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UXM-30LXH-EWA
Communication Protocol Specification

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HOKUYO AUTOMATIC CO.,LTD.

UXM-30LXH-EWA
Communication Protocol Specification

Hokuyo Automatic Co., Ltd.

Rev 1.0

1 Preface

This document describes the specification of the communication protocol and control commands related to the SOKUIKI sensor series UXM-30LXH-EWA of Hokuyo Automatic Co., Ltd.
This specification is a communication protocol complying with Scanning Range Sensor Communication Interface Protocol (SCIP) ([1], [2]). The SCIP specification is a general protocol that does not depend on a particular type of sensor. This specification includes an extension of the SCIP protocol and is defined for communication with SOKUIKI sensors by Hokuyo Automatic Co., Ltd. The communication interface of this product is Ethernet interface and TCP/IP is used for communication.

2 Message

2.1 Communication

In basic communication, the request message is sent from the host computer to the sensor and the response message is returned from the sensor to the host computer. When data for each measurement scan is requested, it is sent from the sensor to the host system sequentially after the response message corresponding to the request message. Measurement scan refers to measurement of a scan by the sensor. The message sent from the sensor for each measurement scan is called scan response message. A scan response message is sent from the sensor to the host until the end of a request message for several scans or a forced stop request message is sent.

2.2 Command Code

A request message from the host includes a command code. The response and scan response messages are defined for each command code. The group of request message, response message and scan response message as function of this code as a whole is called command, and the handling is defined for each sensor. The command code complying with SCIP is expressed by two uppercase alphabet characters. The commands starting with a '%' character are extended commands introduced by Hokuyo Automatic Co. Ltd. Tables 1 and 2 are the lists of command codes.

Table 1: Measurement Commands

Command Code	Function	Request message parameters	Response message status and data	Scan response message status and data
GD GS	Distance acquisition	Start Step End Step Cluster Count	Status Time Distance	
GE	Distance and intensity acquisition	Start Step End Step Cluster Count	Status Time Distance, Intensity	
HD	Multiecho distance acquisition	Start Step End Step Cluster Count	Status Time Multiecho Distance	
HE	Multiecho distance and intensity acquisition	Start Step End Step Cluster Count	Status Time Multiecho Distance and Intensity	
MD MS	Distance acquisition with continuous scanning	Start Step End Step Cluster Count Scan Interval Number of Scans	Status	Status Time Distance
ME	Distance and intensity acquisition with continuous scanning	Start Step End Step Cluster Count Scan Interval Number of Scans	Status	Status Time Distance and Intensity
ND	Multiecho distance acquisition with continuous scanning	Start Step End Step Cluster Count Scan Interval Number of Scans	Status	Status Time Multiecho Distance
NE	Multiecho distance and intensity acquisition with continuous scanning	Start Step End Step Cluster Count Scan Interval Number of Scans	Status	Status Time Multiecho Distance and Intensity

Table 2: Non-measurement Commands

Command Code	Type	Function	Request message parameters	Response message status and data
%ST	State information	Obtain the current sensor condition		Status Current condition
BM	State transition	Transition to measurement state		Status
QT	State transition	Transition to standby state		Status
%SL	State transition	Transition to sleep state		Status
RS	Resetting	Reset		Status
RT	Resetting	Partial reset		Status
RB	Resetting	Reboot		Status
SS	Setup	Communication Speed Setup	Bitrate	Status
TM	Time synchronization	Time Setup	Control code	Status
VV	Information	Obtain Version		Status Version information
PP	Information	Obtain Sensor Parameters		Status Sensor parameters
II	Information	Obtain Sensor State		Status Sensor state
%PG	Information	Obtain synchronization phase value		Status Phase value

2.3 Request Message

Besides the command code and parameters, a request message can include a user defined string as well as a request terminator. The command code is expressed by two or three uppercase alphabet characters. According to that code string, the sensor state and response data is defined. Parameters vary by the command code and are multiple integers starting from zero. The number of digits of each value is fixed and is expressed in ASCII numerical characters (in base 10). When the number of digits of the value is less than the specified number of digits, zeros must be placed in the upper order digits.

```
Example 1 char  1 2 3
        2 chars 01 02 03 23 45
        3 chars 001 002 003 023 045 678 789
```

The user defined string is an optional character string starting with a semicolon, which can be used for identifying a message. The characters that can be used for the character string following the semicolon are alphabets, numerals, and six types of characters ’ ’, ’.’, ’_’, ’+’, ’-’, and ’@’. The request terminator can be either the line feed (LF) character or the carriage return (CR) character, or else both LF and CR as a two characters string code. Figures 1 and 2 show a request message and a user defined string, respectively. Elements that can be omitted are marked with a gray box.

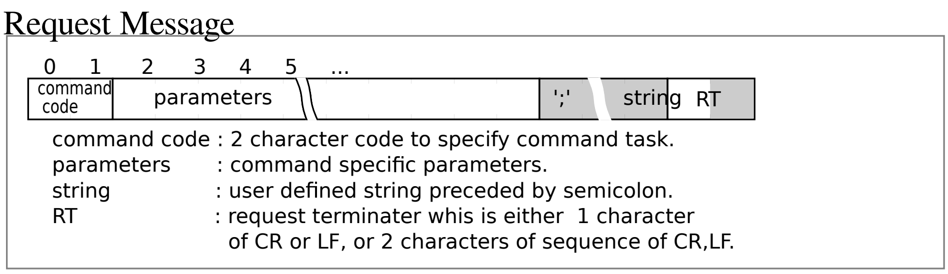

Figure 1: Request Message Format

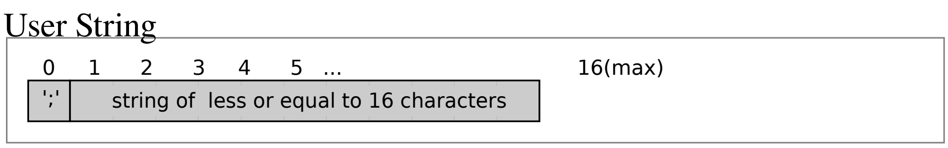

Figure 2: User Defined String

2.4 Response Message

The response message is sent from the sensor to the host system as promptly as possible. The response message is a data string that is defined by an echo back, status and command code. Each of them is delimited by a response delimiter. The echo back is the retransmission of the character string of the request message as it is, excluding just the request terminator. The status is a character string made up with a two-character code defined according to the command code and a check code for the two-character code. Then, optional data strings are added depending on the command code. For the optional data string, a check code is added for each response delimiter. The end of the response message is a consecutive response delimiters. Figure 3 shows the basic format of a response message.

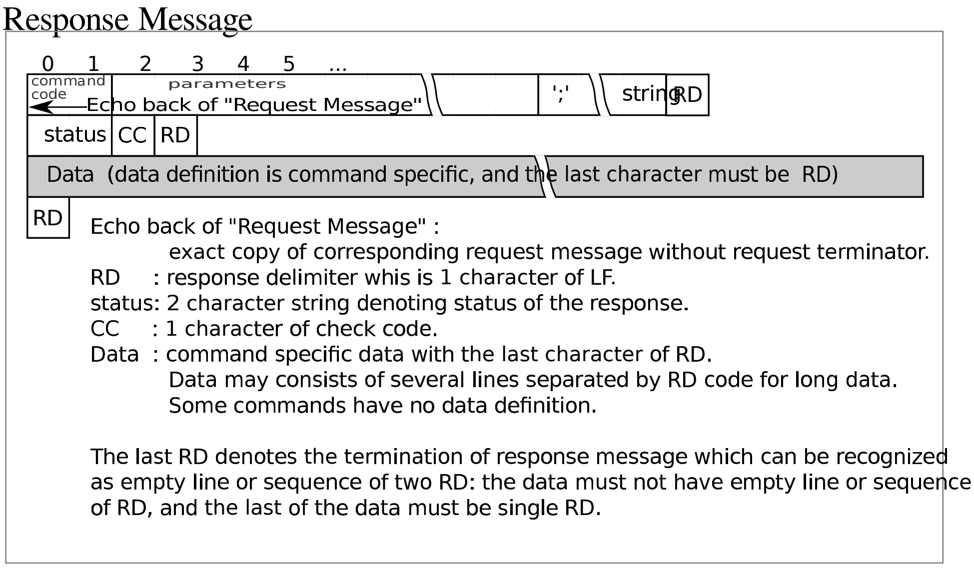

Figure 3: Response Message Format

2.5 Scan Response Message

There is a request command code to obtain scan data for multiple scans in continuous mode. For this, the sensor only sends a response message without measurement data to the host. Then, the sensor sends the measurement data of each scan to the host as a scan response message. The scan response message has the same format as that of a response message. Note that the echo back part is not the character string of the request message as it is. It is partially changed. The status consists of a two-character code that shows the sensor measurement status for each scan and a check code. Figure 4 shows the basic form of the scan response message.

2.6 6-bit Encoding

In SCIP, numerical representation is converted to ASCII readable characters by 6-bit encoding in order to send the numeric data with reduced traffic in the communication channel. Converting a 6-bit integer (i.e., the values from 0 to 63 or 0x00 to 0x3f in hexadecimal) into an ASCII readable character (i.e., in the 0x30 to 0x6f range) by adding an offset 0x30 is called 6-bit encoding. For example, a value 26 (0x1a) is expressed in 6 bit encoding as 0x4a, which corresponds to the alphabetic character ”J”.

```
0x1a + 0x30 = 0x4a
             ’J’
```

2.7 Check Code

The check code corresponds to the sum of the 8 bit integer values of the target character string, then taking the 6 lower order bits and representing it in 6 bit encoding as a single character. Here is an example of the check code of a character string ABC012. The sum of all the characters is 0x159. Then, by taking the 6 lower order bits and representing it in 6 bit encoding, the check code ”I” can be obtained.

```
’A’    ’B’    ’C’    ’0’    ’1’    ’2’
0x41 + 0x42 + 0x43 + 0x30 + 0x31 + 0x32 = 0x159
0x19 + 0x30 = 0x49
             ’I’
```

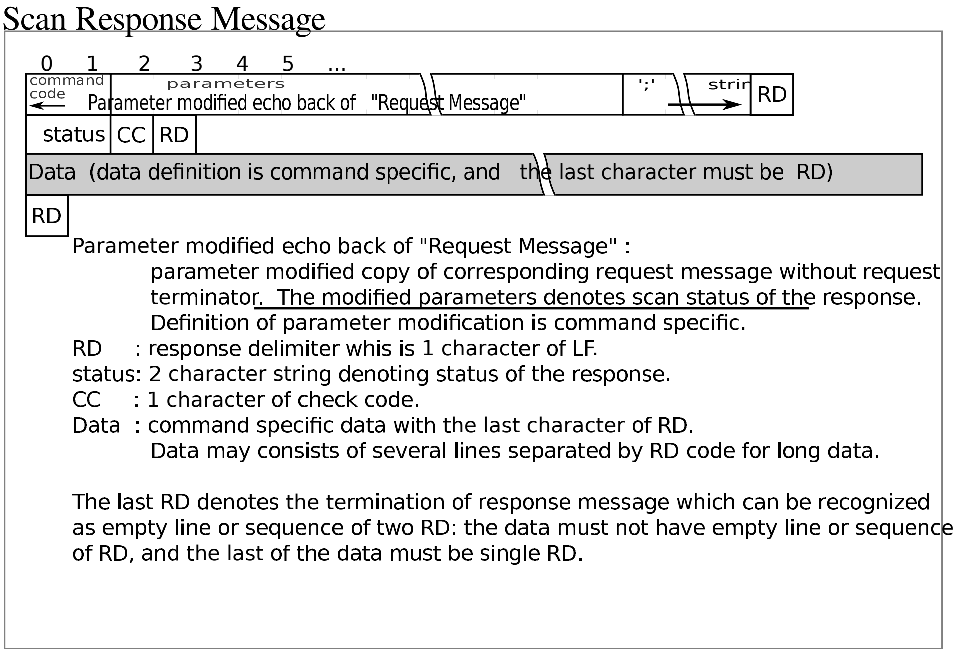

Figure 4: Scan Response Message Format

As for the response message and the scan response message, the check code is calculated using the character string between the response delimiters. Then, the check code is inserted between the character string and the response delimiter following it.

2.8 Character Encoding

The numbers included in the measurement data sent to the host by a response message or a scan response message are represented by integers greater or equal to zero. In SCIP, character encoding method is used in order to compress the data to be sent to the host. In the character encoding method, the numbers are divided in groups of 6 bits and transformed using 6-bit encoded characters. The result of 6 bits encoding is ordered from high order to low order bits. If the number of characters after encoding is two, it is called "two character encoding". If three, it is called "three character encoding", and if four, "four character encoding". Here is an example of encoding the number 1234.

```
Express 1234 (0x4d2) in binary and divide it into the groups of 6 bits.
Insufficient upper bits are padded with zero.
        1234 = 0100 1101 0010 = 010011 010010
                                0x13   0x12
Then, by representing them using 6-bit encoding, the character string "CB" can be obtained.
        0x13 + 0x30 = 0x43      0x12 + 0x30 = 0x42
                      'C'                     'B'
```

Figure 5 shows the syntax of character encoding.

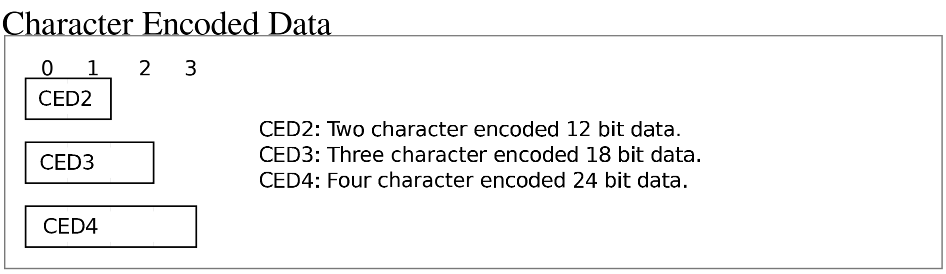

Figure 5: Character Encoded Format

2.9 Timestamp

The sensor keeps an internal counter and its value is called ”time”. The time is used when the sensor time is requested or used as the timestamp information of the measurement data. Time is handled as a 24-bit positive integer value and represented using 4 characters encoding. This time value together with a check code and a response delimiter is called time data. When this 24 bits counter overflows, it goes back to zero and the incremental count continues. Figure 6 shows the form of the time data.

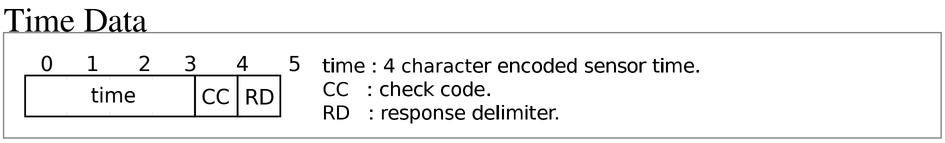

Figure 6: Time Data

2.10 Measurement Data

2.10.1 Step Data

The measurement data in one scan, for response message and the scan response message of measurement commands, is a collection of measurements obtained for each measurement step. In the case of request messages for grouping of steps, data is not obtained for each step but for each group of adjacent steps. Both forms are called step data. The form of data obtained for every step comprises four types of information: distance, distance-intensity pair, multiecho distance and multiecho distance-intensity pair.

Distance

Distance data is a positive integer number expressed in millimeter units, which can represent distance of 12-bit data (up to 4095 [mm]) and 18-bit data (up to 262143 [mm]). Each of them is represented by 2 character encoding and 3 character encoding. As the maximum value that can be returned by the sensor is defined, the maximum value is returned if the actual distance exceeds the value. Figure 7 shows the format.

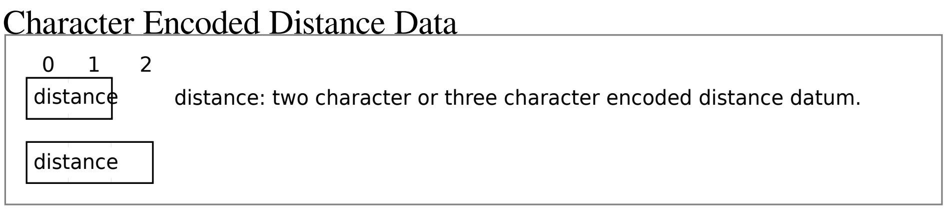

Figure 7: Distance Datum Format

Distance-Intensity Pair

Besides distance data, the reflected intensity data can also be obtained. The reflected laser intensity is a value represented by 18-bit data, and therefore uses 3 characters encoding. The reflected intensity corresponds to the intensity (strength) of the received laser light and is a relative number. The intensity output from the sensor depends upon the internal characteristics of the sensor’s light receiving element and amplifying circuitry. This value is relative: the higher the energy of the received laser light, the higher the intensity value reported by the sensor. Both distance and reflected intensity values are included in the response message or the scan response message, each represented in 3 characters encoding, first the distance value and then intensity value. This is called a distance-intensity pair. Figure 8 shows its form.

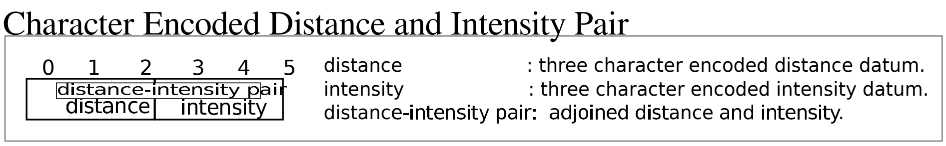

Figure 8: Distance-Intensity Pair Format

Multiecho

The SOKUIKI sensor is able to receive multiple reflected waves for every single step (laser beam), and obtain distance information for every one of those reflections. Receiving multiple distance information is called multiecho. In the step grouping mode, the multiecho data for the step with the smallest distance in each group is returned. The form of the multiecho data includes distance data or distance-intensity pair data ordered from the smallest distance obtained among all the echoes. If there is data for more than one echo, '&' is used as separator. The maximum number of data that can be returned by one step depends on the sensor specification. Figure 9 shows the format of multiecho data.

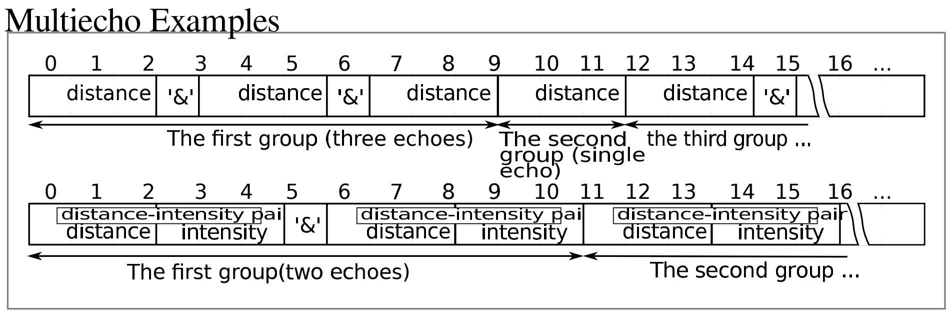

Figure 9: Multiecho Format

2.10.2 Scan Data

The measurement data in a response message or in a scan response message is considered as one scan. Data in one scan consists of either distance, distance-intensity pair, multiecho distance or multiecho distance-intensity pair, ordered in the scan according to the step number. For scans comprising distance or distance-intensity pair, total number of steps in that scan fixes the data load and message length for that scan. However, for multiecho data, the number of data varies by step for each scan. Therefore, the message length will change between scans.

2.10.3 Block Splitting

As the length of the message for each scan becomes very long, in SCIP the scan data is divided into groups of 64 characters and response delimiters are inserted. The divided character string is called block data. For each block, a check code and a response delimiter are added and that is called a block. This operation is called block splitting. The length of the character string of each block is 66 characters. However, as the length of scan data is not always an exact multiple of 64, only the last block might have less than 64 characters in length. Figure 10 shows the basic format of a block.

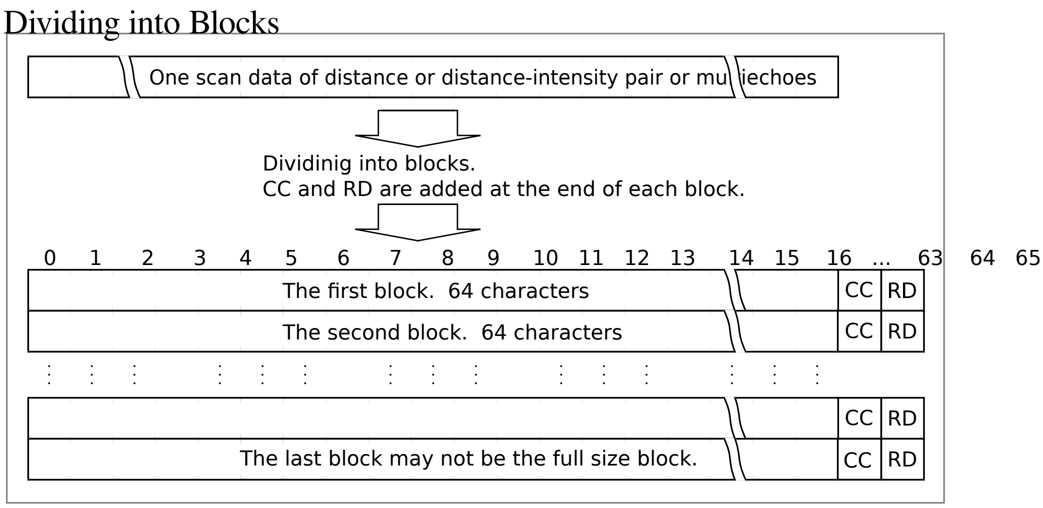

Figure 10: Block Format

3 Commands' Specification

3.1 Command Types

The commands of SOKUIKI sensor series of Hokuyo Automatic Co., Ltd. are grouped into the following categories.

Measurement commands
Commands which return measurement data upon request. The command codes in Table 1, i.e. GD, GS, GE, HD, HE, MD, MS, ME, ND and NE belong to this category. These measurement commands are further divided into the subcategories of measurement data acquisition commands and measurement data acquisition with continuous scanning commands.

Measurement data acquisition commands
Commands which return measurement data when the sensor is in measurement state for some given time. The sensor must be in measurement state beforehand as they are valid only when the sensor is in measurement state. This is a command to include measurement data in the response message, and communication completes by a request and a response. The command codes GD, GS, GE, HD and HE belong to this category.

Measurement data acquisition with continuous scanning commands
Commands which initiate measurement upon request and return measurement data of each scan for the specified number of times. These scan can initiate measurement state when the sensor is in standby (idle) state or during measurement state, by a transition into a measurement and scan response state. This is the command to return measurement data as the scan response message. The communication completes when the specified number of scans finishes or when the end of measurement is requested. The command codes MD, MS, ME, ND and NE belong to this category.

State transition commands
Commands defined in particular to modify the sensor operation state. The command codes BM, QT, and %ST belong to this category. Note that the measurement data acquisition with continuous scanning commands and time synchronization commands can change the state.

Initialization commands
Commands which initialize (reset) the sensor internal parameters as well as switching to the standby state. The command codes RS, RT and RB belong to this category.

Setup commands
Commands which change the sensor parameters. The command codes SS, CR and HS belong to this category.

Time synchronization commands
Commands to synchronize time with the sensor time. The command code TM belong to this category. Time synchronization is performed in a time synchronization state, therefore the TM command also changes the sensor internal operation state.

Information commands
Commands which obtain various types of information from the sensor. The command codes VV, PP and II belong to this category.

3.2 Sensor Operation States

The sensor starts in standby mode right after current is applied, and the operation state will change depending on the type of command. There are the following operation states.

Booting state and Waking-up state
The transitional state by the time when the scanner becomes ready for measurement. When the scanner becomes ready, the state switches to the next state automatically.

Standby state
The sensor is not performing measurement but ready for measurement. The laser is not lighted (activated).

Single scan state
The sensor is taking measurement data for all the available steps. If the BM command is received in the standby state, the sensor switches to measurement state. As the sensor is measuring all the measurement area with the laser activated in this state, the sensor returns the latest measurement data when it receives the measurement data acquisition command.

Multi scan state
Measurement starts and the scan response cycle is in operation. The sensor enters into this state when it receives the measurement data acquisition with continuous scanning command in standby state or in single scan state. In this state, the sensor performs scanning for the specified scan area and the number of scans and returns the scan response message for each scan. If the operation parameters (the scan area and the number of scans) are changed by another continuous scanning command, the sensor resumes measurement with the changed parameters. The sensor switches to the standby state when the specified number of scans are finished or when the sensor receives the scan stop command.

Time synchronization state
A special state to synchronize with the internal timer of the sensor. The sensor switches to this state after receiving the time synchronization commands. While in this state, responses to time queries are sent with the minimum delay.

Sleep state
The state to realize low power mode. The scanner is stopped, and the laser is not lighted.

Abnormal condition state
An abnormal sensor condition was found and the sensor switches from any arbitrary state to this one.

Unstable state
If normal measurements cannot be taken due to some interference, the sensor is retrying to complete the requested operation during some time (from a few seconds to tens of seconds), otherwise it goes to the abnormal condition state. The sensor remains temporally in this state and the sensor status is reported as such, and afterward moves into the abnormal condition state.

The sensor's state transition diagram is presented in Figure 11. The state transition commands, measurement commands as well as the time synchronization commands cause a change in the sensor state. Whether the command can be accepted or not complies with the state transition diagram. The RS, RT and RB commands are exempted and they are treated as follows.

- The initialization (reset) commands RS and RT cause the sensor to switch back to a initialization state (start), so the sensor moves to the standby state from any state other than the abnormal condition state.
- When the reboot command RB is received, the sensor restarts meaning a transition from any state to the restart condition, and then the sensor moves to standby state. However, a special consideration of the RB command is that, if during a period of 1 second 2 round-trips of RB request message and corresponding response message are not received, the actual reboot does not happen and the sensor remains in the previous state.

3.3 Operation Priority

3.3.1 General Status Codes

The common status codes for all the commands are described below. In general, if a request cannot be normally processed, a status other than "Accepted" is returned, and the requested action is not executed.

Accepted (code 00)
A request is accepted normally. The command is received in a valid state and if its parameters are correct the indicated action is performed, including a state transition (if necessary).

Error-abnormal-state (code 0L)
The sensor is in the abnormal condition state and therefore requests cannot be received. The code that shows the type of abnormal condition can be checked by the command to obtain the sensor state.

Error-unstable (code 0M)
The sensor is in the unstable state and therefore requests cannot be received. The code that shows the type of abnormal condition can be checked by the command to obtain the sensor state.

Error-command-not-defined (code 0E)
The command specified in the request message is not defined (unknown).

Error-command-not-supported (code 0F)
The command specified in the request message is not supported in the current sensor.

Error-denied (code 10)
The command specified in the request message cannot be received in the current sensor state.

Error-user-string-long (code 0G)
The length of the user defined string is too long.

Error-user-string-character (code 0H)
The user defined string has a problem.

Error-command-short (code 0C)
The length of the request message is shorter than expected, according to the existing definition.

Error-command-long (code 0D)
The length of the request message is longer than expected, according to the existing definition.

Error-parameter (code 01,02,03.04,05,06,07)
One of the parameters specified in the request message has a problem.

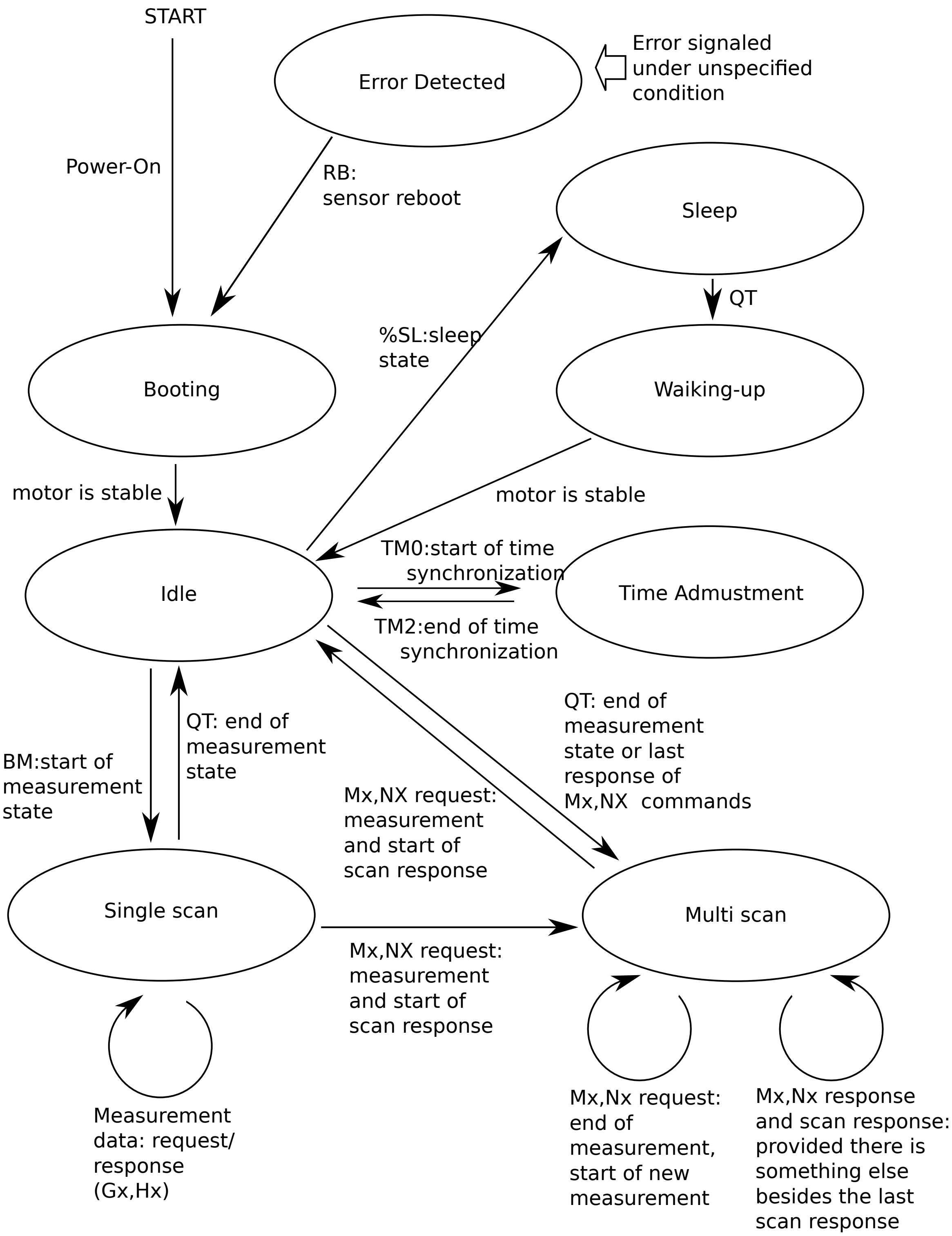

Figure 11: Sensor States

3.3.2 Operation Priority

According to the sensor conditions, the reception of requests and responses is controlled by the following actions. The actions are ordered by priority, and a lower priority value means a higher priority.

1. The sensor was powered up, measurements are not being taken, and the laser is not lighted (activated).
2. An unknown command was received and the sensor returns the Error-command-not-defined status. A command defined in this protocol specification but not supported by the current sensor is received and the sensor returns the Error-command-not-supported status.
3. The PP, II, VV, ST and RB can be received at any sensor state.
4. The sensor is in the abnormal condition state and returns the Error-abnormal-state status.
5. Reset commands (RS, RT) can be received at any sensor state, except the abnormal condition state. The software reset (RS, RT) commands can be accepted during the unstable state. During the unstable state, the transition to standby state command (QT) can be received.
6. The sensor is in the unstable state and returns Error-unstable status.
7. A known command was received but cannot be processed in the current state, and the sensor returns the Error-denied status.
8. The user defined string is too long and the sensor returns the Error-user-string-long.
9. The user defined string could not be parsed and the sensor returns the Error-user-string-character.
10. The length of the received request message is too short and the sensor returns the Error-command-short status.
11. The length of the received request message is too long and the sensor returns the Error-command-long status.
12. A parameter in the request message has a problem and the sensor returns the Error-parameter status.
13. The command was successfully received and the sensor returns the Accepted status.

3.4 Command General Elements

Several of the defined commands share common features.

Initialization state
Whrn the sensor is powered up and is in the standby state, measurements are not being taken and the laser is not lighted (activated).

Distance units
The distance units in all the messages are stated in millimeters (mm).

Maximum distance value
The maximum distance value in the messages depends on the number of bits used to express data and also on the sensor model. When using 2 character encoding, 12 bits are used to represent distance, therefore the maximum value is 4095 mm. When using 3 character encoding, 18 bits are used to represent distance, therefore the maximum value is over 260000 mm, however, the actual maximum distance obtained by the sensor can be shorter.

Operation parameters
The default sensor operation parameters are used after sensor initialization. Operation parameters, such as transmission speed, scanning speed and sensitivity, can be changed by the corresponding commands during the sensor operation. However, during sensor initialization (reset), they are lost and default values are used. Note that there is no parameter that can be changed for this product (UXM-30LXH-EWA).

Shared status codes for measurement with continuous scanning commands
The scan response messages of the measurement with continuous scanning commands share several status codes, and they are presented in Table 3.

Table 3: Shared status codes for measurement with continuous scanning commands

Status	Description
“99”	Normal scan response message

3.5 GD, GS Measurement Commands: Distance Measurement

When a request message is sent for the GD, GS commands, data in the response message from the sensor consists in distance data. These commands are valid when the sensor is in the measurement state. Before using the GD, GS commands, the laser must be lighted first using the BM command. While the laser is being lighted, measurement is performed, and data obtained in the middle of the current scan and of the previous scan are stored. If the scan data for the whole scan is not complete yet, it is not send, only until a scan is complete, the new data is returned. The parameters in the request message of the GD, GS commands are as presented in Table 4. Regarding these parameters, the following regulations apply:

Table 4: GD, GSParameters in the request message for GD, GS commands

Order	Description	Length	Name
1	Position of the starting step	4	start
2	Position of the ending step	4	end
3	Number of grouped steps	2	grouping

- Measurement obtained at the starting step position is included in the data.
- Measurement obtained at the ending step position is included in the data.
- If the number of steps in the group is 0 it is regarded as 1.
- The measurement value representing the group is the smallest distance value. In this case, measurement error codes (distance values outside the scan area) are not considered. However, if all the distances for the steps in the group are errors, the smallest error code is returned.

The response data in the scan response message for the GD, GS commands includes time data and distance data split into blocks. However, if the status in the response message corresponds to an error, the time data and distance data are omitted. The main difference between the GD and the GS commands is the specification of the response message. The GD command uses 3 character encoding (18 bits) to represent distance data, while the GS command uses 2 character encoding (12 bits) for distance data; the smaller bit length the shorter response message. Although the maximum distance of the GS command is small, the transmission time is also small, which is desired for some applications. Figure 12 shows the basic syntax of the response message parameters and their order. Those fields which can be optional (user defined string, time data and distance data block) are presented in gray in the figure.

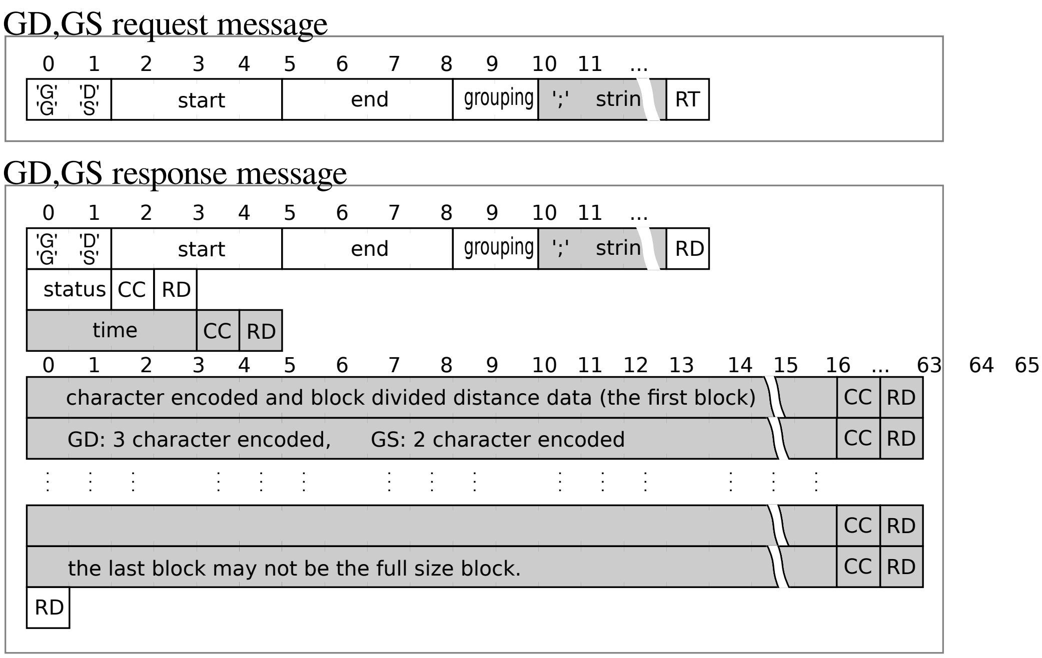

Figure 12: GD, GS Message Format

3.6 GE Measurement Command: Distance and Reflected Intensity Measurement

The GE command operates in the same way as the GD, GS commands. The parameters in the request message of the command are also the same as those in Table 4. The difference is that the response message returns distance-intensity pair, not distance. Both distance and intensity data are represented using 3 character encoding of the measurement data. The measurement value representing the group of steps is distance-intensity pair having the smallest distance value in that group. Figure 13 shows the basic syntax of the response message parameters and their order. Those fields which can be optional (user defined string, time data and distance-intensity pair data block) are presented in gray in the figure.

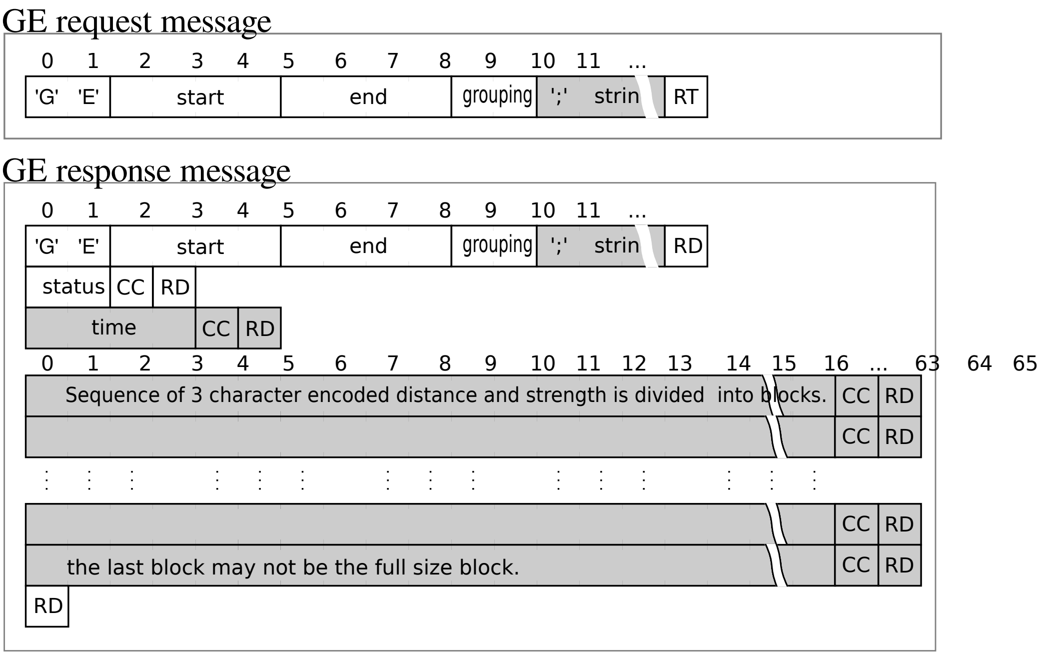

Figure 13: GE Message Format

3.7 HD Measurement Command: Multiecho Distance Measurement

The HD command operates in the same way as the GD, GS commands. The parameters in the request message of the command are also the same as those in Table 4. The difference is that the response message returns multiecho distance, not distance. Multiecho distance data is represented using 3 character encoding of the measurement data. The measurement value representing the group of steps is multiecho distance having the smallest distance value in that group. Figure 14 shows the basic syntax of the response message parameters and their order. Those fields which can be optional (user defined string, time data and multiecho distance data block) are presented in gray in the figure.

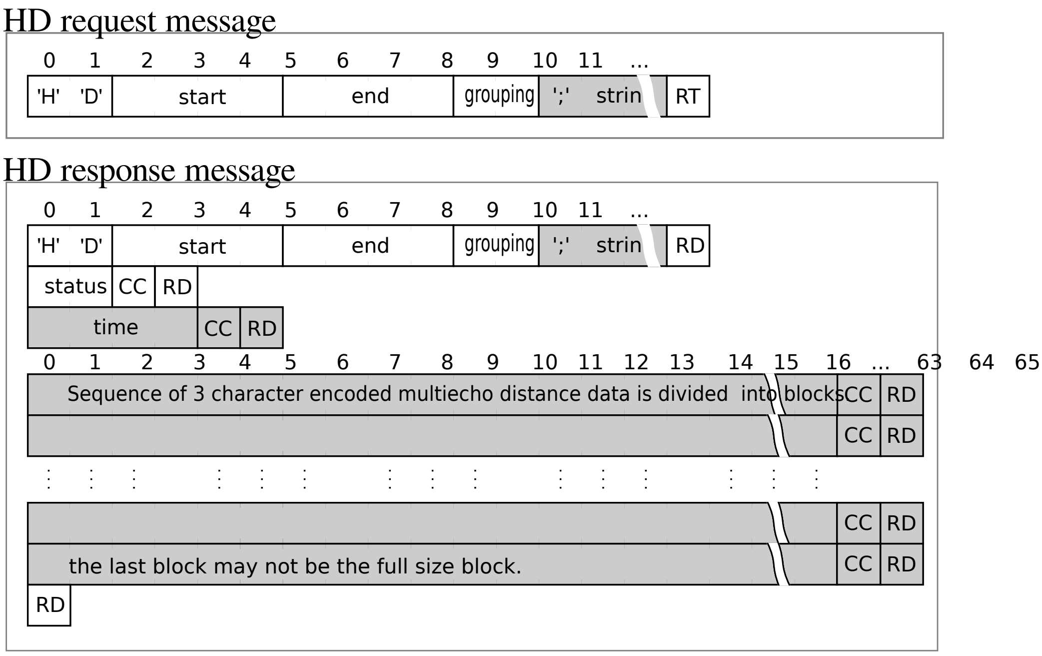

Figure 14: HD Message Format

3.8 HE Measurement Command: Multiecho Distance and Reflected Intensity Measurement

The HE command operates in the same way as the GD, GS commands. The parameters in the request message of the command are also the same as those in Table 4. The difference is that the response message returns multiecho distance-intensity pair, not distance. Both distance and intensity data are represented using 3 character encoding of the measurement data. The measurement value representing the group of steps is multiecho distance-intensity pair having the smallest distance value in that group. Figure 15 shows the basic syntax of the response message parameters and their order. Those fields which can be optional (user defined string, time data and multiecho distance-intensity pair data block) are presented in gray in the figure.

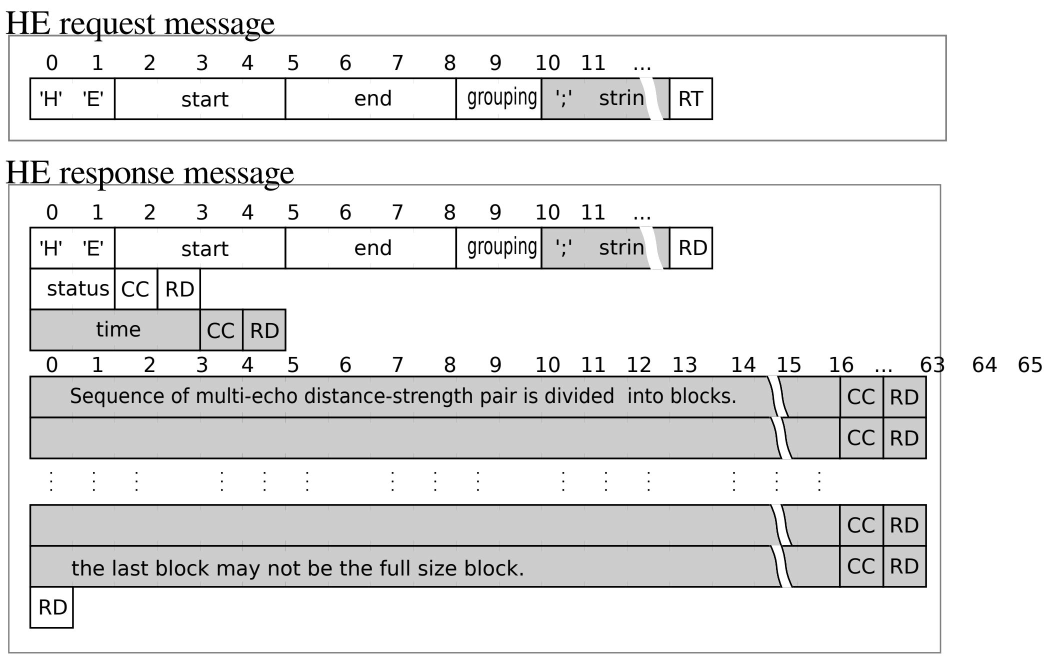

Figure 15: HE Message Format

3.9 MD, MS Measurement Commands: Distance Measurement with Continuous Scanning

These are the commands to start scanning with the conditions specified by the request message and return a scan response message for each measurement scan. These commands are valid during the standby state, the measurement state, and measurement and scan response stateD It is not necessary to use the BM command to light the laser before using the MD, MS commands. The parameters in the request message of the MD, MS commands are as presented in Table 5.

Table 5: Request message parameters of the MD, MS commands

Order	Description	Length	Name
1	Position of the starting step	4	start
2	Position of the ending step	4	end
3	Number of grouped steps	2	grouping
4	Number of scans to skip	1	skips
5	Number of measurement scans	2	scans

Regarding these parameters, the following regulations apply:

- Measurement obtained at the starting step position is included in the data.
- Measurement obtained at the ending step position is included in the data.
- If the number of steps in the group is 0 it is regarded as 1.
- The measurement value representing the group is the smallest distance value. In this case, measurement error codes (distance values outside the scan area) are not considered. However, if all the distances for the steps in the group are error codes the smallest one is returned.
- The scans to skip designate the number of scans to wait (no measurement is computed) after one measurement scan is performed.
- The number of measurement scans designates the total number of scans for which measurement is computed. A value of 0 means unlimited scans, therefore it is necessary to stop the scanning process by the QT command (transition to standby state).

When the sensor receives a request message from MD, MS commands, it sends a response message which has no measurement data. If there is no error in the status of the response message, the sensor will send measurement information in the scan response messages until the end of the scanning process. However, if there are delays in communications, some of the scan response messages might not be delivered. Information about the number of pending scans is included in every scan response message, so it is possible to verify if a scan response message was not delivered. In the very last scan response message sent, the number of pending scans must be zero. The basic syntax of the response message does not include measurement data. The scan response message includes time data and measurement data, however, if the status corresponds to an error, both time data and measurement data are omitted. The scan response message includes a character string portion called the echoback; in this echoback, the scans number part is changed all the time with information about the pending number of scans (the echoback is modified). The pending number of scans indicates how many more scans remain to be read, not including the current message. In the very last scan response message, the number of pending scans is set to 0, and when the number of scans is unlimited, the number of pending scans in all the scan response messages is also 0. When the sensor is in unstable condition, it tries to recover. During recovery, the scan response message with the status showing the unstable condition is returned. When the sensor returns to the normal condition, the scan response message is returned with normal status. If the sensor switches to the abnormal condition, the scan response message with the status showing the abnormal condition is returned and the scan response message is ended. The response data in the scan response message for the MD, MS commands includes time data and distance data split into blocks. However, if the status in the response message corresponds to an error, the time data and distance data are omitted. The main difference between the MD and the MS commands is the specification of the scan response message. The MD command uses 3 character encoding (18 bits) to represent distance data, while the MS command uses 2 character encoding (12 bits) for distance data; the smaller bit length the shorter scan response message. Although the maximum distance of the MS command is small, the transmission time is also small which is desired for some applications. Figure 16 shows the basic syntax of the response message parameters and their order. Those fields which can be optional (user defined string, time data and distance data block) are presented in gray in the figure.

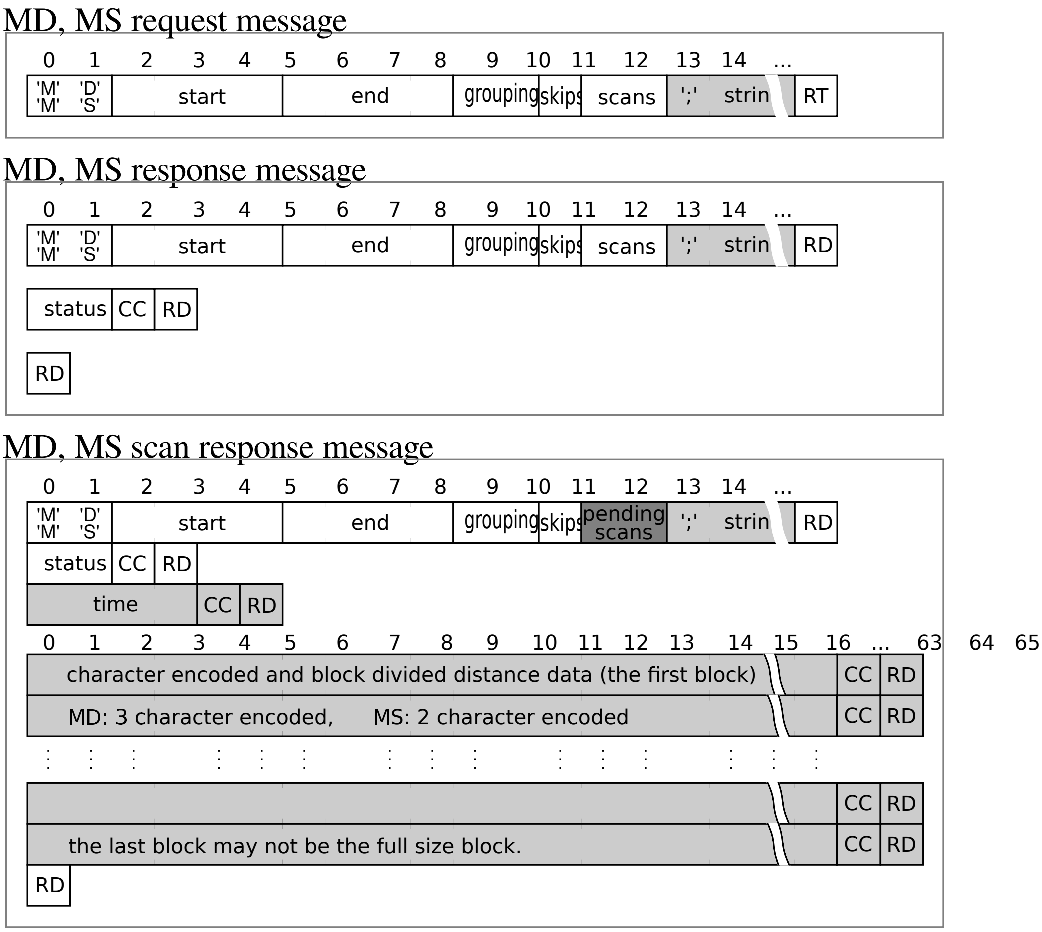

Figure 16: MD, MS Message Format

3.10 ME Measurement Command: Distance and Reflected Intensity Measurement with Continuous Scanning

The ME command operates in the same way as the MD, MS commands. The parameters in the request message of the command are also the same as those in Table 5. The difference is that the response message returns distance-intensity pair, not distance. Both distance and intensity data are represented using 3 character encoding. of the measurement data. The measurement value representing the group of steps is distance-intensity pair having the smallest distance value in that group. Figure 17 shows the basic syntax of the response message parameters and their order. Those fields which can be optional (user defined string, time data and distance-intensity pair data block) are presented in gray in the figure.

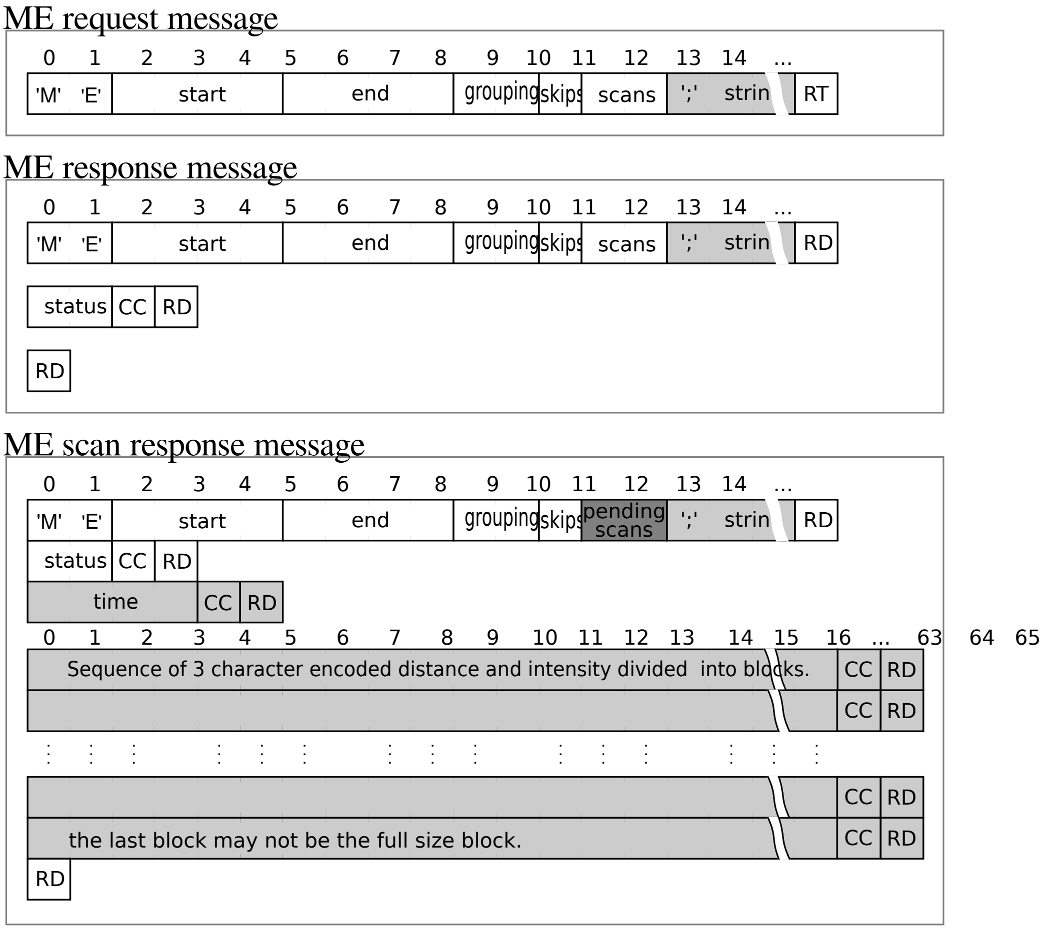

Figure 17: ME Message Format

3.11 ND Measurement Command: Multiecho Distance Measurement with Continuous Scanning

The ND command operates in the same way as the MD, MS commands. The parameters in the request message of the command are also the same as those in Table 5. The difference is that the response message returns multiecho distance, not distance. Multiecho distance of the measurement data is represented using 3 character encoding. of the measurement data. The measurement value representing the group of steps is multiecho distance having the smallest distance value in that group. Figure 18 shows the basic syntax of the response message parameters and their order. Those fields which can be optional (user defined string, time data and multiecho distance data block) are presented in gray in the figure.

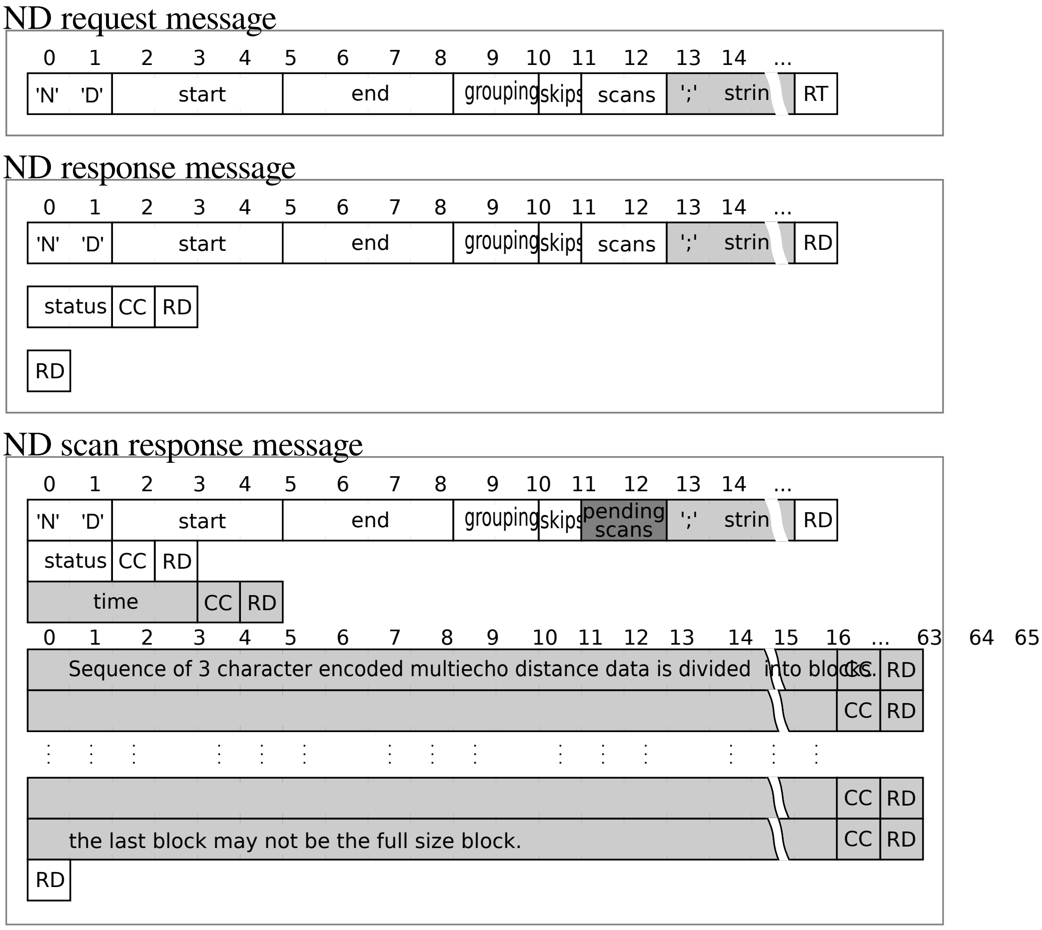

Figure 18: ND Message Format

3.12 NE Measurement Command: Multiecho Distance and Reflected Intensity Measurement with Continuous Scanning

The NE command operates in the same way as the MD, MS commands. The parameters in the request message of the command are also the same as those in Table 5. The difference is that the response message returns multiecho distance-intensity pair, not distance. Multiecho distance-intensity pair is represented using 3 character encoding of the measurement data. The measurement value representing the group of steps is multiecho distance-intensity pair having the smallest distance value in that group. Figure 19 shows the basic syntax of the response parameters and their order. Those fields which can be optional (user defined string, time data and multiecho distance-intensity pair data block) are presented in gray in the figure.

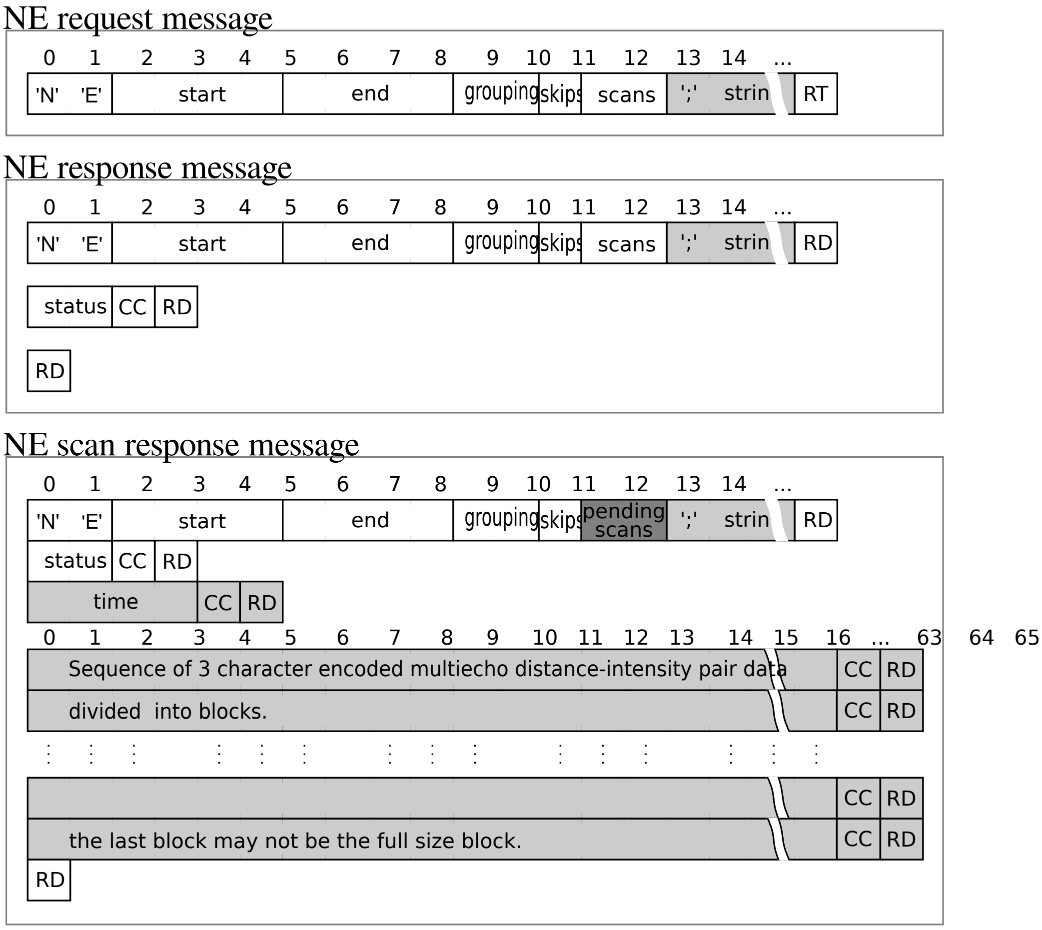

Figure 19: NE Message Format

3.13 %ST State Code Acquisition Command

This is the command to return the current sensor state by a code of 3 characters. It is valid in all the different sensor states. The status values and their meaning in the response message of the %ST command are presented in Table 6. The %ST has no parameters in the request message. Its corresponding response message consists in a 3 character code which corresponds to the current sensor state. The list of 2 character state codes is presented in Table 7. Figure 20 shows the basic syntax of the response message parameters and their order.

Table 6: %ST command status values and description

Status	Description
"00"	Normal

Table 7: State codes returned by %ST command

State code	Description
000	Standby state
100	From standby to unstable state
001	Booting state
002	Time adjustment state
102	From time adjustment to unstable state
003	Single scan state
103	From single scan to unstable state
004	Multi scan state
104	From multi scan to unstable state
005	Sleep state
006	Waking-up state (Recovering from sleep state)
900	Error detected state

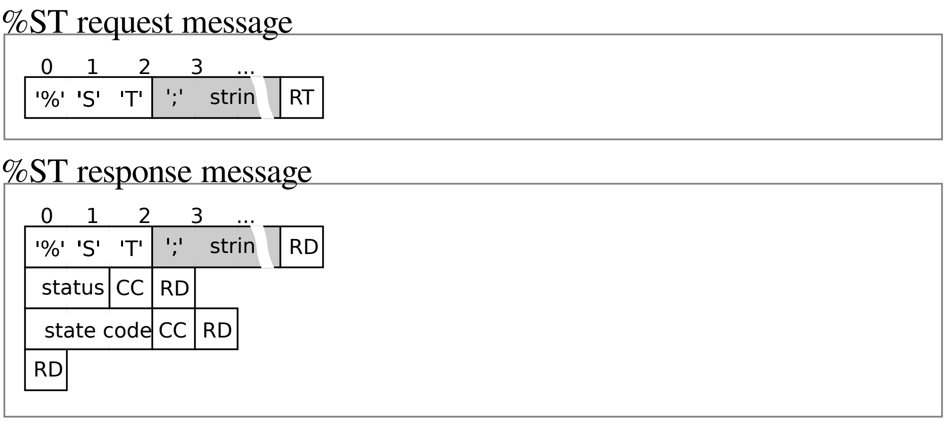

Figure 20: %ST Message Format

3.14 BM State Transition Command: Transition to Measurement State

This is the command to switch the sensor to the measurement state and start the measurement process by lighting (activating) the laser. It is valid in the standby state. The BM has no parameters in the request message. Its corresponding response message does not include any data. The status values and their meaning in the response message of the BM command are presented in Table 8. Figure 21 shows the basic syntax of the response message characters and their order.

Table 8: BM command status values and description

Status	Description
"00"	Normal. The sensor is in measurement state and the laser was lighted.
"01"	The laser was not lighted due to unstable or abnormal condition.
"02"	The sensor is already in measurement state and the laser is already lighted.

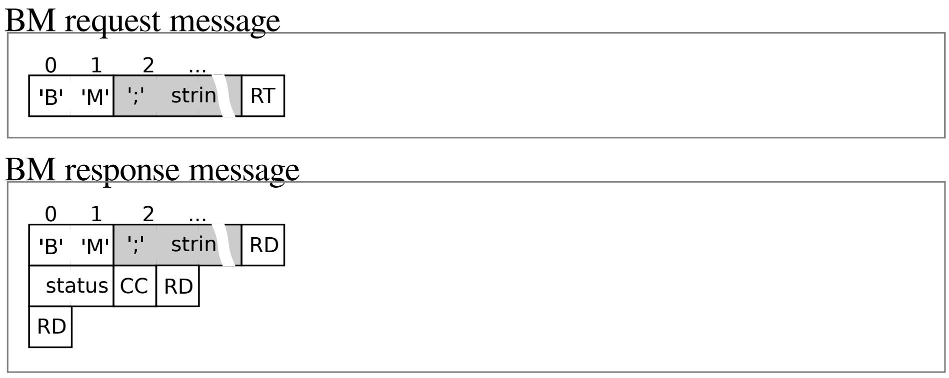

Figure 21: BM Message Format

3.15 QT State Transition Command: Transition to Standby State

This command is to stop the current measurement process and to switch the sensor to the standby state. It is valid while in the measurement state or in the measurement and scan response state. The QT has no parameters in the request message. Its corresponding response message does not include any data. The status values and their meaning in the response message of the QT command are presented in Table 9. Figure 22 shows the basic syntax of the response message characters and their order.

Table 9: QT command status values and description

Status	Description
"00"	Normal. The sensor is in standby state and the laser was turned off.

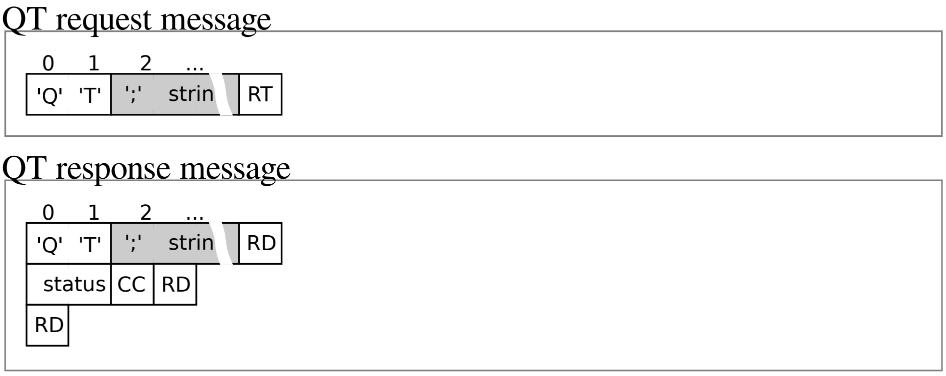

Figure 22: QT Message Format

3.16 %SL State Transition Command: Transition to Standby State

This command is to switch the sensor to the sleep state. When the sensor receives the %SL command, it stops the current measurement process, switches to the sleep state, turns off (deactivates) the laser and stop the motor. This command is valid while in the standby state or in the measurement state. The %SL has no parameters in the request message. Its corresponding response message does not include any data. The status values and their meaning in the response message of the %SL command are presented in Table 10. Figure 23 shows the basic syntax of the response message characters and their order.

Table 10: %SL command status values and description

Status	Description
"00"	Normal. The sensor is in sleep state and the laser was turned off.

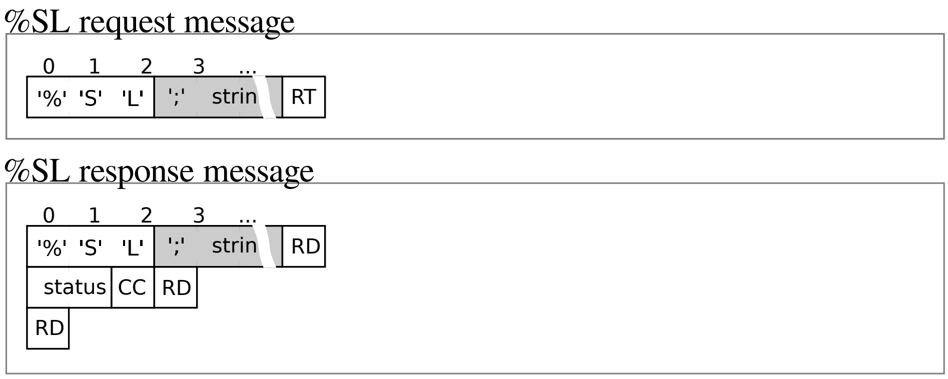

Figure 23: %SL Message Format

3.17 RS Resetting Command

This command is to force the sensor to switch to the standby state and perform the following tasks:

1. Turns off (deactivates) the laser.
2. Sets the motor rotational speed (scanning speed) to the default initialization value.
3. Sets the serial transmission speed (bit rate) to the default initialization value.
4. Sets the internal sensor timer to zero.
5. Sets the measurement sensitivity to the default (normal) value.

However, when the sensor is in the abnormal condition state, the RS command is not received.
The RS has no parameters in the request message. Its corresponding response message does not include any data. The status values and their meaning in the response message of the RS command are presented in Table 11. Figure 24 shows the basic syntax of the response message characters and their order.

Table 11: RS command status values and description

Status	Description
"00"	Normal. The sensor is in standby state and the laser was turned off.

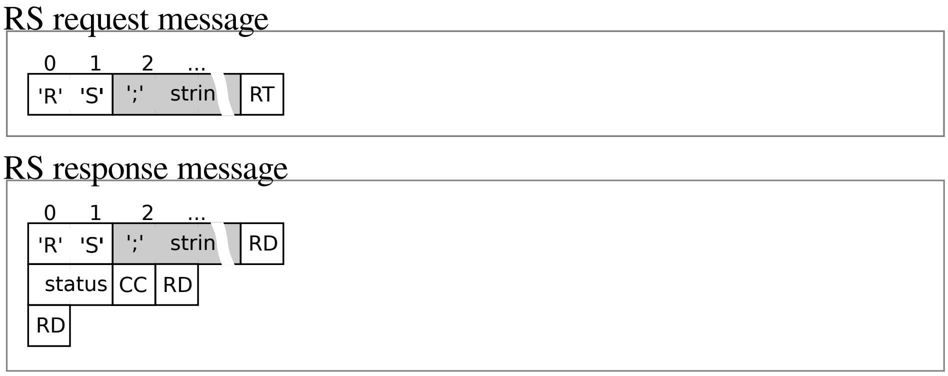

Figure 24: RS Message Format

3.18 RT Resetting Command: Partial Reset

This command is to force the sensor to switch to the standby state and perform the following tasks:

1. Turns off (deactivates) the laser.
2. Sets the internal sensor timer to zero.
3. Sets the measurement sensitivity to the default (normal) value.

This is similar to the RS command, except the motor rotational (scanning) speed and the serial transmission speed are not changed. When the sensor is in the abnormal condition state, the RT command is not received. The RT has no parameters in the request message. Its corresponding response message does not include any data. The status values and their meaning in the response message of the RT command are presented in Table 12. Figure 25 shows the basic syntax of the response message characters and their order.

Table 12: RT command status values and description

Status	Description
"00"	Normal. The sensor is in standby state and the laser was turned off.

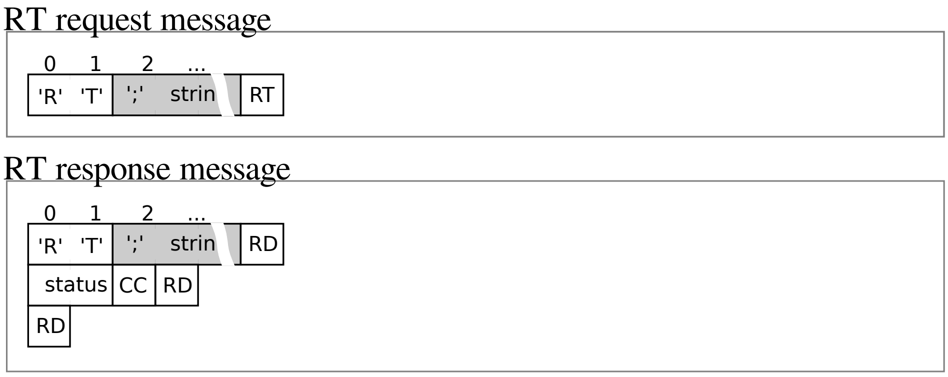

Figure 25: RT Message Format

3.19 RB Resetting Command: Controller Reboot

This RB command is to reboot (restart) the sensor. However, the RB command requires a special procedure to use it. During 1 second, 2 request messages of the RB command must be sent and their corresponding response messages must be received (2 round-trips of the RB command) in order to reset the sensor, otherwise the current sensor state is kept and no reboot is performed. When the sensor receives the RB command, the sensor behaves as if it has just been powered up and switches to standby state. The following tasks are performed:

1. Waits for 1 second, during this time the host system disconnects from the sensor.
2. The sensor stops all communications.
3. Turns off (deactivates) the laser.
4. Sets the motor rotational speed (scanning speed) to the default initialization value.
5. Sets the serial transmission speed (bit rate) to the default initialization value.
6. Sets the internal sensor timer to zero.
7. Sets the measurement sensitivity to the default (normal) value.
8. Initializes other internal parameters, and waits until the scanning speed is stable.
9. Switches to standby state.

RB is the only state transition command that can be received during abnormal condition state.
The RB has no parameters in the request message. Its corresponding response message does not include any data. The status values and their meaning in the response message of the RB command are presented in Table 13. Figure 26 shows the basic syntax of the response message characters and their order.

Table 13: RB command status values and description

Status	Description
"00"	Normal. Received the 2nd RB command request.
"01"	Normal. Received the 1st RB command request.

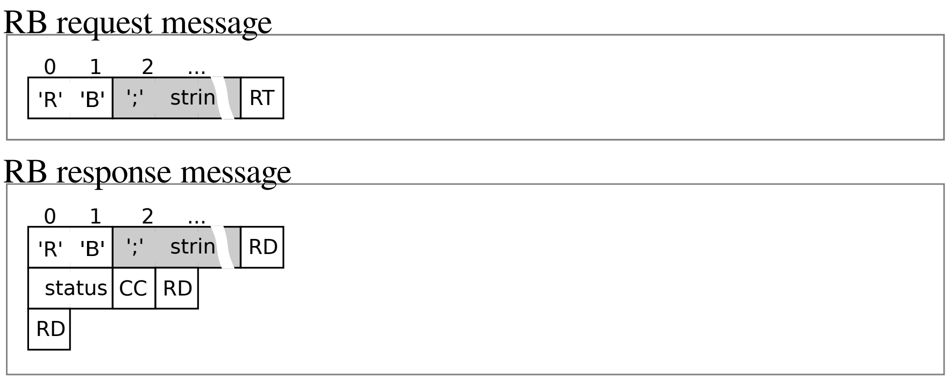

Figure 26: RB Message Format

3.20 TM Time Synchronization Command

Since the (physical) time value, included as part of the measurement data in a response message, depends on the scanning state and the communication state, the time at which a measurement was taken must be judged using just the time value included in the response message. The time value corresponds to the sensor internal timer count, and is expressed in milliseconds (ms) units. To properly judge the time value included in the response messages from the host system, the time values for both host and sensor must be synchronized (adjusted). The TM commands are defined for this time synchronization purpose. The TM0 command makes a transition from the standby state to the time synchronization state, and the TM2 command switches from the time synchronization state back to the standby state. In time synchronization state the TM1 command allows to obtain the current sensor time value, regardless of the sensor scanning state. This is, time synchronization between host and sensor can be achieved by considering only the communication state. Let t_1 be the global time since the host sends the TM1 request message until the sensor receives it, and let t_2 be the global time since the sensor sends its response message until the host system receives it. The global time since the sensor reads its internal timer value until it completes the response message, is assumed to be smaller than 1 ms (timer unit), therefore t_1 and t_2 can be assumed to be equal. If both host and sensor system share the same clock source (e.g., the sensor current timer count), the timer value sent by the TM1 command and the value of t_1 can be considered equal. Please notice that, due to differences in precision of the oscillators used in the sensor timer and in the host timer, there will be time deviations (skew) and the systems can get out of synchronization. The request message and its parameters for the TM command are presented in Table 14.

Table 14: TM command request message and parameters

Order	Description	Length	Name
1	Time control code	1	control code

The list of valid control codes, represented as character strings, is shown in Table 15.

Table 15: TM command control codes

String	Control description
"0"	Transition from standby state to time synchronization state.
"2"	Transition from time synchronization state to standby state.
"1"	Returning time value.

The status values and their meaning in the response message of the TM command are presented in Table 16.

Table 16: TM command status values and description

Status	Description
"00"	Normal.
"01"	Invalid parameter (control code).
"02"	TM0 request was received and the sensor already is in time synchronization state.
"03"	TM2 request was received and the sensor already left the time synchronization state.
"04"	TM1 request was received and the sensor is not in time synchronization state.

Data in the response message for the TM1 command is the current sensor time value. However, if the status value in the response message corresponds to an error (different from Normal), no time data is returned. There is no data in the response message for the TM0 and TM2 commands. For more details about time data, please refer to Section 2.9. Figure 27 shows the basic syntax of the response message characters and their order.

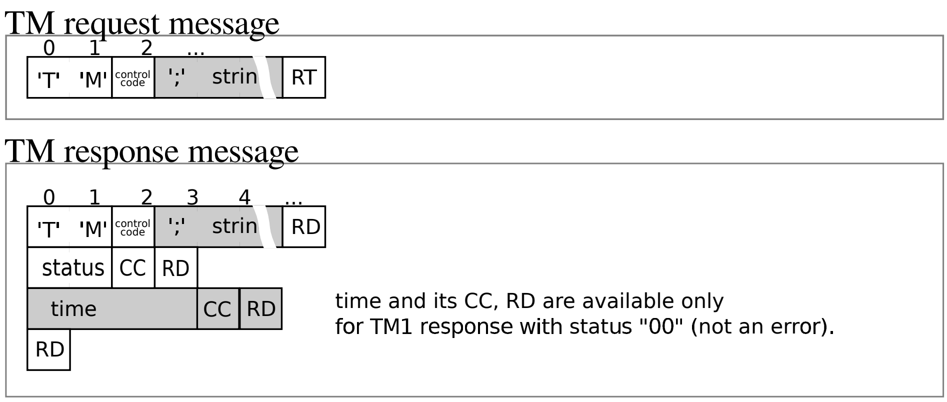

Figure 27: TM Message Format

3.21 VV Information Command: Version

This is a command to obtain manufacturing (version) information of the sensor. The VV information command is valid during any sensor state. The request message of VV information command does not require any parameters. Table 17 shows the description of the status in the response message. Table 18 shows the list of features returned by VV information command.

Table 17: VV command status values and description

Status	Description
"00"	Normal

Table 18: Data in the VV command response message

Description	String sample
Vendor information	VEND:Hokuyo Automatic Co., Ltd.
Product information	PROD:UXM-30LXH-EWA
Firmware version	FIRM:1.1.0 (2011-09-30)
Protocol version	PROT:SCIP 2.2
Sensor serial number	SERI:H0123456

The information string contains a 4 character tag and a colon character ':' at the beginning of the string. Each item in the response message data consists in a description string, followed by a semicolon ';', then a check code and finally a response delimiter. The check code is only for the description string without the semicolon. Notice that this rule applies exclusively for the VV, PP, and II commands. Figure 28 shows the format and the order of the messages of this command.

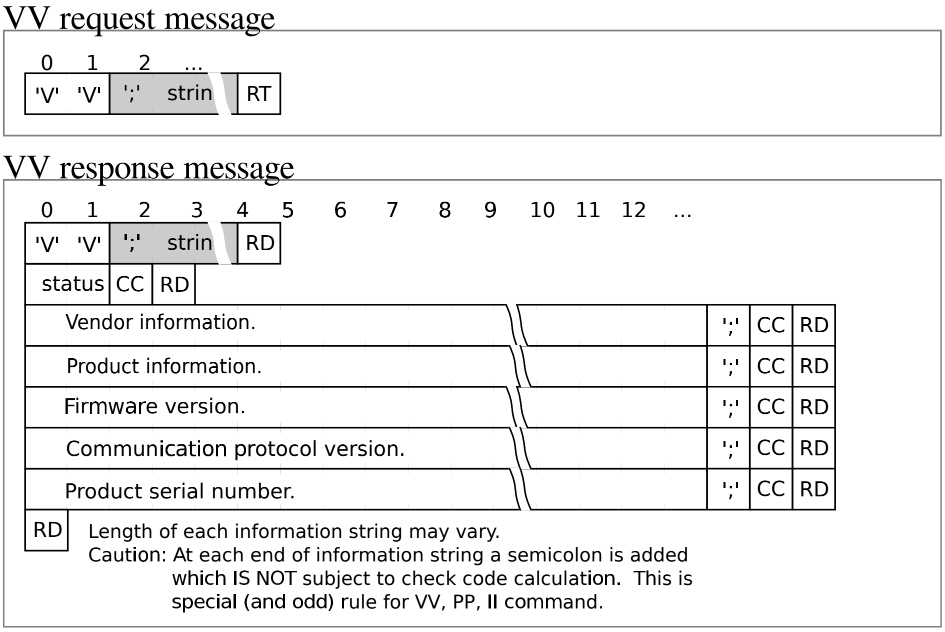

Figure 28: VV Message Format

3.22 PP Information Command: Sensor Parameters

This is the command to obtain information of the sensor internal parameters. The PP information command is valid during any sensor state except during the time synchronization state. The request message of PP information command does not require any parameters. Table 19 shows the description of the status in the response message. Table 20 shows the list of features returned by PP information command.

Table 19: PP command status values and description

Status	Description
"00"	Normal

Table 20: Data in the PP command response message

Description	String sample
Sensor model	MODL:UXM-30LXH-EWA
Minimum measurable distance (in millimeters)	DMIN:23
Maximum measurable distance (in millimeters)	DMAX:60000
Angular resolution (number of partitions in 360 degrees)	ARES:1440
Minimum step number of the scanning area	AMIN:0
Maximum step number of the scanning area	AMAX:1080
Step number of the front direction	AFRT:540
Standard scanning speed (in rpm)	SCAN:2400

The information string contains a 4 character tag and a colon character ':' at the beginning of the string. Each item in the response message data consists in a description string, followed by a semicolon ';', then a check code and finally a response delimiter. The check code is only for the description string without the semicolon. Notice that this rule applies exclusively for the VV, PP, and II commands. Figure 29 shows the format and the order of the messages of this command.

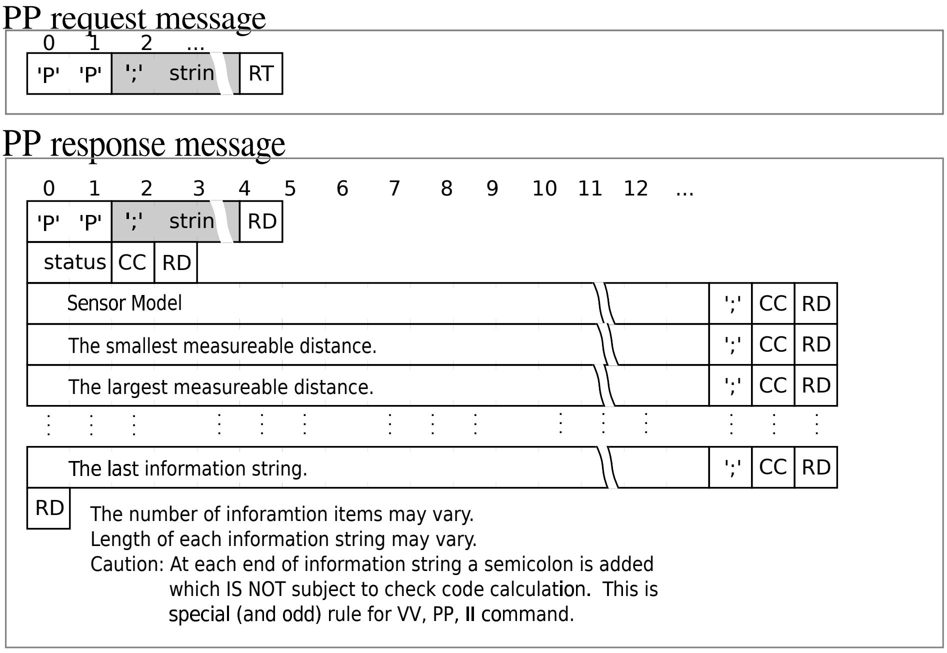

Figure 29: PP Message Format

3.23 II Information Command: Sensor State

This is a command to obtain status information of the sensor. The II information command is valid during any sensor state. The request message of II information command does not require any parameters. Table 21 shows the description of the status in the response message. Table 22 shows the list of status data returned by II information command.

Table 21: Status value description of II information command

Status	Description
"00"	Normal

Table 22: Data in the II command response message

Description	String sample
Sensor model	MODL:UXM-30LXH-EWA
Status of the laser	LASR:OFF
Current scanning speed	SCSP:2400
Current status of sensor and measuring sensitivity	MESM:000 Idle
Current speed of serial communication	SBPS:Ethernet 100 [Mbps]
Current time	TIME:e4y0
Current status of sensor	STAT:Stable 000 stable

The information string contains a 4 character tag and a colon character ':' at the beginning of the string. For details of the sensor status, please refer to the product specification. Each item in the response message data consists in a description string, followed by a semicolon ';', then a check code and finally a response delimiter. The check code is only for the description string without the semicolon. Notice that this rule applies exclusively for the VV, PP, and II commands. Figure 30 shows the format and the order of the messages of this command.

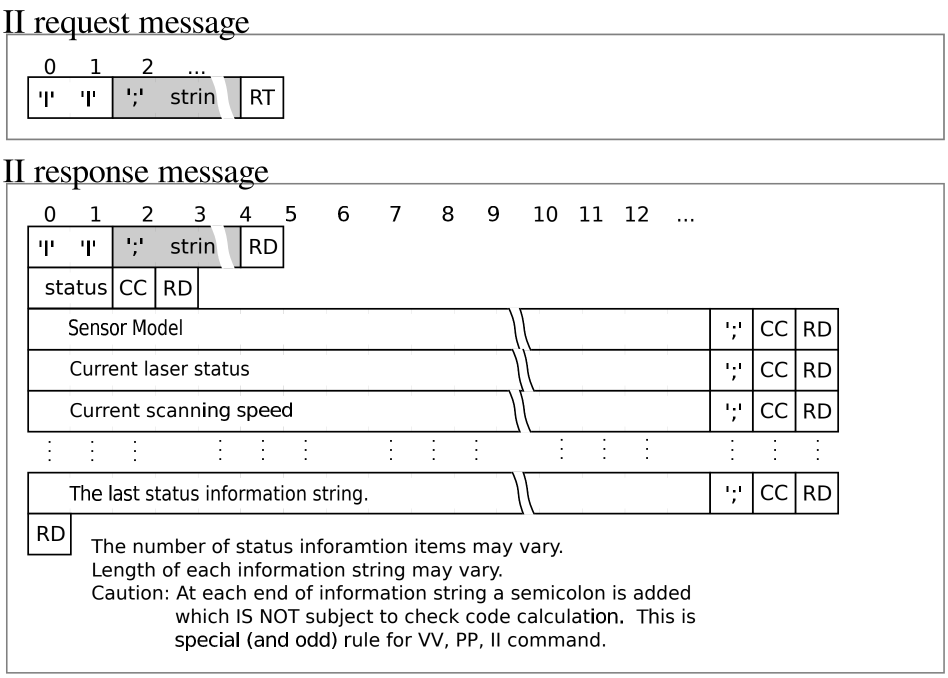

Figure 30: II Message Format

3.24 %PG Information Command: Synchronization Phase

This is a command to obtain the current phase value during motor's rotation synchronization. This command is valid while in the standby state. Table 23 shows the description of the status in the response message. The %PG command has no parameters in the request message. The response message includes the phase value represented in 3 characters, from 000 to 359 and expressed in degree units. Figure 31 shows the format and the order of the messages of this command.

Table 23: %PG command status values and description

Status	Description
"00"	Normal.

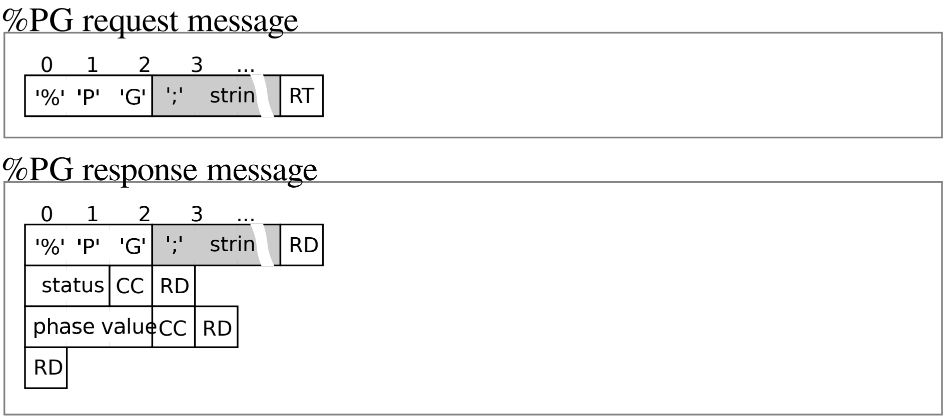

Figure 31: %PG Message Format

References

[1] Jun'ichi IIJIMA, Tomoaki YOSHIDA, Shoichi MAEYAMA, Hirohiko KAWATA, Yoshitaka HARA, Akihisa OHYA, Shin'ichi YUTA "The Command Interface Protocol "SCIP 2.1" for SOKUIKI Sensor", The 26th Annual Conference of The Robotics Society of Japan, 311-08 (2008.9)

[2] Jun'ichi IIJIMA, Tomoaki YOSHIDA, Hirohiko KAWATA, Yoshitaka HARA, Shin'ichi YUTA "The Command Interface Protocol 'SCIP2.2' for Detecting Multiple Reflecting Points Type SOKUIKI Sensor", The 27th Annual Conference of The Robotics Society of Japan (2009)