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# TECHNICAL REPORT

## 860MHz–930MHz Class I Radio Frequency Identification Tag Radio Frequency & Logical Communication Interface Specification Candidate Recommendation, Version 1.0.1

Auto-ID Center

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## OVERVIEW

This document specifies the radio frequency communication interface and Reader commanded functionality requirements for an Auto-ID Center Class I radio frequency identification (RFID) Tag operating in the frequency range of 860MHz-930Mhz. A Class I tag is designed to communicate only its unique identifier and other information required to obtain the unique identifier during the communication process.

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Contents



# 1. DOCUMENT SCOPE

This document specifies the radio frequency communication interface and Reader commanded functionality requirements for an Auto-ID Center Class I radio frequency identification (RFID) Tag operating in the frequency range of 860MHz–930Mhz. A Class I tag is designed to communicate only its unique identifier and other information required to obtain the unique identifier during the communication process.

# 2. RFID SYSTEM GENERAL COMMUNICATION OVERVIEW

The radio frequency (RF) communication interface and Reader commanded functionality requirements specified herein are for a reader talks first passive RFID system. A Class I Tag will communicate only when directed by a properly decoded and interpreted command emitted from a source other than the Tag itself. We will refer to any such source as a Reader.

The data symbols communicated between the reader and the tag are referred to as a binary zero (`0`), a binary one (`1`), a null, and punctuation. The encoding and modulation of these symbols (from the Reader to the Tag and from the Tag to the Reader) are described in later sections of this document.

The Class I RFID Tags will communicate by using backscatter modulation only. The Class I RFID Tags will not modulate their backscatter signal except when directed to by a properly decoded and interpreted command emitted from a Reader. A Class I Tag will respond to all properly decoded and interpreted signals regardless of emitting source (unless that source is the Tag itself).

Communication occurs in a half-duplex manner. A Tag shall not perform communication while it is waiting for communication from a Reader. A Tag shall not interpret communication from a Reader while it is communicating.

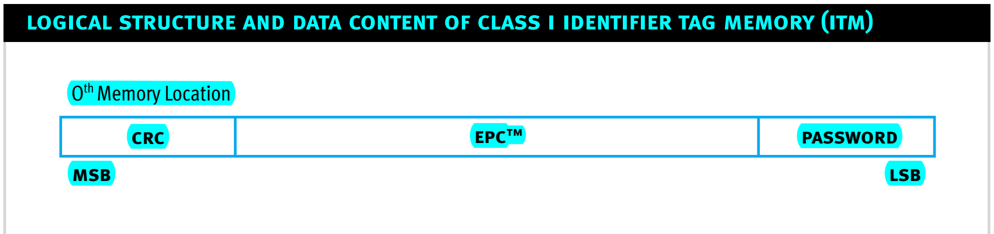
# 3. CLASS I TAG DATA CONTENT

A Class I Tag will contain a unique identifier, error detection/correction code applied to that identifier, and a short password as its only data and information content. The unique identifier will be a valid representation of an EPC™. The error detection/correction code will be a Cyclic Redundancy Check (CRC). There are no restrictions on the password.

The Class I Tag data is logically stored in the Identifier Tag Memory (ITM). The ITM is logically organized as a linear memory with the most significant bit (MSB) of the CRC located at memory location zero (`0`). The least significant bit (LSB) of the CRC is followed by the MSB of the EPC™. The LSB of the EPC™ is followed by the MSB of the Password. The LSB of the Password is the last bit of the ITM.

**Figure 1:** Class I Identifier Tag Memory (ITM) data content and organization




## 3.1. EPC™ Representations

Valid representations of EPCs™ are defined by the Auto-ID Center. All valid EPCs™ contain four sections: version, domain manager, object class, and serial number arranged in that order from MSB to LSB. Thus, the MSB of the EPC™ is the MSB of the version number.

## 3.2. CRC

The CRC is calculated over the entire EPC™ with the most significant byte of the EPC™ being the first byte acted upon by the CRC algorithm. For EPCs™ of length less than or equal to 256 bits, the CRC-CCITT CRC is used. This results in a 16-bit CRC.

## 3.3. Password

The Password is an 8-bit data string used by the `KILL` command as defined in the following section.

# 4. RFID SYSTEM READER-TAG LOGICAL COMMUNICATION

Communication between a reader and a tag occurs in a packetized manner where a single packet contains a complete command from a reader and a complete response from the tag. The command and response permits half-duplex communication between a Reader and a Tag. The commands from the Reader enable selection based upon the Tag's CRC and EPC™, and are meant to reduce the on-Tag state requirements. Section 6.1 describes the structure of the Reader-to-Tag command communication. Section 6.2 describes the commands that a Tag may implement. Section 6.3 describes the Tag-to-Reader reply communication.

## 4.1. Reader-to-Tag Command Communication

A complete command from a reader consists of eight `(8)` fields and five `(5)` parity bits over those fields. The fields and parity bits have the following format:

[PREAMBL][CLKSYNC][SOF][CMD][$P_1$][PTR][$P_2$][LEN][$P_3$][VALUE][$P_4$][$P_5$][EOF]

Each field and parity bit in the Reader command is described in Table 1.

**Table 1:** Description of the Reader-to-Tag Command Partitions

| BASIC COMMAND FIELD | NUMBER OF BITS | FIELD DESCRIPTION |
|---|---|---|
| [PREAMBL] | NA | Every command is prefixed by a period with no RF transmission from a Reader followed by a period of Reader CW transmission. This field is defined in Section 7. |
| [CLKSYNC] | 20 | Every Command is prefixed by a series of 20 binary zeros (0) for on-tag clock synchronization. The synchronization circuitry on the tag uses this part of the message to establish its onboard timing for reading/decoding messages and clocking subsequent replies to the Reader. |
| [SOF] | 1 | Start of Frame indicator. A binary one (1). |
| [CMD] | 8 | Specifies the command being sent to the tags. |
| [$P_1$] | 1 | Odd Parity of the [CMD] field data. |
| [PTR] | 8* | Pointer to a location (or bit index) in the tag identifier. The bit index starts at the MSB ([PTR] value 0) and works towards the LSB. A [PTR] value less than or equal to 254 is represented using 8 bits. A [PTR] value greater than 254 is represented using 2 bytes with the first byte following [$P_1$] having a value of FF in hex, and the second byte having a value of 254 less than the pointer value. This process is repeated for values greater than 510. [PTR] is the starting point for tags to attempt a match with data specified in the [VALUE] field. (Defined below.) |
| [$P_2$] | 1 | Odd Parity of the [PTR] field data. |
| [LEN] | 8* | Length of the data being sent in the [VALUE] field. (Defined below). A [LEN] value less than or equal to 254 is represented using 8 bits. A [LEN] value greater than 254 is represented using 2 bytes with the first byte following [$P_2$] having a value of FF in hex, and the second byte having a value of 254 less than the length value. This process is repeated for values greater than 510. The value of [LEN] must be greater than zero (0). |
| [$P_3$] | 1 | Odd Parity of the [LEN] field data. |
| [VALUE] | Variable | Selection value under ScrollID, PingID, Quiet, Talk, and Kill commands. This is the data that the tag will attempt to match against its own identifier. (From the [PTR] position towards the LSB.) The tag will not match any value that extends into or beyond the last 8 bits of its ITM (the last 8 bits correspond to the Password). In the ProgramID command, this is the value programmed into the ITM. |
| [$P_4$] | 1 | Odd Parity of the [VALUE] field data. |
| [$P_5$] | 1 | Odd Parity of all of the Parity fields. |
| [EOF] | 1 | End of Frame indicator. A binary one (1). |

## 4.2. Reader-to-Tag Commands

The commands that a reader may send to a tag are divided into required commands and identifier programming commands. A tag must implement a required command. A tag will implement identifier programming commands depending upon the type of ITM memory implemented on the tag.

### 4.2.1. Reader-to-Tag Command Codes

The required commands and the tag response, if any, are defined in Table 2.

**Table 2:** Required Commands

| COMMAND NAME | COMMAND CODE (BINARY MSB-LSB) | TAG REPLY |
|---|---|---|
| `ScrollAllID` | `0011 0100` | `ScrollID` Reply |
| `ScrollID` | `0000 0001` | `ScrollID` Reply |
| `PingID` | `0000 1000` | `PingID` Reply |
| `Quiet` | `0000 0010` | None |
| `Talk` | `0001 0000` | None |
| `Kill` | `0000 0100` | None |

The identifier programming commands and the tag response, if any, are defined in Table 3.

**Table 3:** Identifier Programming Commands

| COMMAND NAME | COMMAND CODE (BINARY MSB-LSB) | TAG REPLY |
|---|---|---|
| `ProgramID` | `0011 0001` | None |
| `VerifyID` | `0011 1000` | `VerifyID` Reply |
| `LockID` | `0011 0001*` | None |
| `EraseID` | `0011 0010` | None |

A Class I compliant tag will change its internal state or perform backscatter modulation in response to commands defined in this document only. A Class I compliant tag will interpret all command codes not defined herein as unknown commands and will neither change its internal state nor perform backscatter modulation in response to any such unknown command.

### 4.2.2. Reader-to-Tag Required Command Descriptions

**`ScrollAllID:`** All tags reply by communicating an eight (8)-bit preamble, followed by the CRC (sent MSB first), followed by their entire ID Code (MSB of the tag identifier first).

**`ScrollID:`** Tags matching `[VALUE]` beginning at location `[PTR]` reply by communicating an eight (8)-bit preamble, followed by the CRC (sent MSB first), followed by their entire ID Code (MSB of the tag identifier first).

**`PingID:`** Tags matching `[VALUE]` beginning at location `[PTR]` reply by sending eight (8)-bits of the tag identifier beginning with the bit at location `[PTR] + [LEN]`. The eight-bit reply is communicated during one of eight bins delineated by BinTicks from the reader. The communication bin is chosen to be equal to the value of the first three `(3)` MSBs of the eight bit reply.

**`Quiet:`** Tags matching `[VALUE]` beginning at location `[PTR]` enter a quiet mode where they no longer respond to or execute reader commands. This mode of operation is maintained until a proper `Talk` command is received and correctly interpreted or power has been removed from the tag for at least 1 second and at most 10 seconds. The Reader, after issuing the `Quiet` Command, must transmit 7 binary "0"s after the `[EOF]` to cause the Tag to execute the `Quiet` Command. After the 7 binary "0's" have been sent, the Reader may issue a transaction gap.

**`Talk:`** Tags matching `[VALUE]` beginning at location `[PTR]` enter an active mode where they respond to commands from the reader. This active mode of operation is the same mode that a Tag powers up into. This mode of operation is maintained until a proper `Quiet` command is received and correctly interpreted or power has been removed from the tag for at least 1 second and at most 10 seconds. The Reader, after issuing the `Talk` Command, must transmit 7 binary "0"s after the `[EOF]` to cause the Tag to execute the `Talk` Command. After the 7 binary "0's" have been sent, the Reader may issue a transaction gap.

**`Kill:`** Tags matching the `[VALUE]` (consisting of the complete tag identifier, CRC and an eight (8)-bit Password) beginning at location `[PTR] = 0` are permanently deactivated and will no longer respond to or execute reader commands. This `"self-destruct"` command renders the tag inactive forever.

### 4.2.3. Reader-to-Tag Identifier Programming Command Descriptions

**`ProgramID:`** All tags properly receiving the `ProgramID` command store the data sent in `[VALUE]` in the `[LEN]` bits that begin at location `[PTR]`. The `ProgramID` command programs exactly sixteen (16) bits. `[LEN]` has the decimal value of 16.

The `[PTR]` field must be set to a multiple of 16 beginning with decimal value 0 (e.g., 0, 16, 32, 48, 64, 80, 96). A Tag will ignore a `ProgramID` command if the value in `[PTR]` exceeds its ITM memory size.

If `[PTR]` points to the MSB of the Password, the last eight bits in `[VALUE]` must be 0x00 unless the ITM is being locked (see `LockID` command).

The reader must send binary 0's after the `[EOF]` for the duration of the programming time (a minimum of 30 ms). The program operation is terminated by the tag on receipt of a binary 1 indicating the end of the programming interval. The Reader must transmit seven binary "0"s after the terminating "1" to allow the Tag to perform an orderly shutdown of the erase/program sequence.

Upon receipt of a valid `ProgramID` command, the Tag will execute the appropriate internal timing sequences required to program memory. Transmission of subsequent Identifier Programming Commands must be preceded by a Tag Carrier off interval of at least $8 * T_0$.

**`VerifyID`:** All tags properly receiving the command reply by communicating an 8-bit preamble, followed by the CRC (sent MSB first), followed by their entire ID code (MSB of the tag identifier first) followed by the Password (sent MSB first). The `VerifyID` command is ignored by a tag that has successfully executed a `LockID` command. Transmission of subsequent Identifier Programming Commands must be preceded by a Tag Carrier off interval of at least $8 * T_0$.

**`LockID:`** The `LockID` command prevents any further modification of the tag identifier, CRC, and Password. The `LockID` command is a specific version of the `ProgramID` command. `[PTR]` must contain the value that points to the MSB of the Password. `[LEN]` must be equal to sixteen. The last eight bits of `[VALUE]` must be equal to 0xA5. Transmission of subsequent Identifier Programming Commands must be preceded by a Tag Carrier off interval of at least $8 * T_0$.

**`EraseID`:** The `EraseID` command sets all bits of the tag identifier, CRC, and Password to the value "0". The `EraseID` command is ignored by a tag that has successfully executed a `LockID` command.

The data sent to the Tag in the `[PTR]` and `[VAL]` fields by the Reader is not used by the Tag after validation of the message, and should be set to "0". The `[LEN]` field should be set to the value of 1, and a single "0" should be in the `[VAL]` field.

The Reader must send binary 0's after the `[EOF]` for the duration of the erase time, $T_{erase}$. (a minimum of 30 ms). The erase operation is terminated by the tag on receipt of a binary 1 indicating the end of the erase interval. The Reader must transmit seven binary "0"'s after the terminating "1" to allow the Tag to perform an orderly shutdown of the erase/program sequence.

Upon receipt of a valid `EraseID` Command the Tag will execute the appropriate internal timing sequences required to erase memory. Transmission of subsequent Identifier Programming Commands must be preceded by a Tag Carrier off interval of at least 8 * $T_0$.

### 4.2.4. Reader-to-Tag Identifier Programming Command Restrictions

Identifier programming commands may be required depending upon the type of memory used by the tag. The identifier programming commands are required to the extent that it must be possible to write and prevent any modification of the tag identifier, the CRC, and the password. That is, the ITM must be either read only or capable of being write-once-read-many (WORM) in its use. The combination of memory technology and implemented identifier programming commands must meet this basic requirement.

## 4.3. Tag-to-Reader Communication

A tag does not send commands to a Reader. A tag only executes commands issued by a Reader. Only four commands require a tag to modulate its backscatter for communication to the Reader: `VerifyID, ScrollAllID, ScrollID, and PingID`. All other commands modify the internal state of the Tag.

### 4.3.1. `VerifyID` Reply

Tags receiving the `VerifyID` command respond with the `VerifyID` Reply. The `VerifyID` Reply consists of the following format.

`[PREAMBL][CRC][TAGID][PASSWRD]`

Each field in this reply is described in Table 4.

**Table 4:** Description of the Tag-to-Reader Reply Partitions

| BASIC REPLY FIELD | NUMBER OF BITS | FIELD DESCRIPTION |
|---|---|---|
| `[PREAMBL]` | 8 | Tag modulates the value `FE` (in hex) in an MSB to LSB fashion as a preamble. |
| `[TAGID]` | Variable | Tag modulates the value of its identifier (EPC™) in an MSB to LSB fashion. |
| `[CRC]` | 16* | Tag modulates the value of its CRC in an MSB to LSB fashion. The CRC is 16 bits in length for EPC™ lengths up to 256 bits. |
| `[PASSWRD]` | 8 | Tag modulates the value of its Password in an MSB to LSB fashion. |

### 4.3.2. `ScrollID` Reply

Tags responding to either the `ScrollAllID` command or the `ScrollID` command respond with the `ScrollID` Reply. The `ScrollID` Reply consists of the following format.

`[PREAMBL][CRC][TAGID]`

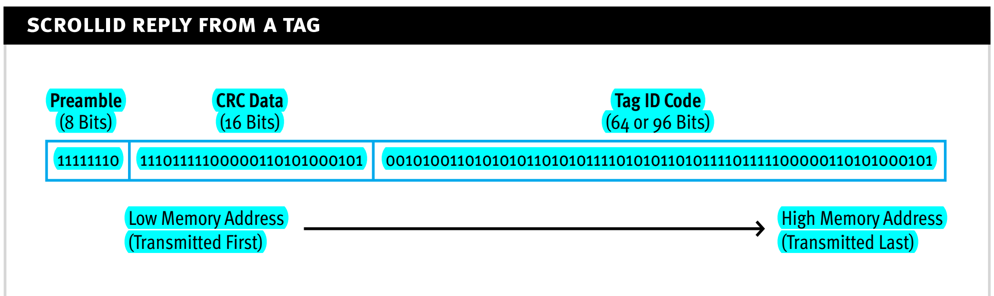
Each field in this reply is described in Table 5.

**Table 5:** Description of the Tag-to-Reader Reply Partitions

| BASIC REPLY FIELD | NUMBER OF BITS | FIELD DESCRIPTION |
|---|---|---|
| `[PREAMBL]` | 8 | Tag modulates the value `FE` (in hex) in an MSB to LSB fashion as a preamble. |
| `[TAGID]` | Variable | Tag modulates the value of its identifier (EPC™) in an MSB to LSB fashion. |
| `[CRC]` | 16* | Tag modulates the value of its CRC in an MSB to LSB fashion. The CRC is 16 bits in length for EPC™ lengths up to 256 bits. |

A Tag `ScrollID` Reply is illustrated in Figure 2.

**Figure 2:** Illustration of `ScrollID` Reply




### 4.3.3. `PingID` Reply

Tags responding to the `PingID` command respond with the `PingID` Reply. The `PingID` Reply consists of the following format.

`[8BITID]`

Each field in this reply is described in Table 6.

**Table 6:** Description of the Tag-to-Reader Reply Partitions

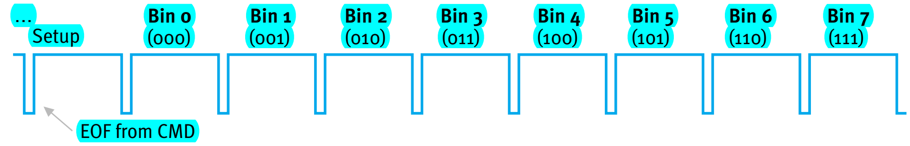
| BASIC REPLY FIELD | NUMBER OF BITS | FIELD DESCRIPTION |
|---|---|---|
| `[8BITID]` | 8 | Tag modulates the 8-bit value in its ITM beginning at memory location `[PTR]+[LEN]` in an MSB to LSB fashion. The tag will not modulate any of the bit values stored in the last 8 bits of its ITM (these bits correspond to the Password). |

The `PingID` Reply is communicated in the PingBin corresponding to the value of the three MSBs of its reply. The Reader delineates PingBins with a BinPulse as described in Section 7. Figure 3 illustrates the bins in a `PingID` Reply.

**Figure 3:** `PingID` Reply Response Period – Reader Modulations (BinTicks) Define Response Bins

**PINGID REPLY RESPONSE PERIOD**




# 5. RFID SYSTEM READER-TAG RF COMMUNICATION

## 5.1. RF Communication Range

The radio frequency (RF) communication interface specified in this document is designed for Class I Tags operating in the frequency range of 860MHz–930Mhz. The intended free space communication range of the tags implemented to this specification is nominally greater than 3 m with at least 2 m at their worst orientation and no more than 10 m at their best orientation.

## 5.2. Reader-Tag Half-Duplex Communication

As specified in Section 6, the Reader-to-Tag and Tag-to-Reader communication occurs in a half-duplex manner. The Reader initiates communication by modulating a complete command. The Reader then transmits an unmodulated continuous wave (CW) signal. The Tag modulates its reflection of the CW signal (backscatter communication).

## 5.3. Reader-to-Tag Communication Signals

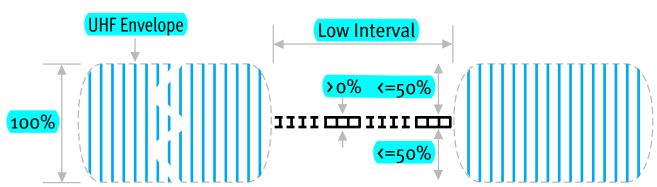
A Reader may emit no signals at any frequency, may emit a CW signal at a single frequency, or may emit a modulated signal at a single frequency.

### 5.3.1. Reader-to-Tag Signal Modulation Depth

The Reader communicates with tags using Amplitude Shift Keying (ASK) with a minimum modulation depth of 30% and a maximum modulation depth of 100%. Modulation shape, depth and rate of modulation are variable within the limits described below. Compliant Tags will adjust their timing over a range of modulation rates to lock to reader transmissions automatically during the `[CLKSYNC]` period of a Reader command.

**Figure 4:** Reader to tag modulation depth

**READER TO TAG MODULATION DEPTH**



The modulation parameters in general are illustrated in Figure 5. Table 7 defines the Region 1 (North American) parameters, and Table 8 defines the Region 2 (Europe) parameters. Specific values are a function of the local regulatory environment.

**Figure 5:** Modulation parameters

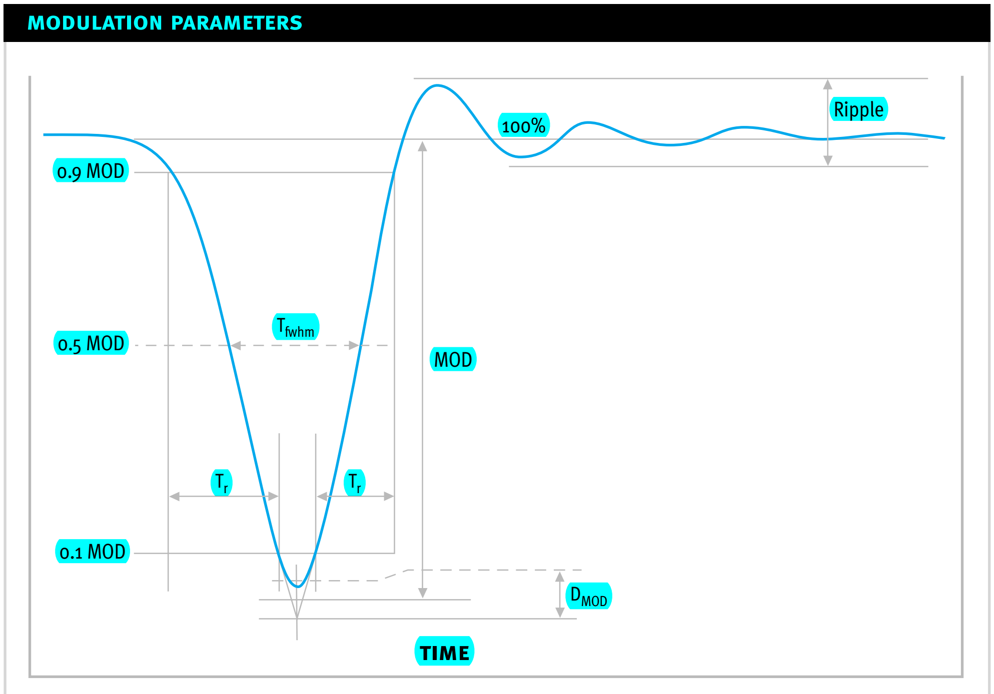



**Table 7:** Definition of the Reader-to-Tag Modulation Parameters

| PARAMETER | DESCRIPTION |
|---|---|
| $T_o$ | Elemental Clock Cycle period. Time for a single bit sent from Reader to Tag. |
| $T_r$ | Rise time of modulation envelope, 10% to 90% of Modulation amplitude variation. |
| $T_f$ | Fall time of modulation envelope, 90% to 10% of Modulation amplitude variation |
| $T_{fwhm}$ | Pulse width of modulation envelope measured at 50% of Modulation amplitude variation. |
| Mod | Amplitude variation of modulated carrier. |
| Ripple | Peak to Peak variation in modulation overshoot and undershoot at edges of intended modulation. |
| $D_{mod}$ | Peak to Peak variation in modulation depth from intended value. |
| $T_{oTol}$ | Master Clock Interval Tolerance, Basic accuracy of reader signaling. |
| $T_{trangap}$ | Pulse width of the Transaction Gap that precedes each transaction. |
| $T_{Coast}$ | Maximum Time duration between EOF and the next Transaction Gap, to ensure that the Tag will be able to detect the transaction gap and re-synchronize to the Reader data stream. |
| $T_{Reset}$ | Minimum Modulation low time to Power down a tag. |

For all Reader modulation sequences, it is anticipated that the Reader clock must be stable to within 1% over the length of a transaction.

All other "Elemental Clock Cycle" timings are proportional to the modulation clock frequency $T_o$.

**Table 8:** Reader-to-Tag Modulation Parameters Nominal Values for Region 1 (North America)

| NOMINAL VALUES FOR THE PULSE MODULATION PARAMETERS | DESCRIPTION | NORTH AMERICAN OPERATION |
|---|---|---|
| $T_o$ | Master Clock Interval | 14.25 us |
| $T_{oTol}$ | Master Clock Interval Tolerance | ± 1% Maximum |
| $1/T_o$ | Data Rate | 70.18 Kbps |
| $T_{fwhm0}$ | Half Width of Binary 0 Feature (1/8 * $T_o$) | 1.78 us |
| $T_{fwhm1}$ | Half Width of Binary 1 Feature (3/8 * $T_o$) | 5.34 us |
| MOD | Modulation Depth | 90% |
| DMOD | Variability in Modulation Depth | 10% |
| $T_f$ | Fall Time | 300 ns nom. |
| $T_r$ | Rise Time | 300 ns nom. |
| Ripple | Ripple | 10 % pp |
| $T_{fwhmBin}$ | Half Width of Bin Modulation Feature, Low Time (3/8 * $T_o$) | 5.34 us |
| $T_{fwhmBinRW}$ | Half Width of Bin Modulation Response Window (8 * $T_o$) | 114.00 us |
| $T_{trangap}$ | Half Width of Transaction Gap (1.25 * $T_o$) | 17.81 us |
| $T_{Coast}$ | Time duration between EOF and the next Transaction Gap | 20 ms max. |
| $T_{Reset}$ | Modulation low time to Power down a tag | 200 us min. |

**Table 9:** Reader-to-Tag Modulation Parameters Nominal Values for Region 2 (Europe)

| NOMINAL VALUES FOR THE PULSE MODULATION PARAMETERS | DESCRIPTION | EUROPEAN OPERATION |
|---|---|---|
| $T_o$ | Master Clock Interval | 66.67 us |
| $T_{o\ Tol}$ | Master Clock Interval Tolerance | ± 1% Maximum |
| $1/T_o$ | Data Rate | 15.00 Kbps |
| $T_{fwhm0}$ | Half Width of Binary 0 Feature (1/8 * $T_o$) | 8.25 us |
| $T_{fwhm1}$ | Half Width of Binary 1 Feature (3/8 * $T_o$) | 24.75 us |
| MOD | Modulation Depth | 50% |
| $T_{fwhmBin}$ | Half Width of Bin Modulation Feature, Low Time (3/8 * $T_o$) | 24.75 us |
| $T_{fwhmBinRW}$ | Half Width of Bin Modulation Response Window (8 * $T_o$) | 533.33 us |
| $T_{trangap}$ | Half Width of Transaction Gap (1.25 * $T_o$) | 83.33 us |
| $T_{Coast}$ | Time duration between EOF and the next Transaction Gap | 20 ms max. |
| $T_{Reset}$ | Modulation low time to Power down a Tag | 200 us |

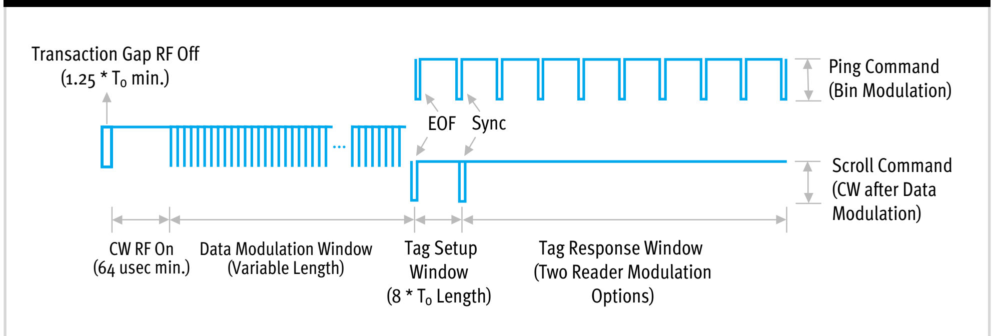
### 5.3.2. Reader-to-Tag Command Signal Phases

There are five distinct phases in the reader-to-tag communication. Reader-to-tag communication begins with a minimum 1.25*$T_o$ off period, or Transaction Gap (the first phase), followed by a 64 µs CW period (no modulation of the emitted signal) before modulation (the second phase). The first and second phases comprise the `[PREAMBL]` of the Reader command. The Reader then modulates its emitted signal to communicate the remainder of the command to the tags. This is referred to as the Data Modulation Window (the third phase). A short setup period (the fourth phase) provides time for the tags to interpret and begin executing the command just issued by the Reader. Finally, the reader enters a low modulation phase during which the tags respond to the just communicated command (the fifth phase).

The low modulation in the Tag reply interval may be either CW or Bin Modulation. Bin Modulation is used during the Tag reply interval of the `PingID` command to specify time slots for Tag responses.

**Figure 6:** Reader-to-Tag modulation overview

**READER TO TAG MODULATION OVERVIEW**




All transactions begin with a transaction gap, $T_{trangap}$, followed by a minimum 64 μs CW period preceding the Data Modulation Window.

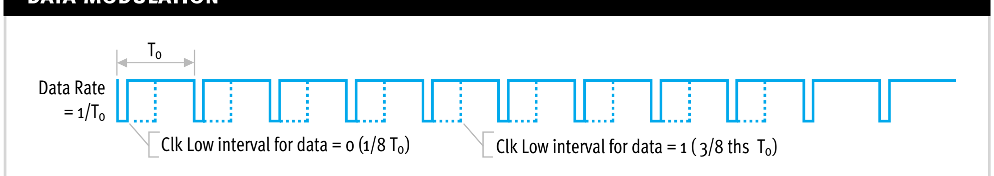
At the beginning of Data Modulation, Readers provide a master clock signal to Tags. This is the `[CLKSYNC]` period of the command. The time between the negative-going edges of the low intervals, $T_0$, determines the Reader-to-Tag data rate.

The Tags are synchronized to the Reader on the negative-going edge of the low interval of the RF envelope. All subsequent signaling is tied to this fundamental frequency in a proportional manner.

Binary data from Reader to Tag is encoded as pulse width modulation of the low level pulse. Logical zeros are defined as a modulation whose width is one eighth (1/8) of the master clock interval, $T_0$. Logical ones are encoded as a modulation whose width is three eighths (3/8) of the master clock interval, $T_0$.

**Figure 7:** Data modulation

**DATA MODULATION**




During Bin Modulation, nine (9) pulses are sent by the Reader to delineate the end of nine time intervals. The first interval, after the EOF, is used for Tags to set up for modulation. The remaining eight are used to delineate response intervals for the Tags.

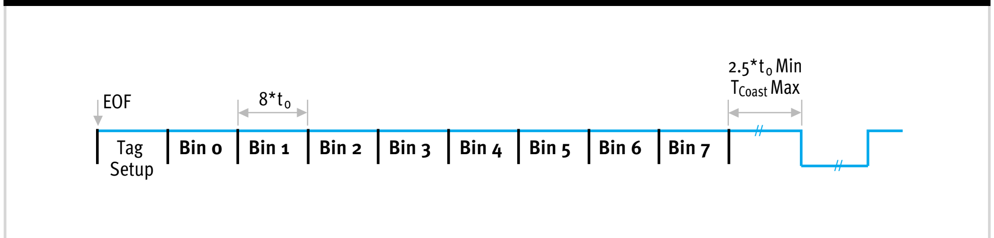
The width of the delineation pulse, $T_{fwhmBin}$, is $(3/8)T_0$ or the equivalent of a logical one. The width of the intervals, $T_{fwhmBinRW}$, is eight `(8)` times $T_0$.

After the last pulse, the Tag must be ready to receive the next transaction gap before 2.5 * $T_0$ intervals, and be able to detect a transaction gap received within a $T_{coast}$ interval. Refer to Figure 8 for an illustration.

**Figure 8:** Bin modulation

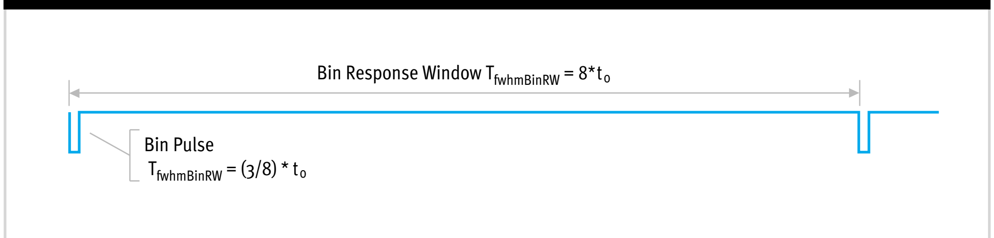
**BIN MODULATION**




A single Bin Response Window is illustrated in Figure 9.

**Figure 9:** Bin response window

**BIN RESPONSE WINDOW**

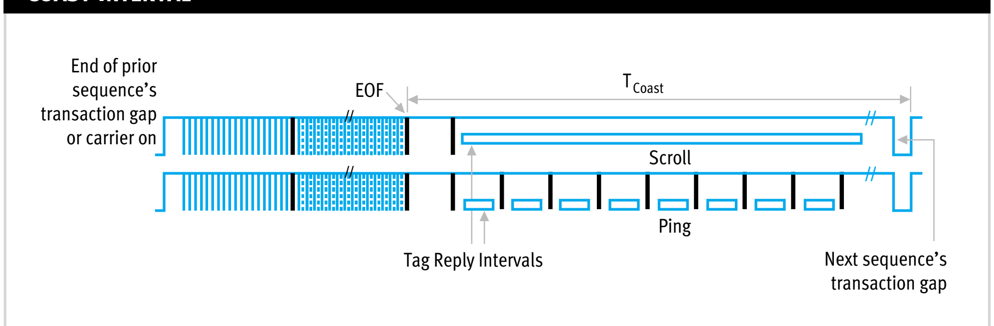



### 5.3.3. Coast Interval

In order for the Tag to be able to detect the next Transaction Gap, the Reader must start the next transaction within the Tcoast interval. This restriction does not apply when the carrier has been turned off for sufficient time for the tag to lose DC power, as the tag will re-synchronize at the next power up.

**Figure 10:** Coast Interval

**COAST INTERVAL**




### 5.3.4. Reader-to-Tag Data Encoding

Binary data from Reader to Tag is encoded as pulse width modulation (PWM) of the low amplitude pulse. The distance between falling edges of consecutive low amplitude pulses is $T_0$. A binary zero `(0)` is encoded by a $T_{data0}$ low amplitude pulse width, and a binary one `(1)` is encoded by a $T_{data1low}$ amplitude pulse width.

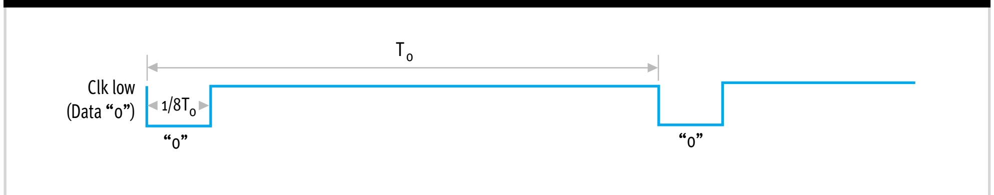
**Table 10:** Reader Data Modulation Timing

| READER DATA MODULATION TIMING | |
|---|---|
| Reader Logic 0 | $T_{data0}$ = 1/8$^{th}$ of $T_0$ |
| Reader Logic 1 | $T_{data1}$ = 3/8$^{th}$ of $T_0$ |

Data Modulation Timing, Tdata0, for Reader-to-Tag clocking when data = "0" is encoded by a "narrow" 1/8 * To pulse width modulation.

**Figure 11:** Data modulation timing for binary zero

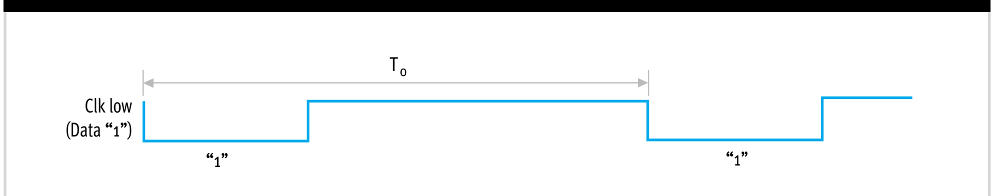
**DATA MODULATION TIMING FOR BINARY ZERO**




Data Modulation Timing, Tdata1, for Reader-to-Tag clocking when data = "1" is encoded by a "wide" 3/8 * $T_0$ pulse width modulation. This timing is also used for EOF, Sync and Bin Pulse features.

**Figure 12:** Data modulation timing for binary one

**DATA MODULATION TIMING FOR BINARY ONE**




Modulation of the negative pulse width (RF interruption period) is used for designating response bins for Tags after a `PingID` command is issued. Table 11 specifies the timing for the bins and bin pulses.

**Table 11:** Reader Bin Modulation Timing

| READER BIN MODULATION TIMING | |
|---|---|
| Reader Bin Designation | $T_{fwhmBin}$ = 3/8 of $T_0$ |
| Bin Width | $T_{fwhmBinRW}$ = 8 * $T_0$ |

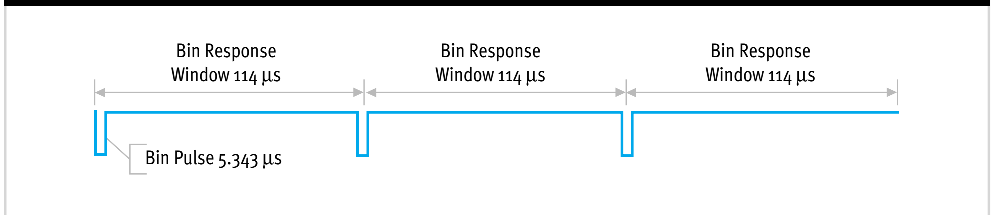
  

#### 5.3.5. `PingID` Reply Bin Modulation Pulses

Bin Modulation Timing for a Reader with a 70.175 KHz master clock interval is illustrated in Figure 13.

**Figure 13:** Bin modulation timing for maximum data rate

**BIN MODULATION TIMING FOR MAXIMUM DATA RATE**

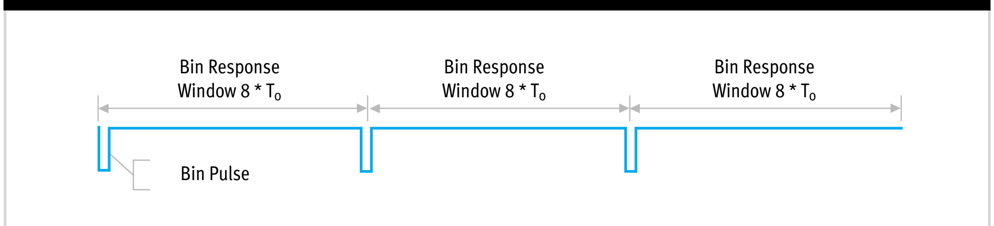



#### 5.3.6. `PingID` Reply Bin Collapse

The Reader may optionally shorten the time for a `PingID` transaction by shortening the Bin Response Window. The Reader may shorten the duration between the Bin Modulation pulses for that bin by 4 * $T_0$ (–50%). This may be applied for each of the eight bins. The middle bin in Figure 14 has been shortened due to no Tag reply.

**Figure 14:** Collapsed bin modulation timing

**COLLAPSED BIN MODULATION TIMING**




## 5.4. Tag-to-Reader Communication Signals

Tags reply to Reader commands with backscatter modulation that follows a four (4)-interval bit cell encoding scheme. Two `(2)` transitions are observed for a binary zero `(0)` and four `(4)` transitions are observed for a binary one `(1)` during a Bit Cell. The nominal data rate for Tag to Reader is twice the Reader to Tag Rate but may vary up to 25% over an 80 bit response window due to oscillator drift in the tag. Data is always transmitted MSB to LSB.

**Table 12:** Tag-to-Reader Parameter Definitions

| PARAMETER | DESCRIPTION |
|---|---|
| $T_0$ | Elemental Clock Cycle period. Time for a single bit sent from Reader to Tag. |
| $T_{tagbitcell}$ | Tag to Reader bit cell interval. |
| Tag Data Rate | Tag to Reader Nominal Data Rate of for the modulated backscatter. |
| $T_{tagscrollDel}$ | Reply delay from Reader EOF to start of Tag Scroll Reply |
| $T_{tagpingDel}$ | Reply delay from Reader EOF to start of Tag Ping Reply |
| $T_{tagreplyNom}$ | Tag to Reader reply duration for 88 bit scroll reply |
| $\_T_{tagbitcell}$ | Tag to Reader bit cell interval variation measured at the last bit of an 88 bit scroll reply. |
| $T_{Coast}$ | Maximum Time duration between EOF and the next Transaction Gap. |

**Table 13:** Tag-to-Reader Parameters for Region 1 (North America)

| TAG TO READER MODULATION PARAMETERS | DESCRIPTION | NORTH AMERICAN OPERATION |
|---|---|---|
| $T_0$ | Master Clock Interval | 14.25 us |
| $T_{tagbitcell}$ | Tag to Reader bit cell interval ($T_0$/2) | 7.13 us |
| Tag Data Rate | Tag to Reader Nominal Data Rate (2/$T_0$) | 140.35 kbps |
| $Tt_{agscrollDel}$ | Reply delay from Reader EOF to start of Tag Scroll Reply (4 * $T_0$ max) | 57.0 us |
| $T_{tagpingDel}$ | Reply delay from Reader EOF to start of Tag Ping Reply (4 * $T_0$ max) | 57.0 us |
| TtagreplyNom | Tag to Reader reply duration for 88 bit scroll reply ($T_0$/2 * 88 bits) | 627 us |
| _$T_{tagbitcell}$ | Tag to Reader bit cell interval variation at last bit of 88 bit scroll reply | ±25 % |
| $T_{Coast}$ | Time duration between EOF and the next Transaction Gap | 20 ms max. |

**Table 14:** Tag-to-Reader Parameters for Region 2 (Europe)

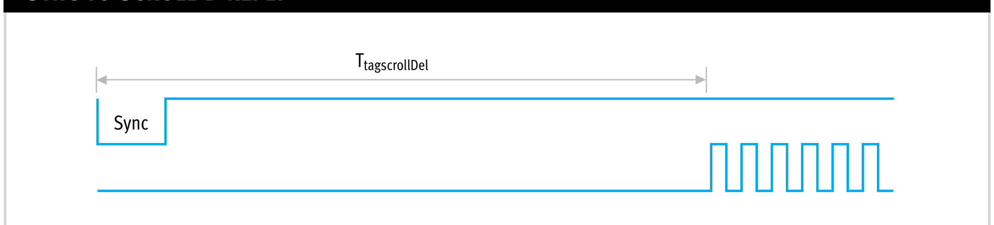
| TAG TO READER MODULATION PARAMETERS | DESCRIPTION | EUROPEAN OPERATION |
|---|---|---|
| $T_0$ | Master Clock Interval | 66.67 us |
| $T_{tagbitcell}$ | Tag to Reader bit cell interval ($T_0$/2) | 33.33 us |
| Tag Data Rate | Tag to Reader Nominal Data Rate (2/$T_0$) | 30.00 kbps |
| $T_{tagscrollDel}$ | Reply delay from Reader EOF to start of Tag Scroll Reply (4 * $T_0$ max) | 267 us |
| $T_{tagpingDel}$ | Reply delay from Reader EOF to start of Tag Ping Reply (4 * $T_0$ max) | 267 us |
| $T_{tagreplyNom}$ | Tag to Reader reply duration for 88 bit scroll reply ($T_0$/2 * 88 bits) | 2.93 ms |
| _$T_{tagbitcell}$ | Tag to Reader bit cell interval variation at last bit of 88 bit scroll reply | ±25 % |
| $T_{Coast}$ | Time duration between EOF and the next Transaction Gap | 20 ms max. |

### 5.4.1. `ScrollID` Reply Delay

The delay from the Sync Pulse to the start of a reply to a `ScrollID` or `VerifyID` Command, TtagscrollDel, is illustrated in Figure 15.

**Figure 15:** Sync to `ScrollID` Reply

SYNC TO SCROLLID REPLY



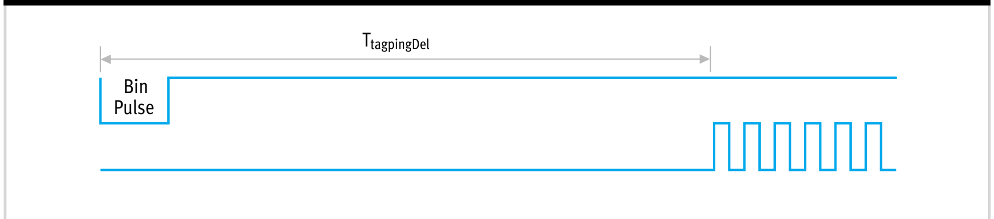

  

### 5.4.2. `PingID` Reply Delay

The delay from a Bin Pulse to the start of a reply to a Ping Command, TtagpingDel, is illustrated in Figure 16.

**Figure 16:** Sync to `PingID` Reply

**SYNC TO PING REPLY**

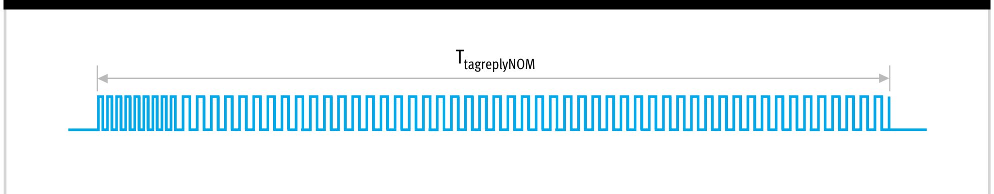



### 5.4.3. `ScrollID` Reply Duration

The duration of a Scroll Reply, $T_{tagreplyNom}$ is illustrated in Figure 17.

**Figure 17:** Tag-to-Reader nominal `ScrollID` Reply Duration

**TAG TO READER NOMINAL SCROLL REPLY DURATION**




### 5.4.4. Tag to Reader Bit Cell Variation

The variation in the bit cell duration _$T_{tagbitcell}$ is illustrated in Figure 18.

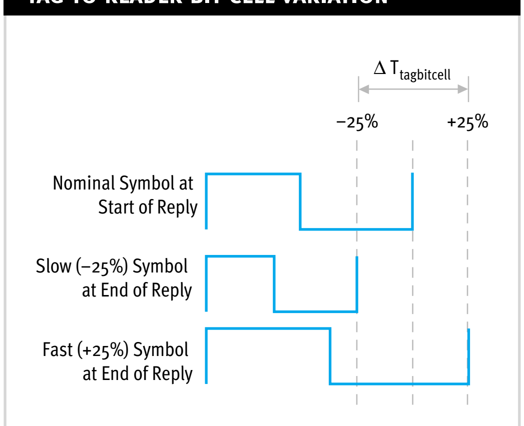
### 5.4.5. Tag to Reader Bit Cell

The Tag backscatter is modulated by a selection of one of two symbols per bit cell. The bit cell $T_{tagbitcell}$ is defined as shown in Figure 19.

**Figure 18:** Tag-to-Reader bit cell variation

**Figure 19:** Tag-to-Reader bit cell encoding

**TAG TO READER BIT CELL VARIATION**




**TAG TO READER BIT CELL ENCODING**