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BMM350

3-axis magnetic sensor with high data rate

BST-BMM350-DS001-27

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高数据速率三轴磁传感器

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1. Basic Description

The BMM350 is a 3-axis magnetic sensor which operates in automatic mode or triggered mode. The magnetic-to-digital conversion technology is based on TMR (tunnel magneto resistance)

The BMM350 is designed to meet all requirements for high performance consumer applications such as magnetic compass, virtual, augmented and mixed reality applications and high-end gaming, platform stabilization applications such as image stabilization, or indoor navigation and dead-reckoning, for example in robotics applications.

Evaluation circuitry converts the output of the magnetic transducer sensing structures, developed, produced and tested in BOSCH facilities. The corresponding chip-sets are packed into one single WLCSP 1.28mm x 1.28mm x 0.5mm housing. For optimum system integration the BMM350 is fitted with digital interfaces (I2C, I3C), offering a wide VDDIO voltage range from 1.72V to 3.6V. To provide maximum performance and reliability each device is tested and ready-to-use calibrated.

The BMM350 has an excellent temperature behaviour with an outstanding low temperature coefficients of the offset (TCO) and of the sensitivity (TCS).

An API is provided for quick integration into the target system.

Key features

Three-axis magnetic field sensor

• Ultra-Small package	**W**afer **L**evel **C**hip **S**cale **P**ackage (9 pins, 0.4mm ball pitch) footprint 1.28 x 1.28 mm^2, height 0.5 mm
• Digital interface	I2C, I3C, 1 interrupt pin, 1 pin for I2C/I3C (legacy) address definition
• Low voltage operation	V_{DD} supply voltage range: 1.72V to 1.98V V_{DDIO} interface voltage range: 1.72V to 3.6V
• Flexible functionality	Magnetic field range typical: ±2000µT (x, y-axis), ±2000µT (z-axis) Magnetic field resolution of ~0.1µT
• On-chip interrupt controller	Interrupt-signal generation for new data
• Ultra-low power	Low current consumption (typ. 200µA @ 100 Hz in regular power preset), short wake-up time
• Normal and forced mode	periodic operation (normal mode) and triggered operation (forced mode)
• Temperature range	-40 °C ... +85 °C
• RoHS compliant, halogen-free	

1. 基本描述

BMM350是一款 一个三轴 磁力传感器 哪个 工作于 自动 mode 或触发模式 模式。磁-数字转换技术基于隧道磁阻（TMR）。

BMM350专为满足高性能消费应用的所有需求而设计，例如磁力计、虚拟、增强和混合现实应用以及高端游戏；平台稳定应用，如图像稳定或室内导航和航位推算；以及机器人应用等。

评估电路转换磁传感器感测结构的输出，这些结构由博世设施开发、生产和测试。相应的芯片组封装在1.28mm x 1.28mm x 0.5mm的WLCSP外壳中。为优化系统集成，BMM350配备了数字接口（I2C、I3C），提供1.72V至3.6V的宽VDDIO电压范围。为确保最佳性能和可靠性，每个器件均经过测试并预校准，可直接使用。

BMM350具有出色的温度特性，其偏移量（TCO）和灵敏度（TCS）的温度系数极低。

提供API以便快速集成至目标系统。

主要特性

三轴磁场传感器

• 超小型封装	晶圆级芯片尺寸封装 (9针，0.4毫米球间距) 占位面积1.28 x 1.28毫米 ^{2}, 高度0.5毫米
• 数字接口	I2C、I3C、1个中断引脚、1个用于I2C/I3C（传统）地址定义的引脚
• 低电压操作	V_{DD} 电源电压范围：1.72V至1.98V V_{DDIO} 接口电压范围：1.72V至3.6V
• 灵活功能	磁场范围典型值： ±2000微特斯拉（X、Y轴），±2000微特斯拉（Z轴） ~0.1微特斯拉磁场分辨率
• 片上中断控制器	新数据中断信号生成
• 超低功耗	低电流消耗（典型值200微安 @ 100赫兹，常规电源预设） 短唤醒时间
• 正常和强制模式	周期性操作（正常模式）和触发操作（强制模式）
• 温度范围	-40 摄氏度 ... +85 摄氏度
• 符合RoHS标准，无卤素	

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 with accelerometer
- Gaming (AR/VR)

General Description

The BMM350 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 TMR technology, performance and features of BMM350 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 digital interfaces I2C or I3C.

Package and interfaces of the BMM350 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 1.28 x 1.28 x 0.5 mm^3 ensures high flexibility in PCB placement.

The BMM350 offers low voltage operation (V_{DD} voltage range from 1.72V to 1.98V, V_{DDIO} voltage range 1.72V to 3.6V) and can be programmed to optimize functionality, performance and power consumption in customer specific applications.

The BMM350 senses the three axis of the terrestrial field in cell phones, handhelds, computer peripherals, man-machine interfaces, virtual reality features and game controllers.

典型应用

- 磁航向信息
- 用于地图旋转、导航和增强现实的倾斜补偿电子罗盘
- 移动设备九自由度应用中的陀螺仪校准
- 室内导航，例如与加速度计结合的计步功能
- 游戏（增强现实/虚拟现实）

概述

BMM350是一款面向消费市场应用的独立地磁传感器，可测量三个垂直轴上的磁场。基于博世专有的隧道磁阻技术，BMM350的性能与功能经过精心调校，完美契合所有三轴移动应用的严苛需求，如电子罗盘、导航或增强现实。

评估电路（专用集成电路）将地磁传感器的输出转换为数字结果，这些结果可通过数字接口I2C或I3C读取。

BMM350的封装和接口设计可满足多种硬件要求。由于该传感器具有超小尺寸和扁平封装，非常适合移动应用。尺寸仅为1.28 x 1.28 x 0.5毫米^3 的晶圆级芯片尺寸封装（WLCSP）确保了在印刷电路板布局上的高度灵活性。

BMM350支持低电压操作（V_{DD} 电压范围1.72V至1.98V，V_{DDIO} 电压范围1.72V至3.6V），并可编程以优化客户特定应用中的功能性、性能和功耗。

BMM350可感知手机、手持设备、计算机外设、人机界面、虚拟现实功能和游戏控制器中的地磁场三轴。

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2. Specification

If not stated otherwise, the given values with minimum/maximum values are mean ±3σ, typical values are mean ±1σ. Room temperature (RT) refers to 25°C, a full-scale sweep (FSS) refers to ±2000 μT. Values are given after API correction. Data refers to parts soldered on PCB and without underfill or encapsulation.

2.1 Electrical operation conditions

Table 1: Electrical operation conditions

Parameter	Symbol	Condition	Min	Typ	Max	Unit
Supply Voltage Internal Domains	VDD		1.72		1.98	V
Supply Voltage I/O Domain	VDDIO		1.72		3.6	V
Voltage Input Low Level	$V_{IL,a}$	I2C&I3C			0.3VDDIO	-
Voltage Input High Level	$V_{IH,a}$	I2C&I3C	0.7VDDIO			-
Voltage Output Low Level	$V_{OL,a}$	I_{OL}<= 2mA			0.23VDDIO	-
Voltage Output High Level	V_{OH}	I_{OH} <= 2mA	0.8VDDIO			-
Operating Temperature	T_A		-40		+85	°C
Current in normal mode	$I_{dd,n,rp}$ $I_{DD,ref}$	ODR=100, 25°C, averaging=2 samples (regular power setting)		200		uA
	$I_{dd,n,ln}$	ODR=100, 25°C , averaging=4 samples (low noise)		350		uA
Current in suspend mode	$I_{dd,sus}$	data retention		1.8		uA
Peak supply current in active mode (normal or forced mode)	$I_{DDpk,m}$	In measurement phase T_A=25°C, before bit reset		3.5		mA
Sensor start-up time (suspend to normal mode)[1]	T_{sus2nm}	Start-up time from suspend mode to normal mode		70		ms
Sensor start-up time (OFF to suspend mode)	$T_{pon2sus}$	Start-up time from OFF to suspend mode		2.5		ms

2. 规格

若无特别说明，给出的最小值/最大值均为±3σ，典型值为±1σ。室温（RT）指25摄氏度，全量程扫描（FSS）指±2000 μ特斯拉。数值为API校正后数据。数据指焊接在印刷电路板上且无底部填充或封装的部件。

2.1 电气操作条件

表1：电气操作条件

参数	符号	条件	Min	Typ	Max	Unit
内部域电源电压	VDD		1.72		1.98	V
I/O域电源电压	VDDIO		1.72		3.6	V
输入电压低电平	伏特IL, a	I2C&I3C			0.3VDDIO	-
输入电压高电平	伏特IH, a	I2C&I3C	0.7VDDIO			-
电压输出低电平	伏特OL, a	I_{OL}<= 2毫安			0.23VDDIO	-
电压输出高电平	V_{OH}	I_{OH} <= 2毫安	0.8倍VDDIO电压			-
工作温度	T_A		-40		+85	°C
正常模式电流	$I_{dd,n,rp}$ $I_{DD,ref}$	输出数据速率=100, 25 摄氏度，平均=2样本 (常规电源设置)		200		uA
	$I_{dd,n,ln}$	输出数据速率=100, 25 摄氏度，平均 =4 样本 (低噪声)		350		uA
电流输入挂起模式	$I_{dd,sus}$	数据保留		1.8		uA
活动模式下的峰值供电电流模式（正常或强制模式）	$I_{DDpk,m}$	在测量阶段 T_A=25°C 时 位复位前		3.5		mA
传感器启动时间（挂起到正常模式）[1]	T_{sus2nm}	启动时间从挂起模式到正常模式		70		ms
传感器启动时间（关断到挂起模式）	$T_{pon2sus}$	从关机到挂起模式的启动时间		2.5		ms

2.2 Magnetometer output signal specification

Table 2: magnetometer property specification

Parameter	Symbol	Condition	Min	Typ	Max	Unit
Magnetic field range, all axes	R_{ng}		-2000		2000	µT
Zero-field offset drift before or after soldering	$off_{,ma}$	25°C		±25		µT
Zero-B offset	$OFF_{m,cal}$	After software calibration with Bosch Sensortec eCompass software[1] -40°C ≤ T_A ≤ +85°C		±2		µT
ODRs in normal mode	ODR	At room temperature, after soldering	Typ -2 %	400 200 100 50 25 25/2 25/4 25/8 25/16	Typ+2%	Hz
Maximum forced mode trigger frequency	FMT_f	averaging=0 only		200		Hz
Relative ODR drift over temperature	$ODR_{,dev,lr}$	Reduced temperature sweep [-5°C,65°C]	-3		3	%
	$ODR_{,dev,fr}$	Full temperature sweep [-40°C,85°C]	-4		4	%
3dB bandwidth	BW	by design		ODR/2		Hz

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

2.2 磁力计输出信号规格

表2：磁力计属性规格

参数	符号	条件	Min	Typ	Max	Unit
磁场 磁场范围, 所有轴	R_{ng}		-2000		2000	µT
零场偏移漂移 焊接前或 焊接后	关闭 ma	25°C		±25		µT
零磁偏置	关闭m,cal	使用博世传感器技术电子罗盘软件进行软件校准后[1]-40摄氏度 ≤ A ≤ T +85 摄氏度		±2		µT
正常模式下的 ODR	ODR	在室温 下, 之后 后	典型值-2%	400 200 100 50 25 25/2 25/4 25/8 25/16	典型值+2百分比	Hz
最大 强制模式 触发频率	FMT_f	平均=0 only		200		Hz
相对 输出数据速率 漂移 over 温度	$ODR_{,dev,lr}$	降低温 度 扫描[-5摄氏度,65摄氏度]	-3		3	%
	$ODR_{,dev,fr}$	全温度 扫描[-40摄氏度,85摄氏度]	-4		4	%
3分贝 带宽	BW	设计上		输出数据率/2		Hz

[1]假设使用博世传感器技术电子罗盘软件进行校准的磁零B偏移。应用包含各种器件方向的校准运动后的典型值（典型器件使用场景）。

Table 3: Magnetometer output signal

Parameter	Symbol	Condition	Min	Typ	Max	Unit
Sensitivity/gain error after soldering [2]	$G_{err,m}$	After API compensation T_A=25°C Nominal V_{DD} supplies x/y axis		+/-1		%
Sensitivity/gain error after soldering [3]	$G_{err,m}$	After API compensation T_A=25°C Nominal V_{DD} supplies Z axis		+/-3		%
Sensitivity Temperature Drift	TCS_m	After API compensation -40°C ≤ T_A ≤ +85°C Nominal V_{DD} supplies all axis		+/-0.010		%/K
TCO error	TCOerr	-40°C to 85°C		±200		nT/K
Hysteresis[4]	$hyst_{xy,\ \%FS}$	RT, after FSS, in % of FSS		0.02		%
	$hyst_{z,\ \%FS}$	RT, after FSS, no reset, in % of FSS		0.4		%
Integral Nonlinearity	$INL_{m,\ FS}$	Max. Deviation to best fit straight line x/y axis		±10		µT
Integral Nonlinearity	$INL_{m,\ FS}$	Max. Deviation to best fit straight line z axis		±20		µT
Output noise rms 3dB BW= ODR/2	$n_{rms,xy}$ x.y channel	ODR=100 averaging=2 samples		190		nTrms
	$n_{rms,z}$ z channel	ODR=100 averaging=2 samples		450		nTrms
Sensitivity drift after magnetic field shock recovery		250 mT	-100		+100	µT
Sensitivity drift after magnetic field shock recovery		250 mT	-1		+1	%

[2] Definition: *gain error* = ((*measured field after API compensation*) / (*applied field*)) – 1, gain measured between +/-1.2 mT
[3] Definition: *gain error* = ((*measured field after API compensation*) / (*applied field*)) – 1, gain measured between +/-1.2 mT
[4] BMM350 z-axis hysteresis after full-scale sweep can be cleared using magnetic reset.

表3：磁力计输出信号

参数	符号	条件	Min	Typ	Max	Unit
焊接后的灵敏度/增益误差 [2]	$G_{err,m}$	API后 补偿 T_A=25摄氏度 标称电压$_{DD}$ 供应x/y轴		+/-1		%
焊接后的灵敏度/增益误差[3]	$G_{err,m}$	API后 补偿 T_A=25摄氏度 标称电压$_{DD}$ 电源 Z轴		+/-3		%
灵敏度 温度漂移	TCS_m	API后 补偿 -40摄氏度 ≤ T_A ≤ +85摄氏度 标称电压$_{DD}$ 全轴供电		+/-0.010		%/K
TCO误差	TCOerr	-40°C至85°C		±200		nT/K
迟滞[4]	$hyst_{xy}$, 满量程百分比	RT, after FSS, 百分比 of FSS		0.02		%
	$hyst_z$, 满量程百分比	RT, after FSS, no 重置，满量程百分比		0.4		%
积分 非线性	非线性误差$_{m,\ FS}$	x/y轴最佳拟合直线最大偏差		±10		µT
积分 非线性	非线性误差$_{m,\ FS}$	z轴最佳拟合直线最大偏差		±20		µT
输出噪声均方根 3dB 带宽= 输出数据率/2	$n_{rms,xy}$ x.y通道	输出数据速率=100 平均=2 样本		190		噪声真有效值
	$n_{rms,z}$ z通道	输出数据速率=100 平均=2 样本		450		噪声真有效值
磁场后灵敏度漂移 冲击恢复		250毫特斯拉	-100		+100	µT
灵敏度漂移 磁场冲击恢复后		250毫特斯拉	-1		+1	%

[2] 定义: 增益误差 = ((*API*补偿后的测量磁场) / (施加磁场)) – 1, 增益测量范围 +/-1.2 毫特斯拉 [3] 定义: 增益误差 = ((*API*补偿后的测量磁场) / (施加磁场)) – 1, 增益测量范围 +/-1.2 毫特斯拉 [4] BMM350 z轴磁滞在全量程扫描后可通过磁复位清除。

3. Absolute maximum ratings

The absolute maximum ratings are provided in Table 4. At or above these maximum ratings operability is not given. The specification limits in chapter 2 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	2	V
	V_{DDIO} Pin	-0.3	3.6	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	+125	°C
None-volatile memory (OTP) Data Retention	T = 85°C	10		year
Mechanical Shock according to JESD22-B104C	Duration ≤ 500µs		20,000	g
	Drop in reel onto hard surfaces		2	m
ESD	HBM, at any Pin		±2	kV
	CDM		±500	V
Latch-up	LU		±100	mA
Magnetic field	Any direction[5]	-250	250	mT

Stress above those listed as “absolute maximum ratings” may cause permanent damage to the device. This is a stress rating only and functional operation of the device under these conditions is not implied. Exposure to maximum rating conditions for extended periods may affect device reliability.

[5] Field shock strengths up to BMFS = 400 mT tested; fields of 250 mT < BMFS < 400 mT will not damage the device but may lead to offset and sensitivity drifts above 100 uT and 1%, respectively.

3. 绝对最大额定值

绝对最大额定值见表4。达到或超过这些最大值时，设备将无法正常工作。第2章节的规格限制仅适用于正常工作条件。

表4：绝对最大额定值

参数	条件	Min	Max	Unit
供电引脚电压	V_{DD} Pin	-0.3	2	V
	V_{DDIO} Pin	-0.3	3.6	V
任意逻辑焊盘电压	非供电引脚	-0.3	VDDIO + 0.3	V
工作温度, T_A	主动运行	-40	+85	°C
被动存储温度范围	≤ 65百分比 rel. H.	-50	+125	°C
非易失性存储器（OTP）数据保留	T = 85摄氏度	10		year
机械冲击 according to JESD22-B104C	持续时间 ≤ 500微秒		20,000	g
	卷盘跌落至硬表面		2	m
ESD	人体模型, 任意引脚		±2	kV
	CDM		±500	V
闩锁效应	LU		±100	mA
磁场	任意方向[5]	-250	250	mT

超过“绝对最大额定值”所列的应力可能会对器件造成永久性损坏。这仅为应力评级，并不意味着器件在这些条件下的功能操作。长时间暴露在最大额定条件下可能会影响器件可靠性。

[5] 场冲击强度最高测试至BMFS = 400 毫特斯拉；250毫特斯拉 < BMFS < 400 毫特斯拉的磁场不会损坏器件，但可能导致偏移及灵敏度漂移分别超过100微特斯拉和1百分比。

4. Block diagram

Figure 1 shows the signal flow block diagram of the BMM350.

A magnetic transducer converts the magnetic field information in X, Y and Z direction into a differential voltage. An additional temperature transducer converts the ASIC die temperature into a differential voltage. A multiplexer selects the X, Y, Z or temperature channel in a predefined timing scheme and feeds the voltage into an amplifier which does a coarse correction for gain deviations. The ADC following that stage converts the analog differential signal into the digital domain. The API software running on the host processor reads out the X, Y, Z and temperature information and further applies gain, offset and temperature effect corrections. The API finally provides corrected X, Y, Z and temperature information to the host as floating point values.

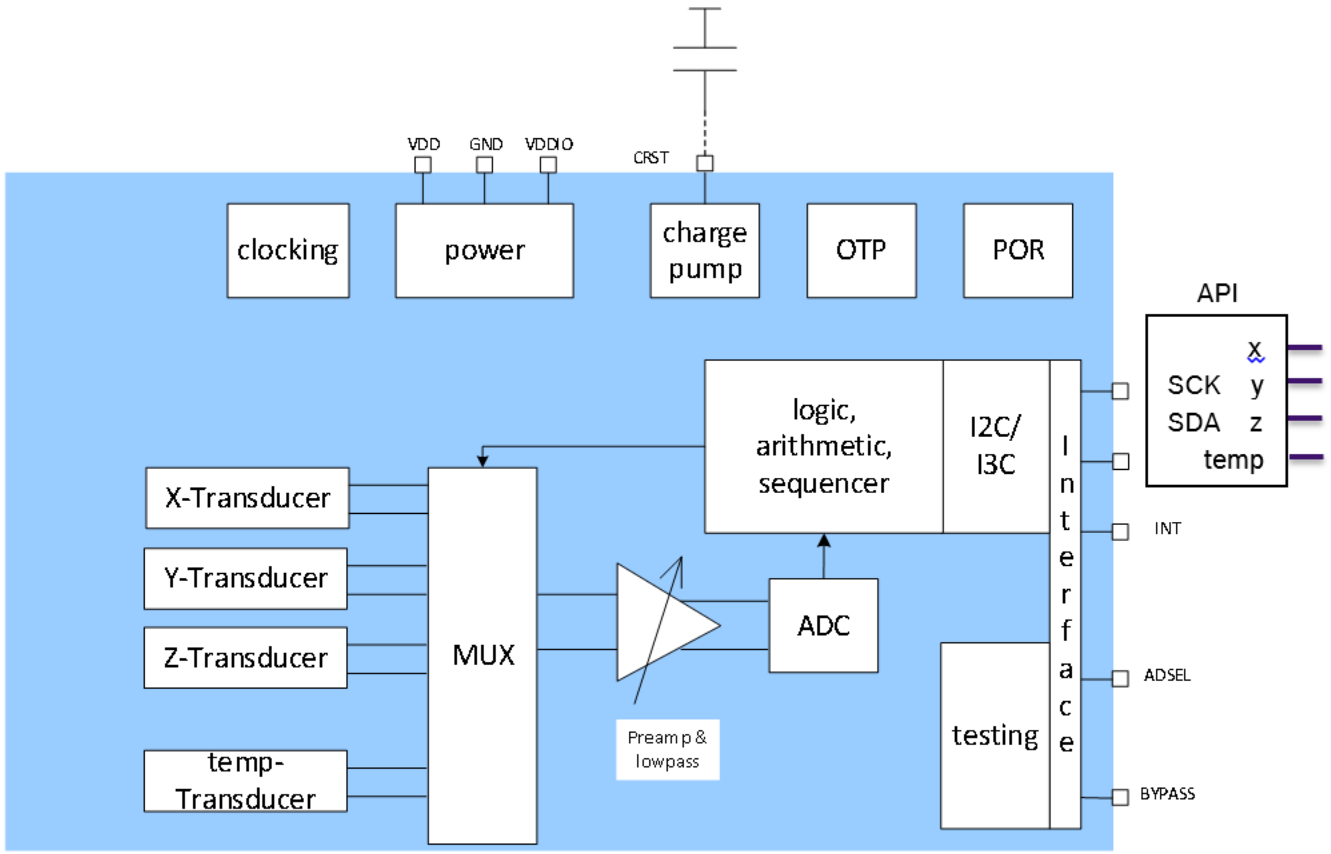


Figure 1: Block diagram

The data are made available via I3C or I2C interface. A data ready interrupt signals when new data are available, either via INT pin or via in-band-interrupt in I3C mode. If status polling is preferred a “data ready” status register can be read out on demand.

4. 框图

图1展示了BMM350的信号流框图。

磁传感器将X、Y和Z方向的磁场信息转换为差分电压。额外的温度传感器将ASIC芯片温度转换为差分电压。多路复用器按照预定义时序方案选择X、Y、Z或温度通道，并将电压馈入放大器进行增益偏差的粗校正。后续的模数转换器将模拟差分信号转换至数字域。运行在主机处理器上的API软件读取X、Y、Z及温度信息，并进一步应用增益、偏移和温度效应校正。最终API将校正后的X、Y、Z及温度信息以浮点值形式提供给主机。

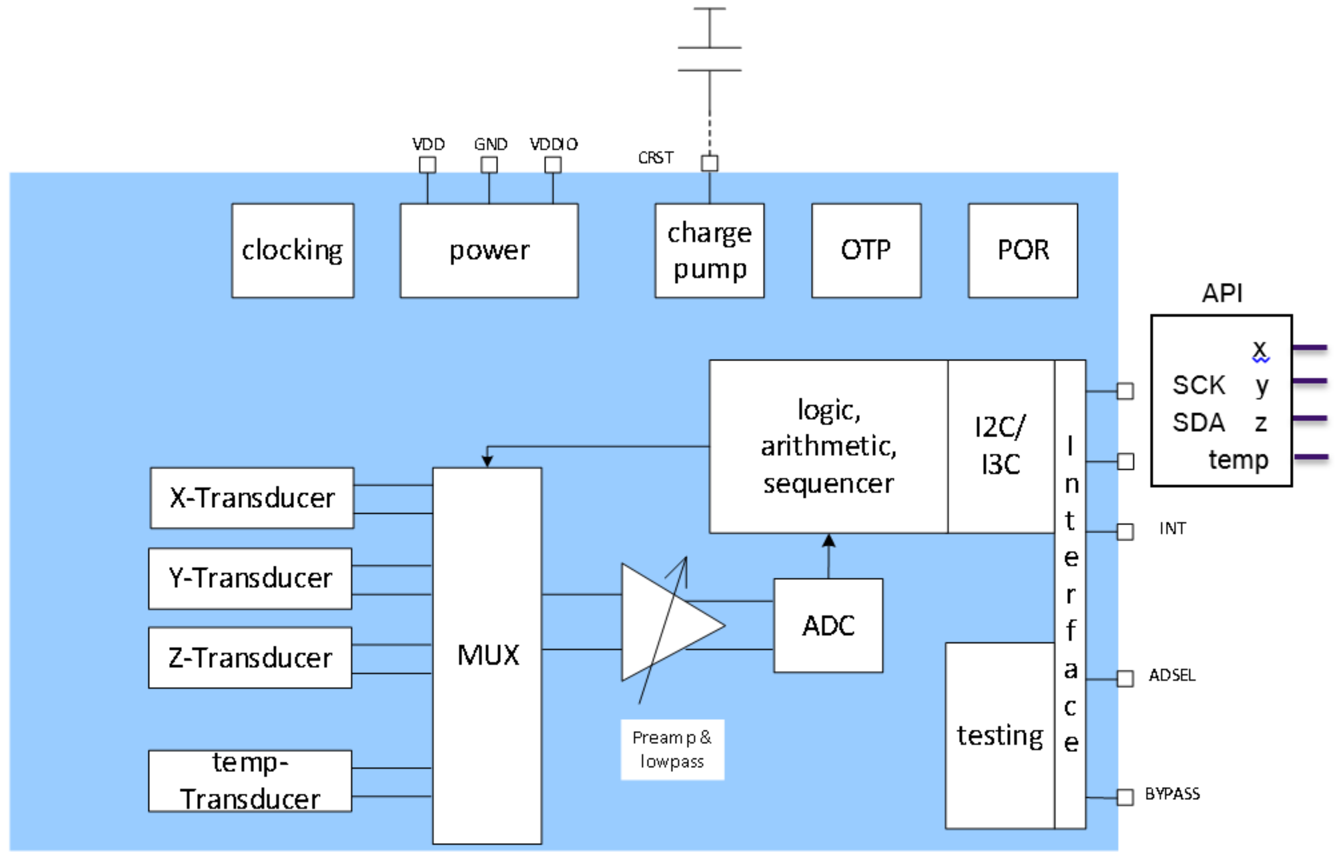


图1：框图

数据通过I3C或I2C接口提供。当有新数据可用时，会通过数据就绪中断发出信号，该中断可通过INT引脚或I3C模式下的带内中断触发。若偏好状态轮询方式，则可按需读取“数据就绪”状态寄存器。

5. Functional description

BMM350 is a triaxial standalone geomagnetic sensor (sensing element and ASIC) in wafer-level-chip-scale package and can be operated via I2C or I3C as a slave device.

The BMM350 has two distinct power supply pins:

- VDD is the main power supply for all internal analog and digital functional blocks;
- VDDIO is a separate power supply pin, used for the supply of the digital interface.

The device can be completely switched off (V_{DD} = 0V) while keeping the V_{DDIO} supply on (V_{DDIO} > 0V) or vice versa. When V_{DDIO}= 0 the voltages at IO pins must not exceed the specified limit of 300mV.

The BMM350 is highly configurable

The major IC control settings are
Power mode (normal, forced, suspend) see chapter 4.1
Data rate ODR, see chapter 4.4
Accuracy/noise, see chapter 4.4
Interrupt settings, see chapter 4.5
Pad drive strength, see chapter 4.6
Enabled axes, see chapter 4.7
I2C watchdog configuration, see chapter 9.1
I3C in-band-interrupt (IBI) configuration, see chapter 4.5.5
Sensortime always available, see chapter 4.8

Many registers provide status information:
CHIP_ID (product ID), see chapter 4.9.1
Interrupt status, see chapters 4.5 and 4.10
Error register, see chapter 4.9.3
PMU (power management) status, effective ODR and accuracy settings, see chapter 4.9.4
I3C errors, see chapter 4.9.5

Digital data registers provide **uncompensated** data about magnetic field strength, temperature and time:
Data registers for X,Y and Z magnetic channel and temperature channel
provide data in 24bit registers in 21bit signed-integer format (21LSBs used)

Sensor time is provided in 24bit format, unsigned integer, with 40us resolution.

For proper temperature compensation is it mandatory to either use the provided API functions or at least look at the API code for own software developments.
To obtain compensated data use API functions, described in chapter 7.

5. 功能描述

BMM350是一款采用晶圆级芯片尺寸封装的三轴独立地磁传感器（包含传感元件和专用集成电路），可作为从设备通过I2C或I3C接口操作。

BMM350 有两个独立的电源引脚：

- VDD 是所有内部模拟和数字功能模块的主电源；
- VDDIO 是一个独立的电源引脚，用于数字接口的供电。

该器件可在保持V_{DDIO} 供电开启(V_{DDIO} > 0V)的同时完全关闭(V_{DD} = 0V)，反之亦然。当V_{DDIO}= 0 时，IO引脚电压不得超过规定的300mV限值。

BMM350具有高度可配置性

主要集成电路控制设置为
电源模式(正常、强制、挂起)，参见章节4.1
数据速率ODR，参见章节4.4
精度/噪声，参见章节4.4
中断设置，参见章节4.5
焊盘驱动强度，参见章节4.6
启用轴，参见章节4.7
I2C看门狗配置，参见章节9.1
I3C带内中断(IBI)配置，参见章节4.5.5
传感器时间始终可用，参见章节4.8

许多寄存器提供状态信息：
CHIP_ID（产品ID），参见章节4.9.1
中断状态，参见章节4.5和4.10
错误寄存器，参见章节4.9.3
电源管理单元(PMU)状态、有效ODR和精度设置，参见章节4.9.4
I3C错误，参见章节4.9.5

数字数据寄存器提供关于磁场强度、温度和时间的**未补偿**数据：
X、Y和Z磁通道及温度通道的数据寄存器
以21位有符号整数格式（使用21个最低有效位）在24位寄存器中提供数据

传感器时间以24位格式、无符号整数形式提供，具有40微秒分辨率。

为实现正确的温度补偿，必须使用提供的API函数或至少参考API代码进行自主软件开发。

要获取补偿数据，请使用第7章中描述的API函数。

5.1 Power modes, boot procedure

The BMM350 knows two major modes of operation, “normal mode” and “forced mode”. “suspend mode” brings the device into minimal power consumption, where settings are retained and communication is possible while data conversions are stopped.
After boot, the device will be in suspend mode, consuming the least current possible offered by this device.
Immediately after boot the API downloads the compensation coefficients from the BMM350 OTP (one-time programmable memory).
This is handled automatically in the API function BMM350_init().
The boot phase must be terminated by writing 0x80 to `OTP_CMD_REG` (also done in BMM350_init*)*.
From then on the OTP is inaccessible to the API unless a power reset or soft reset triggers another boot.

Power modes are selected using register `PMU_CMD.pmu_cmd`.

An API function “BMM350_set_powermode” is provided which handles power mode settings.

5.1.1 Power off

In Power off, VDD and/or VDDIO are unpowered/below brownout threshold and the device does not operate. When only one of VDD or VDDIO is supplied, the magnetic sensor will still be in Power off. Power on/boot is performed immediately after both VDD and VDDIO are raised above their reset release thresholds.
The sequence of raising VDD and VDDIO is left to the user, both voltages can be raised in any desired order.
If power is stable, the internal OTP becomes accessible (OTP access granted).

5.1.2 Suspend mode

Suspend mode is the default power mode of BMM350 after the chip is powered and has finished booting when using BMM350_init API function. This function reads out the OTP which stores compensation coefficients.

Suspend mode can be reached on demand via sending a suspend mode request to register PMU_CMD.pmu_cmd, or it is reached automatically after finishing a “forced mode” conversion.
Current consumption in suspend mode is minimal, so, this mode is useful for periods when data conversion is not needed. Read and write of all registers is possible.

5.1.3 Normal mode

Normal mode is activated via register PMU_CMD.pmu_cmd.
An API function BMM350_set_powermode is provided which helps doing that.
In normal mode the internal oscillator triggers conversions with the chosen ODR (output data rate) with the accuracy that can be expected from an RC oscillator.

The noise performance, tightly coupled with the current consumption, is controlled via the “averaging” setting, see register PMU_CMD_AGGR_SET.avg . As the name indicates 1, 2, 4 or 8 data samples are generated internally and averaged before the result is written into the data register. This improves the noise performance at the cost of current consumption, which is increasing proportionally with the averaging factor setting.

Not all combinations of output data rate and averaging are possible, see Table 5.
An API function BMM350_set_performance is provided which helps setting the averaging/noise performance. The function checks for the combination of ODR and averaging setting and chooses the highest possible averaging setting if the desired averaging setting is too high.

5.1 电源模式，启动程序

BMM350有两种主要操作模式：“正常模式”和“强制模式”。“挂起模式”可使器件进入最低功耗状态，此时设置参数被保留且通信仍可进行，但数据转换会停止。

启动后，器件将处于挂起模式，消耗该器件提供的最小电流。
启动后，应用程序接口会立即从BMM350一次性可编程存储器中下载补偿系数。
可编程存储器）。
这会在API函数BMM350_init()中自动处理。
启动阶段必须通过向`OTP_CMD_REG`写入0x80来终止（此操作也在BMM350_init*)*中完成）。
此后，除非电源复位或软复位触发另一次启动，否则应用程序接口将无法访问一次性可编程存储器。

电源模式通过寄存器`PMU_CMD.pmu_cmd`进行选择。

提供了一个API函数“BMM350_set_powermode”，用于处理电源模式设置。

5.1.1 关机

在关机状态下，VDD和/或VDDIO断电/低于欠压阈值，器件不工作。当仅提供VDD或VDDIO其中之一的电压时，磁力传感器仍将处于关机状态。上电/启动操作会在VDD和VDDIO均超过其复位释放阈值后立即执行。

VDD与VDDIO的电压提升顺序由用户决定，两者可按任意期望顺序进行供电。
若电源稳定，内部一次性可编程存储器（OTP）将变为可访问状态（OTP访问授权）。

5.1.2 挂起模式

挂起模式是BMM350芯片上电并完成启动后的默认电源模式（使用BMM350_init API函数时）。该函数会读取存储补偿系数的一次性可编程存储器（OTP）。

可通过向寄存器PMU_CMD.pmu_cmd发送挂起模式请求主动进入挂起模式，或在完成“强制模式”转换后自动进入该模式。
挂起模式下的电流消耗极低，因此在无需进行数据转换的时段，此模式非常实用。此时仍可对所有寄存器进行读写操作。

5.1.3 正常模式

通过寄存器PMU_CMD.pmu_cmd可激活正常模式。
系统提供了API函数BMM350_set_powermode来辅助完成此操作。
在正常模式下，内部振荡器以选定的输出数据速率(ODR)触发数据转换，其精度符合RC振荡器的预期水平。

噪声性能（与电流消耗密切相关）通过“平均”设置进行调控，详见寄存器PMU_CMD_AGGR_SET.avg。如名称所示，系统内部会生成1、2、4或8个数据样本进行平均处理，再将结果写入数据寄存器。该功能以增加电流消耗为代价（消耗量与平均因子设置成比例上升）来提升噪声性能。

并非所有输出数据速率和平均的组合都可行，请参阅表5。
提供了一个API函数BMM350_set_performance，用于帮助设置平均/噪声性能。该函数会检查输出数据速率与平均设置的组合，若所需平均设置过高，则自动选择最高可行的平均设置。

Table 5: Allowed combinations of output data rate ODR and noise configuration/averaging and related current consumption in µA*.

Noise Mode, number of samples averaged	ODR 400Hz	ODR 200Hz	ODR 100Hz	ODR 50Hz	ODR 25Hz	ODR 12.5Hz	...	ODR 1.5625Hz
"Ultra Low Noise", avg=3 8 samples	-	-	-	325	180	108		50
"Low Noise", avg=2, 4 samples	-	-	335	175	96	57		25
"Regular Power", avg=1, 2 samples	-	370	190	100	55	33		15
"Low Power", avg=0, 1 sample	455	235	122	70	40	23		12

*Approximate values in µA, measurements only for a couple of samples, deviation from specification table possible

5.1.4 Forced mode

By using forced mode, it is possible to trigger new measurements at any rate as long it is below 200Hz. In forced mode, which is available only when the device resides in suspend mode, a conversion of all selected channels (register PMU_CMD_AXIS_EN.en_x/y/z) can be triggered via "forced mode request", writing 0x03 or 0x04 (FM or FM_FAST) into register "PMU_CMD". When finishing the forced mode data conversion the device returns into suspend mode.
The two flavors of forced mode, "FORCED_MODE (FM)" and "FORCED_MODE_FAST (FM_FAST)" shall be used for small (FM) or high (FM_FAST) data rates. For data rates of 25Hz or higher FM_FAST (0x04) can be used. For lower ODRs FM (0x03) must be used.
To reach ODR = 200Hz is only possible by using FM_FAST.
In case the time between BMM350_INIT and the first FM trigger exceeds 0.1s, FM (PMU_CMD = 0x03) has to be used. All further FM calls can then use the FM or FM_FAST depending on the ODR as described above.

A conversion (except the first sample after suspend mode) will carried out within <5e-3 seconds (avg=1sample, FM_FAST, up to 30ms for avg=8samples, FM) and data can be read via data register.

Conversion time will depend on the averaging setting and the choice of fast/normal forced mode; a high averaging value reduces the noise but increases the current consumption as well as the conversion time.
The conversion is guaranteed to finish within the relative timing precision/drift that can be expected from the internal RC oscillator, up to +/-2%.
The "data ready" interrupt or data ready status registers can be used to read data with minimum delay.
A programming example is provided which shows how to poll the status register to achieve high data rates and low latencies.

A temperature conversion will be done for every forced mode trigger.

When a forced mode request is issued before an ongoing forced mode conversion is finished the request will be ignored. Such a request will also be ignored when the device is in normal mode. The maximum forced mode trigger frequency (FMTf) permitted is 200Hz when selecting a noise performance/averaging setting of 1. See also Table 4 for other averaging settings.

表5：允许的输出数据速率ODR与噪声配置/平均组合及相关电流消耗（单位：µA*）。

噪声模式，数量 样本 平均值	ODR 400赫兹	ODR 200赫兹	ODR 100赫兹	ODR 50Hz	ODR 25Hz	ODR 12.5赫兹	...	ODR 1.5625赫兹
"超低噪声"，平均值=3 8个样本	-	-	-	325	180	108		50
"低噪声"，平均值=2, 4个样本	-	-	335	175	96	57		25
"常规功率"，平均值=1, 2个样本	-	370	190	100	55	33		15
"低功耗"，平均值=0, 1个样本	455	235	122	70	40	23		12

*近似值单位为µA，仅针对少量样本进行测量，可能与规格表存在偏差

5.1.4 强制模式

通过强制模式，可以以不超过200赫兹的任意速率触发新测量。该模式仅在器件处于挂起模式时可用，通过向寄存器"PMU¯CMD"写入0x03或0x04（强制模式或强制模式_快速），可触发所有选定通道（寄存器PMU_CMD_AXIS_EN.en_x/y/z）的数据转换。完成强制模式数据转换后，器件将返回挂起模式。

两种强制模式变体——"强制_模式（FM）"与"强制_模式_快速（FM¯快速）"——应分别用于低（FM）或高（FM_快速）数据速率场景。当数据速率为25赫兹或更高时，可采用FM_快速（0x04）。较低输出数据速率则必须使用FM（0x03）。

要达到= 200赫兹输出数据速率 y p仅能通过y using FM_快速模式实现。
若BMM350_INIT与首次强制模式触发间隔超过0.1秒，则必须使用强制模式（PMU_CMD = 0x03）。
后续所有强制模式调用可根据上述输出数据速率选择强制模式或快速强制模式。

转换过程（挂起模式后的首次采样除外）将在<5e-3秒内完成
（平均=1样本时采用快速强制模式，平均=8样本时采用强制模式，最长30毫秒），数据可通过数据寄存器读取。

转换时间取决于平均设置及快速/正常强制模式的选择：高平均值会降低噪声，但同时会增加电流消耗和转换时间。

转换过程保证在内部RC振荡器的相对时序精度/漂移范围内完成，误差不超过±2百分比。

可利用"数据就绪"中断或数据就绪状态寄存器以最小延迟读取数据。
提供的编程示例展示了如何轮询状态寄存器以实现高数据速率和低延迟。

每次强制模式触发都会执行一次温度转换。

若在正在进行的强制模式转换完成前发出强制模式请求，该请求将被忽略。当器件处于正常模式时，此类请求同样会被忽略。在
为1时，允许的最大强制模式触发频率(FMTf)为200赫兹。其他平均设置请参见表4。

Table 6: Highest forced mode trigger rate versus noise performance/ averaging setting

Noise performance/Averaging settings avg	Highest forced mode trigger rate [Hz] , forced mode fast
1	200
2	150
4	80
8	40

An API function is provided to request the BMM350 forced mode, `BMM350_set_powermode`.

The reading of results is handled via the API as well.
Power mode transitions are depicted in Figure 2.

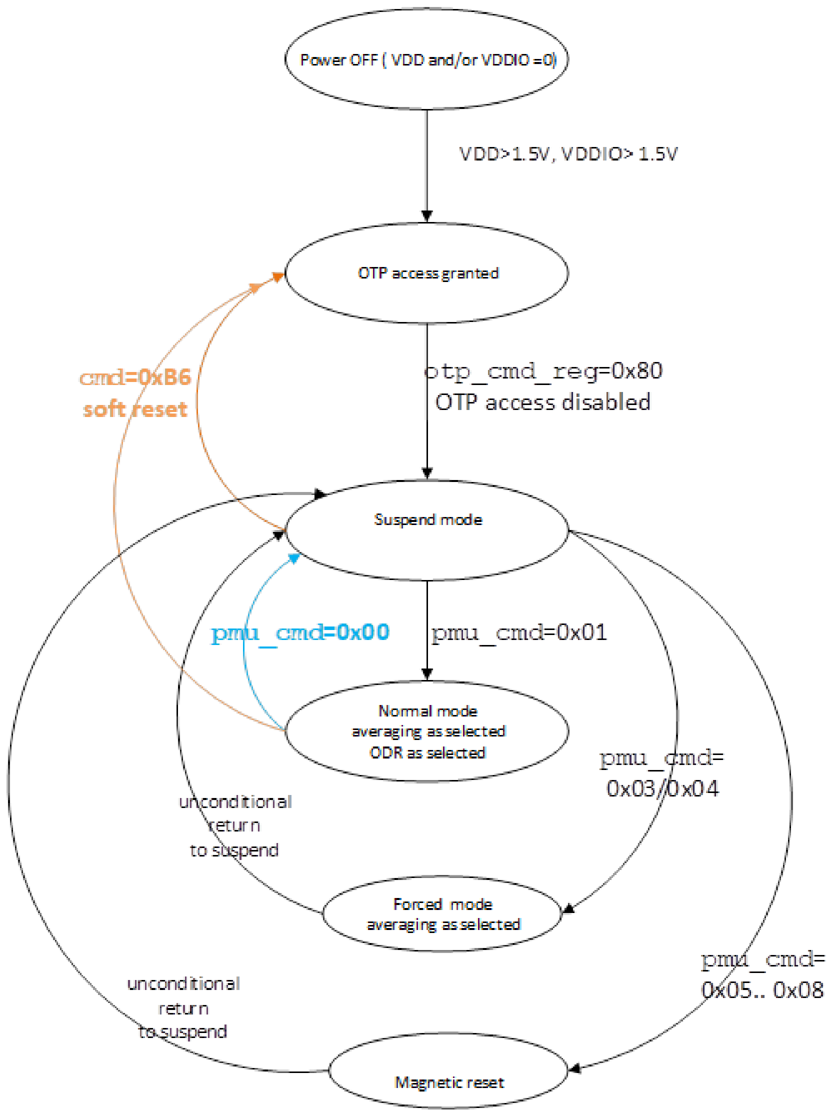


Figure 2: Power mode transitions

Only when being in suspend mode it is possible to switch to forced mode.
A direct transition request from normal mode to forced mode will be ignored by the device.

表6：最高强制模式触发速率与噪声性能/平均设置的对比

噪声性能/平均 设置平均	最高强制模式 触发速率[赫兹]，强制 模式快速
1	200
2	150
4	80
8	40

提供API函数来请求BMM350强制模式， `BMM350_设置_电源模式`。

结果读取同样通过应用程序接口处理。电源模式转换如
图2所示。

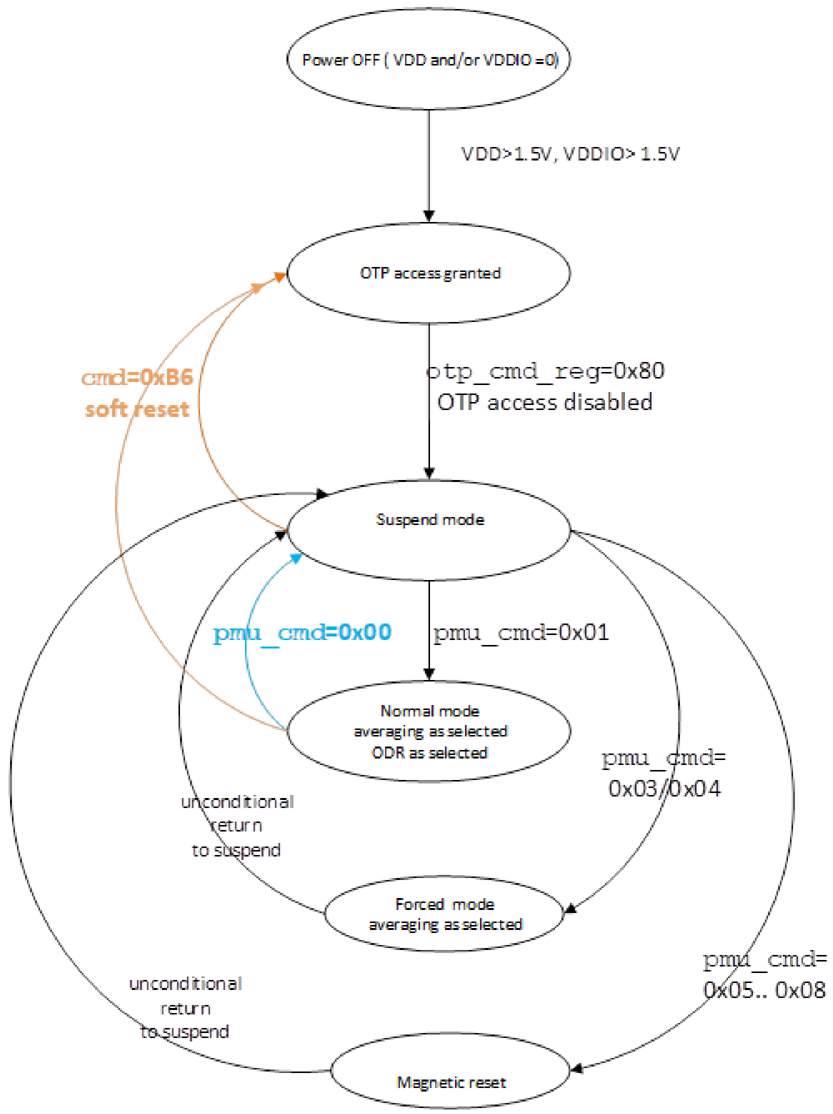


图2：电源模式转换

仅当处于挂起模式时才能切换到强制模式。从正常模式直接切换到强制模式的请求将被器
件忽略。

The API function `BMM350_set_powermode()` allows to switch from normal to forced mode by transitioning via the “suspend mode” state.

5.1.5 Magnetic reset in normal and forced mode/excessive field strengths handling

The BMM350 has measures to recover from excessively strong magnetic fields which would lead to a performance deterioration in competitor products. These measures are called “magnetic reset”.

They can be triggered programmatically via the API function “BMM350_check_for_highfield_and_reset“ which checks for excessive fields during operation and then triggers the reset. As said this works only during operation of the sensor, both in normal and forced mode.
If excessive field exposure has occurred out-of-operation, in a power-off state, users don’t need to care: the magnetic reset is triggered after each boot by the device itself.
If the excessive field exposure has occurred in suspend mode, the sensor will not be able to detect that event itself. If large offset or sensitivity drift indicates that such an event has occurred user can call the API function “`BMM350_magnetic_reset_and_wait`”.

If the system resides in suspend over longer times (> 2s), the user may want to implement a preventive reset policy by issuing the magnetic reset before changing power mode to “forced” or “normal”. To this purpose the user can call the API function “`BMM350_magnetic_reset_and_wait`”.

This function will perform a full magnetic reset.

A programming example is provided with the API.

Hint: In normal and in forced mode the sensor automatically performs a magnetic reset for every ODR tick.

The magnetic reset is triggered using register *PMU_CMD.pmu_cmd*.

The magnetic reset generates magnetic fields inside the sensor which “reset” the magnetic orientation of the magnetic transducer.
Doing so requires the external 2.2uF capacitor attached to pin “CRST” to be charged. Depending on temperature and selected data rate this charging can take more or less time (less than 8ms by design). After finishing the API function `BMM350_init`, the said capacitor is charged, and data conversion can start right away after finishing the `BMM350_INIT`. The capacitor discharge time constant is about 1 second, so, calling “`BMM350_magnetic_reset_and_wait`” after longer time of inactivity recharges the capacitor.

5.1.6 Self Test

The self-test feature allows to test the function of the X and Y channel.
When activating self-test an internal magnetic field in the order of 130µT is generated which adds on to the ambient magnetic field.
Self-test result interpretation thus requires data before activating the self-test and data during activation of the self-test:

□x = mag_x(during self-test) – mag_x(before self-test) >= 130µT
□y = mag_y(during self-test) – mag_y(before self-test) >= 130µT

Self-test can only be activated for 1 axis at a time. The device must be in suspend mode and forced mode must be used to capture data before and after activating self-test.

The API function *`BMM350_perform_self_test`* carries the procedure out automatically.

API函数`BMM350_set_powermode()`允许通过“挂起模式”状态从正常模式切换到强制模式。

5.1.5 正常和强制模式下的磁复位/过强磁场处理

BMM350具备从可能导致竞争对手产品性能恶化的过强磁场中恢复的措施。这些措施被称为“磁复位”。

它们可以通过API函数“BMM350_check_for_highfield_and_reset”以编程方式触发，该函数在运行期间检查过强磁场并触发复位。如前所述，这仅在传感器运行期间有效，无论是在正常模式还是强制模式下。

如果在非运行状态下、断电时发生过强磁场暴露，用户无需担心：磁复位会在每次启动时由器件自身触发。

若在挂起模式中发生过强磁场暴露，传感器自身将无法检测该事件。若出现较大偏移或灵敏度漂移表明此类事件发生，用户可调用API函数“BMM350磁复位并等待”。_ _ _ _

若系统长期处于挂起状态（> 2秒），用户可考虑实施预防性复位策略：在将电源模式切换为“强制”或“正常”前执行磁复位。为此，用户可调用API函数“BMM350_磁_复位_并_等待”。

该函数将执行完整的磁复位操作。

API中提供了编程示例。

提示：在正常模式与强制模式下，传感器会在每个ODR节拍自动执行磁复位。

磁复位通过寄存器*PMU_CMD.pmu_cmd*触发。

磁复位会在传感器内部产生磁场，从而“重置”磁传感器的磁取向。

这需要为连接到引脚“CRST”的外部2.2微法电容充电。根据温度和所选数据速率的不同，充电时间可能长短不一（设计上不超过8毫秒）。完成API函数BMM350初始化后，所述电容即完成充电，数据转换可在BMM350初始化完成后立即开始。_ _电容放电时间常数约为1秒，因此若在_ _ _ _长时间不活动后调用“BMM350磁复位并等待”，会重新为电容充电。

5.1.6 自测

自测功能可用于测试X和Y通道的功能。
激活自测时，会生成约130µT的内部磁场，该磁场会叠加在环境磁场上。

因此，自检结果解读需要激活自测前的数据及激活自测期间的数据：

□X轴 = 磁力计_X(自检期间) – 磁力计_X(自检前) >= 130µT
□Y轴 = 磁力计_Y(自检期间) – 磁力计_Y(自检前) >= 130µT

自检每次只能针对1个轴激活。器件必须处于挂起模式，且需使用强制模式捕获自检激活前后的数据。

API函数 *BMM350perform self test* 会自动执行该程序。_ _ _

5.2 Compensated data access from magnetic and temperature registers

Sensortime, temperature data and magnetic data are made available via data registers located next to each other. This allows reading said data within a single burst read.

Actually, burst read is an absolute "must" for data readout since the read stops data of being updated during readout and thus become inconsistent. The BMM350 halts data register update during a burst read starting at a sensortime, magnetic data or temperature data address. Reading data registers using single reads would allow for data updates between these reads and is strictly discouraged for normal mode.

The host must call API functions to correct data for temperature effects: offset and sensitivity errors will be corrected there as well as temperature effects. Trim values for the correction of offset, gain and temperature effects etc are stored in the BMM350 OTP and will be loaded when the API-function BMM350_init() is called.
For proper operation and best performance it is thus mandatory either to use the API functions or at least use API functions as template for own code, see chapter 7.

An API function "`BMM350_read_mag_data_and_compensate`" is provided which fetches data and calls all necessary compensation routines.

Magnetic data registers, temperature data registers and sensortime registers are located at addresses 0x31 to 0x3F.

5.2.1 Accessing compensation data

Compensation data for offset, gain and temperature effects are stored in the OTP.

The API function "`BMM350_get_compensation_data`" reads the data and stores them in the API memory space during the call of API function "`BMM350_init`". So no explicit user call is needed.
The data is used by API function "`BMM350_read_mag_data_and_compensate`".
Compensation data is stored in the "dev" C structure, which allows to handle different sensors separately.

5.2.2 Sensortime

The API function "`BMM350_read_mag_data_and_compensate`" optionally reads the sensortime information. The 3 sensortime registers at address 0x3D-0x3F form a 24bit register when (and only when!) new data is generated.
If only sensortime is needed by the user the function "`bmm350_read_sensortime`" is provided.
If no new data is generated, either in normal or in forced mode, the sensortime data register is not updated. A sensortime read will provide the time when the last data has been generated.
Due to the synchronicity of ODR and sensortime, the XLSB value in normal mode is always the same when choosing ODR=100Hz or smaller. An ODR=200Hz leads to 2 different XLSB values, and ODR=400Hz to 4 different XLSB values.

The internal sensortime counter is only incremented in normal mode, not in suspend mode or forced mode unless setting register *CTRL_USER.cfg_sens_tim_aon* to 0x1.
After boot sensortime is 0.
Sensortime information is ALWAYS related to new data generation. When setting *CTRL_USER.cfg_sens_tim_aon* to 0x1 in suspend mode the internal sensortime is advanced, but reading sensortime always leads to the same result unless the device is e.g. sent into forced mode and new data is produced.

When reading sensortime after forced mode is finished one can observe that sensortime is now "pointing" to the timepoint where new data has been calculated.

Sensortime wraps around when the 24bit counter wraps around (no saturation).

5.2 从磁性和温度寄存器访问补偿数据

传感器时间、温度数据和磁性数据可通过相邻的数据寄存器获取，这使得可以在一次突发读取中读取上述数据。

实际上，突发读取是数据读出的绝对“必须”，因为读取会阻止数据在读出过程中被更新，从而导致数据不一致。
BMM350在从传感器时间、磁性数据或温度数据地址开始的突发读取期间暂停数据寄存器更新。使用单次读取读取数据寄存器会允许在这些读取之间进行数据更新，在正常模式下严格禁止这样做。

主机必须调用API函数来校正温度效应导致的数据误差：偏移和灵敏度误差将在该过程中得到修正，同时温度效应也会被处理。
用于偏移、增益及温度效应等校正的修整值存储在BMM350的OTP中，并在调用API函数BMM350_init()时加载。

为确保正常运行和最佳性能，必须使用API函数或至少以API函数作为自定义代码的模板，具体参见第7章。

提供了名为“BMM350读取磁数据并补偿”的API函数，该函数可获取数据并调用所有必要的
_ _ _ _ _补偿例程。

磁性数据寄存器、温度数据寄存器及传感器时间寄存器位于地址0x31至0x3F之间。

5.2.1 访问补偿数据

用于偏移、增益及温度效应校正的补偿数据存储于OTP中。

API函数“BMM350 `_get_`补偿数据”会读取数据并将其存储在API内存空间_
期间 调用 of API 功能 “BMM350 _init”. So no 显式 user call is needed.
该数据由API函数“BMM350 `_read_mag_data_and_`compensate”.
补偿数据存储在“dev”C结构体中，可分别处理不同传感器。

5.2.2 传感器时间

应用程序接口函数“BMM350” `_read_mag_data_and_`“补偿”功能可选择性地读取传感器时间信息。3
地址0x3D-0x3F处的传感器时间寄存器在（且仅在！）新数据生成时形成一个24位寄存器。
若用户仅需获取传感器时间，可使用“BMM350读取传感器时间”功能。_ _
若无新数据产生，无论是在正常模式还是强制模式下，传感器时间数据寄存器都不会更新。读取传感器时间将提供最后一次数据生成的时间。
由于输出数据速率与传感器时间的同步性，在正常模式下选择=100赫兹或更小的输出数据速率时，XLSB值始终保持不变。选择=200赫兹的输出数据速率会导致2种不同的XLSB值，而=400赫兹则会得到4种不同的XLSB值。

内部传感器时间计数器仅在正常模式下递增，在挂起模式或强制模式下不会递增，除非将寄存器*CTRL_USER.cfg_sens_tim_aon*设置为0x1。
启动后传感器时间为0。
传感器时间信息始终与新数据生成相关。 在挂起模式下设置*CTRL_USER.cfg_sens_tim_aon*为0x1时，内部传感器时间会推进，但读取传感器时间总是得到相同结果
除非 the 器件 is e.g. sent into 强制 mode and new data is 产生。

当强制模式结束后读取传感器时间时，可以观察到传感器时间现在“指向”新数据被计算的时间点。

当24位计数器溢出时，传感器时间也会回绕（无饱和）。

5.3 Excessive field strengths handling

The BMM350 can handle magnetic field strengths up to +/-2000µT in every X/Y/Z direction.

BMM350 has the limitation for measurement range that the sum of absolute values of each axis should be smaller.
SQRT(Hx^2 + Hy^2 + Hz^2) = 2000µT

An API function "`BMM350_check_for_highfield_and_reset`" is provided which checks whether the field range has been exceeded, and then automatically magnetically resets the sensor. See chapter 4.1.5 for details.
This API function must be called explicitly, it is not called automatically. It should be called directly after "`BMM350_read_mag_data_and_compensate`".
A programming example is provided with the API.

5.4 Data rate and noise performance setting

Output data rate (ODR) is set using register *`PMU_CMD_AGGR_SET.odr`*.

Noise performance is set in register *`PMU_CMD_AGGR_SET.avg`*. In the following text this parameter is also called "averaging" (avg = 0/1/2/3 → averaging = 1/2/4/8).

An API function "`BMM350_set_odr_performance`" is provided which both handles data rate and noise performance setting.

A higher noise performance trades linearly against power consumption: to achieve a better noise performance several data samples are calculated internally and averaged. This is why current consumption is proportional to the averaging setting/noise performance setting, at least at higher ODR rates.

Table 7: Power consumption versus data rate ODR and noise performance setting, allowed combinations of settings. n/a: not allowed.

Averaging value/ noise performance setting PMU_CMD_AGGR_SET.avg	**Noise Mode**
8/3	Ultra Low Noise
4/2	Low Noise
2/1	Regular Power
1/0	Low Power

Power mode after boot is "suspend mode" when using API function `BMM350_init`.

When changing *`PMU_CMD_AGGR_SET.odr`* or *`PMU_CMD_AGGR_SET.avg`* it is necessary to send an "update" command via *`PMU_CMD.pmu_cmd`*
The API function "`BMM350_set_odr_performance`" does that automatically.

5.3 过强磁场处理

The BMM350 can handle 磁场 强度高达 +/-2000µT 输入 每个 X/Y/Z 方向。

BMM350对测量范围有限制，要求各轴绝对值之和应更小。SQRT(Hx^2 + Hy^2 + Hz^2) = 2000µT

提供了一个API函数"BMM350 check for highfield and reset"，用于检查_ _ _ _ _是否超出磁场范围，并自动对传感器进行磁复位。详情参见章节4.1.5。
此API函数必须显式调用，不会自动调用。应在"BMM350读取磁数据并补偿"之后直接调用。
API随附提供了编程示例。

5.4 数据速率和噪声性能设置

输出数据速率(ODR)通过寄存器*PMU CMD AGGR SET.odr*设置。

噪声性能在寄存器*PMU CMDAGGR SET.avg*中设置。下文中该参数也称为"平均"(avg = 0/1/2/3 → 平均 = 1/2/4/8)。

提供了API函数"BMM350 set odr performance"，可同时处理数据速率和噪声性能设置。

更高的噪声性能会线性增加功耗：为实现更好的噪声性能，系统会在内部计算多个数据样本并进行平均处理。这就是为什么电流消耗与平均设置/噪声性能设置成正比，至少在较高输出数据速率下如此。

表7：功耗与数据速率ODR及噪声性能设置的关系，允许的设置组合。n/a：不允许。

平均值/ 噪声性能设置 电源管理单元_命令_模拟增益增益范围_设置.平均值	**噪声模式**
8/3	超低噪声
4/2	低噪声
2/1	常规功率
1/0	低功耗

使用API函数BMM350初始化时，启动后的电源模式为"挂起模式"。

更改*PMU命令AGGRSET.odr*或*PMU命令AGGR SET.avg* 时，需要通过*PMU命令.pmu cmd*发送"更新"命令
API函数"BMM350设置输出数据速率性能"会自动完成该操作。

5.5 Interrupt settings and interrupt status

The BMM350 provides a “data ready” (abbreviated “drdy”) reset which is mapped to the interrupt status register and to the “INTerrupt” pin.

For I3C in-band interrupts see next chapter.

Two API functions are provided, “`BMM350_enable_interrupt`” and “`BMM350_configure_interrupt`” to configure and enable the “traditional” interrupt.

The API function “`BMM350_get_interrupt_status`” can be used to obtain the interrupt status from register `INT_STATUS`: new data ready or not ready.

Reading `INT_STATUS.drdy_data_reg` retrieves the interrupt status, or in other words: whether new data is available since the last data read.
Reading this field clears it in latched mode.
In non-latched mode the bit field clears itself after 1.25ms.

5.5.1 Mapping Interrupt to INT pin

When enabling the data ready interrupt it is automatically mapped to the interrupt pin INT for A-samples. No extra action must be taken if mapping is desired.
Using C samples, mapping can be enabled or disabled using register INT_CTRL.int_output_en.
The setting can be changed using the API function “BMM350_configure_interrupt”.

5.5.2 Interrupt polarity at INT pin

The output at the interrupt pin “INT” can be configured to “active HIGH” or “active LOW” using register *`INT_CTRL.int_pol`*. Setting 0x0 is active LOW, 0x1 is active HIGH.
The setting can be changed using the API function “`BMM350_configure_interrupt`”.

5.5.3 Interrupt drive type: CMOS or open drain

The driver type at the interrupt pin “INT” can be configured to “push-pull” or “open drain” using register *`INT_CTRL.int_od`*. Setting 0x0 is “open drain”, 0x1 is push-pull.
The setting can be changed using the API function “`BMM350_configure_interrupt`”.

5.5.4 Interrupt latching type or non-latching

The interrupt can be configured to “latching” or “non-latching” using register *`INT_CTRL.int_mode`*. Setting 0x0 is “pulsed”, 0x1 is “latched”.
The setting can be changed using the API function “`BMM350_configure_interrupt`”.

5.5.5 In-band interrupt

In I3C mode an in-band interrupt (“IBI”) can be sent to the host using the serial I3C interface. That IBI has to be enabled explicitly using register *`INT_CTRL_IBI.drdy_int_map_to_ibi`*.
Only enabling the IBI is not sufficient, the data ready interrupt itself has to be enabled using register *`INT_CTRL.drdy_data_reg_en`*.

The IBI uses the serial interface for the transmission for the interrupt information.
The time between issuing the interrupt in the sensor and the host receiving the interrupt is not deterministic since high I3C bus traffic can lead to a (repeated) non-acknowledgement of the sensor interrupt request.

5.5 中断设置和中断状态

BMM350提供"数据就绪"（缩写为"drdy"）重置功能，该功能映射至中断状态寄存器及"中断"引脚。

关于I3C带内中断，请参阅下一章节。

提供了两个API函数，“BMM350 _启用 _中断”和“BMM350 _配置 _中断”以配置并启用“传统”中断。

API函数“BMM350 获取中断状态”可用于从寄存器_ _ _获取中断状态
中断状态：新数据就绪或未就绪。_

读取INT STATUS.drdy数据寄存器可获取中断状态，换言之：自上次数据读取后是否有新数据可用
_ _ _。
读取该字段会在锁存模式下清除它。
在非锁存模式下，位字段会在1.25毫秒后自动清除。

5.5.1 将中断映射到INT引脚

当启用数据就绪中断时，它会自动映射到A样本的中断引脚INT。若需映射则无需额外操作。

使用C样本，可通过寄存器INT_CTRL.int_output_en启用或禁用映射功能。
可通过API函数“BMM350_configure_interrupt”更改该设置。

5.5.2 INT引脚的中断极性

中断引脚“INT”的输出可通过寄存器*INT*配置为“高电平有效”或“低电平有效”。

*CTRL.int pol*。设置0x0为低电平有效，0x1为高电平有效。
可通过API函数“BMM350配置中断”更改该设置。_ _

5.5.3 中断驱动类型：CMOS或开漏

中断引脚“INT”的驱动类型可通过寄存器*INT_CTRL.int_od*配置为“推挽”或“开漏”。设置为0x0时为“开漏”，0x1时为推挽。
可通过API函数“BMM350配置中断”更改此设置。_ _

5.5.4 中断锁存类型或非锁存

可通过寄存器配置中断为“锁存”或“非锁存”
*INT_CTRL.int_mode*寄存器。设置为0x0时为“脉冲”，0x1时为“锁存”。_ _
该设置可通过API函数“BMM350配置中断”进行更改。_ _

5.5.5 带内中断

在I3C模式下，可通过串行I3C接口向主机发送带内中断（“IBI”）。该IBI需显式启用寄存器*INT CTRL IBI.drdy_int_map_to_ibi*。_ _ _ _ _ _
仅启用IBI并不足够，还需通过寄存器*INT_CTRL.drdy_data_reg_en*启用数据就绪中断本身。

IBI利用串行接口传输中断信息。
传感器发出中断到主机接收中断之间的时间并不确定，因为高I3C总线流量可能导致传感器中断请求被（重复）未确认。

INT_CTRL_IBI.clear_drdy_int_status_upon_ibi allows to clear the interrupt status register automatically upon sending an IBI.

An API function "`BMM350_set_int_ctrl_ibi`" is provided to configure and enable/disable the IBI.

5.6 Pad drive settings

To avoid problems with signal over- or undershoot with long wires the user can configure the relative pad driver strength via register *PAD_CTRL.drv<2:0>*. A setting of 0 selects the weakest drive strength, a setting of 7 selects the strongest drive strength.

In I3C mode the user does not have control over the value of the pull-up resistor value, so care must be taken to not select a too weak driver strength.
The default relative drive strength is 7 after boot.

An API function "`BMM350_set_pad_drive`" is provided to change the drive strength.

5.7 Enable/disable axis

The user can choose between converting all axes or only a selected set of axes.
Configuration is handled via register *PMU_CMD.en_x/y/z*.
An API function "`BMM350_enable_axes`" is provided to handle that configuration.
The function will ignore requests to disable all axes.
Enabling or disabling an axis is only working in suspend mode, a change on-the-fly in normal mode is ignored by the sensor hardware.
The API function "`BMM350_enable_axes`" will turn the sensor into suspend mode, change the axes enable bits and re-enable normal mode when the sensor is in normal mode at the moment the said API function is called.

5.8 Sensortime always available

For best power saving the internal clocks are only turned on when needed.
In suspend mode, all fast internal clocks are turned off, meaning that the sensortime counter is stopped.
User can decide to keep the main internal oscillator running, which makes sensortime information available all time.

An API function "`BMM350_set_ctrl_user`" is provided which makes sensortime all time available or not. The sensortime reading is updated only when new data are available after data conversion.

5.9 I2C watchdog setting

When I2C communication stalls the bmm350 is able to reset the communication interface using a watchdog. It is possible to choose between 2 timeout intervals, see register description I2C_WDT_SET.
An API function "`BMM350_set_i2c_wdt`" is provided to enable or disable the watchdog and choose the interval length.

5.10 Status information

A few registers provide status or error information.

5.10.1 CHIP_ID

`CHIP_ID` is located at address 0.
Its content is 0x33, read-only. This content is BST product-specific and helps e.g. to check initially whether the BMM350 is properly communicating with the host.

*INT CTRL IBI*清除数据就绪中断状态 允许在发送IBI时_ _ _ _ _ _ _自动清除 中断状态寄存器

提供了一个API函数“BMM350 set int ctrl ibi”用于配置和启用/禁用IBI。_ _ _ _

5.6 焊盘驱动设置

为避免长导线导致信号过冲或下冲问题，用户可通过寄存器*PAD_CTRL.drv<2:0>*配置相对焊盘驱动强度。设置为0时选择最弱的驱动强度，设置为7时选择最强的驱动强度。

在I3C模式下，用户无法控制上拉电阻值，因此必须注意不要选择过弱的驱动强度。

启动后的默认相对驱动强度为7。

提供了API函数“BMM350设置焊盘驱动”以更改驱动强度。_ _ _

5.7 启用/禁用轴

用户可选择转换所有轴或仅转换选定的一组轴。
配置通过寄存器*PMU CMD.en x/y/z*。_ _
一个API函数“BMM350 _启用 _“轴”用于处理该配置。
该功能将忽略禁用所有轴的请求。
启用或禁用轴仅在挂起模式下有效，在正常模式下实时更改会被传感器硬件忽略。

API函数“BMM350启用轴”将使传感器进入挂起模式，更改轴启用位并_ _
当传感器在调用所述API函数时处于正常模式，则重新启用正常模式。

5.8 传感器时间始终可用

为达到最佳省电效果，内部时钟仅在需要时开启。
在挂起模式下，所有快速内部时钟均被关闭，这意味着传感器时间计数器停止运行。
用户可选择保持主内部振荡器持续运行，从而使传感器时间信息始终可用。

提供API函数“BMM350设置用户控制”以决定是否使传感器时间始终可用。_ _ _传感器时间读数仅在数据转换后新数据可用时更新。

5.9 I2C看门狗设置

当I2C通信停滞时，BMM350能够通过看门狗重置通信接口。可选择两者之间的超时间隔，详见寄存器描述I2C_WDT_SET。
提供一个API函数“BMM350 _设置I2C看门狗”用于启用或禁用看门狗并选择间隔长度。_ _

5.10 状态信息

少数寄存器提供状态或错误信息。

5.10.1 芯片ID_

`CHIP_`ID位于地址0。
其内容为0x33，只读。此内容是BST产品特定的，有助于例如初始检查BMM350是否与主机正常通信。

5.10.2 ERR_REG: PMU and boot error

Register *ERR_REG* indicates PMU- and boot-errors.
ERR_REG.pmu_err tells if PMU commands have been issued out-of-time (too early) or in the wrong context.
Error conditions are:

- Forced mode is requested in normal mode (sensor must be in suspend mode if doing that)

To prevent the occurrence of such errors it is recommended to use the API function `BMM350_set_powermode`.

5.10.3 PMU_CMD_STATUS: PMU (command) status

- *PMU_CMD_STATUS_0.pmu_cmd_busy* signals that the PMU is not ready to take new commands. Such a busy condition can be encountered after triggering a magnetic reset, which can take up to 8ms. Another busy condition can be met after issuing a second forced mode request immediately after issuing a first forced mode request. The first forced mode request can take longer as expected, depending on the charging condition of the external 2.2uF capacitor.
- *PMU_CMD_STATUS_0.cmd_is_illegal* indicates illegal commands. Illegal commands are commands which do not appear in the register description of register *PMU_CMD*.
- *PMU_CMD_STATUS_0.pwr_mode_is_normal* indicates whether the sensor is in normal (power) mode.
- *PMU_CMD_STATUS_1.pmu_odr_s* and *PMU_CMD_STATUS_1.pmu_odr_s* indicate the actual noise/performance setting and data rate setting.

To prevent the occurrence of errors it is recommended to use the API function `BMM350_set_powermode` and `BMM350_set_odr_perfromance`.

5.10.4 I3C_ERR: I3C status/error reporting

I3C is a complex protocol. When bringing up a new system status information may be helpful.
I3C_ERR.i3c_err_0 indicates an SDR parity error. See MIPI spec **5.1.2.3.2 Ninth Bit of SDR Master Written Data as Parity.**

I3C_ERR.i3c_err_1 indicates an S0/S1 error, see MIPI spec **5.1.10.1.2 Error Type S0, 5.1.10.1.3 Error Type S1.**

5.10.5 Soft reset, reset detection.

A “soft reset” can be used to reset all sensor settings issued so far.
The soft reset is triggered by sending
`CMD.cmd` = 0xB6 followed by `CMD.cmd` = 0x0

An API function `BMM350_soft_reset_and_wait()` is provided.

5.10.2 错误寄存器：电源管理单元和启动错误_

寄存器*ERR REG*指示电源管理单元和启动错误。
错误寄存器.*PMU*错误指示电源管理单元命令是否在错误时间（过早）或错误上下文中发出。_ _错误条件包括：

- 在正常模式下请求强制模式（若需执行此操作，传感器必须处于挂起模式）

为防止此类错误发生，建议使用API函数 BMM350 _set_电源模式。

5.10.3 电源管理单元_命令_状态: 电源管理单元（命令）状态

- *PMU*命令状态*0.PMU*命令忙表示电源管理单元尚未准备好接收新命令。_ _ _ _ _ 此类忙碌状态可能在触发磁复位后出现，该过程可能耗时长达8毫秒。
  另一种忙碌状态可能出现在连续发出两次强制模式请求时。首次强制模式请求的耗时可能超出预期，具体取决于外部2.2微法电容的充电状态。
- *PMU*命令状态*0.*命令非法表示检测到非法命令。非法命令是指那些_ _ _ _ _
  未出现在寄存器电源管理单元_命令寄存器描述中的指令。
- *PMU CMD*状态*0.*电源模式为正常表示传感器是否处于正常（电源）模式。_ _ _ _ _ _
- *PMU CMD*状态*1.pmu odr s* 和 *PMU CMD*状态*1.pmu odr s* 表示实际噪声/性能
  _ _ _ _ _ _ _ _ _ _ _ 设置及数据速率设置。

为防止错误发生，建议使用API函数BMM350设置电源模式及_ _BMM350_设置_输出数据速率_性能。

5.10.4 I3C_错误：I3C状态/错误报告

I3C是一种复杂协议。在启动新系统时，状态信息可能有所帮助。
*I3C*错误*.i3c err 0* 表示SDR奇偶校验错误。详见MIPI规范 **5.1.2.3.2 SDR主机写入数据的第九位_ _ _作为奇偶校验位。**

*I3C*错误*.i3c err 1* 表示S0/S1错误，详见MIPI规范 **5.1.10.1.2 错误类型S0,_ _ _5.1.10.1.3 错误类型S1。**

5.10.5 软复位，复位检测。

“软复位”可用于重置迄今为止发出的所有传感器设置。
软复位通过发送
命令.cmd = 0xB6 后接 命令.cmd = 0x0 触发

一个API函数 BMM350 _soft_重置 _and_等待()已提供。

6. Pin and package description

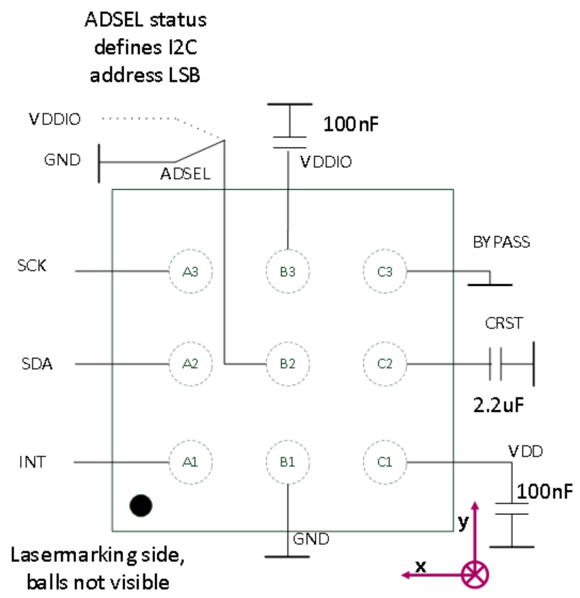


Figure 3: View from lasermarking side, balls invisible, required external components in operation

Pin name	Name	Function
C3	BYPASS	Connect to ground
C2	CRST	Connect to external 2.2uF capacitor, low inductance. e.g. see chapter 14
C1	VDD	Digital and analog supply, use decoupling capacitor
B3	VDDIO	IO supply, use decoupling capacitor
B2	ADSEL	The logic status of ADSEL defines the LSB to the I2C legacy address. Connect ADSEL to GND or VDDIO
B1	GND	Analog, digital and IO ground
A3	SCK	I2C / I3C clock
A2	SDA	I2C / I3C data
A1	INT	Interrupt output

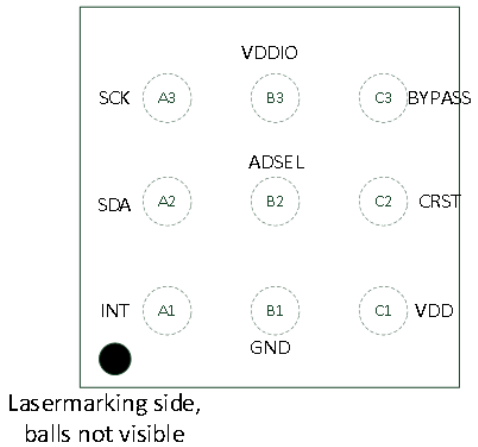


Figure 4: Pin names only, laser marking side

6. 引脚和封装描述

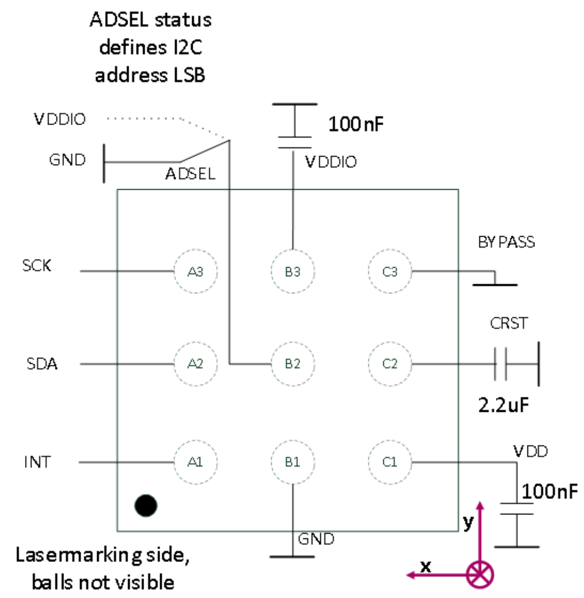


图3：激光标记面视图，球体不可见，操作所需外部组件

引脚名称	Name	功能
C3	旁路	接地
C2	CRST	连接外部2.2微法电容，低电感。例如参见第14章
C1	VDD	数字和模拟电源，使用去耦电容
B3	VDDIO	IO电源，使用去耦电容
B2	ADSEL	ADSEL的逻辑状态定义了I2C传统地址的最低有效位。 将ADSEL连接至地或VDDIO
B1	GND	模拟、数字和IO地
A3	SCK	I2C / I3C 时钟
A2	SDA	I2C / I3C 数据
A1	INT	中断输出

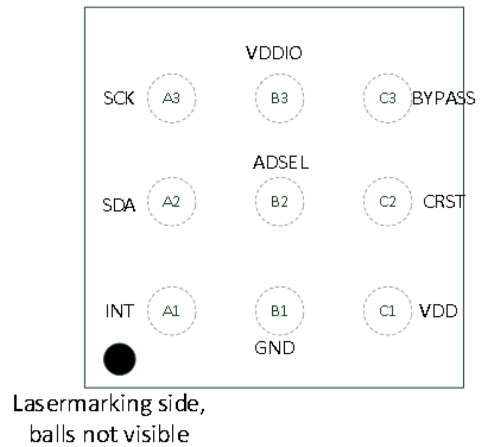


图4：仅引脚名称，激光标记面

5.1 Landing pattern recommendation

For the design of the landing pattern, the dimensions shown in the HSMI are recommended. It is important to note that areas marked in red are exposed PCB metal pads.

- In case of a solder mask defined (SMD) PCB process, the land dimensions should be defined by solder mask openings. The underlying metal pads are larger than these openings.
- In case of a non-solder mask defined (NSMD) PCB process, the land dimensions should be defined in the metal layer. The mask openings are larger than these metal pads.

5.2 Connection diagrams

100nF capacitors should be used for VDD and VDDIO decoupling.
CRST requires a 2.2uF capacitor, recommended type: see chapter 13.

5.3 Recommendations for PCB design

- S IC footprint: IC size 1.28 x 1.28mm, reserve space for 1.3 x 1.3 mm^2 IC size
- ball pitch is 400um (horizontal & vertical)
- the following peak current can flow:
  - 400mA current (very short time < 1us) between CRST capacitor (2.2uF) and CRST pin
  - 400mA current (very short time < 1us) between CRST capacitor (2.2uF) and GND pin
  - 20mA max current (short time, < 10ms) in VDD pin, 750uA maximum average current
- external required components:
  - 100nF capacitor decoupling VDD to GND
  - 100nF capacitor decoupling VDDIO to GND
  - 2.2uF capacitor to CRST, 200mA peak current, need low resistance, low inductance type and non-magnetic properties. Recommended type: see chapter 14.
- Connect pin “ADSEL” either to GND or VDDIO to change I2C legacy address.

5.1 焊盘布局推荐

对于焊盘布局的设计，建议采用HSMI中所示的尺寸。需注意，红色标记区域为裸露的印刷电路板金属焊盘。

- 若采用焊盘定义（SMD）印刷电路板工艺，焊盘尺寸应由阻焊层开窗定义。底层金属焊盘大于这些开窗。
- 若采用非焊盘定义（NSMD）印刷电路板工艺，焊盘尺寸应在金属层中定义。阻焊开窗大于这些金属焊盘。

5.2 连接图

VDD和VDDIO去耦应使用100纳法电容器。
CRST需要一个2.2微法电容，推荐型号：参见章节13。

5.3 PCB设计建议

- S IC封装尺寸：IC尺寸1.28 x 1.28毫米，预留1.3 x 1.3毫米空间^2 IC尺寸
- 焊球间距为400微米（水平与垂直方向）
- 可能流过的峰值电流如下：
  - 400毫安电流（极短时间< 1微秒）流经CRST电容器（2.2微法）与CRST引脚之间
  - 400毫安电流（极短时间< 1微秒）流经CRST电容器（2.2微法）与GND引脚之间
  - 20毫安最大电流（短时< 10毫秒）流经VDD引脚，750微安最大平均电流
- 外部所需元件：
  - 100纳法电容器用于VDD至GND的去耦
  - 100纳法电容器用于VDDIO至GND的去耦
  - 22微法电容连接至CRST，200毫安峰值电流，需具备低电阻、低电感类型及非磁性特性。推荐型号参见第14章。
- 将ADSEL引脚连接至地或VDDIO以更改I2C传统地址。

7. API functions

API functions are documented in
https://github.com/boschsensortec/BMM350_SensorAPI/blob/main/README.md

7. API函数

API函数文档位于
https://github.com/boschsensortec/BMM350_传感器应用程序接口/blob/main/README.md

8. Register Map

Table 8 : 8-bit portrait register map

read/write	read only	write only	reserved

Register Address	Register Name	Default Value	7	6	5	4	3	2	1	0
0x7E	CMD	0x00	cmd							
0x7D	-	-	reserved							
...	-	-	reserved							
0x62	-	-	reserved							
0x61	CTRL_USER	0x00	reserved							cfg_sens_tim_aon
0x60	TMR_SELFTEST_USER	0x00	reserved			ist_en_y	ist_en_x	st_p	st_n	st_igen_en
0x5F	-	-	reserved							
...	-	-	reserved							
0x56	-	-	reserved							
0x55	OTP_STATUS_REG	0x10	error			cur_page_addr				otp_cmd_done
0x54	-	-	reserved							
0x53	OTP_DATA_LSB_REG	0x00	otp_mem_data_lsb							
0x52	OTP_DATA_MSB_REG	0x00	otp_mem_data_msb							
0x51	-	-	reserved							
0x50	OTP_CMD_REG	0x00	otp_cmd			word_addr				
0x4F	-	-	reserved							
...	-	-	reserved							
0x40	-	-	reserved							
0x3F	SENSORTIME_MSB	0x7F	data_st_23_16							
0x3E	SENSORTIME_LSB	0x7F	data_st_15_8							
0x3D	SENSORTIME_XLSB	0x7F	data_st_7_0							

8. 寄存器映射

表8：8位肖像寄存器映射

读/写	只读	只写	保留

Register Address	寄存器名称	默认值	7	6	5	4	3	2	1	0
0x7E	CMD	0x00	cmd							
0x7D	-	-	保留							
...	-	-	保留							
0x62	-	-	保留							
0x61	CTRL_U_SER	0x00	保留							cfg_sen
0x60	隧道磁阻S_ELFTEST用户_	0x00	保留			ist_使能_Y轴		st_p	传感器定时器	传感器定时
0x5F	-	-	保留							
...	-	-	保留							
0x56	-	-	保留							
0x55	一次性可编程存储器 传感器定时器_ ATUS 读_等效增益	0x10	错误			当前_页_地址				otp_命
0x54	-	-	保留							
0x53	一次性可编程存储器 D_ATA 最低有效位_B寄存器_	0x00	otp_mem_数据_最低有效位							
0x52	一次性可编程存储器 D_ATA 最高有效位_ B 寄存器_	0x00	otp_mem_数据_最高有效位							
0x51	-	-	保留							
0x50	一次性可编程存储器C_模式RE_G	0x00	otp_cmd			字 地址_				
0x4F	-	-	保留							
...	-	-	保留							
0x40	-	-	保留							
0x3F	SENSORTIME_最高有效位	0x7F	数据 传感器定时器 23 16_ _ _							
0x3E	SENSORTIME_最低有效位	0x7F	数据st158_ _ _							
0x3D	SENSO室温_XLSB	0x7F	数据st70_ _ _							

0x3C	TEMP_MSB	0x7F	data_t_23_16							
0x3B	TEMP_LSB	0x7F	data_t_15_8							
0x3A	TEMP_XLSB	0x7F	data_t_7_0							
0x39	MAG_Z_MSB	0x7F	data_z_23_16							
0x38	MAG_Z_LSB	0x7F	data_z_15_8							
0x37	MAG_Z_XLSB	0x7F	data_z_7_0							
0x36	MAG_Y_MSB	0x7F	data_y_23_16							
0x35	MAG_Y_LSB	0x7F	data_y_15_8							
0x34	MAG_Y_XLSB	0x7F	data_y_7_0							
0x33	MAG_X_MSB	0x7F	data_x_23_16							
0x32	MAG_X_LSB	0x7F	data_x_15_8							
0x31	MAG_X_XLSB	0x7F	data_x_7_0							
0x30	INT_STATUS	0x00	reserved					drdy_data_reg	reserved	reserved
0x2F	INT_CTRL_IBI	0x00	reserved			clear_drdy_int_status_upon_ibi	reserved			drdy_int_map_to_ibi
0x2E	INT_CTRL	0x00	drdy_data_reg_en	reserved			int_output_en	int_od	int_pol	int_mode
0x2D	-	-	reserved							
...	-	-	reserved							
0x0E	-	-	reserved							
0x0D	TRANSDUCER_REV_ID	0x33	trsdcr_rev_id_fixed						trsdcr_rev_id_otp	
0x0C	-	-	reserved							
...	-	-	reserved							
0x0B	-	-	reserved							
0x0A	I2C_WDT_SET	0x00	reserved						i2c_wdt_sel	i2c_wdt_en
0x09	I3C_ERR	0x00	reserved				i3c_error_3	reserved		i3c_error_0
0x08	PMU_CMD_STATUS_1	0x00	reserved		pmu_avg_s		pmu_odr_s			

0x3C	温度_MSB	0x7F	数据 t 23 16_ _ _							
0x3B	TEMP_LSB	0x7F	数据 t 15 8_ _ _							
0x3A	TEMP_XLSB	0x7F	数据 t 7 0_ _ _							
0x39	磁力计 Z轴 _ _MSB	0x7F	数据 z 23 16_ _ _							
0x38	磁力计 Z轴 _ _LSB	0x7F	数据 z 15 8_ _ _							
0x37	磁力计 Z轴 _ XLSB_	0x7F	数据 z 7 0_ _ _							
0x36	磁力计 Y轴 _ _MSB	0x7F	数据_y_23_16							
0x35	MAG_Y_LSB	0x7F	数据_y_15_8							
0x34	磁力计 Y轴 _ XLSB_	0x7F	数据_y_7_0							
0x33	磁力计 X轴 _ _MSB	0x7F	数据 x 23 16_ _ _							
0x32	磁力计 X轴 _ _LSB	0x7F	数据 X 15 8_ _ _							
0x31	磁力计 X_ XLSB_	0x7F	数据 X 7 0_ _ _							
0x30	中断 传感器定时器_状态	0x00	保留					数据就绪	保留	保留
0x2F	中断 电流类型_电阻负载 带内中断_	0x00	保留			清除 数	保留			数据就绪（缩写）_中断 _映射_至
0x2E	中断 电流类型_电阻负载	0x00	数据就绪（缩 a_寄存器	保留			中断_输出 ut_en	中断 开漏_	中断_极性	中断 模块_ e
0x2D	-	-	保留							
...	-	-	保留							
0x0E	-	-	保留							
0x0D	传感器版本ID_ _	0x33	传感器版本ID固定_ _ _						传感器_版本_ID_一次性可编程存储器	
0x0C	-	-	保留							
...	-	-	保留							
0x0B	-	-	保留							
0x0A	I2C 看门狗定时器_ 时间 设置_	0x00	保留						i2c 看门狗定	I2C 看门狗 _ en
0x09	I3C 错误_读	0x00	保留				I3C 错	保留		I3C 错
0x08	电源管理单元C_ 模式 传感器定时器 _ATUS 1_	0x00	保留		pmu_平均值_s		pmu_输出数据速率_s			

0x07	PMU_CMD_STATUS_0	0x00	pmu_cmd_val			ODR_ovwr	pmu_cmd_busy	AVG_ovwr	ODR_ovwr	pmu_cmd_busy
0x06	PMU_CMD	0x00	reserved				pmu_cmd			
0x05	PMU_CMD_AXIS_EN	0x70	reserved				En_z	En_y	En_x	
0x04	PMU_CMD_AGGR_SET	0x14	reserved		avg		odr			
0x03	PAD_CTRL	0x07	reserved					drv		
0x02	ERR_REG	0x00	reserved							pmu_cmd_error
0x00	CHIP_ID	0x33	chip_id_fixed				chip_id_otp			

0x07	电源管理单元 命令_模式 传感器定时器_状态 0_	0x00	电源管理单元_命令_值			输出数据速	电源管理单	平均值	输出数据速	电源管理单
0x06	电源管理单元 C_模式	0x00	保留				电源管理单元_命令			
0x05	电源管理单元 命令 AXI_S_使能_	0x70	保留				使能Z轴_	En_y	使能X轴_	
0x04	电源管理单元 C_模式 模拟增益_增益范围 灵敏度_时间	0x14	保留		avg		odr			
0x03	焊盘 电流类型_电阻负载	0x07	保留					drv		
0x02	错误 读_等效增益	0x00	保留							电源管理单
0x00	芯片ID_	0x33	芯片_ID_固定				芯片_ID_一次性可编程存储器			

8.1 Register (0x00) CHIP_ID

DESCRIPTION: Chip identification code
RESET: 0x33
DEFINITION (See Chapter 8 Register Map)

Bit	7	6	5	4
Read/Write	R	R	R	R
Reset Value	0	0	1	0
Content	chip_id_fixed			

Bit	3	2	1	0
Read/Write	R	R	R	R
Reset Value	0	0	1	1
Content	chip_id_otp			

chip_id_otp: Programmable (NVM) part of chip id.
chip_id_fixed: Fixed part of chip id.

8.2 Register (0x02) ERR_REG

DESCRIPTION: Reports Sensor Error Flag. Will be cleared on read. If the user writes a 1 into any status bit, this will also clear that bit.
RESET: 0x00
DEFINITION (See Chapter 8 Register Map)

Bit	7	6	5	4	3	2	1	0
Read/Write	n/a	n/a	n/a	n/a	n/a	n/a	R/W	R/W
Reset Value	0	0	0	0	0	0	0	0
Content	reserved							pmu_cmd_error

- pmu_cmd_error: a new PMU_CMD is issued when previous command has not been finished. The new PMU_CMD will be ignored.
  0x0: pmu_ok
  0x1: pmu_error

8.1 寄存器 (0x00) 芯片_ID

描述：芯片识别码 重置：0x33 定义（参见
第8章寄存器映射）

Bit	7	6	5	4
读/写	R	R	R	R
重置值	0	0	1	0
内容	芯片_标识_固定			

Bit	3	2	1	0
读/写	R	R	R	R
重置值	0	0	1	1
内容	芯片_标识_一次性可编程存储器			

chip_id_otp: 芯片ID的可编程部分（NVM）。
chip_id_fixed: 芯片ID的固定部分。

8.2 寄存器 (0x02) ERR_REG

描述: 报告传感器错误标志。读取时清除。如果用户向任何状态位写入1，也将清除该位。

复位：0x00
定义（参见第8章寄存器映射）

Bit	7	6	5	4	3	2	1	0
读/写	n/a	n/a	n/a	n/a	n/a	n/a	R/W	R/W
重置值	0	0	0	0	0	0	0	0
内容	保留							pmu_cmd 错误_

- 电源管理单元_命令_错误：当前一条命令尚未完成时又发出了新的电源管理单元_命令。新的电源管理单元_命令将被忽略。

  0x0: pmu_ok
  0x1: pmu_error

8.3 Register (0x03) PAD_CTRL

DESCRIPTION: Configure pad behavior
RESET: 0x07
DEFINITION (See Chapter 8 Register Map)

Bit	7	6	5	4	3	2	1	0
Read/Write	n/a	n/a	n/a	n/a	n/a	R/W	R/W	R/W
Reset Value	0	0	0	0	0	1	1	1
Content	reserved					drv		

- drv: Set the pad drive capability
  0x0: drv_weakest, 0x7: drv_strongest , 0xn:drv_n_7, n=1..6

8.4 Register (0x04) PMU_CMD_AGGR_SET

DESCRIPTION: configuration of the ODR and AVG
RESET: 0x14
DEFINITION (See Chapter 8 Register Map)

Bit	7	6	5	4	3	2	1	0
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Reset Value	0	0	0	1	0	1	0	0
Content	reserved		avg		odr			

odr: Output Data Rate.

odr		
0x02	odr_400hz	400 Hz odr
0x03	odr_200hz	200 Hz odr
0x04	odr_100hz	100 Hz odr
0x05	odr_50hz	50 Hz odr
0x06	odr_25hz	25 Hz odr
0x07	odr_12_5hz	12.5 Hz odr
0x08	odr_6_25hz	6.25 Hz odr
0x09	odr_3_125hz	3.125 Hz odr
0x0a	odr_1_5625hz	1.5625 Hz odr

avg: Measurements Averages

avg		
0x00	no_avg	no average
0x01	avg_2	average between 2 samples
0x02	avg_4	average between 4 samples
0x03	avg_8	average between 8 samples

reserved: reserved.

8.3 寄存器 (0x03) 焊盘_CTRL

描述：配置焊盘行为
重置: 0x07
定义（参见第8章寄存器映射）

Bit	7	6	5	4	3	2	1	0
读/写	n/a	n/a	n/a	n/a	n/a	R/W	R/W	R/W
重置值	0	0	0	0	0	1	1	1
内容	保留					drv		

- drv：设置焊盘驱动能力
  0x0: 驱动强度_最弱, 0x7: 驱动强度_最强, 0xn:驱动强度_n_7, n=1..6

8.4 寄存器 (0x04) 电源管理单元_命令_模拟增益增益范围_设置

描述: ODR和AVG复位的配置: 0x14

定义（参见第8章寄存器映射）

Bit	7	6	5	4	3	2	1	0
读/写	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
重置值	0	0	0	1	0	1	0	0
内容	保留		avg		odr			

odr: 输出数据速率。

odr		
0x02	odr_400赫兹	400赫兹输出数据速率
0x03	odr_200赫兹	200赫兹输出数据速率
0x04	odr_100赫兹	100赫兹输出数据速率
0x05	odr_50hz	50赫兹输出数据速率
0x06	odr_25hz	25赫兹输出数据速率
0x07	odr_12_5hz	12.5赫兹输出数据速率
0x08	odr_6 25赫兹_	6.25赫兹输出数据速率
0x09	odr_3_125赫兹	3.125赫兹输出数据速率
0x0a	odr_1_5625赫兹	1.5625赫兹输出数据速率

平均值: 测量平均值

avg		
0x00	无_平均值	无平均值
0x01	平均值_2	平均值 两者之间 样本
0x02	平均值_4	平均值 4个之间 样本
0x03	平均值_8	平均值 8个之间 样本

保留: 保留。

8.5 Register (0x05) PMU_CMD_AXIS_EN

DESCRIPTION: axis configuration
RESET: 0x07
DEFINITION (See Chapter 8 Register Map)

Bit	7	6	5	4	3	2	1	0
Read/Write	n/a	R/W	R/W	R/W	W	W	W	W
Reset Value	0	0	0	0	0	1	1	1
Content	reserved					en_z	en_y	en_x

en_x: Enable Axes X

en_x		
0x00	disable	Channel Disabled
0x01	enable	Channel Enabled

en_y: Enable Axes Y

en_y		
0x00	disable	Channel Disabled
0x01	enable	Channel Enabled

en_z: Enables Axes Z

en_z		
0x00	disable	Channel Disabled
0x01	enable	Channel Enabled

8.5 寄存器 (0x05) 电源管理单元_命令_轴_使能

描述: 轴配置
重置: 0x07
定义（参见第8章寄存器映射）

Bit	7	6	5	4	3	2	1	0
读/写	n/a	R/W	R/W	R/W	W	W	W	W
重置值	0	0	0	0	0	1	1	1
内容	保留					en_z	en_y	en_x

en x: 启用X轴_

en_x		
0x00	禁用	通道已禁用
0x01	启用	通道已启用

en_y: 启用Y轴

en_y		
0x00	禁用	通道已禁用
0x01	启用	通道已启用

en z: 启用Z轴_

en_z		
0x00	禁用	通道已禁用
0x01	启用	通道已启用

8.6 Register (0x06) PMU_CMD

DESCRIPTION: PMU cmd configuration
RESET: 0x00
DEFINITION (See Chapter 8 Register Map)

Bit	7	6	5	4	3	2	1	0
Read/Write	n/a	RW	RW	RW	W	W	W	W
Reset Value	0	0	0	0	0	0	0	0
Content	reserved				pmu_cmd			

pmu_cmd: command for PMU mode switch

pmu_cmd		
0x00	SUS	go to SUSPEND mode
0x01	NM	go to NORMAL mode. Note that when being in normal mode, it is possible to require only the SUS and UPD_OAE commands. In case a different command is required, a protection mechanism prevents from propagating that command inside the device and the illegal_command flag is set. Even in this case, before sending another command after the illegal one, the busy bit must be low
0x02	UPD_OAE	update odr and avg parameter: after requiring one odr/avg update, it is mandatory to wait for the data ready interrupt after the busy flag was cleared before requiring the next odr/avg update (this means that the first data set has been generated with the new odr/avg). Note that looking only at the busy flag is not correct because the busy flag can be deasserted too early (A -Si implementation limitation)
0x03	FM	go to FORCED mode with full CRST recharge
0x04	FM_FAST	go to FORCED mode with fast CRST recharge
0x05	FGR	do flux-guide reset with full CRST recharge
0x06	FGR_FAST	do flux-guide reset with fast CRST recharge
0x07	BR	do bit reset with full CRST recharge
0x08	BR_FAST	do bit reset with fast CRST recharge

8.6 寄存器 (0x06) 电源管理单元_命令

描述: PMU命令配置 复位：0x00 定义（参见第8章寄存器映射）

Bit	7	6	5	4	3	2	1	0
读/写	n/a	RW	RW	RW	W	W	W	W
重置值	0	0	0	0	0	0	0	0
内容	保留				pmu_cmd			

pmu_cmd: 电源管理单元模式切换命令

电源管理单元_命令		
0x00	SUS	进入挂起模式
0x01	NM	进入正常模式。注意在正常模式下，可能仅需SUS和UPD_OAE命令。若需执行其他命令，保护机制会阻止该命令在器件内传播，并设置非法_命令标志。即使在此情况下，发送非法命令后再次发送其他命令前，忙碌位必须为低电平
0x02	UPD_OAE	更新输出数据速率和平均参数：请求一次odr/avg更新后，必须等待忙碌标志清除后的数据就绪中断，才能请求下一次odr/avg更新（这意味着首组数据已按新odr/avg生成）。注意仅观察忙碌标志是不正确的，因为忙碌标志可能过早解除（A-Si实现限制）
0x03	FM	进入带完全CRST充电的强制模式
0x04	强制模式快速_	进入强制模式并执行快速CRST充电
0x05	FGR	执行通量引导复位并完成完全CRST充电
0x06	FGR_快速模式	执行通量引导复位并完成快速CRST充电
0x07	BR	执行位复位并完成完全CRST充电
0x08	BR快速_	执行位复位并完成快速CRST充电

8.7 Register (0x07) PMU_CMD_STATUS_0

DESCRIPTION: Sensor Status Flag
RESET: 0x00
DEFINITION (See Chapter 8 Register Map)

Bit	7	6	5	4	3	2	1	0
Read/Write	n/a	n/a	n/a	R	R	R	R	R
Reset Value	0	0	0	0	0	0	0	0
Content	reserved			cmd_is_illegal	pwr_mode_is_normal	AVG_ovwr	ODR_ovwr	pmu_cmd_busy

▶ pmu_cmd_busy: The previous PMU CMD is still in processing
0x0: pmu_ok 0x1: pmu_busy
▶ ODR_ovwr: The previous PMU_CMD_AGGR_SET.odr has been overwritten
0x0: odr_nochange 0x1: odr_ovwr
▶ AVG_ovwr: The previous PMU_CMD_AGGR_SET.avg has been overwritten
0x0: avg_nochange 0x1: avg_ovwr
▶ pwr_mode_is_normal: The chip is in normal power mode
0x0: not_normal 0x1: normal_mode
▶ cmd_is_illegal: cmd value is not allowed
0x0: cmd_ok 0x1: illegal

8.7 寄存器（0x07）电源管理单元_命令_状态_0

描述：传感器状态标志 复位：0x00 定义
（参见第8章寄存器映射）

Bit	7	6	5	4	3	2	1	0
读/写	n/a	n/a	n/a	R	R	R	R	R
重置值	0	0	0	0	0	0	0	0
内容	reserved			cmd_is_illegal	pwr_mode_is_normal	平均值 ovw_r	输出数据速率 ovw_r	电源管理单元_命令busy

▶ pmu_cmd_busy: 前一条PMU命令仍在处理中 0x0: pmu_ok 0x1: pmu_busy▶ ODR_ovwr: 前一条PMU_CMD_AGGR_SET.odr已被覆盖 0x0: odr_nochange 0x1: odr_ovwr▶ AVG_ovwr: 前一条PMU_CMD_AGGR_SET.avg已被覆盖 0x0: avg_nochange 0x1: avg_ovwr▶ pwr_mode_is_normal: 芯片处于正常电源模式 0x0: 非正常 0x1: 正常模式
_ _▶ cmd_is_illegal: 命令值不允许 0x0: cmd_ok 0x1: 非法

8.8 Register (0x08) PMU_CMD_STATUS_1

DESCRIPTION: PMU Status Flag
RESET: 0x00
DEFINITION (See Chapter 8 Register Map)

Bit	7	6	5	4	3	2	1	0
Read/Write	n/a	n/a	R	R	R	R	R	R
Reset Value	0	0	0	0	0	0	0	0
Content	reserved		pmu_avg_s		pmu_odr_s			

- pmu_odr_s: The actual effective PMU_CMD_AGGR_SET.odr value
- pmu_avg_s: The actual effective PMU_CMD_AGGR_SET.avg value

8.9 Register (0x09) I3C_ERR

DESCRIPTION: I3C Bus Error Statistics. Will be cleared on read. If the user writes a 1 into any status bit, this will also clear that bit
RESET: 0x00
DEFINITION (See Chapter 8 Register Map)

Bit	7	6	5	4	3	2	1	0
Read/Write	n/a	n/a	n/a	n/a	RW	n/a	n/a	RW
Reset Value	0	0	0	0	0	0	0	0
Content	reserved				i3c_error_3	Reserved		i3c_error_0

- i3c_error_0: SDR parity error occured.

0x0: i3c0_noerror 0x1: i3c0_error

- i3c_error_3: S0/S1 error occurred. S0/S1 error will be cleared automatically after 60 us or if we see a HDR-exit pattern on the bus.

0x0: i3c3_noerror 0x1: i3c3_error

8.10 Register (0x0A) I2C_WDT_SET

DESCRIPTION: i2c watchdog configure registers
RESET: 0x00
DEFINITION (See Chapter 8 Register Map)

Bit	7	6	5	4	3	2	1	0
Read/Write	n/a	n/a	n/a	n/a	n/a	n/a	RW	RW
Reset Value	0	0	0	0	0	0	0	0
Content	reserved						i2c_wdt_sel	i2c_wdt_en

i2c_wdt_en: i2c watch dog enable.

i2c_wdt_en		
0x00	disabled	Disable I2C watch dog
0x01	enabled	Enable I2C watch dog

8.8 寄存器（0x08）电源管理单元_命令_状态_1

描述: PMU状态标志
复位：0x00
定义（参见第8章寄存器映射）

Bit	7	6	5	4	3	2	1	0
读/写	n/a	n/a	R	R	R	R	R	R
重置值	0	0	0	0	0	0	0	0
内容	保留		电源管理单元_平均值_s		电源管理单元_输出数据速率_s			

▶ 电源管理单元_输出数据速率_s：实际生效的电源管理单元_命令_聚合_设置.输出数据速率值▶ 电源管理单元_平均值_s：实际生效的电源管理单元_命令_聚合_设置.平均值

8.9 寄存器（0x09）I3C_错误

描述：I3C总线错误统计。读取时清除。如果用户向任何状态位写入1，也将清除该位

复位：0x00
定义（参见第8章寄存器映射）

Bit	7	6	5	4	3	2	1	0
读/写	n/a	n/a	n/a	n/a	RW	n/a	n/a	RW
重置值	0	0	0	0	0	0	0	0
内容	保留				i3c_错误_3	保留		i3c_错误_0

- I3C_错误_0：发生SDR奇偶校验错误。

0x0: I3C0 无错误 0x1: I3C0 错误_ _

- I3C_错误_3：发生S0/S1错误。S0/S1错误将在60微秒后自动清除，或在总线上检测到HDR退出模式时清除。

0x0: I3C3 无错误 0x1: I3C3 错误
_ _

8.10 寄存器 (0x0A) I2C_看门狗定时器_设置

描述：I2C看门狗配置寄存器 复位：0x00

定义（参见第8章寄存器映射）

Bit	7	6	5	4	3	2	1	0
读/写	n/a	n/a	n/a	n/a	n/a	n/a	RW	RW
重置值	0	0	0	0	0	0	0	0
内容	保留						i2c_wdt_sel	i2c_wdt_en

i2c_wdt_en: I2C看门狗启用。

I2C看门狗定时器_ _en		
0x00	禁用	禁用I2C看门狗
0x01	启用	启用I2C看门狗

i2c_wdt_sel: i2c watch dog time out period.

i2c_wdt_sel		
0x00	short	I2C watch dog time out after 1.28ms
0x01	long	I2C watch dog time out after 40.96ms

8.11 Register (0x2E) INT_CTRL

H DESCRIPTION: Configuration of interrupts for INT_STATUS register and INT pin
RESET: 0x00
DEFINITION (See Chapter 8 Register Map)

Bit	7	6	5	4	3	2	1	0
Read/Write	R/W	n/a	n/a	n/a	R/W	R/W	R/W	R/W
Reset Value	0	0	0	0	0	0	0	0
Content	drdy_data_reg_en	reserved			int_output_en	int_od	int_pol	int_mode

int_mode: Interrupt Mode
▶ If set, output is in Latched Mode, else in Pulsed Mode

int_mode		
0x00	pulsed	null
0x01	latched	null

int_pol: Interrupt Polarity
▶ If set, output is Active High, else Active Low

int_pol		
0x00	active_low	null
0x01	active_high	null

int_od: Configure output: open-drain or push-pull

int_od		
0x00	open-drain	null
0x01	push-pull	null

int_output_en: Enable mapping of int on INT pin. IMPORTANT: this is not supported in A-Si: this bit is reserved in A-Si.

int_output_en		
0x00	off	Output disabled
0x01	on	Output enabled

drdy_data_reg_en: Enable Mag Data Ready interrupt onto INT pin and INT_STATUS

drdy_data_reg_en		
0x00	disabled	null
0x01	enabled	null

i2c_wdt_sel: I2C看门狗超时 period.

i2c 看门狗定时器 sel_		
0x00	短	I2C看门狗超时 1.28毫秒后
0x01	long	I2C看门狗超时 40.96毫秒后

8.11 寄存器 (0x2E) INT_CTRL

H 描述：INT_状态寄存器和INT引脚的中断配置
复位：0x00
定义（参见第8章寄存器映射）

Bit	7	6	5	4	3	2	1	0
读/写	R/W	n/a	n/a	n/a	R/W	R/W	R/W	R/W
重置值	0	0	0	0	0	0	0	0
内容	数据就绪（缩写）_数据_寄存器_使能	保留			中断_输出_en	中断 开漏_	中断_极性	中断模式_

中断_模式：中断模式
▶ 若设置，输出为锁存模式，否则为脉冲模式

int_mode		
0x00	脉冲	null
0x01	锁存	null

int_pol: Interrupt Polarity
▶ 若设置，输出为高电平有效，否则为低电平有效

int_pol		
0x00	激活 _low	null
0x01	激活 _high	null

int_od：配置输出：开漏或推挽

int_od		
0x00	开漏	null
0x01	推挽	null

int_output_en：启用中断映射至INT引脚。重要提示：非晶硅不支持此功能：该位在非晶硅中保留。

中断_输出_使能		
0x00	off	输出禁用
0x01	on	输出已启用

drdy_数据_寄存器_使能：启用磁力计数据就绪中断至INT引脚和中断_状态

数据就绪（缩写）_数据_寄存器_使能		
0x00	禁用	null
0x01	启用	null

8.12 Register (0x2F) INT_CTRL_IBI

DESCRIPTION: Configuration of interrupts features related to IBI
RESET: 0x00
DEFINITION (See Chapter 8 Register Map)

Bit	7	6	5	4	3	2	1	0
Read/Write	n/a	n/a	n/a	R/W	n/a	n/a	n/a	R/W
Reset Value	0	0	0	0	0	0	0	0
Content	reserved			clear_drdy_int_status_upon_ibi	reserved			drdy_int_map_to_ibi

drdy_int_map_to_ibi: map the drdy interrupt to I3C IBI

drdy_int_map_to_ibi		
0x00	disabled	null
0x01	enabled	null

clear_drdy_int_status_upon_ibi: clear INT_STATUS.drdy upon I3C IBI

clear_drdy_int_status_upon_ibi		
0x00	disabled	null
0x01	enabled	null

8.13 Register (0x30) INT_STATUS

DESCRIPTION: Interrupt Status. Will be cleared on read. If the user writes a 1 into any status bit, this will also clear that bit.
RESET: 0x00
DEFINITION (See Chapter 8 Register Map)

Bit	7	6	5	4	3	2	1	0
Read/Write	n/a	n/a	n/a	n/a	n/a	R/W	n/a	R/W
Reset Value	0	0	0	0	0	0	0	0
Content	reserved					drdy_data_reg	reserved	reserved

▶ drdy_data_reg: Magnetic data ready interrupt

0x0: no_new data
0x1: new_data

8.12 寄存器 (0x2F) INT_CTRL_IBI

描述：与IBI RESET相关的中断功能配置：复位：0x00

定义（参见第8章寄存器映射）

Bit	7	6	5	4	3	2	1	0
读/写	n/a	n/a	n/a	R/W	n/a	n/a	n/a	R/W
重置值	0	0	0	0	0	0	0	0
内容	保留			清除 drd_y_int_stat us_upon_i bi	保留			数据就绪（缩写）_中断_映射_到_带内中断

数据就绪（缩写）_中断_映射_到_带内中断：将数据就绪中断映射至I3C带内中断

数据就绪（缩写）_中断_映射_到_带内中断		
0x00	禁用	null
0x01	启用	null

清除_数据就绪（缩写）_中断_状态_当_带内中断时：在I3C带内中断时清除中断_状态.数据就绪（缩写）

读取时清除_数据就绪（drdy）_中断（int）_状态_通过_带内中断（II		
0x00	禁用	null
0x01	启用	null

8.13 寄存器 (0x30) 中断（INT）_状态

描述：中断状态。读取时清除。如果用户向任何状态位写入1，也会清除该位。

复位：0x00
定义（参见第8章寄存器映射）

Bit	7	6	5	4	3	2	1	0
读/写	n/a	n/a	n/a	n/a	n/a	R/W	n/a	R/W
重置值	0	0	0	0	0	0	0	0
内容	保留					drdy_数据_寄存器	保留	保留

▶ 数据就绪（缩写）_数据_寄存器: 磁数据就绪
中断 0x0: 无新数据_0x1: 新数据_

8.14 Register (0x31) MAG_X_XLSB

DESCRIPTION: magnetometer X-axis extreme LSB byte
RESET: 0x7F
DEFINITION (See Chapter 8 Register Map)

Bit	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
Read/Write	R	R	R	R	R	R	R	R
Reset Value	0	1	1	1	1	1	1	1
Content	data_x_7_0							

8.15 Register (0x32) MAG_X_LSB

DESCRIPTION: magnetometer X-axis LSB byte
RESET: 0x7F
DEFINITION (See Chapter 8 Register Map)

Bit	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
Read/Write	R	R	R	R	R	R	R	R
Reset Value	0	1	1	1	1	1	1	1
Content	data_x_15_8							

8.16 Register (0x33) MAG_X_MSB

DESCRIPTION: magnetometer X-axis MSB byte
RESET: 0x7F
DEFINITION (See Chapter 8 Register Map)

Bit	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
Read/Write	R	R	R	R	R	R	R	R
Reset Value	0	1	1	1	1	1	1	1
Content	data_x_23_16							

8.14 寄存器 (0x31) 磁力计_X轴_XLSB

描述: 磁力计X轴最低有效字节
重置：0x7F
定义（参见第8章寄存器映射）

Bit	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
读/写	R	R	R	R	R	R	R	R
重置值	0	1	1	1	1	1	1	1
内容	数据 x 7 0_ _ _							

8.15 寄存器 (0x32) 磁力计_X_最低有效位

描述：磁力计X轴最低有效字节 重置：0x7F

定义（参见第8章寄存器映射）

Bit	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
读/写	R	R	R	R	R	R	R	R
重置值	0	1	1	1	1	1	1	1
内容	数据 x 15 8_ _ _							

8.16 寄存器 (0x33) 磁力计_X轴_最高有效位

描述：磁力计X轴最高有效位字节 重置：0x7F

定义（参见第8章寄存器映射）

Bit	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
读/写	R	R	R	R	R	R	R	R
重置值	0	1	1	1	1	1	1	1
内容	数据 X轴 23 16 _ _ _							

8.17 Register (0x34) MAG_Y_XLSB

DESCRIPTION: magnetometer Y-axis extreme LSB byte
RESET: 0x7F
DEFINITION (See Chapter 8 Register Map)

Bit	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
Read/Write	R	R	R	R	R	R	R	R
Reset Value	0	1	1	1	1	1	1	1
Content	data_y_7_0							

Data retrieval: see 8.14

8.18 Register (0x35) MAG_Y_LSB

DESCRIPTION: magnetometer Y-axis LSB byte
RESET: 0x7F
DEFINITION (See Chapter 8 Register Map)

Bit	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
Read/Write	R	R	R	R	R	R	R	R
Reset Value	0	1	1	1	1	1	1	1
Content	data_y_15_8							

8.19 Register (0x36) MAG_Y_MSB

DESCRIPTION: magnetometer Y-axis MSB byte
RESET: 0x7F
DEFINITION (See Chapter 8 Register Map)

Bit	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
Read/Write	R	R	R	R	R	R	R	R
Reset Value	0	1	1	1	1	1	1	1
Content	data_y_23_16							

8.20 Register (0x37) MAG_Z_XLSB

DESCRIPTION: magnetometer Z-axis extreme LSB byte
RESET: 0x7F
DEFINITION (See Chapter 8 Register Map)

Bit	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
Read/Write	R	R	R	R	R	R	R	R
Reset Value	0	1	1	1	1	1	1	1
Content	data_z_7_0							

8.17 寄存器 (0x34) 磁力计_Y轴_XLSB

描述: 磁力计Y轴最低有效字节 重置：0x7F

定义（参见第8章寄存器映射）

Bit	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
读/写	R	R	R	R	R	R	R	R
重置值	0	1	1	1	1	1	1	1
内容	数据_Y轴_7_0							

数据检索：参见8.14

8.18 寄存器 (0x35) 磁力计_Y_最低有效位

描述：磁力计Y轴LSB字节
重置：0x7F
定义（参见第8章寄存器映射）

Bit	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
读/写	R	R	R	R	R	R	R	R
重置值	0	1	1	1	1	1	1	1
内容	数据_y_15_8							

8.19 寄存器 (0x36) 磁力计_Y_最高有效位

描述：磁力计Y轴最高有效字节 重置：0x7F

定义（参见第8章寄存器映射）

Bit	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
读/写	R	R	R	R	R	R	R	R
重置值	0	1	1	1	1	1	1	1
内容	数据_Y轴_23_16							

8.20 寄存器 (0x37) 磁力计_Z轴_XLSB

描述：磁力计Z轴最低有效字节
重置：0x7F
定义（参见第8章寄存器映射）

Bit	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
读/写	R	R	R	R	R	R	R	R
重置值	0	1	1	1	1	1	1	1
内容	data_z_7_0							

8.21 Register (0x38) MAG_Z_LSB

DESCRIPTION: magnetometer Z-axis LSB byte
RESET: 0x7F
DEFINITION (See Chapter 8 Register Map)

Bit	7	6	5	4	3	2	1	0
Read/Write	R	R	R	R	R	R	R	R
Reset Value	0	1	1	1	1	1	1	1
Content	data_z_15_8							

8.22 Register (0x39) MAG_Z_MSB

DESCRIPTION: magnetometer Z-axis MSB byte
RESET: 0x7F
DEFINITION (See Chapter 8 Register Map)

Bit	7	6	5	4	3	2	1	0
Read/Write	R	R	R	R	R	R	R	R
Reset Value	0	1	1	1	1	1	1	1
Content	data_z_23_16							

8.23 Register (0x3A) TEMP_XLSB

DESCRIPTION: Temperature extreme LSB byte
RESET: 0x7F
DEFINITION (See Chapter 8 Register Map)

Bit	7	6	5	4	3	2	1	0
Read/Write	R	R	R	R	R	R	R	R
Reset Value	0	1	1	1	1	1	1	1
Content	data_t_7_0							

data_t_7_0: Temperature

8.24 Register (0x3B) TEMP_LSB

DESCRIPTION: Temperature LSB byte.
RESET: 0x7F
DEFINITION (See Chapter 8 Register Map)

Bit	7	6	5	4	3	2	1	0
Read/Write	R	R	R	R	R	R	R	R
Reset Value	0	1	1	1	1	1	1	1
Content	data_t_15_8							

data_t_15_8: Temperature.

8.21 寄存器 (0x38) 磁力计_Z轴_最低有效位

描述: 磁力计Z轴最低有效位字节
重置：0x7F
定义（参见第8章寄存器映射）

Bit	7	6	5	4	3	2	1	0
读/写	R	R	R	R	R	R	R	R
重置值	0	1	1	1	1	1	1	1
内容	data_z_15_8							

8.22 寄存器 (0x39) 磁力计_Z轴_最高有效位

描述：磁力计Z轴最高有效位字节
重置：0x7F
定义（参见第8章寄存器映射）

Bit	7	6	5	4	3	2	1	0
读/写	R	R	R	R	R	R	R	R
重置值	0	1	1	1	1	1	1	1
内容	data_z_23_16							

8.23 寄存器 (0x3A) 温度_XLSB

描述：温度极限最低有效字节
重置：0x7F
定义（参见第8章寄存器映射）

Bit	7	6	5	4	3	2	1	0
读/写	R	R	R	R	R	R	R	R
重置值	0	1	1	1	1	1	1	1
内容	数据 t 7 0_ _ _							

data_t_7_0: 温度

8.24 寄存器 (0x3B) 温度_LSB

描述：温度LSB字节。
重置：0x7F
定义（参见第8章寄存器映射）

Bit	7	6	5	4	3	2	1	0
读/写	R	R	R	R	R	R	R	R
重置值	0	1	1	1	1	1	1	1
内容	data_t_15_8							

数据_时间_15_8：温度。

8.25 Register (0x3C) TEMP_MSB

DESCRIPTION: Temperature MSB byte.
RESET: 0x7F
DEFINITION (See Chapter 8 Register Map)

Bit	7	6	5	4	3	2	1	0
Read/Write	R	R	R	R	R	R	R	R
Reset Value	0	1	1	1	1	1	1	1
Content	data_t_23_16							

data_t_23_16: Temperature.

8.26 Register (0x3D) SENSORTIME_XLSB

DESCRIPTION: Sensor timer extreme LSB byte
RESET: 0x7F
DEFINITION (See Chapter 8 Register Map)

Bit	7	6	5	4	3	2	1	0
Read/Write	R	R	R	R	R	R	R	R
Reset Value	0	1	1	1	1	1	1	1
Content	data_st_7_0							

data_st_7_0: Sensor timer.

8.27 Register (0x3E) SENSORTIME_LSB

DESCRIPTION: Sensor timer LSB byte.
RESET: 0x7F
DEFINITION (See Chapter 8 Register Map)

Bit	7	6	5	4	3	2	1	0
Read/Write	R	R	R	R	R	R	R	R
Reset Value	0	1	1	1	1	1	1	1
Content	data_st_15_8							

data_st_15_8: Sensor timer.

8.28 Register(0x3F) SENSORTIME_MSB

DESCRIPTION: Sensor timer MSB byte.
RESET: 0x7F
DEFINITION (See Chapter 8 Register Map)

Bit	7	6	5	4	3	2	1	0
Read/Write	R	R	R	R	R	R	R	R
Reset Value	0	1	1	1	1	1	1	1
Content	data_st_23_16							

data_st_23_16: Sensor timer.

8.25 寄存器 (0x3C) 温度_最高有效位

描述: 温度最高有效字节。
重置：0x7F
定义（参见第8章寄存器映射）

Bit	7	6	5	4	3	2	1	0
读/写	R	R	R	R	R	R	R	R
重置值内容	0	1	1	1	1	1	1	1
	data_t_23_16							

数据_时间_23_16：温度。

8.26 寄存器 (0x3D) 传感器时间_XLSB

描述: 传感器时间极低有效字节
重置：0x7F
定义（参见第8章寄存器映射）

Bit	7	6	5	4	3	2	1	0
读/写	R	R	R	R	R	R	R	R
重置值内容	0	1	1	1	1	1	1	1
	数据st70_ _ _							

数据st70：传感器定时器。_ _ _

8.27 寄存器 (0x3E) SENSORTIME_最低有效位

描述：传感器定时器LSB字节。
重置：0x7F
定义（参见第8章寄存器映射）

Bit	7	6	5	4	3	2	1	0
读/写	R	R	R	R	R	R	R	R
重置值	0	1	1	1	1	1	1	1
内容	data_st_15_8							

数据 st 15 8: 传感器定时器。_ _ _

8.28 寄存器(0x3F) 传感器时间_最高有效位

描述：传感器定时器最高有效位字节。
重置：0x7F
定义（参见第8章寄存器映射）

Bit	7	6	5	4	3	2	1	0
读/写	R	R	R	R	R	R	R	R
重置值内容	0	1	1	1	1	1	1	1
	数据 传感器定时器 23 16_ _ _							

数据 传感器定时器 23 16:_ _ _ 传感器定时器。

8.29 Register (0x50) OTP_CMD_REG

DESCRIPTION: OTP command and word address register
RESET: 0x00
DEFINITION (See Chapter 8 Register Map)

Bit	7	6	5	4	3	2	1	0
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Reset Value	0	0	0	0	0	0	0	0
Content	otp_cmd			word_addr				

word_addr: word address (DIR_READ, DIR_PRGM_1B, DIR_PRGM) or word start address (EXT_READ, EXT_PRGM)

otp_cmd: otp commands:

001: DIR_READ
010: DIR_PRGM_1B
011: DIR_PRGM
100: PWR_OFF_OTP
101: EXT_READ
111: EXT_PRGM

8.30 Register (0x52) OTP_DATA_MSB_REG

DESCRIPTION: OTP data: most significant byte register: it contains the data to write for a prog command or the read data after a read command has been executed
RESET: 0x00
DEFINITION (See Chapter 8 Register Map)

Bit	7	6	5	4	3	2	1	0
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Reset Value	0	0	0	0	0	0	0	0
Content	otp_mem_data_msb							

otp_mem_data_msb: Most significant byte of 16-bit memory word

8.31 Register (0x53) OTP_DATA_LSB_REG

DESCRIPTION: OTP data: least significant byte register: it contains the data to write for a prog command or the read data after a read command has been executed
RESET: 0x00
DEFINITION (See Chapter 8 Register Map)

Bit	7	6	5	4	3	2	1	0
Read/Write	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
Reset Value	0	0	0	0	0	0	0	0
Content	otp_mem_data_lsb							

otp_mem_data_lsb: Least significant byte of 16-bit memory word

8.29 寄存器（0x50）OTP_命令_寄存器

描述: OTP命令和字地址寄存器
复位：0x00
定义（参见第8章寄存器映射）

Bit	7	6	5	4	3	2	1	0
读/写	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
重置值	0	0	0	0	0	0	0	0
内容	一次性可编程存储器_命令			word_addr				

字地址: 字地址（方向 _读取, 方向 _PRGM_1B, 目录_程序) 或字开始地址 (外部 _读取, EXT_PRGM)

otp_cmd: otp commands:

001: DIR_READ
010: DIR_PRGM_1B
011: DIR_PRGM
100: 电源 _OFF_OTP
101: 外部 _READ
111: 外部 _PRGM

8.30 寄存器（0x52）OTP_数据_最高有效位_寄存器

描述: OTP数据：最高有效字节寄存器：它包含用于程序命令的写入数据或执行读取命令后的读取数据

复位：0x00
定义（参见第8章寄存器映射）

Bit	7	6	5	4	3	2	1	0
读/写	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
重置值	0	0	0	0	0	0	0	0
内容	一次性可编程存储器_内存_数据_最高有效位							

otp_mem_data_msb：16位内存字的最高有效字节

8.31 寄存器（0x53）OTP_DATA_LSB_REG

描述：OTP数据：最低有效字节寄存器：它包含用于程序命令的写入数据或执行读取命令后的读取数据

复位：0x00
定义（参见第8章寄存器映射）

Bit	7	6	5	4	3	2	1	0
读/写	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
重置值	0	0	0	0	0	0	0	0
内容	一次性可编程存储器_mem_数据_最低有效位							

otp_mem_数据_lsb: 16位存储字的最低有效字节

8.32 Register (0x55) OTP_STATUS_REG

DESCRIPTION: OTP status register
RESET: 0x10
DEFINITION (See Chapter 8 Register Map)

Bit	7	6	5	4	3	2	1	0
Read/Write	R	R	R	R	R	R	R	R
Reset Value	0	0	0	1	0	0	0	0
Content	error			cur_page_addr				otp_cmd_done

otp_cmd_done: Command done flag. When this field is = 1, then a new command can be accepted.
Otherwise, SW must wait before sending a new command because the previous one is still being executed
cur_page_addr: Currently selected page out of 8 selectable pages
error: Error register
000: NO_ERROR
001: BOOT_ERR
010: PAGE_RD_ERR
011: PAGE_PRG_ERR
100: SIGN_ERR
101: INV_CMD_ERR

8.33 Register (0x60) TMR_SELFTEST_USER

DESCRIPTION: TMR user selftest reg. Please also consider the following IMPORTANT NOTES for the definition of ST algorithm in API.
1. enabling of internal self test current generator is a precondition for correct functionality of self test
2. the bits st_n and st_p must never be asserted simultaneously, not only because they are conflicting configurations, but because they would generate an internal short during self test execution, yielding wrong results and potentially damaging the circuits
RESET: 0x00
DEFINITION (See Chapter 8 Register Map)

Bit	7	6	5	4	3	2	1	0
Read/Write	n/a	n/a	n/a	R/W	R/W	R/W	R/W	R/W
Reset Value	0	0	0	0	0	0	0	0
Content	reserved			ist_en_y	ist_en_x	st_p	st_n	st_igen_en

st_igen_en: Drives the dc_st_igen_en signal (when 1 it enables the selftest internal current gen)
st_n: when at 1 configures execution of negative field self test (Drives the dc_st_n signal)
st_p: when at 1 configures execution of positive field self test (Drives the dc_st_p signal)
ist_en_x: when at 1 activates internally generated self-test field on X axis,
assuming all other preconditions and configurations are already set (Drives the dc_ist_en_x signal)
ist_en_y: when at 1 activates internally generated self-test field on Y axis
transducer, assuming all other preconditions and configurations are already set (Drives the dc_ist_en_y signal)

8.32 寄存器 (0x55) OTP_状态_寄存器

描述: OTP状态寄存器
重置: 0x10
定义（参见第8章寄存器映射）

Bit	7	6	5	4	3	2	1	0
读/写	R	R	R	R	R	R	R	R
重置值	0	0	0	1	0	0	0	0
内容	错误			cur_page_地址				一次性可编程存储器_命令_完成

一次性可编程存储器_命令_完成: 命令完成标志。当此字段为= 1时，表示可以接受新命令。
否则，软件必须等待发送新命令，因为前一条命令仍在执行中
cur_page_addr: 当前选中的页面（共8个可选页面）
error: Error register
000: 无错误_001: 启动
错误_010: 页面读取错误
_ _011: 页面编程错误
_ _100: 签名错误_
101: 无效命令错误
_ _

8.33 寄存器 (0x60) TMR_自测_用户

描述：TMR用户自测寄存器。关于API中的ST算法定义，请同时参考以下重要说明。

1. 启用内部自测电流发生器是确保自测功能正确的先决条件
2. 位st_n和st_p绝对不可同时置位，这不仅会导致配置冲突，还会在自测执行期间引发内部短路，从而产生错误结果并可能损坏电路 复位：0x00

定义（参见第8章寄存器映射）

Bit	7	6	5	4	3	2	1	0
读/写	n/a	n/a	n/a	R/W	R/W	R/W	R/W	R/W
重置值	0	0	0	0	0	0	0	0
内容	保留			传感器定时器_使能_Y轴	ist en x_ _	st_p	st n_	传感器定时器_igen_电子 n

st_igen_en: Drives the dc_st_igen_en signal (when 1 it enables the selftest internal current gen)
st_n: when at 1 configures execution of negative field self test (Drives the dc_st_n signal)
st_p: when at 1 configures execution of positive field self test (Drives the dc_st_p signal)
ist_en_x: when at 1 activates internally generated self-test field on X axis,
assuming all other preconditions and configurations are already set (Drives the dc_ist_en_x signal)
ist_使能_Y轴: 当值为1时激活内部生成的自检字段于Y轴
传感器，假设所有其他前提条件和配置均已设置（驱动dc_ist_en_y信号）

8.34 Register (0x61) CTRL_USER

DESCRIPTION: user settings register
RESET: 0x00
DEFINITION (See Chapter 8 Register Map)

Bit	7	6	5	4	3	2	1	0
Read/Write	n/a	n/a	n/a	n/a	n/a	n/a	n/a	R/W
Reset Value	0	0	0	0	0	0	0	0
Content	reserved							cfg_sens_ tim_aon

- cfg_sens_tim_aon: It forces the sensor timer to be always running, even in SUSPEND MODE.
- This field can be written only in SUSPEND mode.

0x0: sensortime_while_normal
0x1:sensortime_always

8.35 Register (0x7E) CMD

DESCRIPTION: Command Register
RESET: 0x00
DEFINITION (See Chapter 8 Register Map)

Bit	7	6	5	4	3	2	1	0
Read/Write	W	W	W	W	W	W	W	W
Reset Value	0	0	0	0	0	0	0	0
Content	cmd							

cmd: Available commands (Note: Register will always return 0x00 as read result):

cmd		
0x00	nop	Reserved. No command.
0xb6	softreset	Configuring this command will trigger a power on reset

8.34 寄存器 (0x61) CTRL_用户

描述: 用户设置寄存器
RESET: 0x00
定义（参见第8章寄存器映射）

Bit	7	6	5	4	3	2	1	0
读/写	n/a	n/a	n/a	n/a	n/a	n/a	n/a	R/W
重置值	0	0	0	0	0	0	0	0
内容	保留							配置_灵敏度 _时间 开启_

- cfg_sens_tim_aon：该配置强制传感器定时器始终运行，即使在挂起模式下。
- 此字段仅在挂起模式下可写。

0x0: sensortime_while_normal
0x1:sensortime_always

8.35 寄存器 (0x7E) CMD

描述：命令寄存器
复位：0x00
定义（参见第8章寄存器映射）

Bit	7	6	5	4	3	2	1	0
读/写	W	W	W	W	W	W	W	W
重置值	0	0	0	0	0	0	0	0
内容	cmd							

命令：可用命令（注：寄存器读取结果始终返回0x00）：

cmd		
0x00	nop	保留。无命令。
0xb6	软复位	配置此命令将 触发上电复位

9. Digital Interfaces

The sensor supports the I²C and I3C digital interfaces, where it acts as a “slave” for both protocols. The I²C interface supports the Standard, Fast and Fast+ modes. The I3C interface supports the single-data-rate SDR, high data rate HDR is not supported. However, the device can detect entering HDR mode and immediately stops listening to I3C data traffic until it detects the “leave HDR” I3C message.

The following transactions are supported:
- ▶ Single byte write
- ▶ Multiple byte write (using pairs of register addresses and register data)
- ▶ Single byte read
- ▶ Multiple byte read (using a single register address which is auto-incremented)

I3C additionally supports

- ▶ in-band-interrupt IBI
- ▶ timing control ASYNC

9.1 Interface selection

By default/after reset the I²C interface is active. After receiving the standardized I3C enable message (see I3C specification), the I3C interface is activated and remains active until a reset/power down event.
The correct address must be applied in both communication modes. The I2C (legacy) address is a combination of a fixed value, the value of the level of the pin “ADSEL” at boot time (after reset).

9.2 I²C interface

For detailed timings, please review the NXP original document UM10204.pdf (registration at https://www.nxp.com required).
All modes (standard, fast, fast+) are supported. As the device does not perform clock stretching, the SCL structure is a high-Z input without open drain capability.

The 5 MSB bits are fixed. The last bit is changeable by the pin setting of “ADSEL”. ADSEL will be evaluated at boot time, the I2C address is fixed then.

The ADSEL pin must not be left floating; if left floating, the I²C address will be undefined.

The 7-bit I2C device address is defined according to the following tables.

Table 9: I2C address definition

bit<6>	bit <5>	bit <4>	bit <3>	bit <2>	bit <1>	bit <0>
0	0	1	0	1	OTP backed, is 0	0: ADSEL=LOW

By default bit 1 of the I2C address is 0.

9. 数字接口

该传感器支持I2C和I3C数字接口，在这两种协议中均作为“从设备”运行。I2C接口支持标准模式、快速模式及快速+模式。I3C接口仅支持单数据速率SDR，不支持高数据速率HDR。但该器件可检测到进入HDR模式，并立即停止监听I3C数据通信，直至检测到“离开HDR”I3C消息。

支持以下事务处理：
- ▶ 单字节写入
- ▶ 多字节写入（使用寄存器地址与寄存器数据对）
- ▶ 单字节读取
- ▶ 多字节读取（使用自动递增的单一寄存器地址）

I3C还支持

- ▶ 带内中断IBI
- ▶ 时序控制ASYNC

9.1 接口选择

默认/复位后，I2C接口处于激活状态。接收到标准化的I3C启用消息（参见I3C规范）后，I3C接口将被激活并保持活动状态，直至发生复位/断电事件。
两种通信模式下均需使用正确的地址。I2C（传统）地址由固定值与启动时（复位后）ADSEL引脚电平值组合而成。

9.2 I2C接口

详细时序请查阅恩智浦原始文档UM10204.pdf（需在https://www.nxp.com注册）。

支持所有模式（标准模式、快速模式、快速+模式）。由于器件不执行时钟拉伸，SCL结构为不具备开漏能力的高阻输入。

最高有效位5位固定。最后一位可通过“ADSEL”引脚设置改变。ADSEL将在启动时被评估，此后I2C地址即固定。

ADSEL引脚不得悬空；若悬空，I2C地址将变为未定义状态。

7位I2C设备地址根据以下表格定义。

表9：I2C地址定义

位<6>	位 <5>	位 <4>	位 <3>	位 <2>	位 <1>	位 <0>
0	0	1	0	1	OTP支持 ， is 0	0: ADSEL=低电平

默认情况下，I2C地址的第1位为0。

Table 10: I2C address roll-out

I2C address	OTP content	ADSEL
0x14	0	LOW
0x15	0	HIGH

The I2C interface provides a “watchdog” which monitors the I2C traffic.
In case that no “STOP” condition is detected within a predefined time the I2C core is resetted.

`I2C_WDT_SET.i2c_wdt_en` enables and disables the watchdog.
In I3C mode the watchdog is not active.
Use API function it `bmm350_set_i2c_watchdog` to configure the watchdog.

`I2C_WDT_SET.i2c_wdt_en` allows to switch between a short (setting=0x0) time out (after 1.28ms) or a long (setting=0x1) time out (after 40.96ms) configuration.

The I²C interface uses the following pins:
- SCK: serial clock (SCL)
- SDI: data (SDA)
- ADSEL: Slave address LSB (GND = ‘0’, V_{DDIO} = ‘1’)

The following abbreviations will be used in the I²C protocol figures:
- S Start
- P Stop
- ACKS Acknowledge by slave
- ACKM Acknowledge by master
- NACKM Not acknowledge by master

9.2.1 I²C write

Writing is done by sending the slave address in write mode (RW = ‘0’).
Then the master sends pairs of register addresses and register data. The transaction is ended by a stop condition. This is depicted in Figure 5.

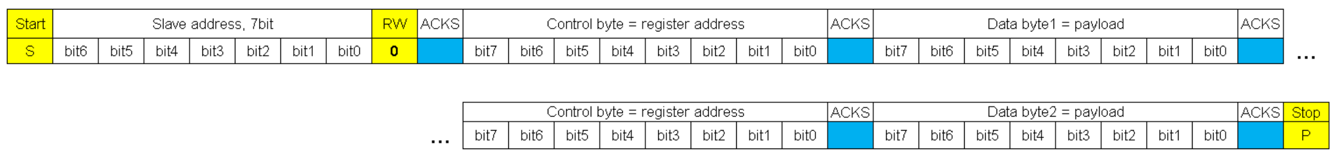


Figure 5: I²C multiple byte write (not auto-incremented)

表10：I2C地址分配

I2C地址	OTP内容	ADSEL
0x14	0	LOW
0x15	0	HIGH

I2C接口提供了一个监控I2C通信的“看门狗”。
若在预定义时间内未检测到“停止”条件，则I2C核心将被重置。

I2C_WDT_设置.I2C _wdt_使能用于启用和禁用看门狗。
在I3C模式下，看门狗处于非激活状态。
使用API函数 it `bmm350_set_i2c_watchdog` 来配置看门狗。

I2C看门狗定时器 设置.I2C 看门狗定时器 使能 允许在短（设置=0x0）超时（1.28毫秒后）_ _ _ _之间切换
或长（设置=0x1）超时（40.96毫秒后）配置。

I2C接口使用以下引脚：
- SCK：串行时钟（SCL）
- SDI：数据（SDA）
- ADSEL：从机地址最低位（地= ‘0’，电压$_{DDIO}$ = ‘1’）

以下缩写将用于I2C协议图中：
- S 开始
- P Stop
- ACKS 从设备确认
- ACKM 主机确认
- NACKM 主机未确认

9.2.1 I²C 写

通过以写入模式（RW = ‘0’）发送从机地址来完成写入。
随后主机发送寄存器地址与寄存器数据对。传输过程通过停止条件终止。该流程如图5所示。

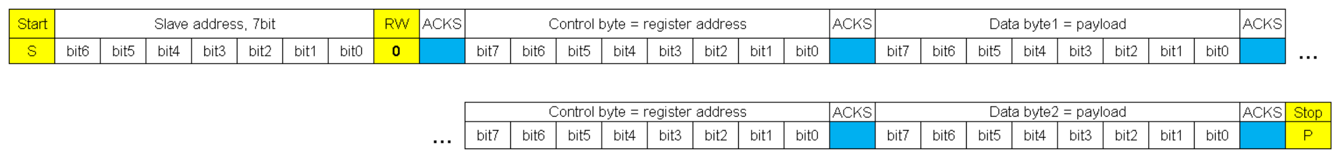


图5: I2C多字节写入（非自动递增）

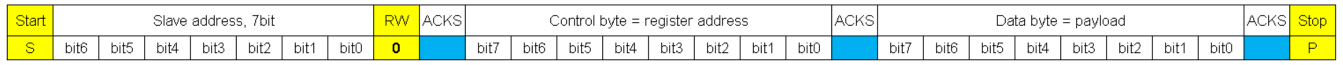


Figure 6: I²C single byte write

9.2.2 I²C read

To be able to read registers, first the register address must be sent in write mode. Then either a stop or a repeated start condition must be generated. After this the slave is addressed in read mode (RW = ‘1’), after which the slave sends out data from auto-incremented register addresses until a NOACKM and stop condition occurs. This is depicted in Figure 7, where register 0xF6 and 0xF7 are read.

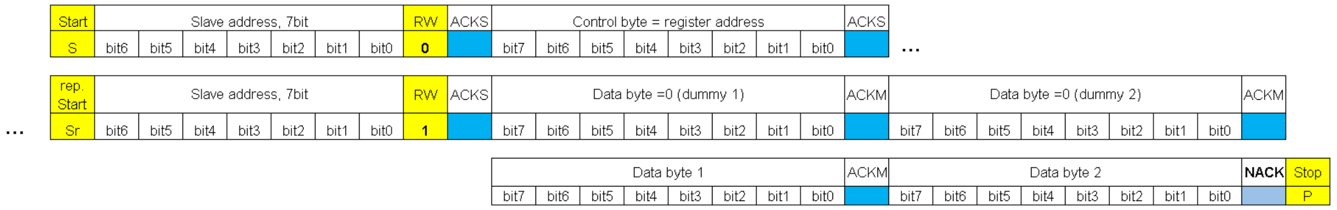


Figure 7: I²C multiple byte read, first 2 bytes transferred must be discarded, they are dummy bytes

9.2.3 Dummy bytes in I2C mode

It is important to note that two dummy bytes are sent <u>when reading registers</u>, which means that during an n byte read actually n+2 bytes have to be read, and the first 2 bytes be discarded.

9.3 I3C interface

The I3C interface is enabled using CCC commands as described in the I3C standard.

The I3C interface uses the following pins:

- SCK: serial clock
- SDA: serial data input/output, open drain or push-pull depending on communication state
- ADSEL: I2C legacy slave address LSB (GND = ‘0’, V_{DDIO} = ‘1’)

A typical I3C data packet looks like this:

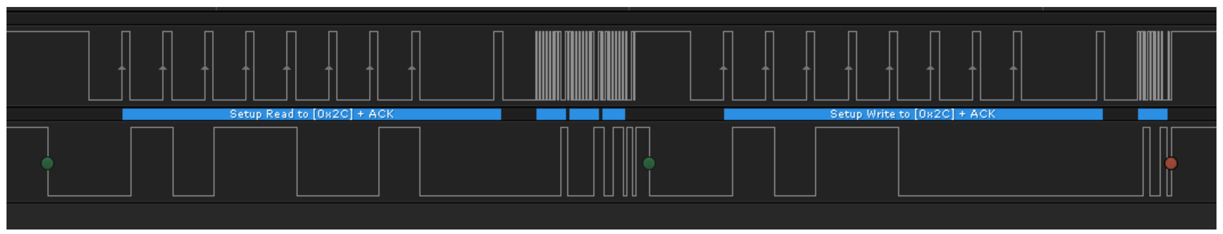


Figure 8: I3C data package

The open-drain address communication at the beginning is done which a low clock speed, while the push-pull data communication towards the end is done with 12.5MHz.
The possible benefit of the 12.5MHz clock is thus only achieved when sending large chunks of data at a time.

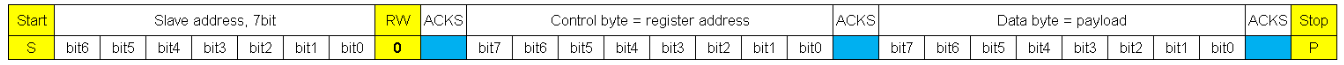


图6：I2C单字节写入

9.2.2 I2C读取

要读取寄存器，首先必须以写入模式发送寄存器地址。随后必须生成停止条件或重复起始条件。接着以读取模式（RW = ‘1’）寻址从设备，之后从设备会从自动递增寄存器地址发送数据，直至出现NOACK信号并触发停止条件。该过程如图7所示，图中读取了寄存器0xF6和0xF7。

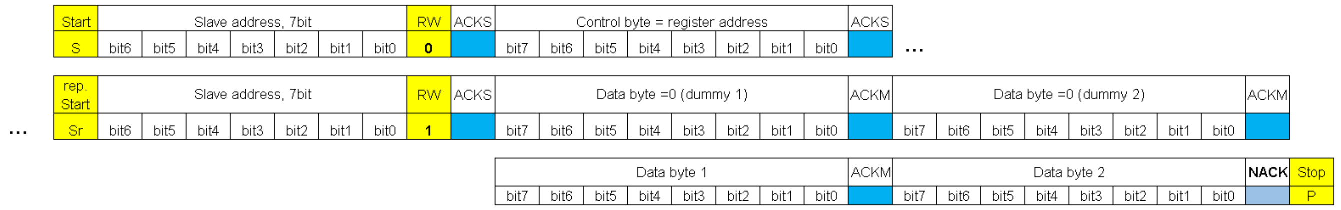


图7：I2C多字节读取，前2个传输字节需丢弃，它们是虚字节

9.2.3 I2C模式中的虚字节

需注意读取寄存器时会发送两个虚字节，这意味着进行n字节读取时实际需读取n+2 字节，且前2字节需丢弃。

9.3 I3C接口

I3C接口通过I3C标准中描述的CCC命令启用。

I3C接口使用以下引脚：

- SCK：串行时钟
- SDA：串行数据输入/输出，根据通信状态采用开漏或推挽模式
- ADSEL：I2C传统从机地址最低有效位（接地= ‘0’，接$_{DDIO}$ = ‘1’）

典型的I3C数据包如下所示：

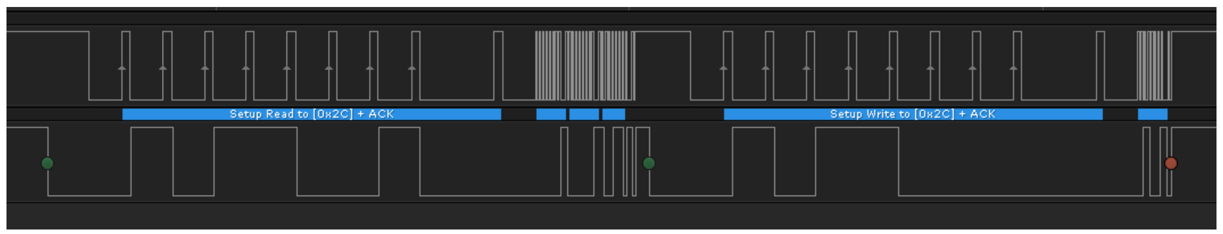


图8：I3C数据包

起始阶段采用低时钟速度进行开漏地址通信，而接近结束时则使用12.5兆赫进行推挽数据通信。

12.5兆赫时钟的潜在优势仅在一次性发送大块数据时才能实现。

9.3.1 Supported CCC

Command	Command code	Default	Description
ENEC	0x00 / 0x80		Enable Target event driven interrupts (broadcast and direct)
DISEC	0x01 / 0x81		Disable Target event driven interrupts (broadcast and direct)
RSTDAA	0x06 / 0x86		Reset the assigned dynamic address (broadcast and direct)
ENTDAA	0x07		Enter the Dynamic Address Assignment procedure (broadcast)
SETAASA	0x29		Tell every target with a static address to use it as dynamic address (broadcast)
SETDASA	0x87		Assign dynamic address using static address (0x14 / 0x15 depending on ADSEL level)
SETNEWDA	0x88		Change dynamic address
RSTACT	0x2A / 0x9A		Configure Target Reset Action and query reset timing (broadcast and direct)
SETXTIME	0x28 / 0x98		Set exchange timing information (broadcast and direct)
GETXTIME	0x99		Get exchange timing information
GETPID	0x8D	0x07 0x70 0x10 0x33 0x00/0x10 0x00	Get target's Provisioned ID PID[1] = 0x00 / 0x10 depending on ADSEL level
GETBCR	0x8E	0x26	Get Bus Characteristic Register (BCR)
GETDCR	0x8F	0x43	Get Device Characteristics Register (DCR)
GETSTATUS	0x90		Get Operating Status
GETCAPS	0x95		Get Optional Capabilities

Table 11: MIPI I3C CCC supported commands

For all the unsupported set type CCCs we will still ACK to 0x7E and dynamic address (if it is a direct CCC), but the CCC will not be effective.
For all the unsupported get type CCCs we will still ACK to 0x7E and dynamic address (get type CCC can only be direct CCC), but will return all zeros.

9.3.1 支持的CCC

命令	命令 code	默认	描述
ENEC	0x00 / 0x80		启用目标事件驱动中断（广播和直接）
DISEC	0x01 / 0x81		禁用目标事件驱动中断（广播和直接）
重置动态地址分配	0x06 / 0x86		重置分配的动态地址（广播和直接）
进入动态地址分配程序	0x07		进入动态地址分配程序（广播）
SETAASA	0x29		通知所有具有静态地址的目标使用其作为动态地址（广播）
SETDASA	0x87		使用静态地址分配动态地址（根据ADSEL电平选择0x14 / 0x15）
SETNEWDA	0x88		更改动态地址
重置动作	0x2A / 0x9A		配置目标重置动作并查询重置时序（广播和直接）
设置交换时序信息	0x28 / 0x98		设置交换时序信息（广播和直接）
GETXTIME	0x99		获取交换时序信息
GETPID	0x8D	0x07 0x70 0x10 0x33 0x00/0x10 0x00	获取目标的预配置ID PID[1] = 0x00 / 0x10 取决于 ADSEL 电平
获取BCR	0x8E	0x26	获取总线特性寄存器 (BCR)
获取设备特性寄存器	0x8F	0x43	获取设备特性寄存器 (DCR)
获取状态	0x90		获取运行状态
获取可选功能	0x95		获取可选功能

表11：MIPI I3C CCC支持的命令

对于所有不支持的设置类型CCC，我们仍会向0x7E和动态地址发送确认（若为直接CCC），但该CCC将不会生效。

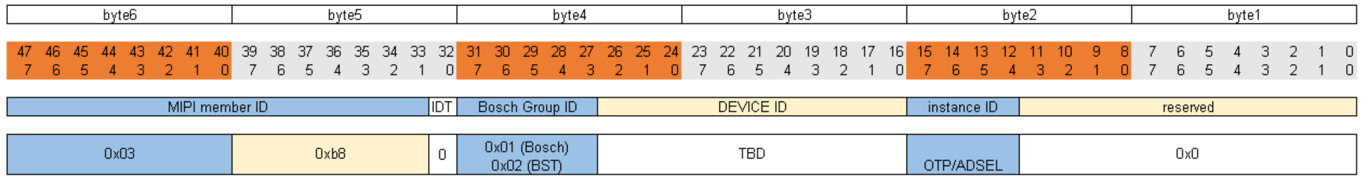
对于所有不支持的获取类型CCCs，我们仍会向0x7E和动态地址发送确认（获取类型CCC只能是直接CCC），但将返回全零值。

9.3.2 Dummy bytes in I3C mode

It is important to note that two dummy bytes are sent when reading registers in I3C mode, which means that during an n byte read actually n+2 bytes have to be read, and the first 2 bytes be discarded.

9.3.3 I3C provisional ID

For dynamic address arbitration the product provides a “provisional ID” which is a 6-byte ID.
(see MIPI chapter 5.1.4.1 “Device Requirements for Dynamic Address Assignment”)



Bits [47:33]/ bytes 5-4: MIPI Member ID 15-bits:
The Bosch MIPI Member ID is 0x03b8.

Bit [32]/byte 4: Provisional ID Type selector 1-bit:
The Provisional ID type selector (IDT) is 0b0 (0= vendor fixed value for bits 31:0).

Bits [31:16] /bytes 3-2 : Part ID 16 bits:
The Part ID is divided into a Bosch Group ID (5 bit i.e. bits 31:27) and a Device ID (11 bit i.e. bits 26:16).

The Bosch Sensortec Group ID is 0b00010

The Device ID consists of an extended ID (3 bits i.e. bits 26:24), and the BMM350 CHIP_ID, bits 23:16. The extended ID is mapped to 0b000.

Bits [15:12] Instance ID:
The LSB of the Instance ID (1-bit i.e. bit 12) is controlled by the level of the ADSEL pin. The other 3-bits of instance ID are mapped into OTP. The user register I3C_trim_0.i3c_instance_id<2:0> are used for this purpose. This register is OTP backed and can be modified when access to address page 1 is granted.

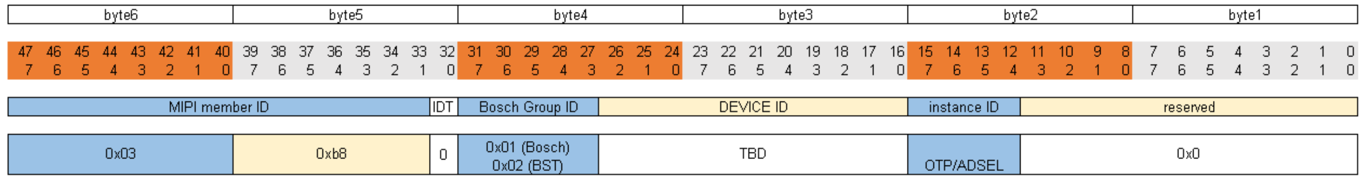
Bits [11:0] Reserved:
The reserved part is 0x00.

9.3.2 I3C模式中的虚字节

需特别注意：在I3C模式下读取寄存器时会发送两个虚字节，这意味着执行n字节读取时实际需读取n+2 字节，且前2字节需丢弃。

9.3.3 I3C临时ID

为实现动态地址仲裁，该产品提供了一个“临时ID”，即6字节ID。（参见MIPI章节
5.1.4.1“动态地址分配设备要求”）



位[47:33]/字节5-4：MIPI会员ID 15位：
博世MIPI会员ID为0x03b8。

位[32]/字节4：临时ID类型选择器1位：
临时ID类型选择器（IDT）为0b0（0= 厂商固定值用于位31:0）。

位[31:16] /字节3-2：零件ID 16位：
零件ID分为博世集团ID（5位，即位31:27）和设备ID（11位，即位26:16）。

博世传感器科技集团ID为0b00010

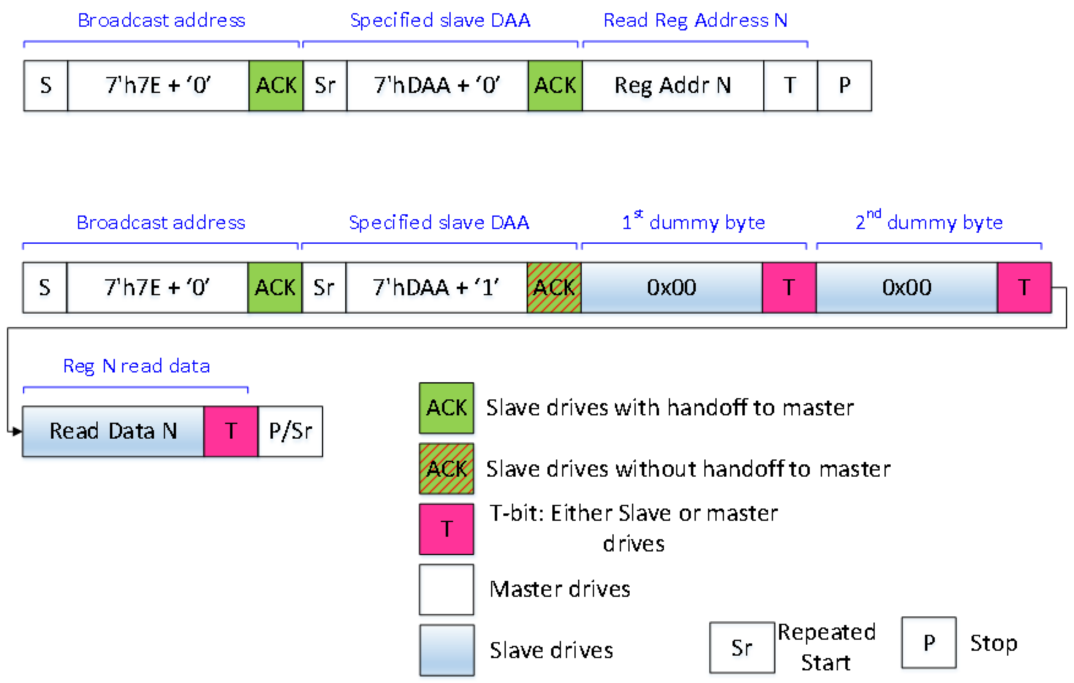
设备ID由扩展ID（3位，即位26:24）和BMM350芯片_ID（位23:16）组成。扩展ID映射为0b000。

位[15:12] 实例ID：
实例ID的最低有效位（1位，即位12）由ADSEL引脚的电平控制。实例ID的其余3位映射到OTP中。用户寄存器I3C_trim_0.i3c_instance_id<2:0> 用于此目的。该寄存器由OTP支持，且在获得地址页1访问权限时可被修改。

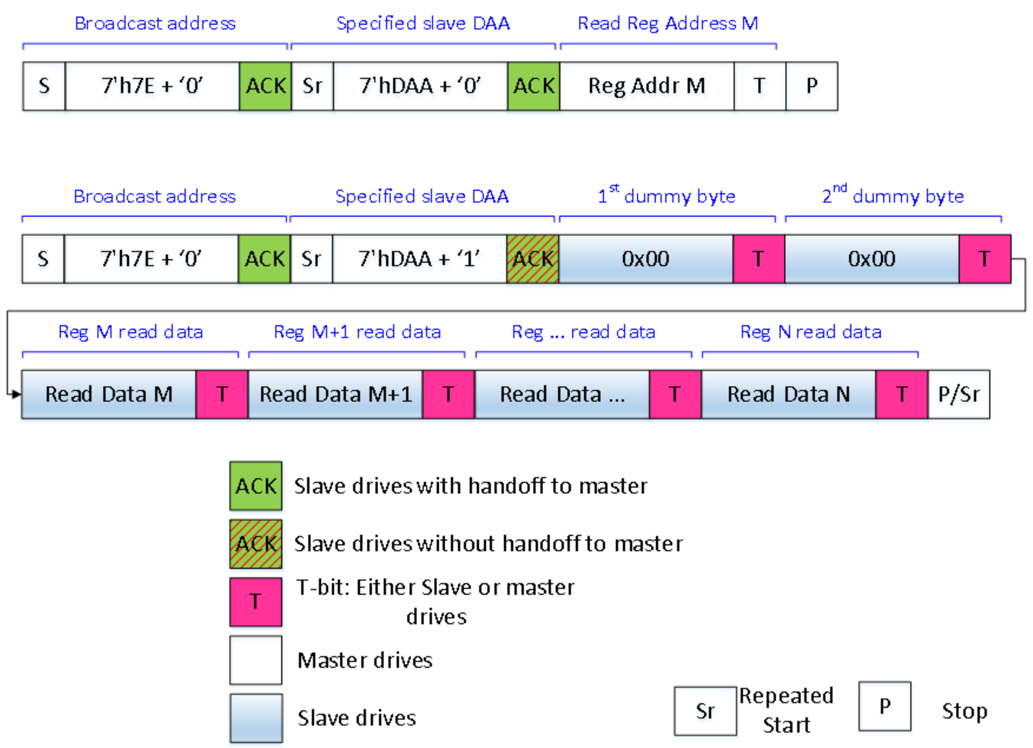
位[11:0] 保留：
保留部分是0x00。

9.3.4 I3C read timing diagrams

9.3.4.1 Single byte read

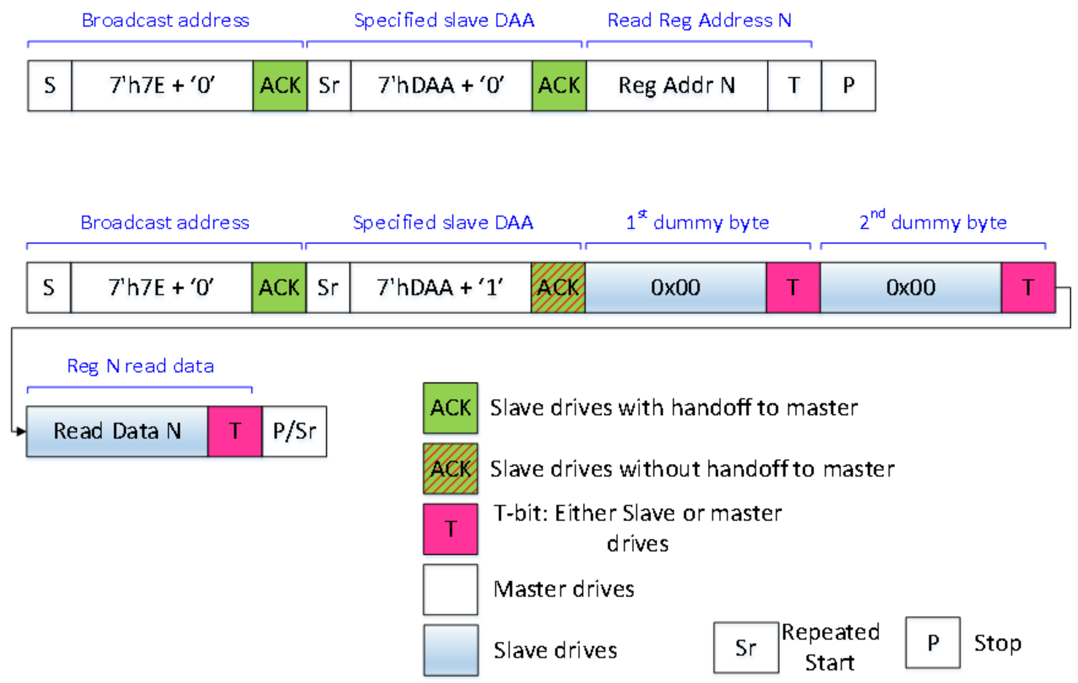


9.3.4.2 Multiple byte read

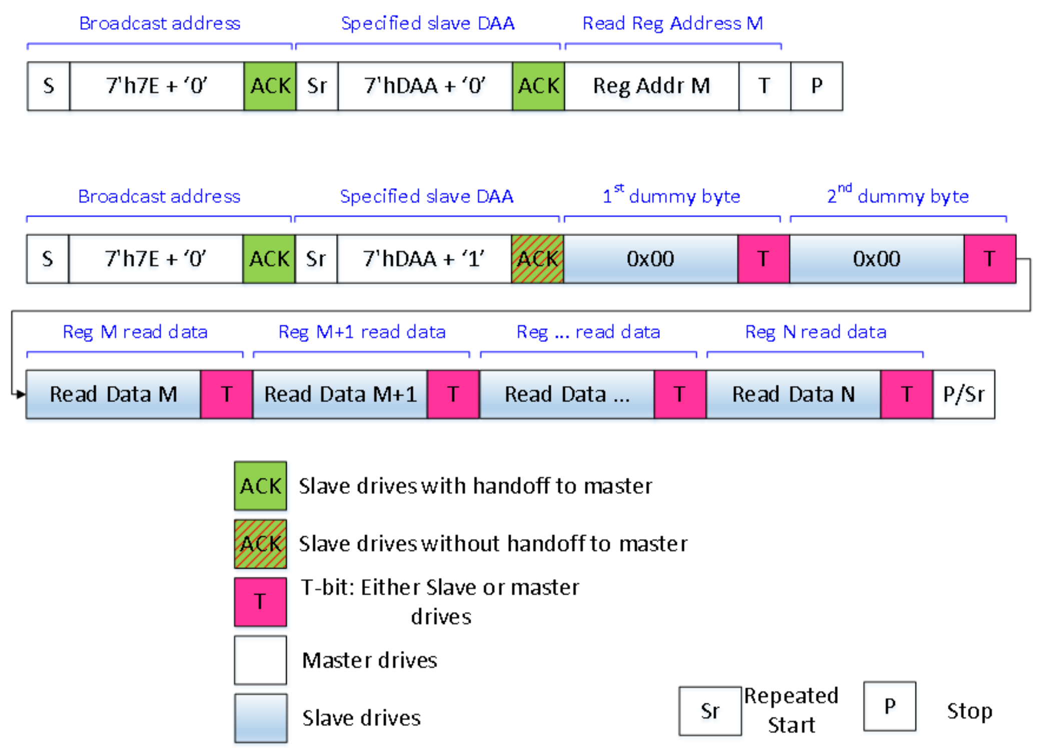


9.3.4 I3C读取时序图

9.3.4.1 单 byte read

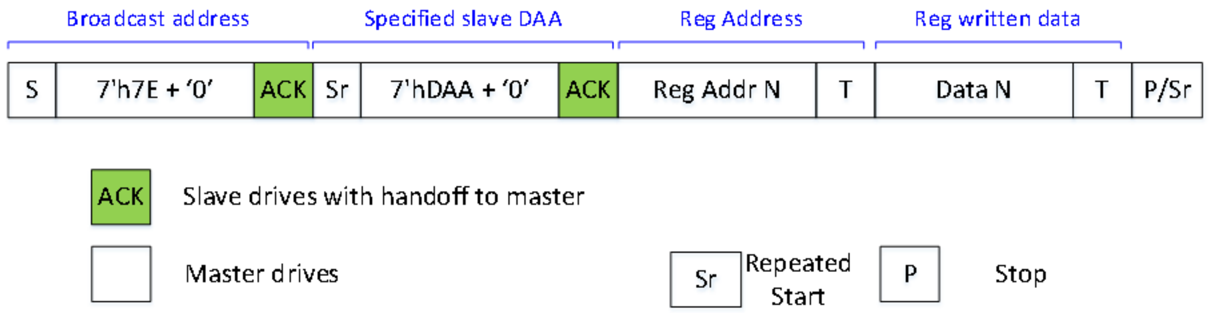


9.3.4.2 多路 byte read

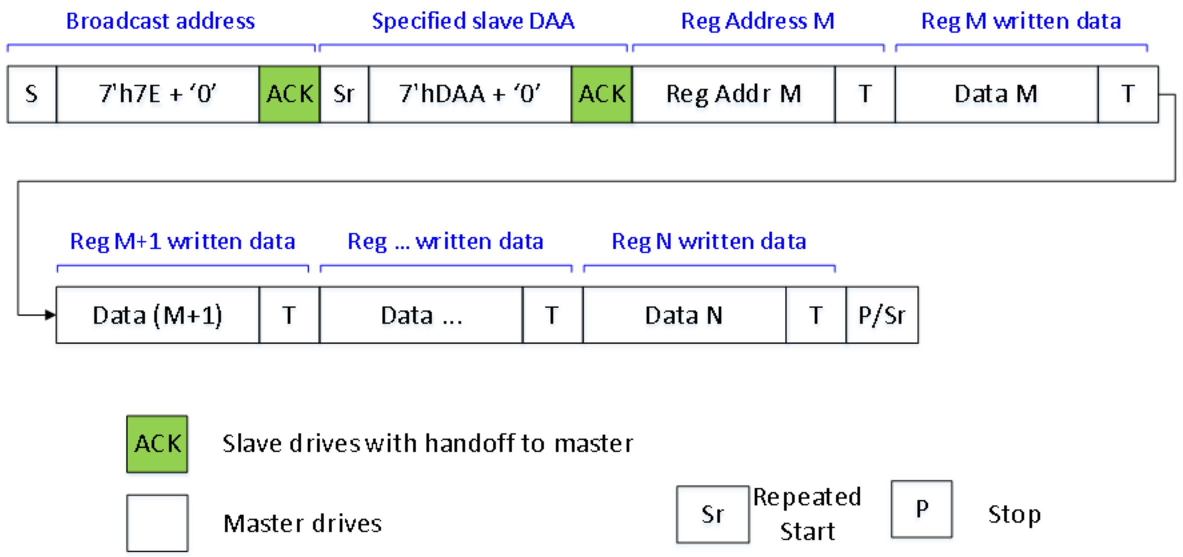


9.3.5 I3C write timing diagrams

9.3.5.1 Single byte write



9.3.5.2 Multiple byte write



9.4 Interface parameter specification

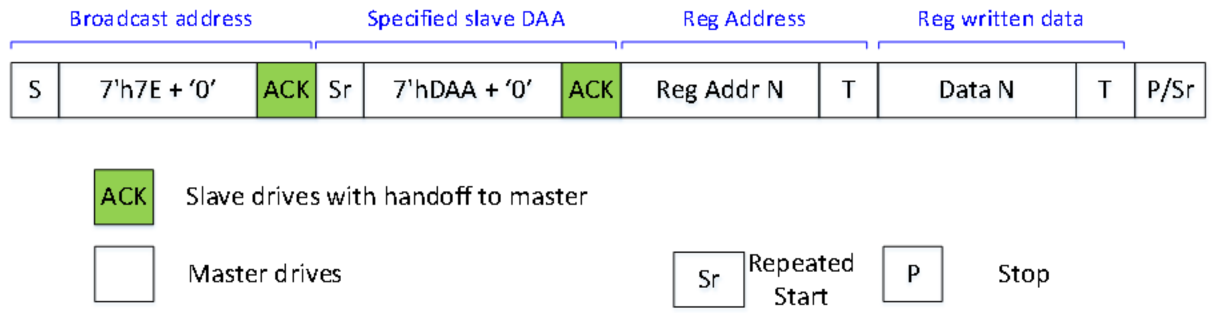
9.4.1 General interface parameters

Table 12: Interface parameters

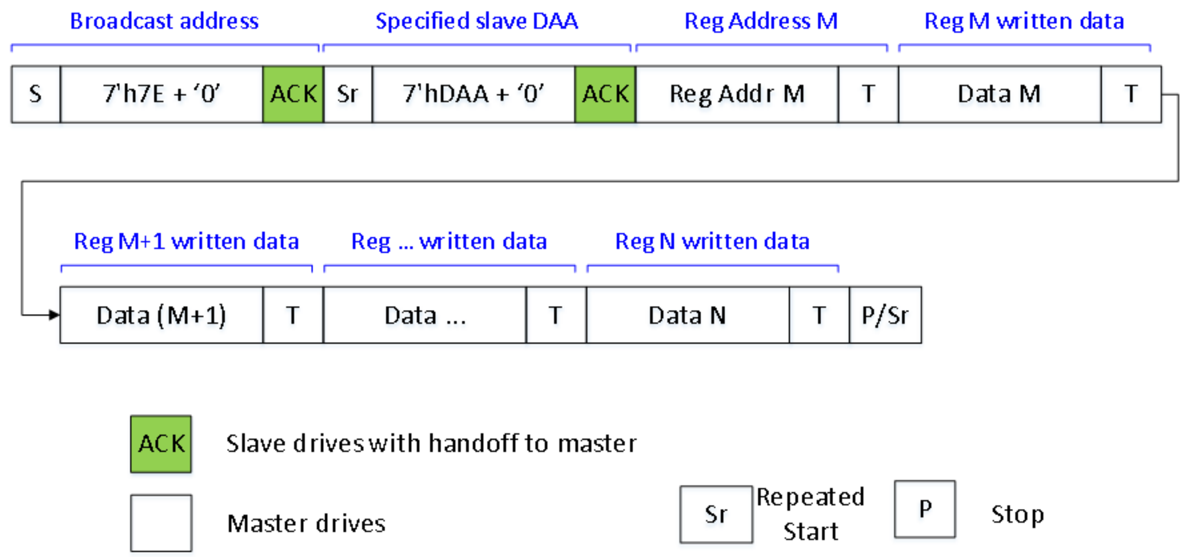
Parameter	Symbol	Condition	Min	Typ	Max	Unit
Input low level	V_{il_si}	V_{DDIO}=1.72 V to 3. 6V			20	%V_{DDIO}
Input high level	V_{ih_si}	V_{DDIO}=1.72 V to 3.6 V	80			%V_{DDIO}
Output low level I²C, I3C	V_{ol_SDI}	V_{DDIO}=1.72 V, I_{ol}=3 mA			20	%V_{DDIO}
Output high level	V_{oh}	V_{DDIO}=1.72 V, I_{oh}=1 mA (SDO, SDI)	80			%V_{DDIO}
Bus load capacitor	C_b	On SDA and SCK			20	pF

9.3.5 I3C写入时序图

9.3.5.1 单路 byte 写



9.3.5.2 多重 byte 写



9.4 接口参数规格

9.4.1 通用接口参数

表12：接口参数

参数	符号	条件	Min	Typ	Max	Unit
输入低电平	伏特$_{il_si}$	电压$_{DDIO}$=1.72 伏特 至 3.6伏特			20	百分比电压$_{DDIO}$
输入高电平	伏特$_{ih_si}$	电压$_{DDIO}$=1.72 伏特 至 3.6 伏特	80			百分比V
输出低电平 I²C, I3C	电压$_{ol}$ 数据_	V_{DDIO}=1.72 伏特, I_{ol}=3 毫安			20	DDIO 百分比V DDIO
输出高电平	V_{oh}	V_{DDIO}=1.72 伏特, I_{oh}=1 毫安 (SDO, 数据)	80			百分比V DDIO
总线负载电容	C_b	开启 SDA 和 SCK			20	pF

9.4.2 I²C timings

For I²C timings, the following abbreviations are used:

- "S&F mode" = standard and fast mode
- "HS mode" = fast+ mode
- C_b = bus capacitance on SDA line

All other naming refers to I²C specification 2.1 (January 2000).

The I²C timing diagram is in Figure 9. The corresponding values are given in Table 14.

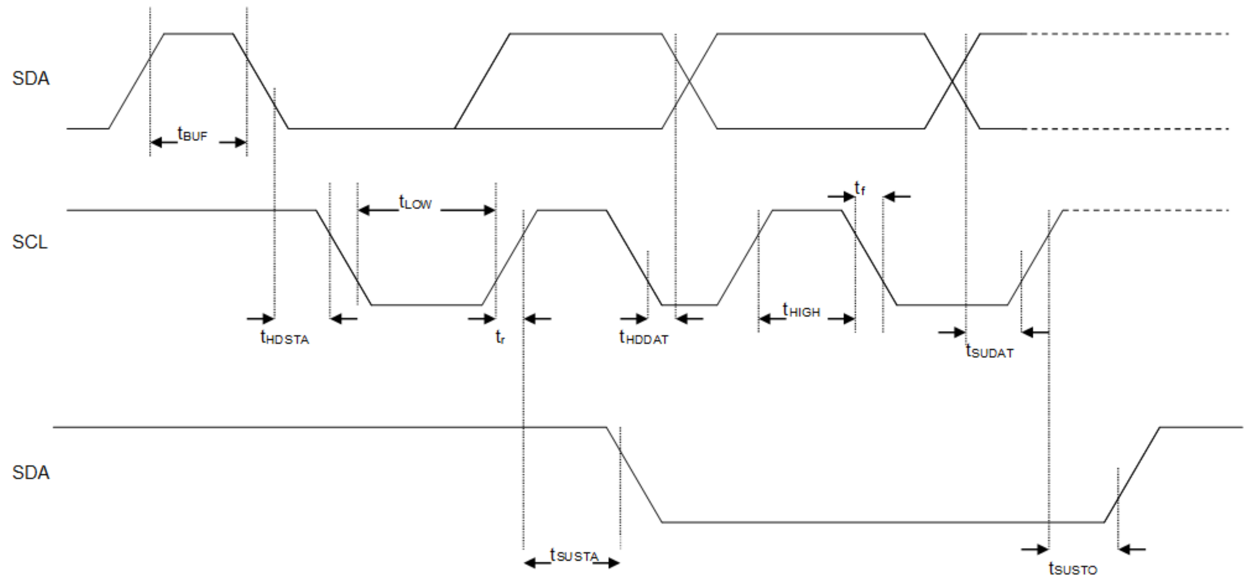


Figure 9: I²C timing diagram

Table 13: I²C timings

Parameter	Symbol	Condition	Min	Typ	Max	Unit
SDA setup time	$t_{SU;DAT}$	S&F Mode HS mode	160 30			ns ns
SDA hold time	$t_{HD;DAT}$	S&F Mode, $C_b \le 100$ pF S&F Mode, $C_b \le 400$ pF HS mode, $C_b \le 100$ pF HS mode, $C_b \le 400$ pF	80 90 18 24		 115 150	ns ns ns ns
SCL low pulse	t_{LOW}	HS mode, $C_b \le 100$ pF V_{DDIO} = 1.62 V	160			ns
SCL low pulse	t_{LOW}	HS mode, $C_b \le 100$ pF V_{DDIO} = 1.2 V	210			ns
SDA setup time	$t_{SU;DAT}$	S&F Mode HS mode	160 30			ns ns

The above-mentioned I²C specific timings correspond to the following internal added delays:

- Input delay between SDA and SCK inputs: SDA is more delayed than SCK by typically 100 ns in Standard and Fast Modes and by typically 20 ns in Fast+ Mode.
- Output delay from SCL falling edge to SDA output propagation is typically 140 ns in Standard and Fast Modes and typically 70 ns in Fast+ Mode.

9.4.2 I2C时序

关于I2C时序，使用以下缩写：

- "S&F模式" = 标准模式和快速模式
- "高速模式" = 快速+ 模式
- C_b = SDA线路上的总线电容

所有其他命名均参照I2C规范2.1（2000年1月）。

I2C时序图见图9，对应数值列于表14。

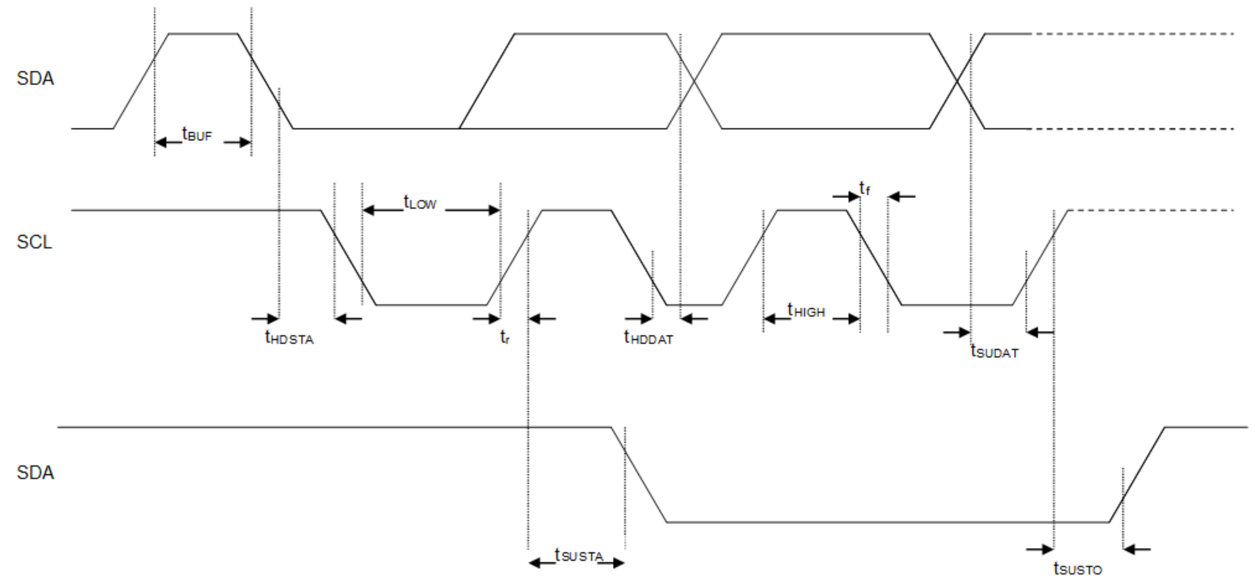


图9：I²C时序图

表13：I²C时序参数

参数	符号	条件	Min	Typ	Max	Unit
SDA建立时间	时间 $_{SU;DAT}$	S&F模式 高速模式	160 30			ns ns
SDA保持时间	时间 $_{HD;DAT}$	S&F模式，$C_b \le 100$ pF S&F模式，$C_b \le 400$ pF 高速模式，$C_b \le 100$ pF 高速模式，$C_b \le 400$ pF	80 90 18 24		 115 150	ns ns ns ns
SCL低脉冲	t_{LOW}	高速模式，$C_b \le 100$ pF V_{DDIO} = 1.62 伏特	160			ns
SCL低脉冲	t_{LOW}	高速模式，$C_b \le 100$ pF V_{DDIO} = 1.2 伏特	210			ns
SDA建立时间	时间 $_{SU;DAT}$	S&F模式 高速模式	160 30			ns ns

上述I²C特定时序对应以下内部附加延迟：

- SDA与SCK输入间的延迟：在标准和快速模式中，SDA通常比SCK延迟100纳秒；在快速+ 模式中，通常延迟20纳秒。
- 在标准和快速模式中，SCL下降沿到SDA输出传播的延迟通常为140纳秒，在快速+ 模式中通常为70纳秒。

9.4.3 I3C timings

The I3C timing values are given in Table 14.

Table 14: I3C timings

Parameter	Symbol	Condition	Min	Typ	Max	Unit
I3C clock i/p frequency	F_i3c		160 30	0.01		12.9
SCL low pulse	T_low_scl		80 90 18 24			
SCL high pulse	T_high_scl		160			
SDA setup time	T_setup_sda		210			
SDA hold time	T_hold_sda		160 30			
SDA output delay	T_delay_sda	50 pF load, V_{DDIO}=1.72V				12

9.4.3 I3C时序

I3C时序值如表14所示。

表14: I3C时序

参数	符号	条件	Min	Typ	Max	Unit
I3C时钟输入频率	F_i3c		160 30	0.01		12.9
SCL低脉冲	T低电平scl _ _		80 90 18 24			
SCL高脉冲	T_高电平_s cl		160			
SDA建立时间	T_建立_ sda		210			
SDA保持时间	T_保持_s da		160 30			
SDA输出延迟	T_延迟_ sda	50 pF负载, V_{DDIO}=1.72伏特				12

10. Package information

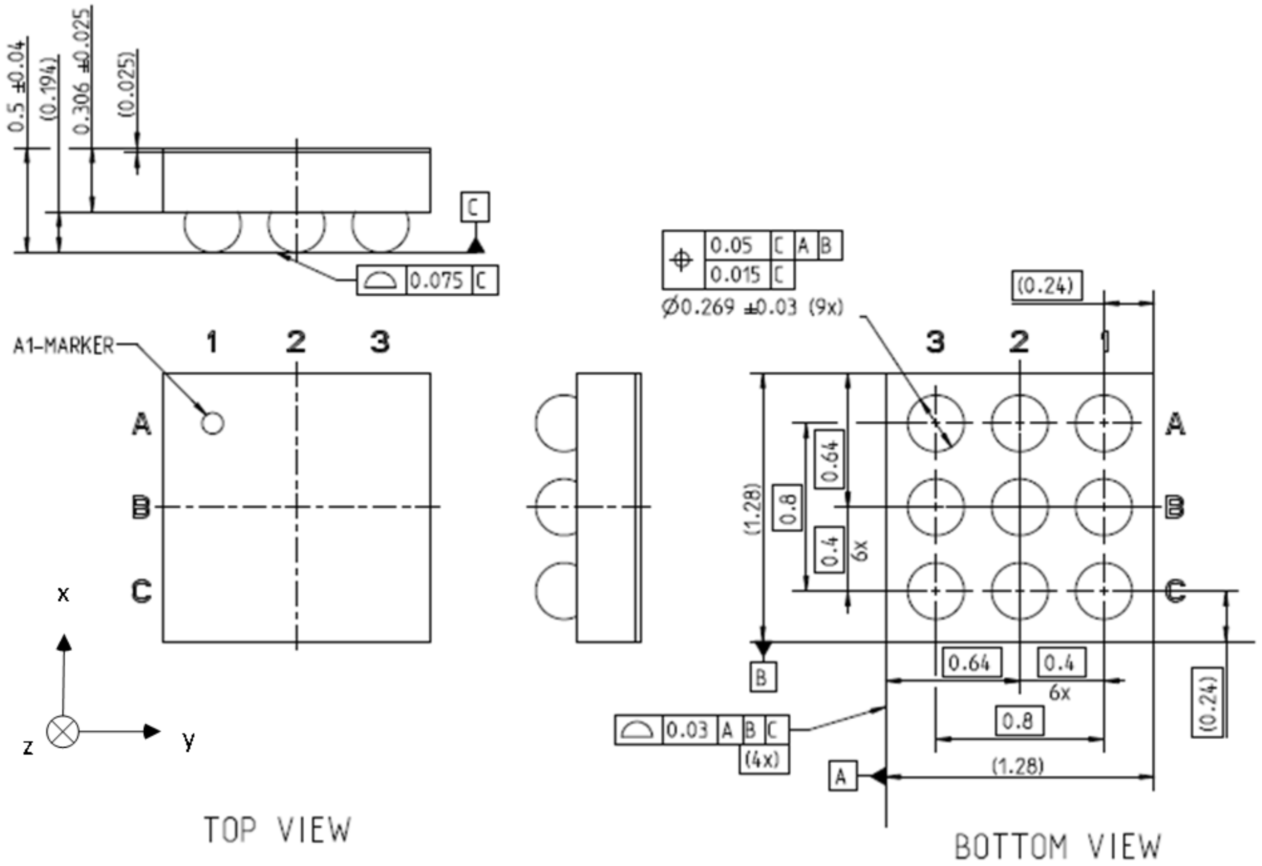


Figure 10: Pin out and package dimensions

10. 封装信息

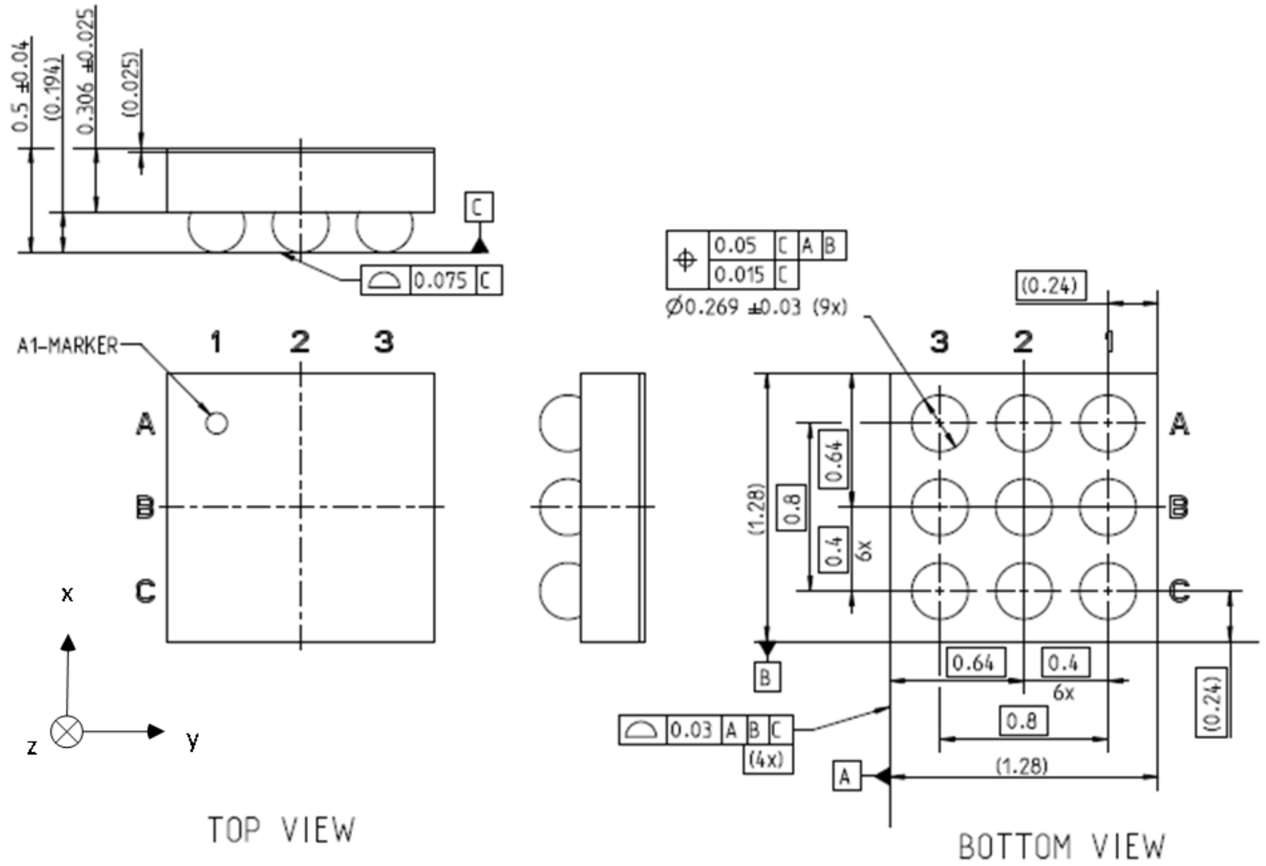


图10: 引脚输出及封装尺寸

10.1 Marking/Lasermarking, coordinate system

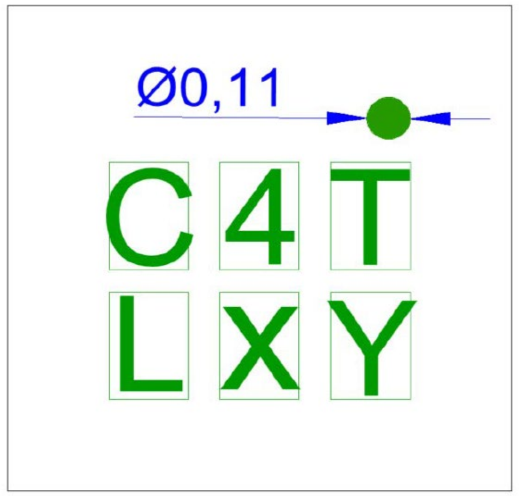


Figure 11: Marking

Lasermarking is done on a per-die basis for engineering samples. The 2nd digit, “variant identifier”, tells which TMR variant is on the die.

10.1 标记/激光标记，坐标系

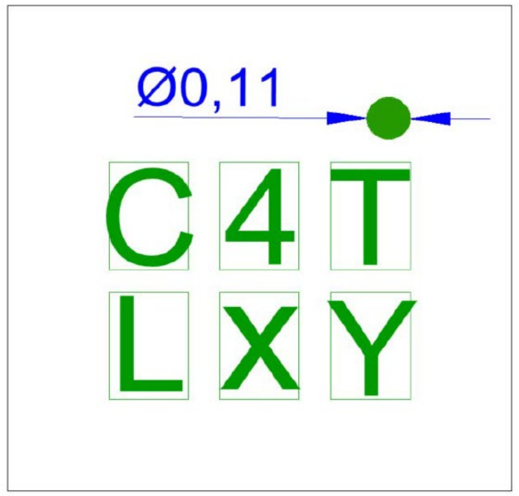


图11: 标记

工程样品的激光标记以单个芯片为单位进行。2nd 数字“变体标识符”表明芯片上采用的是哪种TMR变体。

Marking of Engineering Samples BMM350 (A, C-samples)

<table>
<tr><th>Top view Labeling</th><th>Name</th><th>Marking position</th><th>Remark</th></tr>
<tr><td rowspan="3">•
123
456</td><td>Sample stage, product</td><td>123</td><td>“C4T” : C samples, bmm350</td></tr>
<tr><td>Lot identifier</td><td>4</td><td>Lot identifier</td></tr>
<tr><td>Wafer identifier</td><td>5,6</td><td>(1) One code wafer ID convert table
一碼 ID 轉換表
<table>
<tr><th>Wafer ID</th><th>1-digit ID</th><th>Wafer ID</th><th>1-digit ID</th><th>Wafer ID</th><th>1-digit ID</th></tr>
<tr><td>01</td><td>1</td><td>10</td><td>A</td><td>19</td><td>N</td></tr>
<tr><td>02</td><td>2</td><td>11</td><td>C</td><td>20</td><td>P</td></tr>
<tr><td>03</td><td>3</td><td>12</td><td>D</td><td>21</td><td>R</td></tr>
<tr><td>04</td><td>4</td><td>13</td><td>E</td><td>22</td><td>T</td></tr>
<tr><td>05</td><td>5</td><td>14</td><td>F</td><td>23</td><td>U</td></tr>
<tr><td>06</td><td>6</td><td>15</td><td>H</td><td>24</td><td>X</td></tr>
<tr><td>07</td><td>7</td><td>16</td><td>J</td><td>25</td><td>Y</td></tr>
<tr><td>08</td><td>8</td><td>17</td><td>K</td><td></td><td></td></tr>
<tr><td>09</td><td>9</td><td>18</td><td>L</td><td></td><td></td></tr>
</table></td></tr>
</table>

Marking of Mass Production Parts BMM350

<table>
<tr><th>Top view Labeling</th><th>Name</th><th>Marking position</th><th>Remark</th></tr>
<tr><td rowspan="5">•
4TY
XXX</td><td>Product identifier</td><td>4</td><td>1 digit (alphanumeric), fixed;
for identification of device type
(“4”= BMM350)</td></tr>
<tr><td>Internal number</td><td>T</td><td>internal</td></tr>
<tr><td>Internal number</td><td>Y</td><td>internal</td></tr>
<tr><td>Lot identifier</td><td>XXX</td><td>3 digits (alphanumeric 0–Z), variable, no reset</td></tr>
<tr><td>Pin A1 identifier top side</td><td>●</td><td>n/a</td></tr>
</table>

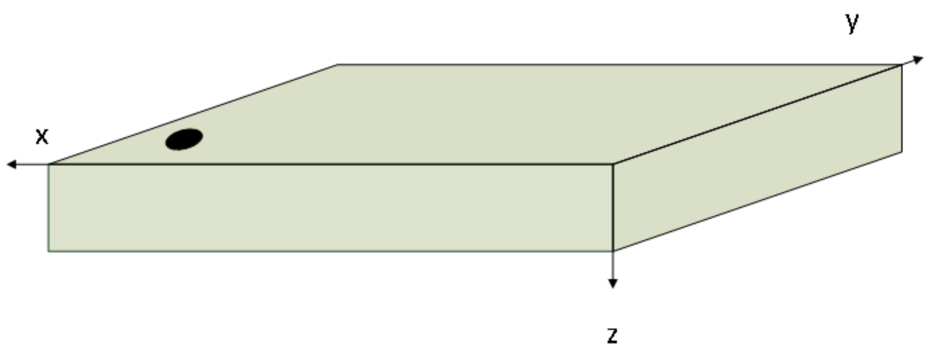


Figure 12: Coordinate system definition, right-handed. lasermarking side up

BMM350工程样品标记（A、C样品）

<table>
<tr><th>顶部视图标记</th><th>Name</th><th>标记位置</th><th>备注</th></tr>
<tr><td rowspan="3">123 •
456</td><td>样品阶段，
产品</td><td>123</td><td>“C4T”：C样本, bmm350</td></tr>
<tr><td>批次标识符</td><td>4</td><td>批次标识符</td></tr>
<tr><td>晶圆标识符</td><td>5,6</td><td>(1) One code wafer ID convert table
一碼 ID 轉換表
<table>
<tr><th>Wafer ID</th><th>1-digit ID</th><th>Wafer ID</th><th>1-digit ID</th><th>Wafer ID</th><th>1-digit ID</th></tr>
<tr><td>01</td><td>1</td><td>10</td><td>A</td><td>19</td><td>N</td></tr>
<tr><td>02</td><td>2</td><td>11</td><td>C</td><td>20</td><td>P</td></tr>
<tr><td>03</td><td>3</td><td>12</td><td>D</td><td>21</td><td>R</td></tr>
<tr><td>04</td><td>4</td><td>13</td><td>E</td><td>22</td><td>T</td></tr>
<tr><td>05</td><td>5</td><td>14</td><td>F</td><td>23</td><td>U</td></tr>
<tr><td>06</td><td>6</td><td>15</td><td>H</td><td>24</td><td>X</td></tr>
<tr><td>07</td><td>7</td><td>16</td><td>J</td><td>25</td><td>Y</td></tr>
<tr><td>08</td><td>8</td><td>17</td><td>K</td><td></td><td></td></tr>
<tr><td>09</td><td>9</td><td>18</td><td>L</td><td></td><td></td></tr>
</table></td></tr>
</table>

批量生产零件标记 BMM350

<table>
<tr><th>顶部视图标记</th><th>Name</th><th>标记位置</th><th>备注</th></tr>
<tr><td rowspan="5">4TY •
XXX</td><td>产品标识符</td><td>4</td><td>1位（字母数字），固定；
用于设备类型识别（“4” = BMM350）</td></tr>
<tr><td>内部编号</td><td>T</td><td>内部</td></tr>
<tr><td>内部编号</td><td>Y</td><td>内部</td></tr>
<tr><td>批次标识符</td><td>XXX</td><td>3位字符（字母数字0-Z），可变，不重置</td></tr>
<tr><td>顶部A1引脚标识</td><td>●</td><td>n/a</td></tr>
</table>

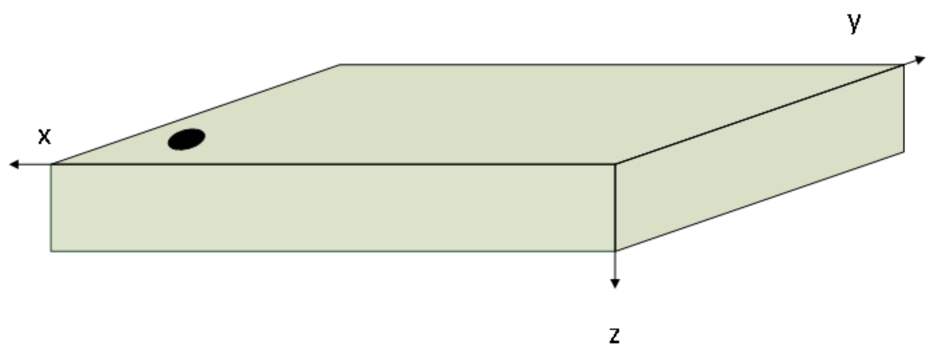


图12：右手坐标系定义，激光标记面朝上

11. Examples of use

The examples are given in the API provided by Bosch Sensortec. Please contact the Sales representative for more Information.

11. 使用示例

示例由博世传感器技术提供的应用程序接口中给出。如需更多信息，请联系销售代表。

12. Timing control

12.1 Timing control Asynchronous mode

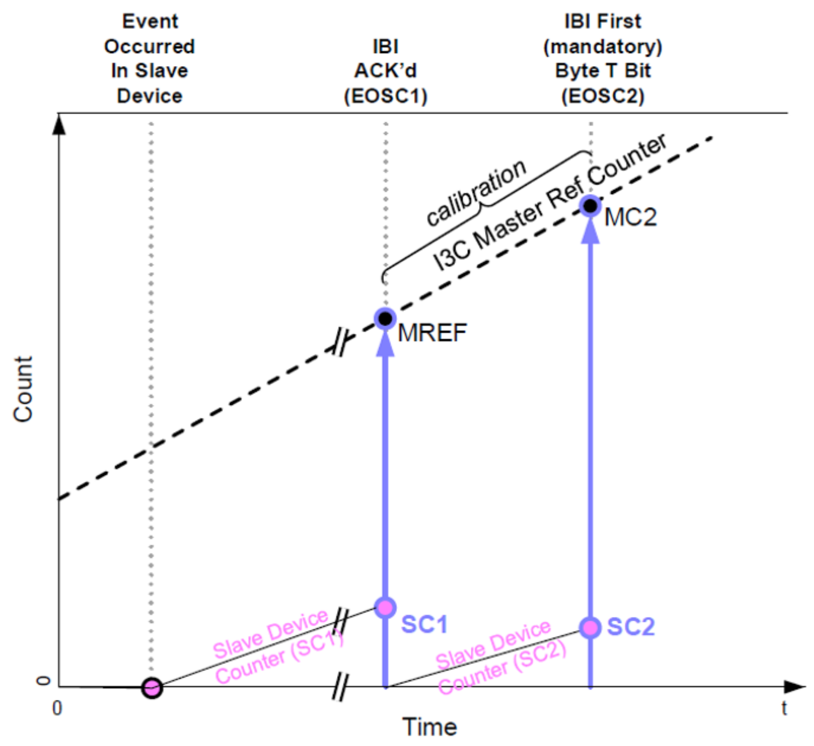


Figure 13: Timing control async mode, from MIPI I3C spec

The BMM350 supports timing control asynchronous mode 0.

In the MIPI I3C specification as of 1-1_r13 (26 July 2019) the functions of this mode are described in chapter 5.1.8.3.1 The BMM350 supports this mode employing t 4.32MHz internal clock as "slave device counter" (see Figure 13). The BMM350 will report the counter values SC1 (time between magnetic data ready and IBI acknowledged) and SC2 (time between IBI acknowledged and IBI first mandatory byte T bit) on the basis of the said 4.32MHz oscillator. The counter value SC2 depicts the read time of the mandatory byte in slave clocks. When doing the math SC2 with vary between 2 and 3, assuming 12.5MHz I3C clock frequency. This small count will lead to a high variation of the timepoint calculation done in the master. To improve accuracy it would be an option to use clock stalling (see MIPI I3C spec 5.1.2.5 "Master clock stalling"), at least for a short initialization period, so that the master can perform an accurate calculation of the slave clock frequency. Clock stalling will reduce the bus bandwidth, so that option should be used with care.
MIPI spec 5.1.2.5.3 "I3C Read Transfer, Transition Bit" explains how to do clock stalling during the mandatory byte read.

For proper function the I3C master will query the BMM350 using the GETXTIME CCC , asking for the oscillator accuracy (in the order of 5%), oscillator frequency in multiples of 500kHz, supported mode (async0 mode and sync mode).
The SETXTIME CCC command will be used to switch the BMM350 into timing control mode, in this chapter to async0 mode.
The timing control async0 functionality is based on in-band interrupts.
After SETXTIME CCC 0xDF (=enter async0 mode) it is not necessary to configure in-band interrupts.

12. 时序控制

12.1 时序控制异步模式

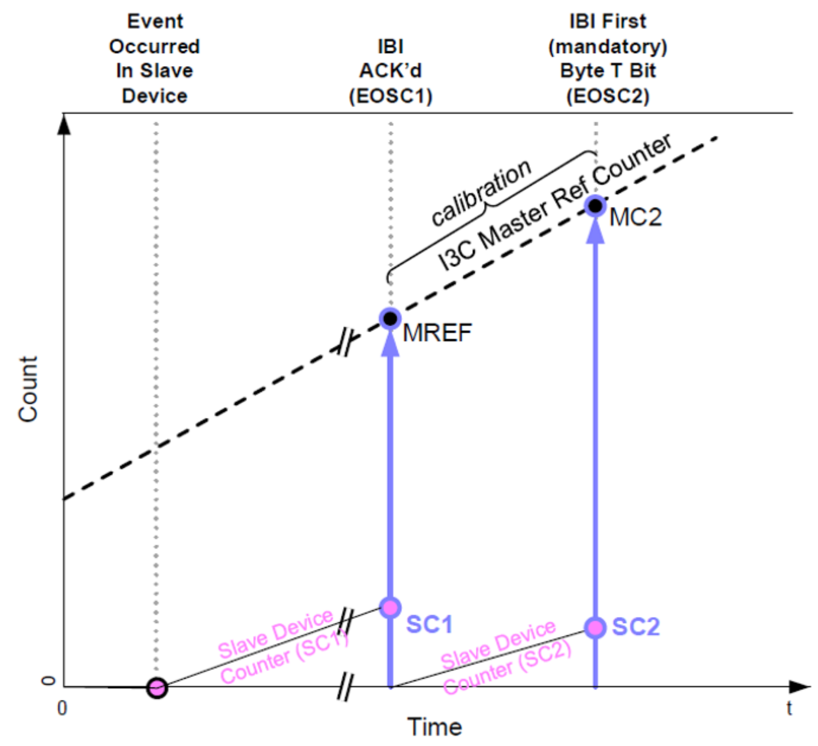


图13：时序控制异步模式，源自MIPI I3C规范

BMM350支持时序控制异步模式0。

在MIPI I3C规范1-1版中 _r13（2019年7月26日）此模式的功能在章节5.1.8.3.1中描述
BMM350支持此模式，采用t 4.32MHz内部时钟作为“从设备计数器”（见图13）。
BMM350将报告计数器值SC1（磁数据准备就绪与IBI确认之间的时间）和SC2（
IBI确认与IBI首个强制字节T位之间的时间），基于上述4.32MHz振荡器。
The 计数器 值 SC2 描述 the read time of the 强制 byte in 从设备 时钟。
当进行 数学 SC2 计算时，假设I3C时钟频率为12.5兆赫，其值在2和3之间变化。
This 小 计数 将导致 a high 变化 时间点 计算 在 主机中完成。
为提高精度，可选择使用时钟停滞功能（参见MIPI I3C规范5.1.2.5“主时钟停滞”），
至少在短暂的初始化阶段启用该功能，以便主机能精确计算从设备时钟频率。时钟停滞会降低总线带宽，因此需谨慎使用此选项。
MIPI规范5.1.2.5.3“I3C读取传输，过渡位”说明了如何在强制字节读取期间实施时钟停滞。

为实现正常功能，I3C主设备将通过GETXTIME CCC查询BMM350，获取振荡器精度（约5%）、以500kHz为单位的振荡器频率以及支持的模式（异步0模式和同步模式）。

SETXTIME CCC命令将用于将BMM350切换到时序控制模式，本章节中为异步0模式。

时序控制异步0功能性基于带内中断实现。
执行SETXTIME CCC 0xDF（=进入异步0模式）后，无需配置带内中断。

13. Recommendations for external capacitor CRST

For the 2.2uF external capacitor a low-inductance low-ESR type is recommended.

The recommended type is
https://product.tdk.com/de/search/capacitor/ceramic/mlcc/info?part_no=CGB4B3X7R0J225K055AB

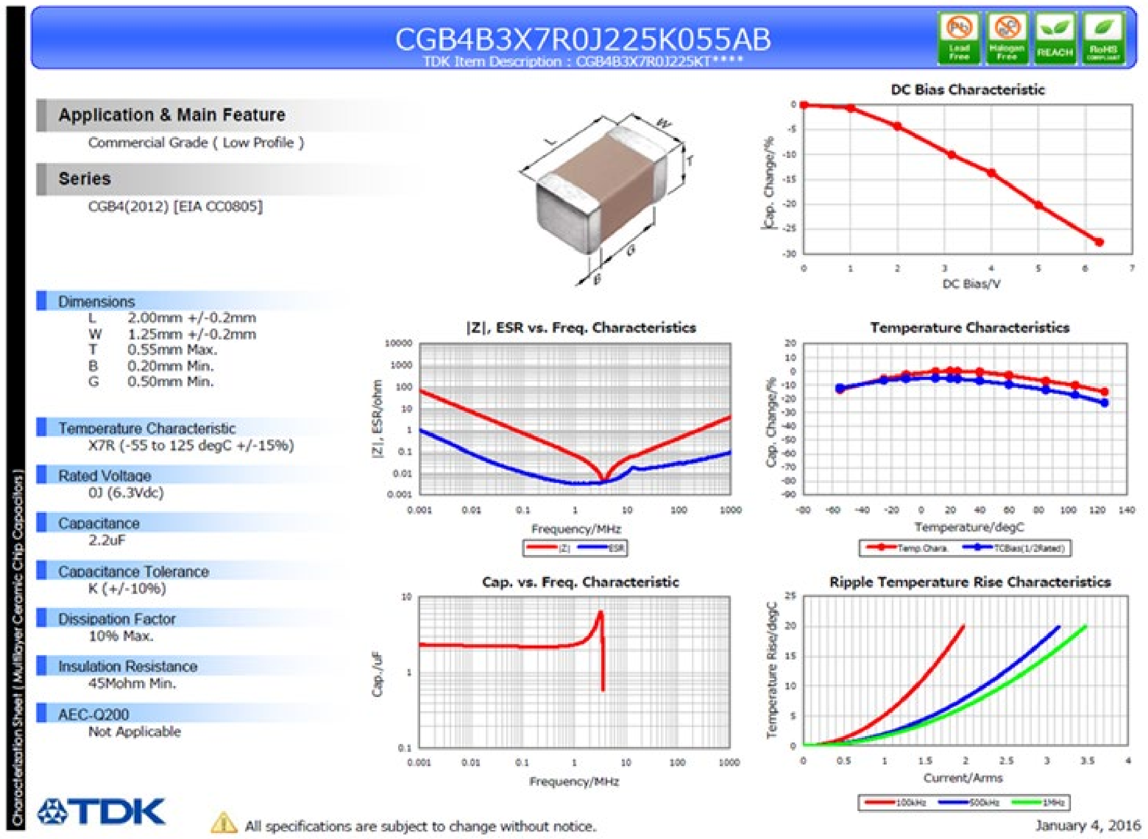


Figure 14. External capacitor

13. 外部电容CRST的建议

对于2.2微法外部电容器，建议采用低电感低ESR类型。

推荐类型为
https://product.tdk.com/zh/search/capacitor/ceramic/mlcc/info?part_no=CGB4B3X7R0J225K055AB

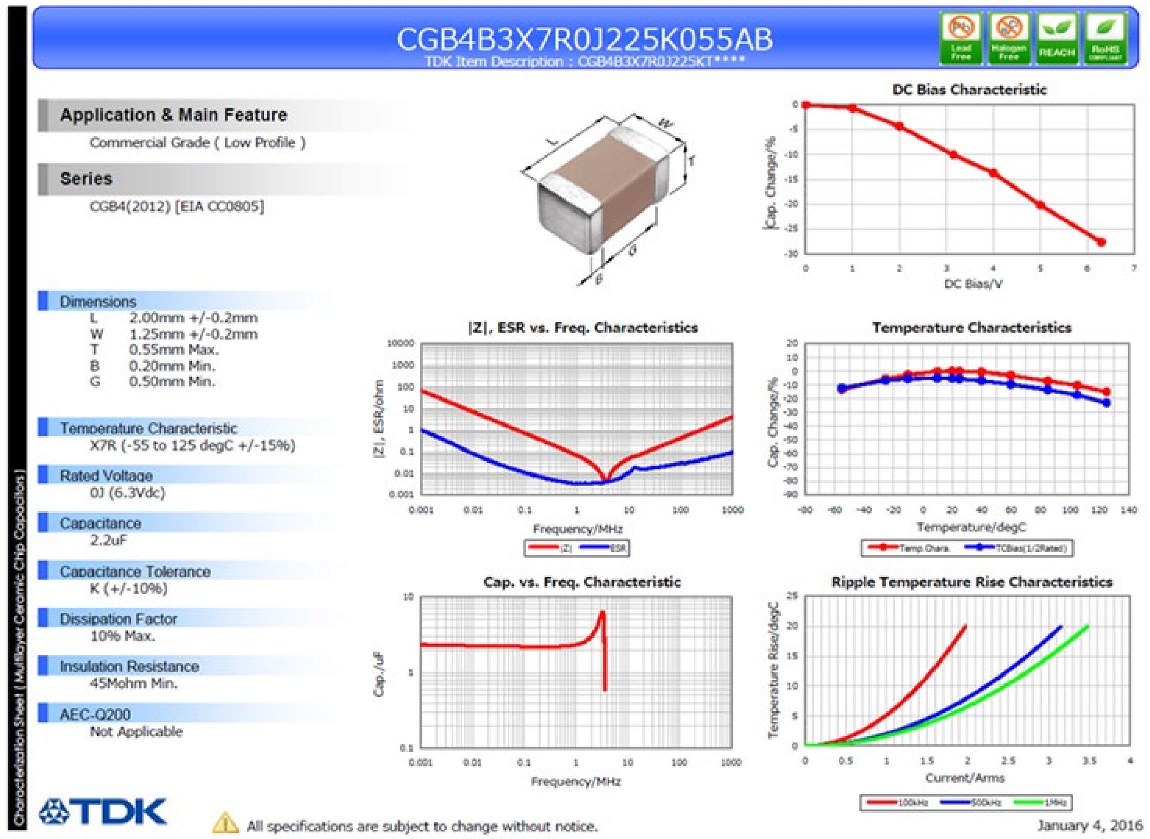


图14. 外部电容

14. Environmental Safety

14.1 RoHS

The BMM350 sensor meets the requirements of the EC restriction of hazardous substances (RoHS) directive, see also: Directive 2015/863/EU (amending Annex II to Directive 2011/65/EU) of the European Parliament and of the Council on the restriction of the use of certain hazardous substances in electrical and electronic equipment.

14.2 Halogen content

The BMM350 is halogen-free. For more details on the analysis results please contact your Bosch Sensortec representative.

14.3 Internal Package Structure

Within the scope of Bosch Sensortec's ambition to improve its products and secure the mass product supply, Bosch Sensortec qualifies additional sources (e.g. 2nd source) for the package of the BMM350.

While Bosch Sensortec took care that all of the technical packages parameters are described above are 100% identical for all sources, there can be differences in the chemical content and the internal structural between the different package sources.

However, as secured by the extensive product qualification process of Bosch Sensortec, this has no impact to the usage or to the quality of the BMM350 product.

14. 环境安全

14.1 有害物质限制

BMM350 传感器符合欧盟有害物质限制（RoHS）指令的要求，另请参阅：欧洲议会和欧盟理事会关于限制在电气和电子设备中使用某些有害物质的指令2015/863/EU（修订指令2011/65/EU附件II）。

14.2 卤素含量

BMM350为无卤素产品。如需了解更多分析结果详情，请联系您的博世传感器技术代表。

14.3 内部封装结构

基于博世传感器技术提升产品性能和保障大规模产品供应的目标，博世为BMM350传感器封装认证了额外供应来源（例如第二来源）。

虽然博世传感器技术确保所有来源的技术封装参数均100%相同，但不同封装来源在化学成分和内部结构上可能存在差异。

但经博世传感器技术严格的产品认证流程验证，这不会对BMM350产品的使用或质量造成影响。

15. Acronyms

ADC	Analog to digital converter
API	application programming interface: set of C functions to configure bmm350 and read out compensated data
avg	A bit field inside the register map, controlling the internal averaging setting of bmm350 and thus the noise performance
AR/VR	Augmented reality/virtual reality
ASIC	Application specific integrated circuit
BW	bandwidth
CCC	Common Command Code (see I3C)
CDM	Charged device model (see ESD)
CRST	pin connected to external 2.2uF capacitor. Said capacitor is called “CRST capacitor”
drdy	Data ready, data ready interrupt
FM	Forced mode: an operation mode which performs a single magnetic-to-digital conversion. Must be used for ODR<25
FM-Fast	Forced mode fast: an operation mode which performs a single magnetic-to-digital conversion.
HBM	Human body model (see ESD)
IBI	In-band-interrupt, I3C serial interrupt
INL	Non-linearity error, here: maximum deviation from sensor output regression curve
ESD	Electrostatic discharge
HDR	High data rate (I3C)
INT	Interrupt, also : interrupt pin
ODR	Output data rate, in samples/s
OTP	One time programmable memory
PCB	Printed circuit board
PMU	Power management unit, not to mix with PMU_CMD: command processor register
RoHS	Restriction of Hazardous Substances
SDR	Single data rate (I3C mode)
TCO	Temperature coefficient offset
TCS	Temperature coefficient sensitivity
TMR	Tunnel Magnetoresistance
VDD	Main supply
VDDIO	IO supply
WLCSP	wafer level chip-scale package
XLSB	Extended LSB: Bits 17-24 of the data and temperature registers

15. 缩写词

ADC	模数转换器
API	应用程序接口：一组用于配置bmm350并读取补偿数据的C函数
avg	寄存器映射中的一个位字段，控制bmm350的内部平均设置，从而影响噪声性能
增强现实/虚拟现实	增强现实/虚拟现实
ASIC	专用集成电路
BW	带宽
CCC	通用命令代码（参见I3C）
CDM	充电器件模型（参见ESD）
CRST	连接外部2.2微法电容器的引脚。该电容器称为“CRST电容器”
drdy	数据就绪，数据就绪中断
FM	强制模式：一种执行单次磁信号到数字信号转换的操作模式。必须用于ODR<25
快速强制模式	强制快速模式：一种执行单次磁信号到数字信号转换的操作模式。
HBM	人体模型（参见ESD）
IBI	带内中断，I3C串行中断
INL	非线性误差，此处指传感器输出回归曲线的最大偏差
ESD	静电放电
HDR	高数据速率（I3C）
INT	中断，亦指：中断引脚
ODR	输出数据速率，单位：样本/秒
OTP	一次性可编程存储器
PCB	印刷电路板
PMU	电源管理单元，勿与PMU_CMD：命令处理器寄存器混淆
RoHS	有害物质限制
SDR	单数据速率（I3C模式）
TCO	温度系数偏移
TCS	温度系数灵敏度
TMR	隧道磁阻
VDD	主电源
VDDIO	IO电源
晶圆级芯片尺寸封装	晶圆级芯片尺寸封装
XLSB	扩展最低有效位：数据和温度寄存器的第17-24位

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17. Document history and modification

Rev. No	Chapter	Description of modification/changes	Date
1.0	-	Initial release	August 2019
1.20	all	Final datasheet	Apr 2023
1.21	Table 2.1	Sensor start-up time description	July 2023
	15	Modified Acronyms	
	5	Deleted POR description	
1.22	3	Added comment to maximum ratings	March 2024
1.23	Table 10	Modification to show accessible registers	March 2024
1.24	Table 9	Modification to show accessible registers	April 2024
1.25	10.1	Laser marking update	July 2024
1.26	7	Modification of API link	November 2024
	6	Deleted figure 5	
1.27	1	Modified typical values of noise	February 2025

17. 文档历史与修改

修订号	章节	修改/变更描述	Date
1.0	-	初始发布	2019年8月
1.20	all	最终数据表	2023年4月
1.21	表2.1	传感器启动时间描述	2023年7月
	15	修改后的缩写	
	5	删除的POR描述	
1.22	3	添加到最大额定值的注释	2024年3月
1.23	表10	显示可访问寄存器的修改	2024年3月
1.24	表9	显示可访问寄存器的修改	2024年4月
1.25	10.1	激光标记更新	2024年7月
1.26	7	API链接修改	2024年11月
	6	删除图5	
1.27	1	修改的噪声典型值	2025年2月

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