Features and Benefits

- 3-Axis Magnetometer device suitable for e-compass applications
- Cost effective and compact solution
- Measurement range ±4912μT
- Magnetic sensitivity 0.15μT/LSB
- Low voltage operation 1.65v to 1.95v
- 16-bit data output for each axis of the magnetic field
- 16-bit data temperature output
- Operating temperature range:- 40℃ to 85℃
- I^2C bus interface modes:
  - ❑ Standard mode (up to 100kHz)
  - ❑ Fast mode (up to 400kHz)
  - ❑ Fast mode plus (up to 1MHz)
- Operational modes:
  - ❑ Power-down
  - ❑ Single measurement
  - ❑ Continuous measurement
- Self-test function
- DRDY function indicates that the measurement results are available
- DOR function indicates that results reading has been skipped
- Magnetic sensor overflow monitor function

Applications

- 3-axis e-compass for Smart phones
- Navigation applications

General Description

The ST480MS is a 3-axis magnetometer. It is a new generation electronic compass for mobile devices. The device includes a Hall sensor combined with an IMC layer for measuring magnetic fields parallel to the surface of the die.

The device measures along each of the 3 axis (X, Y being in-plane parallel to the surface of the die, and Z being perpendicular to the surface). These measurements are converted into 16-bit words which can be read over the I^2C communication channel.

The device transmits compensated measurement data.

The ST480MS is packaged in WL-CSP package.

Order Information

Model Name	Full Scale Range	Package Description
ST480MS	±4912uT	4pin WL-CSP, 0.95*0.95*0.55mm^3

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1. Functional Diagram

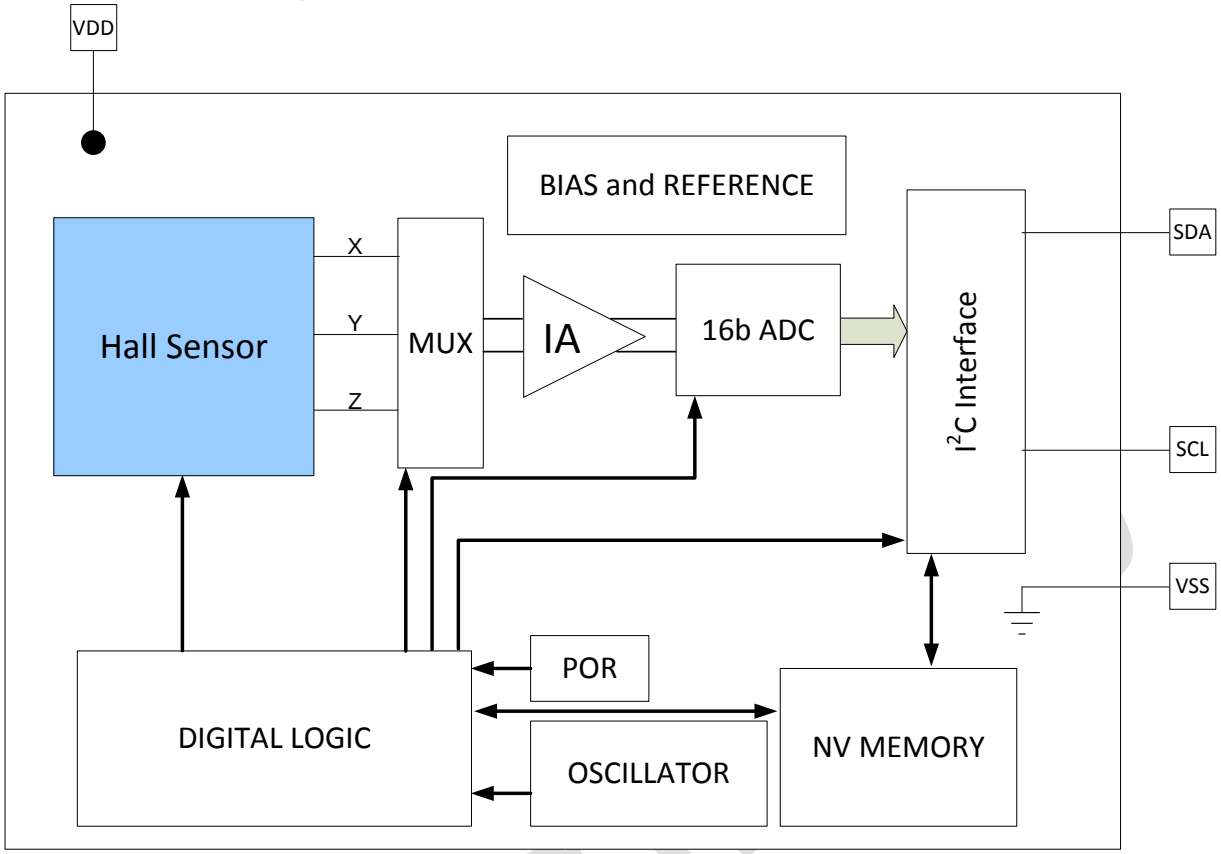


Figure 1: Function block diagram

The device is made of a signal conditioning chain preparing the magnetic Hall signal for conversion to a digital signal with an ADC.

The digital logic block sequences the operations, manages the memory and handles the communication over I^2C.

2. Sensor Specifications

The specifications are applicable at 25°C, unless specified otherwise, and for the complete supply voltage range.

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Unit
Magnetic measurement range	B_{RANGE}	Each axis		±4912		μT
Output at 0 Gauss	OFFS	Signed 15 bit 2's complement output		0		LSB_{S15}
XYZ Magnetic resolution or sensitivity	$SENS_{XYZ}$			0.15		μT/LSB
Noise standard deviation for X and Y axes	$\sigma_{X,Y}$	1.81ms axis conversion time		0.75		μT
Noise standard deviation for Z axis	σ_Z	3.62ms axis conversion time		0.9		μT
Magnetic axis conversion time X and Y(1)	T_{CONVM1}			1.81		ms
Magnetic axis conversion time Z(1)	T_{CONVM2}			3.62		ms
Temperature conversion time	T_{CONVT}			0.32		ms
Oscillator trimming accuracy	T_{OSC_TRIM}		-5		+5	%
Oscillator thermal drift	T_{OSC_THD}		-5		+5	%
Output refresh rate(2)	$T_{REFRESH}$			100		Hz
Operating temperature range(3)	$T_{OPERATING}$		-40	25	+85	°C
Temperature sensor resolution	T_{RES}			50		LSB/°C

(1) This conversion time is defined as the time it takes to acquire a value of the magnetic flux density, for a single axis. When measuring XYZ, they are obtained through time-multiplexing. The total conversion time is obtained by summing up the magnetic & temperature conversion time.

(2) $T_{REFRESH}$ is defined as the period between two sets of measurements. It is relevant for the "*Continuous measurement*" mode and is defined by the parameter MODE[2:0]. $T_{REFRESH}$ is adjustable with the following settings: 10Hz, 20Hz, 50Hz, and 100Hz.

(3) The ST480MS has an on-board sensor which measures the temperature of the sensor. The temperature can be read out via the communication protocol in a digital format

3. Electrical Characteristics

The specifications are applicable at 25°C, unless specified otherwise, and for the complete supply voltage range.

Symbol	Parameter	Condition	Min.	Typ.	Max.	Unit
V_{DD}	Power supply		1.65	1.8	1.95	V
V_{POR_LH}	Power-on reset threshold (rising edge)			1.5		V
V_{POR_HL}	Power-on reset threshold (falling edge)			1.4		
$I_{DD,\ CONVXY}$	Conversion current XY-axis				2.7	mA
$I_{DD,\ CONVZ}$	Conversion current Z-axis				3.6	mA
$I_{DD,CNT}$	Counting state current(1)			60		μA
$I_{DD,PD}$	Power down current(2)			1.5		μA
$I_{DD,\ NOM}$	Nominal current	Data-rate =100Hz, t_{CONV}=7.5mS		2.5		mA

（1） In “Counting” state, the device is in a low power consumption mode, where almost all internal blocks are disabled. For more details see Continuous measurement mode.

（2） In “Power down” mode almost all internal blocks are disabled.

4. Absolute Maximum Ratings

Stress above those listed as “Absolute Maximum Ratings” may cause permanent damage to the device. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

Parameter	Symbol	Min	Max	Unit
Operating supply voltage	V_{DD}		2.3	V
Reverse voltage protection	V_{DD-REV}		-0.3	V
Positive I/O voltage (SDA and SCL pins)	V_{SDA}, V_{SCL}		2.3	V
Reverse output voltage	$V_{SDA-REV}$, $V_{SCL-REV}$		-0.3	V
Junction temperature	T_{JUNC}		+85	℃
Operating temperature	T_{AMB}	-40	+85	℃
Storage temperature range (IC)	T_{ST}	-40	+150	℃
Magnetic flux density	B	-1	1	T
ESD(HBM)	ESD_{HBM}		2000	V

5. Pin Order and Pin Description

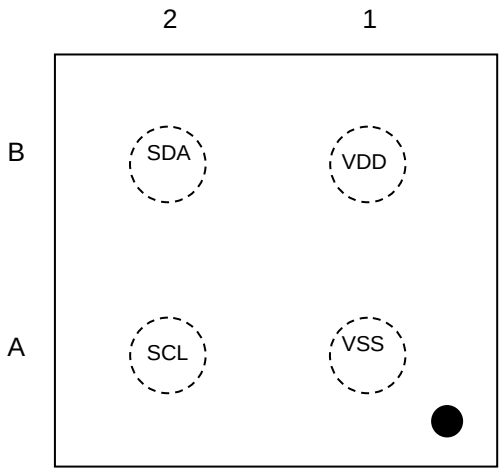


Figure 5.1: PIN order for ST480MS Top view WL-CSP 4pin 0.95 x 0.95 x 0.55 mm³

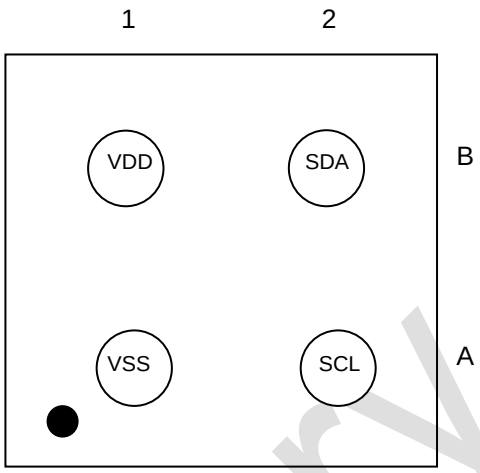


Figure 5.2: ST480MS Bottom view

Table PIN Description

PIN No. ST480MS	PIN Name	PIN Function
A1	V_{SS}	Ground pin.
A2	SCL	I^2C clock input pin
B1	V_{DD}	Positive power supply pin.
B2	SDA	I^2C serial data input/output pin

6. Functional Explanation

6.1 Magnetic Sensor

The sensing elements are located in the center of the die. The measurement data increases as the magnetic flux density increases in the arrow directions.

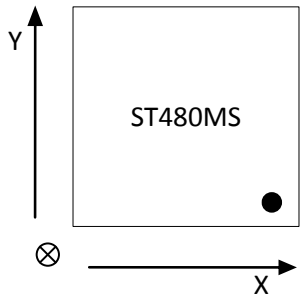


Figure 6.1: Sensor Direction of ST480MS

6.2 Application Mode

The device has the following application modes

- Power-down mode
- Single measurement mode
- Continuous measurement mode (10Hz, 20Hz, 50Hz and100Hz)
- Self-test mode

Application mode is started by setting MODE[2:0] bits in the CTRL register.

It can also be changed at any time by changing the MODE[2:0] bits. To change the application mode, the device needs to be set to "Power-down" mode first, and then to the new mode. For more details see description of the *CTRL – Control register*.

Power-down mode

Power-down mode is minimal power consumption state. Almost all internal blocks are disabled. Only the communication over the I^2C interface is maintained. All data stored into the internal registers remains.

Single measurement mode

"*Single measurement*" mode is for performing one single measurement. When single measurement is finished, signal processing starts. After signal processing, the results are stored in the corresponding registers (X, Y and Z) and the device automatically switches to "*Power-down*" mode.

Continuous measurement mode

"*Continuous measurement*" mode is used to periodically measure the magnetic field. There are 4 "*Continuous measurement*" modes - **10Hz**, **20Hz**, **50Hz** and **100Hz**. Each of the modes is started by changing **MODE[2:0]** bits in the **CTRL** register.

When the device finishes with one measurement, the signal processing is started. After signal processing, the results are stored in the corresponding registers (**X**, **Y** and **Z**) and the device automatically switches to "*Counting*" state, counting down to the next measurement.

In "*Counting*" state, the device is also in low power consumption mode, where almost all internal blocks are disabled.

When it's time for the next measurement, the device automatically starts measuring.

The device can switch to "*Power-down*" mode only by sending a dedicated command.

Self-test mode

When "*Self-test*" mode is set, the device enables the internal coil to generate a Z-field and performs a single measurement. After the measurement and the signal processing are finished the results are stored in the corresponding registers (**X**, **Y** and **Z**) and the device automatically switches to "*Power-down*" mode.

6.3 I²C bus Interface

I²C bus interface is compliant with Standard mode (max 100 kHz), Fast mode (max 400 kHz) and Fast mode plus (max 1MHz).

Slave address

The I²C slave address (7-bits) of the device is 0x0C.

MSB							LSB
0	0	0	1	1	0	0	R/W

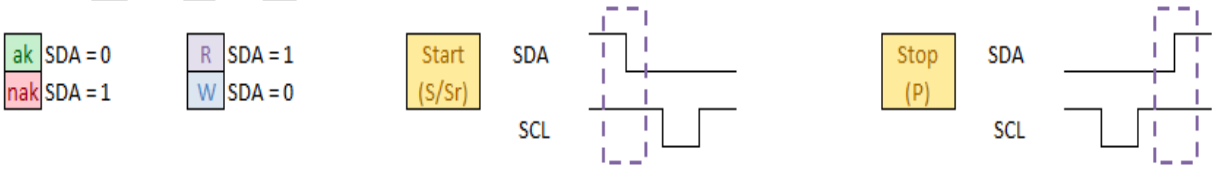
Commands

The following I²C commands are implemented:

- **MEM_DIRECT_READ**: reads data from the memory space, starting from the default address 0x00.
- **MEM_READ**: read data starting from the address specified in the command, the address is incremented for continuous reading until an I²C stop is detected.
- **MEM_WRITE**: write data at the specified address, followed by the data to be stored and is incremented until an I²C stop is detected.
- **ADDRESSED_RESET**: reset the device, based on the I²C Slave Address (reset of addressed devices on the I²C bus only).

In the next sections, the format of the different I²C commands is explained.

The following legend is used:



Read commands

Two read commands are implemented

- **MEM_DIRECT_READ**: reads data from memory, starting from the default address 0x00
- **MEM_READ**: the start address needs to be specified in the command and is incremented for continuous reading until an I²C stop is detected.

MEM_DIRECT_READ (direct read) command

MEM_DIRECT_READ: reads data from memory, starting from the default address 0x00.

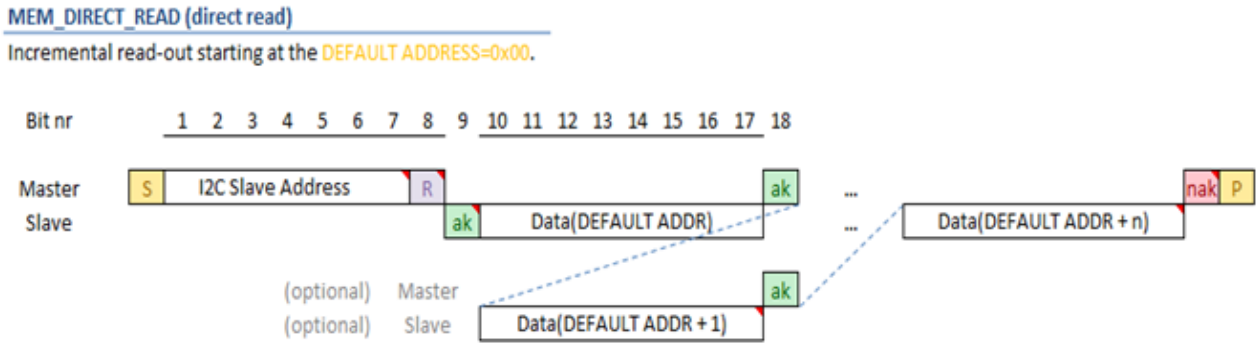


Figure 6.2 I²C - MEM_DIRECT_READ (direct read) command

MEM_READ (addressed read)

MEM_READ: the start address needs to be specified in the command and the address will be incremented for continuous reading until an I²C stop (P) is detected.

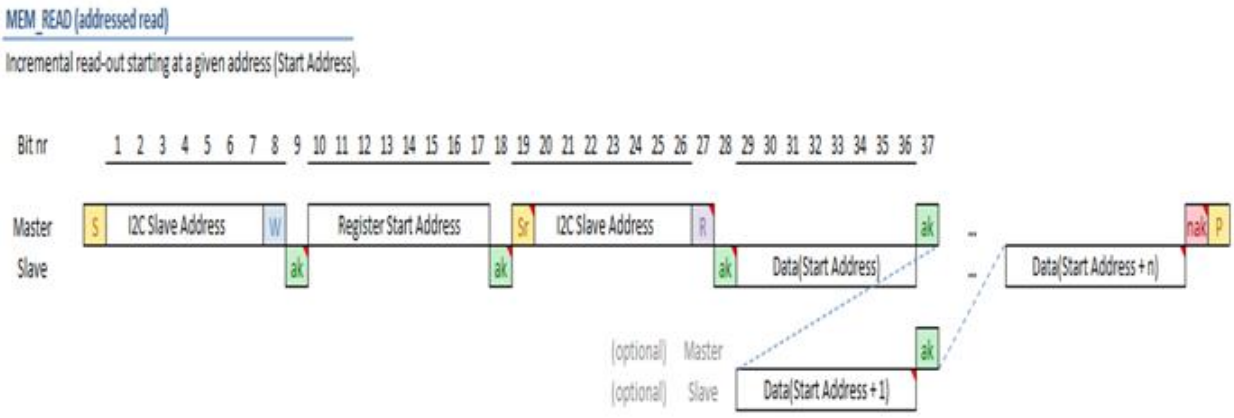


Figure 6.3 I²C - MEM_READ (addressed read)

Note: **Addressed read is only valid when combining directly an addressed write and a direct read through a repeated START condition. In case the read and write part are separated by a STOP condition, or in case read is not directly following write, or the slave address is not identical for both, the command will not be seen as addressed read.**

MEM_WRITE (addressed write) command

MEM_WRITE: the start address needs to be specified followed by the data to be stored at addresses starting from the given start address and incremented until an I²C stop (P) is detected.

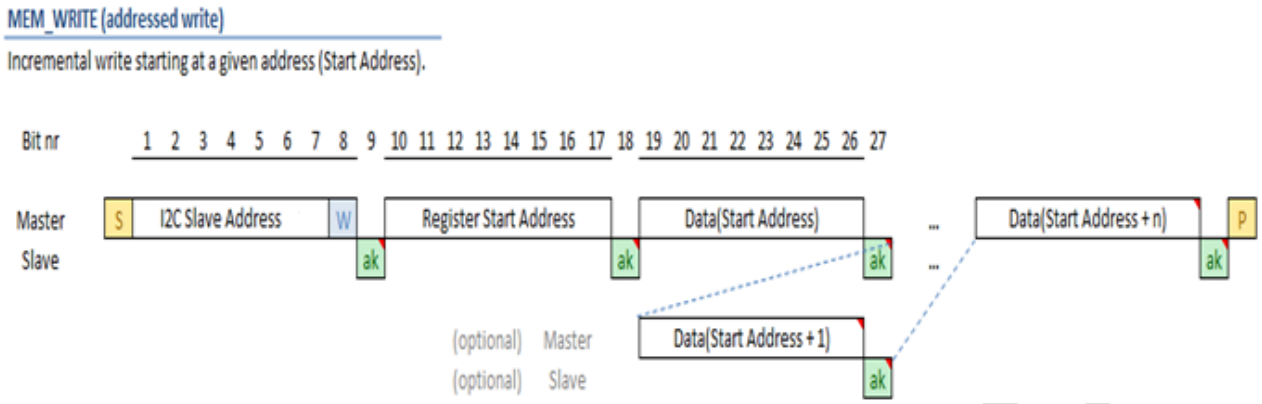


Figure 6.4 I²C - MEM_WRITE (addressed write) command

The slave is sending AK/NAK based on the fact whether it was able to write data.

The slave will automatically increment the address of the read out byte, whether it sends AK or NAK to the master. It is up to the master to re-write the byte afterwards.

ADDRESSED_RESET: Addressed reset

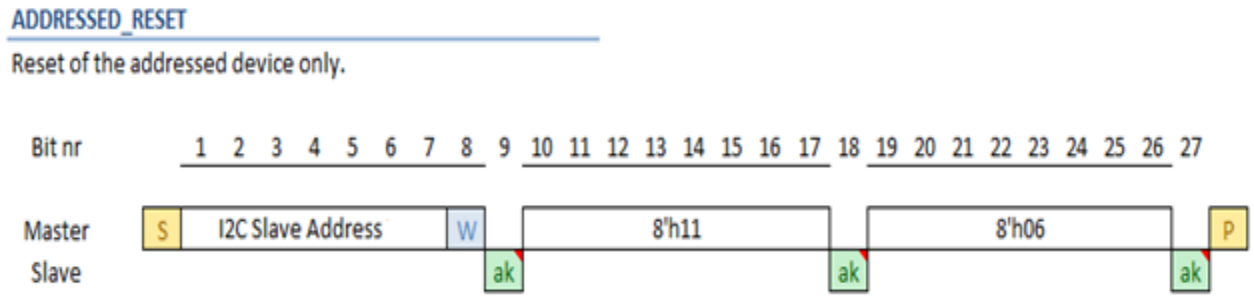


Figure 6.5 Addressed reset command

The addressed reset command brings the device back into a state like it was after power-on.

6.4 Memory Map

ST480MS memory map is shown below. Each address contains 8 bits of data.
Data is transferred to, or received from an external CPU via the I^2C interface. Output data are in 2's complement format.

Address	R/W	Name	Description
0x00	R	STAT1	Status register 1
0x01	R	X[7:0]	X-axis measurement magnetic data [7:0]
0x02	R	X[15:8]	X-axis measurement magnetic data [15:8]
0x03	R	Y[7:0]	Y-axis measurement magnetic data [7:0]
0x04	R	Y[15:8]	Y-axis measurement magnetic data [15:8]
0x05	R	Z[7:0]	Z-axis measurement magnetic data [7:0]
0x06	R	Z[15:8]	Z-axis measurement magnetic data [15:8]
0x07	R	STAT2	Status register 2
0x08	R	T[7:0]	Temperature measurement data lower 8-bit
0x09	R	T[15:8]	Temperature measurement data higher 8-bit
0x0A	R	CID	Company ID[7:0]
0x0B	R	DID	Device ID[7:0]
0x10	R/W	CTRL	Control register
0x11	R/W	RST	Reset
0x12	R	Reserved	Do not use
0x13	R	Reserved	Do not use
0x14	R	Reserved	Do not use
0x15	R	Reserved	Do not use

Figure 6.6 Memory map

The **STAT1** register is mapped at address **0x00**, since it is the default address of **MEM_DIRECT_READ** (direct read) command.

The idea is that, first the user has to read the status bit **DRDY** to check if there is new data available and if so, to continue reading the **X**, **Y** and **Z** registers.

CTRL register is mapped in the other section (**0x10**), since it is not used as often (select the device mode).

Address: 0x00

Default: 0x00

7	6	5	4	3	2	1	0
TAT1_7	STAT1_6	STAT1_5	STAT1_4	RT	STAT1_2	STAT1_1	DRDY
R	R	R	R	R	R	R	R

NOTE: R=Read access; W=Write access.

Figure 6.7 STAT1 – Status register

Bits 7:4 **STAT1[7:4].** Reserved (not used)

Bit 3 **RT**. Reset bit

0 – The device was not reset
1 – The device was reset and this is the first reading. Automatically goes to 0 when STAT1 register is read.

Bits 2:1 **STAT1[2:1].** Reserved (not used)

Bit 0 **DRDY**. Data Ready.

DRDY bit turns to "1" when measurement results are available.
It returns to "0" when any of the measurement data registers (X, Y or Z) is read.
0 – Normal
1 – Data is Ready

Address: 0x07

Default: 0x00

7	6	5	4	3	2	1	0
STAT2_7	STAT2_6	STAT2_5	STAT2_4	STAT2_3	STAT2_2	DOR	HOVF
R	R	R	R	R	R	R	R

NOTE: R=Read access; W=Write access.

Figure 6.8 STAT2 – Status register

Bits 7:2 **STAT2[7:2].** Reserved (not used)

Bit 1 **DOR**. Data OverRun

DOR bit turns to "1" when data reading has been skipped.
It returns to "0" when any of the measurement data registers (**X**, **Y** or Z) is read.

0 – Normal

1 – Data OverRun

Bit 0 **HOVF**. Magnetic Sensor OverFlow

0 – when:

|X|+|Y|+|Z| <**4912μT**

1 – when:

|X|+|Y|+|Z| >**4912μT**

When measurement data register is updated, HOVF bit is updated as well.

Note: The stored measurement data is protected during reading, and during this time the data cannot be updated. STAT2 register has a role to end data protection. This means that when any data register (X, Y or Z) is read, X, Y and Z registers are protected and cannot be updated until STAT2 register is read. Therefore, when any measurement data is read, it is required to read STAT2 register as well.

Address 0x0A & 0x0B provide company ID and device ID information

Address	Bit	Name	Description	Attr.	Default
0x0A	7:0	CID	Company ID	R	0X98
0x0B	7:0	DID	Device ID	R	0XBA

Address: 0x10
Default: 0x00

7	6	5	4	3	2	1	0
CTRL7	CTRL6	CTRL5	CTRL4	CTRL3	MODE2	MODE1	MODE0
R	R	R	R	R	RW	RW	RW

NOTE: R=Read access; W=Write access.

Figure 6.9 CTRL – Control register

Bits 7:3 **CTRL[7:3]**. Reserved (not used)

Bits 2:0 **MODE[2:0].** Application mode

- 0 – Power-down mode
- 1 – Single measurements mode
- 2 – Continuous measurement mode 10Hz
- 3 – Continuous measurement mode 20Hz
- 4 – Continuous measurement mode 50Hz
- 5 – Continuous measurement mode 100Hz
- 6 – Self-test mode
- 7 – Power-down mode

7. Typical Application

7.1 Typical Application Circuit

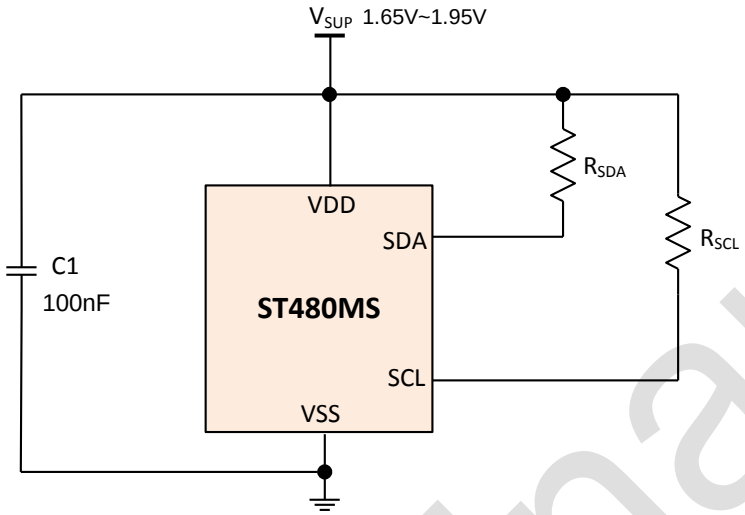


Figure 7.1: Reference Application Circuitry using I²C interface

8. Package Information

8.1 ST480MS WL-CSP 0.95 x 0.95mm Package Outline Dimensions

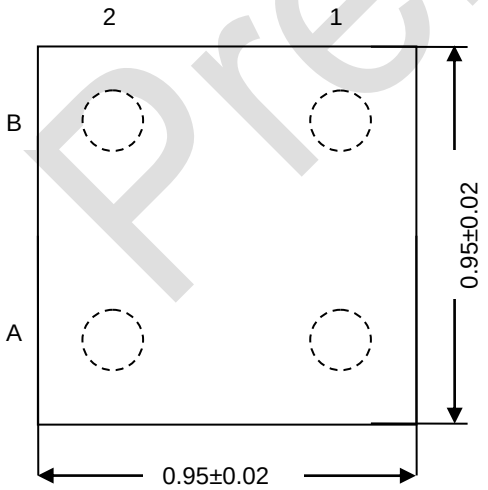


Figure 8.1: Top View (unit mm)

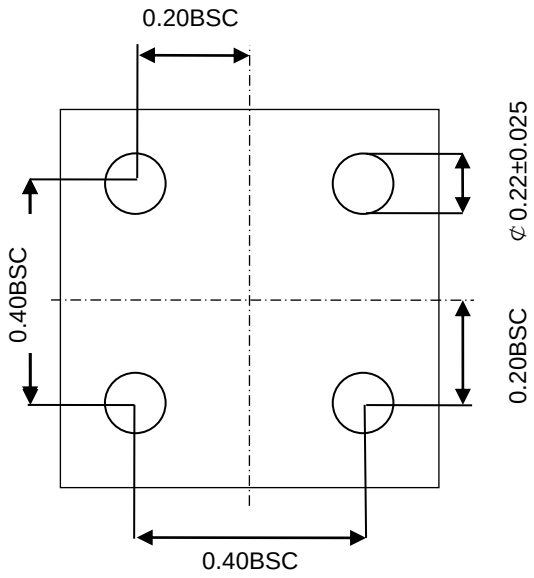


Figure 8.2: Bottom View (unit mm)

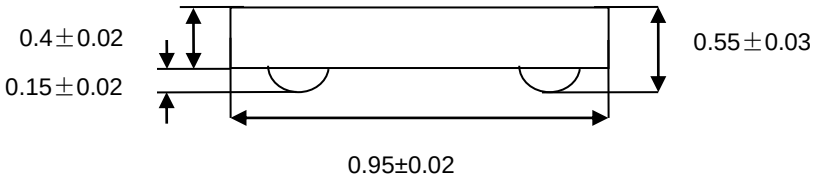


Figure 8.3: Side View (unit mm)

8.2 Package Laser Mark

8.2.1 ST480MS marking

Mark	Symbol	Description	Remark
M82 ●	●	Pin 1 Identifier	
	M	Product Name	Alphabetic M: fixed to identify product name
	82	Trace Code	2 alphanumeric digits, variable to generate mass production trace code: YW (year, week)

8.3 Packing of the Chips

ST480MS packing in Tape & Reel (7''), and meet EIA-481 standard.

8.3.1 Packing direction:

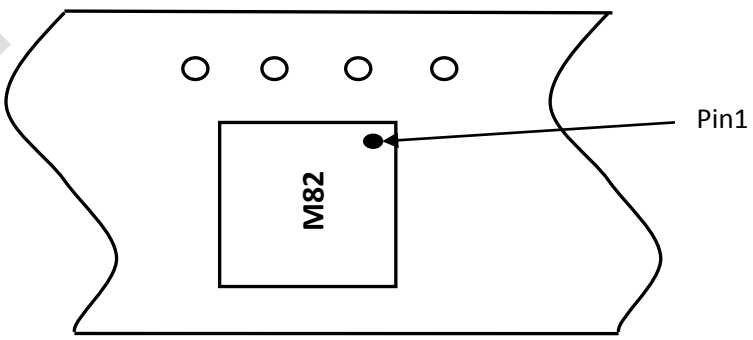


Figure 8.4: Packing direction

8.4 Solder Reflow Curve

Solder Reflow curve follows IPC/JEDEC J-STD-020E standards.

8.4.1 Solder Reflow Curve

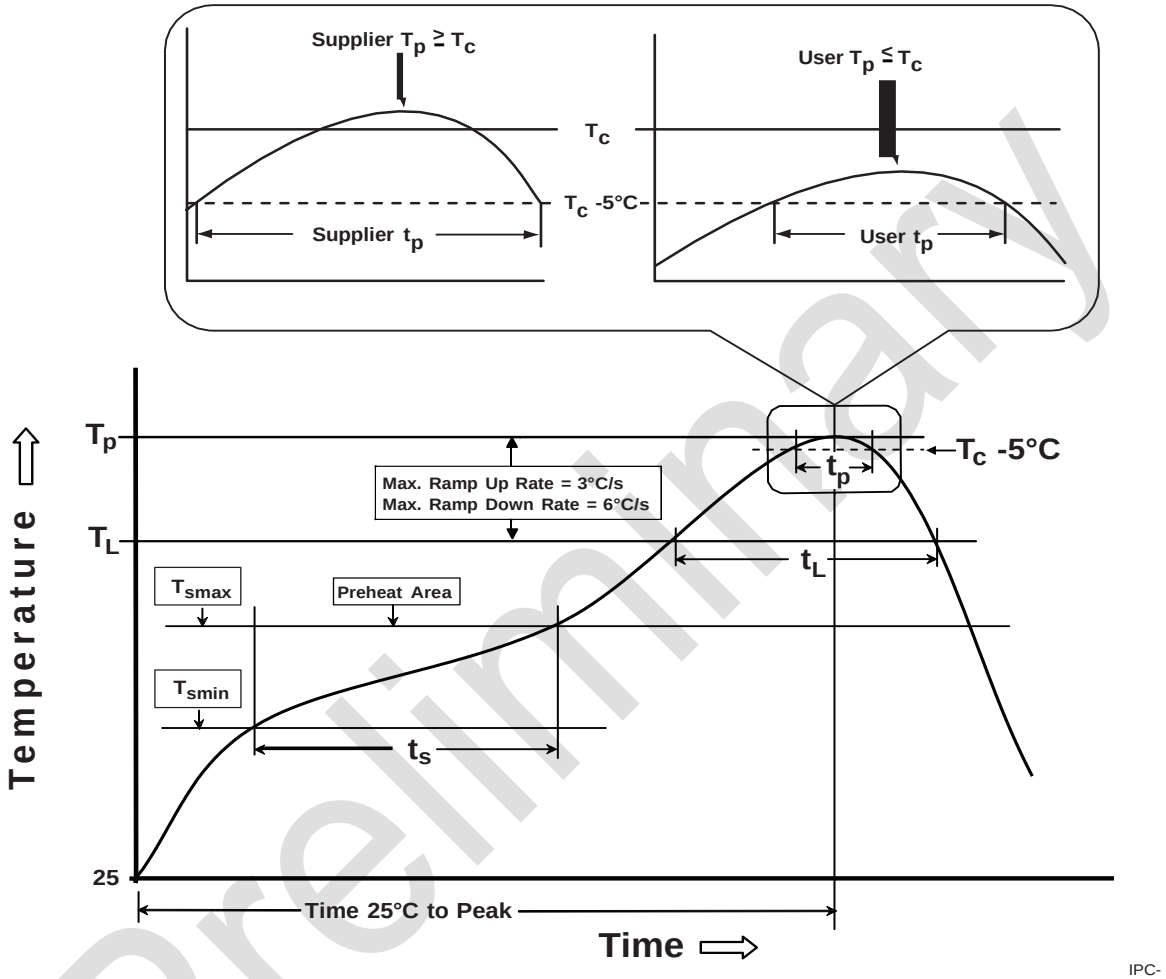


Figure 8.5: Solder Reflow curve

Table 8.2 Classification Reflow Profiles

Profile Fea-	Sn-Pb Eutectic Assembly	Pb-Free Assembly
Preheat/Soak Temperature Min (T_{smin}) Temperature Max (T_{smax}), Time (t_s) from (T_{smin} to T_{smax})	100 °C 150 °C 60-120 seconds	150 °C 200 °C 60-120 seconds
Ramp-up rate (T_L to T_p)	3 °C/second max.	3 °C/second max.
Liquidous temperature (T_L) Time (t_L) maintained above T_L	183 °C 60-150 seconds	217 °C 60-150 seconds
Peak package body temperature (T_p)	For users T_p must not exceed the Classification temp 235°C. For suppliers T must equal or exceed the Classification temp 235°C.	For users T_p must not exceed the Classification temp 260°C. For suppliers T must equal or exceed the Classification temp 260°C.
Time (t_p)* within 5 °C of the specified classification temperature (T_c), see Figure 8.5.	20* seconds	30* seconds
Ramp-down rate (T_p to T_L)	6 °C/second max.	6 °C/second max.
Time 25 °C to peak tem-	6 minutes max.	8 minutes max.
* Tolerance for peak profile temperature (T_p) is defined as a supplier minimum and a user maximum.		

8.4.2 Maintenance temperature is less than 350℃, and duration is less than 30 seconds.

8.5 Storage condition

The storage condition follows JEDEC J-STD-020E, MSL 2.

9. Reliability

ST480MS reliability test plan follows JEDEC 47I standards, Stress-Test-Driven Qualification of Integrated Circuits".

10. Environment Compliant

ST480MS is compliant with RoHS2.0 standards and meet HF requirements.

11. Revision History

Date	Revision	Changes
2018-6-11	1.0	ST480MS initial release
2019-1-14	1.1	Update 6.4 memory map

12. Disclaimer

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