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Data sheet

BMC156
6-axis eCompass

Bosch Sensortec

BOSCH
Invented for life

BMC156: Data sheet

Document revision	1.0
Document release date	16 July 2014
Document number	BST-BMC156-DS000-01
Technical reference code(s)	0 273 141 193
Notes	Data in this document are subject to change without notice. Product photos and pictures are for illustration purposes only and may differ from the real product's appearance. Not intended for publishing.

BMC156

ECOMPASS WITH 3-AXIS GEOMAGNETIC SENSOR AND 12 BIT 3-AXIS ACCELEROMETER

Key features

Three-axis magnetic field sensor and 12bit three-axis accelerometer in one package

- Accelerometer can still be used independently from magnetometer operation
- Ultra-Small package — 12-Pin LGA package, footprint 2.2 × 2.2mm^2, height 0.95 mm
- Digital interface — SPI (4-wire, 3-wire), I²C, 2 interrupt pins (1 acceleration sensor, 1 magnetic sensor interrupt pin)
- 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 — ±1300µT (x, y-axis), ±2500µT (z-axis); Magnetic field resolution of ~0.3µT
- On-chip FIFO — Integrated FIFO with a depth of 32 frames
- 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
- 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
- Temperature sensor
- 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
- Gaming

General Description

The BMC156 is an integrated electronic compass solution for consumer market applications. It comprises a 12bit 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 BMC156 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 BMC156 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 BMC156 senses orientation, tilt, motion, shock, vibration and heading in cell phones, handhelds, computer peripherals, man-machine interfaces, virtual reality features and game controllers.

Index of Contents

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 BMC156.

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}	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	$0.8V_{DDIO}$			-

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
Total Supply Current in Normal Mode	I_{DD}	T_A=25°C, bw = 1kHz V_{DD} = V_{DDIO} = 2.4V		130		µA
Total Supply Current in Low-Power Mode 1	I_{DDlp1}	T_A=25°C, bw = 1kHz V_{DD} = V_{DDIO} = 2.4V sleep duration = 25ms		6.5		µA
Total Supply Current in Low-Power Mode 2	I_{DDlp2}	T_A=25°C, bw = 1kHz V_{DD} = V_{DDIO} = 2.4V sleep duration = 25ms		66		µA
Total Supply Current in Deep Suspend Mode	$I_{DDsm,a}$	T_A=25°C V_{DD} = V_{DDIO} = 2.4V		1		µA
Total Supply Current in Suspend Mode	I_{DDsum}	T_A=25°C V_{DD} = V_{DDIO} = 2.4V		2.1		µA
Total Supply Current in Standby Mode	I_{DDsbm}	T_A=25°C V_{DD} = V_{DDIO} = 2.4V		62		µA
Wake-Up Time 1	$t_{w\_up,a1}$	from Low-power Mode 1 or Suspend Mode or Deep Suspend Mode bw = 1kHz		1.3	1.8	ms
Wake-Up Time 2	$t_{w\_up,a2}$	from Low-power Mode 2 or Stand-by Mode bw = 1kHz		1.0	1.2	µs
Start-Up Time	$t_{s\_up,a}$	POR, bw = 1kHz			3	ms
Non-volatile memory (NVM) write-cycles	n_{NVM}				15	cycles

Parameter	Symbol	Condition	Min	Typ	Max	Unit
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}		0.98		mg
Sensitivity	S_{2g}	g_{FS2g}, T_A=25°C		1024		LSB/g
	S_{4g}	g_{FS4g}, T_A=25°C		512		LSB/g
	S_{8g}	g_{FS8g}, T_A=25°C		256		LSB/g
	S_{16g}	g_{FS16g}, T_A=25°C		128		LSB/g
Sensitivity Temperature Drift	TCS_a	g_{FS2g}, Nominal V_{DD} supplies		±0.02		%/K
Zero-g Offset	Off	g_{FS2g}, T_A=25°C, nominal V_{DD} supplies, over life-time		±80		mg
Zero-g Offset Temperature Drift	TCO	g_{FS2g}, Nominal V_{DD} supplies		±1		mg/K
Bandwidth	bw_8	2nd order filter, bandwidth programmable		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, g_{FS2g}		±0.5		%FS
Output Noise Density	$n_{rms,a}$	g_{FS2g}, T_A=25°C Nominal V_{DD} supplies Normal mode		150		µg/√Hz

Temperature Sensor Measurement Range	T_S		-40		85	°C
Temperature Sensor Slope	dT_S			0.5		K/LSB
Temperature Sensor Offset	OT_S			±2		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[2]		±1300		μT
	$B_{rg,z}$			±2500		μT
Magnetometer heading accuracy [3]	$Ac_{heading}$	30μT horizontal geomagnetic field component, T_A=25°C			±2.5	degree
System heading accuracy[4]	$As_{heading}$	30μT horizontal geomagnetic field component, T_A=25°C			±3.0	degree
Supply Current in Active Mode (average)[5]	$I_{DD,lp,m}$	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
Peak logic supply current in active mode	$I_{DDIOpk,m}$	Only during measurement phase Nominal V_{DDIO} supplies T_A=25°C		210		μA

[2] Full linear measurement range considering sensor offsets.
[3] The heading accuracy depends both on hardware and software. For detailed information of the software performance please contact Bosch Sensortec.
[4] Heading accuracy of the tilt-compensated 6-axis eCompass system, assuming calibration with Bosch Sensortec eCompass software (only available for Android and Windows operating sytems and requires the conclusion of a software licence agreement). Average value over various device orientations (typical device usage).
[5] For details on magnetometer current consumption calculation refer to chapter 4.2.2 and 4.2.3.

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

MAGNETOMETER OUTPUT SIGNAL

Parameter	Symbol	Condition	Min	Typ	Max	Unit
Device Resolution	$D_{res,m}$	T_A=25°C		0.3		µT
Gain error[6]	$G_{err,m}$	After API temperature compensation T_A=25°C Nominal V_{DD} supplies		±2		%
Sensitivity Temperature Drift	TCS_m	After API temperature compensation -40°C ≤ T_A ≤ +85°C Nominal V_{DD} supplies		±0.01		%/K
Zero-B offset	OFF_m	T_A=25°C		±40		µT
Zero-B offset	$OFF_{m,cal}$	After software calibration with Bosch Sensortec eCompass software[7] -40°C ≤ T_A ≤ +85°C		±2		µT
Zero-B offset Temperature Drift	TCO_m	-40°C ≤ T_A ≤ +85°C Nominal V_{DD} supplies		±0.07		µT/K
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

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

[7] Magnetic zero-B offset assuming calibration with Bosch Sensortec eCompass software (only available for Android and Windows operating sytems and requires the conclusion of a software licence agreement). Typical value after applying calibration movements containing various device orientations (typical device usage).

	$n_{rms,lp,m,z}$	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 BMC156. At or above these maximum ratings operability is not given. The specification limits in Chapter 1 only apply under normal operating conditions.

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
None-volatile memory (NVM) Data Retention	T = 85°C, after 15 cycles	10		year
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
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 BMC156:

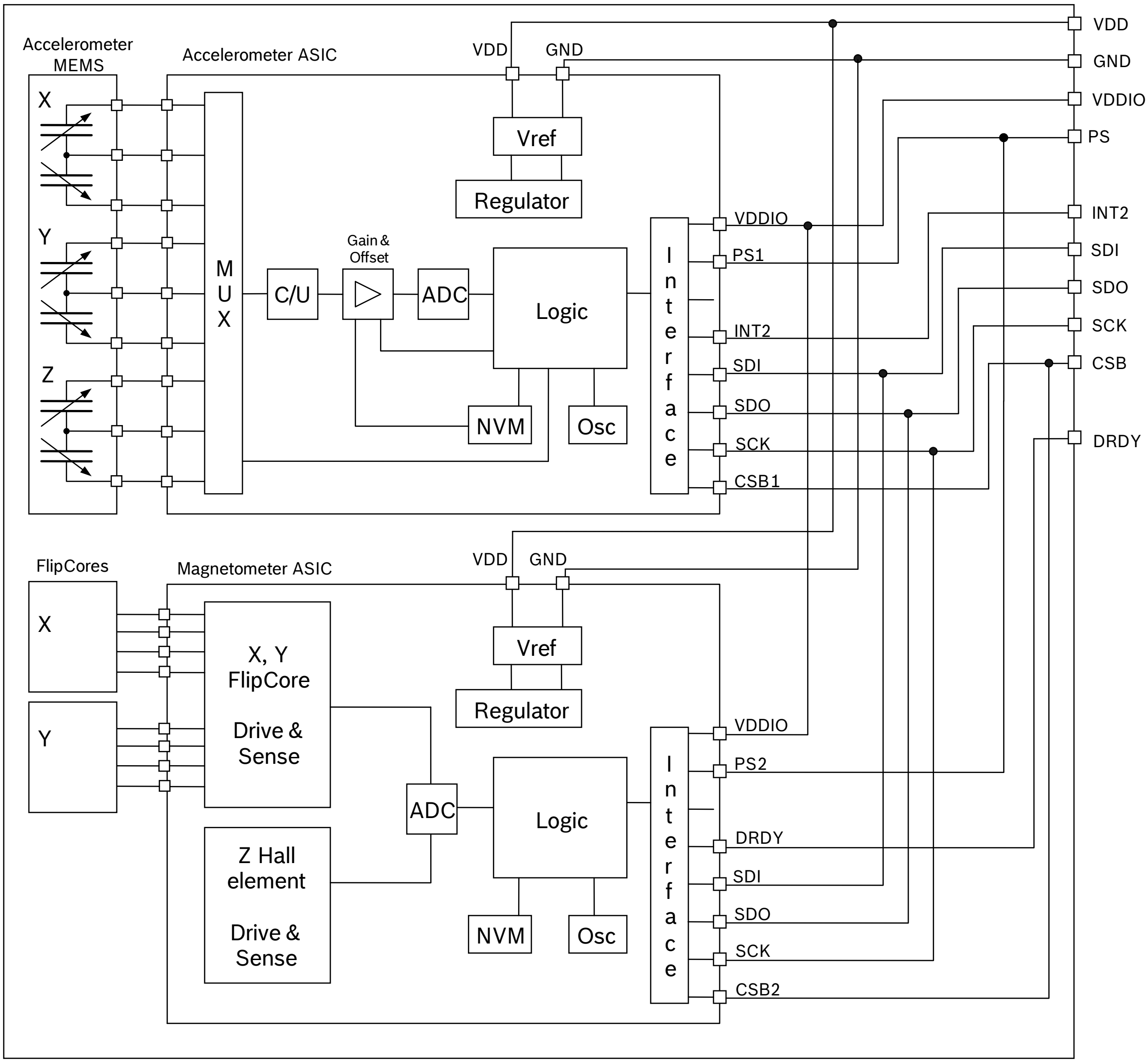

Figure 1: Block diagram of BMC156

4. Functional description

BMC156 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), which allows an independent operation of accelerometer and magnetometer parts in order to fit into a wide range of usage scenarios.

4.1 Supply voltage and power management

The BMC156 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 within operating range 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 → [SDI & SDO & SCK & CSB] ≠ 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}. Please note, that all application specific settings which are not equal to the default settings (refer to register maps chapter 6.2 and 7.2), must be re-set to its designated values after POR.
There are no constraints 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 pin is needed in order to ensure reliable protocol selection. For SPI interface mode the PS pin must be directly connected to GND.

4.2 Power modes

The BMC156 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.

4.2.1 **Accelerometer power modes**

The BMC156 accelerometer part has six different power modes (see Figure 2). Besides normal mode, which represents the fully operational state of the device, there are five energy saving modes: deep-suspend mode, suspend mode, standby mode, low-power mode 1 and low-power mode 2.

The possible transitions between the power modes are illustrated in Figure 2 :

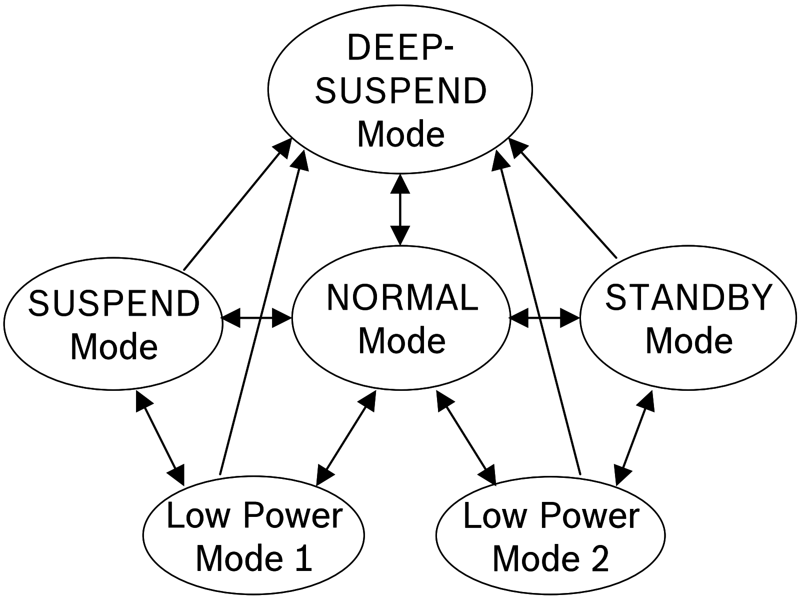

Figure 2: Power mode transition diagram

After power-up the accelerometer part of BMC156 is in normal mode so that this part is held powered-up and data acquisition is performed continuously.

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 (left) by writing ‘1’ (‘0’) to the *(0x11) deep_suspend* bit while *(0x11) suspend* bit is set to ‘0’.. The I^{2}C watchdog timer remains functional. The *(0x11) deep_ suspend* bit, the *(0x34) spi3* bit, *(0x34) i2c_wdt_en* bit and the *(0x34) i2c_wdt_sel* bit are functional in deep-suspend mode. Equally the interrupt level and driver configuration registers *(0x20) int2_lvl*, and *(0x20) int2_od* are accessible. Still it is possible to enter normal mode by performing a softreset as described in chapter 4.8. Please note, that all application specific settings which are not equal to the default settings (refer to 6.2), must be re-set to its designated values after leaving deep-suspend mode.

In **suspend mode** the whole analog part is powered down. No data acquisition is performed. While in suspend mode the latest acceleration data and the content of all configuration registers are kept. Writing to and reading from registers is supported except from the (0x3E) fifo_config_1, (0x30) fifo_config_0 and (0x3F) fifo_data register. It is possible to enter normal mode by performing a softreset as described in chapter.7.6.

Suspend mode is entered (left) by writing ´1´ (´0´) to the *(0x11) suspend* bit after bit *(0x12) lowpower_mode* has been set to '0'. 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 8.2.1).

In **standby mode** the analog part is powered down, while the digital part remains largely operational. No data acquisition is performed. Reading and writing registers is supported without any restrictions. The latest acceleration data and the content of all configuration registers are kept. Standby mode is entered (left) by writing ´1´ (´0´) to the *(0x11) suspend* bit after bit *(0x12) lowpower_mode* has been set to '1'. It is also possible to enter normal mode by performing a softreset as described in chapter 7.6.

In **low-power mode 1**, 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. The sleep phase essentially corresponds to operation in suspend mode. Low-power mode is entered (left) by writing ´1´ (´0´) to the *(0x11) lowpower_en* bit after bit *(0x12) lowpower_mode* has been set to '0'. Read access to registers is possible except from the *(0x3F) fifo_data* register. However, unless the register access is synchronised with the wake-up phase, the restrictions of the suspend mode apply.

Low-power mode 2 is very similar to low-power mode 1, but register access is possible at any time without restrictions. It consumes more power than low-power mode 1. In low-power mode 2 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. The sleep phase essentially corresponds to operation in standby mode. Low-power mode is entered (left) by writing ´1´ (´0´) to the *(0x11) lowpower_en* bit with bit *(0x12) lowpower_mode* set to '1'.

The timing behaviour of the low-power modes 1 and 2 depends on the setting of the *(0x12) sleeptimer_mode* bit. When *(0x12) sleeptimer_mode* is set to '0', the event-driven time-base mode (EDT) is selected. In EDT the duration of the wake-up phase depends on the number of samples required by the enabled interrupt engines. 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 immediately after the required number of acceleration samples have been taken and an active interface access cycle has ended. The EDT mode is recommended for power-critical applications which do not use the FIFO. Also, EDT mode is compatible with legacy BST sensors.

Figure 3 shows the timing diagram for low-power modes 1 and 2 when EDT is selected.

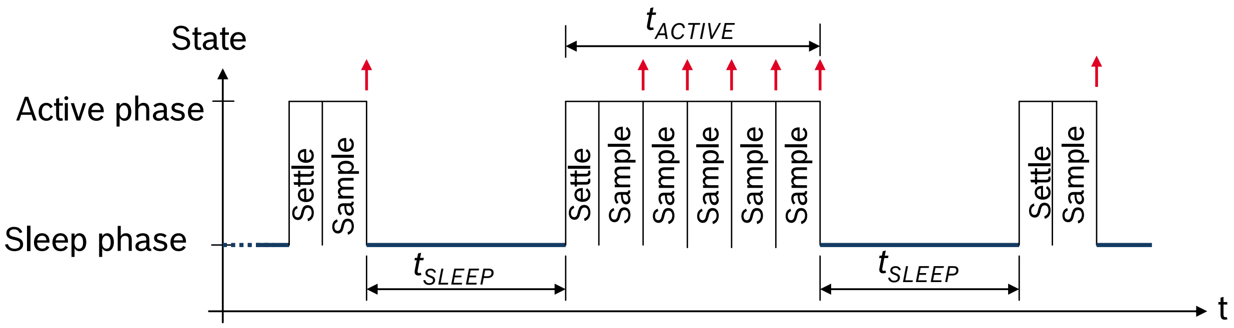

Figure 3: Timing Diagram for low-power mode ½, EDT

When *(0x12) sleeptimer_mode* is set to '1', the equidistant-sampling mode (EST) is selected. The use of the EST mode is recommended when the FIFO is used since it ensures that equidistant samples are sampled into the FIFO regardless of whether the active phase is extended by active interrupt engines or interface activity. In EST mode the sleep time $t_{SLEEP,a}$ is defined as shown in Figure 4. The FIFO sampling time $t_{SAMPLE,a}$ is the sum of the sleep time $t_{SLEEP,a}$ and the sensor data sampling time $t_{SSMP,a}$. Since interrupt engines can extend the active phase to exceed the sleep time $t_{SLEEP,a}$, equidistant sampling is only guaranteed if the bandwidth has been chosen such that $1/(2 * bw) = n * t_{SLEEP,a}$ where n is an integer. If this condition is infringed, equidistant sampling is not possible. Once the sleep time has elapsed the device will store the next available sample in the FIFO. This set-up condition is not recommended as it may result in timing jitter.

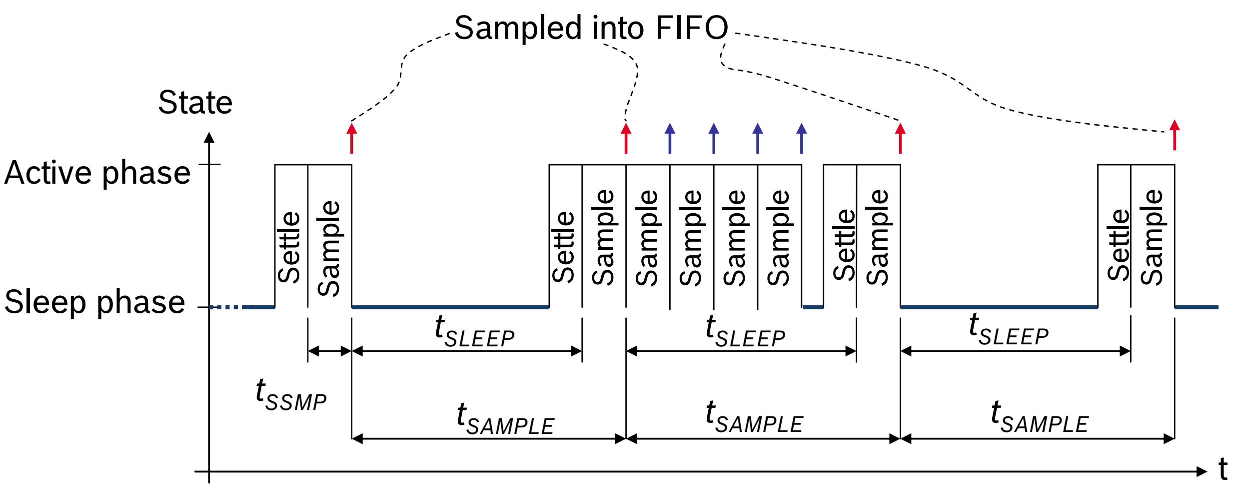

Figure 4: Timing Diagram for low-power mode ½, EST

The sleep time for lower-power mode 1 and 2 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 $t_{SLEEP,a}$
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 BMC156 accelerometer part in low-power mode 1 (I_{DDlp1}) and low-power mode 2 (I_{DDlp2}) can be estimated with the following formulae:

$$I_{DDlp1,a} \approx \frac{t_{sleep,a} \cdot I_{DDsum,a} + t_{active,a} \cdot I_{DD,a}}{t_{sleep,a} + t_{active,a}}$$

$$I_{DDlp2,a} \approx \frac{t_{sleep,a} \cdot I_{DDsbm,a} + t_{active,a} \cdot I_{DD,a}}{t_{sleep,a} + t_{active,a}}$$

When estimating the length of the wake-up phase t_{active}, the corresponding typical wake-up time, $t_{w,up1}$ or $t_{w,up2}$ and t_{ut} (given in table 5) have to be considered:

If bandwidth is >=31.25 Hz:
$t_{active} = t_{ut} + t_{w,up1} - 0.9\ ms$ (or $t_{active} = t_{ut} + t_{w,up2} - 0.9\ ms$)
else:
$t_{active} = 4\ t_{ut} + t_{w,up1} - 0.9\ ms$ (or $t_{active} = 4\ t_{ut} + t_{w,up2} - 0.9\ ms$)

During the wake-up phase all analog modules are held powered-up, while during the sleep phase most analog modules are powered down. Consequently, a wake-up time of at least $t_{w,up1}$ ($t_{w,up2}$) is needed to settle the analog modules so that reliable acceleration data are generated.

4.2.2 Magnetometer power modes

The BMC156 magnetometer part features configurable power modes. The four power modes of the BMC156 magnetometer are decribed in the following chapters.

Power off mode

In Power off mode, V_{DD} and/or V_{DDIO} 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 raised above their detection thresholds.

Suspend mode

Suspend mode is the default power mode of BMC156 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 which store power control bit information and SPI 3 wire enable can be accessed by the user. 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 loose their content, except the control register (*0x4B*). In particular, in this mode a Chip ID read (register *0x40*) returns "0x00" (I^2C) 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 7.6). 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 BMC156. Also, different data output rates from the ones selectable in normal mode can be achieved using forced mode.

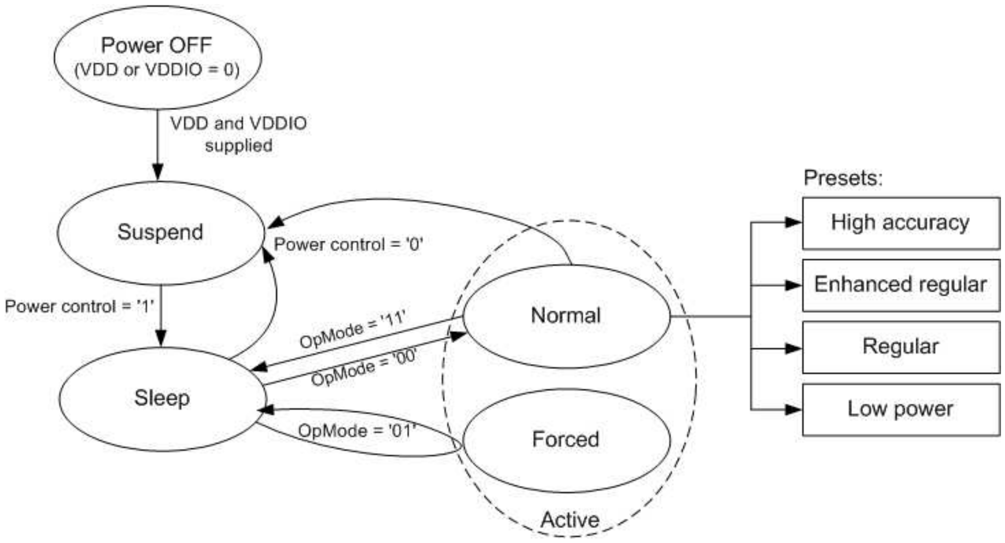

Figure 5: Magnetometer power mode transition diagram

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 7).

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 BMC156 magnetometer part.

The four presets consist of the below register configurations, which are automatically set by the BMC156 API or driver provided by Bosch Sensortec when a preset is selected. Table 6 shows the recommended presets and the resulting magnetic field output noise and magnetometer part current consumption:

Table 6: 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

4.2.3 **BMC156 overall power consumption**

Below, Table 7 shows the overall current consumption of BMC156 (sum of accelerometer and magnetometer part) in typical scenarios such as a tilt-compensated electronic compass application.

Table 7: BMC156 overall current consumption in typical usage scenarios:

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