Magnus-S3 M3D Passive Sensor IC

Temperature, Moisture, and Proximity

Introduction

The Magnus®-S3 M3D Sensor IC (Integrated Circuit) employs Smart Passive Sensing™ technology to enable a new class of maintenance-free and battery-free sensors. The Magnus-S3 M3D can be configured for low-cost sensors that monitor temperature, moisture, and proximity.

A fully compliant sensor is built by combining the Magnus-S3 M3D IC with a low-cost foil antenna. The Magnus-S3 M3D IC can be read by EPC class 1 gen 2 v2.0.1 and ISO/IEC 18000-6C compliant readers. The patented self-tuning Chameleon™ wireless front-end monitors conditions that might detune the sensor antenna and then adapts as needed for precise management of sensor responses.

Features

- Passive wireless sensor IC
- On-chip temperature sensor
- On-chip RSSI sensor
- On-chip RF sensor
- Adaptive RF front-end
    - Maintains consistent performance
    - Mitigates antenna detuning
- Battery-free wireless operation
- Worldwide UHF from 860 to 960 MHz
- Meets EPCglobal™ Gen2 (v. 2.0.1)
- Meets ISO/IEC 18000-6C
- User-accessible memory
    - 64-bit unique Tag ID (read-only)
    - 128-bit EPC
    - 128-bit user memory
- Extended temperature range -40 °C to +125 °C

Contents

1. Functional Description

The Magnus®-S3 M3D Sensor integrated circuit employs Smart Passive Sensing™ technology, enabling a new class of maintenance-free and battery-free sensors. The Magnus-S3 M3D features the Chameleon™ engine which adapts the RF front-end so that the sensor stays tuned to the reader's communication frequency even when placed on multiple surfaces and under adverse antenna conditions. The Chameleon engine automatically adjusts the antenna pins to match environmental conditions, making it possible to maintain high performance while covering all worldwide UHF frequency bands (860 – 960 MHz).

The Magnus-S3 M3D IC incorporates three sensors:

1) The Chameleon engine generates a SENSOR CODE that quantifies the adaptive RF impedance setting used to match the sensor antenna. With a properly designed antenna, the Chameleon engine can function as an RF sensor and is commonly used in this way to measure moisture. This value can be translated into a measurement of the environmental conditions being sensed or monitored by the antenna. This is particularly useful for monitoring moisture levels.
2) An on-chip Received Signal Strength Indicator RSSI monitor indicates the amount of RF power reaching the chip. The generated RSSI CODE can be used to filter large populations of sensors. It also allows the wireless reader to manage its output power for optimum sensor performance.
3) The on-chip temperature sensor generates a TEMPERATURE CODE data value proportional to the temperature. The IC can be calibrated to provide precise temperature measurements.

All three sensor values are retrieved by reading memory locations within the IC.

The Magnus-S3 M3D includes 128 bits of user memory with user-writable EPC formats up to 128-bits in length. Magnus-S3 M3D also includes a 32-bit kill password, and a 64-bit factory-programmed Tag ID (TID). The TID value is unique for each individual RFMicron device and cannot be modified.

1.1. Wireless Communication Standard

Magnus®-S3 M3D fully supports all parts of the EPCglobal Class-1 Generation-2 RAIN/UHF protocol for communications at 860 MHz to 960 MHz, Version 2.0.1, including all mandatory commands.

2. AZN305-DX Performance Data

Wireless Sensor IC for passive temperature, moisture, and proximity sensors.

Table 1: Absolute Maximum Ratings[1]

PARAMETER	Min	Max	Units	Notes
Storage temperature	-40	125	˚C	
Assembly temperature		150	˚C	1-Minute duration
Received RF Power		+10	dBm	800-1000 MHz
ESD immunity		1500	V	Human Body Model (HBM)

NOTES:

1. Absolute maximums are limiting values of operating and environmental conditions, which should not be exceeded under the worst possible conditions. Operation at or near the absolute maximum ratings is not recommended and may damage or reduce device life.

Table 2: Recommended Operating Conditions

PARAMETER	Min	Max	Units	Notes
Operating temperature	-40	+85	˚C	Can Support shorter excursions to 125 ˚C
Carrier Frequency	860	960	MHz	

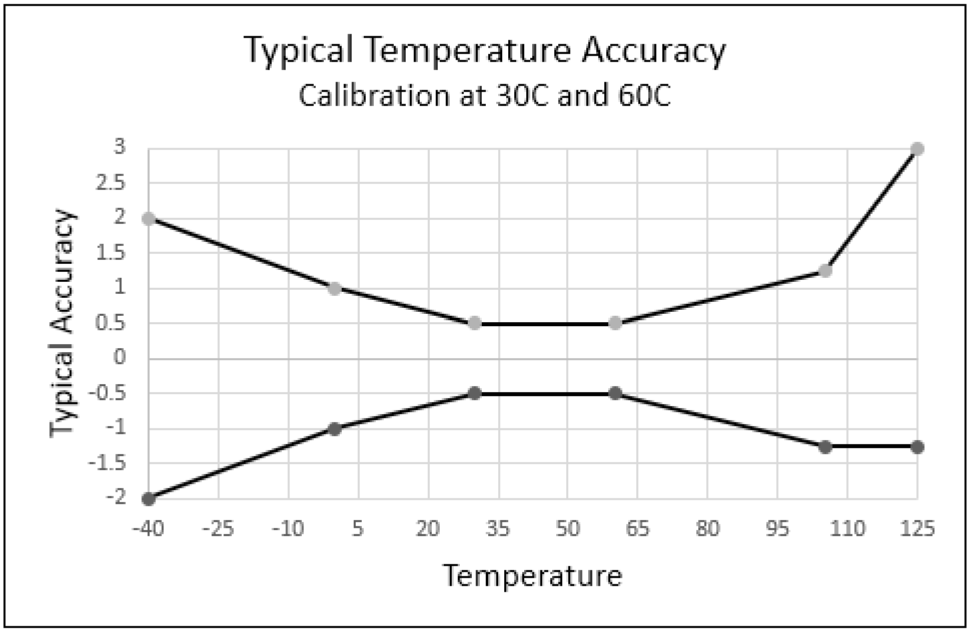
Table 3: Performance Characteristics

PARAMETER	Min	Typ	Max	Units	Notes
Read sensitivity		-16.6		dBm	1, 5
Write sensitivity		-12.3		dBm	1, 5
Data retention	10			years	2
Write and erase endurance		10,000		cycles	2
Equivalent Input resistance, Rp		2,073		ohms	3, 4, 5
Equivalent Input capacitance, Cp		1.9-2.9		pF	3, 4, 5
SENSOR CODE range	0		511		6
RSSI CODE range	0		31	codes	
Calibration temperatures		30, 60		°C	
Temperature accuracy @ 30°		±0.5		°C	7, Figure 1
Codes per °C		7.5		codes	
Compatible standards	EPC Gen2 v 2.0.1; ISO 18000-6C				
TID memory	96-bits				
EPC memory	160-bits supporting up to 128-bit EPC				
User memory	12-Words				

NOTES:

1. DSB-ASK modulation with 90% modulation depth and 25 μs Tari used for reader-to-sensor communication. Miller M=4 encoding with 256 kbps BLF used for sensor-to-reader communication. Ambient temperature: 25 °C.
2. -40 to +85 °C range for minimum Data Retention Life of 10 years.
3. Rp and Cp vary as the Chameleon self-tuning circuit adjusts to find the best overall match to the antenna.
4. At -16.6 dBm input power.
5. Values apply to both Bumped die and QFN IC Formats.
6. The SENSOR CODE will typically saturate at low and at high extremes around 5 and 490.
7. Assumes averaging 10 individual temperature code reads at Ta = 30 °C.

Figure 1: Magnus Typical Temperature Accuracy



3. The Sensor Code

Chameleon technology is a novel self-tuning mechanism that enables the sensor to remain properly tuned over a wide range of frequencies and environmental conditions. Antenna detuning can occur due to environment conditions such as moisture accumulation or proximity to metal to the sensor. The Chameleon engine compensates for these changes to improve wireless sensor read range. Further details are available in whitepaper WP001, “Chameleon Self Tuning”.

3.1. Reading the SENSOR CODE

A READ command is issued for the SENSOR CODE. The nine least significant bits in the word (bits $C7_h$-CF_h in the Reserved Memory Bank) contain the SENSOR CODE; the remaining bits in the word will be zero. Although 9 bits allows for 512 possible states, the SENSOR CODE will typically saturate at low and high extremes of around 5 and 490.

The Magnus-S3 M3D operates with optimum read range when the SENSOR CODE is in the range between 80 and 400. Read range tends to decrease slightly and gradually as the SENSOR CODE moves away from that range.

When used for sensing, the SENSOR CODE value can be monitored for changes over time or at different locations, or it can be checked for changes to a baseline reading that is taken when the sensor is first placed into service. Depending on the needs of the application, the reference or baseline value(s) may be written back into regular User Memory or they may be stored elsewhere on the user’s network.

3.2. Antenna Impedance Characteristics

To achieve optimum performance, the IC and the antenna must have impedances that “match.” In this context, matching means that the impedances are complex conjugates of each other. Achieving a good match at a single frequency for a known environment is easily achieved, but the impedance of an antenna will vary with frequency and can be significantly affected by nearby liquids or metals.

The input impedance of Magnus-S3 M3D is modeled with the parallel resistance/capacitance circuit shown in Figure 2. The range of values are listed In Table 3: Performance Characteristics. Because Chameleon technology tunes the input impedance to match the sensor antenna in the current operating environment, the components will take on a range of values. The variable input impedance enables antenna designers to achieve flat sensitivity response across a range of frequencies. Please consult the RFMicron Antenna Design Guide, AN003, for important information on impedance matching considerations.

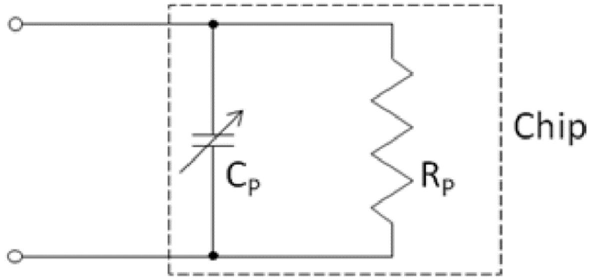


Figure 2: Equivalent input circuit Of Magnus-S3 M3D input impedance.

4. On-chip RSSI

Magnus-S3 M3D incorporates on-chip RSSI (Received Signal Strength Indicator) circuitry that measures the incoming signal strength and converts it to a digital value. The RSSI CODE can be communicated to a reader and used for control purposes.

4.1. RSSI CODE

The RSSI Code is stored in the five bits DB_h-DF_h of the word D_h in the Reserved Memory Bank. The RSSI Code will be returned as the 5 LSBs when executing a standard READ command specifying word address D_h. Magnus-S3 M3D must first receive an On-Chip RSSI Request before the On-Chip RSSI CODE becomes available. If the chip does not receive an On-Chip RSSI Request, the On-Chip RSSI value will be 0 if it is read.

4.2. RSSI Requests

On-Chip RSSI Request allows the reader to specify that it wants to hear only from sensors that receive the desired signal strength. The requested signal strength range can be set for all power levels, or it can be narrowed to request a specific signal strength. In normal use the RSSI request range is narrowed to specify so that only a limited set of sensors respond to the command.

The User Memory Bank bit address $D0_h$ is used as the Select command's Mask Pointer, and the RSSI Threshold values are encoded in the Select command's Mask field. The RSSI request is sent by the reader using a standard Gen 2 SELECT command. The 6-bits of On-Chip RSSI Threshold Value/Control are communicated as part of the Mask sent to the sensors.

Table 4 below from the Gen 2 version 2.0.1 spec shows the format of a SELECT command. To send an On-Chip RSSI Request, the reader issues a SELECT command with:

- MemBank set to 3_h (11_b)
- The On-Chip RSSI Threshold bit address ($D0_h$) in the Pointer field
- Length set to 00001000_b (the On-Chip RSSI request value consists of the lower 6 bits of an 8-bit Mask)
- The On-Chip RSSI request in the lower 6 bits of the Mask, consisting of a leading control bit followed by 5 bits for the On-Chip RSSI Code at which the reader wants to define the sensor response/no-response threshold.

If the control bit is set to 0, the SELECT will be considered matching when the RSSI CODE is less than or equal to the threshold value. If the control bit is 1, the SELECT will be considered matching when its RSSI CODE is greater than the threshold.

The RSSI value is internally generated when the Magnus-S3 M3D receives a SELECT command with the parameters described above. Whether the sensor responds for the rest of the inventory round depends on whether the SELECT matches the sensor.

Table 4: SELECT Command Specification

	Command	Target	Action	MemBank	Pointer	Length	Mask	Truncate	CRC-16
Number of bits	4	3	3	2	EBV	8	Variable	1	16
Description	1010	000: Inventoried (S0) 001: Inventoried (S1) 010: Inventoried (S2) 011: Inventoried (S3) 100: SL 101, 110, 111: RFU	See Gen 2 spec, Table 6.20	00: RFU 01: EPC 10: TID 11: User	Starting Mask Address	Mask Length (bits)	Mask value	0: Disable truncation 1: Enable truncation	

5. Temperature Sensing

Magnus-S3 M3D includes a precise temperature-sensing circuit. The circuit generates a TEMPERATURE CODE when it receives a Temperature Request. The TEMPERATURE CODE can then be retrieved using a standard UHF READ command. The TEMPERATURE CODE is a 12-bit number which can be converted into temperature reading.

5.1. Temperature Requests

The temperature-sensing circuit runs in response to a Temperature Request, which is a standard SELECT command with the parameters given below:

1. MemBank set to 3_h (11_b)
2. The Temperature Sensing Enable bit address ($E0_h$) in the Pointer field
3. Length set to 0_h
4. Mask field empty

The highest precision is achieved when the Temperature Request is followed by at least 2 ms of continuous wave output from the reader before any subsequent commands are sent to provide time to complete and store the TEMPERATURE CODE in the Reserved Memory.

5.2. Reading the Temperature Code

The TEMPERATURE CODE is a 12-bit value, stored in the least significant bits of word E_h in the Reserved Memory Bank, which can be read with a standard READ command. Higher TEMPERATURE CODE values correspond to higher temperatures. The TEMPERATURE CODE is converted to a precise temperature measurement with a linear mapping:

$$T = aC + b$$

T is the temperature in °C. ***C*** is the TEMPERATURE CODE read from Magnus-S3 M3D, and ***a*** and ***b*** are constants, which are custom to each chip. More details on temperature calibration are available in the RFMicron document AN002, “Reading Magnus-S Sensors”.

5.3. Temperature Calibration Data

Magnus-S3 M3D chips come with temperature calibration data stored in the User Memory Bank in addresses 8_h through B_h. This data is generated from a single-point calibration conducted on each chip during manufacturing. If greater precision and/or accuracy is desired, the user can recalibrate the chip.
If the temperature sensor will not be used, this data can be safely overwritten. See RFMicron document AN002, “Reading Magnus-S Sensors” for more information.

6. Magnus-S3 M3D Memory Map

The Magnus-S3 M3D memory map is shown in Table 6, where in addition to the usual Reserved, EPC, Tag Identification (TID) and User Memory Banks, the RSSI CODE, and the TEMPERATURE CODE are shown.

6.1. EPC Memory and Control

As required by the Gen-2 specification, EPC memory contains a 16-bit cyclic-redundancy check word (StoredCRC) at memory addresses 00_h to $0F_h$, the 16 protocol-control bits (StoredPC) at memory addresses 10_h to $1F_h$, and an EPC value beginning at address 20_h.

The protocol control fields include a 5-bit EPC length, a 1-bit user-memory indicator (UMI), a 1-bit extended protocol control indicator, and a 9-bit numbering system identifier (NSI).

On power-up, the IC calculates the StoredCRC over the stored PC bits and the EPC specified by the EPC length field in the StoredPC. For more details about the StoredPC field or the StoredCRC, see the Gen 2 specification.

The StoredCRC, StoredPC, and EPC are stored MSB first (i.e. the EPC's MSB is stored in location 20_h).

6.2. Tag Identification (TID) Memory

The read-only TID memory contains the RFMicron-specific data detailed in Table 5. The RFMicron Mask Designer ID (MDID) is 824_h (bits 08_h to 13_h). The logic 1 in the most significant bit of the MDID, highlighted with a solid black border, indicates the presence of an extended TID consisting of a 16-bit header and a 48-bit serialization. The Magnus-S3 M3D model number is in bits 14_h to $1F_h$, highlighted by the dashed line. The shaded bit locations in TID row 00_h-$0F_h$ store the EPCglobal™ Class ID ($E2_h$).

6.3. Kill Password

The Kill Password is a 32-bit value stored in Reserve Memory 00_h to $1F_h$, MSB first. The default value is all zeroes. A reader can use a sensor kill password once to kill the sensor and render it silent after that. A sensor will not execute a kill operation if its Kill Password is all zeroes.

Table 5: Tag Identification (TID) Bit Mapping)

Memory Bank #	Bit Address	Bit number															
	50-$5F_h$	TID serial number [15:0]															
	40-$4F_h$	TID serial number [31:16]															
	30-$3F_h$	TID serial number [47:32]															
10	20-$2F_h$	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
	10-$1F_h$	0	1	0	0	x	x	x	x	x	x	x	x	x	x	x	x
	00-$0F_h$	1	1	1	0	0	0	1	0	1	0	0	0	0	0	1	0

Table 6: Memory Map

Memory Bank	Bank Name	R/W	Bit Address	Description LSB MSB	Default	Comments
11	USER	READ ONLY	E0-EF	Temperature Sensing Enable	N/A	See Sec. 5.1
			D0-DF	RSSI Threshold	N/A	See Sec. 4.2
		READ/WRITE	B0-BF	Temperature Calibration Data	N/A	See Sec. 5.3
			A0-AF	Temperature Calibration Data	N/A	
			90-9F	Temperature Calibration Data	N/A	
			80-8F	Temperature Calibration Data	N/A	
			70-7F		0	
			60-6F		0	
			50-5F		0	
			40-4F		0	
			30-3F		0	
			20-2F		0	
			10-1F		0	
			00-0F		0	
10	TID	READ ONLY	50-5F	TID[15:0]		See Sec. 6.2
			40-4F	TID[31:16]		
			30-3F	TID[47:32]		
			20-2F	Extended TID Header		
			10-1F	Tag Model Number		
			00-0F	Manufacturer ID		
01	EPC	READ/WRITE	90-9F	EPC#[15:0]	0	See Sec. 6.1
			80-8F	EPC#[31:16]	0	
			70-7F	EPC#[47:32]	0	
			60-6F	EPC#[63:48]	0	
			50-5F	EPC#[79:64]	0	
			40-4F	EPC#[95:80]	0	
			30-3F	EPC#[111:96]	0	
			20-2F	EPC#[127:112]	0	
			10-1F	StoredPC[15:0]	0	
			00-0F	StoredCRC[15:0]	0	

00	RESERVED	READ ONLY	E0-EF	TEMPERATURE CODE	N/A	See Sec. 5.2
			D0-DF	RSSI CODE	N/A	See Sec. 4.1
			C0-CF	SENSOR CODE	0	See Sec. 3.1
		READ/WRITE	30-3F	Reserved for future use	0	
			10-1F	KILL Password[15:0]	0	See Sec. 6.3
			00-0F	KILL Password[31:16]	0	

AXZON

7. Physical Dimensions

7.1. Die Dimensions

Table 7: Die Dimensions

Parameter	Dimension
Die Size	910 µm x 760 µm
Signal Bump Size	66 µm x 66 µm
Minimum Bump Spacing	344 µm
Scribe line width dimensions	X dimension: 86 µm; Y dimension: 80 µm

7.2. Pad Descriptions

Die Pictures are shown in Figure 3. Bumped die pad locations are shown in Figure 4. QFN dimensions are shown in Figure 5. Pad descriptions are provided in Table 8.

Table 8: Pad Descriptions

Pad	Description
RFN	Antenna connection
RFP	Antenna connection
NC	Not connected – pads are for mechanical support and planarity. NC pads should be shorted together but otherwise electrically isolated.

Figure 3: Die Pictures

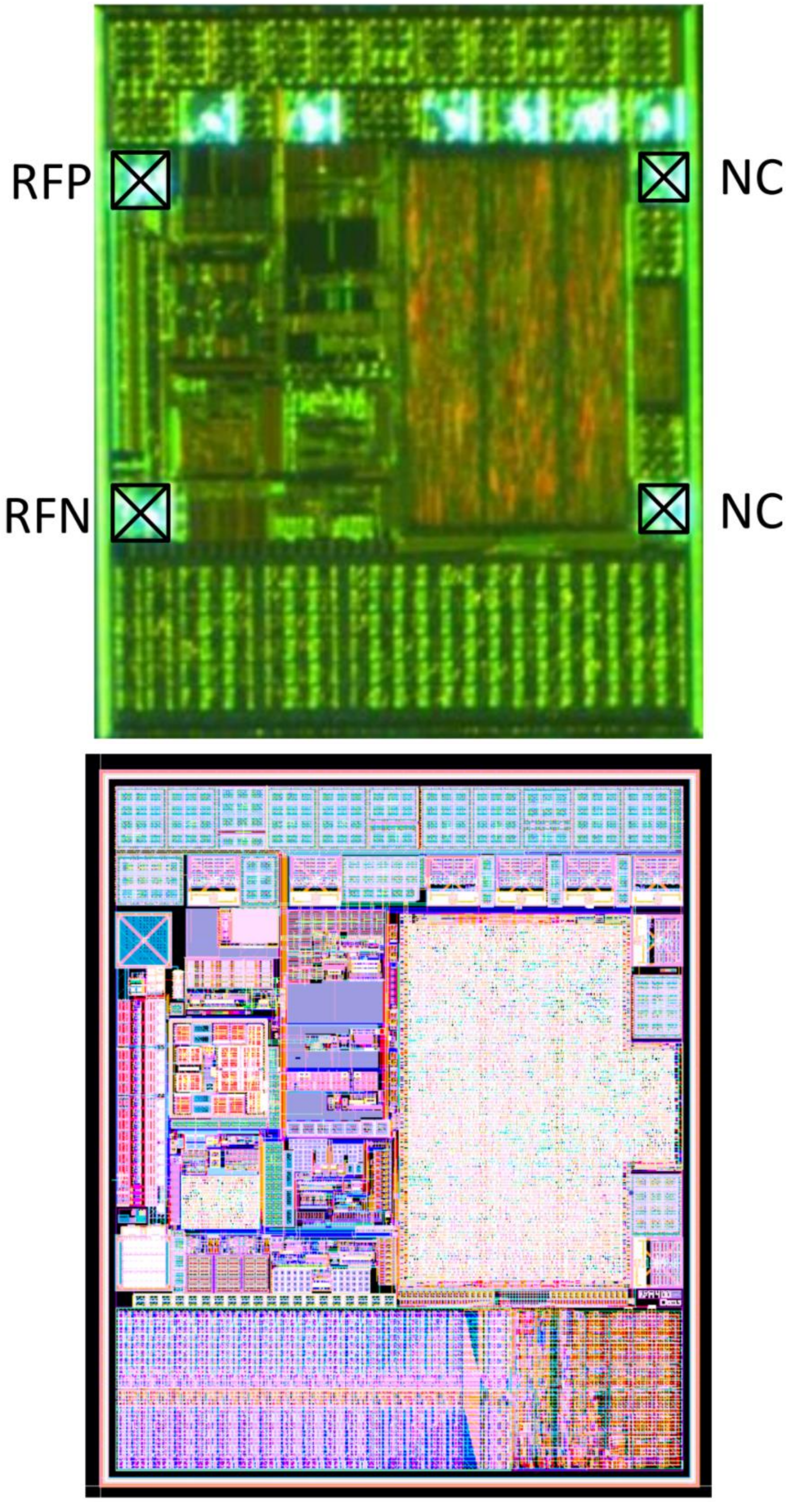
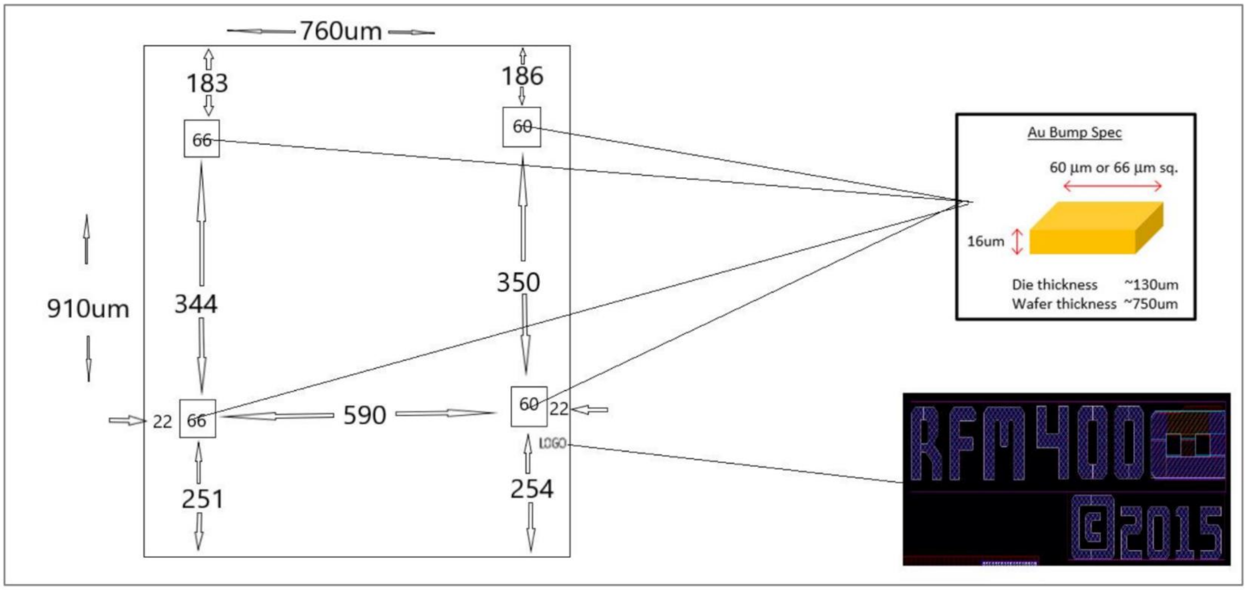


Figure 4: M3D Bumped Pad and Logo Information

The Bumped Pad is square in shape with either 60 or 66 µm on the side.

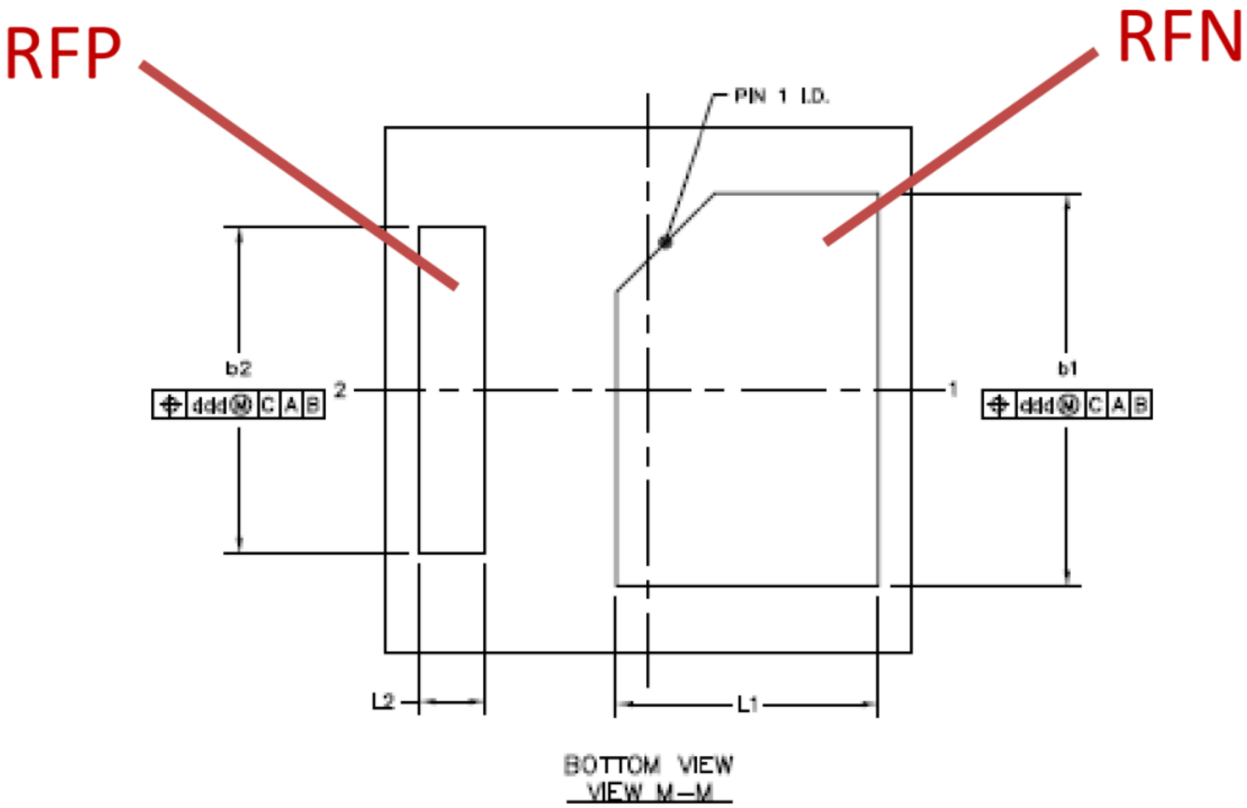
(all dimensions in microns; All dimensions are not to scale)



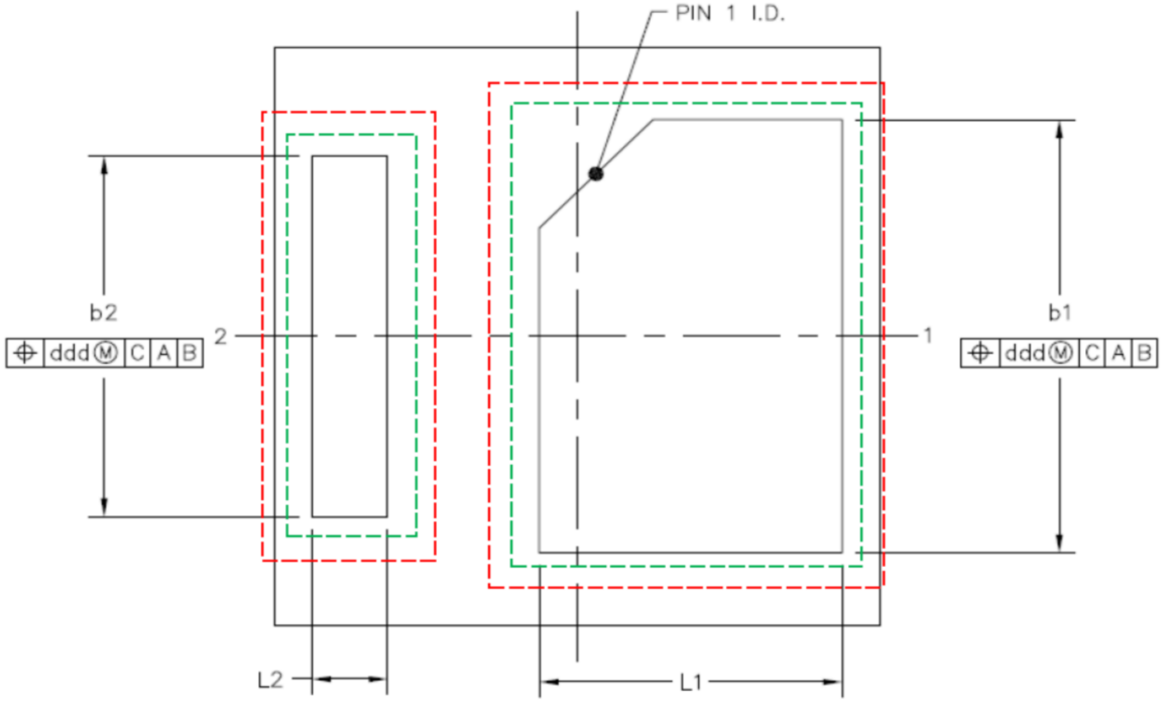
7.3. Magnus-S3 M3D QFN Package Dimensions

Figure 5: Magnus-S3 M3D QFN Dimensions

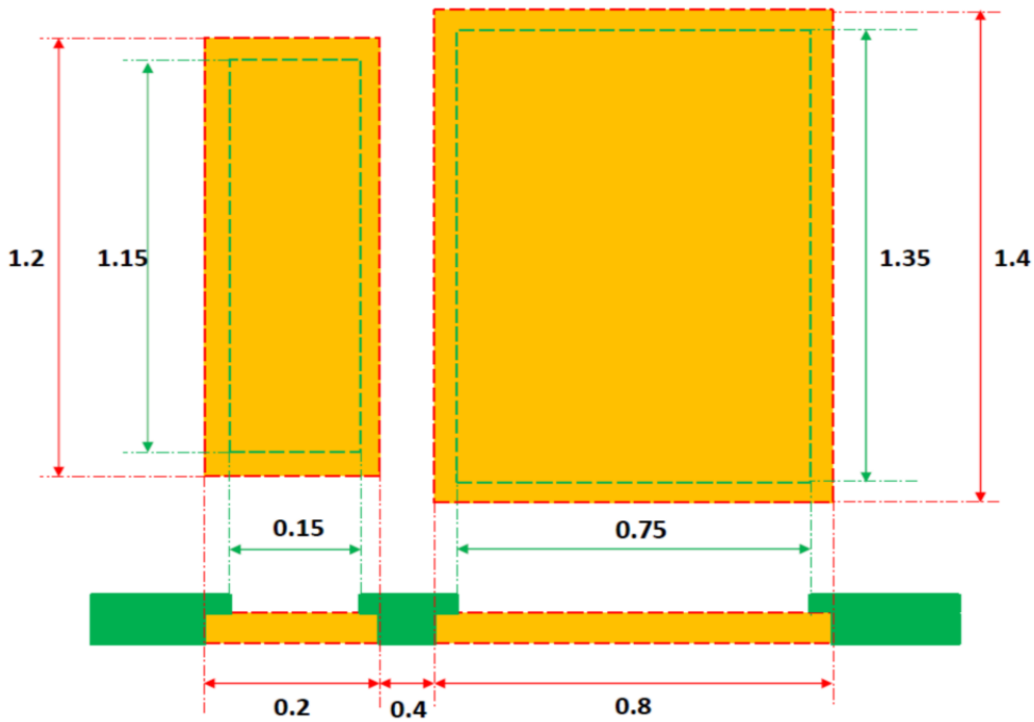
(all dimensions in millimeters)



		SYMBOL	MIN	NOM	MAX
TOTAL THICKNESS		A		0.75	
STAND OFF		A1	0	0.035	0.05
MOLD THICKNESS		A2	---	0.23	---
L/F THICKNESS		A3	0.127 REF		
LEAD WIDTH		b1	1.15	1.2	1.25
LEAD WIDTH		b2	0.95	1	1.05
BODY SIZE	X	D	1.6 BSC		
	Y	E	1.6 BSC		
LEAD LENGTH		L1	0.75	0.8	0.85
LEAD LENGTH		L2	0.15	0.2	0.25
PACKAGE EDGE TOLERANCE		aaa	0.1		
MOLD FLATNESS		bbb	0.1		
COPLANARITY		ccc	0.08		
LEAD OFFSET		ddd	0.1		



ALL DIMENSIONS IN mm



Basic Rules

- Use 25 micron solder mask overlap of the pad

1. Width same as pad.
2. Length 200 microns longer than pad.
3. 25 micron soldermask overlap

8. References

[1] EPCglobal, "EPC™ Radio-Frequency Identity Protocols Generation-2 RAIN/UHF, Version 2.0.1", (November 2013).

9. Revision History

1.0	Initial release
1.1	Labeled the pins in Figure 5: Magnus-S3 M3D QFN Dimensions
1.2	Added Temperature plot. Instruction for NC pads.
1.3	Updated QFN thickness information and Minor proof editing.
1.4	Updated Logo and Formatting

10. Ordering Information

All variants include RSSI CODE support. Additional sensing functions, as well as packaging format, are indicated by the part number as shown below.

AZN305-DG	100 Bumped die in GelPak
AZN305-DW	Finished (Bumped, thinned to 130um, Sawn) Tested Wafer (8 inch)
AZN305-DQT	2-contact 1.6 x 1.6 mm QFN Package in Tape and Reel

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Datasheet DS003F12: Datasheet: AZN305-DX Magnus-S3 M3D Passive Sensor IC, Dec 2018. Patent www.Axzon.com/patents

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