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Data sheet

BMC050
Electronic Compass

Bosch Sensortec

BOSCH
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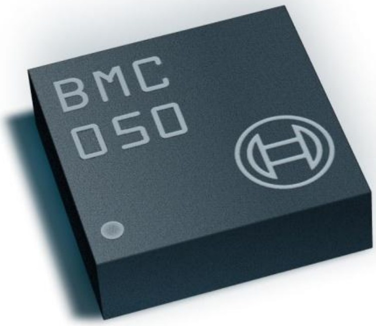

BMC050: Data sheet

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BMC050

ELECTRONIC COMPASS WITH THREE-AXIS MAGNETIC FIELD SENSOR AND THREE-AXIS ACCELEROMETER

Key features

Three-axis magnetic field sensor and three-axis accelerometer in one package

- Accelerometer can still be used independently from magnetometer operation

Ultra-Small package	LGA package (16 pins), footprint 3mm x 3mm, height 0.95mm
Digital interface	SPI (4-wire, 3-wire), I²C, 4 interrupt pins (2 acceleration sensor, 2 magnetic sensor 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	Acceleration ranges ±2g / ±4g / ±8g / ±16g Acceleration Low-pass filter bandwidths 1 kHz - <8Hz Magnetic field range typical ±1000µT Magnetic field resolution of ~0.3µT
On-chip interrupt controller	Motion-triggered interrupt-signal generation for - new data (separate for accelerometer and magnetometer) - any-motion (slope) detection - tap sensing (single tap / double tap) - orientation recognition - flat detection - low-g/high-g detection - magnetic Low-/High-Threshold detection
Ultra-low power	Low current consumption (190µA @ 10 Hz including accelerometer and magnetic sensor 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

- Tilt-compensated electronic compass for map rotation, navigation and augmented reality
- 6-axis orientation for gaming
- Display profile switching
- Menu scrolling, tap / double tap sensing
- Pedometer / step counting
- Free-fall detection
- Drop detection for warranty logging
- Advanced system power management for mobile applications

General Description

The BMC050 is an integrated electronic compass solution for consumer market applications. It comprises a leading edge triaxial, low-g acceleration sensor and an ultra-low power, high precision triaxial magnetic field sensor. It allows measurements of acceleration and magnetic field in three perpendicular axes. Performance and features of both sensing technologies are carefully tuned and perfectly match the demanding requirements of all 6-axis mobile applications such as electronic compass, navigation or augmented reality.
An evaluation circuitry (ASIC) converts the output of the micromechanical sensing structures (MEMS) to digital results which can be read out over the industry standard digital interfaces.

Package and interfaces of the BMC050 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 BMC050 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 sets new standards in terms of flexibility.

The BMC050 senses orientation, tilt, motion, shock, vibration and heading 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. The specifications are split into accelerometer part and magnetometer part of BMC050.

1.1 Compass electrical specification

Table 1: Compass electrical parameter specification

COMPASS 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	$V_{OL,a}$	$V_{DDIO} = 1.62V$ $I_{OL} = 3$ mA, SPI & I²C			$0.2V_{DDIO}$	-
		$V_{DDIO} = 1.2V$ $I_{OL} = 3$ mA, SPI & I²C			$0.23\ V_{DDIO}$	-
Voltage Output High Level	$V_{OH,a}$	$V_{DDIO} = 1.62V$ $I_{OL} = 2$ mA, SPI & I²C	$0.8V_{DDIO}$			-
		$V_{DDIO} = 1.2V$ $I_{OL} = 2$ mA, SPI & I²C	$0.62\ V_{DDIO}$			-

1.2 Accelerometer specification

Table 2: Accelerometer parameter specification

ACCELEROMETER OPERATING CONDITIONS						
Parameter	**Symbol**	**Condition**	**Min**	**Typ**	**Max**	**Unit**
Acceleration Range	g_{FS2g}	Selectable via serial digital interface		±2		g
	g_{FS4g}			±4		g
	g_{FS8g}			±8		g
	g_{FS16g}			±16		g
Supply Current in Normal Mode	$I_{DD,a}$	Nominal V_{DD} supplies T_A=25°C, bw = 1kHz		139		µA
Supply Current in Low-Power Mode	$I_{DDlp,a}$	Nominal V_{DD} supplies T_A=25°C, bw = 1kHz sleep duration ≥ 25ms		7		µA
Supply Current in Suspend Mode	$I_{DDsm,a}$	Nominal V_{DD} supplies T_A=25°C		0.5		µA

Wake-Up Time	$t_{w\_up,a}$	from Low-Power Mode or Suspend Mode, bw = 1kHz		0.8		ms
Start-Up Time	$t_{s\_up,a}$	POR, bw = 1kHz		2		ms
Operating Temperature	T_A	Same for accelerometer and magnetometer	-40		+85	°C

ACCELEROMETER OUTPUT SIGNAL

Parameter	Symbol	Condition	Min	Typ	Max	Unit
Device Resolution	$D_{res,a}$	g_{FS2g}		3.91		mg
Sensitivity	S_{2g}	g_{FS2g}, T_A=25°C		256		LSB/g
	S_{4g}	g_{FS4g}, T_A=25°C		128		LSB/g
	S_{8g}	g_{FS8g}, T_A=25°C		64		LSB/g
	S_{16g}	g_{FS16g}, T_A=25°C		32		LSB/g
Sensitivity Temperature Drift	TCS_a	g_{FS2g}, -40°C ≤ T_A ≤ +85°C Nominal V_{DD} supplies		±0.02		%/K
Zero-g Offset	Off_a	g_{FS2g}, T_A=25°C Nominal V_{DD} supplies		±80		mg
Zero-g Offset Temperature Drift	TCO_a	g_{FS2g}, -40°C ≤ T_A ≤ +85°C Nominal V_{DD} supplies		±1		mg/K
Bandwidth	bw_8	1st order filter, selectable via serial digital interface		8		Hz
	bw_{16}			16		Hz
	bw_{31}			31		Hz
	bw_{63}			63		Hz
	bw_{125}			125		Hz
	bw_{250}			250		Hz
	bw_{500}			500		Hz
	bw_{1000}			1000		Hz
Nonlinearity	$NL_{,a}$	best fit straight line		±0.5		%FS
Output Noise	$n_{rms,a}$	g_{FS2g}, T_A=25°C Nominal V_{DD} supplies Normal mode		0.8		mg/√Hz
Power Supply Rejection Rate	$PSRR_a$	T_A=25°C Nominal V_{DD} supplies			20	mg/V
Temperature Sensor Measurement Range	T_S	T_A=25°C Nominal V_{DD} supplies	-40		+87.5	°C
Temperature Sensor Slope	dT_S	T_A=25°C Nominal V_{DD} supplies		0.5		LSB/K
Temperature Sensor Offset	OT_S	T_A=25°C Nominal V_{DD} supplies		±5		K

ACCELEROMETER MECHANICAL CHARACTERISTICS						
Parameter	**Symbol**	**Condition**	**Min**	**Typ**	**Max**	**Unit**
Cross Axis Sensitivity	S_a	relative contribution between any two of the three axes		1		%
Alignment Error	$E_{A,a}$	relative to package outline		±0.5		°

1.3 Magnetometer specification

Table 3: Magnetometer parameter specification

MAGNETOMETER OPERATING CONDITIONS						
Parameter	**Symbol**	**Condition**	**Min**	**Typ**	**Max**	**Unit**
Magnetic field range	$B_{rg,xy}$	T_A=25°C, full active measurement range		±1000		µT
	$B_{rg,z}$			2500		µT
Magnetometer heading accuracy[1]	$Am_{heading}$	30µT horizontal geomagnetic field component, T_A=25°C			±2.5	degree
System heading accuracy[2]	$As_{heading}$	30µT horizontal geomagnetic field component, T_A=25°C			±3.5	degree
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, ODR=10Hz		0.8		mA
	$I_{DD,ha,m}$	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		µA
Peak supply current in Active Mode	$I_{DDpk,m}$	In measurement phase Nominal V_{DD} supplies T_A=25°C		18		mA

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[1] Theoretical heading accuracy of the 3-axis magnetometer alone, assuming ideal accelerometer and calibration with Bosch Sensortec eCompass software. Average value over various device orientations (typical device usage).

[2] Heading accuracy of the tilt-compensated 6-axis eCompass system, assuming calibration with Bosch Sensortec eCompass software. Average value over various device orientations (typical device usage).

[3] For details on magnetometer current consumption calculation refer to chapter 4.3.2 and 4.3.3.

Peak logic supply current in active mode	$I_{DDIOpk,m}$	Only during measurement phase Nominal V_{DDIO} supplies T_A=25°C		210		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		ms

MAGNETOMETER OUTPUT SIGNAL

Parameter	Symbol	Condition	Min	Typ	Max	Unit
Device Resolution	$D_{res,m}$	T_A=25°C (x,y,z)		0.3		µT
Sensitivity	S_m	After temperature compensation T_A=25°C Nominal V_{DD} supplies		1		µT sensor output per µT applied field
Sensitivity Temperature Drift	TCS_m	After temperature compensation -40°C ≤ T_A ≤ +85°C Nominal V_{DD} supplies		±0.01		%/K
Zero-B offset	OFF_m	T_A=25°C		±10		µT
ODR (data output rate), normal mode	odr_{lp}	Low power preset		10		Hz
	odr_{rg}	Regular preset		10		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

2. Absolute maximum ratings

The absolute maximum ratings provided in Table 4 apply to both the accelerometer and magnetometer part of BMC050.

Table 4: 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
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
Magnetic field	Any direction		> 7	T

3. Block diagram

Figure 1 shows the basic building blocks of the BMC050:

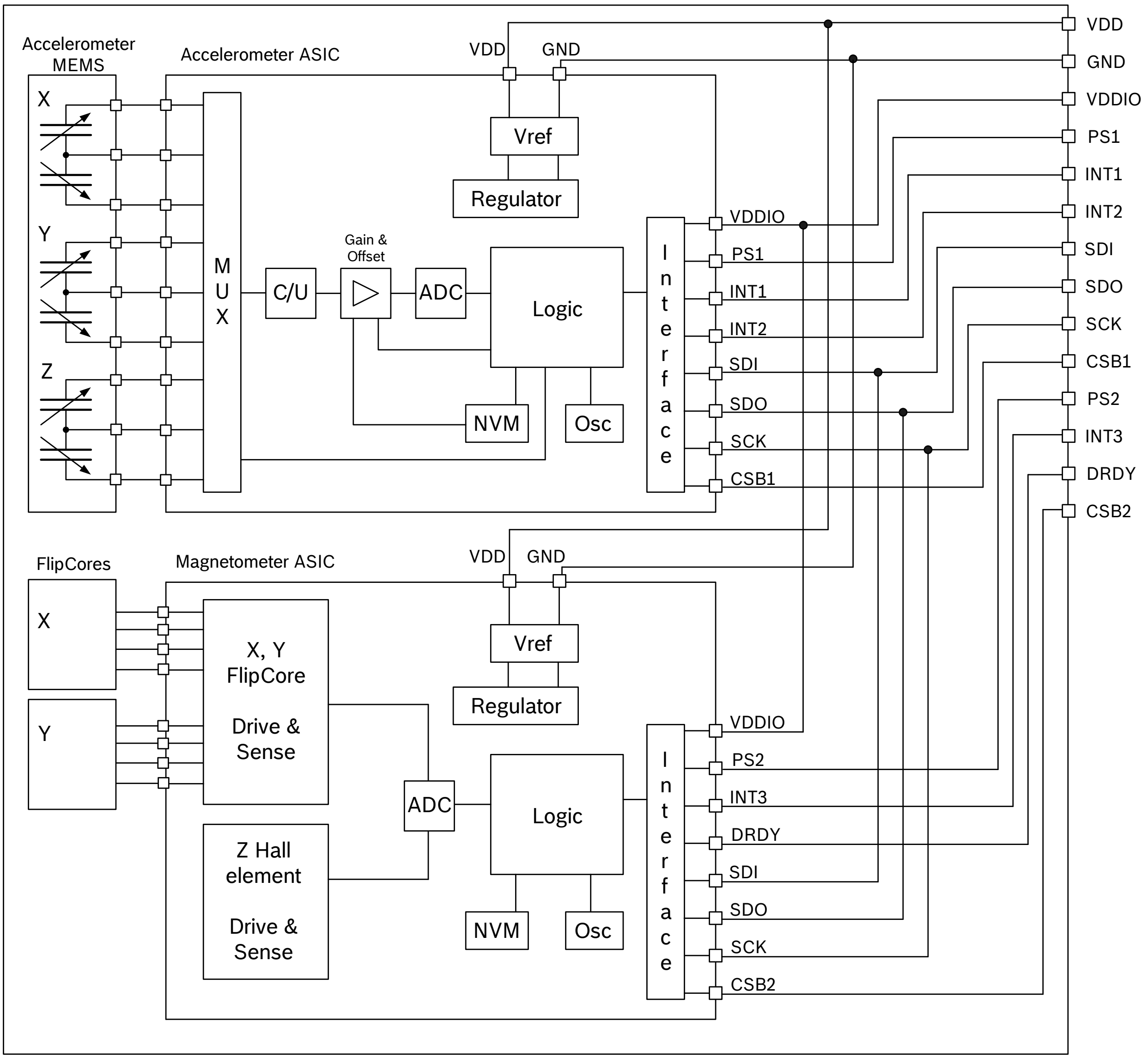

Figure 1: Block diagram of BMC050

4. Functional description

BMC050 is a SiP (system in package) integration of a triaxial accelerometer (Sensing element and ASIC) and a triaxial geomagnetic sensor (Sensing element and ASIC) in one package. The two ASICs act as two separate slave devices on the digital bus (with different I²C address in I²C mode, or separate CSB lines in SPI mode, respectively), which allows an almost independent operation of accelerometer and magnetometer parts in order to fit into a wide range of usage scenarios.

Note: Default values for registers can be found in chapters 5 and 6.

4.1 Power management

The BMC050 has two distinct power supply pins which supply both the acceleration sensor part and the magnetometer sensor part:
- 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 magnetic sensor's logic.

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 (V_{DD} = 0V) while keeping the V_{DDIO} supply on (V_{DDIO} > 0V). To switch off the interface supply (V_{DDIO} = 0V) and keep the internal supply on (V_{DD} > 0V) is safe only in normal mode of the accelerometer part (magnetic sensor will switch to off mode automatically). If the accelerometer part of the device is in low-power mode or suspend mode while V_{DDIO} = 0V, there is a risk of excess current consumption on the V_{DD} supply (non-destructive).

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 & CSB1 & CSB2] ≠ high).

The device contains a power on reset (POR) generator for each of the sensor parts, accelerometer part and magnetometer part. It resets the logic part and the register values of the concerned ASIC after powering-on V_{DD} and V_{DDIO}. There is no limitation on the sequence of switching on both supply voltages. In case the I²C interface is used, a direct electrical connection between V_{DDIO} supply and the PS pins (PS1 and PS2) is needed in order to ensure reliable protocol selection (see chapter 4.2).

4.2 Protocol selection

The BMC050 acts as two separate slave devices (i.e. accelerometer part and magnetometer part), on a digital interface (SPI or I²C) which is controlled by the external bus master (e.g. µC). The master obtains measurement data and status information from the device through the digital interface. In particular, the master can configure the interrupt controllers and read out the interrupt status registers. Moreover, it can freely configure and use the interrupt pins (INT1, INT2, INT3 and DRDY).

All pads are in input mode (no output driver active) during the start-up sequence until the interface type is selected. The start-up sequence is run after power-up and after reset.

Note: It is not possible to select mixed interfaces (I²C for accelerometer part and SPI for magnetometer part or vice versa), because the digital interface uses shared pins.

Figure 2 illustrates the protocol selection:

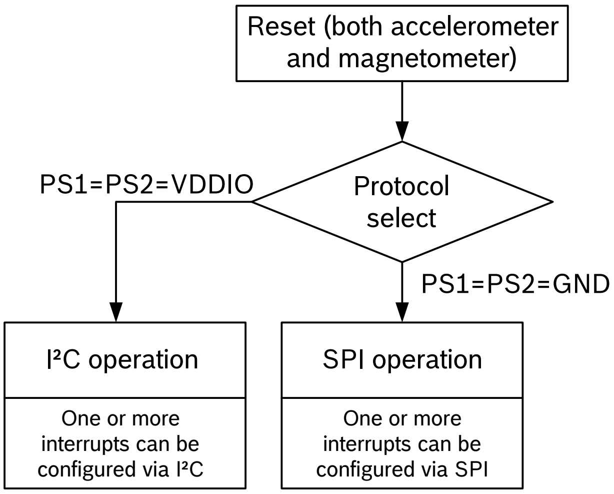

Figure 2: Protocol selection

4.3 Power modes

The BMC050 features separately configurable power modes for the accelerometer and the magnetometer part. The advantage is that different characteristics regarding optimum system power saving of the two sensor types are exploited, and that the accelerometer part may also be used alone in certain usage scenarios where no magnetic field data is required. In such an example, the magnetometer part is able to suspend and save power during the time in which it is not required.

In the following chapters, power modes for both accelerometer and magnetometer part are described.

4.3.1 **Accelerometer power modes**

The BMC050 accelerometer part has four different power modes (see Figure 4). Besides normal mode, which represents the fully operational state of the device, there are two special energy saving modes: low-power mode and suspend mode.

The possible transitions between the power modes are illustrated in Figure 3:

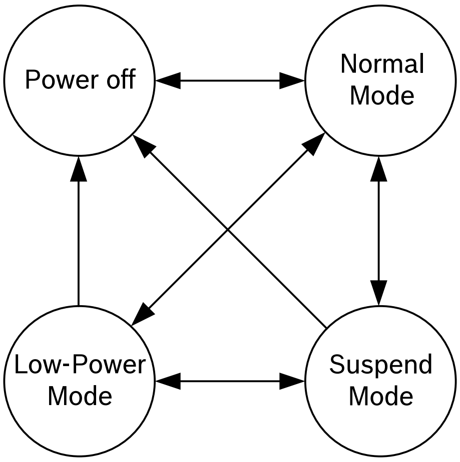

Figure 3: Accelerometer power mode transition diagram

Power off mode is enabled when V_{DD} and/or V_{DDIO} are unpowered. In this state, the accelerometer does not operate. Power on reset is performed after both supply voltages have risen above their detection thresholds.

In **normal mode**, all parts of the electronic circuit are held powered-up and data acquisition is performed continuously.

In contrast to this, in **suspend mode** the whole analog part, oscillators included, is powered down. No data acquisition is performed, the only supported operations are reading registers (latest acceleration data are kept) and writing to the *(0x11) suspend* bit or *(0x14) softreset* register. Suspend mode is entered (left) by writing “1” (“0”) to the *(0x11) suspend* bit.

In **low-power mode**, the device is periodically switching between a sleep phase and a wake-up phase. The wake-up phase essentially corresponds to operation in normal mode with complete power-up of the circuitry. During the sleep phase the analog part except the oscillators is powered down. Low-power mode is entered (left) by writing “1” (“0”) to the *(0x11) lowpower_en* bit.

During the wake-up phase the number of samples required by any enabled interrupt is processed. If an interrupt is detected, the device stays in the wake-up phase as long as the interrupt condition endures (non-latched interrupt), or until the latch time expires (temporary interrupt), or until the interrupt is reset (latched interrupt). If no interrupt is detected, the device enters the sleep phase.

The duration of the sleep phase is set by the *(0x11) sleep_dur* bits as shown in the following table:

Table 5: Sleep phase duration settings

(0x11) *sleep_dur*	Sleep Phase Duration t_{sleepa}
0000b	0.5ms
0001b	0.5ms
0010b	0.5ms
0011b	0.5ms
0100b	0.5ms
0101b	0.5ms
0110b	1ms
0111b	2ms
1000b	4ms
1001b	6ms
1010b	10ms
1011b	25ms
1100b	50ms
1101b	100ms
1110b	500ms
1111b	1s

The current consumption of the BMC050 accelerometer part can be calculated according to this formula:

$$I_{DDlp,a} \approx \frac{t_{sleep,a} \cdot I_{DDsm,a} + t_{active,a} \cdot I_{DD,a}}{t_{sleep,a} + t_{active,a}} .$$

In this formula, the subfix “a” indicates that the current and time variables refer to the accelerometer part of BMC050, to distinguish from the magnetometer part.
When making an estimation about the length of the wake-up phase $t_{active,a}$, the wake-up time, $t_{w\_up,a}$, has to be considered. Therefore, $t_{active,a} = t_{u,at} + t_{w\_up,a}$, where $t_{u,at}$ is given in Table 9. During the wake-up phase all analog modules are held powered-up, while during the sleep phase most analog modules are powered down. As a consequence, a wake-up time of less than 1ms (typ. value 0.8ms) is needed to settle the analog modules in order to get reliable acceleration data.

Table 6 gives an overview of the resulting average supply currents for the different sleep phase durations and a selected bandwidth of 1000Hz, assuming no interrupt is active and thus only one sample per wake-up phase is taken:

Table 6: Accelerometer part average current consumption in low-power mode

Sleep phase duration	Average current consumption
0.5ms	100.5 µA
1ms	78.8 µA
2ms	55.0 µA
4ms	34.5 µA
6ms	25.2 µA
10ms	16.4 µA
25ms	7.4 µA
50ms	4.0 µA
100ms	2.3 µA
500ms	0.9 µA
1s	0.7 µA

4.3.2 **Magnetometer power modes**

The BMC050 magnetometer part has four power modes:

Power off mode

In Power off mode, V_{DD} and/or VDDIO are unpowered. The magnetometer part does not operate in this mode. 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} have risen above their detection thresholds.

Suspend mode

Suspend mode is the default power mode of BMC050 magnetometer part after the chip is powered. When VDD and VDDIO 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 supplied directly by VDDIO which store I^2C slave device address, power control bit information and some others 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 “0x00h” (I²C) or high-Z (SPI).

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.

Active mode

The device can switch into Active mode from Sleep mode by setting OpMode bits (register *0x4C*). In active mode the magnetic field measurements are performed. In active mode, 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 6.6). 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 BMC050. Also, different data output rates from the ones selectable in normal mode can be achieved using forced mode.

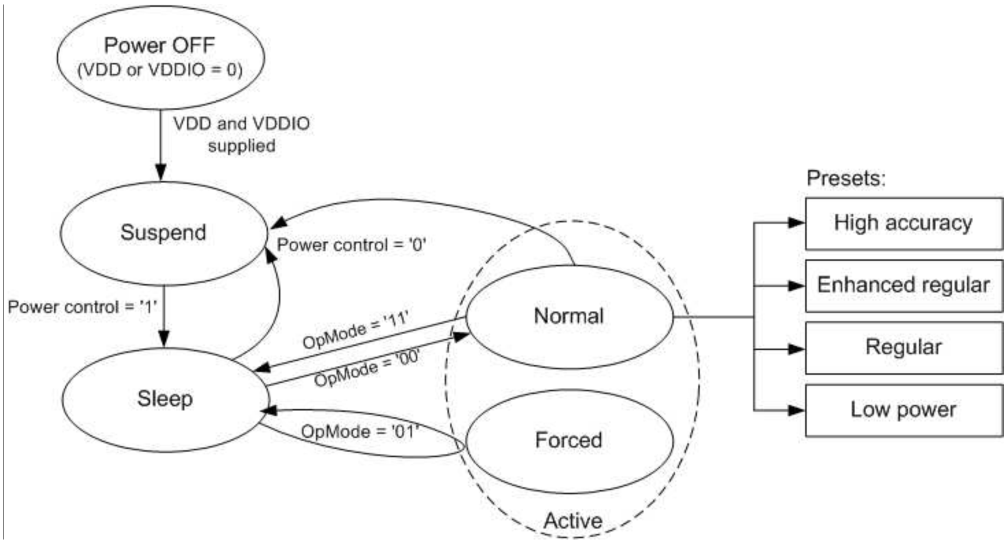

Figure 4: Magnetometer power mode transition diagram

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 6).

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 BMC050 magnetometer part.

The three presets consist of the below register configurations, which are automatically set by the BMC050 API or driver provided by Bosch Sensortec when a preset is selected. Table 7 shows the recommended presets and the resulting magnetic field output noise and magnetometer part current consumption:

Table 7: Magnetometer presets in Active operation and normal mode:

Preset	X/Y rep	Z rep	ODR	ODR_{max} (forced mode)	RMS Noise x/y/z	Average current consumption
Low power preset	3	3	10 Hz	>300 Hz	1.0/1.0/1.4 µT	170 µA
Regular preset	9	15	10 Hz	100 Hz	0.6/0.6/0.6 µT	0.5 mA
Enhanced regular preset	15	27	10 Hz	60 Hz	0.5/0.5/0.5 µT	0.8 mA
High accuracy preset	47	83	20 Hz	20 Hz	0.3/0.3/0.3 µT	4.9 mA

4.3.3 **BMC050 overall power consumption**

Below, Table 8 shows the overall current consumption of BMC050 (sum of accelerometer and magnetometer part) in typical scenarios such as a tilt-compensated electronic compass application.

Table 8: BMC050 overall current consumption in typical usage scenarios:

Compass preset	**Acc. Active / sleep interval**	**Mag. DOR**	**Acc. BW / DOR**	**Mag. avg. current**	**Acc. avg. current**	**Total average current**
Low power preset	8 / 50 ms	10 Hz	62.5 / 17 Hz	170 µA	20 µA	190 µA
Regular preset	16 / 50 ms	10 Hz	31 / 15 Hz	0.5 mA	35 µA	0.54 mA
Enhanced regular preset	16 / 50 ms	10 Hz	31 / 15 Hz	0.8 mA	35 µA	0.84 mA
High accuracy preset	16 /25 ms	20 Hz	31 / 24 Hz	4.9 mA	55 µA	5.0 mA

4.4 Sensor data

4.4.1 **Acceleration data**

The width of acceleration data is 10 bits given in two´s complement representation. The 10 bits for each axis are split into an MSB upper part (one byte containing bits 9 to 2) and an LSB lower part (one byte containing bits 1 and 0 of acceleration and a *(0x02, 0x04, 0x06) new_data* flag). Reading the acceleration data registers shall always start with the LSB part. The content of an MSB register is updated by reading the corresponding LSB register (shadowing procedure). The shadowing procedure can be disabled (enabled) by writing “1” (“0”) to the bit *shadow_dis*. With disabled shadowing, the content of both MSB and LSB registers is updated by a new value immediately. Unused bits of the LSB registers are fixed to 0. The *(0x02, 0x04, 0x06) new_data* flag of each LSB register is set if the data registers are updated, it is reset if either the corresponding MSB or LSB part is read.

Two different streams of acceleration data are available, unfiltered and filtered. The unfiltered data is sampled with 2kHz. The sampling rate of the filtered data depends on the selected filter bandwidth; it is twice the bandwidth. Which kind of data is stored in the acceleration data registers depends on bit *(0x13) data_high_bw*. If *(0x13) data_high_bw* is “0” (“1”), then filtered (unfiltered) data is stored in the registers. Both data streams are separately offset-compensated. Both kinds of data can be processed by the interrupt controller.

The bandwidth of filtered acceleration data is determined by setting the *(0x10) bw* bit as follows:

Table 9: Bandwidth configuration

bw	**Bandwidth**	**Update Time t_{ut}**
00xxx	*)	-
01000	7.81Hz	64ms
01001	15.63Hz	32ms
01010	31.25Hz	16ms
01011	62.5Hz	8ms
01100	125Hz	4ms
01101	250Hz	2ms
01110	500Hz	1ms
01111	1000Hz	0.5ms
1xxxx	*)	-

*) Note: Settings 00xxx result in a bandwidth of 7.81 Hz; settings 1xxxx result in a bandwidth of 1000 Hz. It is recommended to actively use the range from “01000b” to “01111b” only in order to be compatible with future products.

The BMC050's accelerometer part supports four different acceleration measurement ranges. A measurement range is selected by setting the *(0x0F)* range bits as follows:

Table 10: Range selection

Range	Acceleration measurement range	Resolution
0011	±2g	3.91mg/LSB
0101	±4g	7.81mg/LSB
1000	±8g	15.62mg/LSB
1100	±16g	31.25mg/LSB
others	reserved	-

4.4.2 **Temperature data**

The width of temperature data is 8 bits given in two´s complement representation. Temperature values are available in the *(0x08) temp* register.

The slope of the temperature sensor is 0.5K/LSB, its center temperature is 24°C [*(0x08) temp* = 0x00]. Therefore, the typical temperature measurement range is -40°C up to 87.5°C.

4.4.3 **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 6 for detailed register descriptions.

4.4.4 Magnetic field data temperature compensation

The raw register values DATAX, DATAY, DATAZ and RHALL are read out from the host processor using the BMC050 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:

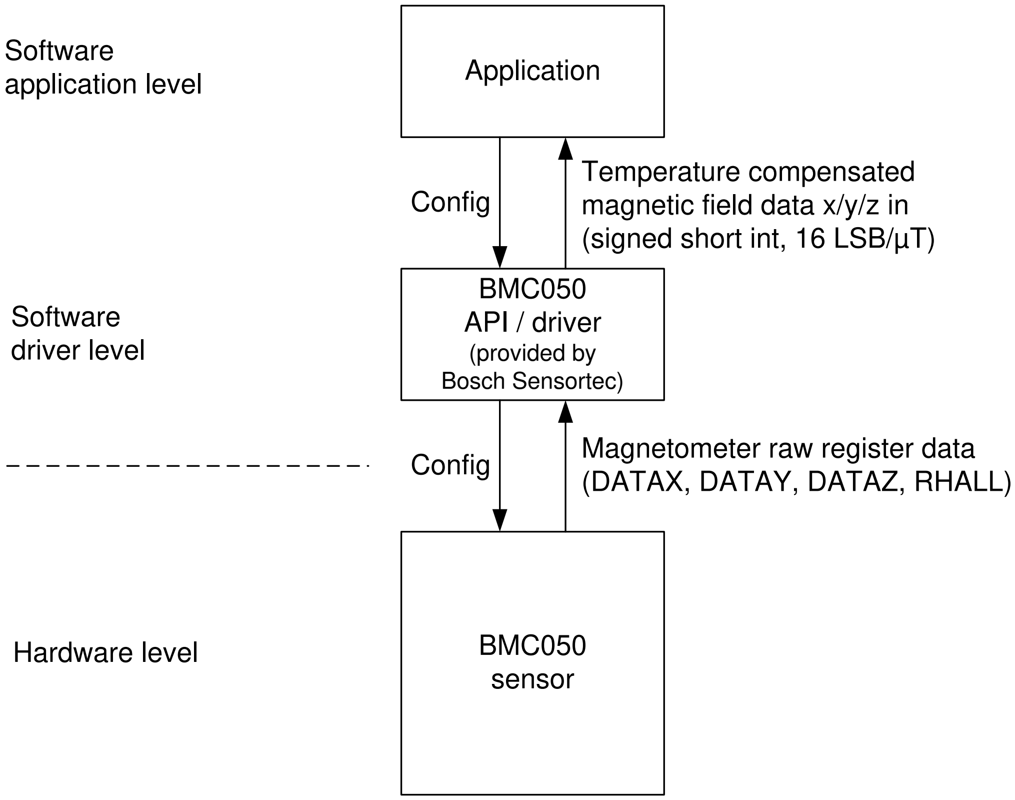

Figure 5: Calculation flow of magnetic field data from raw BMC050 register data

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.