

# SPS1M002

## Smart Passive Sensor™ for Direct Moisture Sensing

The SPS1M002 is a battery-free wireless sensor for moisture level detection on non-metal surfaces. Smart Passive Sensors use the Magnus-S2® Sensor IC from RF Micron, a UHF RFID chip that is powered by RF energy harvesting from the UHF reader. The Magnus-S2 utilizes the patented self-tuning Chameleon engine that adapts the RF front-end to optimize performance in various environmental conditions. Changes in antenna detuning due to moisture contact are digitized by the sensor which can then be read by a standard EPC Gen 2 compliant reader. These sensor tags function in either the FCC defined UHF band or the ETSI UHF band

The small form factor and battery-free capabilities of Smart Passive Sensors allow them to be designed into applications where size and accessibility are at a premium.

### Features

- Single IC, Smart Passive Sensing
- Small Form Factor Packages
- Direct Moisture Contact Sensing
- On-chip RSSI Sensor
- 64 bit TID and 128 bit EPC + 144 bit User Defined Memory
- EPC Class 1 Gen 2 v.2.0.0 ISO 18 000-6C Compliant
- These Devices are Pb-Free, Halogen Free/BFR Free and are RoHS Compliant

### Applications

- Medical
- Industrial
- Facilities Management

### MAXIMUM RATINGS (T<sub>A</sub> = 25°C unless otherwise noted)

| Rating                    | Symbol | Max | Unit |
|---------------------------|--------|-----|------|
| Human Body Model (Note 1) | ESD    | ±1  | kV   |

### THERMAL CHARACTERISTICS

| Characteristic                                  | Symbol                            | Max        | Unit |
|---|-----------------------------------|------------|------|
| Junction and Storage Temperature Range (Note 2) | T <sub>J</sub> , T <sub>stg</sub> | -40 to +85 | °C   |

Stresses exceeding those listed in the Maximum Ratings table may damage the device. If any of these limits are exceeded, device functionality should not be assumed, damage may occur and reliability may be affected.

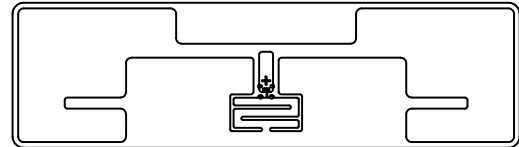
1. Non-repetitive current pulse at T<sub>A</sub> = 25°C, per JS-001 waveform.
2. Shelf Life – minimum 2 years from date of manufacturing.

This document contains information on some products that are still under development. ON Semiconductor reserves the right to change or discontinue these products without notice.



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RF TAG 101.60X31.75 MM  
CASE 888AD/AE

### ORDERING INFORMATION

See detailed ordering and shipping information on page 3 of this data sheet.

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## ELECTRICAL CHARACTERISTICS (T<sub>A</sub> = 25°C unless otherwise noted)

| Parameter                    |      | Min | Max | Units |
|------------------------------|------|-----|-----|-------|
| Operating Frequency (Note 3) | FCC  | 902 | 928 | MHz   |
|                              | ETSI | 866 | 868 | MHz   |
| Read Sensitivity (Note 4)    |      | -16 |     | dBm   |
| Sensor Code                  |      | 5   |     | bits  |
| RSSI Code                    |      | 5   |     | bits  |
| TID                          |      | 64  |     | bits  |
| EPC (Note 5)                 |      | 128 |     | bits  |
| User Memory (Note 5)         |      | 144 |     | bits  |

- Sensors with "A" suffix operate in the FCC defined band and sensors with "B" suffix operate in ETSI band
- Measured in free space, anechoic chamber with a linearly polarized antenna at 50 cm read distance
- User Memory can be configured to be an EPC extension, effectively making a 272 bit EPC code

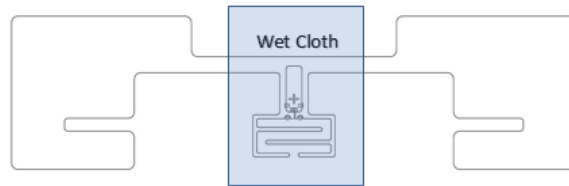


Figure 1. Moisture Contact Test Area

## Moisture Sensing

The SPS1M002 generates sensor codes from 0 to 31, with a free space sensor code average of 18. Figure 1 shows the moisture sensitive portion of the tag used to collect the data in Figure 2. The SPS1M002 with a damp cloth over the sensor yields a sensor value 5 codes lower than the dry test. Due to the Smart Passive Sensors' self-tuning capability, the sensor code does shift over frequency as it tunes itself to maximize reflected power to the reader. This makes it

important to account for the frequency at which the sensor was read. For both the wet and dry tests seen in Figure 1, the resulting sensor values shifted around 5 codes over the FCC frequency range of 902–928 MHz. This factor must be accounted for in the reader software in order to ensure reliable wet vs. dry reads. For more information on how Smart Passive Sensors generate sensor codes, please refer to Application Note AND9209/D.

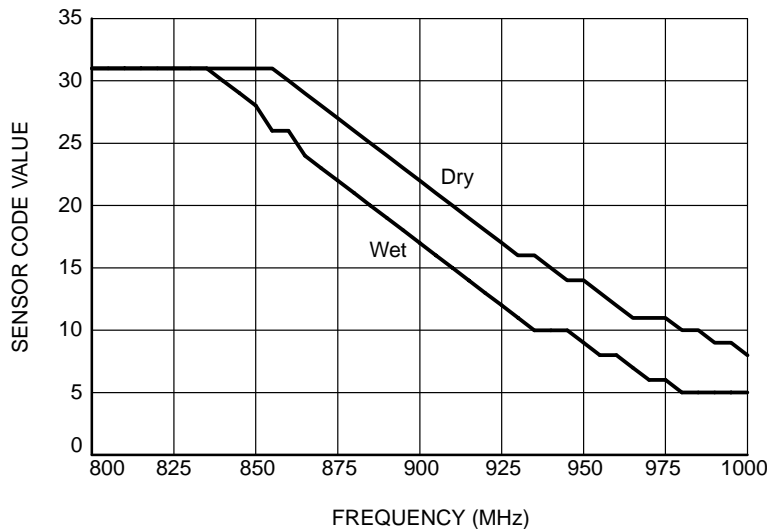


Figure 2. Sensor Code for Wet and Dry Conditions

# SPS1M002

## MEMORY MAP

| Bank #    | Bank Name   | R/W             | Bit Address    | Description LSB MSB    | Default Value |
|-----------|-------------|-----------------|----------------|------------------------|---------------|
| 11        | USER        | N/A             | A0–AF          | On–chip RSSI Threshold | N/A           |
|           |             | READ/WRITE      | 80–8F          | User Memory            | 0             |
|           |             |                 | 70–7F          | User Memory            | 0             |
|           |             |                 | 60–6F          | User Memory            | 0             |
|           |             |                 | 50–5F          | User Memory            | 0             |
|           |             |                 | 40–4F          | User Memory            | 0             |
|           |             |                 | 30–3F          | User Memory            | 0             |
|           |             |                 | 20–2F          | User Memory            | 0             |
|           |             |                 | 10–1F          | User Memory            | 0             |
| 00–0F     | User Memory | 0               |                |                        |               |
| 10        | TID         | READ ONLY       | 50–5F          | TID[15:0]              |               |
|           |             |                 | 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         | WRITE ONLY      | 140–14F        | EPC Configure          | 0             |
|           |             | READ/WRITE      | 90–9F          | EPC#[15:0]             | 0             |
|           |             |                 | 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                      |               |
| READ ONLY | 00–0F       | StoredCRC[15:0] | 0              |                        |               |
| 00        | RESERVED    | READ/WRITE      | F0–FF          | Sensor Overwrite       | 0             |
|           |             | READ ONLY       | D0–DF          | On–chip RSSI Code      | N/A           |
|           |             |                 | B0–BF          | Sensor Code            | N/A           |
|           |             | READ/WRITE      | 50–5F          | Analog Overwrite       | 0             |
|           |             |                 | 30–3F          | Access Password[15:0]  | 0             |
|           |             |                 | 20–2F          | Access Password[31:16] | 0             |
|           |             |                 | 10–1F          | Kill Password[15:0]    | 0             |
|           |             |                 | 00–0F          | Kill Password[31:16]   | 0             |

## ORDERING INFORMATION

| Device    | Feature  | UHF Band            | Attach Material | Package Case Code | Shipping <sup>†</sup> |
|-----------|----------|---------------------|-----------------|-------------------|-----------------------|
| SPS1M002A | Moisture | FCC<br>902–928 MHz  | Non–metal       | 888AD             | 500 / Reel            |
| SPS1M002B | Moisture | ETSI<br>866–868 MHz | Non–metal       | 888AE             | 500 / Reel            |

<sup>†</sup>For information on tape and reel specifications, including part orientation and tape sizes, please refer to our Tape and Reel Packaging Specifications Brochure, BRD8011/D.

## Tag Memory

### Memory Configuration

Memory is organized according to the EPCglobal Generation-2 UHF RFID specification. There are two possible configurations for the EPC ID:

- 8-word EPC code and 9 free words in the USER memory bank, as shown in the Memory Map
- 17-word EPC code and no free USER memory (EPC lengths above 11 words may not be supported on all readers.)

The 8-word configuration is the default. To change to the 17-word configuration, write 0001<sub>h</sub> to the EPC Bank, word address 14<sub>h</sub>. The memory can be reset to the default 8-word EPC configuration by writing 0000<sub>h</sub> to the same location. This EPC configuration can be configured and reconfigured repeatedly as long as the EPC memory bank is not permanently locked by a LOCK command. Once the EPC memory bank is permanently locked, it cannot be reconfigured.

### Reserved Memory – Passwords

Reserved Memory contains the ACCESS and KILL passwords. There is a 32-bit Access Password and a 32-bit Kill Password. The default for both Kill and Access Passwords is 0000<sub>h</sub>.

### Access Password

The Access Password is a 32-bit value stored in Reserved Memory 20<sub>h</sub> to 3F<sub>h</sub> MSB first. The default value is all zeroes. Tags with a non-zero Access Password will require a reader to issue this password before transitioning to the secured state.

### Kill Password

The Kill Password is a 32-bit value stored in Reserve Memory 00<sub>h</sub> to 1F<sub>h</sub>, MSB first. The default value is all zeroes. A reader shall use a tag's kill password once to kill the tag and render it silent thereafter. A tag will not execute a kill operation if its Kill Password is all zeroes.

### EPC Memory – EPC data, Protocol Control Bits, and CRC16

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

The protocol control fields include a five-bit EPC length, a one-bit user-memory indicator (UMI), a one-bit extended protocol control indicator, and a nine-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, please 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<sub>h</sub>).

### Tag Identification (TID) Memory

The read-only Tag Identification memory contains the manufacturer-specific data. The manufacturer Mask Designer ID (MDID) is 824<sub>h</sub> (bits 08<sub>h</sub> to 13<sub>h</sub>). The logic 1 in the most significant bit of the MDID indicates the presence of an extended TID consisting of a 16-bit header and a 48-bit serialization. The Magnus 2 S model number is in bits 14<sub>h</sub> to 1F<sub>h</sub> and the EPCglobal Class ID (E2<sub>h</sub>) is in 00<sub>h</sub> to 07<sub>h</sub>.

## Sensor Functions

### Accessing the Sensor Code

The Magnus-S2 Chameleon engine stores tuning information in a user-accessible memory register. The “Sensor Code” register (B0<sub>h</sub>–BF<sub>h</sub> in the Reserved memory bank) contains the current setting and controls the tuning capacitors that are used to adjust the input impedance.

To get the results of the self-tuning operation, a READ command may be issued for the Sensor Code (B0<sub>h</sub>–BF<sub>h</sub> in the Reserved memory bank). Because the tuning network offers 32 different levels of impedance, only the 5 least significant bits (BB<sub>h</sub>–BF<sub>h</sub>) in the register are actually implemented and used. (The 32 levels represent increasing amounts of capacitance added to the input impedance, with the lowest capacitance applied at level 0.) Returned results will be in the form 0000 0000 000x xxxx, where the 5 LSBs define the current tuning.

For use in sensing applications, the Sensor Code register 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 tag is 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 may be stored elsewhere on the user’s network.

The SPS1M002 may require more than its minimum sensitivity power in order to sense values near the ends of the code range (0–5 and 27–31). The minimum required power tends to increase gradually as the Sensor Code moves from 5 to 0 or from 27 to 31.

### Overriding Default Chameleon® Behavior

By default, the Chameleon engine will self-tune when Magnus-S2 powers up, and the tuning capacitance chosen will be held constant until the chip powers down. There are also two additional modes: Chameleon can tune continuously – not just at power up – and Chameleon can be forced to a user-chosen setting.

To cause Chameleon to adjust continuously while Magnus-S2 is powered up, write 0800<sub>h</sub> to the Analog Overwrite word (address 50<sub>h</sub>–5F<sub>h</sub> in the Reserved Bank) using a standard WRITE command.

To force Chameleon to a desired setting, write 4000<sub>h</sub> to the Analog Overwrite word, and the tuning value to the Sensor Overwrite word (address F0<sub>h</sub>–FF<sub>h</sub> in the Reserved Bank) with standard WRITE commands. The tuning value format is 0000 0000 000x xxxx, where x\_xxxx represents the desired 5-bit tuning. When the above sequence is executed correctly, the setting x\_xxxx will be transferred into the Sensor Code register and will be held constant until the next power-up or until the user writes a different value into the Sensor Overwrite word.

The Analog Overwrite word is non-volatile: values written will persist through chip power cycles. The Sensor

Overwrite word is volatile: if a fixed Chameleon setting is desired, it must be re-written every time Magnus-S2 is powered up.

### On-Chip RSSI Code

Magnus-S2 incorporates circuitry that measures incoming signal strength and converts it to a digital value: the On-Chip RSSI (Received Signal Strength Indicator) Code. This can be communicated to a reader and used for control purposes. The On-Chip RSSI Code has a 32-level range, represented by a 5-bit number.

The On-Chip RSSI Code, in word D0<sub>h</sub>–DF<sub>h</sub> in the Reserved Bank, will be returned as the 5 LSBs of a response to a standard READ command specifying word address D<sub>h</sub>. Magnus-S2 must first receive an On-Chip RSSI Request before the On-Chip RSSI Code becomes available.

### On-Chip RSSI Requests

On-Chip RSSI Request is a tool for a reader to specify that it wants to hear only from tags that are seeing a desired amount of received signal strength. It allows a reader to limit its communications only to nearby tags – or conversely, to “mute” nearby tags in order to attempt communication with tags receiving weak signals.

The On-Chip RSSI Threshold “address” (A0<sub>h</sub> of the User Bank) is used only by Magnus-S2 to interpret a SELECT command and is not an actual memory location. It 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 tags.

Table 4 below from the Gen 2 version 2.0.0 spec shows the format of a SELECT command. To send an On-Chip RSSI Request, the reader issues a SELECT command with:

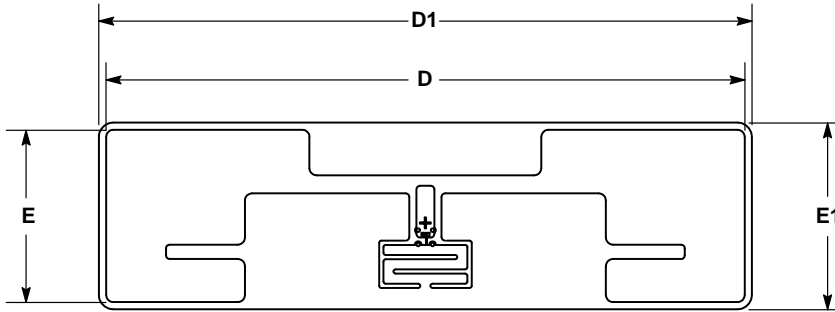
- MemBank set to 3<sub>h</sub> (11<sub>b</sub>)
- The On-Chip RSSI Threshold address (A0<sub>h</sub>) in the Pointer field
- Length set to 00001000<sub>b</sub> (the On-Chip RSSI request value consists of the lower 6 bits of an 8-bit Mask)
- The On-Chip RSSI request in the lower 6 bits of the Mask, consisting of a leading bit for control followed by 5 bits for the On-Chip RSSI Code at which the reader wants to define the tags’ response/no-response threshold.

The control bit determines whether the threshold value is interpreted by Magnus-S2 as a lower or upper threshold. Specifically, if the control bit is set to 0, it will respond if its internally generated On-Chip RSSI Code is less than or equal to the threshold value. If the control bit is 1, it will respond if its On-Chip RSSI Code is greater than the threshold.

# SPS1M002

## PACKAGE DIMENSIONS

RF TAG 91.5x26.5mm  
CASE 888AD  
ISSUE O



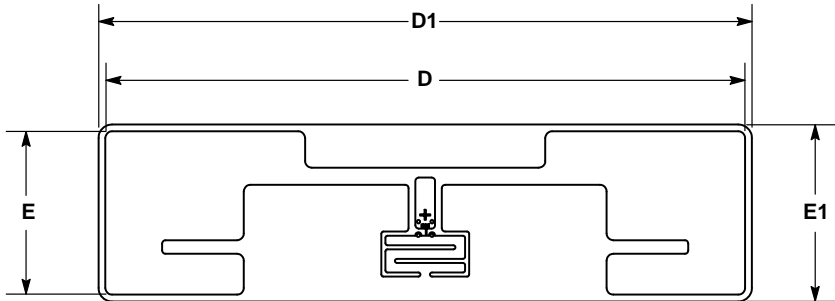
TOP VIEW

NOTES:

1. DIMENSIONING AND TOLERANCING PER ASME Y14.5M, 1994.
2. CONTROLLING DIMENSION: MILLIMETERS.
3. ANTENNA SIZE DETERMINED BY DIMENSIONS D AND E.
4. LABEL SIZE DETERMINED BY DIMENSIONS D1 AND E1.
5. LABEL IS 0.076 THICK PET TAPE. ANTENNA IS 0.009 THICK ALUMINUM.

| DIM | MILLIMETERS |       |
|-----|-------------|-------|
|     | MIN         | MAX   |
| D   | 88.90       | 89.10 |
| E   | 23.90       | 24.10 |
| D1  | 90.50       | 91.50 |
| E1  | 25.50       | 26.50 |

RF TAG 101.60x31.75MM  
CASE 888AE  
ISSUE A




TOP VIEW

NOTES:

1. DIMENSIONING AND TOLERANCING PER ASME Y14.5M, 1994.
2. CONTROLLING DIMENSION: MILLIMETERS.
3. ANTENNA SIZE DETERMINED BY DIMENSIONS D AND E.
4. LABEL SIZE DETERMINED BY DIMENSIONS D1 AND E1.
5. LABEL IS 0.076 THICK PET TAPE. ANTENNA IS 0.009 THICK ALUMINUM.

| DIM | MILLIMETERS |        |        |
|-----|-------------|--------|--------|
|     | MIN         | NOM    | MAX    |
| D   | 93.90       | 94.00  | 94.10  |
| E   | 23.90       | 24.00  | 24.10  |
| D1  | 101.10      | 101.60 | 102.10 |
| E1  | 31.25       | 31.75  | 32.25  |

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