Data sheet

BMM150
Geomagnetic Sensor

Bosch Sensortec

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BMM150: Data sheet

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BMM150

THREE-AXIS GEOMAGNETIC SENSOR

Key features

Three-axis magnetic field sensor

• Ultra-Small package	**W**afer **L**evel **C**hip **S**cale **P**ackage (12 pins, 0.4mm diagonal ball pitch) footprint 1.56 x 1.56 mm^2, height 0.6 mm
• Digital interface	SPI (4-wire, 3-wire), I^2C, 4, 2 interrupt pins
• Low voltage operation	V_{DD} supply voltage range: 1.62V to 3.6V V_{DDIO} interface voltage range: 1.2V to 3.6V
• Flexible functionality	Magnetic field range typical: ±1300µT (x, y-axis), ±2500µT (z-axis) Magnetic field resolution of ~0.3µT
• On-chip interrupt controller	Interrupt-signal generation for - new data - magnetic Low-/High-Threshold detection
• Ultra-low power	Low current consumption (170µA @ 10 Hz in low power preset), short wake-up time, advanced features for system power management
• Temperature range	-40 °C ... +85 °C
• RoHS compliant, halogen-free	

Typical applications

- Magnetic heading information
- Tilt-compensated electronic compass for map rotation, navigation and augmented reality
- Gyroscope calibration in 9-DoF applications for mobile devices
- In-door navigation, e.g. step counting in combination accelerometer
- Gaming

General Description

The BMM150 is a standalone geomagnetic sensor for consumer market applications. It allows measurements of the magnetic field in three perpendicular axes. Based on Bosch's proprietary FlipCore technology, performance and features of BMM150 are carefully tuned and perfectly match the demanding requirements of all 3-axis mobile applications such as electronic compass, navigation or augmented reality.

An evaluation circuitry (ASIC) converts the output of the geomagnetic sensor to digital results which can be read out over the industry standard digital interfaces (SPI and I2C).

Package and interfaces of the BMM150 have been designed to match a multitude of hardware requirements. As the sensor features an ultra-small footprint and a flat package, it is ingeniously suited for mobile applications. The wafer level chip scale package (WLCSP) with dimensions of only 1.56 x 1.56 x 0.6 mm^3 ensures high flexibility in PCB placement.

The BMM150 offers ultra-low voltage operation (V_{DD} voltage range from 1.62V to 3.6V, V_{DDIO} voltage range 1.2V to 3.6V) and can be programmed to optimize functionality, performance and power consumption in customer specific applications. The programmable interrupt engine gives design flexibility to the developer.

The BMM150 senses the three axis of the terrestrial field in cell phones, handhelds, computer peripherals, man-machine interfaces, virtual reality features and game controllers.

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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 operation conditions

Table 1: Electrical parameter specification

OPERATING CONDITIONS						
Parameter	**Symbol**	**Condition**	**Min**	**Typ**	**Max**	**Unit**
Supply Voltage Internal Domains	V_{DD}		1.62	2.4	3.6	V
Supply Voltage I/O Domain	V_{DDIO}		1.2	1.8	3.6	V
Voltage Input Low Level	$V_{IL,a}$	SPI & I²C			$0.3V_{DDIO}$	-
Voltage Input High Level	$V_{IH,a}$	SPI & I²C	$0.7V_{DDIO}$			-
Voltage Output Low Level	V_{OL}	V_{DDIO} = 1. 2V I_{OL} = 3mA, SPI & I²C			$0.2V_{DDIO}$	-
Voltage Output High Level	V_{OH}	V_{DDIO} = 1.62V I_{OH} = 2mA, SPI & I²C	$0.8V_{DDIO}$			-
Magnetic field range	$B_{rg,xy}$	T_A=25°C[1]	±1200	±1300		μT
	$B_{rg,z}$		±2000	±2500		μT
Magnetometer heading accuracy [2]	$Ac_{heading}$	30μT horizontal geomagnetic field component, T_A=25°C			±2.5	deg
Supply Current in Active Mode (average)[3]	$I_{DD,lp,m}$	Low power preset Nominal V_{DD} supplies T_A=25°C, ODR=10Hz		170		μA
	$I_{DD,rg,m}$	Regular preset Nominal V_{DD} supplies T_A=25°C, ODR=10Hz		0.5		mA
	$I_{DD,eh,m}$	Enhanced regular preset Nominal V_{DD} supplies T_A=25°C,		0.8		mA

---

[1] Full linear measurement range considering sensor offsets.

[2] The heading accuracy depends on hardware and software. A fully calibrated sensor and ideal tilt compensation are assumed.

[3] For details on magnetometer current consumption calculation refer to chapter 4.2.1 and 4.2.2.

		ODR=10Hz				
	$I_{DD,ha,m}$	High accuracy preset Nominal V_{DD} supplies T_A=25°C, ODR=20Hz		4.9		mA
Supply Current in Suspend Mode	$I_{DDsm,m}$	Nominal V_{DD}/V_{DDIO} supplies, T_A=25°C		1	3	µA
Peak supply current in Active Mode	$I_{DDpk,m}$	In measurement phase Nominal V_{DD} supplies T_A=25°C		18	20	mA
Peak logic supply current in active mode	$I_{DDIOpk,m}$	Only during measurement phase Nominal V_{DDIO} supplies T_A=25°C		210	270	µA
POR time	$t_{w\_up,m}$	from OFF to Suspend; time starts when VDD>1.5V and VDDIO>1.1V			1.0	ms
Start-Up Time	$t_{s\_up,m}$	from Suspend to sleep			3.0	ms

1.2 Magnetometer output signal specification

MAGNETOMETER OUTPUT SIGNAL						
Parameter	**Symbol**	**Condition**	**Min**	**Typ**	**Max**	**Unit**
Device Resolution	$D_{res,m}$	T_A=25°C		0.3		µT
Gain error[4]	$G_{err,m}$	After API compensation T_A=25°C Nominal V_{DD} supplies		±2	±5	%
Sensitivity Temperature Drift	TCS_m	After API compensation -40°C ≤ T_A ≤ +85°C Nominal V_{DD} supplies		±0.01	±0.03	%/K
Zero-B offset	OFF_m	T_A=25°C		±40		µT
Zero-B offset	$OFF_{m,cal}$	After software		±2		µT

---

[4] Definition: *gain error* = ((*measured field after API compensation*) / (*applied field*)) - 1

		calibration with Bosch Sensortec eCompass software[5] -40°C ≤ T_A ≤ +85°C				
ODR (data output rate), normal mode	odr_{lp}	Low power preset		10		Hz
	odr_{rg}	Regular preset	9.2	10	10.8	Hz
	odr_{eh}	Enhanced regular preset		10		Hz
	odr_{ha}	High accuracy preset		20		Hz
ODR (data output rate), forced mode	odr_{lp}	Low power preset	0		>300	Hz
	odr_{rg}	Regular preset	0		100	Hz
	odr_{eh}	Enhanced regular preset	0		60	Hz
	odr_{ha}	High accuracy preset	0		20	Hz
Full-scale Nonlinearity	$NL_{m,\ FS}$	best fit straight line			1	%FS
Output Noise	$n_{rms,lp,m,xy}$	Low power preset x, y-axis, T_A=25°C Nominal V_{DD} supplies		1.0		µT
	$n_{rms,lp,m,z}$	Low power preset z-axis, T_A=25°C Nominal V_{DD} supplies		1.4		µT
	$n_{rms,rg,m}$	Regular preset T_A=25°C Nominal V_{DD} supplies		0.6		µT
	$n_{rms,eh,m}$	Enhanced regular preset T_A=25°C Nominal V_{DD} supplies		0.5		µT
	$n_{rms,ha,m}$	High accuracy preset T_A=25°C Nominal V_{DD} supplies		0.3		µT
Power Supply Rejection Rate	$PSRR_m$	T_A=25°C Nominal V_{DD} supplies		±0.5		µT/V

---

[5] Magnetic zero-B offset assuming calibration with Bosch Sensortec eCompass software. Typical value after applying calibration movements containing various device orientations (typical device usage).

2. Absolute maximum ratings

The absolute maximum ratings are provided in Table 2. At or above these maximum ratings operability is not given. The specification limits in Chapter 1 only apply under normal operating conditions.

Table 2: Absolute maximum ratings

Parameter	**Condition**	**Min**	**Max**	**Unit**
Voltage at Supply Pin	V_{DD} Pin	-0.3	4.0	V
	V_{DDIO} Pin	-0.3	4.0	V
Voltage at any Logic Pad	Non-Supply Pin	-0.3	VDDIO + 0.3	V
Operating Temperature, T_A	Active operation	-40	+85	°C
Passive Storage Temp. Range	≤ 65% rel. H.	-50	+150	°C
None-volatile memory (NVM) Data Retention	T = 85°C	10		year
Mechanical Shock according to JESD22-B111….	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
Magnetic field	Any direction		> 7	T

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

3. Block diagram

Figure 1 shows the basic building blocks of the BMM150:

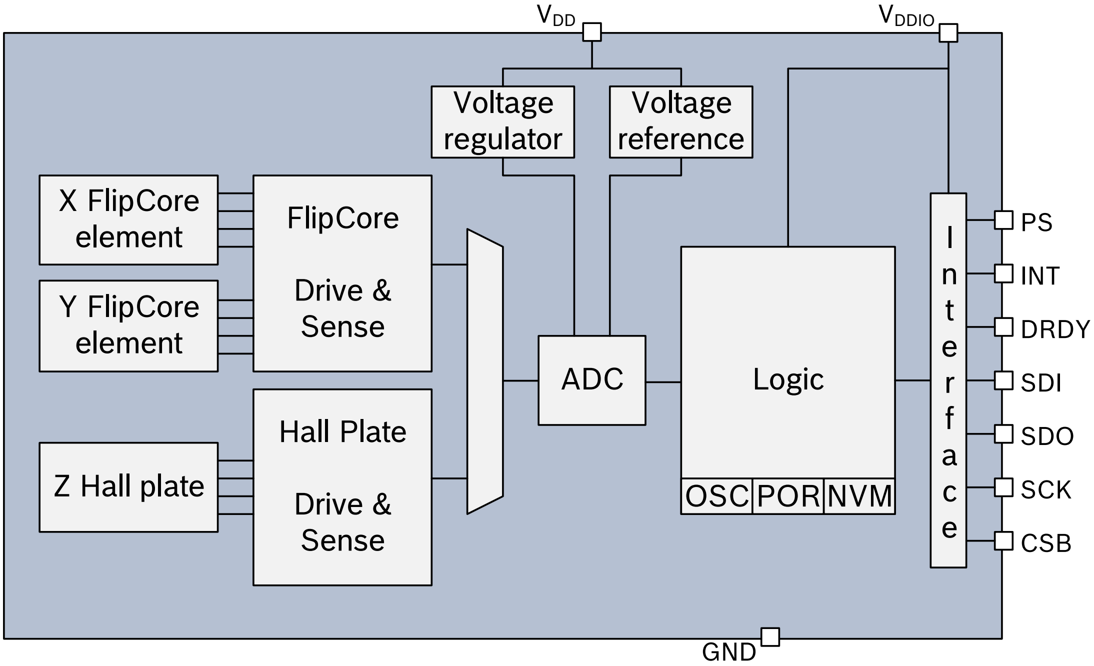


Figure 1: Block diagram of BMM150

4. Functional description

BMM150 is a triaxial standalone geomagnetic sensor (Sensing element and ASIC) in chip scale wafer level package and can be operated via I2C or SPI as a slave device.

4.1 Power management

The BMM150 has two distinct power supply pins:

- V_{DD} is the main power supply for all internal analog and digital functional blocks;
- V_{DDIO} is a separate power supply pin, used for the supply of the digital interface as well as the digital logic.

The device can be completely switched off (V_{DD} = 0V) while keeping the V_{DDIO} supply on (V_{DDIO} > 0V) or vice versa.

It is absolutely prohibited to keep any interface at a logical high level when V_{DDIO} is switched off. Such a configuration will permanently damage the device (i.e. if $V_{DDIO} = 0 \rightarrow$ [SDI & SDO & SCK & CSB] ≠ high).

The device contains a power on reset (POR) generator. It resets the logic part and the register values of the concerned ASIC after powering-on V_{DD} and V_{DDIO}. Please note, that all application specific settings which are not equal to the default settings (refer to register maps in chapter 5.2), must be re-set to its designated values after POR.
In case the I²C interface is used, a direct electrical connection between V_{DDIO} supply and the PS pin is recommended in order to ensure reliable protocol selection.

4.2 Power modes

The BMM150 features configurable power modes. The BMM150 magnetometer part has four power modes:In the following chapters, power modes are described.

4.2.1 Power off mode

In Power off mode, V_{DD} and/or V_{DDIO} are unpowered and the device does not operate. When only one of V_{DD} or V_{DDIO} is supplied, the magnetic sensor will still be in Power off mode. Power on reset is performed after both V_{DD} and V_{DDIO} raised above their detection thresholds.

4.2.2 Suspend mode

Suspend mode is the default power mode of BMM150 after the chip is powered. When V_{DD} and V_{DDIO} are turned on the POR (power on reset) circuits operate and the device's registers are initialized. After POR becomes inactive, a start up sequence is executed. In this sequence NVM content is downloaded to shadow registers located in the device core. After the start up sequence the device is put in the Suspend mode. In this mode only registers which store power control bit information and SPI3 wire enable can be accessed by the user. No other registers can be accessed in Suspend mode. All registers lose their content, except the control register (*0x4B*). In particular, in this mode a Chip ID read (register *0x40*) returns “0x00” (I²C) or high-Z (SPI).

4.2.3 Sleep mode

The user puts device from suspend into Sleep mode by setting the Power bit to “1”, or from active modes (normal or forced) by setting OpMode bits to “11”. In this state the user has full access to the device registers. In particular, the Chip ID can be read. Setting the power control bit to “0” (register *0x4B bit0*) will bring the device back into Suspend mode. From the Sleep mode the user can put the device back into Suspend mode or into Active mode.

4.2.4 Active mode

The device can switch into Active mode from Sleep mode by setting OpMode bits (register *0x4C*). In this mode the magnetic field measurements are performed and all registers are accessible.

In active mode, two operation modes can be distinguished:

- Normal mode: selected channels are periodically measured according to settings set in user registers. After measurements are completed, output data is put into data registers and the device waits for the next measurement period, which is set by programmed output data rate (ODR). From normal mode, the user can return to sleep mode by setting OpMode to “11” or by performing a soft reset (see chapter 5.6). Suspend mode can be entered by setting power control bit to “0”.
- Forced mode (single measurement): When set by the host, the selected channels are measured according to settings programmed in user registers. After measurements are completed, output data is put into data registers, OpMode register value returns to “11” and the device returns to sleep mode. The forced mode is useful to achieve synchronized operation between host microcontroller and BMM150. Also, different data output rates from the ones selectable in normal mode can be achieved using forced mode.

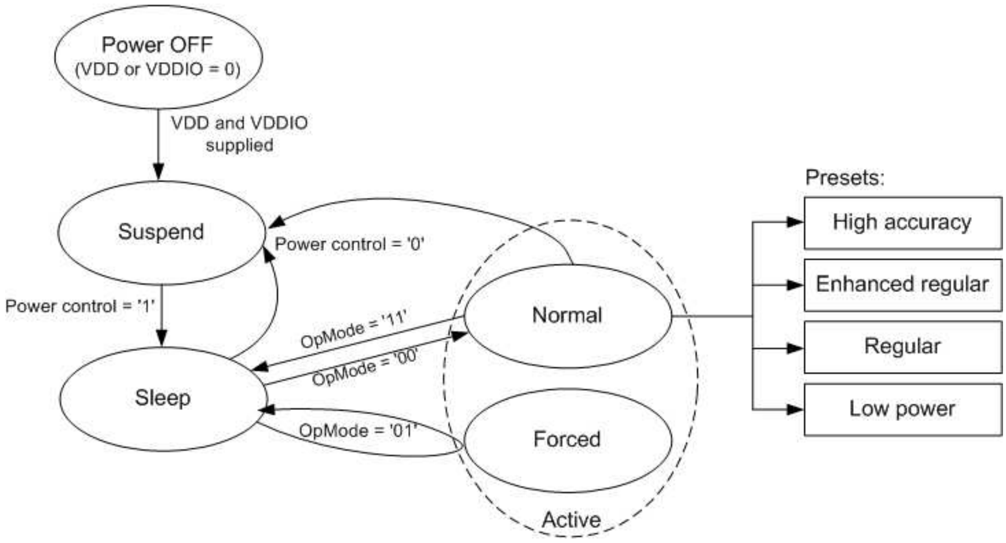


Figure 2: Magnetometer power mode transition diagram

In Active Mode and normal operation, in principle any desired balance between output noise and active time (hence power consumption) can be adjusted by the repetition settings for x/y-axis and z-axis and the output data rate ODR. The average power consumption depends on the ratio of high current phase time (during data acquisition) and low current phase time (between data acquisitions). Hence, the more repetitions are acquired to generate one magnetic field data

point, the longer the active time ratio in one sample phase, and the higher the average current. Thanks to longer internal averaging, the noise level of the output data reduces with increasing number of repetitions.
By using forced mode, it is possible to trigger new measurements at any rate. The user can therefore trigger measurements in a shorter interval than it takes for a measurement cycle to complete. If a measurement cycle is not allowed to complete, the resulting data will not be written into the data registers. To prevent this, the manually triggered measurement intervals must not be shorter than the active measurement time which is a function of the selected number of repetitions. The maximum selectable read-out frequency in forced mode can be calculated as follows:

$$f_{\max,ODR} \approx \frac{1}{145\mu s \times nXY + 500\mu s \times nZ + 980\mu s}$$

Hereby nXY is the number of repetitions on X/Y-axis (not the register value) and nZ the number of repetitions on Z-axis (not the register value) (see description of XY_REP and Z_REP registers in chapter 5).

Although the repetition numbers for X/Y and Z axis and the ODR can be adjusted independently and in a wide range, there are four recommended presets (High accuracy preset, Enhanced regular preset, Regular preset, Low power preset) which reflect the most common usage scenarios, i.e. required output accuracy at a given current consumption, of the BMM150.

The four presets consist of the below register configurations, which are automatically set by the BMM150 API or driver provided by Bosch Sensortec when a preset is selected. Table 3 shows the recommended presets and the resulting magnetic field output noise and current consumption:

Table 3: Recommended presets for repetitions and output data rates:

Preset	**Rep. X/Y nXY**	**Rep. Z nZ**	**recommended ODR [Hz]**	**Max ODR in forced mode fmax,ODR [Hz]**	**RMS Noise x/y/z [µT]**	**Average current consumption at recommended ODR [mA]**
Low power preset	3	3	10	>300	1.0/1.0/1.4	0.17
Regular preset	9	15	10	100	0.6/0.6/0.6	0.5
Enhanced regular preset	15	27	10	60	0.5/0.5/0.5	0.8
High accuracy preset	47	83	20	20	0.3/0.3/0.3	4.9

4.3 Sensor output data

4.3.1 Magnetic field data

The representation of magnetic field data is different between X/Y-axis and Z-axis. The width of X- and Y-axis magnetic field data is 13 bits each and stored in two's complement.
DATAX_LSB (*0x42*) contains 5-bit LSB part [4:0] of the 13 bit output data of the X-channel.
DATAX_MSB (*0x43*) contains 8-bit MSB part [12:5] of the 13 bit output data of the X-channel.
DATAY_LSB (*0x44*) contains 5-bit LSB part [4:0] of the 13 bit output data of the Y-channel.
DATAY_MSB (*0x45*) contains 8-bit MSB part [12:5] of the 13 bit output data of the Y-channel.

The width of the Z-axis magnetic field data is 15 bit word stored in two's complement.
DATAZ_LSB (*0x46*) contains 7-bit LSB part [6:0] of the 15 bit output data of the Z-channel.
DATAZ_MSB (*0x47*) contains 8-bit MSB part [14:7] of the 15 bit output data of the Z-channel.

For all axes, temperature compensation on the host is used to get ideally matching sensitivity over the full temperature range. The temperature compensation is based on a resistance measurement of the hall sensor plate. The resistance value is represented by a 14 bit unsigned output word.
RHALL_LSB (*0x48*) contains 6-bit LSB part [5:0] of the 14 bit output data of the RHALL-channel.
RHALL_MSB (*0x49*) contains 8-bit MSB part [13:6] of the 14 bit output data of the RHALL-channel.

All signed register values are in two´s complement representation. Bits which are marked "reserved" can have different values or can in some cases not be read at all (read will return 0x00 in I²C mode and high-Z in SPI mode).

Data register readout and shadowing is implemented as follows:
After all enabled axes have been measured; complete data packages consisting of DATAX, DATAY, DATAZ and RHALL are updated at once in the data registers. This way, it is prevented that a following axis is updated while the first axis is still being read (axis mix-up) or that MSB part of an axis is updated while LSB part is being read.
While reading from any data register, data register update is blocked. Instead, incoming new data is written into shadow registers which will be written to data registers after the previous read sequence is completed (i.e. upon stop condition in I²C mode, or CSB going high in SPI mode, respectively). Hence, it is recommended to read out at all data at once (*0x42* to *0x49* or *0x4A* if status bits are also required) with a burst read.
Single bytes or axes can be read out, while in this case it is not assured that adjacent registers are not updated during readout sequence.

The "Data ready status" bit (register *0x48 bit0*) is set "1" when the data registers have been updated but the data was not yet read out over digital interface. Data ready is cleared (set "0") directly after completed read out of any of the data registers and subsequent stop condition (I²C) or lifting of CSB (SPI).

In addition, when enabled the "Data overrun" bit (register *0x4A bit7*) turns "1" whenever data registers are updated internally, but the old data was not yet read out over digital interface (i.e. data ready bit was still high). The "Data overrun" bit is cleared when the interrupt status register *0x4A* is read out. This function needs to be enabled separately by setting the "Data overrun En" bit (register *0x4D bit7*)).

Note:
Please also see chapter 5 for detailed register descriptions.

4.3.2 Magnetic field data temperature compensation

The raw register values DATAX, DATAY, DATAZ and RHALL are read out from the host processor using the BMM150 API/driver which is provided by Bosch Sensortec. The API/driver performs an off-chip temperature compensation and outputs x/y/z magnetic field data in 16 LSB/µT to the upper application layer:

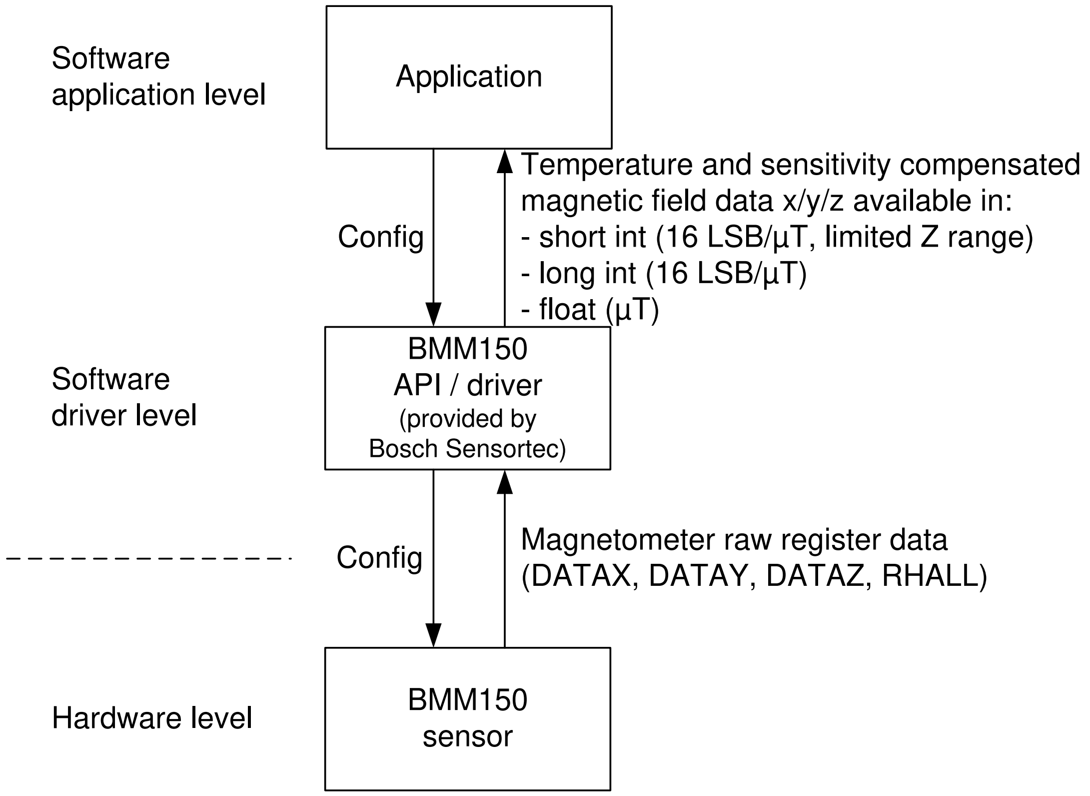


Figure 3: Calculation flow of magnetic field data from raw BMM150 register data

The API/driver performs all calculations using highly optimized fixed-point C-code arithmetic. For platforms that do not support C code, a floating-point formula is available as well.

4.4 Self-test

BMM150 supports two self-tests modes: Normal self-test and advanced self-test.

4.4.1 Normal self test

During normal self-test, the following verifications are performed:
FlipCore signal path is verified by generating signals on-chip. These are processed through the signal path and the measurement result is compared to known thresholds.

- FlipCore (X and Y) connection to ASIC are checked for connectivity and short circuits
- Hall sensor connectivity is checked for open and shorted connections
- Hall sensor signal path and hall sensor element offset are checked for overflow.

To perform a self test, the sensor must first be put into sleep mode (OpMode = “11”). Self-test mode is then entered by setting the bit “Self test” (register *0x4C bit0*) to “1”. After performing self test, this bit is set back to “0”. When self-test is successful, the corresponding self-test result bits are set to “1” (“X-Self-Test” register *0x42 bit0*, “Y-Self-Test” register *0x44 bit0*, “Z-Self-Test” register *0x46 bit0*). If self-test fails for an axis, the corresponding result bit returns “0”.

4.4.2 Advanced self test

Advanced self test performs a verification of the Z channel signal path functionality and sensitivity. An on-chip coil wound around the hall sensor can be driven in both directions with a calibrated current to generate a positive or negative field of around 100 µT.

Advanced self test is an option that is active in parallel to the other operation modes. The only difference is that during the active measurement phase, the coil current is enabled. The recommended usage of advanced self test is the following:

1. Set sleep mode
2. Disable X, Y axis
3. Set Z repetitions to desired level
4. Enable positive advanced self test current
5. Set forced mode, readout Z and R channel after measurement is finished
6. Enable negative advanced self test current
7. Set forced mode, readout Z and R channel after measurement is finished
8. Disable advanced self test current (this must be done manually)
9. Calculate difference between the two compensated field values. This difference should be around 200 µT with some margins.
10. Perform a soft reset of manually restore desired settings

Please refer to the corresponding application note for the exact thresholds to evaluate advanced self-test.

The table below describes how the advanced self-test is controlled:

Table 4: Magnetometer advanced self-test control

(0x4C) Adv.ST <1:0>	Configuration
00b	Normal operation (no self-test), default
01b	Reserved, do not use
10b	Negative on-chip magnetic field generation
11b	Positive on-chip magnetic field generation

The BMM150 API/driver provided by Bosch Sensortec provides a comfortable way to perform both self-tests and to directly obtain the result without further calculations. It is recommended to use this as a reference.

4.5 Non-volatile memory

Some of the memory of the BMM150 magnetometer is non-volatile memory (NVM). This NVM is pre-programmed in Bosch Sensortec fabrication line and cannot be modified afterwards. It contains trimming data which are required for sensor operation and sensor data compensation, thus it is read out by the BMM150 API/driver during initialization.

4.6 Magnetometer interrupt controller

Four magnetometer based interrupt engines are integrated in the BMM150: Low-Threshold, High-Threshold, Overflow and Data Ready (DRDY). Each interrupt can be enabled independently.

When enabled, an interrupt sets the corresponding status bit in the interrupt status register (*0x4A*) when its condition is satisfied.
When the “Interrupt Pin Enable” bit (register *0x4E bit6*) is set, any occurring activated interrupts are flagged on the BMM150’s INT output pin. By default, the interrupt pin is disabled (high-Z status).

Low-Threshold, High-Threshold and Overflow interrupts are mapped to the INT pin when enabled, Data Ready (DRDY) interrupt is mapped to the DRDY pin of BMM150 when enabled. For High- and Low-Threshold interrupts each axis X/Y/Z can be enabled separately for interrupt detection in the registers “High Int Z en”, “High Int Y en”, “High Int X en”, “Low Int Z en”, “Low Int Y En” and “Low Int X En” in register *0x4D bit5-bit0*. Overflow interrupt is shared for X, Y and Z axis.

When the “Data Ready Pin En” bit (register *0x4E bit7*) is set, the Data Ready (DRDY) interrupt event is flagged on the BMM150’s DRDY output pin (by default the “Data Ready Pin En” bit is not set and DRDY pin is in high-Z state).
The interrupt status registers are updated together with writing new data into the magnetic field data registers. The status bits for Low-/High-Threshold interrupts are located in register *0x4A*, the Data Ready (DRDY) status flag is located at register *0x48 bit0*.

If an interrupt is disabled, all active status bits and pins are reset after the next measurement was performed.

4.6.1 General features

An interrupt is cleared depending on the selected interrupt mode, which is common to all interrupts. There are two different interrupt modes: non-latched and latched. All interrupts (except Data Ready) can be latched or non-latched. Data Ready (DRDY) is always cleared after readout of data registers ends.

A non-latched interrupt will be cleared on a new measurement when the interrupt condition is not valid anymore, whereas a latched interrupt will stay high until the interrupts status register (*0x4A*) is read out. After reading the interrupt status, both the interrupt status bits and the interrupt pin are reset. The mode is selected by the "Interrupt latch" bit (register *0x4A bit1*), where the default setting of "1" means latched. Figure 4 shows the difference between the modes for the example Low-Threshold interrupt.

INT and DRDY pin polarity can be changed by the "Interrupt polarity" bit (register *0x4E bit0*) and "DR polarity" (register *0x4E bit2*), from the default high active ("1") to low active ("0").

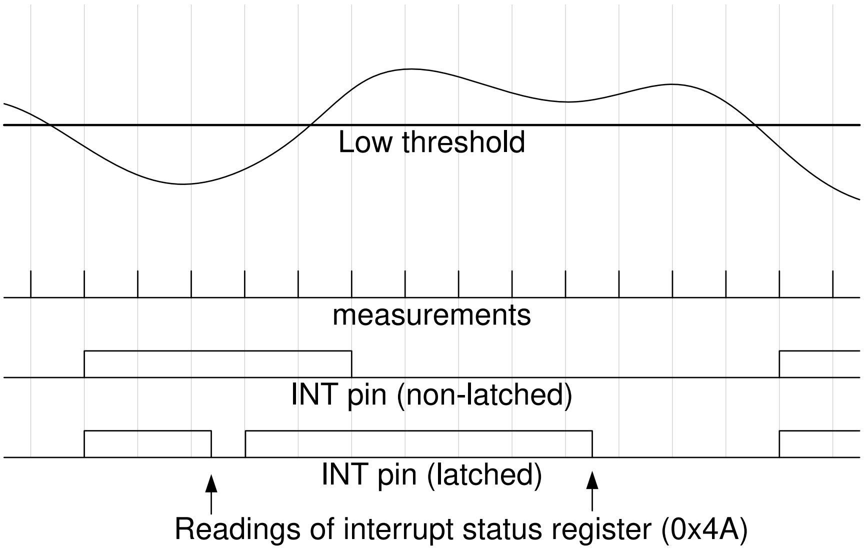


Figure 4: Interrupt latched and non-latched mode

4.6.2 Electrical behavior of magnetic interrupt pins

Both interrupt pins INT and DRDY are push/pull when the corresponding interrupt pin enable bit is set, and are floating (High-Z) when the corresponding interrupt pin enable bit is disabled (default).

4.6.3 Data ready / DRDY interrupt

This interrupt serves for synchronous reading of magnetometer data. It is generated after storing a new set of values (DATAX, DATAY, DATAZ, RHALL) in the data registers:

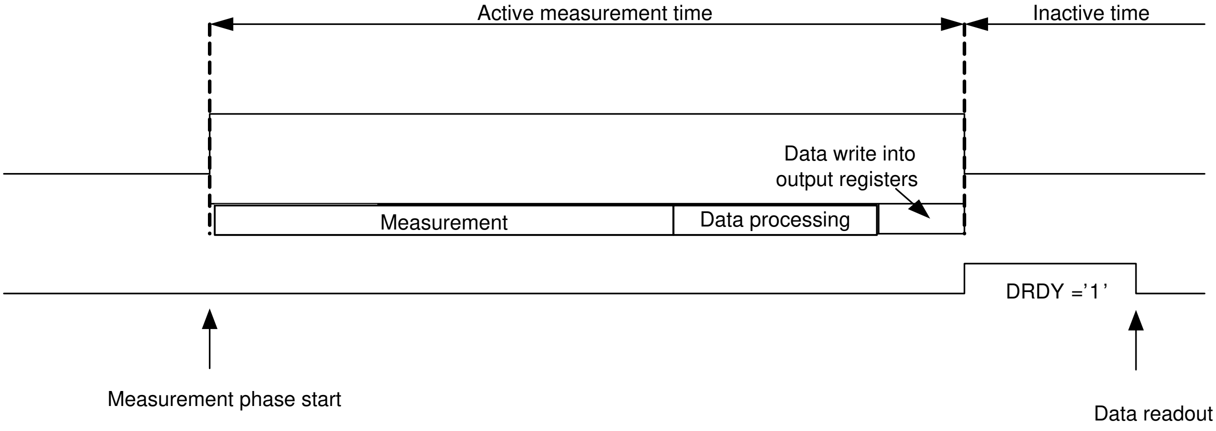


Figure 5: Data acquisition and DRDY operation (DRDY in “high active” polarity)

The interrupt mode of the Data Ready (DRDY) interrupt is fixed to non-latched.
It is enabled (disabled) by writing “1” (“0”) to “Data Ready pin En” in register *0x4E bit7*.

DRDY pin polarity can be changed by the “DR polarity” bit (register *0x4E bit2*), from the default high active (“1”) to low active (“0”).

4.6.4 Low-threshold interrupt

When the data registers’ (DATAX, DATAY and DATAZ) values drop below the threshold level defined by the “Low Threshold register (*0x4F*), the corresponding interrupt status bits for those axes are set (“Low Int X”, “Low Int Y” and “Low Int Z” in register *0x4A*). This is done for each axis independently. Please note that the X and Y axis value for overflow is -4096. However, no interrupt is generated on these values. See chapter 4.6.6 for more information on overflow.

Hereby, one bit in “Low Threshold” corresponds to roughly 6µT (not exactly, as the raw magnetic field values DATAX, DATAY and DATAZ are not temperature compensated).

The Low-threshold interrupt is issued on INT pin when one or more values of the data registers DATAX, DATAY and DATAZ drop below the threshold level defined by the “Low Threshold” register (*0x4F*), and when the axis where the threshold was exceeded is enabled for interrupt generation:

Result = (DATAX < “Low Threshold” x 16) AND “Low Int X en” is “0” OR
(DATAY < “Low Threshold” x 16) AND “Low Int Y en” is “0” OR
(DATAZ < “Low Threshold” x 16) AND “Low Int Z en” is “0”

Note: Threshold interrupt enable bits (“Low INT [XYZ] en”) are active low and “1” (disabled) by default.

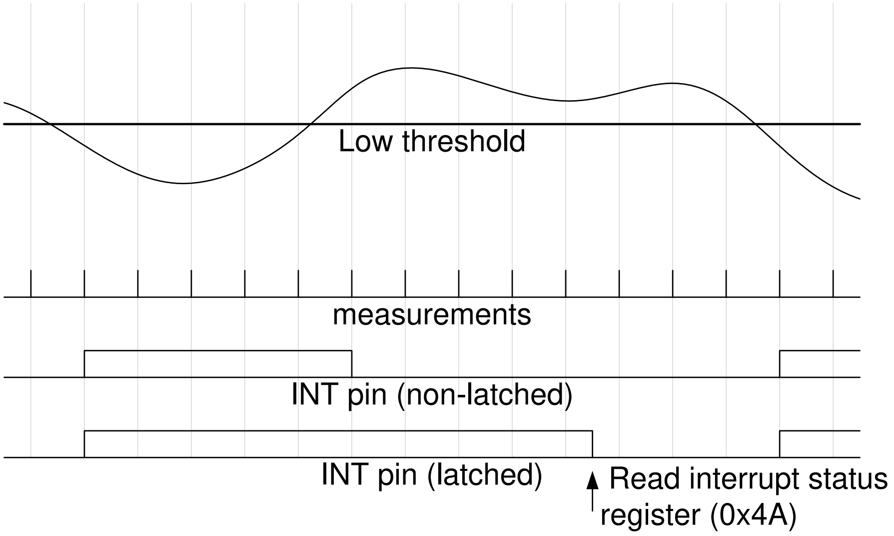


Figure 6: Low-threshold interrupt function

4.6.5 High-threshold interrupt

When the data registers' (DATAX, DATAY and DATAZ) values exceed the threshold level defined by the "High Threshold register (*0x50*), the corresponding interrupt status bits for those axes are set ("High Int X", "High Int Y" and "High Int Z" in register *0x4A*). This is done for each axis independently.
Hereby, one bit in "High Threshold" corresponds to roughly 6µT (not exactly, as the raw magnetic field values DATAX, DATAY and DATAZ are not temperature compensated).

The High-threshold interrupt is issued on INT pin when one or more values of the data registers DATAX, DATAY and DATAZ exceed the threshold level defined by the "High Threshold" register (*0x50*), and when the axis where the threshold was exceeded is enabled for interrupt generation:

Result = (DATAX > "High Threshold" x 16) AND "High Int X en" is "0" OR
(DATAY > "High Threshold" x 16) AND "High Int Y en" is "0" OR
(DATAZ > "High Threshold" x 16) AND "High Int Z en" is "0"

Note:
Threshold interrupt enable bits ("High INT [XYZ] en") are active low and "1" (disabled) by default.

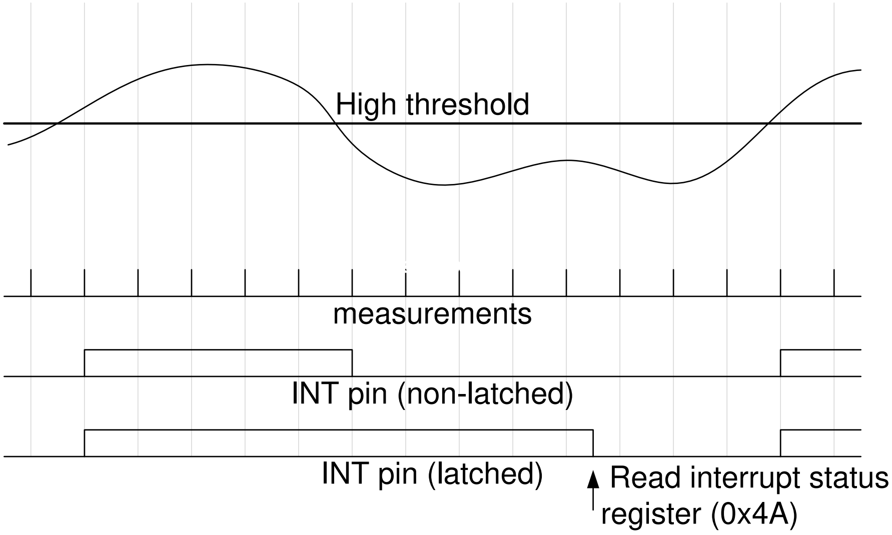


Figure 7: High-threshold interrupt function

4.6.6 Overflow

When a measurement axis had an overflow, the corresponding data register is saturated to the most negative value. For X and Y axis, the data register is set to the value -4096. For the Z axis, the data register is set to the value -16384.
The "Overflow" flag (register *0x4A bit6*) indicates that the measured magnetic field raw data of one or more axes exceeded maximum range of the device. The overflow condition can be flagged on the INT pin by setting the bit "overflow int enable" (register *0x4D bit6,* active high, default value "0"). The channel on which overflow occurred can by determined by assessing the DATAX/Y/Z registers.

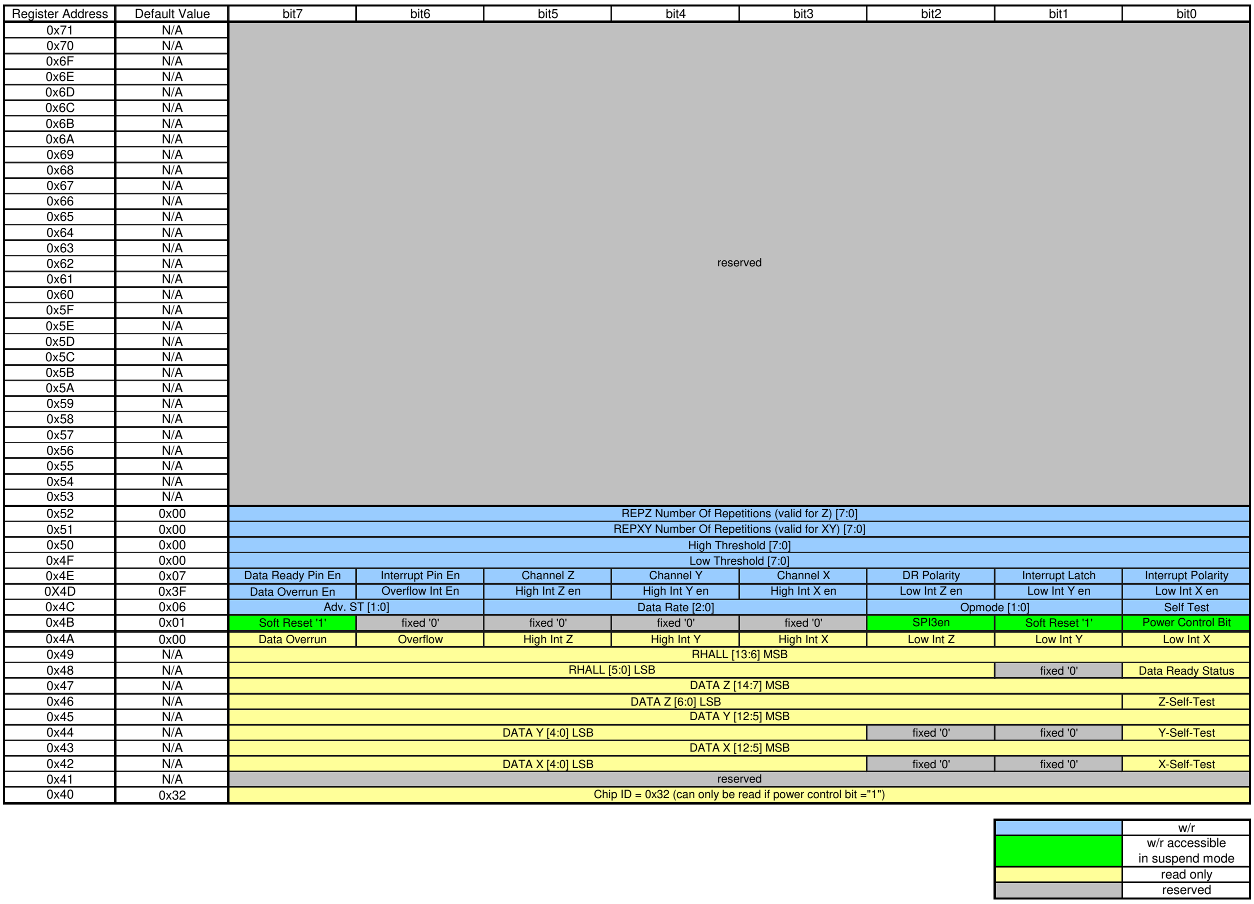
5. Register Description

5.1 General Remarks

The entire communication with the device's magnetometer part is performed by reading from and writing to registers. Registers have a width of 8 bits; they are mapped to a common space of 50 addresses from *(0x40)* up to *(0x71)*. Within the used range there are several registers which are marked as 'reserved'. Any reserved bit is ignored when it is written and no specific value is guaranteed when read. Especially, in SPI mode the SDO pin may stay in high-Z state when reading some of these registers.

Registers with addresses from *(0x40)* up to *(0x4A)* are read-only. Any attempt to write to these registers is ignored.

5.2 Register map



Register Address	Default Value	bit7	bit6	bit5	bit4	bit3	bit2	bit1	bit0
0x71	N/A	reserved							
0x70	N/A								
0x6F	N/A								
0x6E	N/A								
0x6D	N/A								
0x6C	N/A								
0x6B	N/A								
0x6A	N/A								
0x69	N/A								
0x68	N/A								
0x67	N/A								
0x66	N/A								
0x65	N/A								
0x64	N/A								
0x63	N/A								
0x62	N/A								
0x61	N/A								
0x60	N/A								
0x5F	N/A								
0x5E	N/A								
0x5D	N/A								
0x5C	N/A								
0x5B	N/A								
0x5A	N/A								
0x59	N/A								
0x58	N/A								
0x57	N/A								
0x56	N/A								
0x55	N/A								
0x54	N/A								
0x53	N/A								
0x52	0x00	REPZ Number Of Repetitions (valid for Z) [7:0]							
0x51	0x00	REPXY Number Of Repetitions (valid for XY) [7:0]							
0x50	0x00	High Threshold [7:0]							
0x4F	0x00	Low Threshold [7:0]							
0x4E	0x07	Data Ready Pin En	Interrupt Pin En	Channel Z	Channel Y	Channel X	DR Polarity	Interrupt Latch	Interrupt Polarity
0X4D	0x3F	Data Overrun En	Overflow Int En	High Int Z en	High Int Y en	High Int X en	Low Int Z en	Low Int Y en	Low Int X en
0x4C	0x06	Adv. ST [1:0]		Data Rate [2:0]			Opmode [1:0]		Self Test
0x4B	0x01	Soft Reset '1'	fixed '0'	fixed '0'	fixed '0'	fixed '0'	SPI3en	Soft Reset '1'	Power Control Bit
0x4A	0x00	Data Overrun	Overflow	High Int Z	High Int Y	High Int X	Low Int Z	Low Int Y	Low Int X
0x49	N/A	RHALL [13:6] MSB							
0x48	N/A	RHALL [5:0] LSB						fixed '0'	Data Ready Status
0x47	N/A	DATA Z [14:7] MSB							
0x46	N/A	DATA Z [6:0] LSB							Z-Self-Test
0x45	N/A	DATA Y [12:5] MSB							
0x44	N/A	DATA Y [4:0] LSB					fixed '0'	fixed '0'	Y-Self-Test
0x43	N/A	DATA X [12:5] MSB							
0x42	N/A	DATA X [4:0] LSB					fixed '0'	fixed '0'	X-Self-Test
0x41	N/A	reserved							
0x40	0x32	Chip ID = 0x32 (can only be read if power control bit ="1")							

🟦	w/r
🟩	w/r accessible in suspend mode
🟨	read only
▨	reserved

5.3 Chip ID

Register *(0x40)* *Chip ID* contains the magnetometer chip identification number, which is 0x32. This number can only be read if the power control bit (register *0x4B bit0*) is enabled.

Table 5: Chip identification number, register *(0x40)*

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

Register *(0x41)* *is reserved*

5.4 Magnetic field data

Register *(0x42)* contains the LSB part of x-axis magnetic field data and the self-test result flag for the x-axis.

Table 6: LSB part of x-axis magnetic field, register *(0x42)*

(0x42) Bit	Name	Description
Bit 7	DATAX_lsb <4>	Bit 4 of x-axis magnetic field data
Bit 6	DATAX_lsb <3>	Bit 3 of x-axis magnetic field data
Bit 5	DATAX_lsb <2>	Bit 2 of x-axis magnetic field data
Bit 4	DATAX_lsb <1>	Bit 1 of x-axis magnetic field data
Bit 3	DATAX_lsb <0>	Bit 0 of x-axis magnetic field data = x LSB
Bit 2	-	(fixed to 0)
Bit 1	-	(fixed to 0)
Bit 0	SelfTestX	Self-test result flag for x-axis, default is “1”

Register *(0x43)* contains the MSB part of x-axis magnetic field data.

Table 7: MSB part of x-axis magnetic field, register *(0x43)*

(0x43) Bit	Name	Description
Bit 7	DATAX_msb <12>	Bit 12 of x-axis magnetic field data = x MSB
Bit 6	DATAX_msb <11>	Bit 11 of x-axis magnetic field data
Bit 5	DATAX_msb <10>	Bit 10 of x-axis magnetic field data
Bit 4	DATAX_msb <9>	Bit 9 of x-axis magnetic field data
Bit 3	DATAX_msb <8>	Bit 8 of x-axis magnetic field data
Bit 2	DATAX_msb <7>	Bit 7 of x-axis magnetic field data
Bit 1	DATAX_msb <6>	Bit 6 of x-axis magnetic field data
Bit 0	DATAX_msb <5>	Bit 5 of x-axis magnetic field data

Register *(0x44)* contains the LSB part of y-axis magnetic field data and the self-test result flag for the y-axis.

Table 8: LSB part of y-axis magnetic field, register *(0x44)*

(0x44) Bit	Name	Description
Bit 7	DATAY_lsb <4>	Bit 4 of y-axis magnetic field data
Bit 6	DATAY_lsb <3>	Bit 3 of y-axis magnetic field data
Bit 5	DATAY_lsb <2>	Bit 2 of y-axis magnetic field data
Bit 4	DATAY_lsb <1>	Bit 1 of y-axis magnetic field data
Bit 3	DATAY_lsb <0>	Bit 0 of y-axis magnetic field data = y LSB
Bit 2	-	(fixed to 0)
Bit 1	-	(fixed to 0)
Bit 0	SelfTestY	Self-test result flag for y-axis, default is “1”

Register *(0x45)* contains the MSB part of y-axis magnetic field data.

Table 9: MSB part of y-axis magnetic field, register *(0x45)*

(0x45) Bit	Name	Description
Bit 7	DATAY_msb <12>	Bit 12 of y-axis magnetic field data = y MSB
Bit 6	DATAY_msb <11>	Bit 11 of y-axis magnetic field data
Bit 5	DATAY_msb <10>	Bit 10 of y-axis magnetic field data
Bit 4	DATAY_msb <9>	Bit 9 of y-axis magnetic field data
Bit 3	DATAY_msb <8>	Bit 8 of y-axis magnetic field data
Bit 2	DATAY_msb <7>	Bit 7 of y-axis magnetic field data
Bit 1	DATAY_msb <6>	Bit 6 of y-axis magnetic field data
Bit 0	DATAY_msb <5>	Bit 5 of y-axis magnetic field data

Register *(0x46)* contains the LSB part of z-axis magnetic field data and the self-test result flag for the z-axis.

Table 10: LSB part of z-axis magnetic field, register *(0x46)*

(0x46) Bit	Name	Description
Bit 7	DATAZ_lsb <6>	Bit 6 of z-axis magnetic field data
Bit 6	DATAZ_lsb <5>	Bit 5 of z-axis magnetic field data
Bit 5	DATAZ_lsb <4>	Bit 4 of z-axis magnetic field data
Bit 4	DATAZ_lsb <3>	Bit 3 of z-axis magnetic field data
Bit 3	DATAZ_lsb <2>	Bit 2 of z-axis magnetic field data
Bit 2	DATAZ_lsb <1>	Bit 1 of z-axis magnetic field data
Bit 1	DATAZ_lsb <0>	Bit 0 of z-axis magnetic field data = z LSB
Bit 0	SelfTestZ	Self-test result flag for z-axis, default is “1”

Register *(0x47)* contains the MSB part of z-axis magnetic field data.

Table 11: MSB part of z-axis magnetic field, register *(0x47)*

(0x47) Bit	Name	Description
Bit 7	DATAZ_msb <14>	Bit 14 of y-axis magnetic field data = z MSB
Bit 6	DATAZ_msb <13>	Bit 13 of y-axis magnetic field data
Bit 5	DATAZ_msb <12>	Bit 12 of y-axis magnetic field data
Bit 4	DATAZ_msb <11>	Bit 11 of y-axis magnetic field data
Bit 3	DATAZ_msb <10>	Bit 10 of y-axis magnetic field data
Bit 2	DATAZ_msb <9>	Bit 9 of y-axis magnetic field data
Bit 1	DATAZ_msb <8>	Bit 8 of y-axis magnetic field data
Bit 0	DATAZ_msb <7>	Bit 7 of y-axis magnetic field data

Register *(0x48)* contains the LSB part of hall resistance and the Data Ready (DRDY) status bit.

Table 12: LSB part of hall resistance, register *(0x48)*

(0x48) Bit	Name	Description
Bit 7	RHALL_lsb <5>	Bit 5 of hall resistance
Bit 6	RHALL_lsb <4>	Bit 4 of hall resistance
Bit 5	RHALL_lsb <3>	Bit 3 of hall resistance
Bit 4	RHALL_lsb <2>	Bit 2 of hall resistance
Bit 3	RHALL_lsb <1>	Bit 1 of hall resistance
Bit 2	RHALL_lsb <0>	Bit 0 of hall resistance = RHALL LSB
Bit 1	-	(fixed to 0)
Bit 0	Data Ready Status	Data ready (DRDY) status bit

Register *(0x49)* contains the MSB part of hall resistance.

Table 13: MSB part of hall resistance, register *(0x49)*

(0x49) Bit	Name	Description
Bit 7	RHALL_msb <13>	Bit 13 of hall resistance = RHALL MSB
Bit 6	RHALL_msb <12>	Bit 12 of hall resistance
Bit 5	RHALL_msb <11>	Bit 11 of hall resistance
Bit 4	RHALL_msb <10>	Bit 10 of hall resistance
Bit 3	RHALL_msb <9>	Bit 9 of hall resistance
Bit 2	RHALL_msb <8>	Bit 8 of hall resistance
Bit 1	RHALL_msb <7>	Bit 7 of hall resistance
Bit 0	RHALL_msb <6>	Bit 6 of hall resistance