SL3 ICS 10

UCODE EPC G2

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1. General description

The EPC global UHF Generation 2 Standard allows the commercialised provision of mass adaption of UHF EPC technology for passive smart tags and labels. Main fields of applications will be especially the supply chain management and logistics for worldwide use with especial consideration of European and US regulations to ensure that operating distances of several meters can be realized.

The UCODE EPC G2 IC is a dedicated chip for passive, intelligent tags and labels supporting the EPCglobal Class 1 Generation 2 UHF RFID standard. It is especially suited for applications where operating distances of several meters and high anti-collision rates are required.

The UCODE EPC G2 IC is a product out of the NXP Semiconductors UCODE product family. The entire UCODE product family offers anti-collision and collision arbitration functionality. This allows a reader to simultaneously operate multiple labels / tags within its antenna field. A UCODE EPC G2 based label / tag requires no external power supply.

Its contactless interface generates the power supply via the antenna circuit by propagative energy transmission from the interrogator (read / write device), while the system clock is generated by an on-chip oscillator. Data transmitted from interrogator to label / tag is demodulated by the interface, and it also modulates the interrogator's electromagnetic field for data transmission from label / tag to interrogator. A label / tag can be operated without the need for line of sight or battery, as long as it is connected to a dedicated antenna for the targeted frequency range. When the label / tag is within the interrogator's operating range, the high-speed wireless interface allows data transmission in both directions.

2. Features

2.1 Key features

- Interface fully compatible with UHF EPC G2 standard
- Long-range solutions
- Suitable for UHF RFID, allowing one IC to be used worldwide
- Fast data rate
- Forward link: 40 - 160 kbits/s
- Return link: 40 - 640 kbits/s
- 512 bit of on-chip memory
- 96 bit EPC
- 64 bit tag Identifier
- 224 bit programmable user memory
- 32 bit access password
- 32 bit kill password
- Runs on the same hardware infrastructure as the UCODE HSL and the UCODE EPC1.19

2.2 Key benefits

- Tags / labels and readers available from various suppliers
- First UHF EPC product operating worldwide
- Highly advanced anti-collision resulting in highest identification speed
- Reliable and robust RFID technology suitable for dense reader and noisy environment
- Secure UHF communication; readers do not transmit EPC data
- Broadest industry back-up – EPCglobal and ISO 18000-6C
- Reader portfolio covers all regional demands

2.3 RF Interface Features

- Contact-less transmission of data and supply energy (no battery needed)
- Long-range operating distance
- Operating frequency within the released operating bands from 860 MHz to 960 MHz
- High data integrity: 16 bit CRC, framing
- High anti-collision and inventory speed
- Data rates:
  - R -> T: 40 – 160 kbps,
  - T -> R: 40 – 465 kbps (Divide ratio DR = 8) or 95 – 640 kbps (DR = 64/3)
- Uses a slotted random anti-collision algorithm where the UCODE EPC G2 IC loads a random (or pseudo-random) number into a slot counter, decrement this slot counter based on interrogator commands, and reply to the interrogator when their slot counter reaches zero. Supports the full mandatory command set as well as optional and Customer commands according to the standard

2.4 Memory Features

- 96 bit EPC numbers supported
- 64 bit tag identifier (TID)
- 32 bit kill password to permanently disable the tag
- 32 bit access password to allow a transition into the secured transmission state
- 224 bit user memory with free definable memory organization
- Inventoried flags and selected flag support the handling of persistence information

2.5 Security Features

- Lock mechanism (write protection) for individual passwords and individual memory banks allow for permanent lock (permalock) status of a password or memory bank.

3.   Applications

- Supply Chain Management
- Asset Management
- Container Identification
- Pallet & Case Tracking

4.   Quick reference data

The SL3 ICS 10 supports global operation in different frequency bands. In principle, the SL3 ICS 10 has no restriction on the operating frequency. Based on regulation requirements the SL3 ICS 10 is released for the following frequency band.

Table 1:   Quick reference data

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
UHF	Frequency band		860	-	960	MHz

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5. Block diagram

The SL3 ICS 10 IC consists of three major blocks:

Analog RF Interface

Digital Controller

EEPROM

The analog part provides stable supply voltage and demodulates data received from the reader for being processed by the digital part. Further, the modulation transistor of the analog part transmits data back to the reader.

The digital section includes the state machines, processes the protocol and handles communication with the EEPROM, which contains the EPC and the user data.
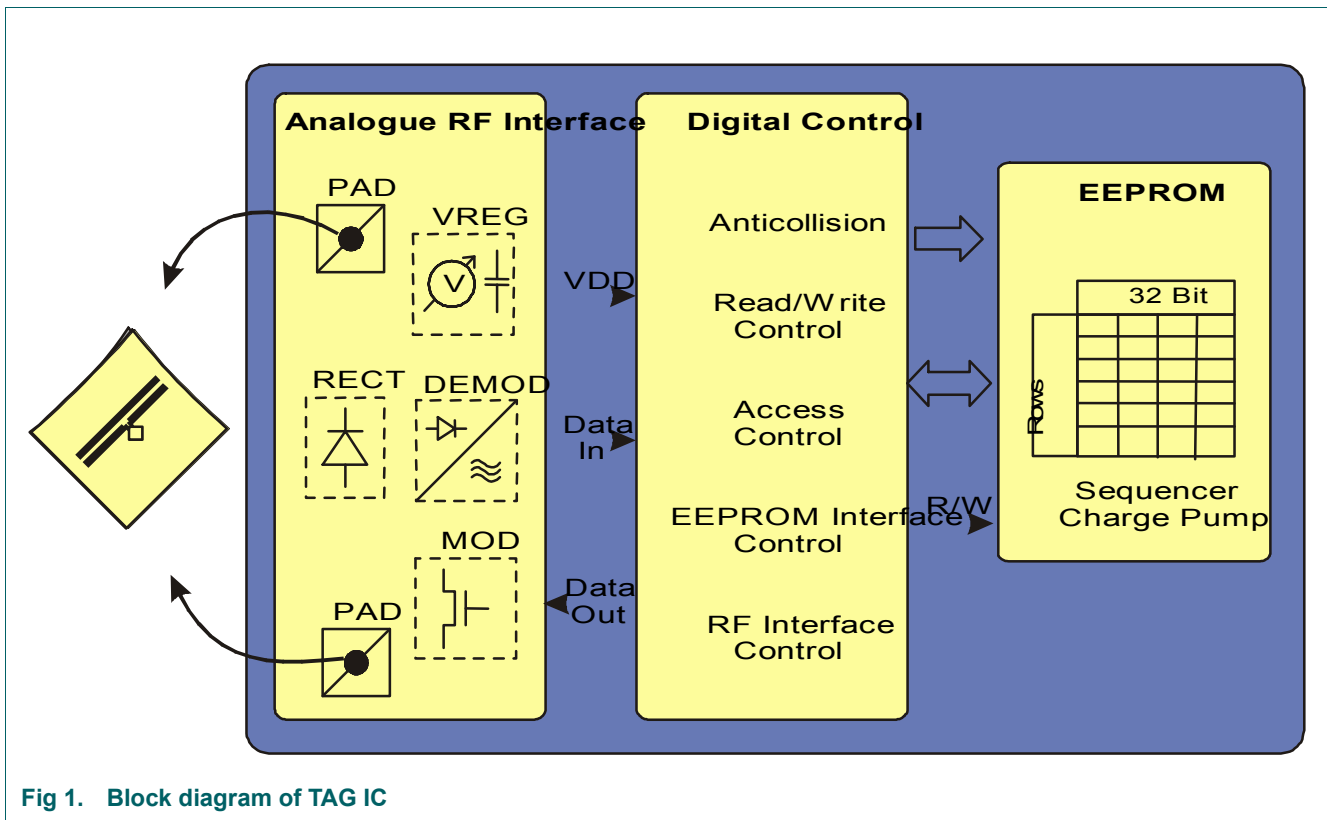

Fig 1. Block diagram of TAG IC

6. Functional description

6.1 Power Transfer

The reader provides an RF field that powers the UCODE EPC G2 tag, which contains the SL3 ICS 10 connected to an antenna. The tag antenna transforms the impedance of free space to the chip input impedance in order to get the maximum possible power for the SL3 ICS 10 on the tag.

The RF field, which is oscillating on the operating frequency provided by the reader, is rectified to provide a smoothed DC voltage to the analog and digital modules of the IC.

The antenna that is attached to the chip may use a DC connection between the two antenna pads. Therefore the UCODE EPC G2 IC also enables loop antenna design. Possible examples of supported antenna structures can be found in the antenna design guide.

6.2 Data Transfer

6.2.1 Reader to tag Link

An interrogator transmits information to the UCODE EPC G2 tag by modulating an RF signal in the 860 MHz – 960 MHz frequency range. The tag receives both information and operating energy from this RF signal. Tags are passive, meaning that they receive all of their operating energy from the interrogator's RF waveform.

An interrogator is using a fixed modulation and data rate for the duration of at least an inventory round. It communicates to the tags by modulating an RF carrier using DSB-ASK, SSB-ASK or PR-ASK with PIE encoding.

For further details refer to Section 11, Ref. 1, section 6.3.1.2. Interrogator-to-tag (R=>T) communications.

6.2.2 Tag to reader Link

An interrogator receives information from the UCODE EPC G2 tag by transmitting a continuous-wave RF signal to the tag; the tag responds by modulating the reflection coefficient of its antenna, thereby backscattering an information signal to the interrogator. The system is reader talks first (RTF) system, meaning that a tag modulates its antenna reflection coefficient with an information signal only after being directed by the interrogator.

UCODE EPC G2 IC backscatter uses a combination of ASK and PSK modulation depending on the tuning and bias point. The backscattered data is either modulated with FM0 baseband or Miller subcarrier.

For further details refer to Section 11, Ref. 1, section 6.3.1.3. tag-to-interrogator (T=>R) communications.

6.3 Operating Distances

RFID tags based on the UCODE EPC G2 SL3 ICS 10 silicon may achieve maximum operating distances according the following formula:

(1)

$$P_{tag} = EIRP \cdot G_{tag}\left(\frac{\lambda}{4\pi R}\right)^{2} \cdot \eta$$

(2)

$$R_{max} = \sqrt{\frac{EIRP \cdot G_{tag} \cdot \lambda^{2}}{(4\pi)^{2} P_{tag}} \cdot \eta}$$

Note:

P_{tag}....Minimum required RF power for the tag

G_{tag}.... Gain of the tag antenna

EIRP   .... Transmitted RF power

λ .... Wavelength

R_{max}....Maximum achieved operating distance for a λ/2-dipole.

η .... Loss factor assumed to be 0.5 considering matching and package losses

Table 2.   **Operating distances for UCODE EPC G2 based tags and labels in released frequency bands**

Frequency range	Region	Available power	Calculated read distance single antenna [4][5]	Unit
868.4 to 868.65 MHz (UHF)	Europe [1]	0.5 W ERP	3.6	m
865.5 to 867.6 MHz (UHF)	Europe [2]	2 W ERP	7.1	m
902 to 928 MHz (UHF)	America [3]	4 W EIRP	7.5	m

[1]   CEPT/ETSI regulations [CEPT1], [ETSI1].

[2]   New CEPT/ETSI regulations. [ETSI3].

[3]   FCC 47 part 15 regulation [FCC1].

[4]   These read distances are maximum values for general tags and labels. Practical usable values may be lower due to damping by object materials and environmental conditions. A special tag antenna design can help achieve higher values.

[5]   The maximum write distance is around 70% of the read distance.

6.4 Air Interface Standards

The SL3 ICS 10 fully supports all parts of the "Specification for RFID Air Interface EPCglobal, EPCTM Radio-Frequency Identity Protocols, Class-1 Generation-2 UHF RFID, Protocol for Communications at 860 MHz – 960 MHz, Version 1.0.9".

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7. Physical Layer and Signaling

The interrogator transmits information to the UCODE EPC G2 tag by modulating an RF signal in the 860 – 960 MHz frequency range. The tag receives both information and operating energy from this RF signal. Tags are passive, meaning that they receive all of their operating energy from the interrogator's RF waveform.

An interrogator receives information from the tag by transmitting a continuous-wave RF signal to the tag; the tag responds by modulating the reflection coefficient of its antenna, thereby backscattering an information signal for the interrogator. The system is RTF (reader talks first), meaning that a tag modulates its antenna coefficient with an information signal only after being directed to do so by an interrogator.

7.1 Reader to Tag Communication

7.1.1 Physical layer

For interrogator-to-tag link modulation refer to Section 11, Ref. 1, annex H.1 Baseband waveforms, modulated RF, and detected waveforms.

7.1.2 Tag population management layer

An Interrogator manages tag populations using three basic operations:

Select: The operation of choosing a tag population for inventory and access. A Select command may be applied successively to select a particular tag population based on user-specified criteria. This operation is analogous to selecting records from a database.

Inventory: The operation of identifying tags. An Interrogator begins an inventory round by transmitting a Query command in one of four sessions. One or more tags may reply. The interrogator detects a single tag reply and requests the PC, EPC, and CRC-16 from the tag. Inventory comprises multiple commands. An inventory round operates in one and only one session at a time.

Access: The operation of communicating with (reading from and/or writing to) a tag. An individual tag must be uniquely identified prior to access. Access comprises multiple commands, some of which employ one-time-pad based cover-coding of the R=>T link.

7.1.3 Modulation

An interrogator sends information to one or more tags by modulating an RF carrier using double-sideband amplitude shift keying (DSB-ASK), single-sideband amplitude shift keying (SSB-ASK) or phase-reversal amplitude shift keying (PR-ASK) using a pulse-interval encoding (PIE) format. Tags receive their operating energy from this same modulated RF carrier.

Section 11, Ref. 1: Annex H, as well as chapter 6.3.1.2.2.

The UCODE EPC G2 IC is capable of demodulating all three modulation types.

7.1.4 Data Encoding

The R=>T link is using PIE. For the definition of the therefore relevant reference time interval for interrogator-to-tag signaling (Tari) refer to Section 11, Ref. 1, chapter 6.3.1.2.3. The Tari is specified as the duration of a data-0.

7.1.5 Data rates

Interrogators shall communicate using Tari values between 6.25 μs and 25 μs, inclusive. For interrogator compliance evaluation the preferred Tari values of 6.25 μs, 12.5 μs or 25 μs should be used. For further details refer to Section 11, Ref. 1, chapter 6.3.1.2.4.

7.1.6 RF Envelope for R=>T

A specification of the relevant RF envelope parameters can be found in Section 11, Ref. 1, chapter 6.3.1.2.5.

7.1.7 Interrogator power-up/down waveform

For a specification of the interrogator power-up and power-down RF envelope and waveform parameters refer to Section 11, Ref. 1, chapters 6.3.1.2.6 and 6.3.1.2.7.

7.1.8 Preamble and frame-sync

An interrogator shall begin all R=>T signaling with either a preamble or a frame-sync. A preamble shall precede a Query command and denotes the start of an inventory round. For a definition and explanation of the relevant R=>T preamble and frame-sync refer to Section 11, Ref. 1, chapter 6.3.1.2.8.

7.2 Tag to reader Communication

An interrogator receives information from a tag by transmitting an unmodulated RF carrier and listening for a backscattered reply. The UCODE EPC G2 IC backscatters by switching the reflection coefficient of its antenna between two states in accordance with the data being sent. For further details refer to Section 11, Ref. 1, chapter 6.3.1.3.

7.2.1 Modulation

The UCODE EPC G2 tags communicate information by backscatter-modulating the amplitude and/or phase of the RF carrier. Interrogators shall be capable of demodulating either demodulation type.

7.2.2 Data Encoding

The encoding format, selected in response to interrogator commands, is either FM0 baseband or Miller-modulated subcarrier. The interrogator commands the encoding choice.

7.2.2.1 FM0 baseband

FM0 inverts the baseband phase at every symbol boundary; a data-0 has an additional mid-symbol phase inversion. For FM0 basis functions and generator state diagram, FM0 symbols and sequences and how FM0 transmissions should be terminated refer to Section 11, Ref. 1, chapter 6.3.1.3.2.1.

7.2.2.2 FM0 Preamble

T=>R FM0 signaling begin with one of two defined preambles, depending on the value of the Trext bit specified in the Query command that initiated the inventory round. For further details refer to Section 11, Ref. 1, chapter 6.3.1.3.2.2.

7.2.2.3 Miller-modulated subcarrier

Baseband Miller inverts its phase between two data-0s in sequence. Baseband Miller also places a phase inversion in the middle of a data-1 symbol. For a detailed explanation of the Miller basis functions, generator state diagram, subcarrier sequences and terminating subcarrier transmissions refer to Section 11, Ref. 1, chapter 6.3.1.3.2.3.

7.2.2.4 Miller subcarrier preamble

T=>R subcarrier signaling begins with one of the two defined preambles. The choice depends on the value of the Trext bit specified in the Query command that initiated the inventory round. For further details refer to Section 11, Ref. 1, chapter 6.3.1.3.2.4.

7.2.3 Data Rates

The SL3 ICS 10 IC supports tag to interrogator data rates and link frequencies as specified in Section 11, Ref. 1, chapter 6.3.1.3.3.

7.3 Link Timing

For the interrogator interacting with a UCODE EPC G2 tag population exact link and response timing requirements must be fulfilled, which can be found in Section 11, Ref. 1, chapter 6.3.1.5.

7.3.1 Regeneration Time

The regeneration time is the time required if a tag is to demodulate the interrogator signal, measured from the last falling edge of the last bit of the tag response to the first falling edge of the interrogator transmission. This time is referred to as T2 and can vary between 3.0 Tpri and 20 Tpri. For a more detailed description refer to Section 11, Ref. 1, chapter 6.3.1.5.

7.3.2 Start-up Time

For a detailed description refer to Section 11, Ref. 1, chapter 6.3.1.3.4.

7.3.3 Persistence Time

An interrogator chooses one of four sessions and inventories tags within that session (denoted S0, S1, S2, and S3). The interrogator and associated UCODE EPC G2 tag population operate in one and only one session for the duration of an inventory round (defined above). For each session, tags maintain a corresponding inventoried flag. Sessions allow tags to keep track of their inventoried status separately for each of four possible time-interleaved inventory processes, using an independent inventoried flag for each process. Two or more interrogators can use sessions to independently inventory a common UCODE EPC G2 tag population.

A session flag indicates whether a tag may respond to an interrogator. Tags maintain a separate inventoried flag for each of four sessions; each flag has symmetric A and B values. Within any given session, interrogators typically inventory tags from A to B followed by a re-inventory of tags from B back to A (or vice versa).

Additionally, the UCODE EPC G2 IC has implemented a selected flag, SL, which an interrogator may assert or deassert using a Select command.

For a description of Inventoried flags S0 – S3 refer to Section 11, Ref. 1 chapter 6.3.2.2 and for a description of the Selected flag refer to Section 11, Ref. 1, chapter 6.3.2.3. For tag flags and respective persistence time refer to Section 11, Ref. 1, table 6.15.

7.4 Bit and Byte Ordering

The transmission order for all R=>T and T=>R communications respects the following conventions:

- within each message, the most-significant word is transmitted first, and
- within each word, the most-significant bit (MSB) is transmitted first,

whereas one word is composed of 16 bits.

To represent memory addresses and mask lengths EBV-8 values are used. An extensible bit vector (EBV) is a data structure with an extensible data range. For a more detailed explanation refer to Section 11, Ref. 1, Annex A.

7.5 Data Integrity

The UCODE EPC G2 IC ignores invalid commands. In general, "invalid" means a command that (1) is incorrect given the current the UCODE EPC G2 IC state, (2) is unsupported by the UCODE EPC G2 IC, (3) has incorrect parameters, (4) has a CRC error, (5) specifies an incorrect session, or (6) is in any other way not recognized or not executable by the UCODE EPC G2 IC. The actual definition of "invalid" is state-specific and defined, for each tag state, in Section 11, Ref. 1 Annex B and Annex C.

All UCODE EPC G2 IC backscatter error codes are summarized in Section 11, Ref. 1 Error codes, Annex I. For a detailed description of the individual backscatter error situations which are command specific please refer to the Section 11, Ref. 1 individual command description section 6.3.2.10.

7.6 CRC

A CRC-16 is a cyclic-redundancy check that an interrogator uses when protecting certain R=>T commands, and the UCODE EPC G2 IC uses when protecting certain backscattered T=>R sequences. To generate a CRC-16 an interrogator or the UCODE EPC G2 IC first generates the CRC-16 precursor shown in Section 11, Ref. 1 Table 6.14, then take the ones-complement of the generated precursor to form the CRC-16. For a detailed description of the CRC-16 generation and handling rules refer to Section 11, Ref. 1, chapter 6.3.2.1.3.

The CRC-5 is only used to protect the Query command (out of the mandatory command set). It is calculated out of $X5 + X3 + 1$. For a more detailed CRC-5 description refer to Section 11, Ref. 1, table 6.17.

For exemplary schematic diagrams for CRC-5 and CRC-16 encoder/decoder refer to Section 11, Ref. 1, Annex F.

For a CRC calculation example refer to Section 9.1, Table 15 and Table 16.

8. TAG Selection, Inventory and Access

This section contains all information including commands by which a reader selects, inventories, and accesses a tag population.

An Interrogator manages UCODE EPC G2 tag populations using three basic operations. Each of these operations comprises one or more commands. The operations are defined as follows:

Select: The process by which an Interrogator selects a tag population for inventory and access. Interrogators may use one or more Select commands to select a particular tag population prior to inventory.

Inventory: The process by which an interrogator identifies UCODE EPC G2 tags. An interrogator begins an inventory round by transmitting a Query command in one of four sessions. One or more tags may reply. The interrogator detects a single tag reply and requests the PC, EPC, and CRC-16 from the tag. An inventory round operates in one and only one session at a time. For an example of an interrogator inventorying and accessing a single tag refer to Section 11, Ref. 1, Annex E.

Access: The process by which an Interrogator transacts with (reads from or writes to) individual tags. An individual tag must be uniquely identified prior to access. Access comprises multiple commands, some of which employ one-time-pad based cover-coding of the R=>T link.

8.1 Tag selection, inventory and access

For a detailed description refer to Section 11, Ref. 1, section 6.3.2.

8.1.1 Tag Memory

For the general memory layout according to the standard Section 11, Ref. 1, refer to Figure 6.17. The tag memory is logically subdivided into four distinct banks.

In accordance to the standard Section 11, Ref. 1, section 6.3.2.1. The tag memory of the SL3 ICS 10 is organized in following 4 memory sections:

- Reserved memory
- EPC memory
- TID memory
- User memory

The logical address of all memory banks begin at zero (00h).

8.1.1.1 Memory Details

Table 3.   Memory Details

Address	Type	Content	Initial [1]	Remark
00h – 1Fh	Reserved	kill password: refer to Section 11, Ref. 1, chapter 6.3.2.1.1	all 00h	unlocked memory
20h – 3Fh	Reserved	access password: refer to Section 11, Ref. 1, chapter 6.3.2.1.2	all 00h	unlocked memory
00h – 0Fh	EPC	CRC-16: refer to Section 11, Ref. 1, chapter 6.3.2.1.3		memory mapped calculated CRC
10h – 14h	EPC	Protocol-control bits: refer to Section 11, Ref. 1, chapter 6.3.2.1.4	all 00h	unlocked memory
15h – 16h	EPC	RFU: refer to Section 11, Ref. 1, chapter 6.3.2.1.4	00b	unlocked memory; to be set to 00b for Class-1 Tags
17h –1Fh	EPC	NSI: refer to Section 11, Ref. 1, chapter 6.3.2.1.4	00h	unlocked memory
20h - 7Fh	EPC	EPC: refer to Section 11, Ref. 1, chapter 6.3.2.1.2.3 or 6.3.2.1.5	undefined [2]	unlocked memory
00h – 07h	TID	allocation class identifier: refer to Section 11, Ref. 1, chapter 6.3.2.1	1110 0010b	locked memory
08h – 13h	TID	tag mask designer identifier: refer to Section 11, Ref. 1, chapter 6.3.2.1	0000 0000 1100b	locked memory
14h – 1Fh	TID	tag model number: refer to Section 11, Ref. 1, chapter 6.3.2.1	TMNR	locked memory
20h – 3Fh	TID	serial number: refer to [Section 11, Ref. 1, chapter 6.3.2.1	SNR	locked memory
00h – DFh	User	user memory: refer to Section 11, Ref. 1, chapter 6.3.2.1	undefined [2]	unlocked memory

[1]   This is the initial memory content when delivered by NXP Semiconductors

[2]   Contents of this memory area is not defined during chip production

8.1.1.2 User Memory

The User Memory bank contains a sequential block of 224 bits of unspecific user data.

Table 4.   Sequential rows of User Memory, each comprised of 4 bytes

Memory row	Byte order / row			
	3	**2**	**1**	**0**
6	User_27	User	User	User
5	User	User	User	User
4	User	User	User	User
3	User	User	User	User
2	User	User	User	User
1	User	User	User	User
0	User	User	User	User_0

8.1.1.3 Supported EPC types

The EPC types are defined in the EPC Tag Standards document from EPCglobal.

These standards define completely that portion of EPC tag data that is standardized, including how that data is encoded on the EPC tag itself (i.e. the EPC Tag Encodings), as well as how it is encoded for use in the information systems layers of the EPC Systems Network (i.e. the EPC URI or Uniform Resource Identifier Encodings).

The EPC Tag Encodings include a Header field followed by one or more Value Fields. The Header field defines the overall length and format of the Values Fields. The Value Fields contain a unique EPC Identifier and optional Filter Value when the latter is judged to be important to encode on the tag itself.

8.1.2 Sessions and inventoried flags

For a description refer to Section 11, Ref. 1, section 6.3.2.2.

8.1.3 Selected flag

For a description refer to Section 11, Ref. 1, section 6.3.2.3.

8.1.4 Tag States and slot counter

For a description refer to Section 11, Ref. 1, section 6.3.2.4.

8.1.5 Tag State Diagram

For a description refer to Section 11, Ref. 1, section 6.3.2.4 Tag states and slot counter.

- Ready state
- Arbitrate state
- Reply state
- Acknowledged state
- Open state
- Secured state
- Killed state
- Slot counter

Please find the Tag state diagram in Section 11, Ref. 1, figure 6.19. Refer also to Section 11, Ref. 1, Annex B for the associated state-transition tables and to Section 11, Ref. 1, Annex C for the associated command-response tables.

8.2 Managing tag populations

For a detailed description on how to manage an UCODE EPC G2 tag population refer to Section 11, Ref. 1, chapter 6.3.2.6.

8.3 Selecting tag populations

For a detailed description of the UCODE EPC G2 tag population selection process refer to Section 11, Ref. 1, section 6.3.2.7.

8.4 Inventorying tag populations

For a detailed description on accessing individual tags based on the UCODE EPC G2 IC refer to Section 11, Ref. 1, section 6.3.2.8.

8.5 Accessing individual tags

For a detailed description on accessing individual tags based on the UCODE EPC G2 IC refer to Section 11, Ref. 1, section 6.3.2.9.

Please find an example inventory and access of a single UCODE EPC G2 tag in Section 11, Ref. 1, Annex E.1.

8.6 Interrogator commands and tag replies

For a detailed description refer to Section 11, Ref. 1, section 6.3.2.10.

8.6.1 Commands

Please find an overview of Interrogator to tag commands in Section 11, Ref. 1, Table 6.16.

Please note that all mandatory commands are implemented on the UCODE EPC G2 IC according to the standard. Additionally the optional commands Access and BlockWrite are supported by the UCODE EPC G2 IC (for details refer to Section 8.10 "Optional Access Command". Besides also customer commands are implemented on the SL3 ICS 10 (for details refer to Section 8.11 "Custom Commands".

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8.6.2 State Transition Tables

The UCODE EPC G2 IC responses to interrogator commands are defined by State Annex B transition tables in Section 11, Ref. 1. Following states are implemented on the UCODE EPC G2 IC:

- Ready, for a description refer to Section 11, Ref. 1, Annex B.1.
- Arbitrate, for a description refer to Section 11, Ref. 1, Annex B.2.
- Reply, for a description refer to Section 11, Ref. 1, Annex B.3.
- Acknowledged, for a description refer to Section 11, Ref. 1, Annex B.4.
- Open, for a description refer to Section 11, Ref. 1, Annex B.5.
- Secured, for a description refer to Section 11, Ref. 1, Annex B.6.
- Killed, for a description refer to Section 11, Ref. 1, Annex B.7.

8.6.3 Command response tables

The UCODE EPC G2 IC responses to interrogator commands are described in following Annex C sections of Section 11, Ref. 1:

- Power-up, for a description refer to Section 11, Ref. 1, Annex C.1.
- Query, for a description refer to Section 11, Ref. 1, Annex C.2.
- QueryRep, for a description refer to Section 11, Ref. 1, Annex C.3.
- QueryAdjust, for a description refer to Section 11, Ref. 1, Annex C.4.
- ACK, for a description refer to Section 11, Ref. 1, Annex C.5.
- NAK, for a description refer to Section 11, Ref. 1, Annex C.6.
- Req_RN, for a description refer to Section 11, Ref. 1, Annex C.7.
- Select, for a description refer to Section 11, Ref. 1, Annex C.8.
- Read, for a description refer to Section 11, Ref. 1, Annex C.9.
- Write, for a description refer to Section 11, Ref. 1, Annex C.10.
- Kill, for a description refer to Section 11, Ref. 1, Annex C.11.
- Lock, for a description refer to Section 11, Ref. 1, Annex C.12.
- Access, for a description refer to Section 11, Ref. 1, Annex C.13.
- BlockWrite, for a description refer to Section 11, Ref. 1, Annex C.14.
- T2 timeout, for a description refer to Section 11, Ref. 1, Annex C.16.
- Invalid command, for a description refer to Section 11, Ref. 1, Annex C.17.

8.6.4 Example data-flow exchange

For data flow-exchange examples refer to Section 11, Ref. 1, Annex K:

- K.1 Overview of the data-flow exchange
- K.2 Tag memory contents and lock-field values
- K.3 Data-flow exchange and command sequence

8.7 Mandatory Select Commands

Select commands select a particular UCODE EPC G2 tag population based on user-defined criteria.

8.7.1 Select

For a detailed description of the mandatory Select command refer to Section 11, Ref. 1, section 6.3.2.10.1.1.

8.8 Mandatory Inventory Commands

Inventory commands are used to run the collision arbitration protocol.

8.8.1 Query

For a detailed description of the mandatory Query command refer to Section 11, Ref. 1, section 6.3.2.10.2.1.

8.8.2 QueryAdjust

For a detailed description of the mandatory QueryAdjust command refer to Section 11, Ref. 1, section 6.3.2.10.2.2.

8.8.3 QueryRep

For a detailed description of the mandatory QueryRep command refer to Section 11, Ref. 1, section 6.3.2.10.2.3.

8.8.4 ACK

For a detailed description of the mandatory ACK command refer to Section 11, Ref. 1, section 6.3.2.10.2.4.

8.8.5 NACK

For a detailed description of the mandatory NACK command refer to Section 11, Ref. 1, section 6.3.2.10.2.5.

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8.9 Mandatory Access Commands

Access commands are used to read or write data from or to the UCODE EPC G2 IC memory. For a detailed description of the mandatory Access command refer to Section 11, Ref. 1, section 6.3.2.10.3.

8.9.1 REQ_RN

Access commands are used to read or write data from or to the UCODE EPC G2 IC memory. For a detailed description of the mandatory Access command refer to Section 11, Ref. 1, section 6.3.2.10.3.1.

8.9.2 READ

For a detailed description of the mandatory Req_RN command refer to Section 11, Ref. 1, section 6.3.2.10.3.2.

8.9.3 WRITE

For a detailed description of the mandatory Write command refer to Section 11, Ref. 1, section 6.3.2.10.3.3.

8.9.4 KILL

For a detailed description of the mandatory Kill command refer to Section 11, Ref. 1, section 6.3.2.10.3.4.

8.9.5 LOCK

For a detailed description of the mandatory Lock command refer to Section 11, Ref. 1, section 6.3.2.10.3.5.

8.10 Optional Access Command

8.10.1 Access

For a detailed description of the optional Access command refer to Section 11, Ref. 1, section 6.3.2.10.3.6.

8.10.2 BlockWrite

For a detailed description of the mandatory BlockWrite command refer to Section 11, Ref. 1, section 6.3.2.10.3.7.

8.11 Custom Commands

8.11.1 BlockLock

BlockLock supports an additional locking mechanism, which allows the locking of individual 32 bit blocks (rows) in the 224 bit User Memory. Once locked these locks cannot be unlocked. Both, the permalock for the User Memory and the state of the individual block locks are checked, before executing a Write or a BlockWrite command addressing the User memory. If either lock applies for the addressed memory, the write command will fail and the response according to Table 8 should be performed.

Each EEPROM row can be addressed by either of the two related WordPointers:

Table 5.   Either of two WordPointers can address one single User Memory row

WordPointer	User EEPROM row
0 or 1	0
2 or 3	1
4 or 5	2
6 or 7	3
8 or 9	4
10 or 11	5
12 or 13	6

If UCODE EPC G2 IC receives a BlockLock, the BlockLock succeeds only in secured state. If a UCODE EPC G2 IC whose addressed EEPROM block (row) is already locked receives a BlockLock, it shall not write to the EEPROM, but backscatter the reply shown in Table 7.

If an interrogator issues a BlockLock command to an UCODE EPC G2 IC whose User memory is permalocked or the WordPointer addresses a nonexistent EEPROM Row, the UCODE EPC G2 IC ignores the entire BlockLock command and instead backscatter an error code.

A BlockLock shall be prepended with a frame-sync.

After issuing a BlockLock an interrogator shall transmit CW for the lesser of TREPLY or 20ms, where TREPLY is the time between the interrogator's BlockLock command and the UCODE EPC G2 tag's backscattered reply. An interrogator may observe several possible outcomes from a BlockLock, depending on the success or failure of the tag's memory-write operation:

- The BlockLock succeeds: After completing the BlockLock a UCODE EPC G2 tag backscatters the reply shown in Table 7 comprising a header (a 0-bit), the tag's handle, and a CRC-16 calculated over the 0-bit and handle. If the interrogator observes this reply within 20ms then the BlockLock completed successfully.

- The tag encounters an error: The UCODE EPC G2 tag backscatters an error code during the CW period rather than the reply shown in Table 7 (see Section 11, Ref. 1, Annex I for error-code definitions and for the reply format

- The BlockLock does not succeed: If the interrogator does not observe a reply within 20ms then the BlockLock did not complete successfully. The interrogator may issue a Req_RN command (containing the tag's handle) to verify that the tag is still in the interrogator's field, and may reissue the BlockLock command.

The UCODE EPC G2 tag's reply to the BlockLock command uses the extended preamble shown in Section 11, Ref. 1, figure 6.11 or figure 6.15), as appropriate (i.e. the tag replies as if TRext=1 regardless of the TRext value in the Query that initiated the round.

Table 6. BlockLock command

	Command	WordPointer	RN	CRC-16
# of bits	16	EBV	16	16
description	11100000 00000000	Corresponding word address for a EE row	handle	

Table 7. Tag reply to a successful BlockLock command

	Header	RN	CRC-16
# of bits	1	16	16
description	0	handle	

Table 8. BlockLock command-response table

Starting State	Condition	Response	Next State
ready	all	–	ready
arbitrate, reply, acknowledged	all	–	arbitrate
open	all	–	open
secured	invalid address or permalocked	Backscatter error code	secured
	valid handle & user memory not locked & row already locked	Backscatter handle	secured
	valid handle & user memory not permalocked	Backscatter handle, when done	secured
	invalid handle	–	secured
killed	all	–	killed

8.11.2 ChangeEAS

ChangeEAS allows an interrogator to set or reset the EAS System Bit. Tags execute ChangeEAS from the secured state.

The ChangeEAS command further includes the tag's handle and a CRC-16. The CRC-16 is calculated over the first command code bit up to the last handle bit. A ChangeEAS shall be prepended with a frame-sync.

If a UCODE EPC G2 tag in the open or secured states receives a ChangeEAS with a valid CRC-16 but an invalid handle, it ignores the ChangeEAS and remains in its current state.

After issuing a ChangeEAS an interrogator shall transmit CW for the lesser of TREPLY or 20ms, where TREPLY is the time between the interrogator's ChangeEAS command and the tag's backscattered reply. An interrogator may observe several possible outcomes from a ChangeEAS, depending on the success or failure of the tag's memory write operation:

- **The Write succeeds:**

  After completing the ChangeEAS a UCODE EPC G2 tag backscatters the reply shown in Table 10 made up of a header (a 0-bit), the tag's handle, and a CRC-16 calculated over the 0-bit and the handle. If the interrogator observes this reply within 20ms then the ChangeEAS completed successfully.

- **The tag encounters an error:**

  The UCODE EPC G2 tag backscatters an error code during the CW period rather than the reply shown in Table 10 (see Section 11, Ref. 1, Annex I for error-code definitions and for the reply format).

- **The Write does not succeed:**

  If the interrogator does not observe a reply within 20ms then the ChangeEAS did not complete successfully. The interrogator may issue a Req_RN command (containing the tag's handle) to verify that the tag is still in the interrogator's field, and may then reissue the ChangeEAS command.

The UCODE EPC G2 tag's reply to a successful ChangeEAS uses the extended preamble, as appropriate. A tag replies as if TRext=1 regardless of the TRext value in the Query that initiated the round.

Table 9.   ChangeEAS command

	Command	ChangeEAS	RN	CRC-16
# of bits	16	1	16	16
description	11100000 00000011	1 ... set EAS system bit 0 ... reset EAS system bit	handle	

Table 10.   Tag reply to a successful ChangeEAS command

	Header	RN	CRC-16
# of bits	1	16	16
description	0	handle	

Table 11.   ChangeEAS command-response table

Starting State	Condition	Response	Next State
ready	all	–	ready
arbitrate, reply, acknowledged	all	–	arbitrate
open	all	–	open
secured	Valid handle	Backscatter handle, when done	secured
	invalid handle	–	secured
killed	all	–	killed

8.11.3   EASAlarm

EASAlarm causes the UCODE EPC G2 IC to backscatter its ALARM code. To enable this command the corresponding prior ChangeEAS command must have been carried out successfully (to set the EAS System Bit).

If the EAS System Bit is set, the UCODE EPC G2 IC backscatters the EAS Code.

If the EAS System Bit is reset, the UCODE EPC G2 IC ignores this command. UCODE EPC G2 tags execute EASAlarm only from the ready state.

EASAlarm includes the following fields:

- DR (TRcal divide ratio) sets the T=>R link frequency as described in Section 11, Ref. 1, section 6.3.1.2.8 and Table 6.11.
- M (cycles per symbol) sets the T=>R data rate and modulation format as shown in Section 11, Ref. 1, Table 6.12.
- TRext chooses whether the T=>R preamble is prepended with a pilot tone as described in Section 11, Ref. 1, sections 6.3.1.3.2.2 and 6.3.1.3.2.4.

Interrogators shall prepend a EASAlarm with a preamble (see Section 11, Ref. 1, section 6.3.1.2.8).

The EAS Code is generated by means of the CRC-5 generator. Upon receiving an EASAlarm, the CRC-5 register is preloaded with b01001. To generate the 64 bit code the register is clocked 64 times with its input fixed to logic 1. The EAS Code is derived from the so-generated sequence by taking the MSBit of the CRC-5 register value at each clock cycle.

The UCODE EPC G2 tag's reply to an EASAlarm is protected by an CRC-16, calculated from the header bit to the last EAS code bit.

Table 12.   EASAlarm command

	Command	Inv_Command	DR	M	Trext	CRC-16
# of bits	16	16	1	2	1	16
description	11100000 00000100	00011111 11111011	0: DR=8 1: DR=64/3	00: M=1 01: M=2 10: M=4 11: M=8	0: No pilot tone 1: Use pilot tone	

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Table 13.   Tag reply to a successful EASAlarm command

	Header	EAS Code	CRC-16
# of bits	1	64	16
description	0	CRC5(MSB)	

Table 14.   EASAlarm command-response table

Starting State	Condition	Response	Next State
ready	EAS System Bit is set	Backscatter Alarm code	ready
	EAS System Bit is reset	–	ready
arbitrate, reply, acknowledged, open, secured[1]	EAS System Bit is set	-	arbitrate
killed	all	–	killed

[1]   If EAS EEPROM system bit is reset, ignore this command.

9. Support information

9.1 CRC Calculation EXAMPLE

old RN = 3D5Bh

Table 15. Practical example of CRC calculation for a 'Req_RN' command by the reader

CRC Calculated @ Reader

		F	F	F	F	
Cmd Code for Req_RN	1	F	F	F	E	
	1	F	F	F	C	
	0	E	F	D	9	
	0	C	F	9	3	
	0	8	F	0	7	
	0	0	E	2	F	
	0	1	C	5	E	
	1	**2**	**8**	**9**	**9**	
First Byte of RN	0	5	1	3	A	
	0	A	2	7	4	
	1	4	4	E	8	
	1	9	9	F	1	
	1	3	3	E	2	
	1	7	7	E	5	
	0	E	F	C	A	
	1	**D**	**F**	**9**	**4**	
Second Byte of RN	0	A	F	0	9	
	1	5	E	1	2	
	0	B	C	2	4	
	1	7	8	4	8	
	1	E	0	B	1	
	0	D	1	4	3	
	1	A	2	8	6	
	1	**4**	**5**	**0**	**C**	**-> ones complement:** **B A F 3**

=> Command-Sequence: C1 3D 5B BA F3 hex

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Table 16. Practical example of CRC calculation for a 'Req_RN' command by the reader

CRC Calculated @ Tag

		F	F	F	F
Cmd Code for Req_RN	1	F	F	F	E
	1	F	F	F	C
	0	E	F	D	9
	0	C	F	9	3
	0	8	F	0	7
	0	0	E	2	F
	0	1	C	5	E
	1	**2**	**8**	**9**	**9**
First Byte of RN	0	5	1	3	A
	0	A	2	7	4
	1	4	4	E	8
	1	9	9	F	1
	1	3	3	E	2
	1	7	7	E	5
	0	E	F	C	A
	1	**D**	**F**	**9**	**4**
Second Byte of RN	0	A	F	0	9
	1	5	E	1	2
	0	B	C	2	4
	1	7	8	4	8
	1	E	0	B	1
	0	D	1	4	3
	1	A	2	8	6
	1	**4**	**5**	**0**	**C**
First Byte of CRC	1	9	A	3	9
	0	2	4	5	3
	1	5	8	8	7
	1	A	1	2	F
	1	4	2	5	E
	0	8	4	B	C
	1	0	9	7	8
	0	**1**	**2**	**F**	**0**
Second Byte of CRC	1	3	5	C	1
	1	7	B	A	3
	1	E	7	6	7
	1	C	E	C	E
	0	8	D	B	D
	0	0	B	5	B
	1	0	6	9	7
	1	**1**	**D**	**0**	**F**	**-> Residue OK**

10. Abbreviations

Table 17. Abbreviations

Acronym	Description
CRC	Cyclic redundancy check
CW	continuos wave
EEPROM	Electrically Erasable Programmable Read Only Memory
EPC	Electronic Product Code (containing Header, Domain Manager, Object Class and Serial Number)
FM0	Bi phase space modulation
G2	Generation 2
IC	Integrated Circuit
LSB	Least Significant Byte/bit
MSB	Most Significant Byte/bit
NRZ	Non-return to zero coding
RF	Radio Frequency
RTF	Reader Talks First
Tari	Type A Reference Interval (ISO 18000-6)
UHF	Ultra High Frequency
xx_{hex}	Value in hexadecimal notation

11. References

The following referenced documents are indispensable to the application of this specification. For dated references, only the edition cited applies. For undated references, the latest edition (including any amendments) applies.

[1] EPCglobal: EPC Radio-Frequency Identity Protocols Class-1 Generation-2 UHF RFID Protocol for Communications at 860 MHz – 960 MHz, Version 1.0.9 Ref. 1

[2] EPCglobal: EPC Tag Data Standards

[3] EPCglobal (2004): FMCG RFID Physical Requirements Document (draft)

[4] EPCglobal (2004): Class-1 Generation-2 UHF RFID Implementation Reference (draft)

[5] European Telecommunications Standards Institute (ETSI), EN 302 208: Electromagnetic compatibility and radio spectrum matters (ERM) – Radio-frequency identification equipment operating in the band 865 MHz to 868 MHz with power levels up to 2 W, Part 1 – Technical characteristics and test methods

[6] European Telecommunications Standards Institute (ETSI), EN 302 208: Electromagnetic compatibility and radio spectrum matters (ERM) – Radio-frequency identification equipment operating in the band 865 MHz to 868 MHz with power levels up to 2 W, Part 2 – Harmonized EN under article 3.2 of the R&TTE directive

[7] [CEPT1]: CEPT REC 70-03 Annex 1

[8] [ETSI1]: ETSI EN 330 220-1, 2

[9] [ETSI3]: ETSI EN 302 208-1, 2 V<1.1.1> (2004-09-Electromagnetic compatibility And Radio spectrum Matters (ERM) Radio Frequency Identification Equipment operating in the band 865 - MHz to 868 MHz with power levels up to 2 W Part 1: Technical characteristics and test methods.

[10] [FCC1]: FCC 47 Part 15 Section 247

[11] ISO/IEC Directives, Part 2: Rules for the structure and drafting of International Standards

[12] ISO/IEC 3309: Information technology – Telecommunications and information exchange between systems – High-level data link control (HDLC) procedures – Frame structure

[13] ISO/IEC 15961: Information technology, Automatic identification and data capture – Radio frequency identification (RFID) for item management – Data protocol: application interface

[14] ISO/IEC 15962: Information technology, Automatic identification and data capture techniques – Radio frequency identification (RFID) for item management – Data protocol: data encoding rules and logical memory functions

[15] ISO/IEC 15963: Information technology — Radio frequency identification for item management — Unique identification for RF tags

[16] ISO/IEC 18000-1: Information technology — Radio frequency identification for item management — Part 1: Reference architecture and definition of parameters to be standardized

[17] ISO/IEC 18000-6: Information technology automatic identification and data capture techniques — Radio frequency identification for item management air interface — Part 6: Parameters for air interface communications at 860–960 MHz

[18] ISO/IEC 19762: Information technology AIDC techniques – Harmonized vocabulary – Part 3: radio-frequency identification (RFID)

[19] U.S. Code of Federal Regulations (CFR), Title 47, Chapter I, Part 15: Radio-frequency devices, U.S. Federal Communications Commission.

12. Revision history

Table 18.   Revision history

Document ID	Release date	Data sheet status	Change notice	Doc. number	Supersedes
Modifications:	7 September 2006	Product data sheet	-	109930	Revision 2.0

- The format of this data sheet has been redesigned to comply with the new identity guidelines of NXP Semiconductors.
- Legal texts have been adapted to the new company name where appropriate.
- Section 2.1 "Key features" on page 2:
  - Long-range solutions; removed: "($\geq$ 7.5 m in the US and 7.1 m in Europe)"
- Section 2.3 "RF Interface Features" on page 2:
  - Operating distance, depending on antenna geometry and local regulation; removed: "$\geq$ 7.5 m for a single antenna"
- Section 6.3 "Operating Distances" on page 7:
  - rewording Note of "η"
- Section 7.3 "Link Timing" on page 10:
  - corrected reference "Section 11, Ref. 1, chapter 6.3.1.6 to "**chapter 6.3.1.5**"
- Section 7.3.1 "Regeneration Time" on page 10:
  - corrected reference "Section 11, Ref. 1, chapter 6.3.1.6 to "**chapter 6.3.1.5**"
- Section 7.3.3 "Persistence Time" on page 10:
  - corrected reference "Section 11, Ref. 1, table 6.14 to "**table 6.15**"
- Section 7.6 "CRC" on page 11:
  - corrected references "Section 11, Ref. 1, table 6.11 to "**table 6.14**" and Section 11, Ref. 1, table 6.12 to "**table 6.17** " and added in: For a CRC calculation example refer to Section 9.1, "**Table 15 and Table 16**".
- Section 8.1.1.1 "Memory Details" on page 13:
  - Table 3: corrected references, address of EPC: 20h - 80h to "**20h - 7Fh**" and Initial of TID: 0000 0000 01b to"**TMNR**"
- Section 8.6.2 "State Transition Tables" on page 16:
  - added in the first paragraph "**Annex B**"
- Section 8.6.3 "Command response tables" on page 16:
  - added in the first paragraph "**Annex C**"
- Section 8.6.4 "Example data-flow exchange" on page 16:
  - added in the first paragraph "**Annex K**"
- Section 8.11 "Custom Commands" on page 19:
  - renamed Section title
- Section 8.11.3 "EASAlarm" on page 22:
  - corrected references of Table 6.9 to "**Table 6.11**" and Table 6.10 to "**Table 6.12**"
- Section 11 "References" on page 27:
  - corrected in reference [1]: Version 1.1.0 -> "Version 1.0.9"

Document ID	Release date	Data sheet status	Change notice	Doc. number	Supersedes
Modifications:	29 June 2006	Preliminary data sheet	-	109920	Revision 1.2

Table 18. Revision history *…continued*

Document ID	Release date	Data sheet status	Change notice	Doc. number	Supersedes
		• Section 2.1 "Key features" on page 2: - corrected: Long-range solutions (up to 7 m in the US and 6.6 m in Europe) to "($\geq$ 7.**5 m in the US and 7.1 m in Europe**)"			
		• Section 2.3 "RF Interface Features" on page 2: - corrected: Operating distance, depending on antenna geometry and local regulations, up to 7 m for a single antenna ->"$\geq$ **7.5 m for a single antenna**"			
		• Section 6.3 "Operating Distances" on page 7: - corrected formula of: "P_{tag} and R_{max}" and rewording Note of "R_{max}" and added Note "η"			
		• Section 7.3 "Link Timing" on page 10: - corrected reference "Section 11, Ref. 1, chapter 6.3.1.5 to "**chapter 6.3.1.6**"			
		• Section 7.3.1 "Regeneration Time" on page 10: - corrected reference "Section 11, Ref. 1, chapter 6.3.1.5 to "**chapter 6.3.1.6**"			
		• Section 7.3.2 "Start-up Time" on page 10: - corrected reference "Section 11, Ref. 1, chapter 6.3.2.16 and 6.3.2.1.7 to "**chapter 6.3.1.3.4**"			
		• Section 7.3.3 "Persistence Time" on page 10: - corrected reference "Section 11, Ref. 1, table 6.25 to "**table 6.14**"			
		• Section 7.5 "Data Integrity" on page 11: - corrected references "Section 11, Ref. 1, table 6.14 to "**table 6.11**" and Section 11, Ref. 1, table 6.17 to "**table 6.12**"			
		• Section 7.6 "CRC" on page 11: - corrected references "Section 11, Ref. 1, chapter 6.3.1.5 -> "**chapter 6.3.2.1.3**"			
		• Section 8.1.1 "Tag Memory" on page 12: - rewording and corrected references			
		• Section 8.1.1.1 "Memory Details" on page 13: - Table 3: corrected references, address of EPC: 20h - 5Fh to "**20h - 80h**" and Initial of TID: 0000 0000 01b to "**0000 0000 1100**b"			
		• Section 8.4 "Inventorying tag populations" on page 15: - corrected references			
		• Section 8.6.3 "Command response tables" on page 16: - removed "BlockErase"			
		• Section 8.9.1 "REQ_RN" on page 18: - corrected reference			
		• Section 8.9.2 "READ" on page 18: - corrected reference			
		• Section 8.11.2 "ChangeEAS" on page 21: - Table 9: corrected "ChangeEAS'			
		• Section 8.11.3 "EASAlarm" on page 22: - corrected references of Table 6.11 to "**Table 6.9**" and Table 6.12 to "**Table 6.10**" - Table 8 "BlockLock command-response table" on page 20: rewording conditions of secured			
Modifications:	20 February 2006	Objective data sheet	-	109912	Revision 1.1
		• Section 6.1 "Power Transfer" on page 6: - rewording last paragraph: "**The antenna that is attached** ....."			
		• Section 7.1.5 "Data rates" on page 9: - corrected following values of: 6.25 s, 12.5 s, 25 s -> "μs"			

13. Legal information

13.1 Data sheet status

Document status[1][2]	Product status[3]	Definition
Objective [short] data sheet	Development	This document contains data from the objective specification for product development.
Preliminary [short] data sheet	Qualification	This document contains data from the preliminary specification.
Product [short] data sheet	Production	This document contains the product specification.

[1] Please consult the most recently issued document before initiating or completing a design.

[2] The term 'short data sheet' is explained in section "Definitions".

[3] The product status of device(s) described in this document may have changed since this document was published and may differ in case of multiple devices. The latest product status information is available on the Internet at URL http://www.nxp.com.

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15. Tables

16. Figures

17. Contents

Please be aware that important notices concerning this document and the product(s) described herein, have been included in section 'Legal information'.

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