



Ultra Small 3-axis Magnetic Sensor, With I²C Interface

MMC314xMR

FEATURES

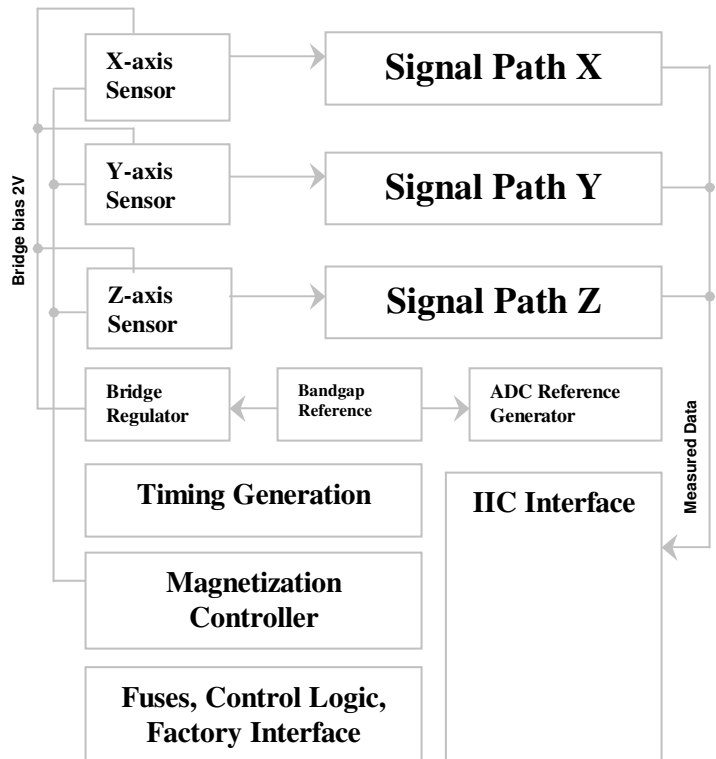
- Full integration of 3-axis magnetic sensors and electronics circuits resulting in less external components needed
- Small Low profile package 3.0x3.0x1.0mm
- Low power consumption: typically 0.55mA@3V with 50 measurements per second
- Power up/down function available through I²C interface
- 512counts/gauss
- I²C Slave, FAST (≤ 400 KHz) mode
- 1.8V compatible IO
- 2.7V~5.25V wide power supply operation supported
- RoHS compliant

APPLICATIONS:

Electronic Compass
GPS Navigation
Position Sensing
Magnetometry

DESCRIPTIONS:

The MMC314xMR is a 3-axis magnetic sensor, it is a complete sensing system with on-chip signal processing and integrated I²C bus, allowing the device to be connected directly to a microprocessor eliminating the need for A/D converters or timing resources. It can measure magnetic field with a full range of ± 4 gauss and a sensitivity of 512counts/gauss @3.0 V at 25°C.



FUNCTIONAL BLOCK DIAGRAM

The MMC314xMR is packaged in an ultra small low profile LGA package (3.0 x 3.0 x 1.0 mm) and is available in operating temperature ranges of -40°C to +85°C.

The MMC314xMR provides an I²C digital output with 400 KHz, fast mode operation.

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SPECIFICATION (Measurements @ 25°C, unless otherwise noted; $V_{DA} = V_{DD} = 3.0V$ unless otherwise specified)

Parameter	Conditions	Min	Typ	Max	Units
Field Range (Each Axis)	Total applied field	-4		+4	gauss
Supply Voltage	V_{DA}	2.7	3.0	5.25	V
	V_{DD} (I ² C interface)	1.62	3.0	5.25	V
Supply Current	50 measurements/second		0.55		mA
Power Down Current				1.0	μA
Operating Temperature		-40		85	°C
Storage Temperature		-55		125	°C
Linearity Error (Best fit straight line)	±1 gauss		0.1		%FS
	±4 gauss		1.0		%FS
Hysteresis	3 sweeps across ±4 gauss		0.1		%FS
Repeatability Error	3 sweeps across ±4 gauss		0.1		%FS
Alignment Error			±1.0	±3.0	degrees
Transverse Sensitivity			±2.0	±5.0	%
Noise Density	1~25Hz, RMS		600		μgauss
Accuracy ¹			±2.0	±5.0	degrees
Bandwidth			25		Hz
Sensitivity		-10		+10	%
		461	512	563	counts/gauss
Sensitivity Change Over Temperature	Based on 512counts/gauss		±1100		ppm/°C
Null Field Output		-0.2		+0.2	gauss
			4096		counts
Null Field Output Change Over Temperature ²	Delta from 25°C		±0.4		mgauss/°C
Disturbing Field		5.5			gauss
Maximum Exposed Field				10000	gauss
Power up Time	Time to operate device after Vdd valid			20	μS
Power down Time	Time to enter power down mode			1	μS

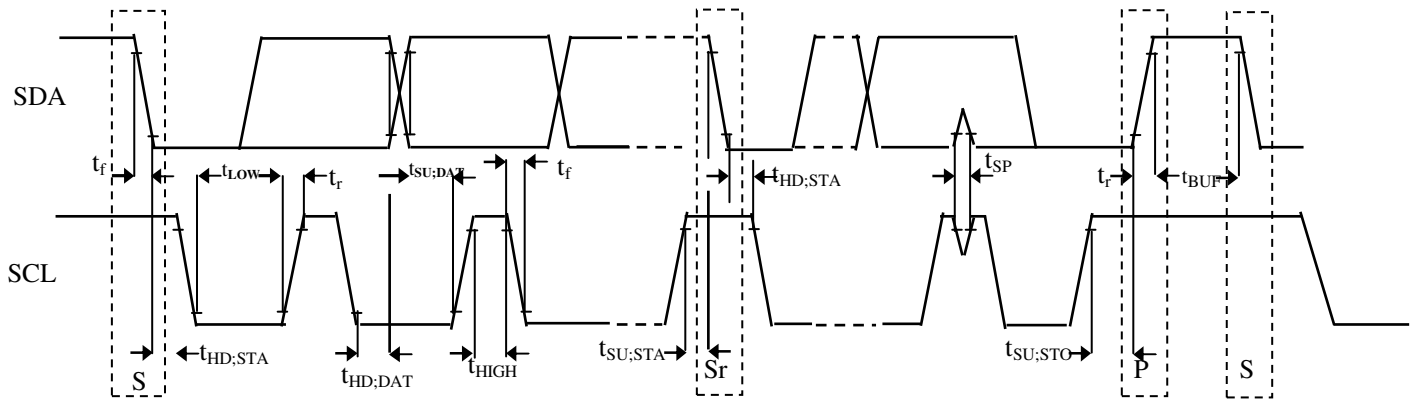
Note: ¹: Accuracy is dependent on system design, calibration and compensation algorithms used.

The specification is based upon using the MEMSIC evaluation board and associate software.

²: It can be significantly improved when using MEMSIC's proprietary software or algorithm.

I²C INTERFACE I/O CHARACTERISTICS (V_{DD}=3.0V)

Parameter	Symbol	Test Condition	Min.	Typ.	Max.	Unit
Logic Input Low Level	V _{IL}		-0.5		0.3* V _{DD}	V
Logic Input High Level	V _{IH}		0.7*V _{DD}		V _{DD}	V
Hysteresis of Schmitt input	V _{hys}		0.2			V
Logic Output Low Level	V _{OL}				0.4	V
Input Leakage Current	I _i	0.1V _{DD} <V _{in} <0.9V _{DD}	-10		10	μA
SCL Clock Frequency	f _{SCL}		0		400	kHz
START Hold Time	t _{HD,STA}		0.6			μS
START Setup Time	t _{SU,STA}		0.6			μS
LOW period of SCL	t _{LOW}		1.3			μS
HIGH period of SCL	t _{HIGH}		0.6			μS
Data Hold Time	t _{HD,DAT}		0		0.9	μS
Data Setup Time	t _{SU,DAT}		0.1			μS
Rise Time	t _r	From V _{IL} to V _{IH}			0.3	μS
Fall Time	t _f	From V _{IH} to V _{IL}			0.3	μS
Bus Free Time Between STOP and START	t _{BUF}		1.3			μS
STOP Setup Time	t _{SU,STO}		0.6			μS



Timing Definition

ABSOLUTE MAXIMUM RATINGS*

Supply Voltage (V_{DD})-0.5 to +7.0V
 Storage Temperature-55°C to +125°C
 Maximum Exposed Field10000 gauss

*Stresses above those listed under Absolute Maximum Ratings may cause permanent damage to the device. This is a stress rating only; the functional operation of the device at these or any other conditions above those indicated in the operational sections of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Pin Description: LGA-10 (3x3x1mm) Package

Pin	Name	Description	I/O
1	C+	Short together, minimize the connection resistance to smaller than 50mOhm	I
2	C-		I
3	CAP	Connect to External Capacitor	I
4	TEST	Factory Use Only, Leave Open/No Connect	NC
5	V_{DA}	Power Supply	P
6	V_{DD}	Power Supply for I ² C bus	P
7	SDA	Serial Data Line for I ² C bus	I/O
8	SCL	Serial Clock Line for I ² C bus	I
9	FM	Factory Use Only, Leave Open/No Connect, Internally Pulled Down	NC
10	GND	Connect to Ground	P

All parts are shipped in tape and reel packaging with 5000pcs per 13"reel.

Caution: ESD (electrostatic discharge) sensitive device.

ORDERING GUIDE

MMC314xMR

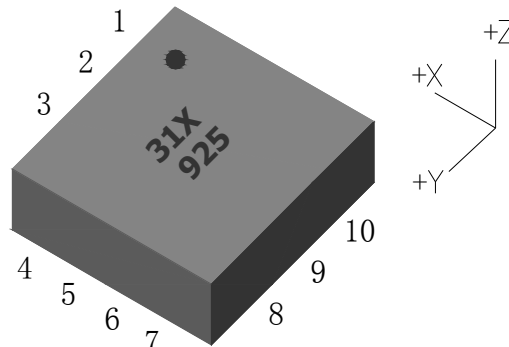
Package type:	
Code	Type
R	LGA10 (3x3x1.0mm) RoHS compliant

Performance Grade:	
Code	Performance Grade
M	Temp compensated

Address code: 0~3

Number	7-bit I ² C Address
0	0110000b
1	0110010b
2	0110100b
3	0110110b

MARKING ILLUSTRATION



Number	Part number
31X	
310	MMC3140MR
311	MMC3141MR
312	MMC3142MR
313	MMC3143MR

Small circle indicates pin one (1).

THEORY

The anisotropic magnetoresistive (AMR) sensors are special resistors made of permalloy thin film deposited on a silicon wafer. During manufacturing, a strong magnetic field is applied to the film to orient its magnetic domains in the same direction, establishing a magnetization vector. Subsequently, an external magnetic field applied perpendicularly to the sides of the film causes the magnetization to rotate and change angle. This in turn causes the film's resistance to vary. The MEMSIC AMR sensor is included in a Wheatstone bridge, so that the change in resistance is detected as a change in differential voltage and the strength of the applied magnetic field may be inferred.

However, the influence of a strong magnetic field (more than 5.5 gauss) along the magnetization axis could upset, or flip, the polarity of the film, thus changing the sensor characteristics. The MEMSIC magnetic sensor can provide an electrically-generated strong magnetic field to restore the sensor characteristics.

PIN DESCRIPTIONS

V_{DA} – This is the supply input for the circuits and the magnetic sensor. The DC voltage should be between 2.7 and 5.25 volts. Refer to the section on PCB layout and fabrication suggestions for guidance on external parts and connections recommended.

GND – This is the ground pin for the magnetic sensor.

SDA – This pin is the I²C serial data line, and operates in FAST (400 KHz) mode.

SCL – This pin is the I²C serial clock line, and operates in FAST (400 KHz) mode.

V_{DD} – This is the power supply input for the I²C bus, and is 1.8V compatible can be 1.62V to 5.25V.

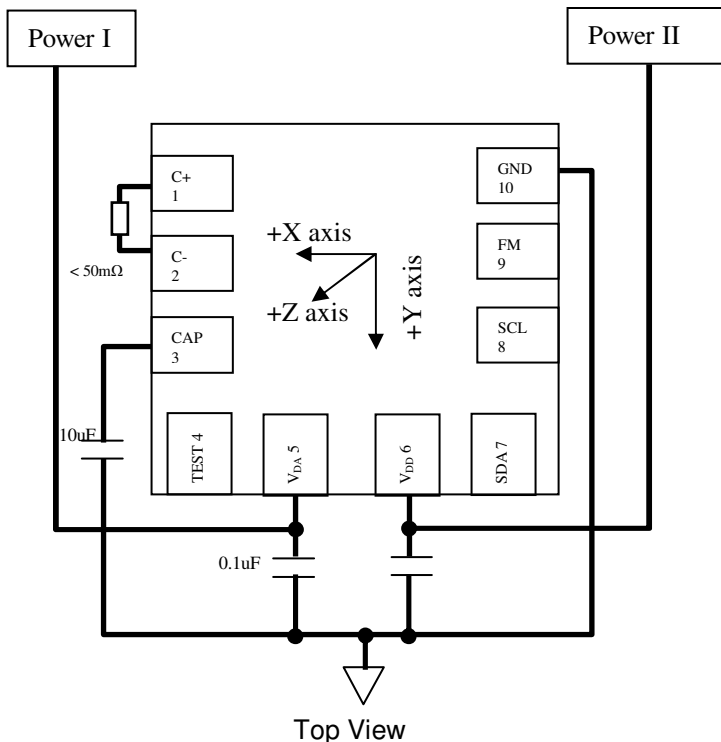
FM – Factory use only, Leave Open/No Connect, internally pulled down.

TEST – Factory use only, Leave Open/No Connect.

CAP – Connect a 10uF low ESR ceramic capacitor.

C+, C- – Short together with resistance smaller than 50 mOhm.

EXTERNAL CAPACITOR CONNECTION



POWER CONSUMPTION

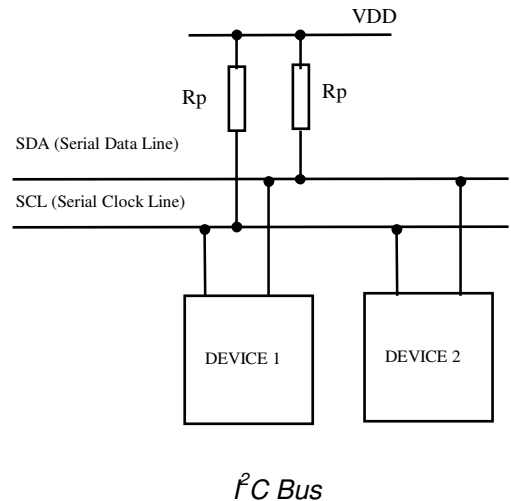
The MEMSIC magnetic sensor consumes 0.55mA (typical) current at 3V with 50 measurements/second, but the current is proportional to the number of measurements carried out, for example, if only 20 measurements/second are performed, the current will be $0.55 \times 20 / 50 = 0.22\text{mA}$.

I²C INTERFACE DESCRIPTION

A slave mode I²C circuit has been implemented into the MEMSIC magnetic sensor as a standard interface for customer applications. The A/D converter and MCU functionality have been added to the MEMSIC sensor, thereby increasing ease-of-use, and lowering power consumption, footprint and total solution cost.

The I²C (or Inter IC bus) is an industry standard bi-directional two-wire interface bus. A master I²C device can operate READ/WRITE controls to an unlimited number of devices by device addressing. The MEMSIC magnetic sensor operates only in a slave mode, i.e. only responding to calls by a master device.

I²C BUS CHARACTERISTICS



The two wires in I²C bus are called SDA (serial data line) and SCL (serial clock line). In order for a data transfer to start, the bus has to be free, which is defined by both wires in a HIGH output state. Due to the open-drain/pull-up resistor structure and wired Boolean “AND” operation, any device on the bus can pull lines low and overwrite a HIGH signal. The data on the SDA line has to be stable during the HIGH period of the SCL line. In other words, valid data can only change when the SCL line is LOW.

Note: Rp selection guide: 4.7Kohm for a short I²C bus length (less than 4inches), and 10Kohm for less than 2inches I²C bus.

DATA TRANSFER

A data transfer is started with a “START” condition and ended with a “STOP” condition. A “START” condition is defined by a HIGH to LOW transition on the SDA line while SCL line is HIGH. A “STOP” condition is defined by a LOW to HIGH transition on the SDA line while SCL line is HIGH. All data transfer in I²C system is 8-bits long. Each byte has to be followed by an acknowledge bit. Each data transfer involves a total of 9 clock cycles. Data is transferred starting with the most significant bit (MSB). After a “START” condition, master device calls specific slave device, in our case, a MEMSIC device with a 7-bit device address “[0110xx0]”. To avoid potential address conflict, either by ICs from other manufacturers or by other MEMSIC device on the same bus, a total of **4 different addresses** can be pre-programmed into MEMSIC device by the factory. Following the 7-bit address, the 8th bit determines the direction of data transfer: [1] for READ and [0] for WRITE. After being addressed, available MEMSIC device being called should respond by an “Acknowledge” signal, which is pulling SDA line LOW. In order to read sensor signal, master device should operate a WRITE action with a code of [xxxxxxx1] into MEMSIC device 8-bit internal register. Note that this action also serves as a “wake-up” call.

Bit	Name	Function
0	TM (Take Measurements)	Initiate measurement sequence for “1”, this bit will be cleared by circuit outside of I2C core after measurement and A/D are finished. More specifically, it will be automatically cleared by TM_DONE signal after the action is finished.
1	RM	Writing “1” will electrically magnetize the MR. It will be automatically cleared after the action is finished.
2	Reserved	
3	Reserved	
4	Reserved	
5	Reserved	
6	Reserved	

After writing code of [xxxxxxx1] into control register and a zero memory address pointer is also written, and if a “READ” command is received, the MEMSIC device being called transfers 8-bit data to I²C bus. If “Acknowledge” by master device is received, MEMSIC device will continue to transfer next byte. The same procedure repeats until 7 byte of data are transferred to master device. Those 7 bytes of data are defined as following:

1. Internal register
2. MSB X-axis
3. LSB X-axis
4. MSB Y-axis
5. LSB Y-axis
6. MSB Z-axis
7. LSB Z-axis

Even though each axis consists two bytes, which are 16bits of data, the actual resolution is limited 13bits. Unused MSB should be simply filled by “0”s.

POWER DOWN MODE

MEMSIC MR sensor will enter power down mode automatically after data acquisition is finished. A data acquisition is initiated when master writes in to the control register a code of [xxxxxxx1].

EXAMPLE OF TAKE MEASUREMENT

First cycle: START followed by a calling to slave address [0110xx0] to WRITE (8th SCL, SDA keep low). [xx] is determined by factory programming, total 4 different addresses are available.

Second cycle: After a acknowledge signal is received by master device (MEMSIC device pulls SDA line low during 9th SCL pulse), master device sends “[00000000]” as the target address to be written into. MEMSIC device should acknowledge at the end (9th SCL pulse). Note: since MEMSIC device has only one internal register that can be written into, so user should always use “[00000000]” as the write address.

Third cycle: Master device writes to internal MEMSIC device memory the code “[00000001]” as a wake-up call to initiate a data acquisition. MEMSIC device should send acknowledge.

A STOP command indicates the end of write operation.

A minimal 7ms wait period should be given to MEMSIC device to finish a data acquisition and return a valid output. The TM bit (Take Measurement bit in control register) will be automatically reset to “0” after data from A/D converter is ready. The transition from “1” to “0” of TM bit also indicates “data ready”. The device will go into sleep mode afterwards. Analog circuit will be powered off, but I²C portion will continue be active and data will not be lost.

Fourth cycle: Master device sends a START command followed by calling MEMSIC device address with a WRITE (8th SCL, SDA keep low). A acknowledge should be send by MEMSIC device at the end.

Fifth cycle: Master device writes to MEMSIC device a “[00000000]” as the starting address to read from which internal memory. Since “[00000000]” is the address of internal control register, reading from this address can serve as a verification operation to confirm the write command has been successful. Note: the starting address in principle can be any of the 5 addresses. For example, user can start read from address [0000001], which is X channel MSB.

Sixth cycle: Master device calls MEMSIC device address with a READ (8th SCL cycle SDA line high). MEMSIC device should acknowledge at the end.

Seventh cycle: Master device cycles SCL line, first addressed memory data appears on SDA line. If in step 7, “[00000000]” was sent, internal control register data should appear (in the following steps, this case is assumed). Master device should send acknowledge at the end.

Eighth cycle: Master device continues to cycle the SCL line, next byte of internal memory should appear on SDA line (MSB of X channel). The internal memory address pointer automatically moves to the next byte. Master acknowledges.

Ninth cycle: LSB of X channel.

Tenth cycle: MSB of Y channel.

Eleventh cycle: LSB of Y channel.

Twelfth cycle: MSB of Z channel.

Thirteenth cycle: LSB of Z channel.

Master ends communications by NOT sending ‘Acknowledge’ and also followed by a ‘STOP’ command.

EXAMPLE OF MAGNTIZATION

First cycle: START followed by a calling to slave address [0110xx0] to WRITE (8th SCL, SDA keep low). [xx] is determined by factory programming, total 4 different addresses are available.

Second cycle: After a acknowledge signal is received by master device (MEMSIC device pulls SDA line low during 9th SCL pulse), master device sends “[00000000]” as the target address. MEMSIC device should acknowledge at the end (9th SCL pulse). Note: since MEMSIC device has only one internal register can be written into, user should always use “[00000000]” as the write address.

T Third cycle: Master device writes to internal MEMSIC device memory the code “[00000010]” as a wake-up call to initiate a magnetization action. The

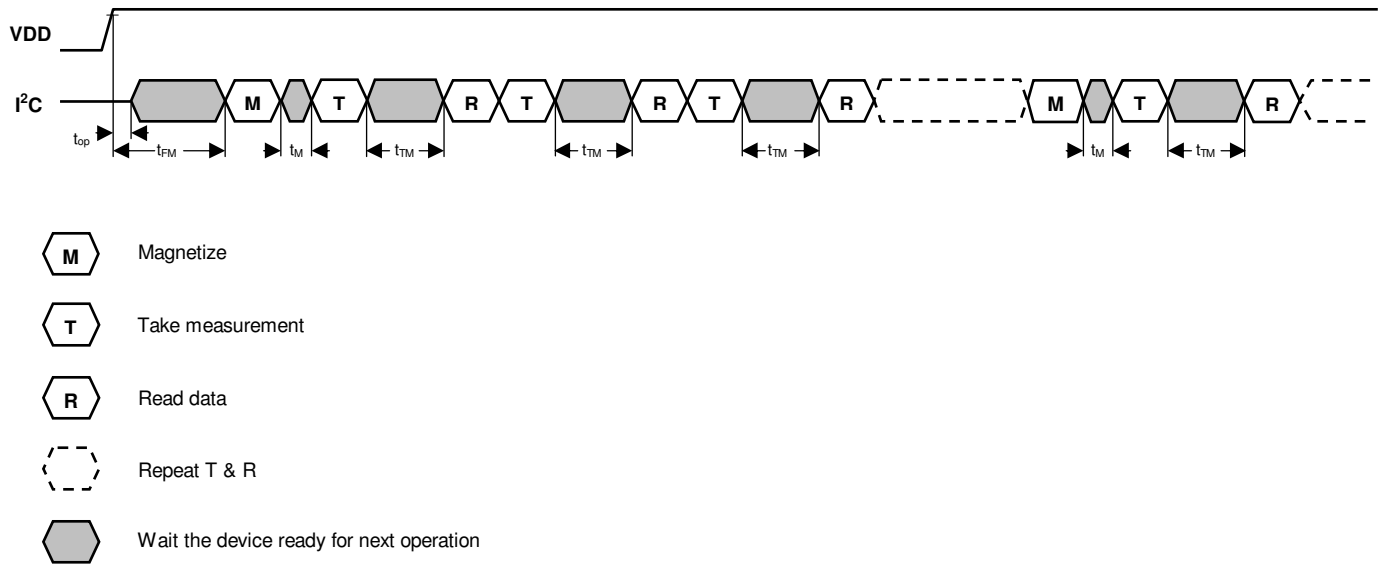
wait time from power on to RM command should be a minimal 10ms. MEMSIC device should send acknowledge. A STOP command indicates the end of write operation.

A minimal of 50us wait should be given to MEMSIC device to finish magnetization action before taking a measurement. The RM bit will be automatically reset

to "0" after RM is done. And the device will go into sleep mode afterwards.

Note 1: at power-on, internal register and memory address pointer are reset to "0".

OPERATING TIMING



Operating Timing Diagram

Parameter	Symbol	Min.	Typ.	Max.	Unit
Time to operate device after Vdd valid	t_{op}			20	μ S
Wait time from power on to RM command	t_{FM}	10			mS
Time to finish magnetization	t_M	50			μ S
Time to measure magnetic field	t_{TM}	7			mS

STORAGE CONDITIONS

Temperature: <30°C
Humidity: <60%RH
Period: 1 year (after delivery)

Moisture Sensitivity Level: 2

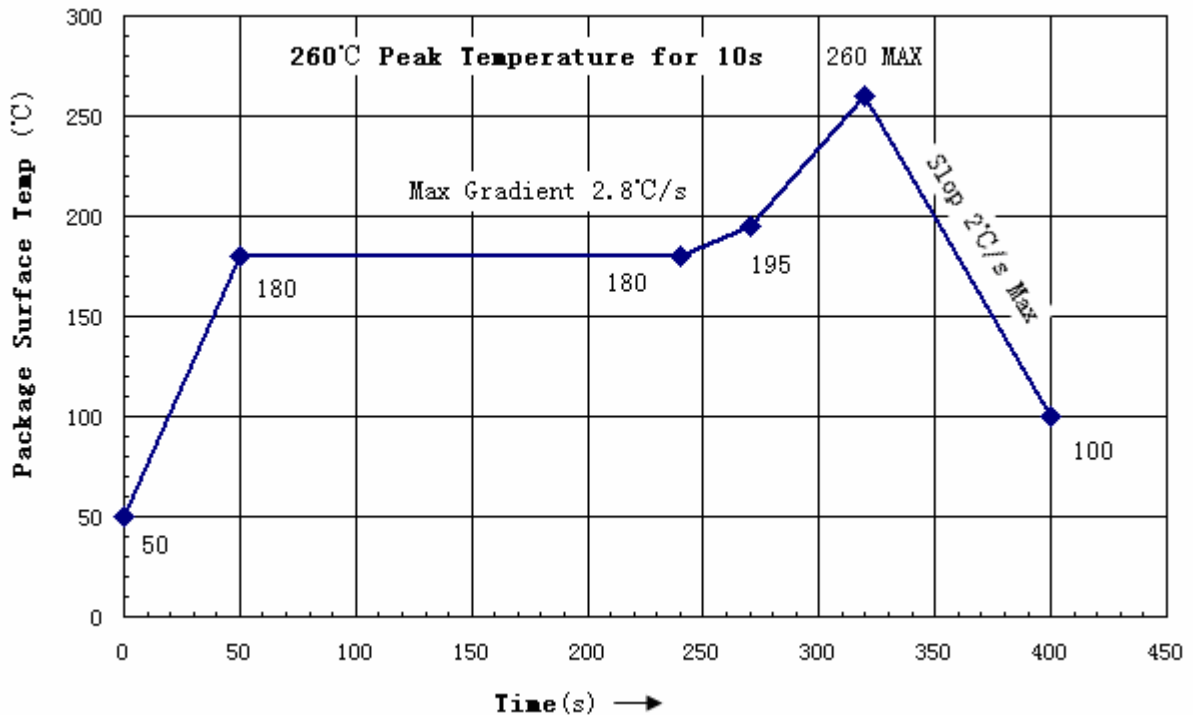
Bake Prior to Reflow: storage period more than 1 year, or humidity indicator card reads >60% at 23±5°C

Bake Procedure: refer to J-STD-033

Bake to Soldering: <1 week under 30°C/60%RH condition

SOLDERING RECOMMENDATIONS

MMC314xMR is capable of withstanding an MSL2 / 260°C solder reflow. Following is the reflow profile:



Note:

- Reflow is limited by 2 times
- The second reflow cycle should be applied after device has cooled down to 25°C (room temperature)
- This is the reflow profile for Pb free process
- The peak temperature on the sensor surface should be limited under 260°C for 10 seconds.
- Solder paste's reflow recommendation can be followed to get the best SMT quality.

If the part is mounted manually, please ensure the temperature could not exceed 260°C for 10 seconds.

PACKAGE DRAWING

