RAIN RFID TRANSPONDER IC WITH CAPACITIVE SENSOR INTERFACE

DESCRIPTION

em|aura-sense is a member of the latest generation family of EM Microelectronic RAIN RFID™ devices. The chip combines capacitive sensing and RAIN RFID technology used for long range application purposes.

Target applications and market segments include smart manufacturing and industry 4.0 applications, predictive maintenance, Internet of Things (IoT), industrial sensing, and home automation.

The chip is compliant with ISO/IEC 18000-63 and EPC™ Gen2v2.

The em|aura-sense device allows to interface and capture sensing data with external sensor(s). Sensor commands are available to request sensing acquisition and store in the memory.

The capacitive sensor is external to the chip and can either be integrated in the inlay or as a separately mounted component, e.g. as an SMD component.

The em|aura-sense device is capable of supplying energy and/or driving external component.

em|aura-sense offers a versatile non-volatile memory which is accessible via the RAIN RFID air interface and can be used for storing sensing information. Each IC is manufactured with a 96-bit unique Tag Identifier (TID) and delivered with a default 96-bit EPC encoded value that is a copy of the 96-bit TID.

RAIN RFID is a trademark of the RAIN RFID Alliance.

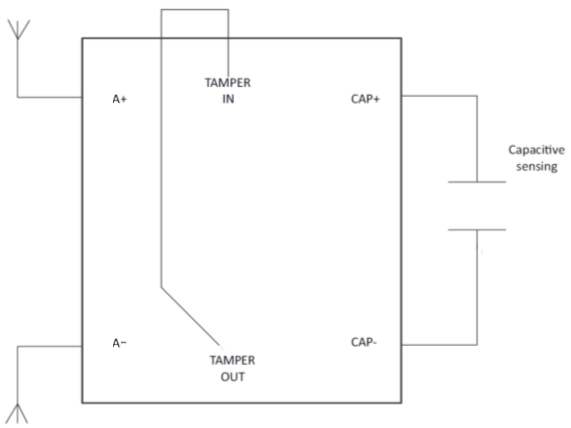
EPC is a trademark of EPCglobal Inc.

FEATURES

- Advanced RAIN RFID technology
- Sensing sensitivity: -18dBm with dipole antenna
- Read sensitivity with sensing disabled: -20dBm with dipole antenna
- Sensing and data storing: -15.5dBm with dipole antenna
- Capacitance sensing effective range: 17pF
- 7-bit analog to digital conversion of inlay sensing capacitance
- Sensitivity:160fF/LSB, noiseRMS: 125fF
- Sensing at boot and reporting with standard commands
- On demand sensing using *Select* or *Write/BlockWrite* command
- External supply power capability: 420uW
- User Memory up to 2kbit memory
- Compatible with sensor + 1-step inlay manufacturing caps/resistive sensor
- Minimum 10 years data retention
- Extended temperature range: -40 to +85C
- Available in DFN package or bumped wafers

APPLICATIONS

- Smart manufacturing and industry 4.0 applications
- predictive maintenance in industrial and aerospace settings
- IoT, industrial sensing, and home automation



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1. PRODUCT DESCRIPTION

em|aura-sense is used in passive UHF applications operating at 860MHz-960MHz. It is powered by the RF energy transmitted by the UHF reader, which is received and rectified to generate a supply voltage for the IC.

This device is compliant with the following UHF standards:

- "ISO/IEC 18000-63:2015 Information technology – Radio frequency identification for item management – Part 63: Parameters for air interface communications at 860 MHz to 960 MHz Type C", Publication Date: 2015-10
- "EPC^{TM} Radio-Frequency Identity Protocols, Generation-2 UHF RFID, Specification for RFID Air Interface Protocol for Communications at 860 MHz - 960 MHz, Release 2.1, Ratified, Jul 2018" from GS1 EPCglobal Inc.

In addition to the preceding standards, the device is able to handle sensor acquisitions, triggered by standard commands. These sensing operating modes are described in the following section 2. This product includes the vendor defined snapshot sensor in accordance with the pending revision of ISO/IEC 18000-63.

2. TYPICAL APPLICATION

em|aura-sense is designed to handle 5 typical applications. Any other combinations are not guaranteed. The typical application diagrams are described in the sections below.

2.1. CAPACITIVE SENSING TYPICAL APPLICATION

The typical application for is to connect a sensing capacitor CSENSE to the CAP+/CAP- pads and A+/A- to the antenna see Figure 1 and Figure 5. In this application, the capacitance value of CSENSE is dependent on the physical parameter intended to be measured. The operational modes are described in section 5.1.

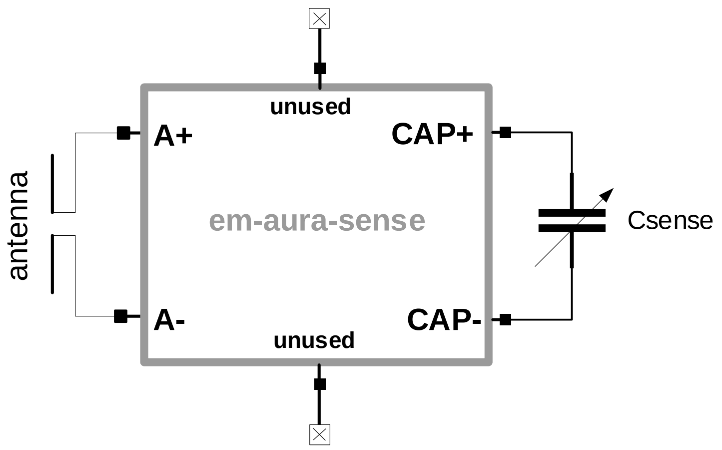

Figure 1 Example of application capacitive sensing without tamper loop

2.2. TAMPER LOOP TYPICAL APPLICATION

Tamper loop can be configured and used with the following application diagram below. The operational modes are described in section 5.2.

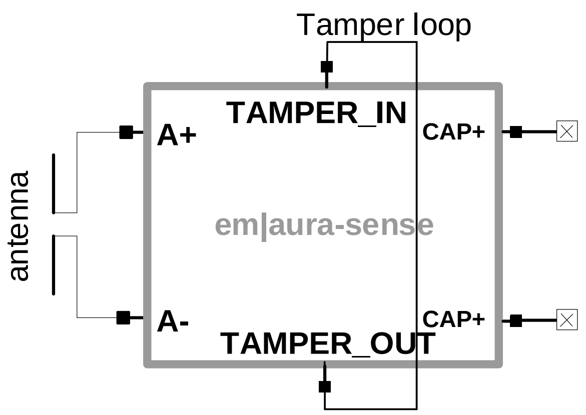

Figure 2 Example of application with tamper loop only

2.3. EXTERNAL DEVICE SUPPLY&SWITCH TYPICAL APPLICATION

em|aura-sense has the capability to supply and provide energy to an external device through the pins SWITCH1 and SWITCH2 as shown in the diagram below. The operational modes are described in section 5.3.

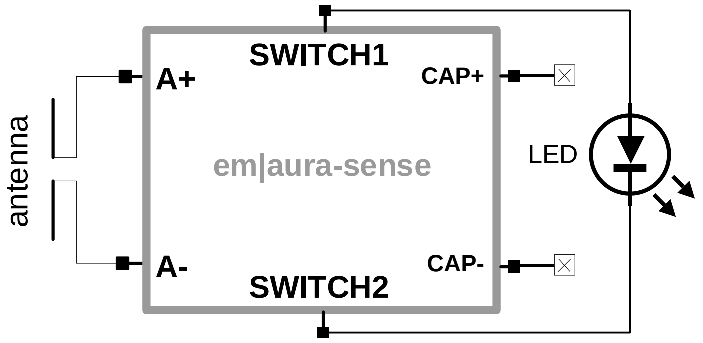

Figure 3 Example of application with external LED diode supplied through SWITCH1/SWITCH2

An external device can also be connected through the 2 pins SWITCH1 and SWITCH2. Each pin can be driven to a low, a high potential or be kept floating. The operational modes are described in section 5.3.

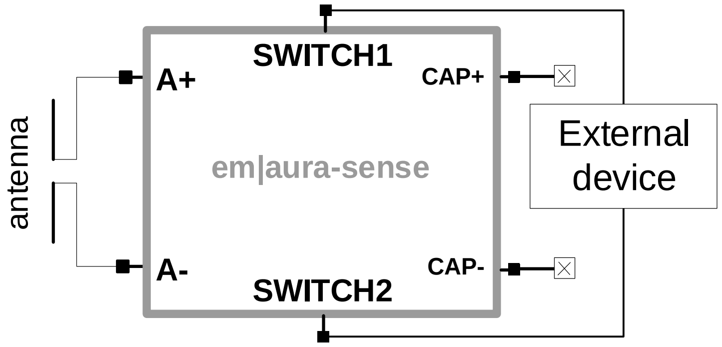

Figure 4 Example of application with external device supplied through SWITCH1/SWITCH2

2.1. COMBINATION OF TAMPER AND SENSING FUNCTIONS

The tamper function and the sensing capability can be combined in one application diagram as shown in the figure below.

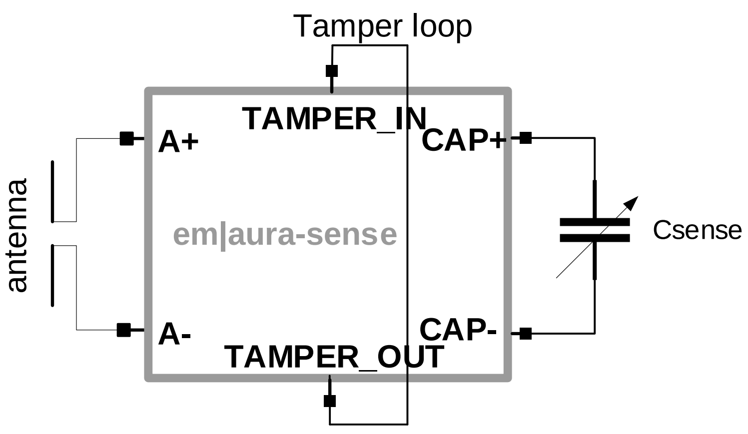

Figure 5 Example of application capacitive sensing with tamper loop

3. BLOCK DIAGRAM

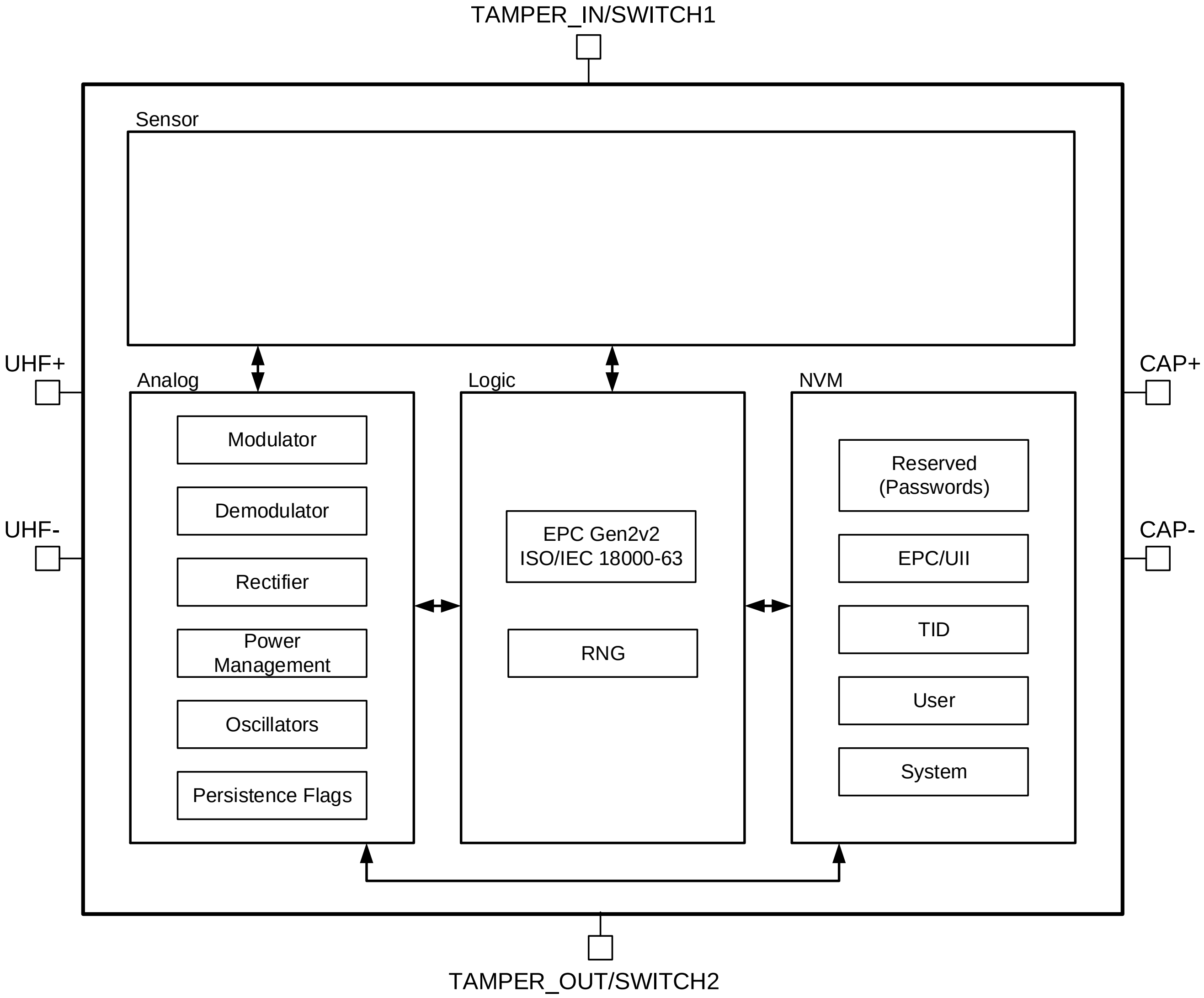

Figure 6 em|aura-sense Block Diagram

4. ELECTRICAL SPECIFICATIONS

4.1. ABSOLUTE MAXIMUM RATINGS

PARAMETER	VALUE		UNIT
	MIN	MAX	
RF power at antenna attached to A+, A- 1)		25	dBm
Storage Temperature Range (T_{STG})	-50	125	°C
Electrostatic discharge to ANSI/ESDA/JEDEC JS-001 for HBM 2)	-2000	2000	V

Note 1: Antenna matched to IC impedance at read sensitivity (P_{READ})

Note 2: Human Body Model (HBM; 100pF; 1.5kOhm) for all combinations between pads/pins. ESD measurements are made with die mounted into CDIP packages

Table 1 Absolute maximum ratings

Stresses above these listed maximum ratings may cause permanent damages to the device. Exposure beyond specified operating conditions may affect device reliability or cause malfunction.

WARNING: The device is not functional when exposed to light, it is mandatory to protect the device from light during the assembly process or in the use case.

4.2. OPERATING CONDITIONS

PARAMETER	SYMBOL	MIN	TYP	MAX	UNIT
Operating temperature	T_{OP}	-40	25	+85	°C
Operating RF power at antenna attached to A+, A-	P_{MAX-OP}			20	dBm
RF carrier frequency	f_A	860		960	MHz

Table 2 Operating Conditions

4.3. ELECTRICAL CHARACTERISTICS

Unless otherwise specified: T_{OP}=25°C

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNIT
IC equivalent serial input impedance when sensor is activated3)	Z_{AB}	f_A=866MHz, at read sensitivity P_{READ} f_A=915MHz, at read sensitivity P_{READ}		24.7-j284.3 23.7-j270.4		Ω Ω
IC equivalent serial input impedance when sensor is deactivated3		f_A=866MHz f_A=915MHz		17.8-j286 17.6-j271.9		Ω Ω
IC read sensitivity 4)5)6)	P_{READ}	Sensing is deactivated and for V001 (see section 5.1) f_A=866MHz f_A=915MHz		-18 -18		dBm dBm
IC write sensitivity 4)5)6)	P_{WRITE}	Sensing activated or deactivated and for V001 f_A=866MHz f_A=915MHz		-13.5 -13.5		dBm dBm
IC sense and read sensitivity 4)5)6)	P_{SENSE}	Sensing activated f_A=915MHz		-16		dBm

Note 3: Measured directly on wafer with a 100Ω differential network analyzer at minimum operating RF power level

Note 4: IC impedance conjugate matched to antenna at read sensitivity (P_{SENSE})

Note 5: Interrogator using PR-ASK modulation with link parameters Tari = 25 µs, PR = 1.5, BLF = 256 KHz with Miller-4 encoding

Note 6: Sensitivity values are for IC devices in die form and do not include antenna gain

Table 3 Electrical Specifications for UHF communication

Unless otherwise specified: T_{OP}=25°C

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNIT
C_{SENSE} Sensing capacitance range	C_{RANGE}		0		17	pF
Sensing resolution	C_{RES}		-	7	-	bit
Capacitive Sensitivity	$C_{SENSITIVITY}$	Ideal regression sensitivity curve (excluding Non-linearity and noise)		150		fF/LSB
Noise	$NOISE_{RMS}$	RMS noise at room temperature C_{SENSE} <17pF		0.161		pF
Integral Non-Linearity	INL_{SENSE}	Error between the measured capacitance and best fit line on 25%-85% of the sensing capacitance range at room temperature C_{SENSE} <15		0.3		pF
Fixed Manufacturing Offset	ManufacturingOffset	Capacitance measured on the wafer at 25deg.C	-8		16.5	LSB

Table 4 Electrical Specifications for capacitive sensing

Unless otherwise specified: T=T_{OP}

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNIT
Tamper loop maximum capacitance	C_{MAX}	Measured between tamper pads			12.5	pF
Tamper loop maximum inductance	L_{MAX}	Measured between tamper pads			40	nH
Resistance connected between TAMPER_IN and TAMPER_OUT to assure a closed (short) loop	R_{CLOSED}	Cloadmax between tamper pads/pins = 12.5pF; Tamper loop enabled			1	MΩ
Resistance connected between TAMPER_IN and TAMPER_OUT to assure an open (broken) loop	R_{OPEN}	Cloadmax between tamper pads/pins = 12.5pF; Tamper loop enabled	10			MΩ
Input impedance between TAMPER_IN and TAMPER_OUT	Z_{TAMPER}	RF power = P_{READ}; Pads configured for HI-Z; f_A = 866MHz		5.2 -j106		Ω
		RF power = P_{READ}; Pads configured for Tamper Loop; f_A = 866MHz		17.5 -j106		Ω
		RF power = P_{READ}; Pads configured for HI-Z; f_A = 915MHz		5.1 -j101		Ω
		RF power = P_{READ} ; Pads configured for Tamper Loop; f_A = 915MHz		16.1 -j101		Ω

Table 5 Electrical Specifications for tamper loop

Unless otherwise specified: $T=T_{OP}$

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNIT
External device Supply Power	P_{SUPPLY}	Power provided to a red LED diode in Typical conditions		420	-	uW
IC equivalent serial input impedance when driving a red LED diode with P_{SUPPLY} 7)	$Z_{ABSUPPLY}$	f_A=915MHz, at read sensitivity P_{SUPPLY}	-	118.5-j212.8	-	Ω

Note 7: Measured directly on wafer with a 100Ω differential network analyzer at minimum operating RF power level

Table 6 External device supply specifications

4.4. NVM ELECTRICAL CHARACTERISTICS

Unless otherwise specified: $T=T_{OP}$

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNIT
Retention	T_{RET}	T = 55ºC	10			Years

Table 7 NVM Electrical Specifications

4.5. TIMING Characteristics

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNIT
Conversion leadtime	$T_{CONVERSIONLT}$	excluding the settling time		0.572		ms

Table 8 Timing Characteristics

5. FUNCTIONAL DESCRIPTION

5.1. SENSING FUNCTIONALITIES

The em|aura-sense device is capable of measuring the capacitance value of a capacitor connected between the two pads CAP+ and CAP-. Specifications for the capacitive sensing are described in 5.1.1.

The device is able to perform a sensor measurement during power-up or on demand from an interrogator depending on "*Sense At Control*" configuration selected (see Table 34). When *SensAtBoot* is enabled, Tag initiates a sensor measurement during power-up sequence as described in section 5.1.3, Sensing at Boot. When *SensAtSelect* is enabled, Interrogator can initiate on demand a sensor measurement by using a *Select* command on XPC_W2 (see 5.1.4.1, Sensing at Select).When *SensAtWrite* is enabled, Interrogator can initiate on demand sensor measurement by using a *Write*/*BlockWrite* command to XPC_W2 as described 5.1.4.2, Write instructed request.

In any cases, the *SensorData* (defined in Table 26) will be reported into XPC_W2 word either in *ACK* reply or using a *Read* command.

5.1.1. CAPACITIVE MEASUREMENT

The em|aura-sense capacitive sensor is producing a 8-bit positive value from the measurement of the external capacitor connected to its CAP+ and CAP- pad. This *RawData* is defined as follow:

$$RawData = \frac{C_{SENSE}}{C_{SENSITIVITY}} + ManufacturingOffset + 128$$

With $C_{SENSITIVIY}$ ManufacturingOffset and C_{SENSE} as defined in Table 4 and Figure 1 .

Note 8: The value of C_{SENSE}, taken into account in the calculation, is the sum of the sensing capacitor and the parasitic capacitor (internal and external to the IC) connected to the CAP+ and CAP- pads.

The error on the C_{SENSE} measurement is the accumulation of $NOISE_{RMS}$ and INL_{SENSE} defined in Table 4.

This device is offering the ability to calibrate the reported measurement. The calibrated sensing data (*SensingData*), a 10-bit signed integer reported in the XPC_W2, is defined as follows:

$$SensingData = RawData - \text{CalibrationData}$$

With *CalibrationData* being an 8-bit positive data stored into NVM and may be changed using SENSOR_CALIB register (see Table 33).

5.1.2. MEASUREMENT ERROR HANDLING

em|aura-sense is able to report an error through the XPC_W2 (see Table 26) if :

- power supply goes too low during the acquisition to perform reliable measurement
- *RawData* variation is not as expected (eg. going below the *CalibrationData*) as defined in Table 16

5.1.3. SENSING AT BOOT

When *SensAtBoot* is enabled (see Table 34), the sensor performs the sensor measurement during power-up after the device boot operation is completed, during T_S (see Figure 7). The sensing is available starting with the first inventory round which includes the Tag; Data will be reported via XPC_W2 (see Table 25) during the next *ACK* reply (see Figure 7) or using a *Read* command.

No NVM operation is required for this operation thus the sensitivity when sensing at boot is lower than the write sensitivity (see Table 3).

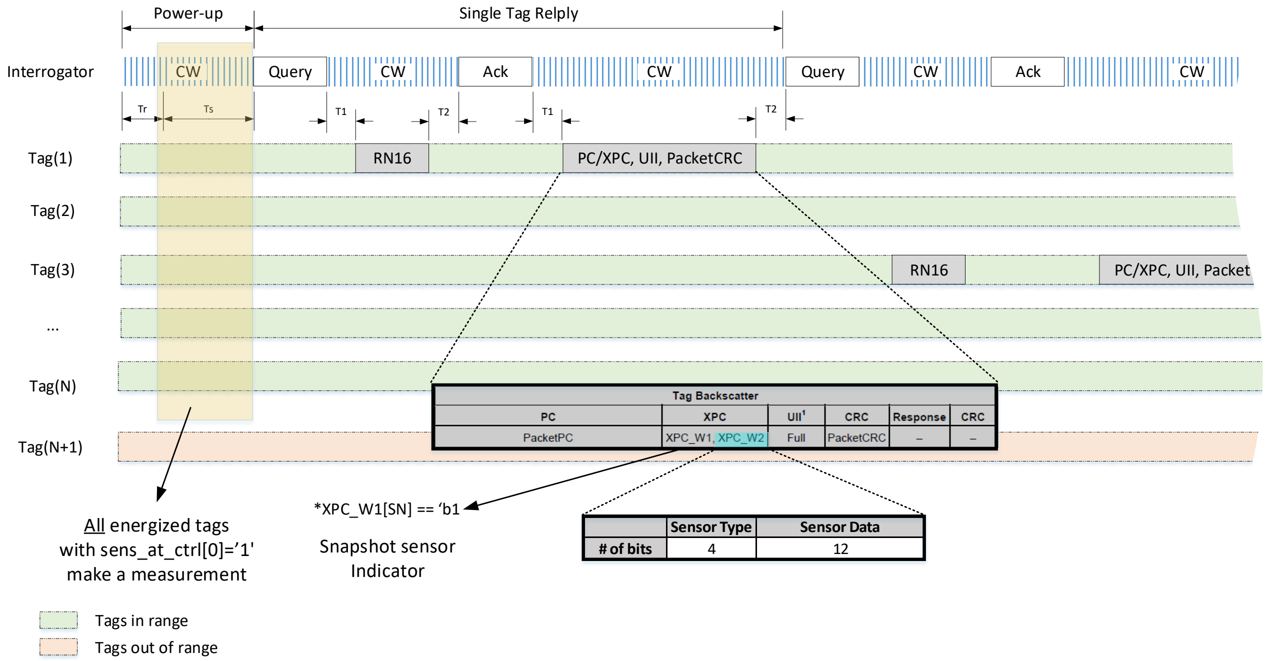

Figure 7 Sense at Boot example

5.1.4. SENSING ON DEMAND

5.1.4.1. SENSING AT SELECT

When *SensAtSelect* is enabled (see Table 34), an Interrogator may initiate on demand sensor measurement by using a *Select* command on XPC_W2, i.e. with MemBank=01_2, Pointer=8420_h (EBV format for 220_h), Length=10_h, and Mask as defined in Table 9 and Table 10. The sensor measurement occurs during T_4 (see Figure 8) and the Snapshot Sensor information shall be available starting with the next inventory round which includes the Tag if it remains energized. If T_4 is shorter than the sensor measurement time then the Tag might not remain energized. It is recommended to use a *Select* command to first create a population of Snapshot Sensor Tags and then use a *Select* command on XPC_W2.

Note 9: These SensAtSelect operations are requiring an extension of minimum T_4 between 15.625us and 62.5us parameter up to 1.2ms

WORD	MSB 0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	LSB F
22_h	Cmd	SelectedSensor [14:0]														

Table 9 XPC_W2 as accessed by a *Select* command

FIELD NAME	DESCRIPTION	COMMENT
Cmd	Sensor Command	0: Tag shall not initiate measurements. 1: Tag shall initiate a measurement if *SelectedSensor[0]* = 1_b and *SensAtSelect* is enabled.
Selected Sensor	Sensor selector	em|aura-sense shall be considered matching when *SelectedSensor[0]* = 1_b and shall be considered non-matching if *SelectedSensor[0]* ≠ 1_b. Note 1: *SelectedSensor[14:1]* are considered as don't care.

Table 10 XPC_W2 as accessed by a *Select* command fields

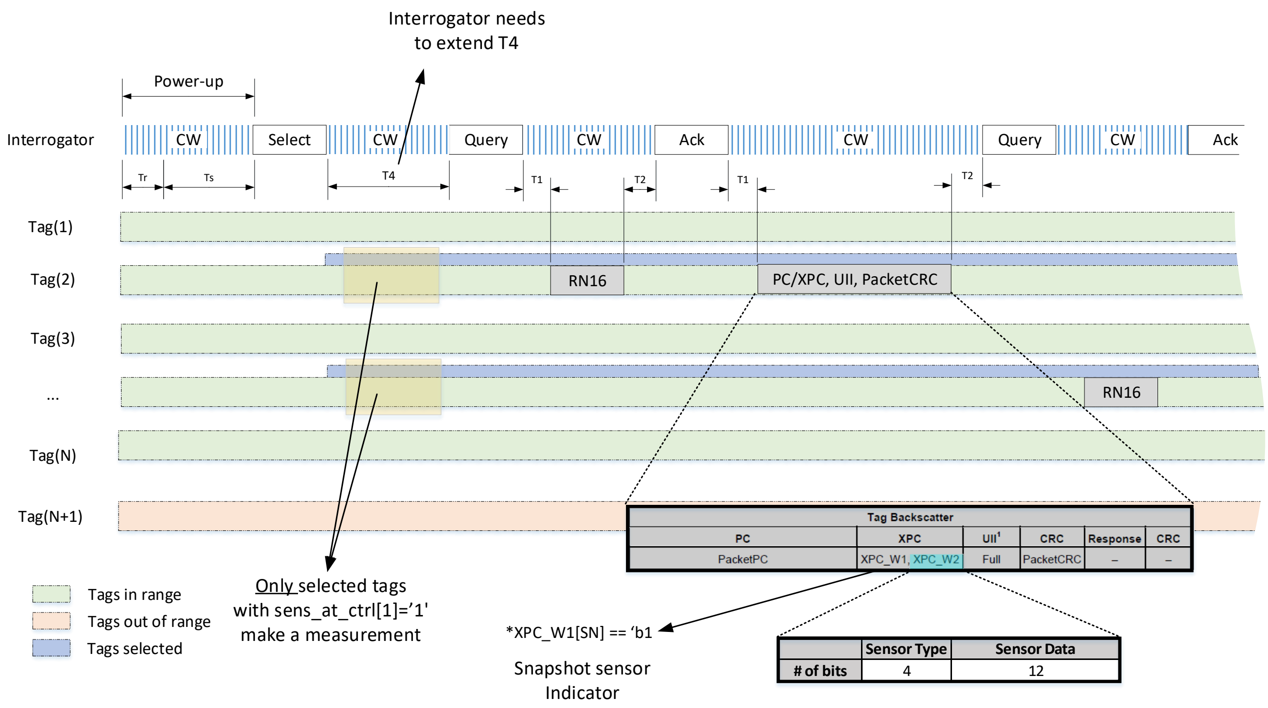

Figure 8 Sense at Select example

5.1.4.2. WRITE INSTRUCTED REQUEST

When *SensAtWrite* is enabled (see Table 34), Interrogator can initiate on demand a sensing acquisition by using *Write* or *BlockWrite* command to XPC_W2, i.e. with MemBank=01_2, WordPtr=22_h, and Data as defined in Table 11 and Table 12 for *Write*, and MemBank=01_2, WordPtr=22_h, WordCount=1_h, and Data as defined in Table 11 and Table 12 for *BlockWrite*. An Interrogator may initiate a measurement regardless of the lock or permalock status of EPC/UII memory. The sensor measurement occurs during T_5 (see Figure 9) and the Snapshot Sensor information shall be available for a subsequent *Read* of XPC_W2 and/or starting with the next inventory round which includes the Tag.

WORD	MSB 0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	LSB F
22_h	WI_CMD[3:0]				WI_PARAM[11:0]											

Table 11 Structure of the write instructed sensor request

When a reader issue a *Write*/*BlockWrite* command to XPC_W2, the sensor tag interprets the Data field and executes the action as described Table 12 below.

<table>
<tr><th>COMMAND WI_CMD</th><th>ACTION</th><th>NVM WRITE</th><th>SENSOR ACQUISITION</th></tr>
<tr><td>$1xxx_2$</td><td>Sense only: Launch one sensing acquisition if WI_PARAM[0] = 1_b. If WI_PARAM[0] ≠ 1_b Tag treat this Write operation as NOT SUPPORTED.</td><td>No</td><td>Yes</td></tr>
<tr><td>0001_2</td><td>Sense and Store: Launch one sensing acquisition and store the result into the NVM if no acquisition failure (e.g. low vsup error) occurs.
This stored data is accessible through a read into SENSOR_DATA_STORED register (see Table 35). WI_PARAM[11:0] is ignored.
Note: In case of Calibration Error, as defined in 5.6, SensingData is stored into NVM.</td><td>Yes</td><td>Yes</td></tr>
<tr><td>0010_2</td><td>Sense and Calibrate: Launch sensing acquisition and store the raw (non calibrated) sensing value into the NVM, if no acquisition failure (e.g. low vsup error) occurs. This stored value will be used as CalibrationData for the following reported calibrated sensing Data (see section 5.1.1). This command also set calibration margin to be apply and optionally lock the calibration according to WI_PARAM value as follow :
<table>
<tr><th>PARAM</th><th>11</th><th>10</th><th>9</th><th>8</th><th>7</th><th>6</th><th>5</th><th>4</th><th>3</th><th>2</th><th>1</th><th>0</th></tr>
<tr><td>WI_PARAM [11:0]</td><td colspan="6">RFU</td><td>Calibration Lock</td><td colspan="5">Calibration Margin</td></tr>
</table>
Note 1: RFUs are don't care.
Note 2: Tag is generating and ERROR LOCKED response in case "Sense and Calibrate" operation is requested when the calibration is already locked. No acquisition is done.</td><td>Yes</td><td>Yes</td></tr>
<tr><td>All others</td><td>Reserved for Future Use. Tag Treat these command as NOT SUPPORTED</td><td>No</td><td>No</td></tr>
</table>

Note 10: in table above, 'x' means don't care.

Table 12 Write instructed command

Once the action described in the previous table is performed, the tag sends a delayed reply to the reader as it would for any other *Write* command (see Figure 9 below).

The sensing data will be then reported, either by a read of XPC_W2 using a *Read* command or within an *ACK* reply.

The entire write instruction operation is described in Figure 9.

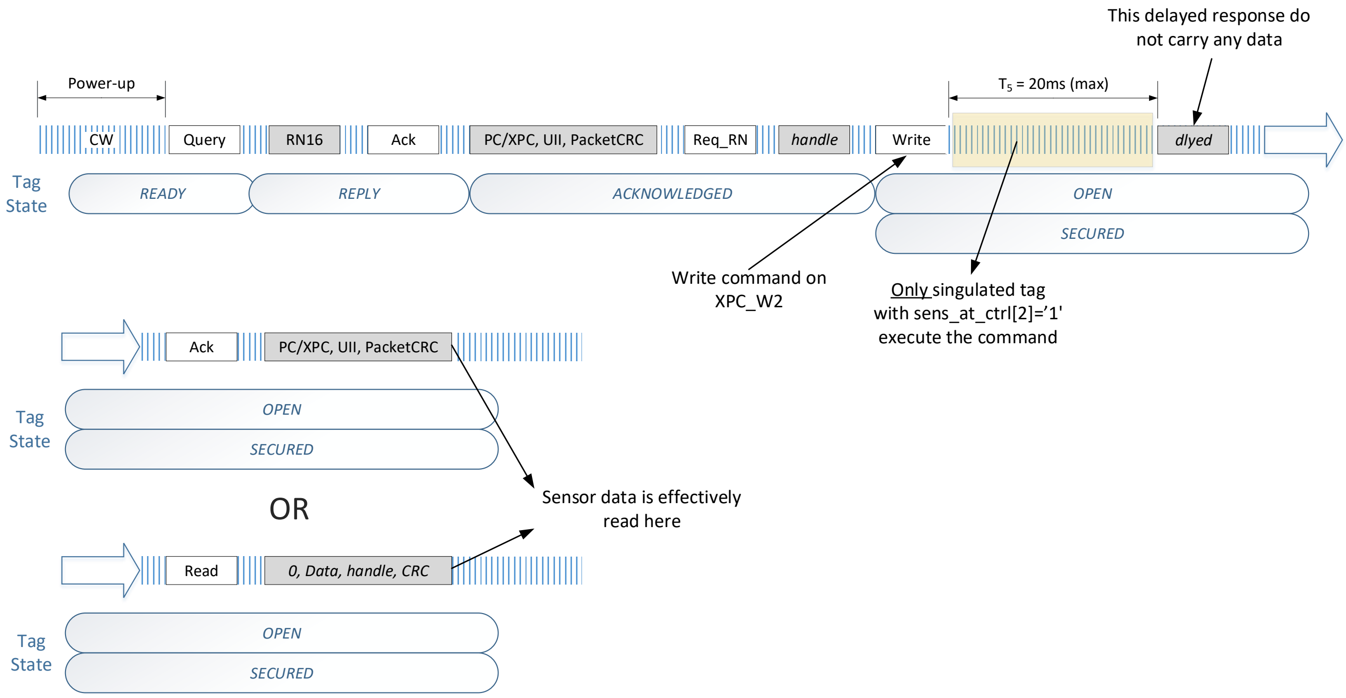

Figure 9 Write instructed sensing operation example

5.2. TAMPER FUNCTIONALITY

em|aura-sense provides a tamper detection feature that is user programmable. Refer to 6.5.2 for further information. If enabled, the device checks impedance of a continuity loop between two pads/pins during power-up. Tamper Detection can be implemented using a simple continuity loop, with heat sensitive fuse wire, with sensors having both high and low impedance states, or with external devices controlling an electronic switch such as a MOSFET. Tamper Detection is checked every transition from POR to Ready state. The Tamper alarm is both a registered value (volatile memory) and a latched value (non-volatile memory) when sufficient RF power is available to support an NVM write operation. The device performs a logical OR of both the volatile and non-volatile Tamper alarms when reporting the Tamper status. Tamper status is reported to an Interrogator via the Sensor Alarm indicator (SA) in the XPC_W1 word.

5.3. EXTERNAL DEVICE SUPPLY FUNCTIONALITY

5.3.1. OVERVIEW

em|aura-sense is capable of supplying an external device connected between the 2 pads SWITCH1 and SWITCH2. The SWITCH1/SWITCH2 pads can be put in 2 states (ON or OFF) depending on the chip configuration and on the current chip state. The five different ON/OFF condition possible are described in section 5.3.2 below. The pad configuration associated to ON and OFF state is defined in section 5.3.3.

5.3.2. ON/OFF MODE CONFIGURATION

The ON/OFF mode is defined by the "*ExtPadCtrl At Control*" configuration selected within EXTPADCTRL_CONF register (see Table 36). Each of the possible ON/OFF mode is described below.

5.3.2.1. ALWAYS OFF

When "*ExtPadCtrl At Control*" = $0xx_2$, the Supply&Switch functionality is always deactivated. The SWITCH1 and SWITCH2 pads will always stay OFF.

5.3.2.2. ALWAYS ON

When "*ExtPadCtrl At Control*" = 100_2, the Supply&Switch functionality stays ON after tag has done initialization and until UHF field is off as shown in Figure 10 below.

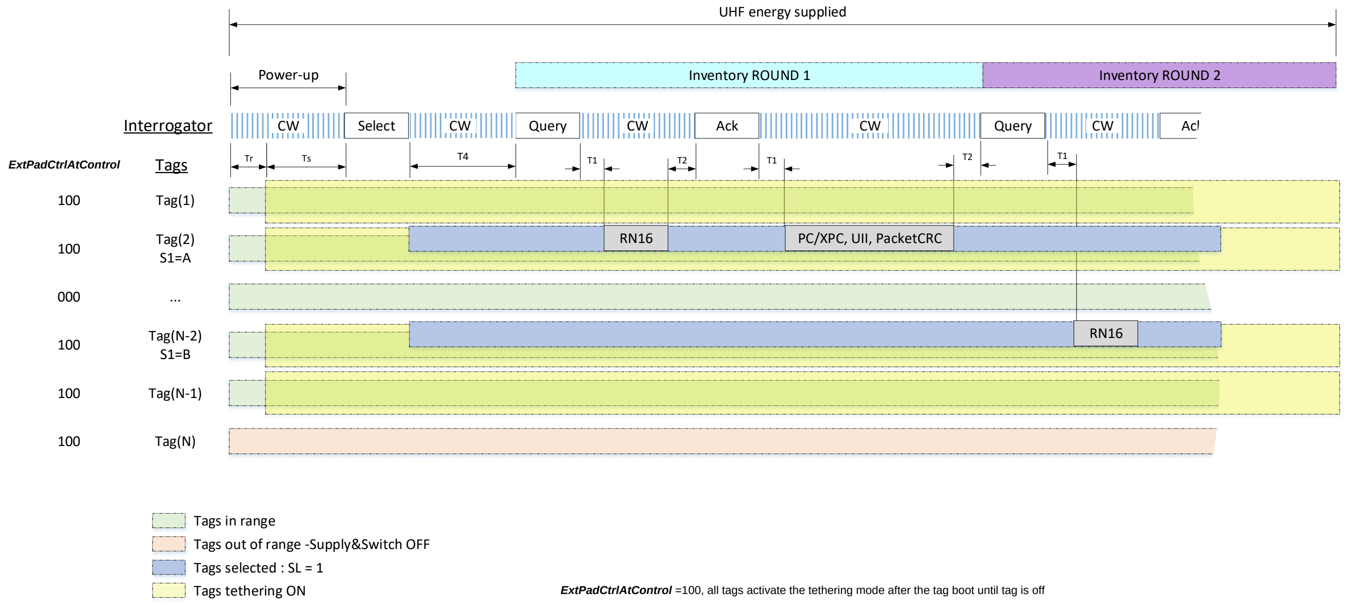

Figure 10 AlwaysOn Mode

5.3.2.3. IN INVENTORY ROUND

When "*ExtPadCtrl At Control*" = 101_2, only tags participating to the current inventory round, ie. being in Arbitrate, Reply, Acknowledged, Open or Secure state, will have their Supply&Switch pads in ON state as shown in Figure 11 below.

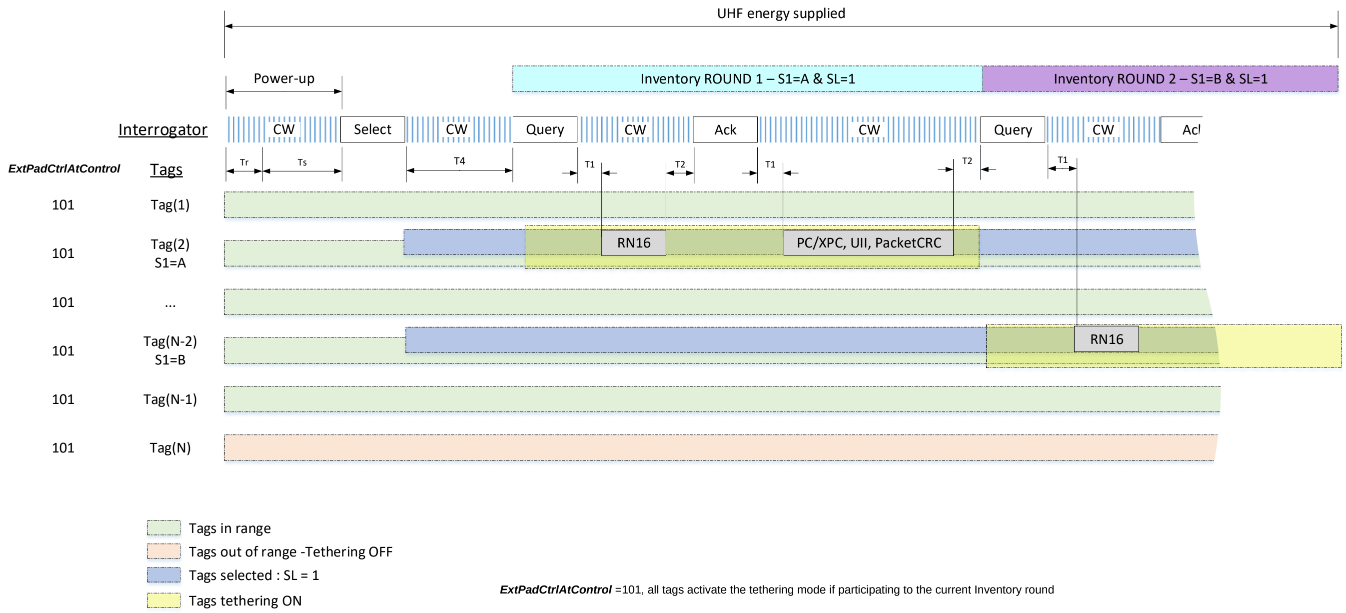

Figure 11 In InventoryRound Mode

5.3.2.4. SINGULATED

When "*ExtPadCtrl At Control*" = 110_2, only the singulated tag, ie. being in Acknowledged, Open or Secure state, will have their Supply&Switch Function in ON state as shown in Figure 12 below.

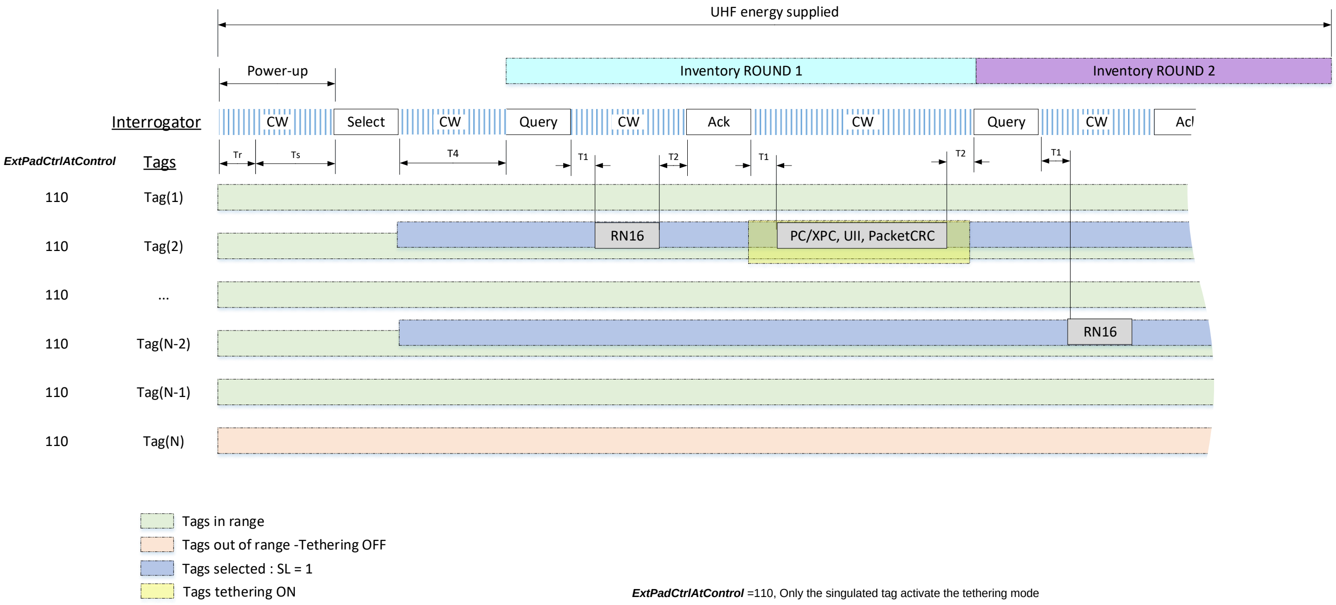

Figure 12 Singulated Mode

5.3.2.5. SELECTED

When "*ExtPadCtrl At Control*" = 111_2, all tags with SL flag asserted will have their Supply&Switch Function in ON state as shown in Figure 13 below.

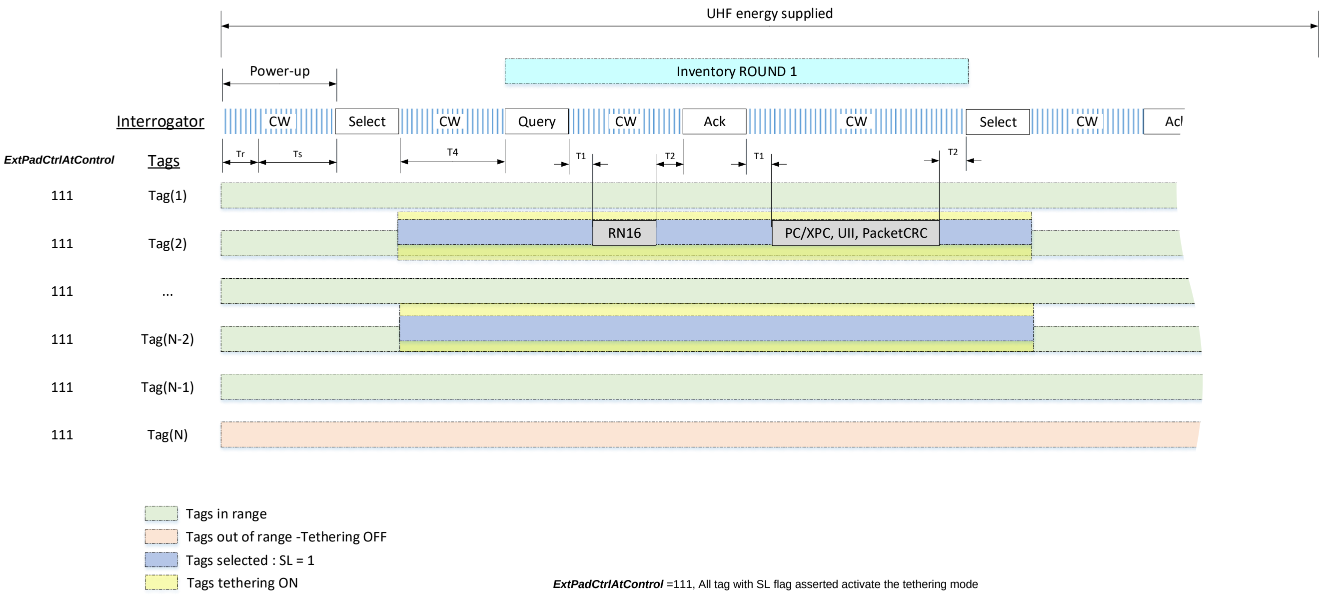

Figure 13 Selected Mode

5.3.3. PAD CONFIGURATION

The definition of ON and OFF pad state is defined by the "*ExtPadCtrl Switch Mode*", "*ExtPadCtrl OFF State*" and "*ExtPadCtrl Active Pad*" configurations bits within EXTPADCTRL_CONF register (see Table 36) and summarized in the Table 13 below.

ExtPadCtrl Switch Mode	ExtPadCtrl OFF State	ExtPadCtrl Active Pad	ON State		OFF State	
			SWITCH1	SWITCH2	SWITCH1	SWITCH2
0	0	0	**VDD**	VSS	Floating	Floating
0	0	1	VSS	**VDD**	Floating	Floating
0	1	0	**VDD**	VSS	VSS	VDD
0	1	1	VSS	**VDD**	VDD	VSS
1	0	0	**VSS**	**VSS**	Floating	Floating
1	0	1	**VDD**	**VDD**	Floating	Floating
1	1	0	**VSS**	**VSS**	VDD	VDD
1	1	1	**VDD**	**VDD**	VSS	VSS

Table 13 Pad state definition

5.4. COMMANDS

5.4.1. LIST OF AVAILABLE COMMANDS

COMMAND	COMMENT
QueryRep	
ACK	
Query	
QueryAdjust	
Select	
NAK	
Req_RN	
Read	
Write	
Kill	Failed *Kill* command sequence results in a security timeout (~100ms typical). Note : Tag should have its configuration locked (see 6.5.2) in order to execute this command
Lock	Note : Tag should have its configuration locked (see 6.5.2) in order to execute this command
Access	Failed *Access* command sequence results in a security timeout (~100ms typical).
BlockWrite	Supports writing one to eight 16-bit words.
BlockPermalock	User memory block size is four words.
Untraceable (see below)	See section 5.4.2 below. U indicator bit and EPC field are not supported (ignored). Note : Tag should have its configuration locked (see 6.5.2) in order to execute this command

Table 14 List of commands supported by em|aura-sense

5.4.2. UNTRACEABLE COMMAND

The *Untraceable* command was introduced in Gen2V2 and may be used to hide some or all memory in the TID, EPC/UII, and/or User memory banks. *Untraceable* may also be used to reduce the read range of the Tag. The *Untraceable* command may only be used by an Interrogator that enters the Secured state using a non-zero Access password. Tags reply to an *Untraceable* using a delayed Tag reply.

INTERROGATOR TO TAG	# BITS	DECRIPTION
Command Code	16	$E200_h$
RFU	2	00_2
U	1	not supported (don't care)
EPC	6	Msb: must be 0 = show memory above **L** 5 lsb's (length): **L** value must be the same as the **L** value in StoredPC
TID	2	00_2 = hide none 01_2 = hide some (memory above 20h inclusive) 10_2 = hide all 11_2 = RFU
User	1	0 = show 1 = hide
Range	2	00_2 = normal 01_2 = toggle (no effect) 10_2 = reduced (deactivated) 11_2 = RFU
RN	16	handle
CRC	16	CRC-16

Table 15 Untraceable command

5.5. PRIVACY USING UNTRACEABLE COMMAND

Untraceable allows an Interrogator to instruct the em|aura-sense to (a) hide memory from Interrogators with a deasserted Untraceable privilege, and/or (b) reduce its operating range for all Interrogators. The memory that a Tag may hide includes words of the Tag serialization in TID memory, all of TID memory, and/or User memory. Untraceable and traceable Tags behave identically from a state-machine and command-response perspective; the difference between them is (a) the memory the Tag exposes to an Interrogator with a deasserted Untraceable privilege and/or (b) the Tag's operating range.

Untraceable may be used to change the operational read range of a Tag. em|aura-sense supports this feature in a manner that permits having either full read range (normal operation) or no read range (deactivated operation). A deactivated Tag always remains in the Ready state and will not participate in any inventory operations.

The Range parameter in the *Untraceable* command is used to specify the persistent operational read range of the Tag. If Range = 00_2 then the Tag persistently enables normal operation. If Range = 10_2 then the Tag persistently enables deactivation and the Tag becomes deactivated immediately upon reply to the *Untraceable* command. If Range = 01_2 then it has no effect on the Tag.

A deactivated Tag may be temporarily reactivated (normal operation) by any Interrogator using a *Select* command with any of the assigned EM Microelectronic Mask Designer ID's (MDID's) provided that the MDID is not untraceably hidden. The *Select* command parameters are MemBank = 10_2, Pointer = 08_h, and either Length = $0C_h$ with matching Mask = $00B_h$ or = $40B_h$ or = $80B_h$ or = $C0B_h$, or Length = 10_h with matching Mask = $00BX_h$ or = $40BX_h$ or = $80BX_h$ or = $C0BX_h$ where X can be any hexadecimal value. Whenever a Tag is temporarily reactivated, it remains in the normal operational mode until the Tag loses power or executes another *Untraceable* with Range = 10_2.

5.6. USING THE TAG NOTIFICATION (TN) INDICATOR

em|aura-sense allows to detect significant changes in the sensing data and report through the Tag Notification flag (TN) that is part of the XPC_W1, itself part of the Tag reply to an ACK command. The detection is triggered when the calibrated data is bigger than a programmable value called CalibrationMargin. As the sensing data is affected by internal noise as described in section 5.1.1 and in table Table 4, applying a CalibrationMargin that is bigger than the noise will avoid to trigger the detection on the noise. Depending on the application, we want to detect significant changes that may be of positive sign, negative sign or both. Depending on the application, a significant negative change or a significant positive change may be considered as an anomaly and then reported as an error. Several cases can be configured using TN_Reporting[1:0] bits of System Configuration Word 1 see Table 31.

If TN_Reporting[1:0] = 00_2, the meaning of TN = 0 or TN = 1 is defined by the application. TN may only be modified by an authenticated Interrogator that asserts the TN privilege. The TN indicator bit may be modified regardless of the lock/permalock status of the EPC memory bank.

If TN_Reporting[1:0] = 01_2, 10_2 or 11_2, TN flag value depends on the value of SensingData Calibration margin and TN_REPORTING. The table below describes how the detection is settled. When SensingData changes in unexpected direction and magnitude, an error is raised in XPC_W2 see Table 16.

TN_REPORTING[1:0]	REPORTING TYPE	DETECTION AND ERROR			
00_2	Application defined	TN bit writeable by the application ErrCalib is as per TN_REPORTING[1:0] = 01_2			
		SensingData	< -CalibrationMargin	-CalibrationMargin … 0 … +CalibrationMargin	> +CalibrationMargin
01_2	Reports when *SensingData* is above the calibration margin		Error TN = 0 ErrCalib = 1	Margin Area TN = 0 ErrCalib = 0	Detection TN = 1 ErrCalib = 0
10_2	Reports when *SensingData* is below the calibration margin		Detection TN = 1 ErrCalib = 0	Margin Area TN = 0 ErrCalib = 0	Error TN = 0 ErrCalib = 1
11_2	Reports when *SensingData* is out of calibration margin		Detection TN = 1 ErrCalib = 0	Margin Area TN = 0 ErrCalib = 0	Detection TN = 1 ErrCalib = 0

Table 16 Notification setting

6. MEMORY

Memory is organized in blocks of 64 bits, 4 words per block.

6.1. MEMORY ORGANIZATION

The EEPROM is allocated to the four memory banks as described in the following manner:

MEMORY BANK	WORD ADDRESS	CONTENTS	BLOCK NUMBER FOR *BLOCKPERMALOCK*	COMMENT
00_2: Reserved	00_h - 01_h	Kill Password	n/a	See section 6.2
	02_h - 03_h	Access Password	n/a	See section 6.2
01_2: EPC/UII	00_h	StoredCRC	n/a	See section 6.3.1
	01_h	StoredPC	n/a	See section 6.3.2
	02_h – $1F_h$	EPC/UII	n/a	Max encoding size is 480 bits EPC/UII up to 128bit: Sense at Boot (see section 5.1.1) without tamper can be done with standard 1.5ms boot time EPC/UII up to 480bit: Sense at Boot (see section 5.1.1) without tamper can be done with extended 1.9ms boot time See section 6.3.3
	21_h	XPC_W1	n/a	See section 6.3.4
	22_h	XPC_W2	n/a	Including the sensor data see section 6.3.5
10_2: TID	00_h - 05_h	TID	n/a	See section 0
11_2: User (File_0)	00_h - 03_h	User Defined	0	See section 6.5.1
	03_h - 07_h		1	
	…		…	
	78_h - $7B_h$		30	
	120_h - 130_h	System Memory	n/a	See section 6.5.2

Table 17 Memory organization

The four memory banks are described in the four sections below.

6.2. RESERVED MEMORY BANK

Reserved memory is as defined in ISO/IEC 18000-63 and EPC Gen2V2 specs.

WORD	MSB 0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	LSB F
00_h	Kill Password [31:16]															
01_h	Kill Password [15:0]															
02_h	Access Password [31:16]															
03_h	Access Password [15:0]															

Table 18 Description of the reserved memory bank

6.3. EPC/UII MEMORY BANK

EPC/UII memory is as defined in ISO/IEC 18000-63 and EPC Gen2V2 specs.

The Tag reply to an *ACK* includes a field that is commonly referred to as the PC word. The format and definition of the PC word for Gen2V2 is significantly different from their previous versions associated to the EPC Gen2 V1.x specifications. A description of the PC word in the *ACK* reply is provided below in section 6.3.2.

6.3.1. STOREDCRC WORD

A memory self-check is performed for the EPC/UII memory at every power-up if the EPC/UII Memory Bank is locked or permalocked. The self-check compares the result of the dynamic CRC calculation for the StoredCRC during power-up with the static CRC calculation for the StoredCRC stored in NVM. If the CRC values do not match then Tag will reply to *ACK* with **L**=00000_2 in the PC word regardless of the actual value. An Interrogator could then consider the Tag for exception handling.

6.3.2. STOREDPC WORD

6.3.2.1. GEN2 V2.X FORMAT

The StoredPC word is described in the following table (Gen2 V2.1= Legacy Gen2 format disabled)

WORD	MSB 0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	LSB F
01_h	L (Length)					UMI	XI=0	T=0	B	C	SLI	TN	U	K	NR	H
	L (Length)					UMI	XI=1	T=0	RFU							
	L (Length)					UMI	XI	T=1	ISO Application Family Identifier (AFI)							

Table 19 Description of the StoredPC word for Gen2 V2.X

PARAMETER NAME	WRITE ACCESS
L	Writeable
UMI	Fixed to 1: User memory always exist
XI	Computed
T	Writeable
AFI	Writeable
RFU	Fixed = 00_h

Table 20 Write access for Gen2 V2.X

6.3.2.2. GEN2 V1.X FORMAT

The StoredPC word is described in the following table (Gen2 V1.x = Legacy Gen2 format enabled)

WORD	MSB 0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	LSB F
01_h	L (Length)					UMI	XI=0	T=0	Numbering System Identifier (NSI) LSB's							
	L (Length)					UMI	XI=0	T=1	ISO Application Family Identifier (AFI)							

Table 21 Description of the StoredPC word for Gen2 V1.X

PARAMETER NAME	WRITE ACCESS
L	Writeable
UMI	Writeable
XI	Fixed to 0
T	Writeable
AFI	Writeable
NSI	Writeable

Table 22 Write access for Gen2 V1.X

6.3.3. EPC/UII WORDS

EPC: Electronic Product code or

UII: Unique Item Identifier

Following ISO/IEC 18000-63 and EPC Gen2V2 specs.

6.3.4. XPC_W1

A description of the XPC_W1 word is provided below.

WORD	MSB 0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	LSB F
21_h	XEB	0	0	0	SA	0	0	SN	B =0	C =0	SLI	TN	U =0	K	NR	H

Table 23 Description of the XPC_W1

BIT NAME	DESCRIPTION	COMMENT
XEB	XPC_W2 indicator	0: All bits of XPC_W2 are zero-valued 1: At least one bit of XPC_W2 is nonzero
SA	Tamper Alarm indicator	0: Tamper detection is not enabled or the Tag is not reporting a Tamper Alarm condition 1: Tag is reporting a Tamper Alarm condition
SN	Snapshot Sensor indicator	0: Chip version do not support Sensing Feature 1: Chip version support Sensing Feature See Table 37.
B	Battery assisted passive indicator	Fixed to 0: Not supported by em|aura-sense.
C	Computed response indicator	Fixed to 0: Not supported by em|aura-sense
SLI	SL-flag indicator	0: indicates the SL flag is deasserted 1: indicates the SL flag is asserted Upon receiving a *Query* the Tag maps its SL flag into the SLI and retains this SLI setting until starting a subsequent inventory round.
TN	Tag-notification indicator	This bit is used to indicate the state of the TN function defined by the application.
U	Untraceable indicator	Fixed to 0: Not supported by em|aura-sense.
K	Killable indicator	0: indicates the tag is not killable 1: indicates the tag is killable using the Kill password K = [(logical OR of all 32 bits of the kill password) OR (kill-pwd-read/write=0) OR (kill-pwd-permalock=0)]. ○ If any bits of the kill password are 1 then the Tag is killable ○ If kill-pwd-read/write is 0 then the Tag is killable ○ If kill-pwd-permalock is 0 then the Tag is killable
NR	Nonremovable indicator	0: indicates the Tag is removable 1: indicates the Tag is nonremovable. This bit is default 0 unless changed by an Interrogator via a *Write* or *BlockWrite*.
H	Hazmat indicator	0: indicates the Tag is not affixed to hazardous material 1: indicates the Tag is affixed to hazardous material. The bit is default 0 unless changed by an Interrogator via a *Write* or *BlockWrite*.

Table 24 Description of the XPC_W1 bits

6.3.5. XPC_W2

The XPC_W2 reported content is defined as follows:

WORD	MSB 0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	LSB F
22_h	SensorType = 0000_h				SensorData											

Table 25 Description of the XPC_W2

FIELD NAME	DESCRIPTION	COMMENT
SensorType	Type of reported sensor	Fixed to 0000_h : em|aura-sense embed a Vendor Defined sensor
SensorData	Sensor Data reported	2-bit data type || 10-bit data value as follows: • 00_2 || 1111111111_2 (error): Error cases are described in 5.1.2. • 11_2 || 10-bit signed integer: The sensor data (*SensingData*) is defined as described in 5.1.1

Table 26 Description of the XPC_W2 fields

Once powered, XPC_W2 will be always reported within ACK reply as long as any sensing acquisition request has been done.

Before any attempt to perform a sensor acquisition, XPC_W2 will be read as 0000_h and will not be reported within the ACK reply.

6.4. TID MEMORY BANK

TID memory is as defined in ISO/IEC 18000-63 and EPC Gen2V2 specs.

WORD	MSB 0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	LSB F
00$_h$	ISO/IEC 15963 Allocation Class (= E2$_h$)								Tag MDID MSB's (= 80$_h$)							
01$_h$	Tag MDID LSB's (= B$_h$)				Tag Model Number											
					Model										Options	
	1	0	1	1	0	0	0	1	0	0	1	0	0	0	see below	
02$_h$	XTID (= 2000$_h$)															
03$_h$	IC Serial Number [47:32]															
	00$_h$								Customer Number [7:0]							
04$_h$	IC Serial Number [31:16]															
05$_h$	IC Serial Number [15:0]															

Table 27 Description of the TID memory

Options:

BIT E	USER CONFIGURATION
0	Tag is not performing Tamper detection
1	Tag is performing Tamper detection only on compatible tag version (see section 8.1)

Note 11: this bit reflect chip configuration bit "Pad Mode [0]". See System Configuration Word 1.

Table 28 TID option - Tamper detection

BIT F	USER CONFIGURATION
0	Tag is using standard PC Word definition : StoredPC and PacketPC are as defined in 6.3.2.1
1	Tag is using Legacy PC Word definition : StoredPC and PacketPC are compatible with prior versions of Gen2 as defined in 6.3.2.2

Note 12: This bit reflect chip configuration bit "Legacy PC". See System Configuration Word 1.

Table 29 TID option - Legacy PC

The 48-bit IC Serial Number used for the UHF TID. The 48-bit IC Serial Number is encoded with even parity. An Interrogator should calculate even parity with bitwise exclusive-OR as follows:

P = IC Serial Number [47] ⊕ IC Serial Number [46] ⊕ … ⊕ IC Serial Number [1] ⊕ IC Serial Number [0]

If P = 0 then the IC Serial Number is correct. If P = 1 then the IC Serial Number has an error in it.

6.5. USER MEMORY BANK

The User Memory Bank contains two segments: User memory and System memory. User memory, also known as File_0, is as defined in ISO/IEC 18000-63 and EPC Gen2V2 specs.

6.5.1. FILE_0 MEMORY

File_0 memory is containing 124 16-bits words addressed from 00_h to $7B_h$.
This memory section is accessible according to ISO/IEC 18000-63 and EPC Gen2V2 specs.

6.5.2. SYSTEM MEMORY

6.5.2.1. OVERVIEW

System memory consists of several 16-bits words addressed from 120_h to 130_h depending on Tag's feature.
Write into System memory can be done using *Write* command or single block *BlockWrite* (ie. With WordCount=1_h) command.
Any access to the System Memory require the tag to be in Secured State. Any special access right are described in Table 30.
All RFU bits are not writeable and will be read as zeroes.

The content of the System memory is described below:

Logical Address	Name	Description	Access Right
120_h	SYS_CONF_W1	System Configuration Word 1	Configuration Lock = '0' : Read/Write allowed Configuration Lock = '1' : Read/Write cause error response from the Tag.
121_h	SYS_TAMPER_LOCK	Tamper Lock Word	Configuration Lock = '0' OR Tamper feature not available : Read/Write cause error response from the Tag. Configuration Lock = '1' : Write allowed Read as 0000_h
122_h	SENSOR_CALIB	Sensor Calibration Word	Calibration Lock = '0' : Read/Write allowed Calibration Lock = '1' OR Sensor feature not available : Read/Write cause error response from the Tag.
123_h	SENSOR_CTRL_W1	Sensor Control Word 1	Sensor feature is available : Read/Write allowed Sensor feature not available : Read/Write cause error response from the Tag.
124_h	SENSOR_DATA_STORED	Sensor Data Stored Word	Sensor feature is available : Read only Write cause error response from the Tag. Sensor feature not available : Read/Write cause error response from the Tag.
125_h - $12F_h$	RFU	Reserved for Future Use	Read/Write cause error response from the Tag.
130_h	EXTPADCTRL_CONF	Extended Pad Control Word	ExtPadCtrl Lock = '0' : Write allowed ExtPadCtrl Lock = '1' OR Supply feature not available : Read/Write cause error response from the Tag.

Table 30 System memory register map

6.5.2.2. SYSTEM MEMORY REGISTERS DETAIL

Word 120_h	MSB 0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	LSB F
Description	Pad mode		Legacy PC enable	Tamper function		TN Reporting		Access Password Untraceable privilege	Access Password TN privilege	Configuration Lock	Backscatter configuration		RFU			

Content	Description
Pad Mode	Configures the non-antenna pads/pins 00_2: Disabled (HI-Z, HI-Z) 01_2: Tamper Loop (TAMPER IN, TAMPER OUT) with tamper sensed when loop is not intact (open) 10_2: Package Test (VSUP, VSS) NOTE : Switches to disabled (HI-Z, HI-Z) when Configuration Lock = 1. 11_2: Tamper Loop (TAMPER IN, TAMPER OUT) with tamper sensed when loop is intact (closed) If chip does not support tamper see Table 37, Pad Mode should be set to 00_2
Legacy PC enable	Selects the PC Word behavior 0: Disabled = New PC Word (StoredPC, PacketPC) is as defined in Gen2V2. 1: Enabled = Old PC Word (StoredPC, PacketPC) is compatible with prior versions of Gen2. All bits in the StoredPC are writeable except XI which is set = 0 regardless of the XPC_W1 and XPC_W2 values.
Tamper Function	Tamper detection can be used to modify the normal Tag behavior 00_2: Tamper detection is reported but does not modify the normal Tag behavior 01_2: Tamper detection disables Tag and if tamper detection was logged to NVM it kills the Tag 10_2: RFU 11_2: RFU
TN Reporting	00_2: XPC_W1 TN bits is application defined and is writeable directly through *Write*/*BlockWrite* commands 01_2, 10_2, 11_2: XPC_W1 TN bit is used to report sensing detection as defined in section 5.6
Access Password Untraceable Privilege	Identifies if the Access Password has the Untraceable privilege. This privilege allows an Interrogator authenticated by a nonzero Access Password to use the *Untraceable* command and to read/write untraceably hidden memory 0: Access Password does not have the Untraceable privilege 1: Access Password does have the Untraceable privilege
Access Password TN Privilege	Identifies if the Access Password has the TN privilege. This privilege allows an Interrogator authenticated by a nonzero Access Password to set/clear the TN indicator bit in XPC_W1 0: Access Password does not have the TN privilege 1: Access Password does have the TN privilege
Configuration Lock	Locks System Configuration as described in 6.5.2.1 0: System Configuration Block 1 unlocked 1: System Configuration Block 1 locked
Backscatter configuration	em|aura-sense features two levels of backscatter strengths. Per default, minimum backscatter strength is enabled in order to limit radiated emission power during the tag reply. To increase the read range reverse, max. backscatter strength can be turned on using following configuration bit: 00_2: RFU 01_2: RFU 10_2: Min. backscatter strength 11_2: Max. backscatter strength
RFU	Reserved for Future Use

Table 31 Description of SYS_CONF_W1

Tamper Lock Word

Word 121_h	MSB 0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	LSB F
Description	Tamper Lock Read/Write allowed when System Configuration is locked Read is always 0000_h Write any value to set the Tamper Lock and enable logging of Tamper Alarm into NVM															

Content	Description
Tamper Lock	Once Set, Device is logging Tamper Alarm event into NVM without executing SensAtBoot, if enabled The tamper alarm is logged only once in the NVM for the first tamper alarm event This Lock is permanent and cannot be unset.

Table 32 Description of SYS_TAMPER_LOCK

Sensor Calibration Word

Word 122_h	MSB 0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	LSB F
Description	Calibration Lock	Calibration Margin					RFU		Calibration Data							

Content	Description
Calibration Lock	Lock the calibration data 0: Unlocked – New Calibration Data can be stored. 1: Locked – The calibration Data cannot be changed.
Calibration Margin	Define the margin to be applied for Sensing data reporting and Sensor Detection See 5.1 and 5.6 00000_2: Margin is 0 00001_2: Margin is 1 … 11111_2: Margin is 32
RFU	Reserved for Future Use
Calibration Data	8-bit positive value to be used as reference for Sensing Data reporting. See 5.1.1 Capacitive Measurement

Table 33 Description of SENSOR_CALIB

Sensor Control Word 1

Word 123_h	MSB 0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	LSB F
Description	Sense At Control			RFU												

Content	Description
Sense At Control	Enable the different option to trigger a sensor acquisition. 000_2: No Sensing operation is enable $xx1_2$: Sense At Boot is enabled as described in 5.1.3 $x1x_2$: Sense At *Select* is enabled as described in 5.1.4.1 $1xx_2$: Sense At *Write/BlockWrite* is enabled as described in 5.1.4.2 Note 1: “x” means “don’t care”. Note 2: Any combination of “Sense At Control” is allowed. E.g. Sense At Control = 011_2 will enable Sense At Boot and Sense At *Select* operation,
RFU	Reserved for Future Use

Table 34 Description of SENSOR_CTRL_W1

Sensor Data Stored

Word 124_h	MSB 0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	LSB F
Description	0000_2				11_2		Stored Sensor Data									

Content	Description
Stored Sensor Data	10-bit signed integer stored during Sense and Store operation (see Table 12)

Table 35 Description of SENSOR_DATA_STORED

Extended Pad Control Word

Word 130h	MSB 0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	LSB F
Description	RFU							ExtPadCtrl Lock	ExtPadCtrl At Control			ExtPadCtrl Switch Mode	ExtPadCtrl Off State	ExtPadCtrl Active Pad	RFU	

Content	Description
ExtPadCtrl Lock	Lock the Extended Pad Control Features : 0: Configuration of Extended Pad Control Features is unlocked 1: Configuration of Extended Pad Control Features is locked
ExtPadCtrl At Control	Define the ON state condition for Extended Pad Control Features : $0xx_2$: *AlwaysOff*: The Supply&Switch functionality is always OFF as described in 5.3.2.1 100_2: *AlwaysOn*: The Supply&Switch functionality is ON when tag is powered by UHF wave as described in 5.3.2.2 101_2: *InInventoryRound*: The Supply&Switch functionality is ON when it is participating in the current inventory round meaning the device state is Arbitrate, Reply, Acknowledged, Open, or Secured as described in 5.3.2.3 110_2: *Singulated*: The Supply&Switch functionality is ON when it is singulated meaning the device state is Acknowledged, Open, or Secured as described in 5.3.2.4 111_2: *Selected*: The Supply&Switch functionality is ON when it is selected meaning the Select Flag (SL) is set as described in 5.3.2.5
ExtPadCtrl Switch Mode	Enable Switch mode : 0: Pad Ctrl in supply mode 1: Pad Ctrl in switch mode – Both pads will be connected to same reference when ON
ExtPadCtrl OFF State	Define Pad OFF state : 0: Pad is in High-Z (floating) 1: Pads are reverted
ExtPadCtrl Active Pad	Define which Pad is the active one : 0: Active Pad is SWITCH1 1: Active Pad is SWITCH2
RFU	Reserved for Future Use

Table 36 Description of EXTPADCTRL_CONF

7. PRODUCT LIFE CYCLE

IC Initialization (EM)	• IC Serial Number is written and permalocked • All other memory is unlocked and writeable • EPC/UII memory is 8 blocks • Legacy PC format is disabled • Tamper detection feature is disabled • Disabled (HI-Z, HI-Z) • Access Password does not have the Untraceable nor TN privilege • XPC_W1 TN bit is application defined and is writeable directly through *Write*/*BlockWrite* commands • System Configuration Block 1 unlocked • Sensing is not activated by default • calibration data is Unlocked
⇓	

Inlay Configuration	• Inlay configuration is performed using the air interface:
	  ◦ User specifies if Legacy PC format is enabled/disabled
	  ◦ User specifies if tamper detection feature is enabled/disabled, the tamper loop polarity, and the corresponding tamper functionality
	  ◦ User specifies if the Access Password privilege for Untraceable or TN privilege
	  ◦ User specifies “Sense At Control” or “Extended Pad Control”
	  ◦ User specifies Tag notification and Error reporting if applicable
	  ◦ Configuration lock when appropriate
	  ◦ Tamper detection feature, if enabled, is tested and then activated for logging into NVM

⇓	

Tag/Label Personalization	• Tag/Label personalization (a.k.a. encoding) is performed:
	  ◦ Write application data to EPC/UII memory and, User memory,
	  ◦ Permalock application data as appropriate
	• Password insertion is performed using the air interface:
	• Insert Access Password and Kill Password into memory and permalock

⇓	

Inlay installation	• Application specific product configuration is performed and permalocked if applicable using the air interface:
	  ◦ User specifies if tamper detection feature is enabled/disabled, the tamper loop polarity, and the corresponding tamper functionality
	  ◦ User specifies “Sense At Control” when appropriate
	• Tamper detection feature, if enabled, is tested and then activated for logging into NVM
	• Calibration: User performs a calibration using calibration command as described in Table 12 or by writing in the CalibrationData as described in Table 33.
	• User locks the Calibration or leaves the calibration unlocked

⇓	

Application (End Users or Consumers)	• Operations performed as needed for the application(s) which might include any combination of the following:
	  ◦ Inventory Tag using EPC/UII, or TID
	  ◦ Read/Write application data to/from EPC/UII memory, User memory
	  ◦ Enable/disable privacy features
	  ◦ Drive the pads using Supply&Switch function
	  ◦ Set/clear TN indicator flag
	  ◦ Trigger sensing acquisition
	  ◦ Read/store sensing data
	  ◦ Tamper detection, if enabled
	  ◦ Kill the Tag

8. DELIVERY INFORMATION

8.1. ORDERING INFORMATION

Part Nb	Package form	Delivery form	Description	Sensing	Tamper	Supply &Switch
EM4152V001WS6U	Sawn wafer / Gold bumped + PI : wafer thickness of 6 mils	Sawn wafer	Standard version programmed for capacitive sensing delivery wafer in Gold bump[13)]	√	√	
EM4152V002WS6U	Sawn wafer / Gold bumped + PI : wafer thickness of 6 mils	Sawn wafer	Standard version programmed for external supply and switch functions delivery wafer in Gold bump[13)]			√
EM4152V003WS6U	Sawn wafer / Gold bumped + PI : wafer thickness of 6 mils	Sawn wafer	Standard version programmed for UHF and tamper delivery wafer in Gold bump[13)]		√	

Note 13: standard IC version delivered with gold bumps. Other bumping technologies under discussion

Table 37 Ordering Information

For other delivery formats please contact EM Microelectronics representative

8.2. BUMPED BARE DIE PIN DESCRIPTION

NO.	NAME	I/O TYPE	DESCRIPTION
1	A-	RF	antenna terminal
2	TAMPER_OUT/ SWITCH2	analog	Tamper pad: connected to the tamper loop SWITCH2: connected to the external device for Supply&Switch function Unused in application: HI-Z
3	CAP+	analog	Connection pad to the sensor
4	CAP-	analog	Connection pad to the sensor
5	TAMPER_IN/ SWITCH1	analog	Tamper pad: connected to the tamper loop SWITCH1: connected to the external device for Supply&Switch function Unused in application: HI-Z
6	A+	RF	antenna terminal

Table 38 Pin-out description

8.3. BARE DIE BUMP LOCATION

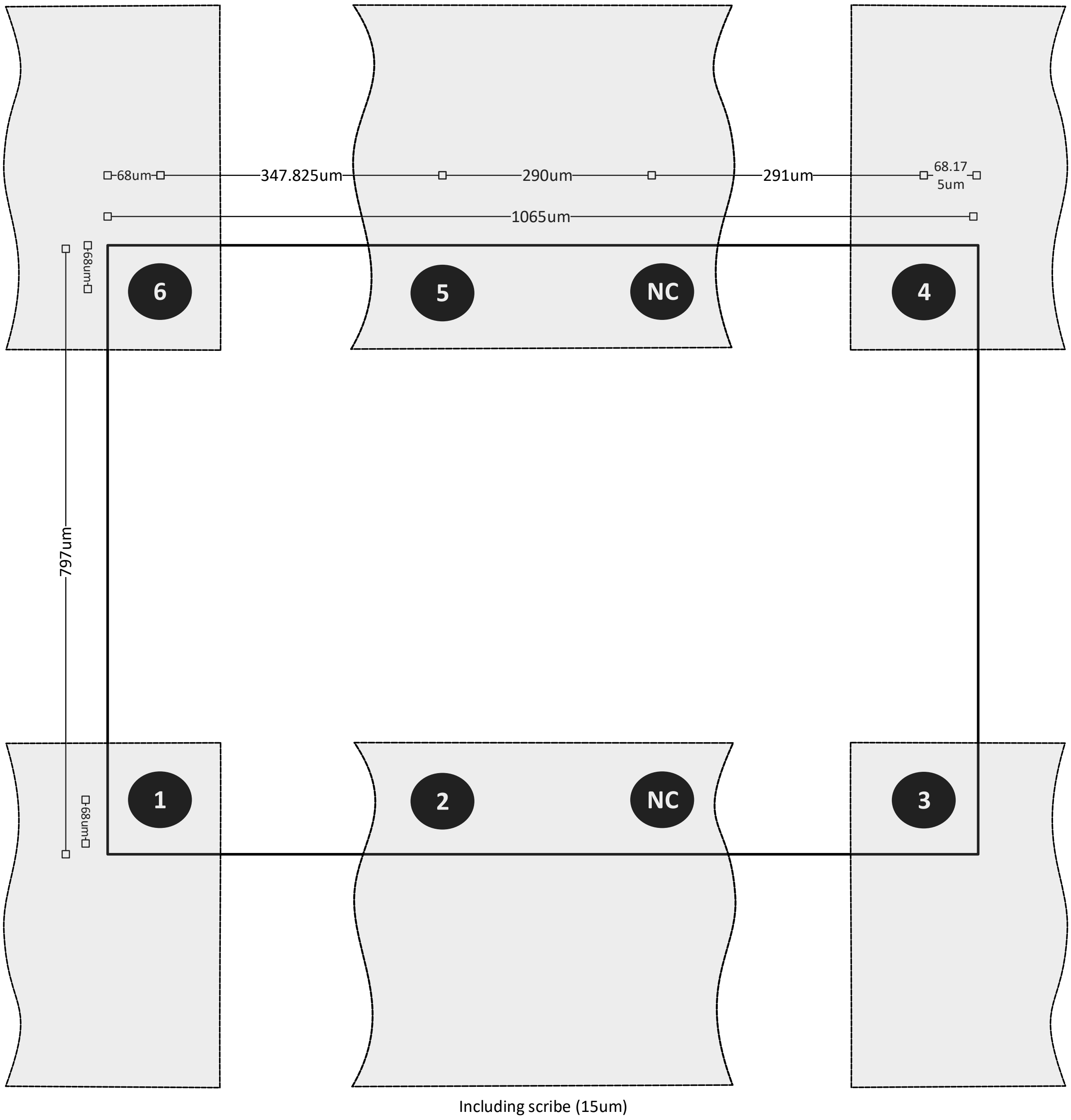

Figure 14 PCB bump position without scribe

Note 14: Bump dimension is 71um
Note 15: NC i.e. Non Connected bumps can be connected to neighboring bumps

9. HANDLING PROCEDURES

This device has built-in protection against high static voltages or electric fields; however, anti-static precautions must be taken as for any other CMOS component. Unless otherwise specified, proper operation can only occur when all terminal voltages are kept within the voltage range. Unused inputs must always be tied to a defined logic voltage level.