after each read access as long as CSB stays active low.

6.1.2 SPI interface of accelerometer part

In case of read operations of the accelerometer part, the requested data is not sent immediately, but instead first a dummy byte is sent, and after this dummy byte the actual reqested register content is transmitted.
This means that – in contrast to the description in section 6.1.1 – a single byte read operation requires to read 2 bytes in burst mode, of which the first received byte can be discarded, while the second byte contains the desired data.
The same applies to burst-read operations. For example, to read the accelerometer values in SPI mode, the user has to read 7 bytes, starting from address 0x12 (ACC data). From these bytes the user must discard the first byte and finds the acceleration information in byte #2 – #7 (corresponding to the content of the addresses 0x12 – 0x17).
The **data bits** are used as follows:

- Bit #0: Read/Write bit. When 0, the data SDI is written into the chip. When 1, the data SDO from the chip is read.
- Bit #1-7: Address AD(6:0).
- Bit #8-15:
  - When in write mode, these are the data SDI, which will be written into the address.
  - When in read mode, these bits contain unpredictable values, and the user has to read Bit #16-23 to get the actual data from the reading address.

6.2 Inter-integrated circuit (I²C)

The I²C bus uses SCL (= SCx pin, serial clock) and SDA (= SDx pin, serial data input and output) signal lines. Both lines are connected to VDDIO externally via pull-up resistors so that they are pulled high when the bus is free.

The I²C interface of the BMI090L is compatible with the I²C Specification UM10204 Rev. 03 (19 June 2007), available at http://www.nxp.com. The BMI090L supports I²C standard mode and fast mode, only 7-bit address mode is supported.

The **default I²C addresses** are:

- Accelerometer:
  - SDO1 pin pulled to 'GND': 0011000b (0x18)
  - SDO1 pin pulled to 'VDDIO': 0011001b (0x19)
- Gyroscope:
  - SDO2 pin pulled to 'GND': 1101000b (0x68)
  - SDO2 pin pulled to 'VDDIO': 1101001b (0x69)

The timing specification for I²C of the BMI090L is given in table 13:

Table 13: I²C timings

Parameter	**Symbol**	**Min**	**Max**	**Units**
Clock Frequency	f_{SCL}		400	kHz
SCL Low Period	t_{LOW}	1.3		µs
SCL High Period	t_{HIGH}	0.6		
SDA Setup Time	t_{SUDAT}	0.1		
SDA Hold Time	t_{HDDAT}	0.0		
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}	1.3		
Idle time between write accesses, normal mode	$t_{IDLE\_wacc\_nm}$	2		µs
Idle time between write accesses, suspend mode	$t_{IDLE\_wacc\_sum}$	1000		µs

Figure 3 shows the definition of the I²C timings given in table 13:

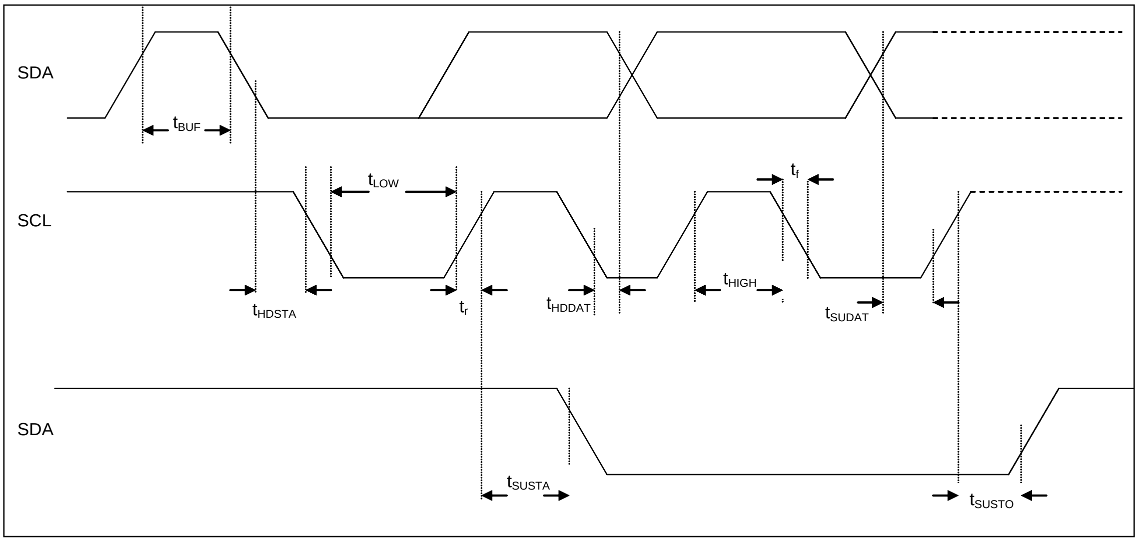


Figure 3: I²C timing diagram

The I²C protocol works as follows:

START: Data transmission on the bus begins with a high to low transition on the SDA line while SCL is held high (start condition (S) indicated by I²C bus master). Once the START signal is transferred by the master, the bus is considered busy.

STOP: Each data transfer should be terminated by a Stop signal (P) generated by master. The STOP condition is a low to HIGH transition on SDA line while SCL is held high.

ACK: Each byte of data transferred must be acknowledged. It is indicated by an acknowledge bit sent by the receiver. The transmitter must release the SDA line (no pull down) during the acknowledge pulse while the receiver must then pull the SDA line low so that it remains stable low during the high period of the acknowledge clock cycle.

In the following diagrams, these abbreviations are used:

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

A START 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.

I²C write access:
I²C 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 (ACK = 0) and releases the bus. Then the master sends the one byte register address. The slave again acknowledges the transmission and waits for the 8 bits of data, which 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 I²C write access to the accelerometer, writing 0xA8 to address ox40 (i.e. setting continuous filter function, averaging to 4 samples, ODR to 100Hz):

Start	Slave address (0x18)							RW	ACKS	dummy	Register address (0x40)							ACKS	Data (0xA8)								ACKS	Stop
S	0	0	1	1	0	0	0	0	A	0	1	0	0	0	0	0	0	A	1	0	1	0	1	0	0	0	A	P

Figure 4: I²C write

I²C read access:
I²C read access also can be used to read one or multiple data bytes in one sequence.

A read sequence consists of a one-byte I²C write phase followed by the I²C read phase. The two parts of the transmission must be separated by a repeated start condition (Sr). The I²C write phase addresses the slave and sends the register address to be read. After slave acknowledges the transmission, the master generates again a start condition and sends the slave address together with a read bit (RW = 1). Then the master releases the bus and waits for the data bytes to be read out from slave. After each data byte the master has to generate an acknowledge bit (ACK = 0) to enable further data transfer. A NACKM (ACK = 1) from the master stops the data being transferred from the slave. The slave releases the bus so that the master can generate a STOP condition and terminate the transmission.
The register address is automatically incremented and, therefore, more than one byte can be sequentially read out. Once a new data read transmission starts, the start address will be set to the register address specified in the latest I²C 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.

Example of an I²C read access to the accelerometer, reading all 6 bytes containing acceleration data (0x12-0x17):

Start	Slave address (0x18)							RW	ACKS	dummy	Register address (0x12)							ACKS
S	0	0	1	1	0	0	0	0	A	x	0	0	1	0	0	1	0	A

Start	Slave address (0x18)							RW	ACKS	Read data (0x12)								ACKM	Read data (0x13)								ACKM	
Sr	0	0	1	1	0	0	0	1	A	x	x	x	x	x	x	x	x	A	x	x	x	x	x	x	x	x	A	…

	ACKS	Read data (0x14)								ACKM	Read data (0x15)								ACKM	
…	A	x	x	x	x	x	x	x	x	A	x	x	x	x	x	x	x	x	A	…

	ACKS	Read data (0x16)								ACKM	Read data (0x17)								NACKM	Stop
…	A	x	x	x	x	x	x	x	x	A	x	x	x	x	x	x	x	x	NA	P

Figure 5: I²C multiple read

7. Pin-out and connection diagram

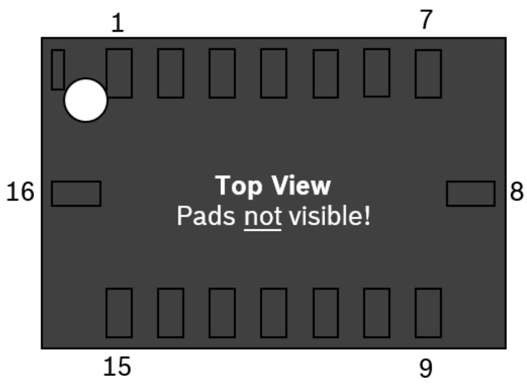


Figure 6: Pin-out top view

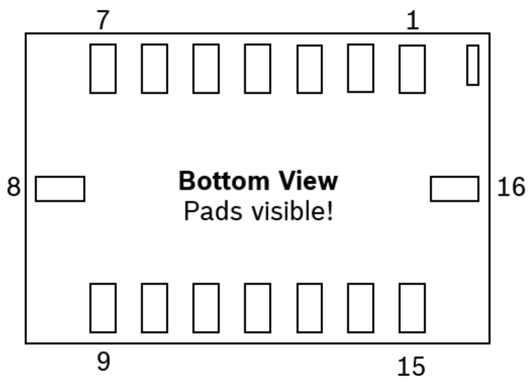


Figure 7: Pin-out bottom view

7.1 Pin-out

Table 14: Pin description

Pin#	Name	I/O Type	Description	SPI mode	I²C mode
1*	INT2	Digital I/O	Interrupt pin 2 (accel int #2)	INT2	INT2
2	NC	--	--	GND	GND
3	VDD	Supply	Power supply analog & digital domain (2.4 – 3.6V)	VDD	VDD
4	GNDA	Ground	Ground for analog domain	GND	GND
5	CSB2	Digital in	SPI Chip select Gyro	CSB2	DNC (float)
6	GNDIO	Ground	Ground for I/O	GND	GND
7	PS	Digital in	Protocol select gyroscope (GND = SPI, VDDIO = I²C)	GND	VDDIO
8	SCL / SCK	Digital in	SPI: serial clock SCK I²C: serial clock SCL	SCK	SCL
9	SDA / SDI	Digital I/O	I²C: SDA serial data I/O SPI 4W: SDI serial data I SPI 3W: SDA serial data I/O	SDI	SDA
10	SDO2	Digital out	SPI Serial data out Gyro Address select in I²C mode see chapter 9.2	SDO2	GND for default addr.
11	VDDIO	Supply	Digital I/O supply voltage (1.2V … 3.6V)	VDDIO	VDDIO
12*	INT3	Digital I/O	Interrupt pin 3 (gyro int #1)	INT3	INT3
13*	INT4	Digital I/O	Interrupt pin 4 (gyro int #2)	INT4	INT4
14	CSB1	Digital in	SPI Chip select Accel	CSB1	VDDIO or DNC (float)
15	SDO1	Digital out	SPI Serial data out Accel Address select in I²C mode see chapter 9.2	SDO1	GND for default addr.
16*	INT1	Digital I/O	Interrupt pin 1 (accel int #1)	INT1	INT1

*** If INT are not used, do not connect them (DNC)!**

7.2 Connection diagram SPI

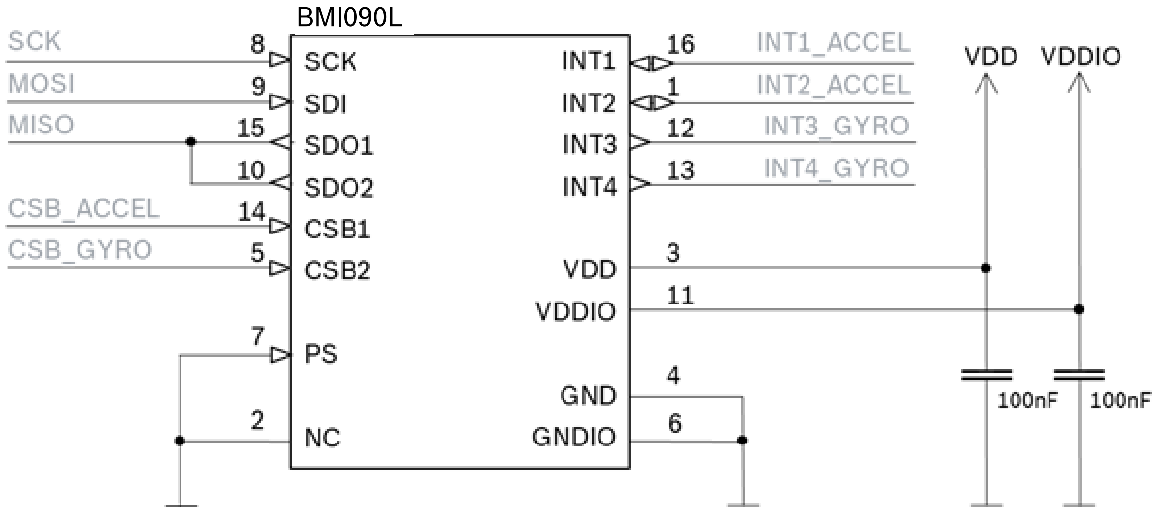


Figure 8: SPI connection

7.3 Connection diagram I²C

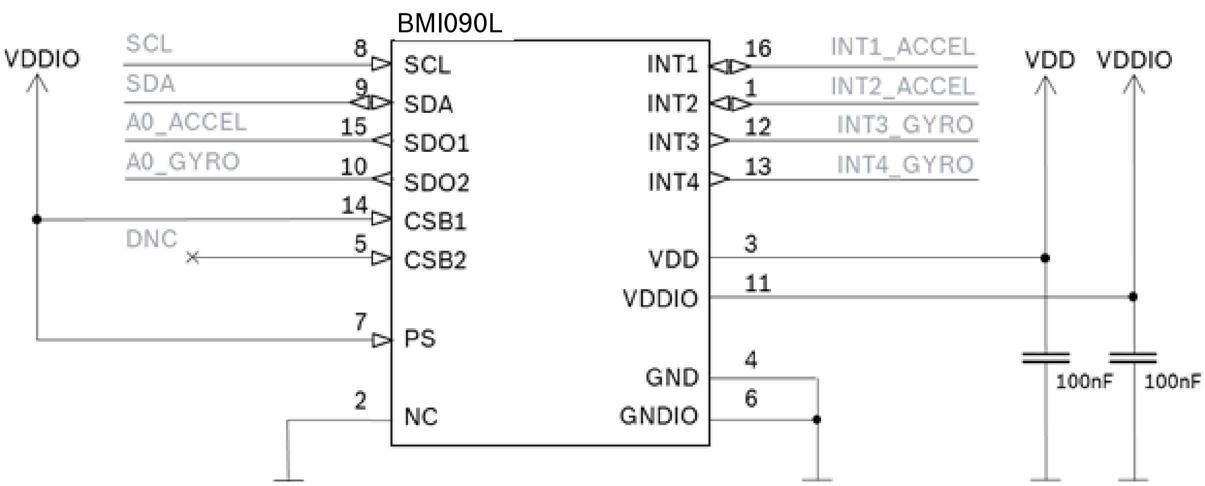


Figure 9: I²C connection

8. Package

8.1 Outline dimensions

The sensor housing is a standard LGA package. Its dimensions are the following.
Unit is mm. Note: Unless otherwise specified tolerance = decimal ± 0.05

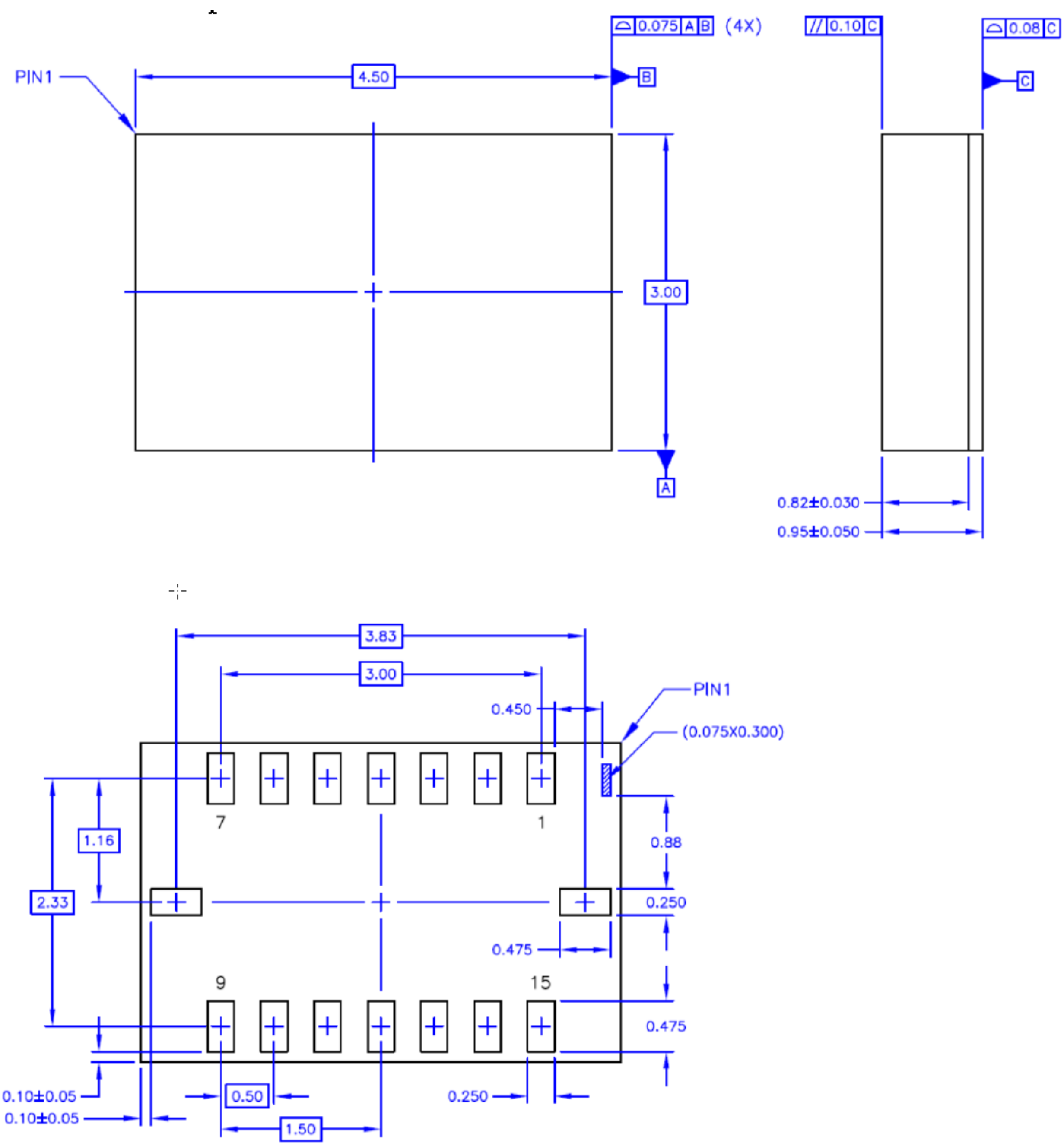


Figure 10: Package dimensions

8.2 Landing pattern

For the design of the landing patterns, we recommend the following dimensioning:

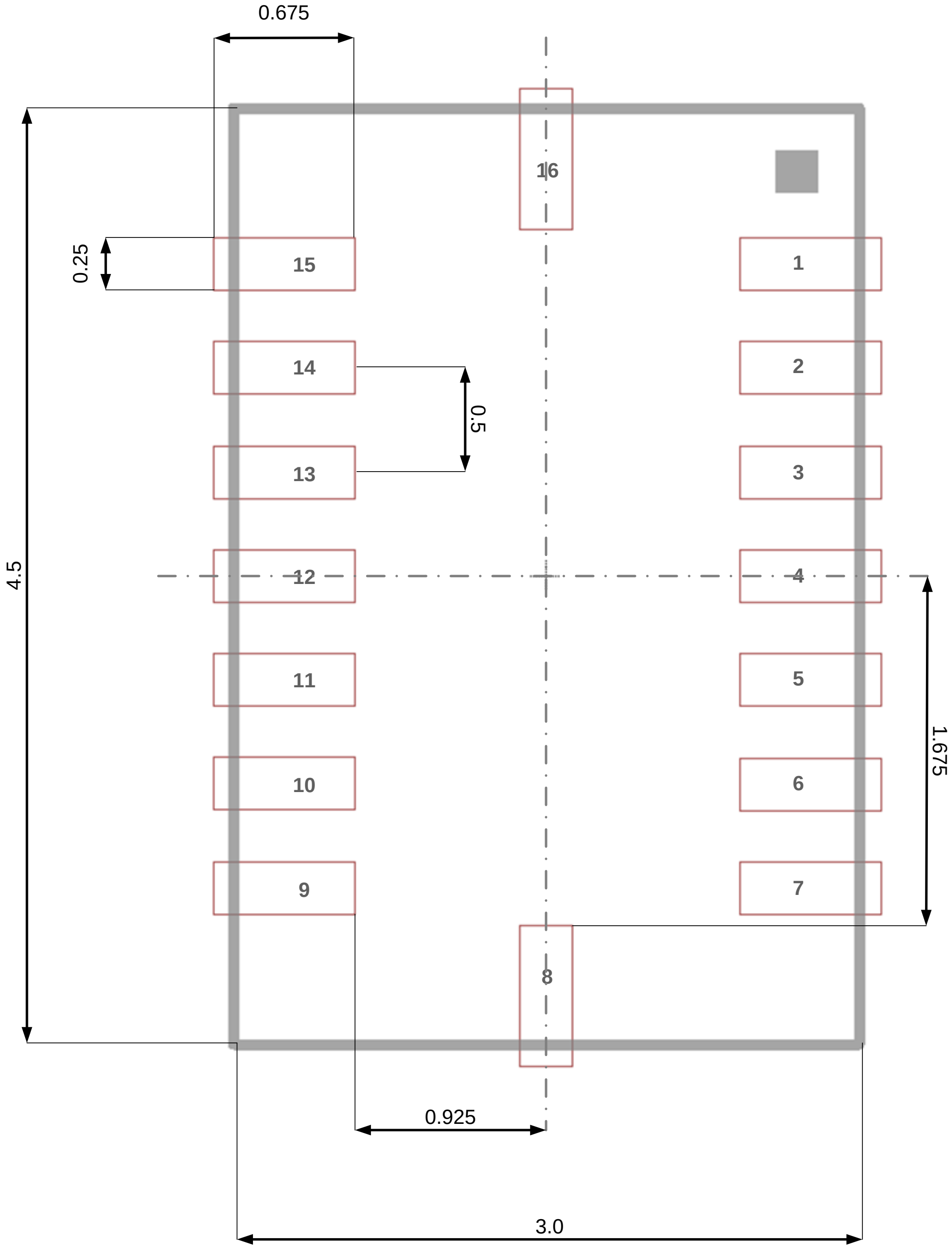


Figure 11: Landing pattern recommendation

Same tolerances as given for the outline dimensions in 8.1 should be assumed. A wiring no-go area in the top layer of the PCB below the sensor is strongly recommended (e.g. no vias, wires or other metal structures).

8.3 Sensing axes orientation

If the sensor is accelerated and/or rotated in the indicated directions, the corresponding channels of the device will deliver a positive acceleration and/or yaw rate signal (dynamic acceleration). If the sensor is at rest without any rotation and the force of gravity is acting contrary to the indicated directions, the output of the corresponding acceleration channel will be positive and the corresponding gyroscope channel will be “zero” (static acceleration).

Example: If the sensor is at rest or at uniform motion in a gravity field according to the figure given below, the output signals are:

- 0g for the X ACC channel and 0°/sec for the Ω_X GYR channel
- 0g for the Y ACC channel and 0°/sec for the Ω_Y GYR channel
- + 1g for the Z ACC channel and 0°/sec for the Ω_Z GYR channel

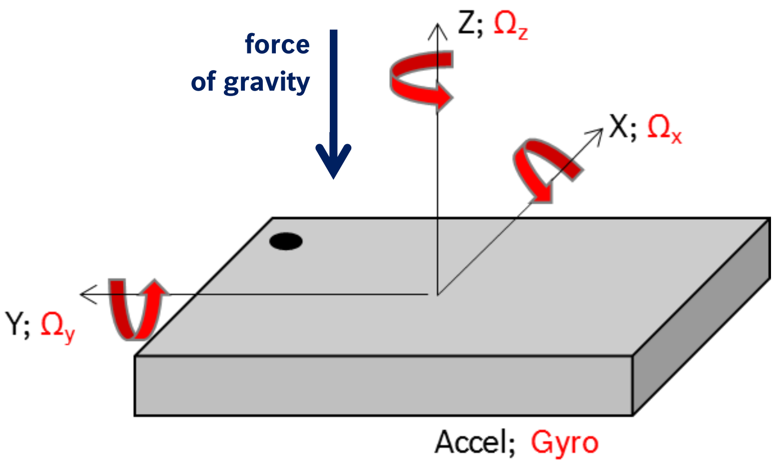
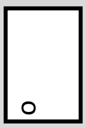
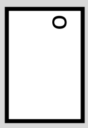


Figure 12: Orientation of sensing axis

The following table lists all corresponding output signals on X, Y, Z while the sensor is at rest or at uniform motion in a gravity field under assumption of a top down gravity vector as shown above.
The gyroscope signals Ω_X, Ω_Y, Ω_Z show 0dps output under these static conditions.

Table 15: Output signals depending on device orientation

Sensor orientation (gravity vector ↓)						
Output Signal X	0g	+1g	0g	-1g	0g	0g
Output Signal Y	-1g	0g	+1g	0g	0g	0g
Output Signal Z	0g	0g	0g	0g	+1g	-1g

8.4 Marking

8.4.1 Mass production samples

Table 16: Marking of mass production parts

Labeling	**Name**	**Symbol**	**Remark**
● 365 LYYWW CCC	Product number	365	3 numeric digits, fixed to identify product type
	Sub-con ID	L	1 alphanumeric digit, variable to identify sub-con
	Date-Code	YYWW	4 numeric digits, fixed to identify YY = “year” WW = “working week
	Lot counter	CCC	3 alphanumeric digits, variable to generate mass production trace-code
	Pin 1 identifier	●	--

8.4.2 Engineering samples

Table 17: Marking of engineering samples

Labeling	**Name**	**Symbol**	**Remark**
● 088N PYYWW CC	Eng. sample ID	N	1 alphanumeric digit, fixed to identify engineering sample, N = “+” or “e” or “E”
	Sample ID	PYYWW	P: assembly house YYWW: Year (last 2 digits)/Work week
	Counter ID	CC	C-samples; lot number (e.g.C5: C-samples, 5th lot)
	Pin 1 identifier	●	--

8.5 PCB layout and soldering guidelines

The following general **layout rules** are recommended

- PCB land width = LGA solder pin width
- PCB land length = LGA solder pin length + 0.1 mm on each side
- Solder mask opening width = PCB land width + 0.05 mm on each side
- Solder mask opening length = PCB land length + 0.05 mm on each side

Recommendation about **stencil design and solder paste application**

- It is recommended to keep the openings of the stencil mask for the signal pads between 70% and 90% of the PCB pad area.
- An accurate alignment of the stencil and the printed circuit board (within 0.025mm) is recommended.
- A stencil thickness of 80 – 150 µm is recommended for screen printing

The **moisture sensitivity level** (MSL) of the BMI090L sensors corresponds to JEDEC Level 1. See also:

- IPC/JEDEC J-STD-020E "Joint Industry Standard: Moisture/Reflow Sensitivity Classification for non-hermetic Solid State Surface Mount Devices"
- IPC/JEDEC J-STD-033D "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.

For more details, refer the Handling, Soldering and Mounting Instructions document available at https://www.bosch-sensortec.com/bst/support_tools/downloads/overview_downloads

8.6 Handling instructions

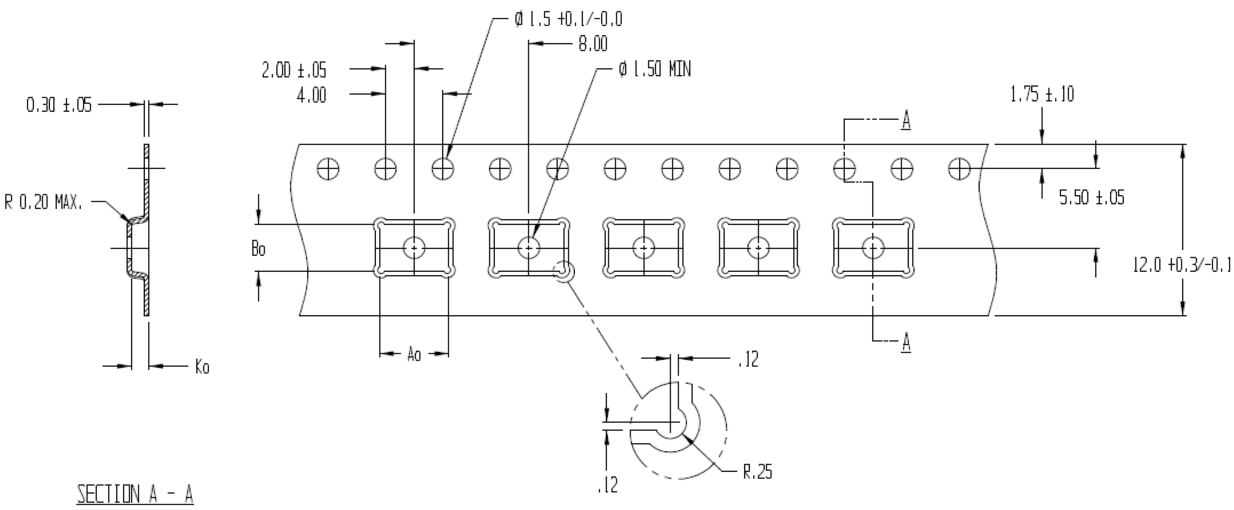
Micromechanical sensors are designed to sense acceleration with high accuracy even at low amplitudes and contain highly sensitive structures inside the sensor element. The MEMS sensor can tolerate mechanical shocks up to several thousand *g*'s. However, these limits might be exceeded in conditions with 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.

8.7 Tape and reel specification

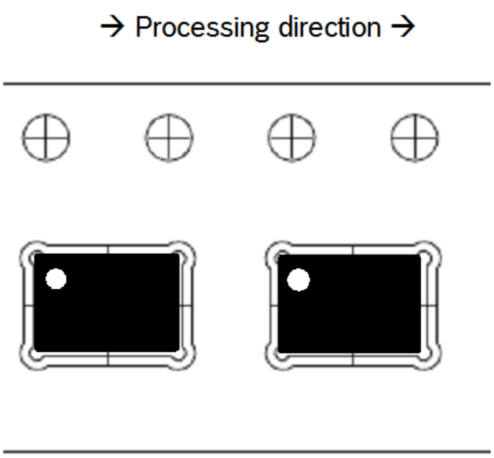
BMI090L is shipped in a standard cardboard box. The box dimension for each reel is L x W x H = 35cm x 35cm x 5cm. Each reel contains 2,500pcs of BMI090L.



A_0 = 4.85; B_0 = 3.35; K_0 = 1.20

Tape and reel dimensions in mm

8.7.1 Orientation within the reel



Orientation of the BMI090L devices relative to the tape

8.8 Environmental safety

The BMI090L sensor meets the requirements of the EC restriction of hazardous substances (RoHS) directive:

RoHS – Directive 2011/65/EU and its amendments, including the amendment 2015/863/EU on the restriction of the use of certain hazardous substances in electrical and electronic equipment.

8.8.1 Halogen content

The BMI090L is halogen-free. For more details on the analysis results please contact your Bosch Sensortec representative.

9. Legal disclaimer

9.1 Engineering samples

Engineering Samples are marked with an asterisk (*), (E) 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.

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9.3 Application examples and hints

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10. Document history and modification

Rev. No	Chapter	Description of modification/changes	Date
1.0	-	Initial release	Apr-2020
1.1	4.10	Updated Integrated feature set description	Sep-2020
2.0	9	Disclaimer update	Nov-2020
2.1	4.10.1	Included Axis remapping feature set	Mar-2021
	5.3	Updated Accelerometer register map	
	5.3.1	ACC Chip ID updated	
	All	Updated with respect to the latest template	

[1]Longevity Disclaimer

Bosch Sensortec strives to maintain the supply of longevity product variants for a period of 10 years (from SOD/product introduction date), including the notification period. During such period, in case of significant volume decrease or manufacturing changes Bosch Sensortec may decide to

(i) replace the product by another (comparable) product
and/or
(ii) change the technology, manufacturing facilities and/or process

Any change will be notified to customers using the standard Bosch Sensortec product/process change policy (PCN).

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