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URM Series Communication Protocol Specification

Symbol	Amended Reasons			Pages	Date	Amended by	DWG.No.
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1 Preface

This document describes the specification of the communication protocol and control commands related to the SOKUIKI sensor series URM of Hokuyo Automatic Co., Ltd.

This specification conforms to the Sensor Communication Interface Protocol (SCIP) and includes some extensions based on it. In addition, URM has LX mode and LA mode, and some functions in its communication protocol are limited in LA mode.

2 Communication interface

The communication interface of this sensor is Ethernet interface.

- Ethernet 100BASE-T

TCP/IP is used for communication. The factory default for the network address settings are listed below.

IP adderss	:	192.168.0.10
Subnet mask	:	255.255.255.0
Default gateway	:	192.168.0.1
Port number	:	10940(Fixed)

Please refer to the product specification for more information related to the communication.

3 SCIP Message

3.1 Communication

In basic communication, the request message is sent from the host to the sensor and the response message is returned from the sensor to the host. 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. In each scan, message sent from the sensor is called scan response message. Scan response message is sent from the sensor to the host until request message for specified scan or terminate request message is sent.

3.2 Command Code

Message from the host includes a command code. 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 is called command, and determined separately for each sensor. The command code complying with SCIP is expressed with two uppercase alphabet characters. The command starting with a '%' character are extended command introduced by Hokuyo Automatic Co. Ltd. Tables 3.2.1 and 3.2.2 command codes.

Table 3.2.1: 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 and Intensity	
HD	Multi-echo distance acquisition	Start Step End Step Cluster Count	Status Time Multi-echo distance	
HE	Multi-echo distance and intensity acquisition	Start Step End Step Cluster Count	Status Time Multi-echo 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, intensity
ND	Multi-echo distance acquisition with continuous scanning	Start Step End Step Cluster Count Scan Interval Number of Scans	Status	Status Time Multi-echo distance
NE	Multi-echo distance and intensity acquisition with continuous scanning	Start Step End Step Cluster Count Scan Interval Number of Scans	Status	Status Time Multi-echo distance, intensity

Table 3.2.2: Non-measurement Commands

Command Code	Function	Request message parameters	Response message status and data	Scan 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	Initialization	Initialization		Status
RT	Initialization	Partial Initialization		Status
RB	Initialization	Reboot		Status
TM	Time synchronization	Time Setup	Control code	Status Time
VV	Information	Obtain Version		Status Version information
PP	Information	Obtain Sensor parameter		Status Sensor parameters
II	Information	Obtain sensor state		Status Sensors State
%PG	Information	Obtain synchronization phase value		Status Phase information

- About other commands

  URM Series does not respond to below Command code used in other SOKUIKI sensor series of Hokuyo Automatic Co., Ltd.

  SS, CR, HS, DB, and other SCIP 1.1 Command Code

3.3 Request Message

Besides the command code and parameters, a request message can include a user defined string as well as a request terminator. Command code is expressed in two or three uppercase alphabet characters. Codes defines the sensor operation and response data. Parameters vary with the command code and multiple integers starting from 0. The digit number of each value is fixed and expressed in ASCII character decimal number. When value of digits number is less than the specified digits number, 0 must be placed in the upper order digits.

Example: If the number of digits is less than decimal digits

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

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 character string following the semicolon are alphabets, numbers, and six types of characters ‘ ’ (space), ‘.’, ‘_’, ‘+’, ‘−’, and ‘@’. The request terminator can be either line feed (LF) character or carriage return (CR) character, or both LF and CR as two characters string code. Figures 3.3.1 and 3.3.2 shows
a request message and a user defined string, respectively. Items displayed in gray box can be omitted.

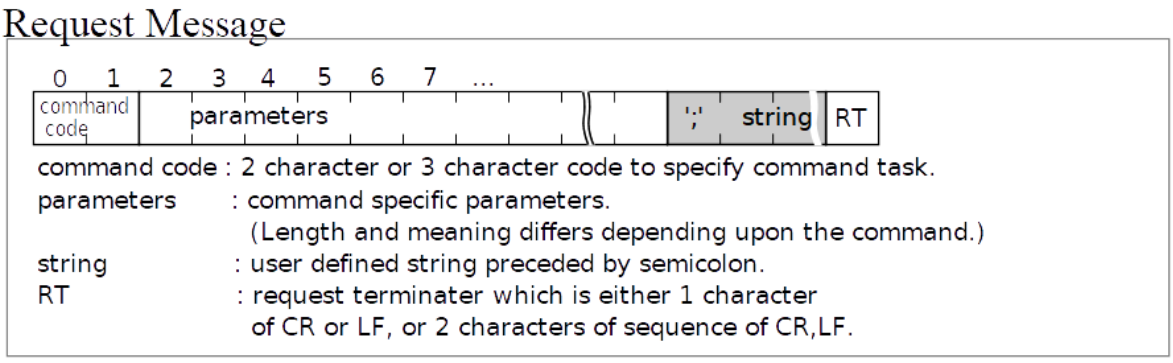


Figure 3.3.1: Request Message Format

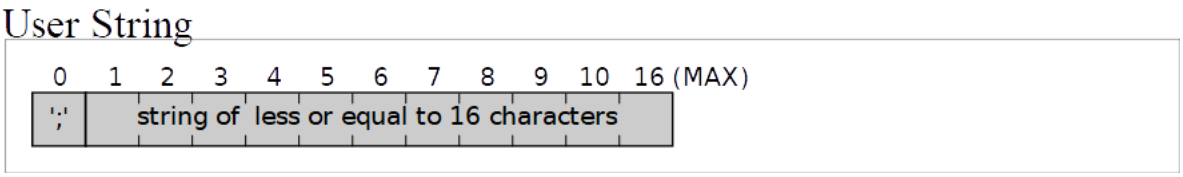


Figure 3.3.2: User Defined String

3.4 Response Message

Response message is sent from the sensor to the host system as promptly as possible. 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. Echo back character string of the request message as it is, request terminator. Character string a two-character code defined according to the command code and check code for the two-character code. Then, optional data strings are added depending on the command code. For optional data string, a check code is added for each response delimiter. The end of response message is a continuous response delimiters. Figure 3.4.1 shows the basic format of a response message. About sensor’s specific response message will be described later.

Response Message

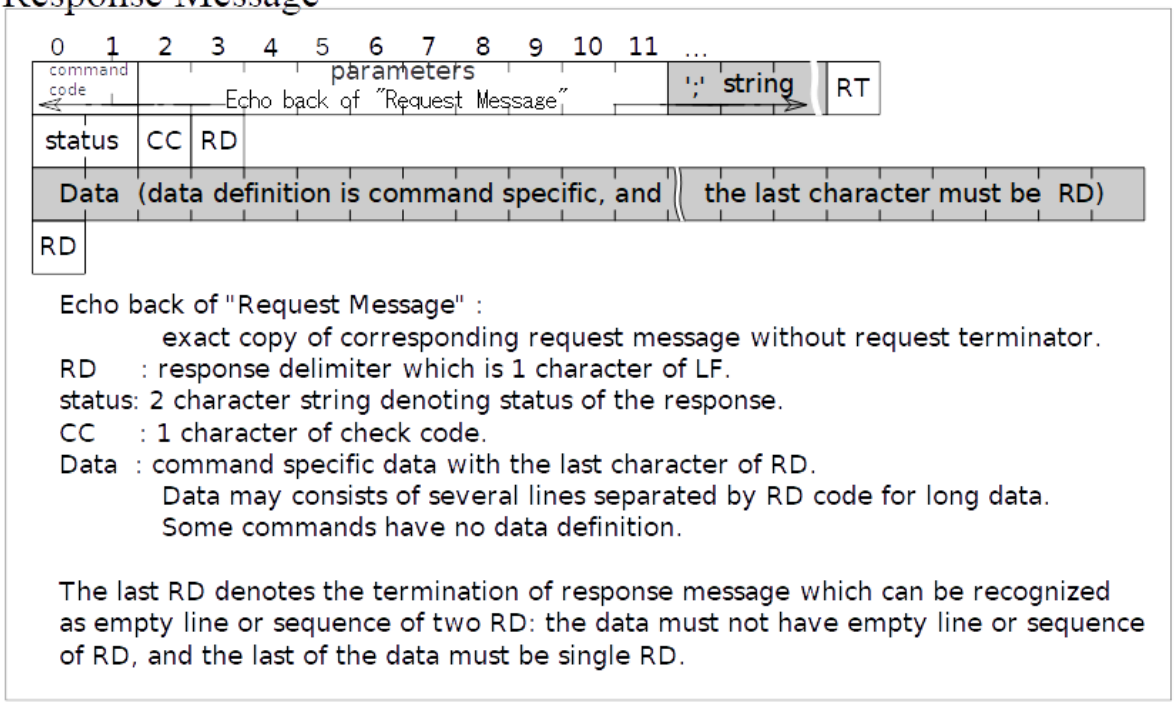


Figure 3.4.1: Response Message Format

3.5 Scan Response Message

There is a request command code to obtain scan data for multiple scans in continuous mode. During this, sensor only sends response message without measurement data to the host. Then, 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 echo back part, will not be same as the character string. It will be partially changed. The status consists of two-character code which shows the sensor measurement status for each scan and check code. Figure 3.5.1 shows the basic form of the scan response message.

Scan Response Message

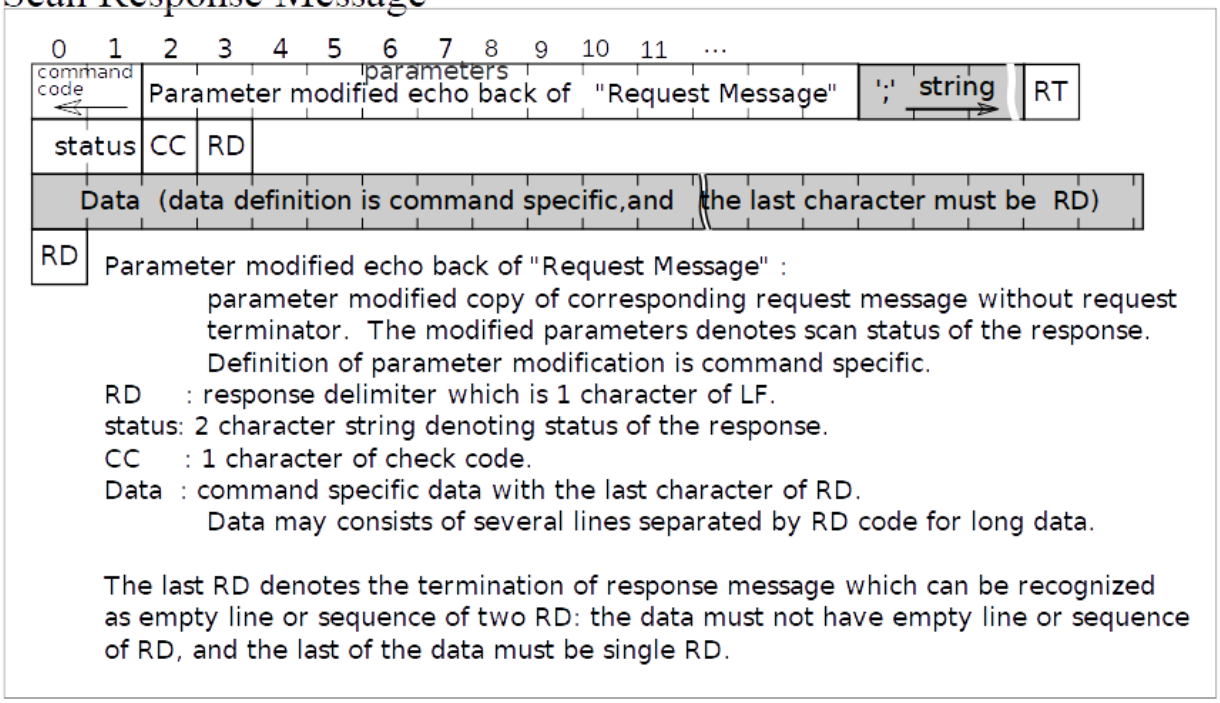


Figure 3.5.1 Scan Response Message Format

3.6 6-bit Encoding

In SCIP, numerical representation is converted to ASCII character by 6-bit encoding in order to compress the data send to the host. Converting a 6-bit (0 to 63 or 0x00 to 0x3f in hexadecimal) into ASCII character (0x30 to 0x6f range) by adding an offset 0x30 is called 6-bit encoding. For example, 26 (0x1a) is expressed in 6 bit encoding as 0x4a, which corresponds to the alphabetic character "J".

0x1a + 0x30 = 0x4a('J')

3.7 Check Code

Check code corresponds to the sum of the 8 bit integer values of the target character string, then lower order 6 bits represent 6 bit encoding as a single character. Here is an example of the check code of a character string ABC012. The sum of all characters is 0x159. Then, changed the lower order 6 bits to 6 bit encoding, check code "I" can be obtained.

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

Response message and scan response message, check code is calculated using the character string between the response delimiters. Then, check code is inserted between character string and follows immediately with response delimiter.

3.8 Character Encoding

The numbers included in response message or measurement data of scan response message returned to host represents with 0 or more than 0 integers. In SCIP, character encoding method is used in order to compress the data 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. 6 bits encoding result arranged in the higher order to lower 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 1234. Figure 2.5 shows the syntax of character encoding. Express 1234 (0x4d2) in binary and divide it into the groups of 6 bits. Insufficient upper bits are padded with 0.

1234 = 0100 1101 0010 = 010011 010010
0x13 0x12

Then, use 6 bit encoding to represent them, character string “CB” can be obtained.

0x13 + 0x30 = 0x43 0x12 + 0x30 = 0x42
’C’ ’B’

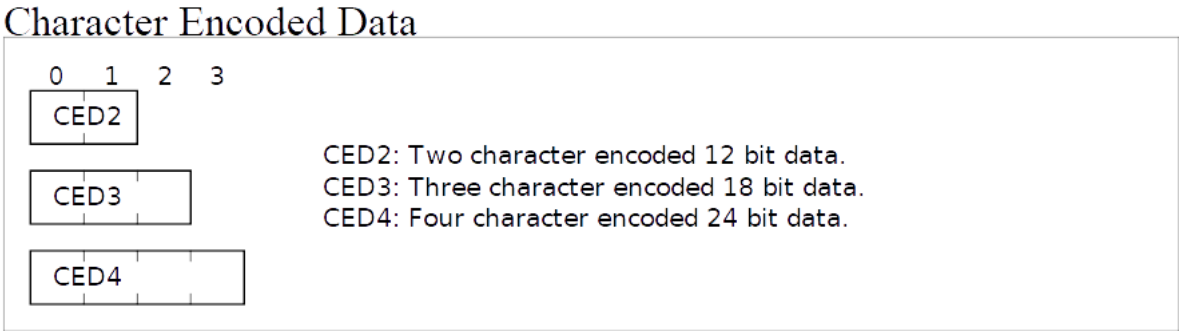


Figure 3.8.1: Character Encoded Format

3.9 Time stamp

Sensor has an internal counter, and its value is known as “time”. During this time when the sensor time is requested then used time stamp information of measurement data. Time is a 24-bit integer value represented using 4 characters encoding. This time value together with check code and response delimiter is called time data. When this 24 bit counter over run, it returns back to 0 and count continues. Figure 3.9.1 shows the time data.

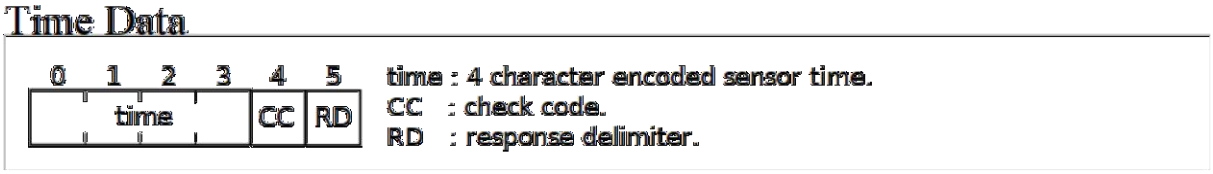


Figure 3.9.1:Time Data

3.10 Measurement Data

3.10.1 Step Data

One scan measurement data, for response message and scan response message of measurement command, is collection of data 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. Measurement data of each step has four types: distance, distance-intensity pair, multi-echo distance and multi-echo distance-intensity pair.

- Distance

  Distance data is in mm unit, represents in 12-bit data (Maximum 4095 (mm)) and 18-bit data (Maximum 262143 (mm)). Each of them is represented in 2 character encoding and 3 character encoding. Also, defined the maximum return value of the sensor, returns the maximum value if exceeds the value. Figure 3.10.1.1 shows the distance datum format.

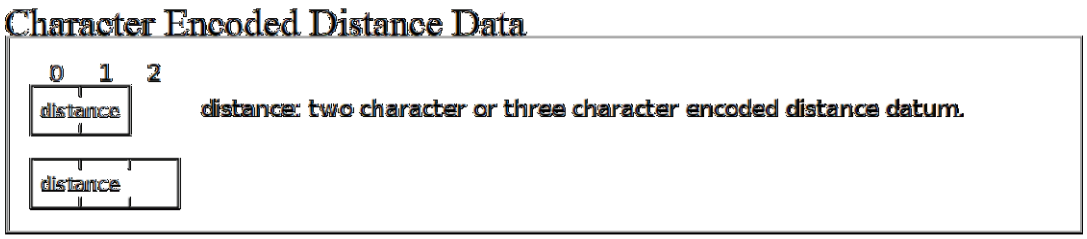


Figure 3.10.1.1: Distance Datum Format

- Distance Intensity pair

  Distance data, reflected intensity data can also be obtained. The reflected laser intensity is 18-bit data, and represents in 3 characters encoding. Intensity is the reflected strength of the laser. Sensor intensity output depends upon the internal characteristics of sensor's light receiving element and amplifier circuit. This value is relative: the higher the energy of the received laser light, the higher the intensity value reported by the sensor. In response message or scan response message, always return in distance and reflected intensity. Each represent in 3 character encoding in the order of distance and intensity. This is called a distance-intensity pair. Figure 3.10.1.2 shows its form.

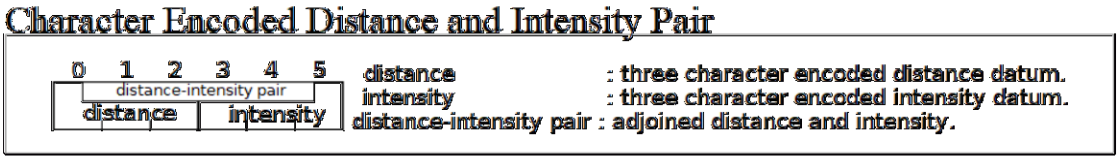


Figure 3.10.1.2: Distance-Intensity Pair Format

- Multi-echo

  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 2.9 shows the format of multiecho data.

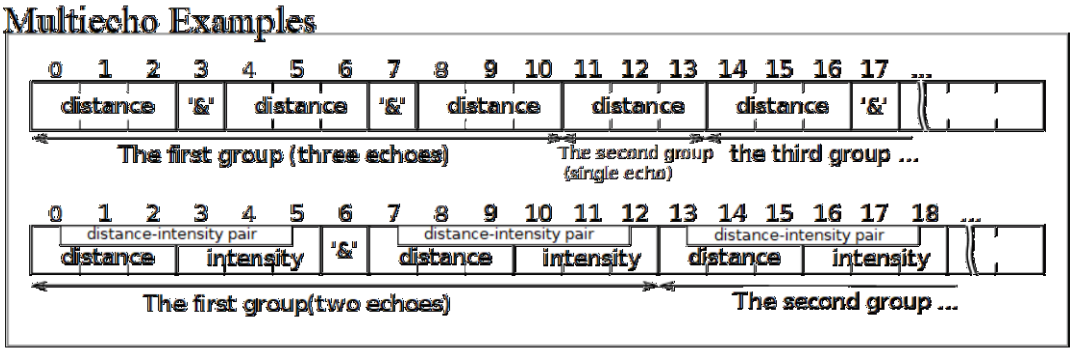


Figure 3.10.1.3: Multi- Echo Data Format

3.10.2 Scan Data

Measurement data in a response message or scan response message is considered as one scan. One scan data consists of either distance, distance-intensity pair, multi-echo distance or multi-echo distance-intensity pair, in the order of each step. For distance or distance-intensity pair, fixes the data amount with number of steps and message length. However, for multiecho data, the number of data varies by step for each scan. Therefore, the message length will differ between scans.

3.10.3 Block Splitting

When the message length of each scan becomes very long, in SCIP scan data is divided into 64 character group and response delimiters are inserted. Divided character string is called block data. In each block, a check code and a response delimiter are added and that is called a block. This operation is called block splitting. 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 3.10.3.1 shows the block.

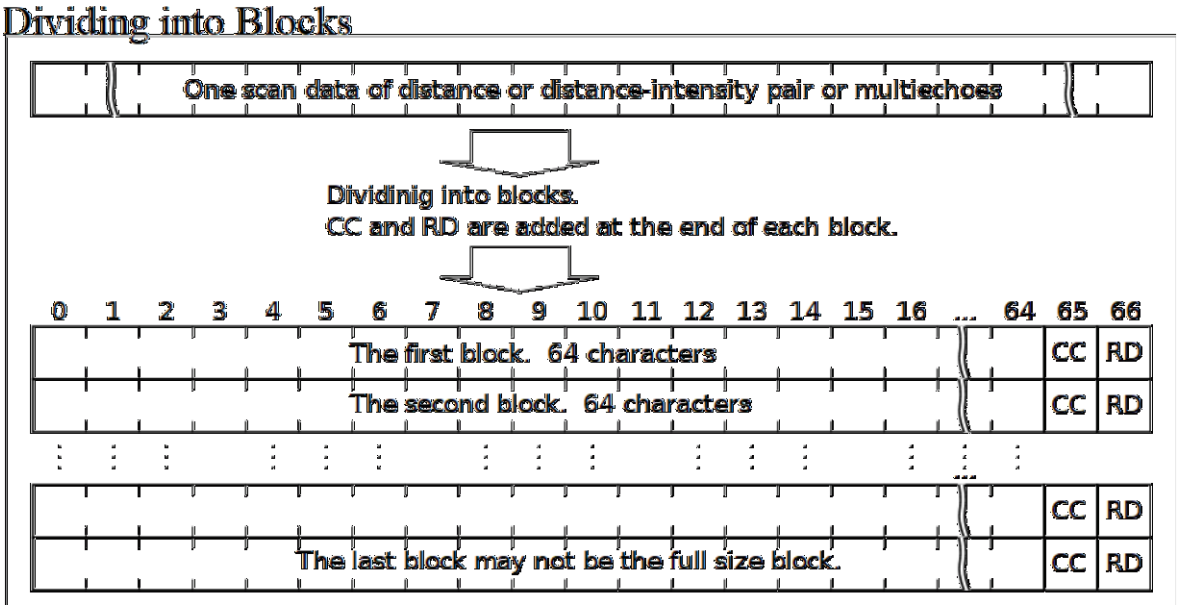


Figure 3.10.3.1: Block Format

4 LA Mode

The commands that can be used during LA mode are limited to the following.

The following commands are used for measurement acquisition

- Distance acquisition command (GD,MD)
- Distance and intensity acquisition command (GE,ME)

The following commands are used for information acquisition

- Version acquisition (VV)
- Sensor's parameters acquisition (PP)
- Sensor's state information acquisition (II)

The following commands are used for sensor's state change

- Transition to measurement state (BM)
- Stop continuous mode and move to Normal measurement state[1] (QT)
- Sensor reboot (RB)

[1] Only the steps of predefined area will return to measurement status.

5 Command Specification

5.1 Command Types

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

- Measurement command

  This command is used to return measurement data upon request. The command codes in Table 2.1, GD, GS, GE, HD, HE, MD, MS, ME, ND and NE belong to this category. These measurement command are further divided into the subcategories of measurement data acquisition command and measurement data acquisition with continuous scanning command.

- Measurement data acquisition command

  This command used to return measurement data when the sensor is in measurement state. Only this command is valid when the sensor is in measurement state. This command includes measurement data in the response message, and completes the communication upon request and response. GD, GS, GE, HD and HE command codes belong to this category.

- Measurement data acquisition with continuous scanning commands

  This command used to start measurement upon request and in each scan returns measurement data of specified scan number. When sensor is in standby (idle) state or measurement state, switch to measurement scan response state. This command is used to return measurement data as scan response message. Completes the communication when finishes specified scan number or when termination of measurement is requested. MD, MS, ME, ND and NE command codes belong to this category.

- State transition command

  This command defined in particular is used to change the state of the sensor. BM, QT, and %ST command codes belong to this category. Note that measurement data acquisition with continuous scanning command and time synchronization command can change the state.

- Initialization command

  This command used to initialize (reset) the sensor internal parameters as well as switch to standby state. RS, RT and RB command codes belong to this category.

- Setup command

  This command used to change the parameters of the sensor. SS, CR and HS command codes belong to this category. Although, URM Series does not respond to the command.

- Time synchronization command

  This command is used to synchronize time with the sensor time. TM command code belong to this category. Time synchronization is performed in time synchronization state, therefore TM command also changes the internal operation state of the sensor.

- Information command

  This command is used to obtain version information of the sensor. VV, PP and II command codes belong to this category.

5.2 Sensor Operation States

Starts in standby mode, after power supplied to the sensor and the operation state will change depending on command type. These are the following operation states.

- Booting state and Waking-up state
  The transitional state until the scanner becomes ready for measurement. When the scanner becomes ready, switch to next state automatically.

- Standby state
  The sensor is not measuring but in the state to start measurement. The laser is not emitting.

- Signal scan state
  The sensor measures data for all measurement possible steps. If BM command is received during standby state, the sensor switch to measurement state. During this state, the laser emits and sensor measures all measurement area when sensor receives measurement data acquisition command, returns the latest measurement data.

- Multi-scan state
  Starts measurement and in measurement scan response state. When sensor receives measurement data continuous acquisition command in standby state or measurement state. In this state, sensor scans the specified measurement area, scan numbers and return the scan response in each scan. In this state, if measurement data continuous acquisition command is received, changes parameters of measurement area and scan number continuous the measurement with the changed parameters. Sensor switch to standby state when the specified scan number is completed or when receives scan stop command.

- Time synchronization state
  Synchronize possible state with the internal timer of the sensor. Sensor switch to this state after receiving time synchronization command. While in this state, responses to time queries are sent with minimum delay.

- Sleep state
  This state is for low power consumption mode. Stops the scanner, and does not emit the laser.

- Abnormal state
  When detects sensor's abnormal state, sensor switch to abnormal state from other state.

- Unstable state
  If normal measurement cannot be performed due to some interference, sensor tries to recover during certain period (from few sec to 10 sec).Even sensor remains temporally in this state and sensor reply the status.

Figure 5.2.1 shows the sensor's transition state diagram. The state transition command, measurement command as well as time synchronization command changes the sensor state. Whether the command can be accepted or not complies with the state transition diagram. Regardless sensor status RS, RT and RB command operates exceptionally in the following ways:

- The initialization command RS and RT return the sensor to initialization state therefore sensor switch to standby state from any state except abnormal state.

- When RB initial command is received, restarts the sensor from any state, and switch to standby state. However, it requires a special procedure to use it. Within1 second, 2 request message should be sent and their corresponding response message should be received. Otherwise, the sensor continues to be in the same state and does not reboot.

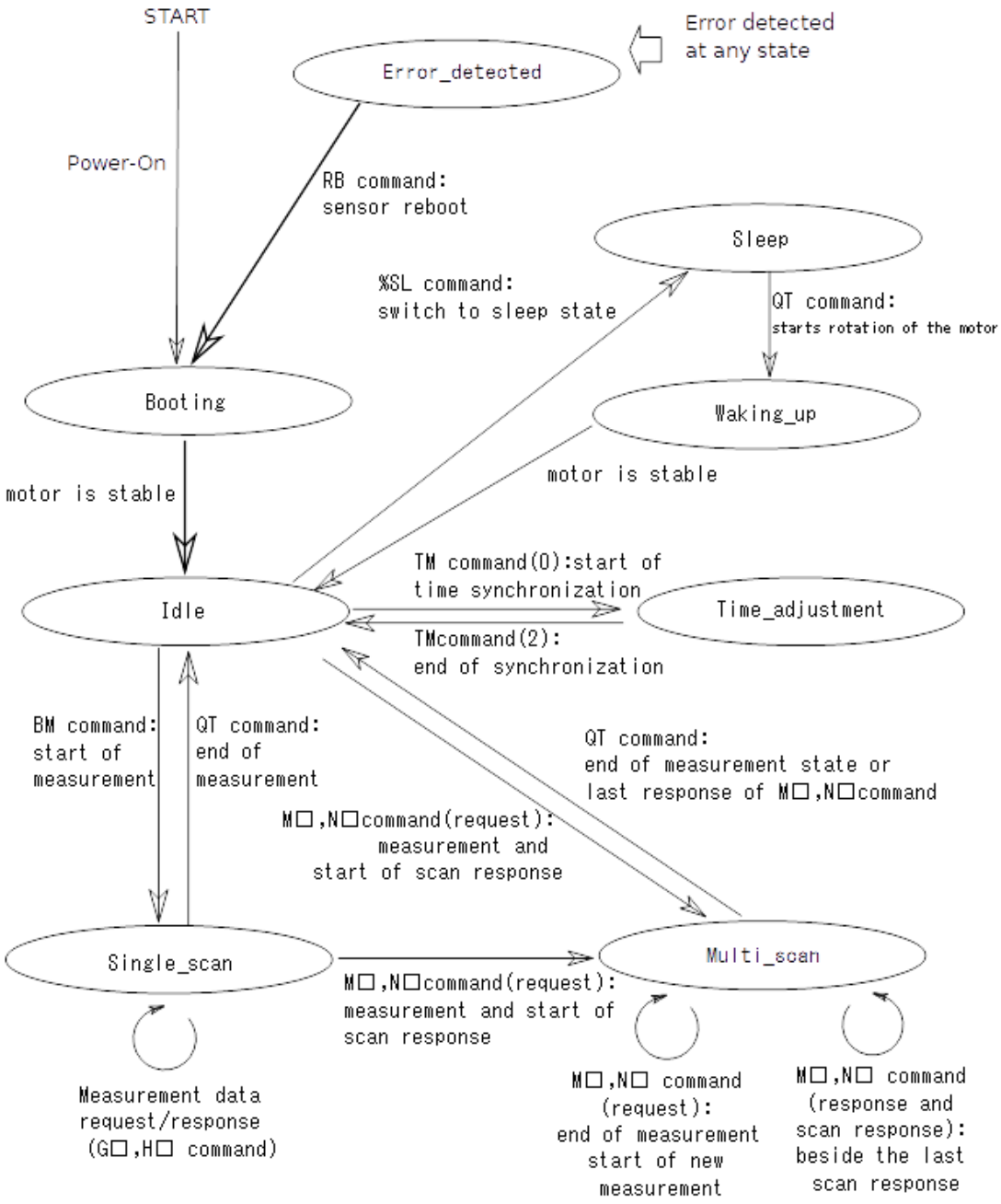


Figure 5.2.1: Sensor States

5.3 Operation Priority

5.3.1 General Status Codes

The common status codes for command are described below. In general, if a request cannot be normally processed, a status other than "Accepted" is returned, and requested operation is not performed.

- Accepted (code 00)
  A request is accepted normally. The command is received in a valid state and performs specified operation if parameters are correct. In some case includes state transition.

- Error-abnormal-state (code 0L)
  The sensor is in the abnormal state therefore request cannot be received. The code that shows abnormal type condition can be checked sensor information acquisition state command.

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

- 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 does not support 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)
  User defined string length is too long.

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

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

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

- Error-parameter (code 01, 02, 03, 04, 05, 06, 07)
  The request message has a problem.

5.3.23.3.2 Operation Priority

According to the sensor conditions, requests and responses is controlled by the following actions.
Operation priority order, lower value is of higher priority.

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

5.4 General Command

Several defined command have common features.

- Initialization state
  Laser does not emit immediately after power supplied to the sensor.

- Distance unit
  Distance data unit is in mm in all messages.

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

- Operation parameter
  Sensor memorize the default value of operation parameters. Operation parameters, such as transmission speed, scanning speed and sensitivity, can be changed by corresponding command. However, during reboot of the sensor, returns to default value. Note that there is no parameter that can be changed for this product.
  (URM Series)

- Common status codes for measurement with continuous scanning commands
  Continuous scanning acquisition command scan response message have several status codes, and they are shown in Table 5.4.1.

Table 5.4.1: Common status codes for measurement with continuous scanning commands

Status	Description
99	Normal scan response message
0L	Abnormal scan response message due to failure
0M	Abnormal scan response message due sensor unstable

5.5 GD, GS Measurement Commands: Distance Measurement

When sensor receives request message is sent for GD, GS command, return distance data as response message data. These commands are valid when the sensor is in measurement state. Before using GD, GS command, the laser must be ON first using BM command. While the laser is emitting, performs measurement and saves scan data all the time. During measurement of scan data, returns the latest completed data. GD, GS command request message parameter are shown in Table 5.5.1.Scan response message status as shown in Table 5.5.2.

Table 5.5.1: GD, GS Parameters 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

Regarding these parameters, the following regulations apply:

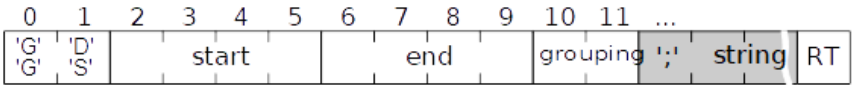
- Measurement obtained at the starting step position is included in the data.
- Measurement obtained at the ending step position is included in the data.
- If the number of steps in the group is 0 it is regarded as 1.
- The measurement value representing the group is the smallest distance value in the group. 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.

Table 5.5.2: GD, GS command status and description

Status	Description
00	Normal.
01	Non-numeric characters in the starting step.
02	Non-numeric characters in the ending step.
03	Non-numeric characters in grouped steps.
04	End step is greater than maximum step.
05	Start step is greater than end step.

The response data of GD, GS command scan response message includes time data and distance data split into blocks. However, if the status in the response message has an error, time data and distance data are omitted. The main difference between GD and GS command is format of response message. GD command uses 3 character encoding 18 bits to represent distance data, while GS command uses 2 character encoding 12 bits for distance data; the smaller bit length the shorter response message. Although the maximum distance of GS command is small, transmission time is also small, which is desired for some applications. Figure 5.5.1 shows the sequences of response message parameters. In the figure user defined string, time data and distance data block in gray field can be optional.

GD,GS request message



GD,GS response message

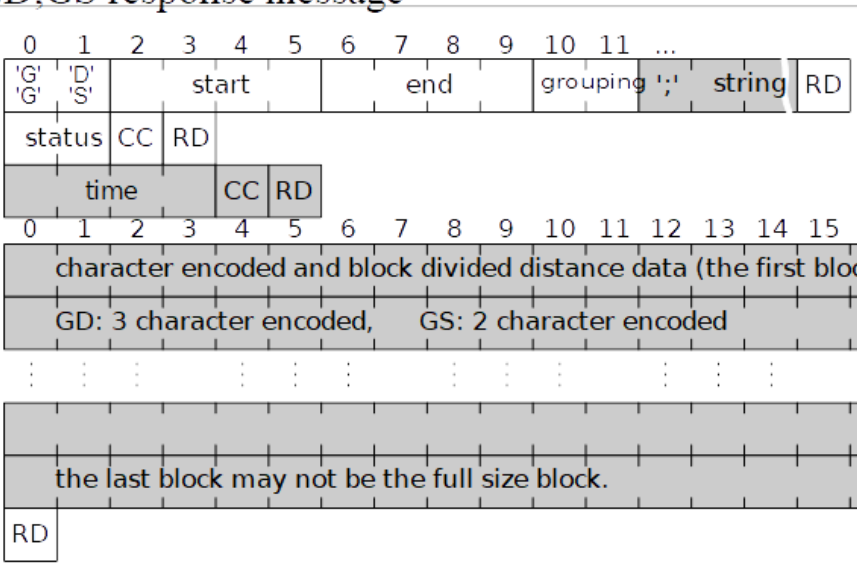


Figure 5.5.1: GD, GS Message Format

5.6 GE Measurement Command: Distance and Reflected Intensity Measurement

GE command operates in the same way as GD, GS command. Request message command parameters are also same as in Table 5.5.1. The difference is that the response message returns not only distance-intensity pair but also distance. Both distance and intensity data are represented using 3 character encoding of measurement data. Measurement value representing the group of steps is distance-intensity pair with minimum distance value in that group. Figure 5.6.1 shows the sequence of string containing parameter and data in message format. In the figure user defined string, time data and distance-intensity pair data block in the gray field can be optional.

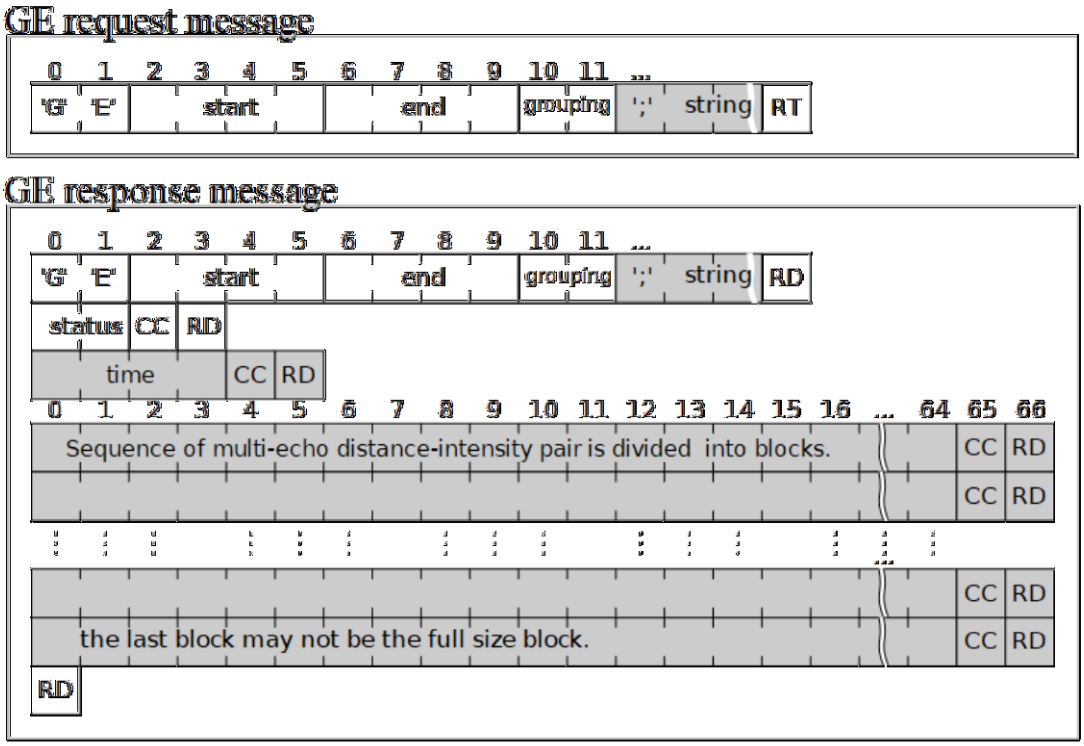


Figure 5.6.1: GE Message Format

5.7 HD Measurement Command: Multi-echo Distance Measurement

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 5.5.1. 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 5.7.1 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.

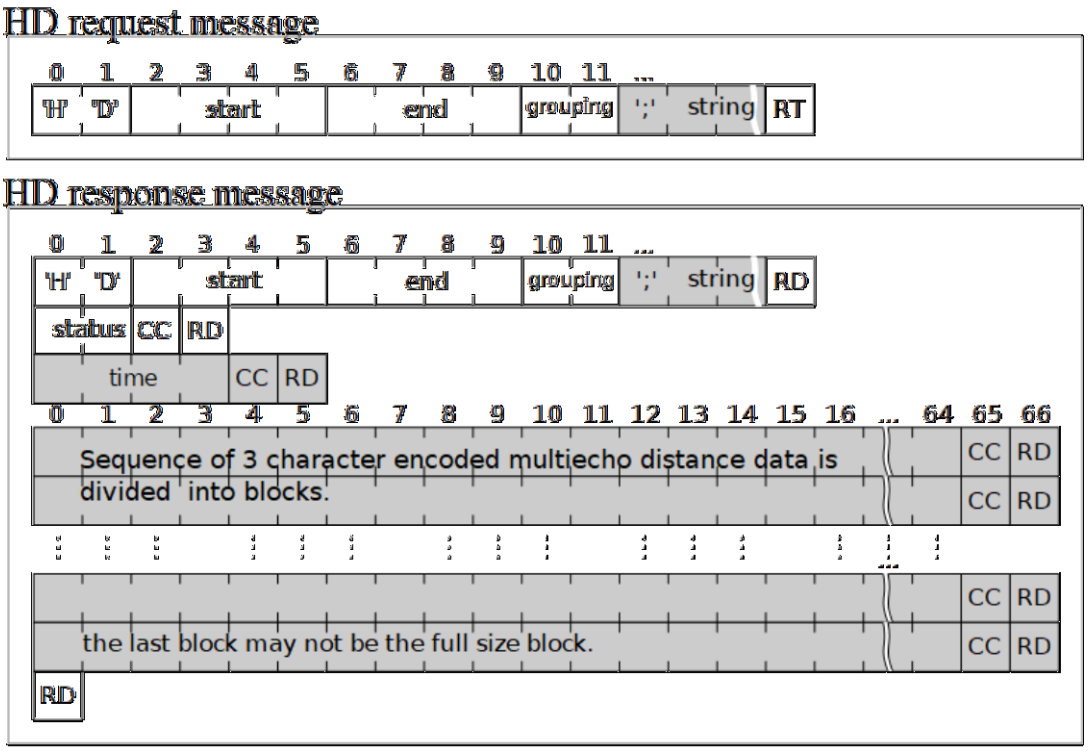


Figure 5.7.1: HD Message Format

5.8 HE Measurement Command: Multi-echo Distance Measurement

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 5.5.1. 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 5.8.1 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.

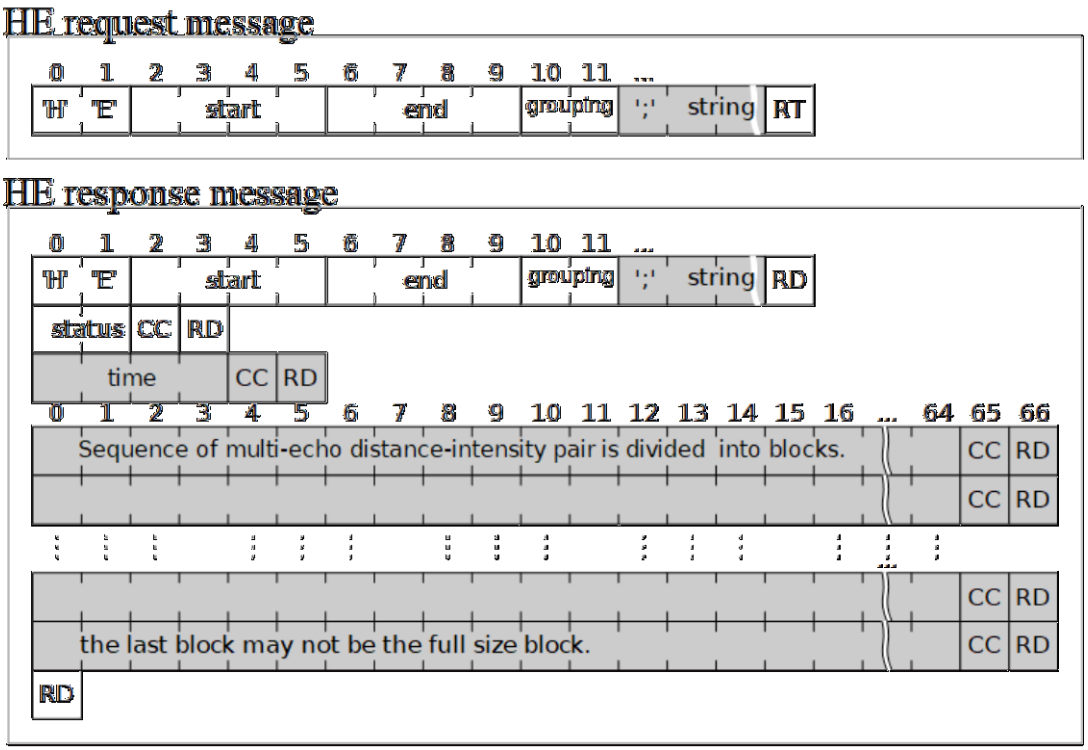


Figure 5.8.1: HE Message Format

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

These commands are used to start scan with specified conditions in the request message and returns scan response message in each measurement scan. These commands are valid during standby state, measurement state and measurement scan response state. It is not necessary to use BM command to turn ON the laser before using MD, MS command. MD, MS command request message parameters are as shown in Table 5.9.1 MD, MS command response message status is shown in Table 5.9.2.

Table 5.9.1: MD, MS command status and description

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 the group. 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.
- Scan skip count is the number of scans to skip (not scanned) during measurement.
- Scan count is the number of measurement scans. In case of 0 it means unlimited scans, therefore use QT command (switch to standby state) to stop the measurement.

Table 5.9.2: MD, MS command status and description

Status	Description
00	Normal.
01	Non-numeric characters in the starting step.
02	Non-numeric characters in the ending step.
03	Non-numeric characters in grouped step.
04	End step is greater than maximum step.
05	Start step is greater than end step
06	Non-numeric characters in scan skip count.
07	Non-numeric characters in measurement scans count.

If there is no error in the response message, the sensor will send measurement information in the scan response messages until scanning process ends. However, if there is delay in communication, some of the scan response messages might not be sent. 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 sent. In the very last scan response message sent, the number of pending scans must be 0.

The basic format of response message does not include measurement data. In scan response message includes time data and measurement data, however, if in error status, both time data and measurement data are omitted. The scan response message includes a character string portion called echo-back; in this echo-back, scan count part is changed to remaining scan count all the time. In remaining scan indicates how many more scans remain to be read, not including the current message. In last scan response message, remaining scan count is set 0, when scan count is unlimited, the remaining scan count is 0 all the time.

When sensor is in unstable condition, it tries to recover. During recovery, scan response message with status showing the unstable condition is returned. When sensor returns to normal condition, scan response message is returned with normal status. If sensor switch to abnormal state, scan response message with status showing the abnormal condition is returned and scan response message is ended.

In response data of MD, MS command scan response message includes time data and distance data split into blocks. However, if response message has an error, time data and distance data are omitted. The main difference between MD and MS command is response data format. MD command uses 3 character encoding 18 bits to represent distance data, while 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 MS command is small, transmission time is also small which is desired for some applications. Figure 5.9.1 shows sequences of response message parameters. In the figure user defined string, time data and distance data block shown in gray field can be optional. Also, remaining scans are presented in gray hatching in the figure.

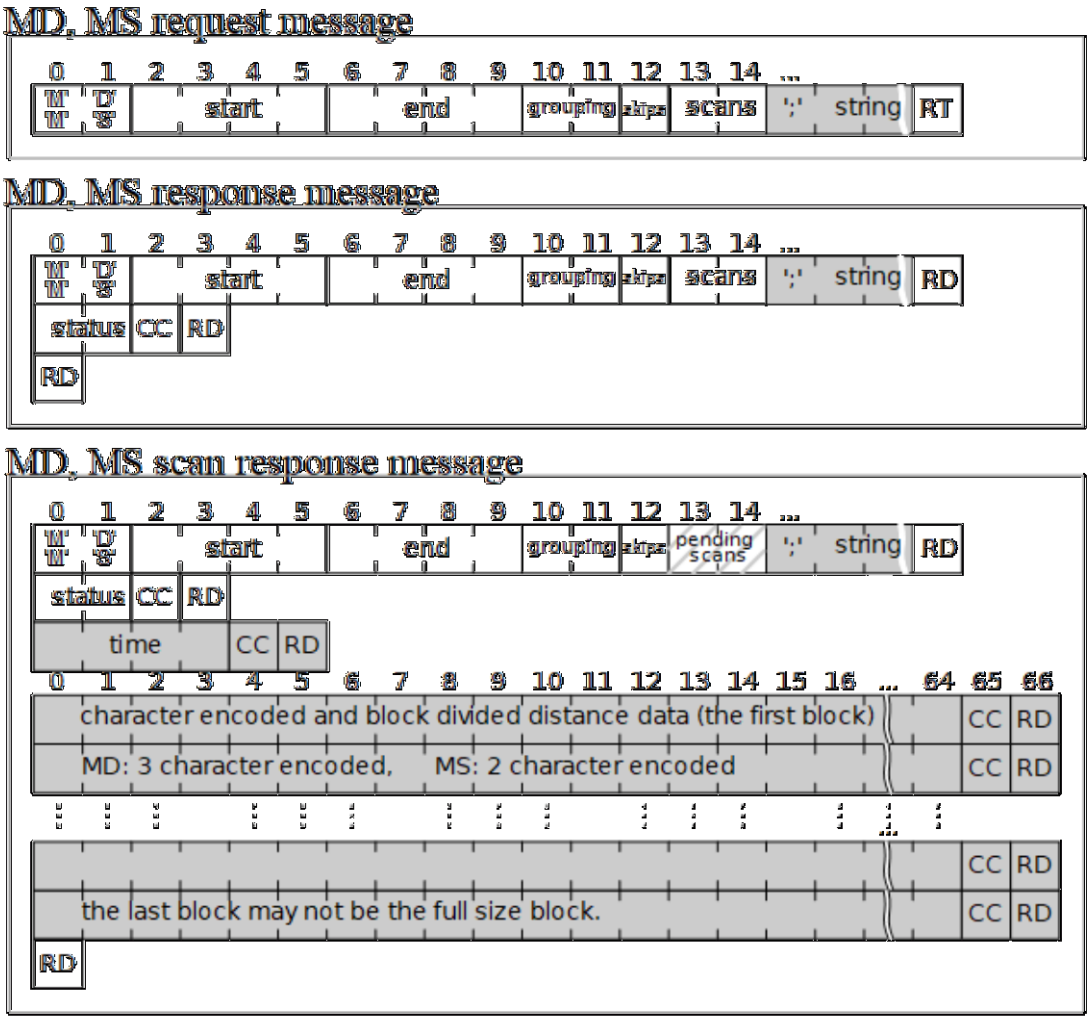


Figure 5.9.1: MD, MS Message Format

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

ME command operates in the same way as MD, MS command. Request message command parameters are also same as in Table 5.9.1. The difference is that the response message returns not only distance but also distance-intensity pair. Both distance and intensity data are represented using 3 character encoding of measurement data. The measurement value representing the group of steps is distance-intensity pair having the smallest distance value in that group. Figure 5.10.1 shows the sequence of response message parameter. In the figure user defined string, time data and distance-intensity pair data block in gray field can be optional.

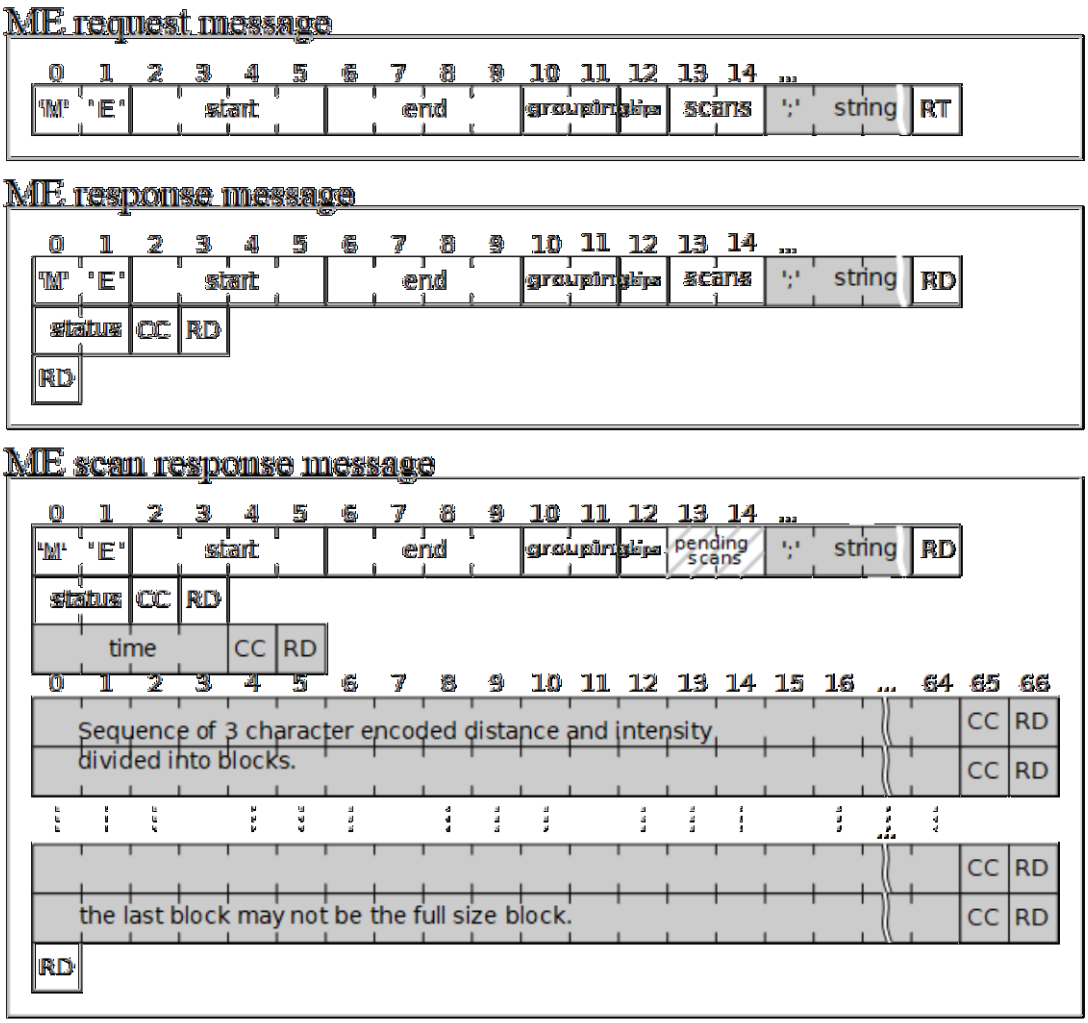


Figure 5.10.1: ME Message Format

5.11 ND Measurement Command: Multi-echo Distance Measurement with Continuous Scanning

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 5.9.1.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 5.11.1 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. Also, remaining scans are presented in gray hatching in the figure.

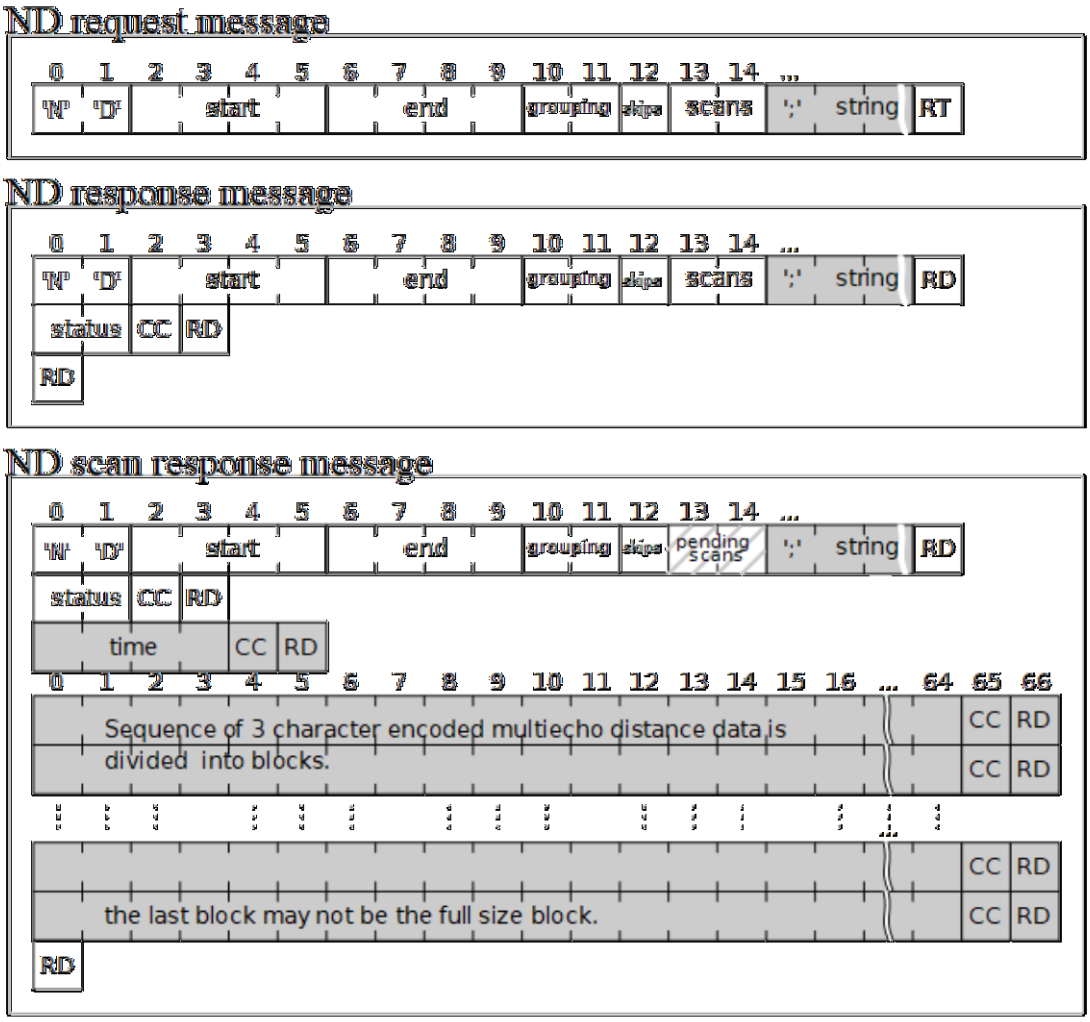


Figure 5.11.1: ND Message Format

5.12 NE Measurement Command: Multi-echo Distance and Reflected Intensity Measurement with Continuous Scanning

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 5.9.1. 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 5.12.1 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. Also, remaining scans are presented in gray hatching in the figure.

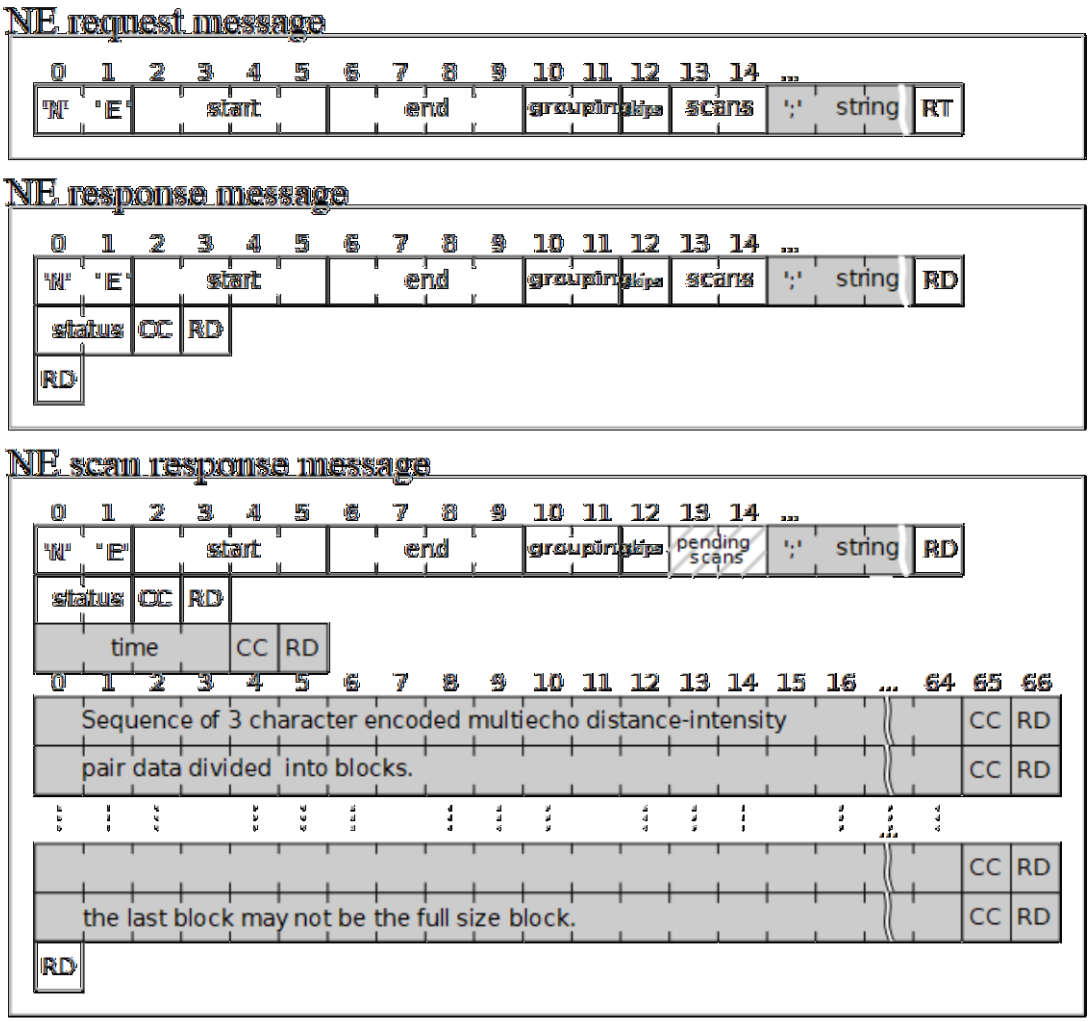


Figure 5.12.1: NE Message Format

5.13 %ST State Code Acquisition Command

This command is used to return sensor current state a code of 3 characters. It is valid in all different state of the sensor. %ST command response message status is shown in Table 5.13.1. %ST command response message has no parameter. Also, response message consists in 3 character code which corresponds to sensor current state. 3 character state codes list is shown in Table 5.13.2. Figure 5.13.1 shows the sequences of response message parameter.

Table 5.13.1: %ST command status and description

Status	Description
00	Normal.

Table 5.13.2: State codes

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

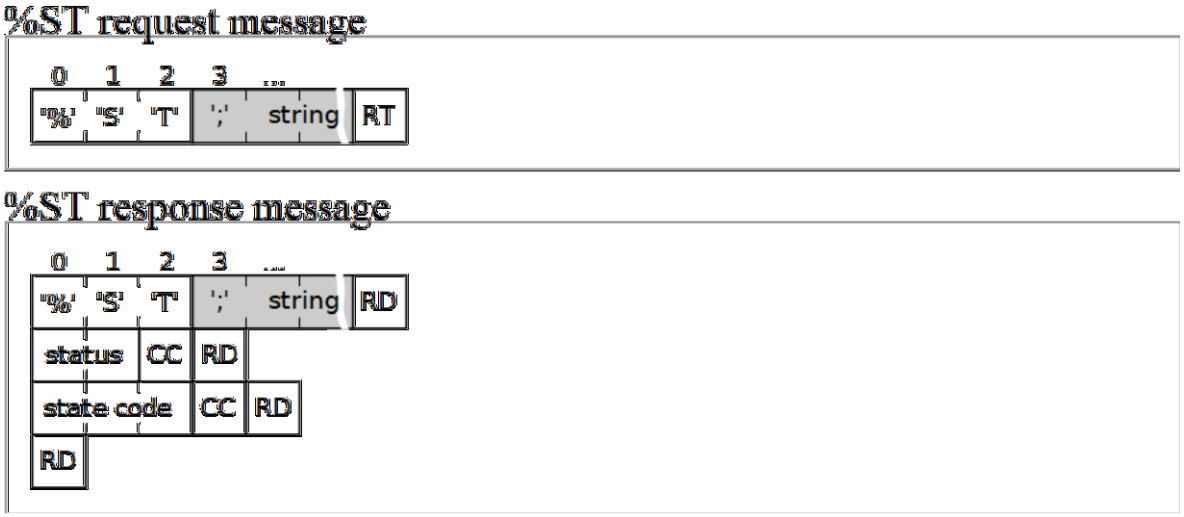


Figure 5.13.1: %ST Message Format

5.14 BM State Transition Command: Transition to Measurement State

This command is used to switch the sensor to measurement state and starts measurement emitting the laser. This command is valid, when sensor is in standby state. BM command request message has no parameter. Also, response message does not include any data. BM command response message status of BM command is shown in Table 5.14.1. Figure 5.14.1 shows the sequences of response message characters.

In SCIP-LA, this command is used to switch from current area limited measurement into full field measurement state.

Table 5.14.1: BM command status and description

Status	Description
00	Normal. The sensor is in measurement state and laser is emitting.
01	Laser emission is stopped due to internal error.
02	Already sensor is in measurement state and laser is emitting.

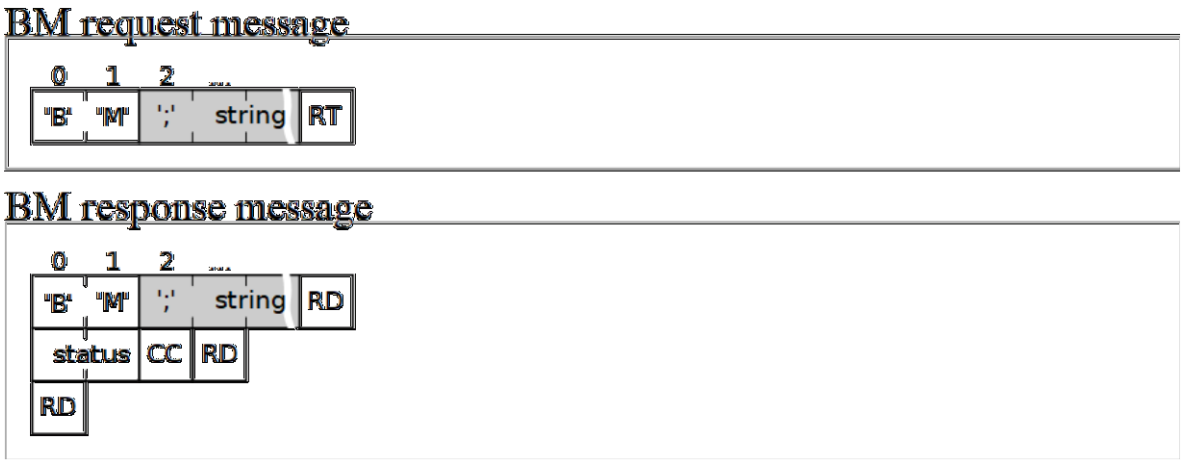


Figure 5.14.1: BM Massage Format

5.15 QT State Transition Command: Transition to Standby State

This command is used to stop the current measurement process and switch the sensor to standby state. This command is valid while in measurement state or in measurement scan response state. QT command request message has no parameter. Also, response message does not include any data. Response message state of QT command is shown in Table 5.15.1. Figure 5.15.1 shows the sequences of response message character.

In SCIP-LA, this command is used to stop transmitting the data during continuous mode. Also, returns to normal state during the measurement of data with laser activated for all steps.

Table 5.15.1: QT Command status and description

Status	Description
00	Normal. The sensor is in standby state and stops emitting the laser.

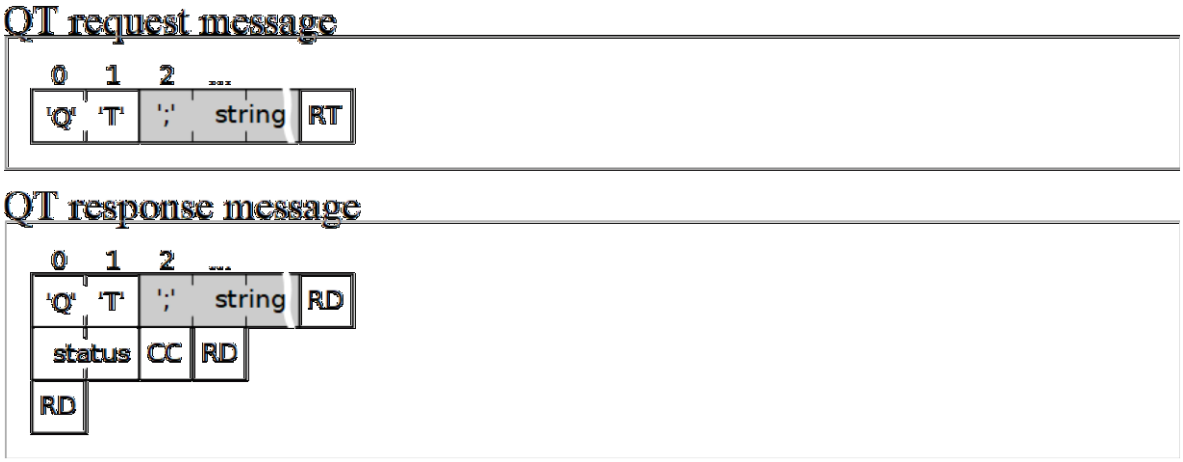


Figure 5.15.1: QT Message Format

5.16 %SL State Transition Command: Transition to Standby State

This command is used to switch the sensor to sleep state. When sensor receives %SL command, it stops current measurement process, switch to sleep state, stops the laser and motor. This command is valid when sensor is in standby state. %SL command request message has no parameter. Also, response message does not include any data. %SL command response message status is shown in Table 5.16.1. Figure 5.16.1 shows the sequences of response message character.

Table 5.16.1: %S L command status and description

Status	Description
00	Normal. The sensor is in sleep state and stops emitting the laser.

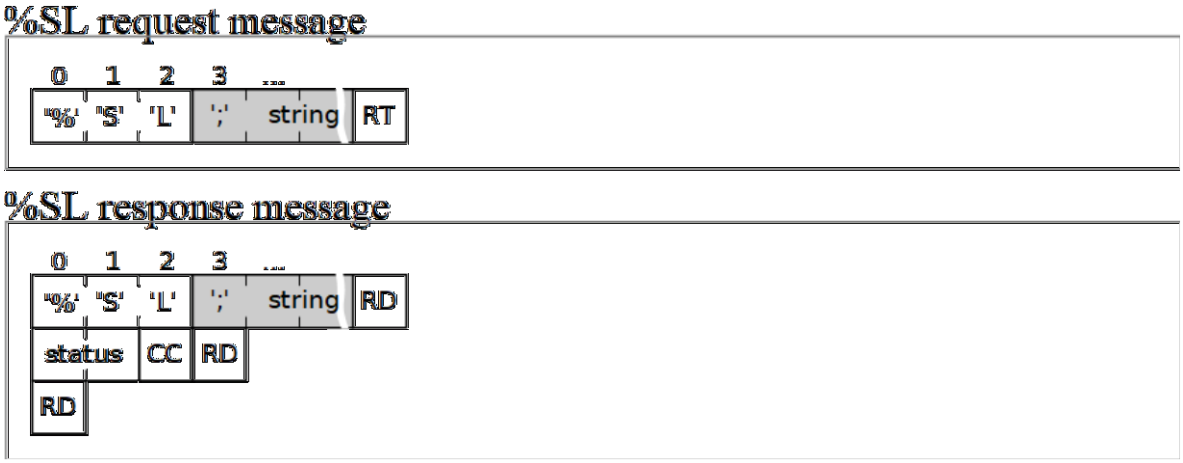


Figure 5.16.1: %SL Message Format

5.17 RS Resetting Command

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

1. Stops the laser.
2. Returns the motor scan speed to initial value.
3. Returns the serial transmission speed to initial value.
4. Returns the sensor internal timer to 0.
5. Set the measurement sensitivity to normal.

However, when sensor is in abnormal state, RS command is not received. RS command request message has no parameter. Also, response message does not include any data. RS command response message is shown in Table 5.17.1. Figue 5.17.1 shows the sequences of the response message character.

Table 5.17.1: RS command status and description

Status	Description
00	Normal. The sensor is in standby state and stops the laser.

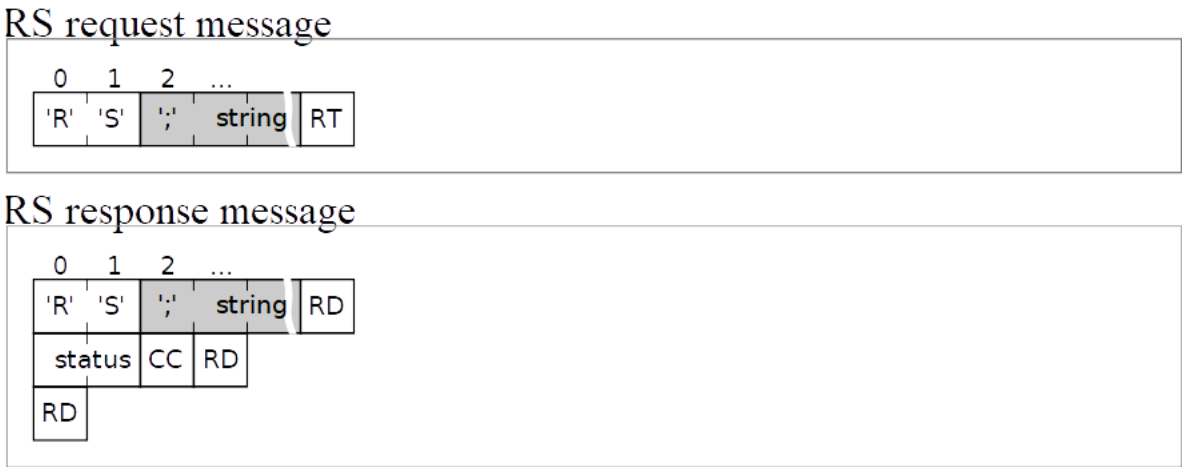


Figure 5.17.1: RS Message Format

5.18 RT Resetting Command: Partial Reset

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

1. Stops the laser.
2. Returns the sensor internal timer to 0.
3. Set the measurement sensitivity to normal.

This is similar to RS command, except motor scan speed and serial transmission speed are not changed. When sensor is in abnormal state, RT command is not received. RT command request message has no parameter. Also, response message does not include any data. RT command response message status is shown in Table 5.18.1. Figure 5.18.1 shows the sequences of response message character.

Table 5.18.1: RTcommand status and description

Status	Description
00	Normal. The sensor is in standby state and stops the laser.

図 5.18.1: RT Message Format

5.19 RB Resetting Command: Controller Reboot

RB command is used to reboot the sensor. However, RB command requires a special procedure to use it. Within 1 second, 2 request messages of RB command must be sent and their corresponding response messages must be received. Otherwise the sensor continues to be in the same state and does not reboot. When sensor receives RB command, the sensor operates similar as if power supplied and switch to standby state. The following tasks are performed:

1. Waits for 1 second, during this time the host system disconnects from the sensor.
2. Sensor stops all the communications.
3. Stops the laser.
4. Returns the motor scan speed to initial value.
5. Returns the serial transmission speed to initial value.
6. Returns the sensor internal timer to 0.
7. Sets the measurement sensitivity to normal.
8. Initializes other internal parameters, and waits until scanning speed becomes stable.
9. Switch to standby state.

In SCIP-LA, this RB command is only valid when sensor stops due to error.

RB command is only state transition command that can be received during abnormal state. RB command request message has no parameter. Also, response message does not include any data. RB command response message status is shown in Table5.19.1. Figure5.19.1 shows sequences of response message character.

Table 5.19.1: RB command status and description

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

Figure 5.19.1: RB Message Format

5.20 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 t1 be the global time since the host sends the TM1 request message until the sensor receives it, and let t2 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 t1 and t2 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 t1 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 5.20.1.

Table 5.20.1: TM command request message parameter

Order	Description	Length	Name
1	Time control code	1	control code

In table 5.20.2 shows the valid control code list as character string.

Table 5.20.2: TM command request message parameter

String	Control description
0	Transition from standby state to time synchronization state.
2	Transition from time synchronization state to standby state.
1	Returns the time.

TM command response message status is shown in Table 5.20.3.

Table 5.20.3: TM command status and description

Status	Description
00	Normal.
01	Invalid parameter (control code).
02	Received TM0 request and already the sensor is in time synchronization state.
03	Received TM2 request and already the sensor left the time synchronization state.

TM1 command response message is sensor current time. However, if response message status has an error (different from Normal), no time data is returned, there is no data for TM0 and TM2 command response data. For more details about time data, please refer to Section 3.9. Figure 5.20.1 shows the sequences of message character.

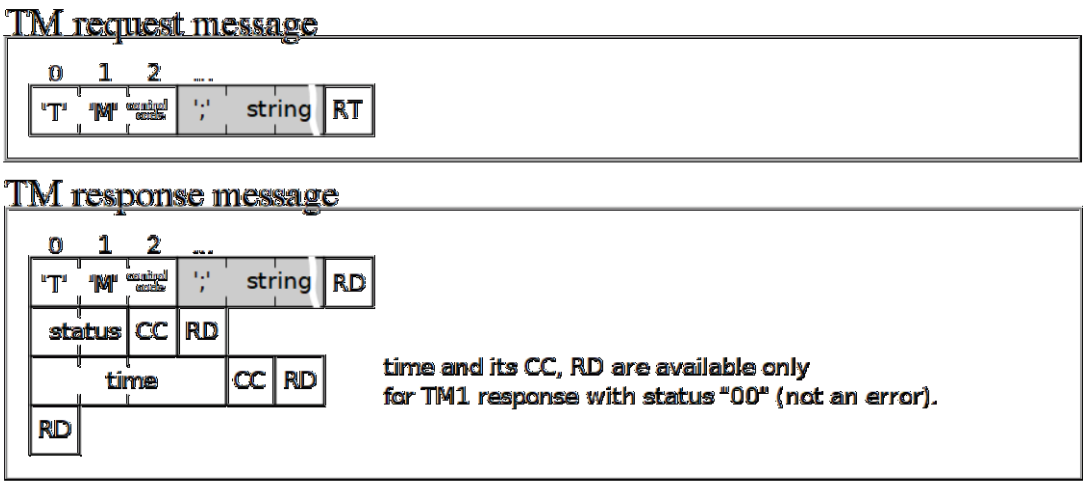


Figure 5.20.1: TM Message Format

5.21 VV Information Command: Version

This command used to obtain version information of the sensor. VV information command is valid during any state of the sensor. VV command request message does not include parameter. Table 5.21.1 shows response message. Table 5.21.2 shows VV command returned information list.

Table 5.21.1: VVcommand status and description

Status	Description
00	Normal.

Table 5.21.2: VV command status and description

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

The first string always consists of 4 character tag and colon. Each item of response message data consists string, semicolon ';', check code and response delimiter. Check code is only for description string without semicolon. Notice that this rule applies specially for VV, PP, and II command only. Figure 5.21.1 shows the character sequences of the messages.

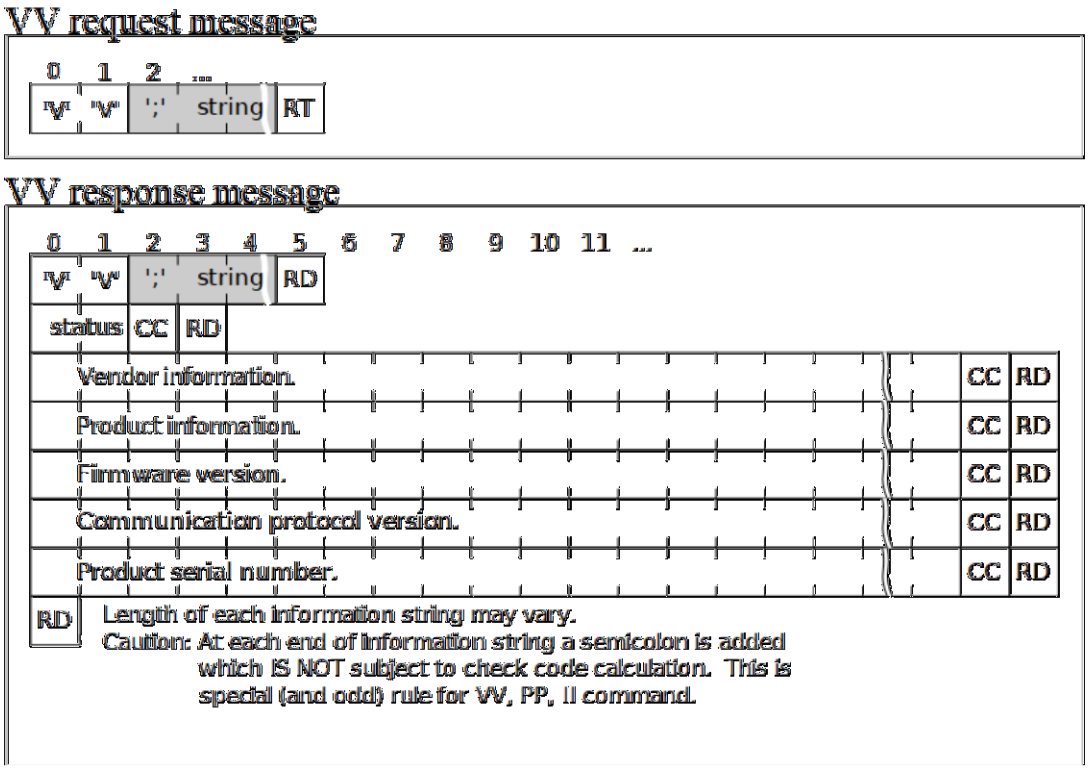


Figure 5.21.1: VV Message Format

5.22 PP Information Command: Sensor Parameters

This command is used to obtain sensor internal parameter information. PP information command is valid during any state of the sensor. PP command does not include any parameter. Table 5.22.1 shows the response message status. Table 5.22.2 shows PP command returned information list.

Table 5.22.1: PP command status and description

Status	Description
00	Normal.

Table 5.22.2: PP command status and description

Description	String Sample
Sensor model	MODL:UXM-30LXH-EHA
Minimum measurable distance (mm)	DMIN:23
Maximum measurable distance (mm)	DMAX:120000
Angular resolution (360 degrees)	ARES:2880
Minimum step number of the scanning area	AMIN:0
Maximum step number of the scanning area	AMAX:1520
Step number of the front direction	AFRT:760
Standard scanning speed (rpm)	SCAN:1200

The first string always consists of 4 character tag and colon. Each item of response message data consists a description semicolon ';', check code and response delimiter. Check code is only for description string without semicolon. Notice that this rule applies specially for VV, PP, and II command only. Figure 5.22.1 shows the character sequences of the messages.

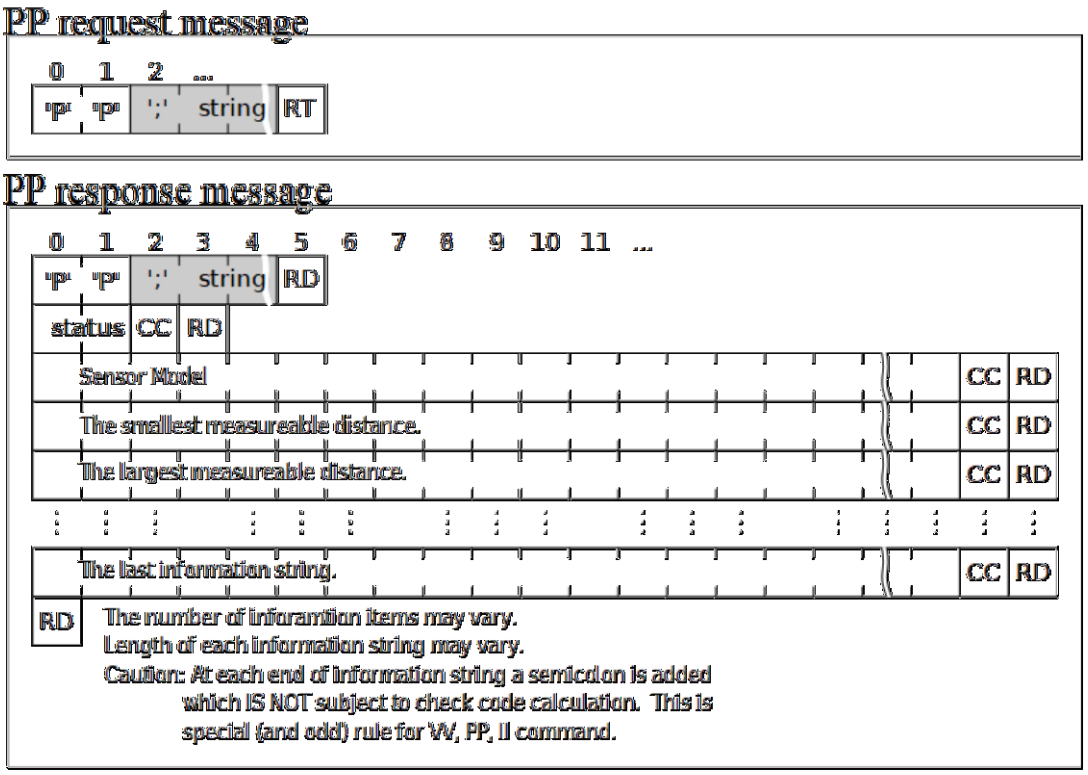


Figure 5.22.1: PP Message Format

5.23 II Information Command: Sensor State

This command is used to obtain sensor status information. II information command is valid during any state of the sensor. II information command does not include any parameters. Table 5.23.1 shows the response message status. Table 5.23.2 shows II command returned information list.

Table 5.23.1: II command status and description

Status	Description
00	Normal.

Table 5.23.2: I I command status and description

Description	String Sample
Sensor model	MODL:UXM-30LXH-EHA
Status of the laser	LASR:OFF
Current scanning speed (rpm)	SCSP:1200
Current status of sensor *3 Character value is same as the status code obtained with % ST command	MESM:000 Idle
Current communication speed	SBPS:Ethernet 100 [Mbps]
Current time * hexadecimal digit (ms)	TIME:001E3B
Current status of sensor	STAT:Stable 000 no error.

The first string always consists of 4 character tag and colon. For details of sensor status, please refer to the product specification. Each item of response message data consists in a description string, semicolon ';', check code and response delimiter. Check code is only for description string without semicolon. Notice that this rule applies specially for VV, PP, and II command only. Figure 5.23.1 shows the format and sequences of the messages.

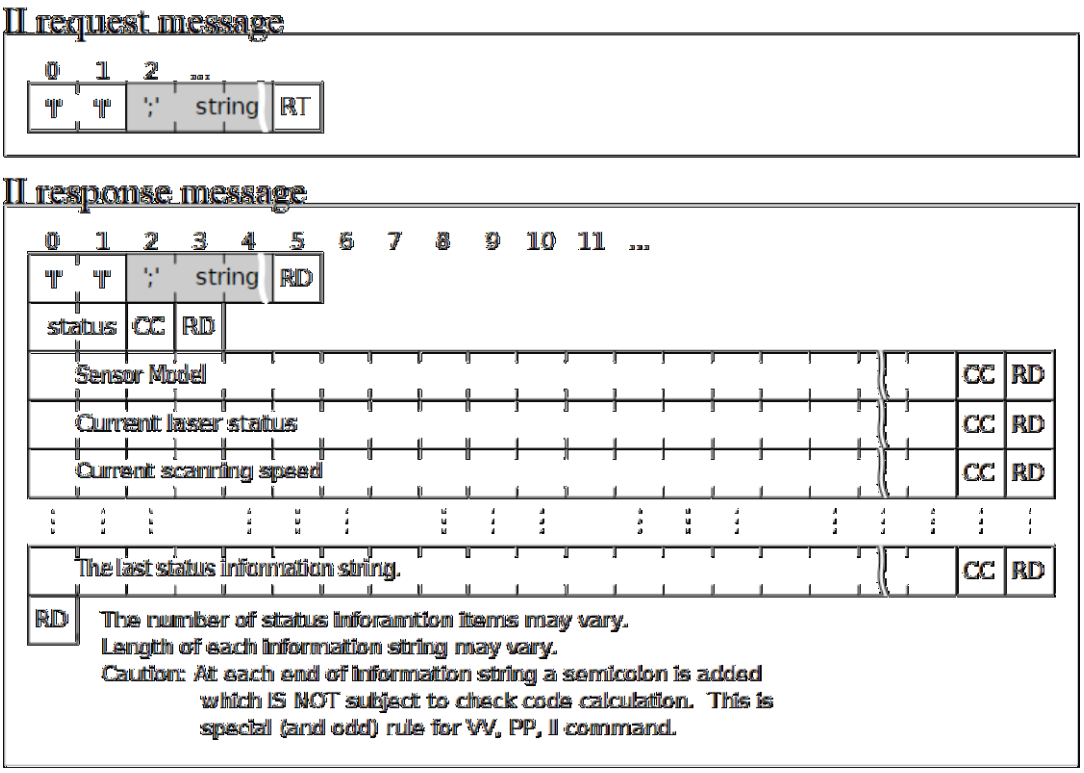


Figure 5.23.1: II Message Format

5.24 %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 3.23 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 5.24.1 shows the format and the order of the messages of this command.

Table 5.24.1: %PG command status and description

Status	Description
00	Normal.

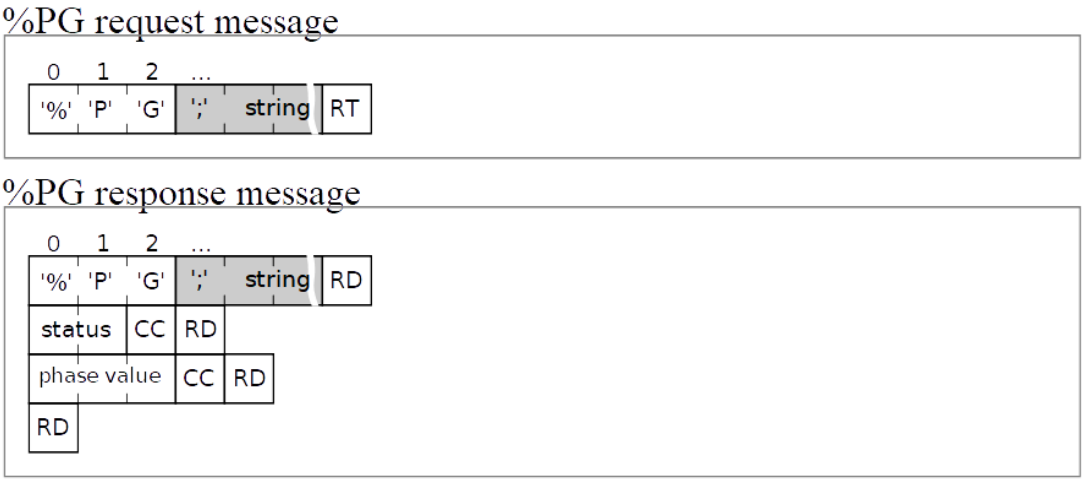


Figure 5.24.1: %PG Message Format

References

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2: Jun’ichi IIJIMA, Tomoaki YOSHIDA, Hirohiko KAWATA, Yoshitaka HARA, Shin’ichi YUTA, The Com-mand Interface Protocol “SCIP2.2” for Detecting Multiple Reflecting Points Type SOKUIKI Sensor, 2009