INTERNATIONAL STANDARD

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Information technology — Radio frequency identification for item management —

Part 64: Parameters for air interface communications at 860 MHz to 960 MHz Type D

Technologies de l'information — Identification par radiofréquence (RFID) pour la gestion d'objets —

Partie 64: Paramètres de communications d'une interface radio entre 860 MHz et 960 MHz, Type D

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Foreword

ISO (the International Organization for Standardization) and IEC (the International Electrotechnical Commission) form the specialized system for worldwide standardization. National bodies that are members of ISO or IEC participate in the development of International Standards through technical committees established by the respective organization to deal with particular fields of technical activity. ISO and IEC technical committees collaborate in fields of mutual interest. Other international organizations, governmental and non-governmental, in liaison with ISO and IEC, also take part in the work. In the field of information technology, ISO and IEC have established a joint technical committee, ISO/IEC JTC 1.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of the joint technical committee is to prepare International Standards. Draft International Standards adopted by the joint technical committee are circulated to national bodies for voting. Publication as an International Standard requires approval by at least 75 % of the national bodies casting a vote.

ISO/IEC 18000-64 was prepared by Joint Technical Committee ISO/IEC JTC 1, *Information technology*, Subcommittee SC 31, *Automatic identification and data capture techniques*.

ISO/IEC 18000 consists of the following parts, under the general title *Information technology — Radio frequency identification for item management*:

— *Part 1: Reference architecture and definition of parameters to be standardized*

— *Part 2: Parameters for air interface communications below 135 kHz*

— *Part 3: Parameters for air interface communications at 13,56 MHz*

— *Part 4: Parameters for air interface communications at 2,45 GHz*

— *Part 6: Parameters for air interface communications at 860 MHz to 960 MHz General*

— *Part 61: Parameters for air interface communications at 860 MHz to 960 MHz Type A*

— *Part 62: Parameters for air interface communications at 860 MHz to 960 MHz Type B*

— *Part 63: Parameters for air interface communications at 860 MHz to 960 MHz Type C*

— *Part 64: Parameters for air interface communications at 860 MHz to 960 MHz Type D*

— *Part 7: Parameters for active air interface communications at 433 MHz*

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Introduction

This part of ISO/IEC 18000 describes a passive backscatter radio frequency identification (RFID) system that supports the following system capabilities:

- identification and communication with multiple tags in the field;
- reading from individual tags;
- data integrity protection;
- tag-to-Interrogator communications link with error detection;
- support for both passive back-scatter tags with or without batteries.

This part of ISO/IEC 18000 specifies the physical and logical requirements for a passive-backscatter, RFID system operating in the 860 MHz to 960 MHz frequency range. The system comprises Interrogators, also known as readers, and tags, also known as labels.

An Interrogator transmits a continuous-wave (CW) RF signal in the 860 MHz to 960 MHz frequency range. The tag receives operating energy from this RF signal and responds by modulating the reflection coefficient of its antenna, thereby backscattering an information signal to the Interrogator. Passive tags are those which receive all of their operating energy from the Interrogator's RF waveform. If tags maintain a battery then they may operate using some passive principles; however, they do not necessarily get all their operating energy from the Interrogator's RF waveform.

This part of ISO/IEC 18000 contains an optional Tag Only Talks After Listening (TOTAL), an enhanced Tag Talks Only (TTO) technique. A Type D tag shall announce itself when it detects CW emitted by an Interrogator, only after it has detected the absence of ITF modulation as defined in ISO/IEC 18000 part 6. Type D uses Pulse-Position Encoding (PPE) or Miller encoding in the return link and does not define a dedicated forward link. Tags may implement a forward link of one of the types defined in ISO/IEC 18000 part 6 in order to allow enhanced tag access techniques.

The International Organization for Standardization (ISO) and International Electrotechnical Commission (IEC) draw attention to the fact that it is claimed that compliance with this document may involve the use of patents concerning radio frequency identification technology.

ISO and IEC take no position concerning the evidence, validity and scope of these patent rights.

The holders of these patent rights have assured ISO and IEC that they are willing to negotiate licences under reasonable and non-discriminatory terms and conditions with applicants throughout the world. In this respect, the statements of the holders of these patent rights are registered with ISO and IEC.

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Information technology — Radio frequency identification for item management —

Part 64:
Parameters for air interface communications at 860 MHz to 960 MHz Type D

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1 Scope

This part of ISO/IEC 18000 defines the air interface for radio frequency identification (RFID) devices operating in the 860 MHz to 960 MHz Industrial, Scientific, and Medical (ISM) band used in item management applications. It provides a common technical specification for RFID devices that can be used by ISO committees developing RFID application standards. This part of ISO/IEC 18000 is intended to allow for compatibility and to encourage inter-operability of products for the growing RFID market in the international marketplace. It defines the forward and return link parameters for technical attributes including, but not limited to, operating frequency, operating channel accuracy, occupied channel bandwidth, maximum effective isotropic radiated power (EIRP), spurious emissions, modulation, duty cycle, data coding, bit rate, bit rate accuracy, bit transmission order, and, where appropriate, operating channels, frequency hop rate, hop sequence, spreading sequence, and chip rate. It further defines the communications protocol used in the air interface.

This part of ISO/IEC 18000 specifies the physical and logical requirements for a passive-backscatter, Tag Only Talks After Listening (TOTAL) RFID system. The system comprises Interrogators, also known as readers, and tags, also known as labels. An Interrogator receives information from a tag by transmitting a continuous-wave (CW) 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 TOTAL, meaning that a tag modulates its antenna reflection coefficient with an information signal upon entering an Interrogator's field after first listening for Interrogator modulation in order to determine if the system is ITF or not.

In detail, this part of ISO/IEC 18000 contains Type D.

Type D is TOTAL based on Pulse Position Encoding or Miller M=2 encoded subcarrier.

This part of ISO/IEC 18000 specifies

- physical interactions (the signalling layer of the communication link) between Interrogators and tags,
- Interrogator and tag operating procedures,
- the collision arbitration scheme used to identify a specific tag in a multiple-tag environment.

2 Conformance

2.1 Claiming conformance

To claim conformance with this part of ISO/IEC 18000, an Interrogator or tag shall comply with all relevant clauses of this part of ISO/IEC 18000, except those marked as “optional”. The Interrogator or tag shall also operate within local radio regulations, which can further restrict operation.

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Relevant conformance test methods are provided in ISO/IEC TR 18047-6.

Conformance can also require a license from the owner of any intellectual property utilized by said device.

2.2 Interrogator conformance and obligations

To conform to this part of ISO/IEC 18000, an Interrogator shall

— support Type D;

— receive/demodulate a sufficient set of the electrical signals defined in the signalling layer of this part of ISO/IEC 18000 to communicate with conformant tags; and

— operate within the applicable local regulations.

To conform to this part of ISO/IEC 18000, an Interrogator may

— implement one of the types defined in ISO/IEC 18000 part 6 or proprietary commands in order to allow enhanced tag access techniques.

2.3 Tag conformance and obligations

To conform to this part of ISO/IEC 18000, a tag shall:

— support Type D;

— operate over the frequency range from 860 MHz to 960 MHz, inclusive;

— modulate a backscatter signal only after listening for the absence of ITF modulation; and

— conform to local radio regulations.

To conform to this part of ISO/IEC 18000, a tag may

— implement one of the types defined ISO/IEC 18000 part 6 or proprietary commands in order to allow enhanced tag access techniques.

To conform to this part of ISO/IEC 18000, a tag shall not:

— modulate a backscatter signal before listening for the absence of ITF modulation as defined in ISO/IEC 18000 part 6.

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3 Normative references

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

ISO/IEC 7816-6, *Identification cards — Integrated circuit cards — Part 6: Interindustry data elements for interchange*

ISO/IEC 15961, *Information technology — Radio frequency identification (RFID) for item management — Data protocol: application interface*

ISO/IEC 15962, *Information technology — Radio frequency identification (RFID) for item management — Data protocol: data encoding rules and logical memory functions*

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ISO/IEC 15963, *Information technology — Radio frequency identification for item management — Unique identification for RF tags*

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

ISO/IEC 19762 (all parts), *Information technology — Automatic identification and data capture (AIDC) techniques — Harmonized vocabulary*

EPCglobal Tag Data Standards version 1.5 and above, EPCglobal Inc.

4 Terms, definitions, symbols and abbreviated terms

4.1 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO/IEC 19762 (all parts) and the following apply.

4.1.1
collision arbitration
algorithm used to prepare for and handle a dialogue between an Interrogator and a tag

4.1.2
physical layer
data coding and modulation waveforms used in Interrogator-to-tag and tag-to-Interrogator signalling

4.1.3
battery assistance
battery support for radio frequency communication

4.1.4
battery assisted mode
working mode of battery-assisted tags with non-empty battery

4.1.5
passive mode
working mode of passive tags or battery assisted tags with battery drained below a manufacturer-specific threshold

4.1.6
Simple Sensors
sensors that are factory programmed and not user configurable, producing a single output observation such as a fail/pass condition or simple measurement of a particular sensor activity

4.1.7
Simple Sensor functionality
functionality whereby sensors provide a valid Simple Sensor data address and transmit Simple Sensor data subsequent to the UII as part of the reply to the *ACK* command (Type C) or as part of the TagMsg (Type D)

4.2 Symbols

BAP	battery assisted passive
BLF	backscatter-link frequency
Cht	carrier high-level tolerance

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Clt	carrier low-level tolerance
Tcf	carrier fall time
Tcr	carrier rise time
Tfhf	carrier FHSS fall time
Tfhr	carrier FHSS rise time
Tfhs	carrier FHSS steady time
UII	unique item identifier
$xxxx_2$	binary notation
$xxxx_h$	hexadecimal notation

4.3 Abbreviated terms

AFI	application family identifier
BAP	battery assisted passive
CRC	cyclic redundancy check
CRC-16	sixteen bit CRC
CRC-5	five bit CRC
CW	continuous wave
DSFID	data storage format identifier
DSSS	direct sequence spread spectrum
EPC™	electronic product code
FCC	Federal Communications Commission
FHSS	frequency hopping spread spectrum
ITF	Interrogator-talks-first NOTE The common usage is RTF (Reader-talks-first) but the more precise term is ITF, which is used throughout this part of ISO/IEC 18000.
LSB	least significant bit
MSB	most significant bit
PPE	pulse position encoding
RFU	reserved for future use
SDT	symbol detect time
SS	Simple Sensor
SSD	simple sensor data
TID	tag-identification or tag identifier, depending on context
TOTAL	tag only talks after listening
TTF	tag talks first
TTO	tag talks only
Word	16 bits

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5 Overview

5.1 Parameter tables

Table 1, Table 2, Table 3 and Table 4 contain the parameters for Type D in accordance with ISO/IEC 18000-1. Detailed description of the operating modes and parameters are specified in the subsequent clauses.

Table 1 — Interrogator to tag link parameters

Ref.	Parameter Name	Description
Int:1	Operating Frequency Range	860 MHz – 960 MHz, as required by the local regulations
Int:1a	Default Operating Frequency	In accordance with the local radio regulations.
Int:1b	Operating Channels (spread-spectrum systems)	In accordance with the local radio regulations.
Int:1c	Operating Frequency Accuracy	In accordance with the local radio regulations.
Int:1d	Frequency Hop Rate (frequency-hopping [FHSS] systems)	In accordance with the local radio regulations.
Int:1e	Frequency Hop Sequence (frequency-hopping [FHSS] systems)	In accordance with the local radio regulations.
Int:2	Occupied Channel Bandwidth	In accordance with the local regulations
Int:2a	Minimum Receiver Bandwidth	In accordance with the local regulations
Int:3	Interrogator Transmit Maximum EIRP	In accordance with the local regulations
Int:4	Interrogator Transmit Spurious Emissions	In accordance with the local radio regulations.
Int:4a	Interrogator Transmit Spurious Emissions, In-Band (spread-spectrum systems)	Not applicable.
Int:4b	Interrogator Transmit Spurious Emissions, Out-of-Band	In accordance with the local radio regulations.
Int:5	Interrogator Transmitter Spectrum Mask	Not applicable.
Int:6	Timing	Not applicable.
Int:6a	Transmit-to-Receive Turn-Around Time	Not applicable.
Int:6b	Receive-to-Transmit Turn-Around Time	Not applicable.
Int:6c	Dwell Time or Interrogator Transmit Power-On Ramp	1500 µs, maximum settling time
Int:6d	Decay Time or Interrogator Transmit Power-Down Ramp	Not applicable.
Int:7	Modulation	Not applicable.
Int:7a	Spreading Sequence (direct-sequence [DSSS] systems)	Not applicable.
Int:7b	Chip Rate (spread-spectrum systems)	Not applicable.
Int:7c	Chip Rate Accuracy (spread-spectrum systems)	Not applicable.
Int:7d	Modulation Depth	Not applicable.

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Ref.	Parameter Name	Description
Int:7e	Duty Cycle	Not applicable.
Int:7f	FM Deviation	Not applicable.
Int:8	Data Coding	Not applicable.
Int:9	Bit Rate	Not applicable.
Int:9a	Bit Rate Accuracy	Not applicable.
Int:10	Interrogator Transmit Modulation Accuracy	Not applicable.
Int:11	Preamble	Not applicable.
Int:11a	Preamble Length	Not applicable.
Int:11b	Preamble Waveform(s)	Not applicable.
Int:11c	Bit Sync Sequence	Not applicable.
Int:11d	Frame Sync Sequence	Not applicable.
Int:12	Scrambling (spread-spectrum systems)	Not applicable.
Int:13	Bit Transmission Order	Not applicable.
Int:14	Wake-up process	Not applicable.
Int:15	Polarization	Not applicable.

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Table 2 — Tag to Interrogator link parameters

Ref.	Parameter Name	Description
Tag:1	Operating Frequency Range	860 MHz – 960 MHz, inclusive
Tag:1a	Default Operating Frequency	The tag shall respond to an Interrogator signal within the frequency range specified in Tag: 1.
Tag:1b	Operating Channels (spread-spectrum systems)	The tag shall respond to an Interrogator signal within the frequency range specified in Tag: 1.
Tag:1c	Operating Frequency Accuracy	The tag shall respond to an Interrogator signal within the frequency range specified in Tag: 1.
Tag:1d	Frequency Hop Rate (frequency-hopping [FHSS] systems)	Not applicable.
Tag:1e	Frequency Hop Sequence (frequency-hopping [FHSS] systems)	Not applicable.
Tag:2	Occupied Channel Bandwidth	In accordance with the local regulations
Tag:3	Transmit Maximum EIRP	In accordance with the local regulations
Tag:4	Transmit Spurious Emissions	In accordance with the local regulations
Tag:4a	Transmit Spurious Emissions, In-Band (spread spectrum systems)	In accordance with the local regulations
Tag:4b	Transmit Spurious Emissions, Out-of-Band	In accordance with the local regulations
Tag:5	Transmit Spectrum Mask	In accordance with the local regulations
Tag:6a	Transmit-to-Receive Turn-Around Time	Not applicable.
Tag:6b	Receive-to-Transmit Turn-Around Time	Not applicable.

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Ref.	Parameter Name	Description
Tag:6c	Dwell Time or Transmit Power-On Ramp	Not applicable.
Tag:6d	Decay Time or Transmit Power-Down Ramp	Not applicable.
Tag:7	Modulation	ASK
Tag:7a	Spreading Sequence (direct sequence [DSSS] systems)	Not applicable.
Tag:7b	Chip Rate (spread spectrum systems)	Not applicable.
Tag:7c	Chip Rate Accuracy (spread spectrum systems)	Not applicable.
Tag:7d	On-Off Ratio	Not specified.
Tag:7e	Subcarrier Frequency	512 kHz
Tag:7f	Subcarrier Frequency Accuracy	+/- 20%
Tag:7g	Subcarrier Modulation	Miller, at the data rate
Tag:7h	Duty Cycle	Random hold-off as specified
Tag:7i	FM Deviation	Not applicable.
Tag:8	Data Coding	PPE or Miller (M=2)
Tag:9	Bit Rate	256 kbit/s
Tag:9a	Bit Rate Accuracy	+/- 20%
Tag:10	Tag Transmit Modulation Accuracy (frequency-hopping [FHSS] systems)	Not applicable.
Tag:11	Preamble	Required
Tag:11a	Preamble Length	As specified
Tag:11b	Preamble Waveform	As specified
Tag:11c	Bit-Sync Sequence	None
Tag:11d	Frame-Sync Sequence	Not applicable.
Tag:12	Scrambling (spread-spectrum systems)	Not applicable.
Tag:13	Bit Transmission Order	MSB is transmitted first
Tag:14	Reserved	Deliberately left blank.
Tag:15	Polarization	Tag dependent; not specified by this document
Tag:16	Minimum Tag Receiver Bandwidth	Tag dependent; not specified by this document.

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Table 3 — Protocol parameters

Ref.	Parameter Name	Description
P:1	Who talks first	Tag after listening
P:2	Tag addressing capability	As specified
P:3	Tag ID	Contained in tag memory
P:3a	Tag ID Length	64 bits
P:3b	Tag ID Format	See clause 6.3.2
P:4	Read size	Not Applicable.
P:5	Write Size	Not Applicable.
P:6	Read Transaction Time	Not Applicable.
P:7	Write Transaction Time	Not Applicable.
P:8	Error detection	Tag to Interrogator : CRC-16 on TID Structured data uses 5 bit CRC with page down counter.
P:9	Error correction	None
P:10	Memory size	Unlimited 64 bit pages
P:11	Command structure and extensibility	Not Applicable.

Table 4 — Anti-collision parameters

Ref.	Parameter Name	Description
A:1	Type (Probabilistic or Deterministic)	Probabilistic
A:2	Linearity	Nearly linear up to 500 tags depending on anti-collision parameter.
A:3	Tag inventory capacity	Unlimited depending on anti-collision parameter.

6 Type D

6.1 Physical layer

6.1.1 Interrogator power-up waveform

The Interrogator power-up waveform shall comply with the mask specified in Figure 1 and Table 5.

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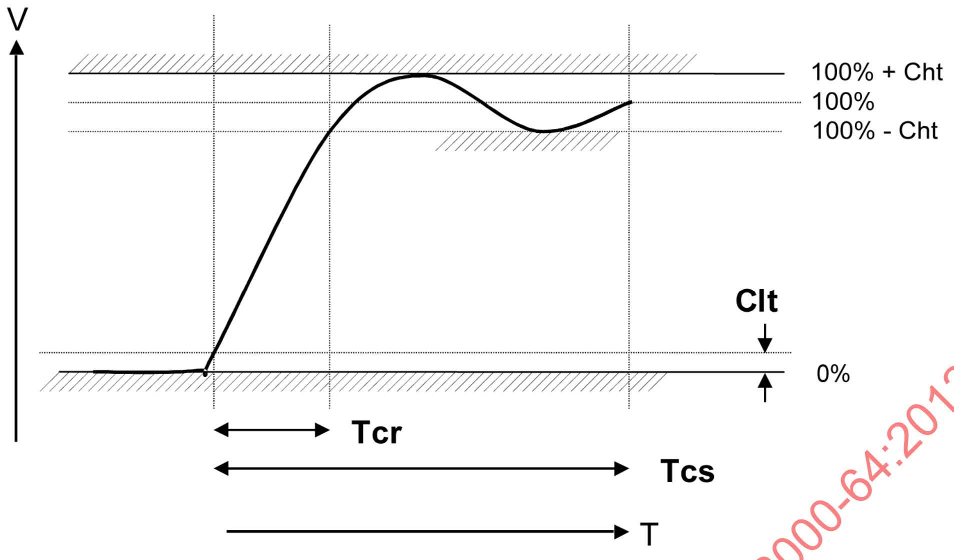

Figure 1 — Interrogator power-up waveform

Table 5 — Interrogator power-up waveform parameter values

Parameter	Min	Max
Tcs		1500µs
Tcr	1 µs	500 µs
Cht		10%
Clt		1%

6.1.2 Interrogator power-down

Once the carrier level has dropped below the ripple limit Cht, power down shall be monotonic and of duration Tcf, as specified in Figure 2 and Table 6.

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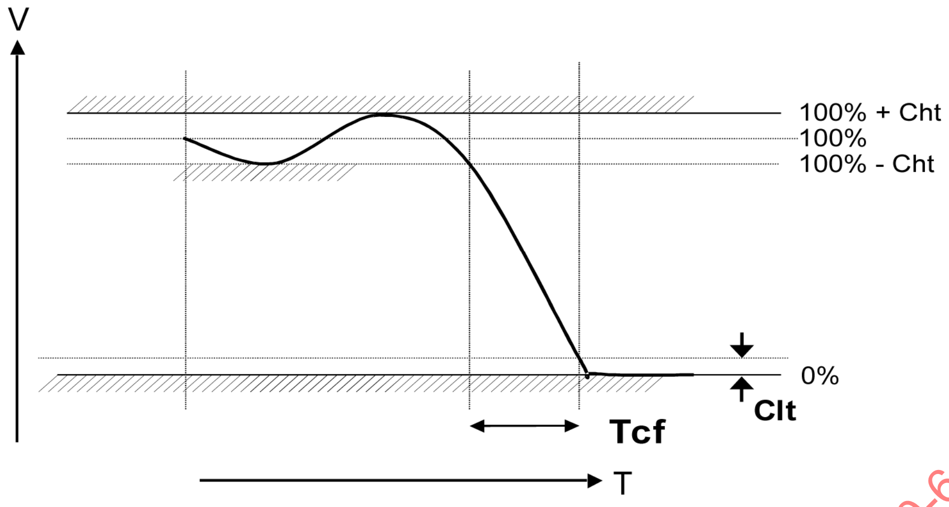


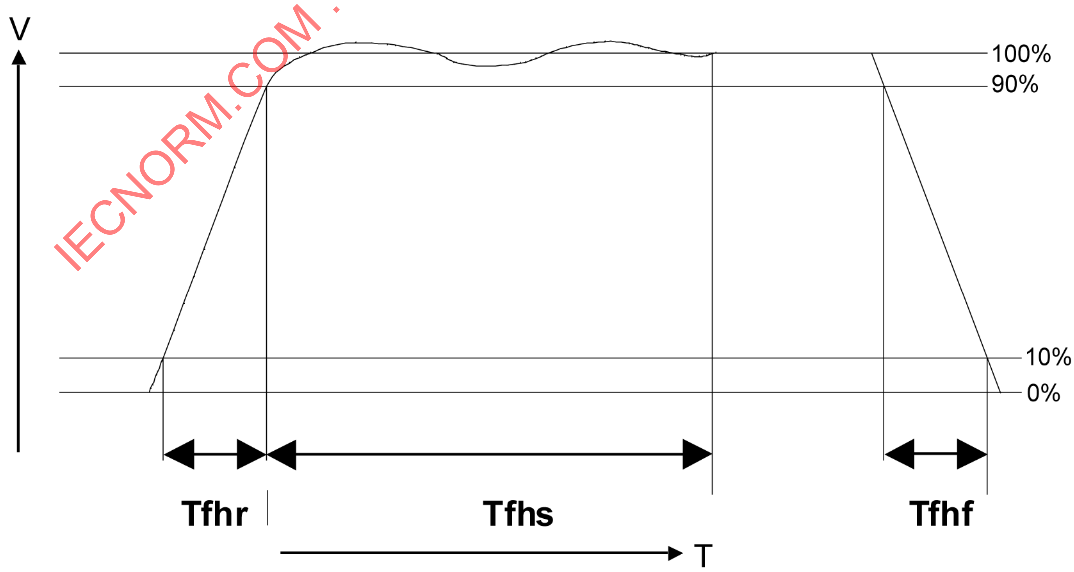
Figure 2 — Interrogator power-down waveform

Table 6 — Interrogator power-down timings

Parameter	Min	Max
Tcf	1 µs	500 µs
Cht		± 5% of steady state (100 %) level
Clt		1 %

6.1.3 Frequency hopping carrier rise and fall times

When the Interrogator operates in the frequency operating hopping spread spectrum mode (FHSS), the carrier rise and fall times shall conform to the characteristics specified in Figure 3 and Table 7. The Interrogator shall complete a frequency hop in a time not exceeding 30 µs (to ensure that the tag is not reset by the frequency hop). The frequency hop is measured from the beginning of Tfhf to the end of Tfhr.



NOTE Ripple is ± 5 % of 100 % of steady state level

Figure 3 — FHSS carrier rise and fall characteristics

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Table 7 — FHSS carrier rise and fall parameters

Parameter	Min	Max
Tfhr		30 µs
Tfhs	400 µs	
Tfhf		30 µs

6.2 Protocol overview

6.2.1 General

Type D uses a TOTAL air interface. TOTAL is a TTF air interface for RFID Tags and Interrogators which uses propagating wave backscatter for Tag to Interrogator transmission. The system uses "random hold-off and repeat" Tag transmissions for collision arbitration. A Tag only transmits after listening for Interrogator modulation. A Tag shall always listen for Interrogator modulation when it is not transmitting. The Tag suspends transmissions when it detects Interrogator modulation until or after a specified time not detecting Interrogator modulation, unless it is able to decode and execute the Interrogator modulation. The normal use of Type D is TTO. The Interrogator used in a Type D system is thus not required to transmit commands to one or more Tags. There is no requirement for the Interrogator to modulate its carrier. Hence, Type D does not specify a forward link. In order to write to or program a Tag, the Tag may implement a command decoder from another type defined in ISO/IEC 18000 part 6. If implemented, it shall follow the command types and command structure specified in the respective standard. Type D may be implemented with any combination of Protocol Types as defined in ISO/IEC 18000 part 6 or proprietary commands.

A Tag may derive its operating power by one of two methods. Either as a passive Tag using a portion of the incident energy which is rectified and smoothed to power the circuits or alternatively as a battery assisted passive (BAP) Tag using an on board battery. In both cases the Tag shall use modulated backscatter to transmit its message.

When a Tag enters the energizing field of an Interrogator and when the field is of adequate strength, the Tag shall initiate a power-on routine internally and shall begin the TOTAL sequence.

When the energizing carrier is pure CW, then the Tag shall wait for a random hold-off time between minimum_listen_time and maximum_hold-off_time and then at the end of the random hold-off time the Tag shall backscatter its message. This sequence is repeated until the Tag detects modulations or the energizing signal falls below an adequate field strength. A low duty cycle of random distributed Tag transmission allows for the Interrogator to detect multiple Tags.

When the Tag is not backscattering a message and for as long as it is powered up, it shall listen continuously for modulation on the energizing carrier. If at any time the energised Tag detects modulation during listening, then it shall suspend the transmission sequence and perform the following action:

- If the Tag is able to process the transmission, it shall do so and return to its random backoff and repeat sequence while listening.
- If the Interrogator transmission is not directed at the specific Tag; the Tag shall remain suspended till it leaves the energizing field or after not detecting further modulation for a specified period of time.

A Tag message (TagMsg) shall consist of the TID, optional data pages and an optional Simple Sensor data page.

- The TagMsg shall be transmitted in pages of fixed size of page_data_bits. The number of user data pages and the sensor page to be transmitted in the Tag message shall be configured in the Tag.
- The TID shall be permanently programmed at the time of manufacture of the chip.

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User memory may be written and optionally locked by a user. An Interrogator usually writes to a Tag over the air; however there is nothing to preclude the writing of Tags by contact means.

6.2.2 Protocol parameter values

Table 8 provides a summary of the Type D protocol parameters.

Table 8 — Type D protocol parameters

Parameter	Value	Description
minimum_listen_time	5 ms for 1st hold-off (Rt_1) symbol_detect_time for subsequent hold-offs (Rt_n)	Minimum time to detect ITF modulation
symbol_detect_time	125 µs	
maximum_hold-off_time	≥ 30 ms	This value controls the arbitration time for a Type D Tag. This time may be configured in the Tag, but shall never be less than 30ms.
TOTAL_data_rate	256 kbit/s	sub_carrier_freq/2 kb/s
sub_carrier_freq	512 kHz	For both PPE and Miller M=2
freq_tolerance	± 20%	freq_tolerance applies to all timing parameters, i.e. minimum_listen_time, symbol_detect_time, maximum_hold-off_time, TOTAL_data_rate, sub_carrier_freq, TOTAL_Wakeup_timeout
page_separation	8 symbols	between pages
page_data_bits	64 bits	The amount of data bits in a page
TOTAL_Wakeup_timeout	25 ms	The minimum time period a Tag must detect no Interrogator modulation before returning to TOTAL mode after suspension

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6.2.3 Tag arbitration

Tag arbitration is accomplished in two ways to ensure the most efficient use of the radio spectrum and to ensure that compatibility and non-interference is maintained in mixed Tag populations.

- Multiple TOTAL Tags

  A Tag shall transmit its message at randomly spaced intervals in a method known as random hold-off and repeat as described in 6.2.3.1.

- Mixed Tag populations

  The TOTAL Tags shall mute or execute the Interrogator commands on detecting Interrogator commands as described in 6.2.3.2.

6.2.3.1 Multiple TOTAL Tags

Tag collision arbitration uses a “random hold-off and repeat” Tag transmission method based on the Aloha principle. The Tag shall incorporate a random or pseudo-random number generator, which shall be used to trigger TagMsg transmissions at random time intervals between minimum_listen_time and maximum_hold-off_time. By selecting an appropriate maximum_hold-off_time, collision arbitration can be optimised to provide optimum throughput for the number of Tags expected to be present in the Interrogator field at any one time. Figure 4 shows a typical distribution of random Tag transmissions.

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In order to detect TOTAL Tags, Interrogators shall only radiate an unmodulated carrier wave (CW). A Tag in TOTAL mode shall transmit at random its TagMsg until it detects Interrogator modulation.

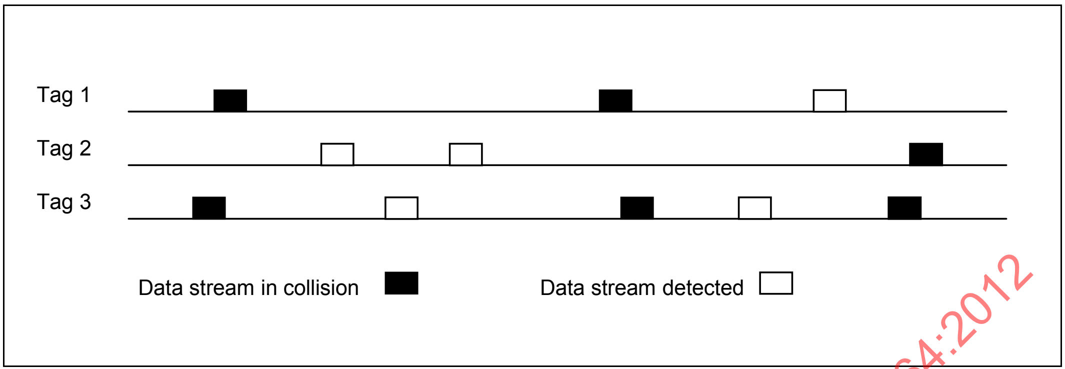

Figure 4 — Typical TOTAL Tag transmissions

6.2.3.2 Mixed population of ITF and TOTAL Tags

An Interrogator complying with this clause shall have the ability to manage mixed populations of ITF and TOTAL Tags present in the field at the same time.

To identify ITF Tags, ITF Interrogators shall run their command/response protocol as specified in ISO/IEC 18000 part 6. TOTAL Tags shall have the capability to detect Interrogator modulation and deal with it according to 6.2.4.

6.2.4 Operating procedure

Figure 5 shows the TOTAL state diagram. Figure 6 defines the timing parameters for the TOTAL PAUSE and TOTAL TRANSMIT states.

The state of a Tag not detecting an RF field shall be OFF. After entering an RF field and undergoing the power-on routine the Tag shall change into TOTAL PAUSE state.

In order to prevent collisions with ITF backscatter, TOTAL Tags shall listen for Interrogator modulation during TOTAL PAUSE and TOTAL QUIET states, see 6.2.10.

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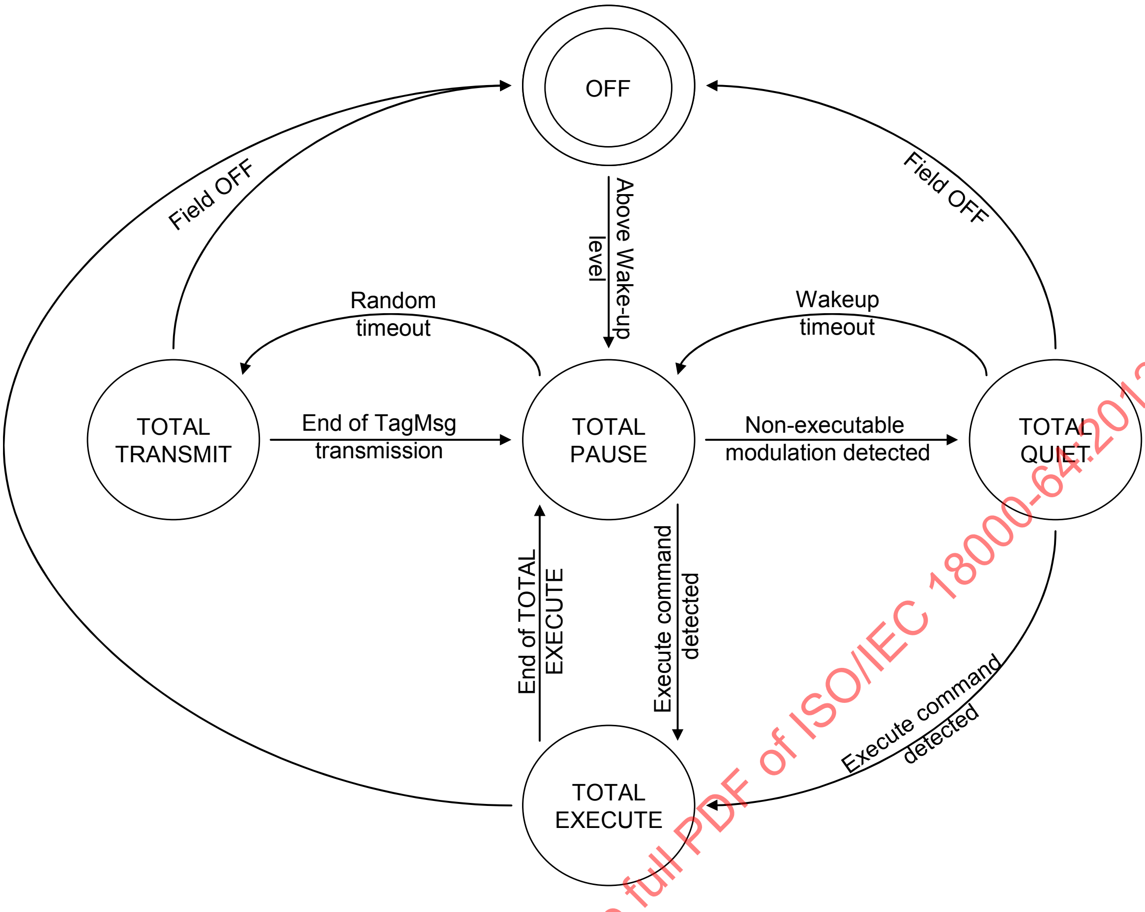

Figure 5 — TOTAL state diagram

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When a Tag enters TOTAL PAUSE the random hold-off time (Rt_n) is calculated. This is a value between minimum_listen_time and maximum_hold-off_time. Based on the outcome of the listen period a Tag shall act as follows:

- While in TOTAL PAUSE: At the end of the hold-off time, when no interrogator modulation was detected, the tag shall change into the TOTAL TRANSMIT state. The tag shall transmit the TagMsg and return to TOTAL PAUSE.
- While in TOTAL PAUSE or TOTAL QUIET:
  - If interrogator modulation is detected, which cannot be decoded as a command for this tag, then the tag shall change to TOTAL QUIET.
  - If interrogator modulation is detected, which can be decoded as a command for this tag, then the tag shall change to TOTAL EXECUTE. The tag shall process the command and return to TOTAL PAUSE.
- While in TOTAL QUIET: If no modulation was detected for the TOTAL_Wakeup_timeout period the tag shall change into the TOTAL PAUSE state.

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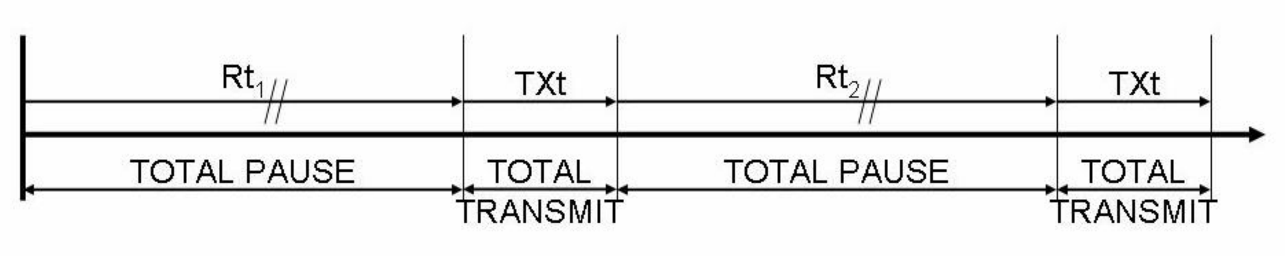

Figure 6 — TOTAL timing

Interrogator detection takes place during TOTAL PAUSE and TOTAL QUIET. The following calculations and definitions shall apply:

- TXt = TOTAL TagMsg transmit time based on modulation and TagMsg length
- Rt_n = Random wait hold-off time for the n^{th} TagMsg transmission – the Tag shall listen for ITF modulation during Rt_n
    - minimum_listen_time ≤ Rt_1 ≤ maximum_hold-off_time

      A Type D Tag, upon entering an energizing RF field, shall not backscatter or otherwise modulate the energizing RF field for a period of at least the minimum_listen_time after entering the RF field.

      For a randomly chosen Type D Tag population entering an energizing RF field, the Rt_1 time at which the Tags first respond to an Interrogator shall be distributed between the minimum_listen_time and the maximum_hold-off_time. The mean of this distribution shall be no less than maximum_hold-off_time / 2. The median of this distribution shall be no less than maximum_hold-off_time / 2. The Tag population shall be sufficiently large to ensure a 95% confidence in the mean and median values.

    - symbol_detect_time ≤ Rt_n ≤ maximum_hold-off_time

      For a Type D Tag in an energizing RF field that has waited the minimum_listen_time and provided a first response to an Interrogator, the Rt_n time interval between successive Tag responses shall be distributed between the symbol_detect_time and the maximum_hold-off_time. The mean of this distribution shall be no less than maximum_hold-off_time / 2. The median of this distribution shall be no less than maximum_hold-off_time / 2. The number of Tag responses shall be sufficiently large to provide a 95% confidence in the mean and median values.

6.2.5 TagMsg

The TagMsg is of variable length consisting of one or more fixed length pages (page_data_bits) and begins with the TID as defined in 6.3.2. The TagMsg is defined according to the Tag configuration, see 6.3.4.

A TagMsg contains either unstructured data (see 6.3.2.1.2) or structured data (see 6.3.3). A structured data TagMsg shall contain one or more TID pages and at least 1 data page which contains:

- a UII (see 6.3.3.3),
- additional item-related data (see 6.3.3.4), and/or
- Simple Sensor data (see 6.3.3.5).

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6.2.6 CW control

For CW control see 6.1.1, 6.1.2, and 6.1.3.

6.2.7 Message encoding

The Tag shall support Pulse Position Encoding or Miller M=2 encoded subcarrier.

6.2.7.1 Pulse Position Encoding – PPE

In PPE a data-1 shall be represented by a HIGH in the first quarter of a symbol period, while a data-0 shall be represented by a HIGH in the third quarter of a symbol period. Figure 7 shows the bit encoding rule.

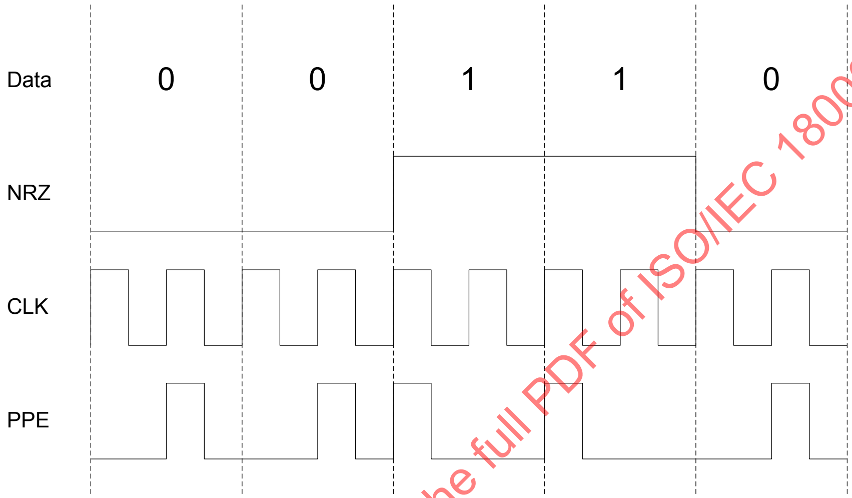

Figure 7 — PPE encoding

6.2.7.2 Miller (M=2) encoded subcarrier

Figure 8 shows basis functions and a state diagram for generating Miller encoding. 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. The state diagram in Figure 8 maps a logical data sequence to baseband Miller basis functions. The state labels, S_1–S_4, indicate four possible Miller-encoded symbols, represented by the two phases of each of the Miller basis functions. The state labels also represent the baseband Miller waveform that is generated upon entering the state. The transmitted waveform is the baseband waveform multiplied by a square-wave at M times the symbol rate. The labels on the state transitions indicate the logical values of the data sequence to be encoded. For example, a transition from state S_1 to S_3 is disallowed because the resulting transmission would have a phase inversion on a symbol boundary between a data-0 and a data-1.

Figure 9 shows Miller-modulated subcarrier sequences for two subcarrier cycles per bit (M=2). The duty cycle of a 0 or 1 symbol, measured at the modulator output, shall be a minimum of 45% and a maximum of 55%, with a nominal value of 50%. Miller encoding has memory; consequently, the choice of Miller sequences in Figure 9 depends on prior transmissions. Miller signalling shall always end with a “dummy” data-1 bit at the end of a transmission, as shown in Figure 10.

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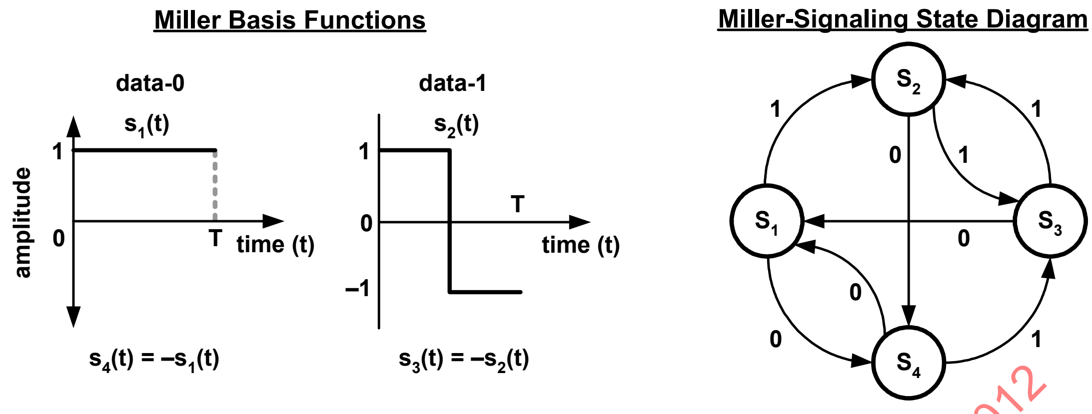

Figure 8 — Miller basis functions and generator state diagram

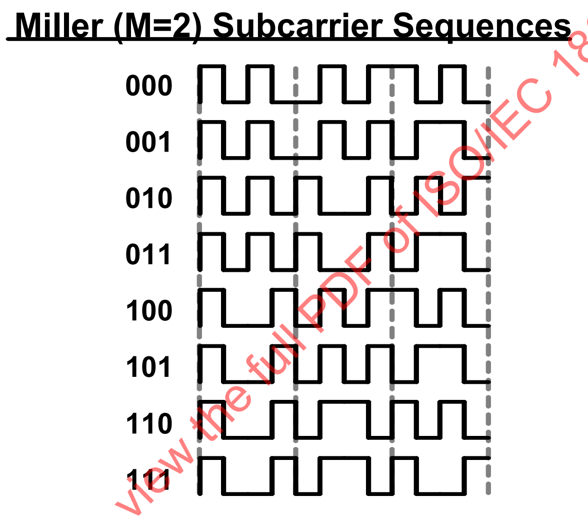

Figure 9 — Miller (M=2) subcarrier sequences

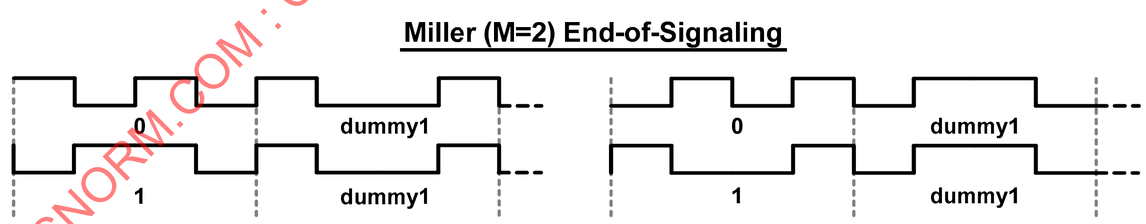

Figure 10 — Terminating Miller (M=2) subcarrier transmissions

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6.2.8 Symbol modulation

The Tag shall transmit symbols by impedance modulating the Tag antenna circuit (backscatter-modulation). The Tag antenna reflectivity shall be switched between two states. A LOW shall be represented by the normal condition in which the Tag is powered by the Interrogator and able to receive. A HIGH state shall be the alternative condition created by changing the antenna configuration or termination.

6.2.9 Page modulation

A TagMsg consists of one or more pages. Link timing of multiple pages is described in 6.2.9.5.

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6.2.9.1 Bit order

Pages shall be transmitted most significant bit first.

6.2.9.2 PPE page modulation

The page length shall comprise 75 symbols.

- The first 11 symbols form the preamble. The preamble shall start with 8 0_2 data symbols followed by a SYNCH sequence comprising a low period of 2 symbols duration followed by a data-1 bit (see Figure 11).
- 64 data symbols

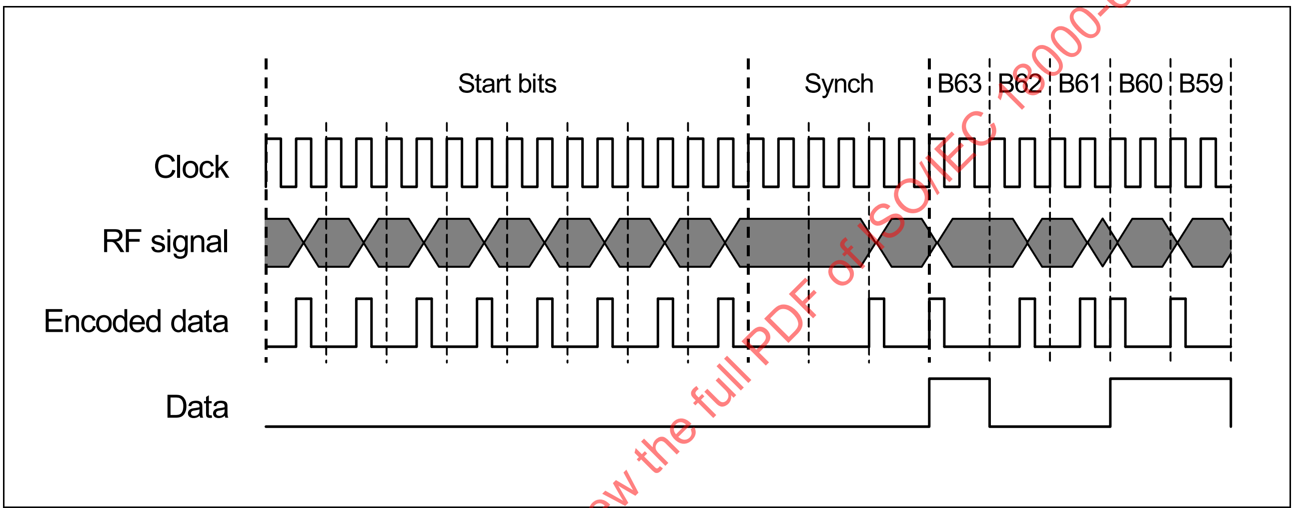

Figure 11 — PPE page modulation

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6.2.9.3 Miller page format

The Miller page shall comprise either 87 or 95 symbols.

- The first 22 symbols are the extended preamble. The preamble shall start with 32 cycles of subcarrier (16 symbol periods) followed by a SYNCH sequence comprising either Miller encoded symbols 010111_2 indicating no page link bits are included or 010110_2 indicating page link bits are included. See Figure 12.
- 64 data symbols.
- If SYNCH sequence is 010110_2 then 8 Miller encoded symbols representing the page link bits with the 3 MSBs indicating the number of pages modulo 8 remaining in the TagMsg and the 5 LSBs indicating a CRC-5 value. The polynomial used to calculate the CRC-5, $x^5 + x^3 + 1$, and the encoding procedure is described in Annex A.1. The CRC-5 is calculated to include the previous page's CRC-5, with the first page using 00000_2 as the previous page's CRC-5. The CRC-5 does not include the dummy '1', time separation between pages, the extended preamble, nor the SYNCH sequence. See Figure 13.
- A dummy '1' must be appended at the end as described in 6.2.7.2.

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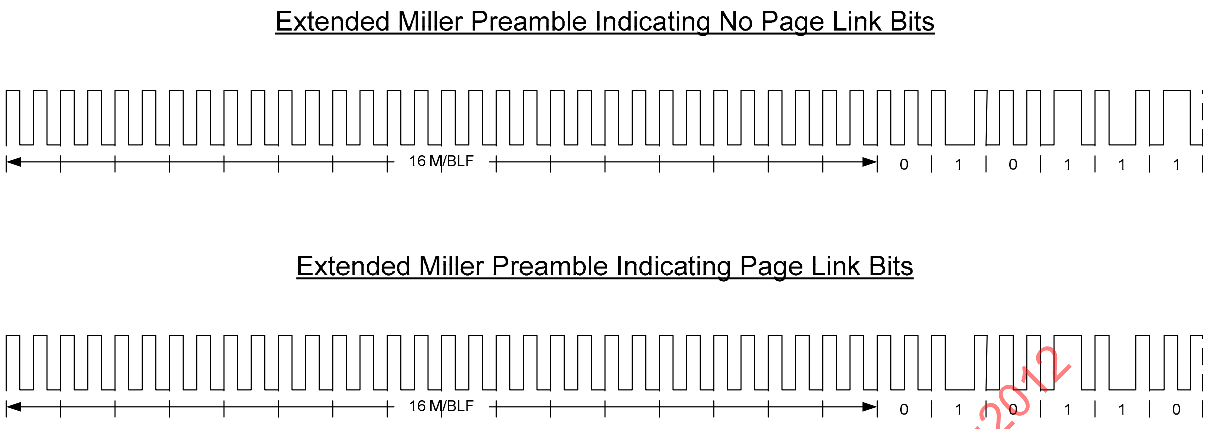

Figure 12 — Miller preambles

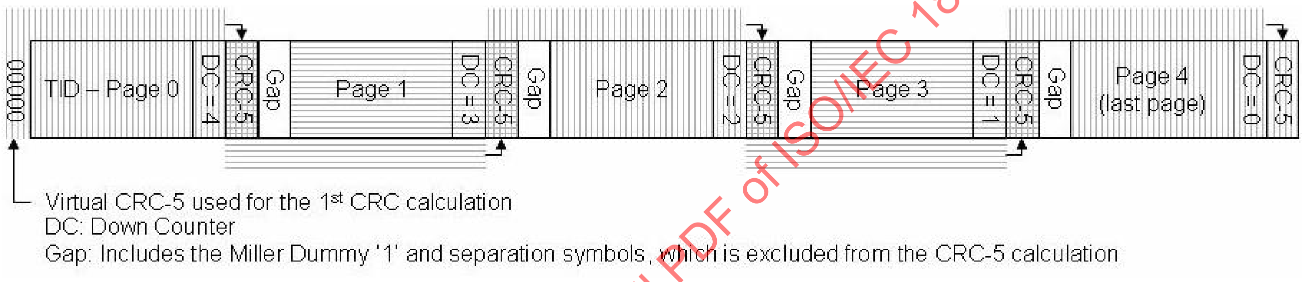

Figure 13 — Page link bits

6.2.9.4 Return link T=>R

The Tag backscatter transmission shall use a backscatter link frequency (BLF) of 512 kHz.

6.2.9.5 Link timing

There is no link timing associated with Tag transmissions; Tags shall transmit their TagMsg at random time intervals, see 6.2.4.

There is no link timing associated with Interrogator to Tag and Tag to Interrogator turn-around because the Interrogator is not required to modulate.

When a Tag transmits multiple concatenated messages, the messages shall be separated by a time of 8 Tag symbol periods, i.e. 32 µs ±20% (see Figure 14).

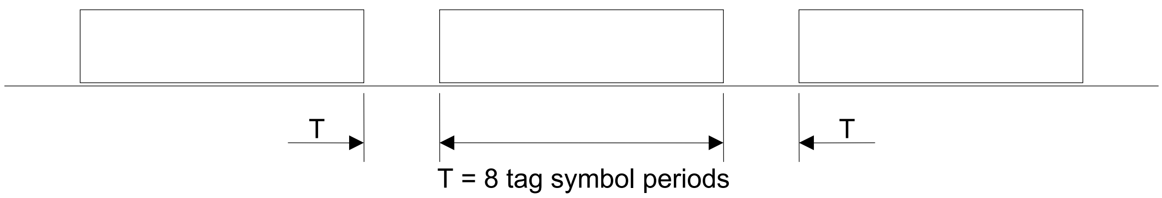

Figure 14 — Multi-page TagMsg timing

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6.2.10 Interrogator modulation detection

A Tag shall listen for Interrogator modulation during TOTAL PAUSE and TOTAL QUIET. The Interrogator modulation has been simplified to a mute sequence as depicted in Figure 15. It is thus not necessary to build a command decoder. Instead, 5 pulses can be recognized as the mute sequence. These 5 pulses represent 4 symbols where the symbol is defined as a pulse in case that the time from the last pulse is up to the symbol_detect_time. If the whole mute sequence is not detected the Tag should continue with TOTAL PAUSE or TOTAL QUIET.

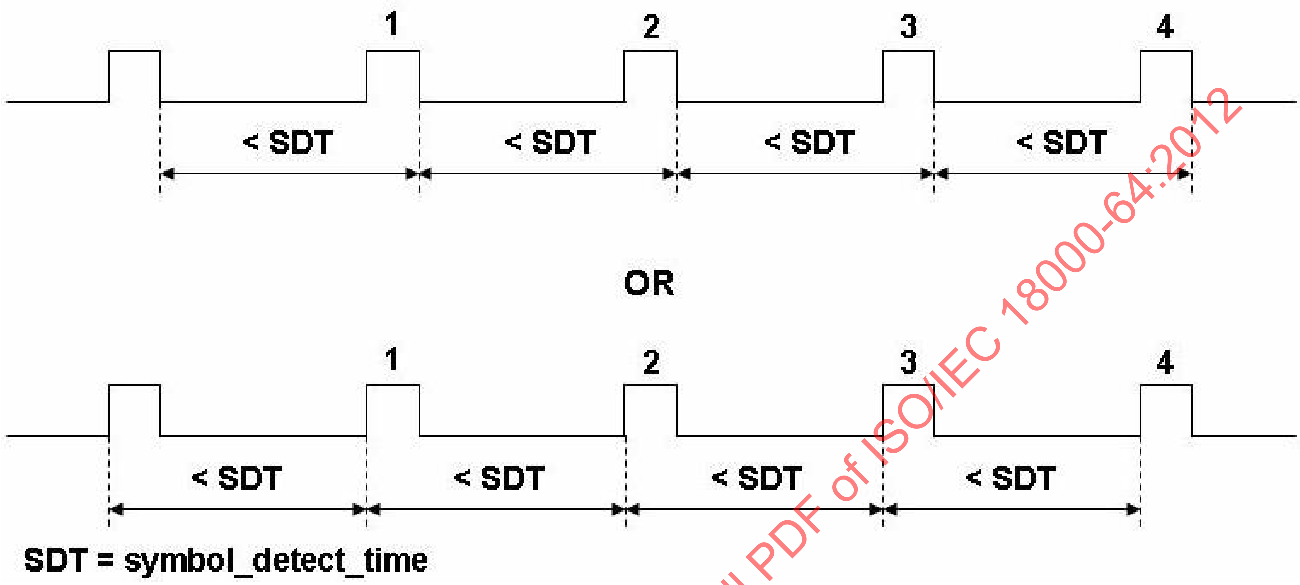

Figure 15 — Correct mute sequence

Type D Tags shall be able to detect Interrogator modulation pulses for Types as defined in ISO/IEC 18000 part 6. Additionally, such capability shall be ensured over the whole operating range, meaning from minimum wake-up sensitivity until maximum received power according to local radio regulations.

6.3 Type D Data

6.3.1 General

Logical memory shall be organised in pages of 64 bits. All Tags shall contain a unique TID and shall be programmed permanently at the time of manufacture. It shall not be possible to erase, change or re-program the TID at any later stage.

The logical memory of a programmable Tag shall be organised as an array of N x 64 bit pages. The bit numbering for each page is from 63 (MSB) to 0 (LSB).

Table 9 — Programmable Tag memory map

Page number	Function
0 to L-1	TID (L pages)
L upwards	User memory
Sensor Page	Sensor Data

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6.3.2 TID

The TID is a Tag unique serial number. Two TID formats are defined in Table 10; TID-U for unstructured data and TID-S for structured data, which includes the UII. The two MSBs (extension bits) shall provide information about the format of the TID. Table 10 shows the meaning of the extension bits. The extension bits for TID-S are also the two MSBs of the Class-identifier value as specified in ISO/IEC 15963, see Table 10 and 6.3.2.2.

Table 10 — Extension bits assignment

Value	Meaning
00	TID-U only (read-only)
01	TID-U with unstructured data
10	Reserved for future extensions
11	TID-S with structured data

6.3.2.1 TID-U

TID-U defines the TID to be used for TID only and unstructured data TagMsgs. Figure 16 shows the structure of the TID-U page (extension bits 00_2 and 01_2).

EXT	MAN	UID	CRC
Bit 63,62	Bit 61-57	Bit 56-16	Bit 15-0

EXT: 2 extension bits
MAN: 5 bits manufacturer's code according to ISO15963 D2.2 (INCITS 256)
UID: 41 bits serial number
CRC: 16 bits CRC according to 6.3.2.1.1

Figure 16 — TID-U data structure

6.3.2.1.1 TID-U sixteen bit cyclic redundancy check

The 16 bit CRC shall be calculated on the TID bits 63 to 16, most significant bit first. The polynomial used to calculate the CRC is $x^{16} + x^{15} + x^2 + 1$. The 16 bit register shall be preloaded with $FFFF_h$. The resulting CRC value shall be appended to the TID at bit positions 15 to 0, the most significant bit of the CRC-16 at bit position 15. A schematic of a possible implementation is provided in Annex A.

6.3.2.1.2 Unstructured data

Unstructured data is defined by the application and consist of 0 or more data pages.

6.3.2.2 TID-S

The TID-S is encoded with one of the following structures and shall be unique among all classes of Tags defined in ISO/IEC 15693. Class-identifier values to be used by Type D Tags shall be limited to values of which the 2 MSB bits are set to 11_2. These 2 bits correspond to the extension bits meaning "TID-S with structured data", see Table 10 and Figure 16.

ISO/IEC 15963 Class-identifier value $E0_h$:

- Page 0, bits 63 to 56 shall contain the ISO/IEC 15963 Class-identifier value $E0_h$.

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- Page 0, bits 55 to 48 shall contain an 8-bit manufacturer identifier as defined in ISO 7816-6.
- Page 0, bits 47 to 0 shall contain a 48-bit Tag serial number (assigned by the manufacturer).

ISO/IEC 15963 Class-identifier value $E2_h$:

- Page 0, bits 63 to 56 shall contain the ISO/IEC 15963 Class-identifier value $E2_h$.
- Page 0, bits 55 to 44 shall contain a 12-bit mask designer identifier as defined in version 1.5 and above of the EPCglobal Tag Data Standards.
- Page 0, bits 43 to 32 shall contain a 12-bit vendor defined model number as defined in version 1.5 and above of the EPCglobal Tag Data Standards.
- Page 0, bits 31 to 16 shall contain a 16-bit XTID Header as defined in version 1.5 and above of the EPCglobal Tag Data Standards when the MSB of the mask designer identifier has a value of one. The 3 LSBs of the XTID Header shall be treated as an unsigned integer and a non-zero value indicates the presence and length of the Tag serial number. Length in bits = 48 + ((value-1) * 16) which provides a minimum length of 48 bits and a maximum length of 144 bits.
- Page 0, bits 15 to 0 shall contain the 16 MSBs of the Tag serial number (assigned by the manufacturer).
- Page 1, bits 63 to 0 shall contain the continuation of the Tag serial number starting with bit 63. Any portion of the page not used for the Tag serial number shall be undefined. This page exists only when the Tag serial number exists.
- Page 2, bits 63 to 0 shall contain the continuation of the Tag serial number starting with bit 63. Any portion of the page not used for the Tag serial number shall be undefined. This page exists only when the Tag serial number exceeds 80 bits in length.

ISO/IEC 15963 Class-identifier value $E3_h$:

- Page 0, bits 63 to 56 shall contain the ISO/IEC 15963 Class-identifier value $E3_h$.
- Page 0, bits 55 to 48 shall contain an 8-bit manufacturer identifier as defined in ISO 7816-6.
- Page 0, bit 47 shall contain a User Memory flag to note the existence of User Memory.
- Page 0, bits 46 to 32 shall contain a 15-bit User Memory size (in bits).
- Page 0, bits 31 to 0 shall contain the 32 MSBs of the 48-bit Tag serial number (assigned by the manufacturer).
- Page 1, bits 63 to 48 shall contain the 16 LSBs of the 48-bit Tag serial number (assigned by the manufacturer).
- Page 1, bit 47 shall contain an XTID flag to note the existence of data in the XTID Header.
- Page 1, bits 46 to 32 shall contain the 15-bit XTID Header.
- Page 1, bits 31 to 0 shall be undefined.

The eight MSBs of the Tag serial number for Allocation Classes $E0_h$ and $E3_h$ shall contain an 8-bit vendor defined model number.

The TID-S shall be followed by at least 1 data page containing the encoded structured data, see 6.3.3. The structured data is a set of contiguous data pages as configured in 6.3.4.

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6.3.3 Structured data encoding

Structured data encoding defines how the user memory is configured to support data compliant with the ISO/IEC 15962 RFID encoding rules.

A structured data encoding has a number of encoding segments presented in the following sequence, see Figure 17:

- Shall include a UII segment, which includes a CRC-16, calculated over the bits from bit 63 of TagMsg Page 0 (beginning of the TID-S) to the end of the UII segment. The UII segment is of variable length and may occupy 1 or more data pages.
- May include an item-related data segment, with its encoded data protected by a separate CRC-16. The data segment is of variable length and may occupy 1 or more data pages.
- May include a single Simple Sensor segment

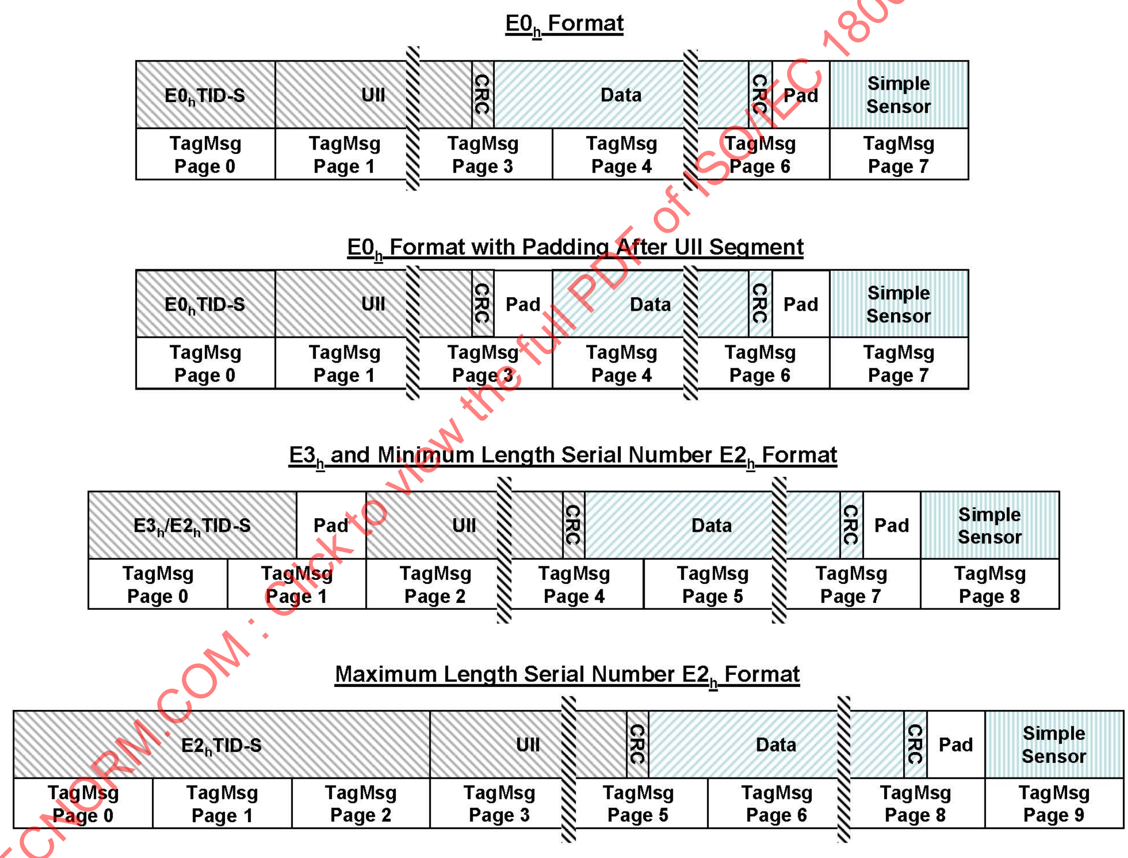

Figure 17 — Examples of a structured TagMsg

NOTE If necessary, padding is used after the UII segment CRC to align with a lock boundary, as illustrated in the second example in Figure 17.

The following sub-clauses define each of the components in detail.

6.3.3.1 Basic encoding to ISO/IEC 15962 rules

The basic encoding unit in user memory shall be a 16 bit word. The ISO/IEC 15962 encoding procedures, through rules defined for the Type D Tag Driver, ensure that this is achieved for each encoding segment.

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An individual segment may be locked in its entirety, or individual data sets may be locked without being contiguous. All locking shall comply with the locking capabilities of the Tag.

6.3.3.2 The CRC-16 applied to the UII segment and Item-related data segment

The polynomial used to calculate the CRC-16, $x^{16} + x^{12} + x^5 + 1$, is the CRC-CCITT International Standard, ITU Recommendation X.25). The encoding procedure is described in Annex A.2.

The range of data bits used to compute each CRC-16 and encoded location of these is defined in the relevant sub-clauses.

6.3.3.3 The UII segment

The UII segment shall be encoded using the rules of ISO/IEC 15962 from the beginning of the first data page and the length may be less than one complete page, exactly the size of a single page, or span multiple pages to encode the UII. If the UII encoding does not end on a word boundary, then the remaining bits in the word shall be zero filled.

Bit positions 63 to 48 of the first data page shall encode the Protocol Control word and the structure of this is defined in 6.3.3.3.1.

6.3.3.3.1 The Protocol Control word

The Protocol Control word shall have the following structure, and as shown in Figure 18:

- Bit positions 63 to 59 encode the length of the UII segment starting with the Protocol Control word to the end of the CRC-16. The length shall be expressed in words.
- If the value of bit position 58 is = 1, this signals that the item-related data segment follows the UII segment. If the value of bit position 58 is = 0, then the encoding has ended, but the Tag may still contain a Simple Sensor segment.
- If the value of bit position 57 = 1, this signals that the Simple Sensor segment is present.
- The value of bit position 56 = 1 signals that the following 8 bits encode the AFI as registered for the application under the rules of ISO/IEC 15961-2.
- Bit positions 55 to 48 encode the AFI.

Bit position	63	62	61	60	59	58	57	56	55	54	53	52	51	50	49	48
Function	Length of UII segment					Item-related segment indictor	Simple sensor indicator	AFI indicator	AFI							

Figure 18 — The structure of the Protocol Control word

6.3.3.3.2 CRC-16 for the UII segment

The CRC-16 shall be the last word in the UII segment and be calculated as defined in 6.3.3.2 on the complete bit string from the beginning of the TID-S (bit 63 of TagMsg Page 0) to the end of the word preceding the CRC-16 in the UII segment. The UII segment may end on any 16 bit boundary. If there is no item related data segment then any portion of the page not used for the UII segment shall be zero filled.

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6.3.3.4 The optional item-related data segment

The optional item-related data segment is encoded if the Protocol Control word bit 58 is set = 1. This segment begins with the first non-zero word that occurs after the end of the UII segment.

The first word (bit positions n to {n-15} of the item-related data segment shall be the length-lock indicator and DSFID, where bits:

- n to {n-5} indicate the encoded length of this segment in words, from bit position n to the end of the CRC-16 where:
  - 000011_2 indicates 3 words (effectively the shortest possible encoding)
  - 111111_2 indicates 63 words (effectively the longest possible encoding)
- {n-6} to {n-7} provide some information about the lock status of the pages as follows:
  - 00_2 indicates that none of the pages encoding this segment are locked
  - 01_2 indicates that some of the pages encoding this segment are locked, starting with the first page and being contiguous
  - 10_2 indicates that some of the pages encoding this segment are locked, but in an unspecified sequence
  - 11_2 indicates that all of the pages encoding this segment are locked
- {n-8} to {n-15} shall be the DSFID for this segment, which may be different from the DSFID of the UII segment.

The item-related data is encoded from bit {n-16} of the item-related data segment until the end of the segment, using the rules of ISO/IEC 15962. Data-sets within the encoded sequence may be selectively locked. Any data-set, or contiguous data-sets that are to be locked, shall be on the lock size.

The CRC-16 for the item-related data segment shall be calculated as defined in 6.3.3.2.

If the encoding from the beginning of the length-lock indicator (bit n of the segment) requires an odd number of bytes, then an additional pad byte shall be encoded.

6.3.3.5 Simple sensor encoding segment

The Tag may support one Simple Sensor as part of structured data. Its data shall be transmitted as the last page of the TagMsg when enabled. The presence of the optional Simple Sensor segment is indicated in the Tag configuration, see 6.3.4.

The Protocol Control word bit 57 is used to enable or disable the Simple Sensor segment and the sensor page shall be sent when the bit is set = 1. This bit may be linked with the Tag configuration of sensors, see 6.3.4.

Simple sensors are defined in 7.3 and are designed to deliver a complete information package of their function, configuration and observation results.

The Simple Sensor data bits will be mapped starting from bit 63 in the sensor page. The last 5 bits of the sensor data page shall contain a CRC-5. The polynomial used to calculate the CRC-5, $x^5 + x^3 + 1$, and the encoding procedure is described in Annex A.1. The CRC-5 is calculated on the complete bit string from the beginning of the sensor page.

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6.3.4 Tag configuration

The Tag configuration should contain the parameters as shown in Table 11; whereas only the applicable parameters need to be implemented and are vendor defined. Configuration settings may be determined by use of the vendor model number within the TID and/or a vendor defined memory locations within the Tag.

Table 11 — Tag configuration parameters

Function	Comments
Type of encoding	PPE or Miller (only required when encoding method is selectable).
Page link bits present	Only for Miller encoding (only required when page link bits is selectable).
maximum_hold-off_time	This value controls the Tag arbitration capability.
Available user pages	Adding TID-S, “Available user pages” and “Number of TagMsg data pages” this value shall be 1 or more.
First TagMsg data page	First page to be part of the TagMsg. The parameters shall be set to 1 or more if “Number of TagMsg data pages” is non zero.
Number of TagMsg data pages	Number of data pages to be part of the TagMsg. It is assumed that the data pages will be contiguous. This value must be at least 1 when structured data is used.
Data locked	Data locking is implemented on vendor defined block boundaries that shall have a size of either 16 bits, 32 bits, or 64 bits.
Simple sensor present	This setting should be locked by the manufacturer.
Sensor page part of TagMsg	When set then the sensor page will be transmitted as the last page of the TagMsg. It is desirable that the Sensor Bit in the Protocol Control Word is automatically set. See Figure 18.

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6.4 Encoding and decoding TID-S Tags

6.4.1 Encoding rules

6.4.1.1 Encoding the UII segment

The data byte string for the UII segment shall be created according to the rules of ISO/IEC 15962, where the rules cover the span from the Protocol Control word up to, but excluding, the CRC-16.

The encoder-Interrogator shall confirm the value of bits 63 – 57 of the Protocol Control word. It shall also compute the CRC-16 over the byte string that begins with the TID-S and encode the result as the least significant word of the UII. Pad words shall be added to align with a lock boundary irrespective of whether the UII segment is locked or not.

The complete byte string shall be subdivided into page segments, starting from the Protocol Control word. The last page may be incomplete and only transferred for encoding on the Tag if the item-related data segment does not require encoding.

6.4.1.2 Encoding the item-related data segment

The data byte string for the optional item-related data segment shall be created according to the rules of ISO/IEC 15962, where the rules cover the span from the length-lock indicator up to, but excluding the CRC-16.

The encoder-Interrogator shall confirm the value of length-lock indicator. It shall also compute the CRC-16 over the byte string that begins with the length-lock indicator byte.

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The complete byte string shall be appended to the UII segment and subdivided into page segments. All the pages, including any partially ended final page shall be transferred for encoding on the Tag.

6.4.2 Decoding rules

A successful transmission from the Tag to the Interrogator may include the UII segment, the item-related data segment and the Simple Sensor segment. These are self-declaring and error detecting as defined in the following sub-clauses.

6.4.2.1 Decoding the UII segment

The complete transmitted message for this segment shall include the TID-S permanently locked, followed by the UII segment, including the CRC-16. This may, or may not, end on a page boundary and the actual length is determined by the length bits in the protocol control word (see 6.3.3.3.1).

The following steps shall be used to decode the UII segment:

1. Determine the length of the message in 16-bit words, where the total length equals the length declared in the Protocol Control word + 4 * number of pages used for the TID-S.

2. Calculate and confirm the CRC-16. If valid, continue at the next step, else abandon decoding the segment.

3. Store the TID-S.

4. Discard the CRC-16.

5. Extract additional information from the Protocol Control word about whether the Tag contains an item-related data segment and/or a Simple Sensor segment. This is to validate the decoding of these segments.

6. Store the entire bit string starting from the Protocol Control word for transmission to a data decoder.

6.4.2.2 Decoding the item-related data segment

The complete transmitted message for this segment shall include the length-lock indicator and DSFID word, followed by the item-related data segment, including the CRC-16. This may, or may not, begin and end on a page boundary and the actual length is determined by the length-lock indicator DSFID word in the first word of the segment.

The following steps shall be used to decode the item-related data segment:

1. Determine the length of the message in 16-bit words, where the total length equals the length declared in the length-lock indicator byte.

2. Calculate and confirm the CRC-16. If valid, continue at the next step, else abandon decoding the segment.

3. Discard the CRC-16.

4. Store the entire bit string from the length-lock indicator for transmission to a data decoder.

6.4.2.3 Transfer to the ISO/IEC 15962 decoder

The Interrogator shall concatenate the decoded UII segment and the decoded item-related data segment (if present) into a single byte stream. This is then transferred to an ISO/IEC 15962 decoder for data decoding into user-based data.

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6.4.2.4 Processing the Simple Sensor segment

The Simple Sensor data is decoded according to Annex B.

NOTE Although based on different standards, the sensor decoder and the data decoder may be incorporated on the same device or software platform. It is an implementation issue for the Interrogator interface to take into account whether the transfer is to two separate devices or a single device.

7 Sensor support

7.1 Applicability

In case an Interrogator or Tag supports any response or feature of Clause 7 then this Interrogator or Tag shall support all mandatory responses or features and it may support all optional responses or features of Clause 7.

In case an Interrogator or Tag does not support any response or feature of Clause 7 then Clause 7 does not apply for this device.

7.2 Overview

This clause describes an optional extension to Type D that adds sensor support for Simple Sensors. A Simple Sensor is programmed at source and is not required to be user programmed. A Simple Sensor by its nature delivers its payload as a Simple Sensor Data (SSD) block, appended to the object-related UII as a Tag is inventoried, and therefore does not require a separate dialogue to collect the sensor data.

The three fundamental characteristics of a Simple Sensor are:

- the sensor data is appended to the UII,
- the sensor does not need to be user programmed and
- the sensor computes pass/fail based on its characteristics, however it may also provide more details (e.g. an 8 bit sensor value)

The SSD block includes information about:

- the type of sensor, limited to a few basic environmental features
- measurement spans
- thresholds
- alarm status, indicating pass / fail conditions

7.3 Simple Sensors

Although called "Simple Sensors", the devices are required to support features common to any type of sensor device. The Simple Sensor has to monitor the environmental characteristic for which it is designed, take samples at defined intervals, compare and process against criteria, and report its status.

The Simple Sensor transmits its data as a Simple Sensor Data (SSD) block which is appended to the Tag UII. The SSD block shall consist of 32 bits or 48 bits depending on the type of Simple Sensor. The SSD block comprises the sensor type, measure span, ACC, sampling regime, high in-range limit, low in-range limit, monitor delay, high out-of-range alarm delay, low out-of-range alarm delay, and alarms, all as defined in Annex B.

Clause 6.3.3.3.1 Type D Protocol Control word defines the Tag Sensor functionality. The SSD block is transmitted as part of the data packet for a Type D Tag as defined in 6.3.3.5.

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Annex A
(informative)

Calculation of 5-bit and 16-bit cyclic redundancy checks

A.1 Example CRC-5 encoder/decoder

An exemplary schematic diagram for a CRC-5 encoder/decoder is shown in Figure A.1, using the polynomial and preset defined in Table A.1.

Table A.1— CRC-5 definition

CRC-5 Definition				
CRC Type	**Length**	**Polynomial**	**Preset**	**Residue**
—	5 bits	$x^5 + x^3 + 1$	01001_2	00000_2

To calculate a CRC-5, first preload the entire CRC register (i.e. Q[4:0], Q4 being the MSB and Q0 the LSB) with the value 01001_2 (see Table A.2), then clock the data bits to be encoded into the input labelled DATA, MSB first. After clocking in all the data bits, Q[4:0] holds the CRC-5 value.

To check a CRC-5, first preload the entire CRC register (C[4:0]) with the value 01001_2, then clock the received data and CRC-5 {data, CRC-5} bits into the input labelled DATA, MSB first. The CRC-5 check passes if the value in Q[4:0] $=00000_2$.

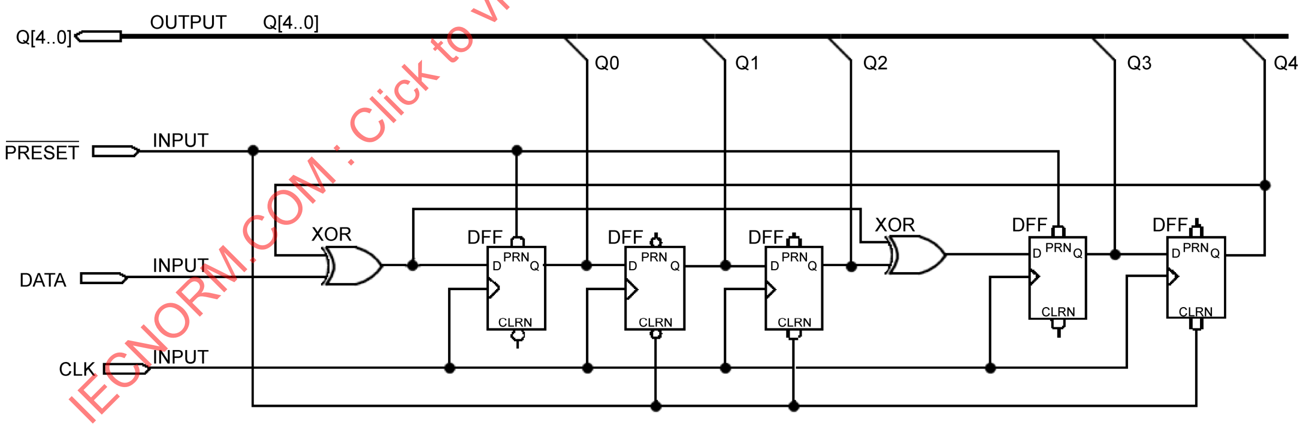

Figure A.1 — Example CRC-5 circuit

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Table A.2 — CRC-5 register preload values

Register	Preload value
Q0	1
Q1	0
Q2	0
Q3	1
Q4	0

A.2 Example TID-S CRC-16 encoder/decoder

An exemplary schematic diagram for a TID-S CRC-16 encoder/decoder is shown in Figure A.2, using the polynomial and preset defined in Table A.3 (the polynomial used to calculate the CRC-16, $x^{16} + x^{12} + x^5 + 1$, is the CRC-CCITT International Standard, ITU Recommendation X.25).

Table A.3 — CRC-16 precursor

CRC-16 precursor				
CRC Type	**Length**	**Polynomial**	**Preset**	**Residue**
ISO/IEC 13239	16 bits	$x^{16} + x^{12} + x^5 + 1$	**$FFFF_h$**	**$1D0F_h$**

To calculate a CRC-16, first preload the entire CRC register (i.e. Q[15:0], Q15 being the MSB and Q0 the LSB) with the value $FFFF_h$. Second, clock the data bits to be encoded into the input labelled DATA, MSB first. After clocking in all the data bits, Q[15:0] holds the ones-complement of the CRC-16. Third, invert all the bits of Q[15:0] to produce the CRC-16.

There are two methods to check a CRC-16:

Method 1: First preload the entire CRC register (Q[15:0]) with the value $FFFF_h$, then clock the received data and CRC-16 {data, CRC-16} bits into the input labelled DATA, MSB first. The CRC-16 check passes if the value in Q[15:0]=$1D0F_h$.

Method 2: First preload the entire CRC register (Q[15:0]) with the value $FFFF_h$. Second, clock the received data bits into the input labelled DATA, MSB first. Third, invert all bits of the received CRC-16, and clock the inverted CRC-16 bits into the input labelled DATA, MSB first. The CRC-16 check passes if the value in Q[15:0]=0000_h.

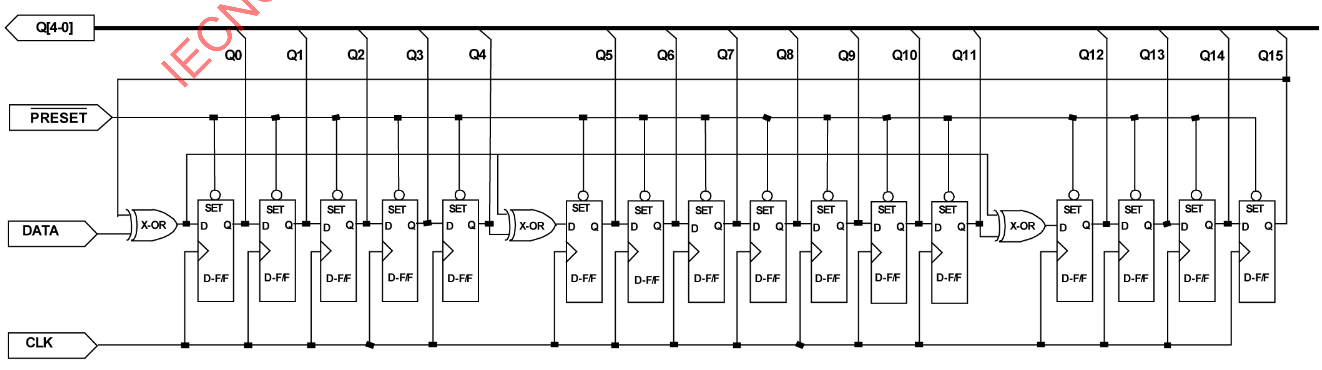

Figure A.2 — Example TID-S CRC-16 circuit

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A.3 Example TID-U CRC-16 encoder/decoder

The polynomial used to calculate the TID-U CRC-16 is $x^{16} + x^{15} + x^2 + 1$.

A possible implementation is using a 16-bit shift register as defined in Figure A.3. The 16-bit CRC register is named Q15 to Q0, with Q15 being the MSB and Q0 being the LSB. The 16-bit register must be preloaded with 0xFF (HEX).

The 48 bits of data must be clocked through the CRC register, using the MSB first. The 16 CRC bits are then appended to the 48 data bits, MSB first.

For checking the CRC-16 the 48 data bits concatenated with the 16 CRC bits are clocked through the register, MSB first. After the LSB of the CRC-16 bit is clocked through, the 16-bit CRC register should contain all zeros.

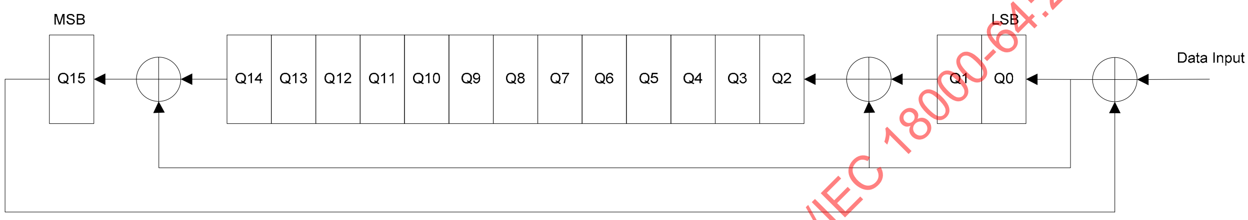

Figure A.3 — Example TID-U CRC-16 circuit

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Annex B
(normative)

Simple Sensors Data Block

B.1 Simple sensor types

This Annex provides detailed specifications for all defined types of Simple Sensor. Table B.1 and Table B.2 show the overall bit structure of the Simple Sensor Data Block and subsequent tables expand on each of the component fields.

Table B.1 — Structure of the 32-bit Simple Sensor Data Block

Simple Sensor Type	MSB 31 30 29 28	27 26 25	24 23	22 21 20 19	18 17 16	15 14 13	12 11 10	9 8 7	6 5 4	3 2 1 0 LSB
Temperature Span 14 C	Sensor type 0000	Measure span	Acc	Sampling regime	High in-range limit	Low in-range limit	Monitor delay	High out-of-range alarm delay	Low out-of-range alarm delay	Alarms
Temperature Span 28 C	Sensor type 0001	Measure span	Acc	Sampling regime	High in-range limit	Low in-range limit	Monitor delay	High out-of-range alarm delay	Low out-of-range alarm delay	Alarms
Relative Humidity	Sensor type 0010	Measure span	Acc	Sampling regime	High in-range limit	Low in-range limit	Monitor delay	High out-of-range alarm delay	Low out-of-range alarm delay	Alarms
Impact	Sensor type 0011	Measure span	Acc	Null values	Defined by bits 25 to 27	Null values	Null values	High out-of-range alarm delay	Null values	Alarms
Tilt	Sensor type 0100	Measure span	Acc	Null values	Defined by bits 25 to 27	Null values	Null values	High out-of-range alarm delay	Null values	Alarms
Reserved	Sensor type 0101 to 0111	Reserved for Future Use (see note)								Alarms
Write Access	RFID Tag Manufacturer			Authorized User						No Access (Internal)

NOTE: The length of the Simple Sensor block is determined by the MSB of the sensor type. All 32-bit sensor data blocks are assigned with the next available sensor type code value with subsequent codes being assigned in increments of 1.

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Table B.2 — Structure of the 48-bit Simple Sensor Data Block

<table>
<tr><th rowspan="2">Simple Sensor Type</th><th colspan="32">MSB</th></tr>
<tr><th>47</th><th>46</th><th>45</th><th>44</th><th>43</th><th>42</th><th>41</th><th>40</th><th>39</th><th>38</th><th>37</th><th>36</th><th>35</th><th>34</th><th>33</th><th>32</th><th>31</th><th>30</th><th>29</th><th>28</th><th>27</th><th>26</th><th>25</th><th>24</th><th>23</th><th>22</th><th>21</th><th>20</th><th>19</th><th>18</th><th>17</th><th>16</th></tr>
<tr><td>Reserved</td><td colspan="4">Sensor type 1000 to 1111</td><td colspan="24">Reserved for Future Use (see note)</td><td colspan="4">Alarms</td></tr>
<tr><td>Write Access</td><td colspan="4">RFID Tag Manufacturer</td><td colspan="24">Authorized User</td><td colspan="4">No Access (Internal)</td></tr>
</table>

<table>
<tr><th rowspan="2">Simple Sensor Type</th><th colspan="16">LSB</th></tr>
<tr><th>15</th><th>14</th><th>13</th><th>12</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>Reserved</td><td colspan="16">Reserved for Future Use (see note)</td></tr>
<tr><td>Write Access</td><td colspan="16">Authorized User</td></tr>
</table>

NOTE: The length of the Simple Sensor block is determined by the MSB of the sensor type. All 48-bit sensor data blocks are assigned with the next available sensor type code value with subsequent codes being assigned in increments of 1.

B.2 General bit-based rules

The following fields shall be encoded by the RFID Tag manufacturer and shall be read-only with support for one-time-programming unless the RFID Tag provides a secure mechanism for reconfiguring the sensor: sensor type, measurement span and accuracy.

The following fields may be user programmed: sampling regime, high in-range limit, low in-range limit, monitor delay, high out-of-range alarm delay, low out-of-range alarm delay.

The 4-bit alarm field is generated internally by the RFID Tag and is read-only across the air interface. If any of the dynamic alarm parameters indicate that the sensor has been triggered then any future user programming of such a sensor is invalid unless the RFID Tag provides a secure mechanism for reconfiguring the sensor.

B.3 Temperature sensor with 14° C span

B.3.1 Monitored measurement span

This Simple Sensor is capable of monitoring in 1°C resolution on temperatures, within a measurement span of 14°C, with a range of ±7°C of the centre of the span. This sensor type supports a choice of one of eight spans as shown in Table B.3.

Table B.3 — Measurement Span Bit Map - Temperature ±7°C

Measurement span	
000	-22±7°C
001	-15±7°C
010	-8±7°C
011	-1±7°C
100	+6±7°C
101	+13±7°C
110	+20±7°C
111	+27±7°C

B.3.2 Accuracy

This Simple Sensor is capable of reporting to one of three levels of accuracy as shown in Table B.4.

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