URG Series
Communication Protocol Specification
SCIP-Version2.0

SYMBOL	CORRECTED REASON	PAGES	DATE	CORRECTOR	NO
⚠3 X 5	1. Change of URL. 2. Added explanation about LED blinking. 3. Added detail explanation about MD/MS command due to bug fix from F/W version 3.1.04. 4. Baud Rate -> Bit Rate.	2, 8, 13	03/Aug./2007	Kawata	PR5325
⚠2 X 6	1. Added link to IROS paper. 2. Notice on release of URG_Configure.exe. 3. Corrected mistakes in encoding_example. 4. Added detail explanation about string characters.	2, 4, 5	08/Dec./2006	Kawata	PR5205
⚠1 X 3	Add explanation about Firmware update mode	5, 19	01/Nov./2006	Kawata	PR5181

APPROVED BY	CHECKED BY	DRAWN BY	DESIGNED BY	TITLE	URG-Series Communication Protocol Specification (SCIP Version 2.0) -		
Mori	Maejima	Kawata	Kawata	DRAWING NO.	C－42－03320B		1/15

URG-Series Communication Protocol Specification (SCIP Version2.0)

♦ Introduction ♦

  URG-Series are laser scanning-sensors (SOKUKI sensor) developed for robotic applications[*1]. Its communication specifications are designed to comply with command system in SCIP ver2.0 and SCIP ver1.1 developed by sensor interface research group[*2]. Command systems in SCIP are the set of pre-defined characters that are used to communicate between host (computer) and sensor in order to perform different sensor tasks or settings. This specification explains the command system defined in SCIP ver2.0.

  To use SCIP ver2.0 the sensor must be updated with the compatible firmware (see the Table1 for the details). Firmware and updating tools can be downloaded form the company's web site http://www.hokuyo-aut.jp/02sensor/07scanner/urg.html(See below of the page.). △3

Table 1

Firmware Version	SCIP ver1.1	SCIP ver2.0
0.2.91a or earlier	YES	NO
3.0.00	YES	YES

  [*1] See our paper for details about the sensor. △2
     H. Kawata, W. Santosh, T. Mori, A. Ohya and S. Yuta, "Development of ultra-small lightweight optical range sensor system", IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS2005), pp.3277-3282, 2005-8, Edmonton

  [*2] For detail, contact Intelligent Robot Lab. Univ. of Tsukuba: http://www.roboken.esys.tsukuba.ac.jp/

♦ Switching to SCIP Ver2.0 ♦

Even if the sensor is SCIP Ver2.0 compatible it will always start in SCIP Ver1.1 by default. It should be switched to SCIP Ver2.0 by sending the following **[SCIPver2.0 Changing Command]**

 [SCIPVer2.0 Changing Command]
    (HOST → SENSOR)

S	C	I	P	2	.	0	LF

    (SENSOR → HOST)

S	C	I	P	2	.	0	LF	Status	LF	LF

      ● Status: 00 --- Changed to SCIPver2.0 successfully.

NOTE1:
  Default setting causes sensor to always start in SCIP ver1.1 mode even if it was changed to SCIP ver2.0 earlier. However by using specific software "**URG_Configurer.exe**" it can be made to start in SCIP ver2.0 by default. This software has been released. To download this tool, access http://www.hokuyo-aut.jp/02sensor/07scanner/urg.html △2 △3

NOTE2: △3
  SCIP2.0 prescribes that sensor must turn off its laser till receiving commands which mean to turn on it. Therefore, the sensor's LED blinks after switching to SCIP2.0 by this command.

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♦ Interface ♦

Sensor is equipped with RS232C and USB for external interface. Communication between sensor and host can be established using any one of these devices. However, if host and sensor is connected with both the devices, USB connection will have priority. It is also possible to switch between USB and RS232C connection by connecting and disconnecting with host by the USB cable even when the sensor is operating.

USB has Communication Device Class (CDC) standard with its settings similar to RS232C. Therefore programs written for RS232C can also be used for USB. RS232C and USB setting details are given below.

RS232C
Bit Rate   :19.2Kbps(initial setting),57.6Kbps,115.2Kbps, 250Kbps, 500Kbps, 750 Kbps
Parity   :None
Data Bit   :8
Stop Bit   :1
Flow Control:None

USB
Version   :2.0
Speed   :Full Speed
               (Windows: 9Mbps, Linux: 256 Kbps when using standard driver)
Class   :Communication Device Class

Caution:
Port should be opened only after the OS assigns it to the device. Access to the device from the application should be done only when the host-device configuration is complete and host recognizes the device.

♦ Measurement and Data Encoding ♦

Angular resolution of URG-series is 0.3515625° (360° /1024 step). Step numbers 0, 384 and 768 represents sensor angles -135°, 0° and +135°with sensor's front axis (measurement reference) respectively (Figure 1). Sensor's measurable range is 240° between step 44 and 725.
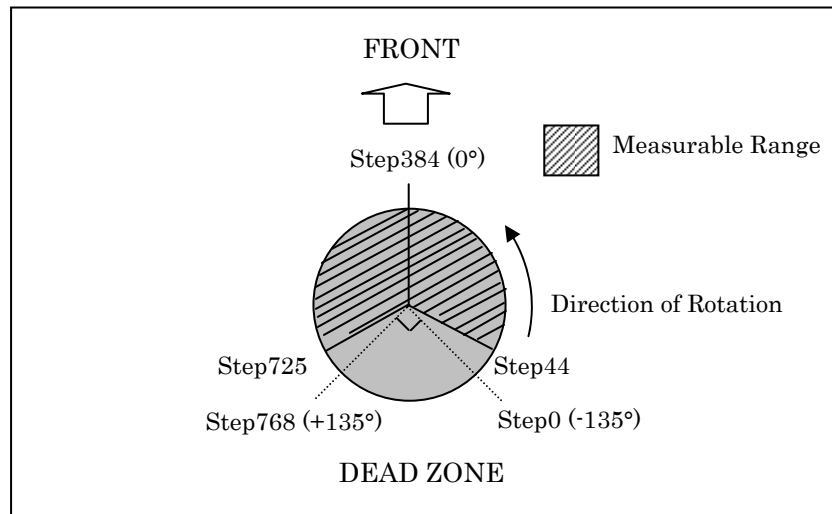

Figure 1: Top View

 Sensor outputs measurement data of each step from 44 to 725 (Figure 1). Minimum measurement is 20mm and maximum can be set to either 4095 or 5600mm. Measurement data are supplied to the host after encoding.

 Data are expressed in 12 bits and encoded to 2-characters in 4095mm mode. It is expressed in 18 bits and encoded to 3 characters in 5600mm mode. In order to reduce the data volume, 6-bits binary data are converted to 1-byte character codes.

 The encoding process is very simple where, the 12 or 18 bits data is separated into 6 bits each and 30H added to them.

 Decoding is reverse of encoding where 30H is subtracted form every 6 bits. And if data are 2-characters 12 bits are merged or 18 bits merged if they are 3-characters

2-Character Coding Example:

$1234mm = 010011010010_2$

↓ Separation

$(010011_2, 010010_2) = (13H, 12H)$

↓ Add 30H

$(43H, 42H) = (C, B)$ △2

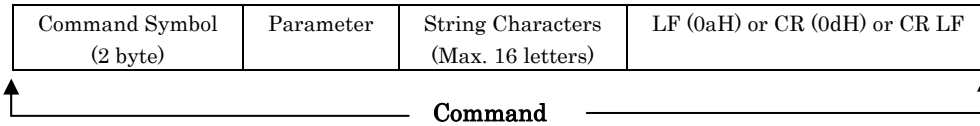**3-Character Coding Example:**

$5432mm = 1010100111000_2$

↓ Separation

$(000001_2, 010100_2, 111000_2) = (1h, 14h, 38h)$ △2

↓ Add 30H

$(31h, 44h, 68h) = (1, D, h)$ △2

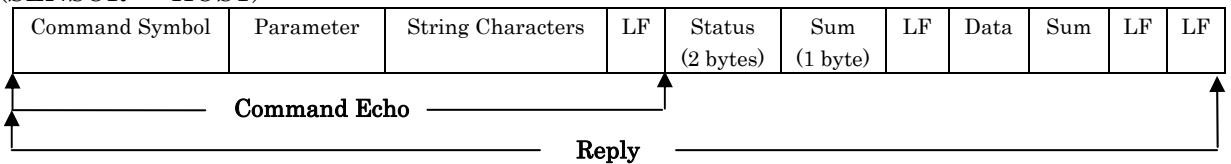| TITLE	URG-Series Communication Protocol Specification (SCIP Version 2.0) -	DRAWING NO.	C－42－0332OB	4/15

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♦ Communication Format ♦

The basic communication format in SCIP system is shown below. Communication always starts from host side by sending pre-defined **Command** consisting of Command Symbol, Parameter and String Characters (optional) followed by line feed or carriage return or both. When sensor receives the command it sends **Reply** with the **Command Echo**, status, sum, line feed, data related to the command, sum and two continuous line feed as a termination code.

(HOST → SENSOR)

Command Symbol (2 byte)	Parameter	String Characters (Max. 16 letters)	LF (0aH) or CR (0dH) or CR LF

Command

(SENSOR → HOST)

Command Symbol	Parameter	String Characters	LF	Status (2 bytes)	Sum (1 byte)	LF	Data	Sum	LF	LF

Command Echo

Reply

- **Command Symbol** is 2 bytes code at the beginning of the command. Each command has specific symbols for verification.

- **Parameter** is information that is required to change sensor settings in some commands or to request the additional data in others.

- **String Characters** are optional information in the command. They are used to verify the reply of two or more same command e.g. by sending different String Characters in each command and checking the command echo. Maximum length of the String Characters is 16-letters made with combination of any English letters, numbers, blank space(20H) and symbols '+'(2bH), '-'(2dH), '.'(2eH), '@'(40H) and '_'(5fH). **Note that they must be separated by semicolon ' ; '(3bH) at the beginning of them.** △2

- **Line Feed (LF) or Carriage Return (CR)** is terminating code. Command can have LF or CR or both as termination code but reply will always have two continuous LF as its termination code.

- **Status** is 2 bytes data in the reply that informs normal processing if command is authenticated or errors if undefined, invalid or incomplete command is received by sensor. Status other than 00 and 99 are error codes

- **Sum** is 1 byte data used in authentication. It is calculated by adding data between two linefeeds, taking the lower 6 byte of this sum and finally adding 30H to this sum.

   Example:

   [LF] Hokuyo [LF] = 48H+6fH+6bH+75H+79H+6fH = 27fH = 1001 $\underline{111111}_2$

   Sum = $\underline{111111}_2$ +30H = 3fH+30H = 6fH = o

- **Data** is main information related to the command. It is separated by LF and sum after every 64 bytes if exceeds 64 bytes.

- **IMPORTANT:** $(24H) is a reserved letter for special mode. Do not use it in the commands. △1

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There are 7-types of predefined commands in SCIPver2.0 system.

1. Sensor Information Command (3 types)

    [VV-Command] [PP-Command] [II-Command]

2. Measurement Enable/Disable Command

    [BM-Command] [QT-Command]

3. RS232C Bit Rate Setting Command

    [SS-Command]

4. Distance Acquisition Command (2 types)

    [MDMS-Command] [GDGS-Command]

5. Motor Speed Setting Command

    [CR-Command]

6. Time Stamp Adjusting/Acquisition Command

    [TM-Command]

7. Reset Command

    [RS-Command]

NOTE:

- Host can send multiple commands at one time to sensor and sensor replies to each command progressively. However sensor will not accept multiple commands of same type sent at once from the host. In such case sensor will reply only once and sends error code thereafter.

- Comparing the command echo and sum can identify errors in communication.

- All the characters in the **Command** and **Reply** are _ASCII_ code.

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♦ Command Types ♦

[MDMS-Command]

This is a sensor data acquisition command. Whenever sensor receives this command it sends measurement taken after the command is processed.

(HOST→ SENSOR)

M (4dH)	D (44H) or S (53H)	Starting Step (4bytes)	End Step (4 bytes)	Cluster Count (2bytes)	Scan Interval (1 byte)

Number of Scans (2 bytes)	String Characters	LF

- Command symbol can be either MD or MS. MD is for three character data and MS is for two character data (see **Sensor Data Encoding**)
- Starting Step and End Step:
    Starting step and End Step can be any points between 0 and 768. End Step should be always greater than Starting step.
    Example:
        To obtain data from step 10 to 750.
        Starting point   :   0010 (30H, 30H, 31H, 30H)
        End Point   :   0750 (30H, 37H, 35H, 30H)
- Cluster Count:
    Cluster Count is the number of adjacent steps that can be merged into single data. When cluster count is more than 1, step having minimum measurement value (excluding error) in the cluster will be the output data.
    Example: If Cluster Count is 3 and measurement values of 3 steps in this cluster are 3059, 3055 and 3062, the received data from the sensor will be 3055.
- Scan Interval and Number of Scans:
    Skipping the number of scans when obtaining multiple scan data can be set in Scan Interval and required number of scan data in Number of Scan. If Number of Scan is set to 00 the data will be supplied indefinitely unless canceled using **[QT-Command]** or **[RS-Command]**.

(SENSOR → HOST)

1.   When Status is not '99'

M	D or S	Starting Step	End Step	Cluster Count	Scan Interval
Number of Scans		String Characters	LF		
Status	Sum	LF	LF		

2.   When Data is less than 64 bytes

M	D or S	Starting Step	End Step	Cluster Count	Scan Interval
Remaining Scans		LF			
9	9	b	LF	Time Stamp (4byte)	Sum	LF
Data	Sum	LF	LF		

3.   When data is more than 64 bytes and terminates without remaining bytes

M	D or S	Starting Step	End Step	Cluster Count	Scan Interval
Remaining Scans		LF			
9	9	b	LF	Time Stamp (4byte)	Sum	LF
Data Block 1 (64 byte)		Sum	LF		
-------------------------------		Sum	LF		
Data Block N (64 byte)		Sum	LF	LF	

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4. When data is more than 64 bytes and terminates with remaining bytes

M	D or S	Starting Step	End Step	Cluster Count	Scan Interval

Remaining Scans	LF				

9	9	b	LF	Time Stamp (4byte)	Sum	LF

Data Block 1 (64 byte)	Sum	LF	
-----------------------------	Sum	LF	
Data Block N-1 (64 byte)	Sum	LF	
Data Block N (n byte)	Sum	LF	LF

- When the host requests multiple measurement data, reply from the sensor will be the number of remaining scan (Remaining Scans) in the echo instead of Number of Scan.

- Status:
    00 --- Command received without any Error
    01 --- Starting Step has non-numeric value.
    02 --- End Step has non-numeric value.
    03 --- Cluster Count has non-numeric value.
    04 --- End Step is out of range.
    05 --- End Step is smaller than Starting Step.
    06 --- Scan Interval has value more than 9.
    07 --- Number of Scan has value more than 99.
    20~49 --- Communication stopped to detect possible malfunctions corresponding to error status.
    50~89 --- Motor, Laser or similar malfunctions.
    98 --- Recovery from communication stopped status or Laser malfunction confirmation.
        Note: ③
        If errors occur during continuous data acquisition there is a possibility to stop the communication to diagnose the problem. If problem is not detected after the diagnosis sensor will continue processing the command sending the status 98 at least once. If the malfunction is confirmed sensor will stop and sensor's reply always contain the error status. (F/W version 3.1.04 and later)

- Time Stamp:
    Sensor has 24bit internal timer with 1msec resolution. Time stamp is a timer value at 0th step of every scan (Figure 1).
    Received Time Stamp is 4-byte encoded data. To convert it into msec, subtract 0x30 from each byte, take upper byte as most significant byte (MSB) and convert it to 24 bits.

    Example:
            Received data:
                0G2f = (30H, 47H, 32H, 66H)

            Calculation:
                $30H-30H = 00H = 000000_2$
                $47H-30H = 17H = 010111_2$
                $32H-30H = 02H = 000010_2$
                $66H-30H = 36H = 110110_2$

            Merging
                $000000\ 010111\ 000010\ 110110_2 = 94390$ [msec]

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Table 1: ERROR CODES

Error Code	Error Type
0	Detected object is possibly at 22m
1	Reflected light has low intensity
2	Reflected light has low intensity
6	Others
7	Distance data on the preceding and succeeding steps have errors
8	Intensity difference of two waves
9	The same step had error in the last two scan
10～17	Others
18	Error reading due to strong reflective object
19	Non-Measurable Step

[BM Command]

This command will illuminate the sensor's laser sending it to measurement state.

(HOST → SENSOR)

B (42H)	M (4dH)	String Characters	LF

(SENSOR → HOST)

B	M	String Characters	LF	Status	Sum	LF	LF

● Status:
    00 ⋯ Command received without any Error
    01 ⋯ Unable to control due to laser malfunction.
    02 ⋯ Laser is already on.
● Note:
    Laser is initially switched off and sensor's measurement state is disabled by default in SCIP ver2.0 system.

[QT Command]

This command will switch off the laser disabling sensor's measurement state.

(HOST → SENSOR)

Q (51H)	T (54H)	String Characters	LF

(SENSOR → HOST)

Q	T	String Characters	LF	0	0	P	LF	LF

[RS Command]

This command will reset all the settings that were changed after sensor was switched on. This turns Laser off, sets motor speed and bit rate back to default as well as reset sensor's internal timer. However communication protocol will not return to SCIP1.0.

(HOST → SENSOR)

R (52H)	S (53H)	String Characters	LF

(SENSOR→HOST)

R	S	String Characters	LF	0	0	P	LF	LF

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[GD-GS Command]

Whenever sensor receives this command it supplies the latest measurement data to the host.

(HOST→ SENSOR)

G (47H)	D (44H) or S (53H)	Starting Step (4bytes)	End Step (4 bytes)	Cluster Count (2bytes)	String Characters	LF

● Parameters are same as explained in [MDMS-Command].
● This command will not be accepted while the sensor process for MSMS-Command.

(SENSOR → HOST)

1. When status is not 00

G	D or S	Starting Step	End Step	Cluster Count	String Characters	LF
Status	Sum	LF	LF			

2. When data is less than 64 bytes

G	D or S	Starting Step	End Step	Cluster Count	String Characters	LF
0	0	P	LF	Time Stamp	Sum	LF
Data	Sum	LF	LF			

3. When data is more than 64 bytes and terminates without remaining bytes

G	D or S	Starting Step	End Step	Cluster Count	String Characters	LF
0	0	P	LF	Time Stamp	Sum	LF
Data Block 1 (64 bytes)		Sum	LF			
-----------------------------		Sum	LF			
Data Block N (64 bytes)		Sum	LF	LF		

4. When data is more than 64 bytes and terminates with n-remaining bytes

G	D or S	Starting Step	End Step	Cluster Count	String Characters	LF
0	0	P	LF	Time Stamp	Sum	LF
Data Block 1 (64 bytes)		Sum	LF			
-----------------------------		Sum	LF			
Data Block N-1 (64 bytes)		Sum	LF			
Data Block N (n bytes)		Sum	LF	LF		

● Status:
    01 --- Starting Step has non-numeric value.
    02 --- End Step has non-numeric value
    03 --- Cluster Count has non-numeric value.
    04 --- End Step is out of range
    05 --- End Step is smaller than Starting Step.
    10 --- Laser is off.
    50 --- and More --- Hardware trouble (such as laser, motor malfunction etc.)
● Time Stamp:
    Same as in [MDMS-Command].

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[TM Command]

This command is used to adjust (match) the host and sensor time. Sensor should be switched to adjust mode before requesting its time and mode should be switched off after the adjustment. When the sensor is in adjustment mode laser is switched off and it will not accept any other commands unless the mode is terminated.

Sending multiple TM Command with different string lengths and comparing the time can estimate average data transmission time between sensor and host.

(HOST → SENSOR)

T (54H)	M (4dH)	Control Code(1 byte)	String Characters	LF

● Control Code:
    0 --- Adjust mode on
    1 --- Time request
    2 --- Adjust mode off

(SENSOR → HOST)

1. When the Control Code is 0 or 2 or status is not 00.

T	M	Control Code	String Characters	LF	Status	Sum	LF	LF

● Status:
    00 --- Command received without any Error
    01 --- Invalid Control Code.
    02 --- Adjust mode on command is received when sensor's adjust mode is already on
    03 --- Adjust mode off command is received when sensor's adjust mode is already off
    04 --- Adjust mode is off when requested for time.

2. When the Control Code is 1

T	M	1	String Characters	LF	0	0	P	LF	Time(4 byte)	Sum	LF	LF

● Time:
    Sensor's internal timer reading. The data is 4-byte encoded data same as
    [MDMS-Command].

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[SS Command] △3

This command will change the bit rate of the sensor when connected with RS232C

(HOST → SENSOR)

S (53H)	S (53H)	Bit Rate(6 byte)	String Characters	LF

● Bit Rate:
019200 --- 19.2 Kbps
057600 --- 57.6 Kbps.
115200 --- 115.2 Kbps.
250000 --- 250.0 Kbps
500000 --- 500.0 Kbps
750000 --- 750.0 Kbps.

(SENSOR → HOST)

S	S	Bit Rate	String Characters	LF	Status	Sum	LF	LF

● Status:
00 --- Command received without any Error
01 --- Bit Rate has non-numeric value.
02 --- Invalid Bit Rate
03 --- Sensor is already running at the defied bit rate.
● Note:
1. Sensor initially starts with default bit rate 19.2 Kbps. This default bit rate can be changed with "URG_Configurer.exe".
2. Bit rate change is implemented only after sensor returns the status 00.
3. When sensor is connected with USB, bit rate change will not have any effect on the communication speed, but it will be accepted and implemented when connection is changed to RS232C.

[CR Command]

This command is used in adjusting the sensor's motor speed. Setting range is 540~600rpm.

When multiple sensors are used in the same environment their motors are made to run at different speed to avoid light interference.

(HOST → SENSOR)

C (43H)	R (52H)	Speed Parameter (2 byte)	String Characters	LF

● Speed Parameter:
00 --- 600 rpm   01 --- 594 rpm
02 --- 582 rpm   03 --- 576 rpm
04 --- 570 rpm   05 --- 564 rpm
06 --- 558 rpm   07 --- 552 rpm
08 --- 546 rpm   09 --- 540 rpm
99 --- Reset to default speed.

(SENSOR → HOST)

C	R	Speed Ratio	String Characters	LF	Status	Sum	LF	LF

● Status:
00 --- Command received without any Error
01 --- Invalid Speed Ratio
02 --- Speed Ratio is out of range.
03 --- Motor is already running on the defined speed.

● Note:
1. Sensor's motor initially rotates with 600rpm. This default motor speed can be changed with "URG_Configurer.exe".

[VV Command]

This command supplies the sensors version details such as, serial number, firmware version etc.

.

(HOST → SENSOR)

V (56H)	V	String Characters	LF

.

(SENSOR → HOST)

V	V	String Characters	LF	0	0	P	LF

Vendor Information	;	Sum	LF	
Product Information	;	Sum	LF	
Firmware Version	;	Sum	LF	
Protocol Version	;	Sum	LF	
Sensor Serial Number	;	Sum	LF	LF

Example:
> V V [LF] 0 0 P[L$_F$]
> VEND:Hokuyo Automatic Co., Ltd.;[[L$_F$]
> PROD:SOKUIKI Sensor URG-04LX;[[L$_F$]
> FIRM: 3.0.00(11/Oct./2006);d [L$_F$]
> PROT:SCIP 2.0;N [L$_F$]
> SERI: H0508486;T [L$_F$][L$_F$]

[PP Command]

This command supplies the sensor specification.

(HOST → SENSOR)

P (56H)	P	String Characters	LF

.

(SENSOR → HOST)

P	P	String Characters	LF	0	0	P	LF

Sensor Model	;	Sum	LF	
Minimum Measurement [mm]	;	Sum	LF	
Maximum Measurement [mm]	;	Sum	LF	
Total Number of Steps in 360º range	;	Sum	LF	
First Step of the Measurement Range	;	Sum	LF	
Last Step of the Measurement Range	;	Sum	LF	
Step number on the sensor's front axis	;	Sum	LF	
Standard motor speed [rpm]	;	Sum	LF	LF

Example:
> PP [LF] 0 0 P [LF]
> MODL:URG-04LX(Hokuyo Automatic Co., Ltd.);N [LF]
> DMIN: 20; 4 [LF]
> DMAX: 5600; _ [LF]
> ARES: 1024;/ [LF]
> AMIN: 44; 7 [LF]
> AMAX: 725; o [LF]
> AFRT: 384;6 [LF]
> SCAN: 600;e [LF] [LF]

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[II Command]

This command supplies the sensor specification.

(HOST → SENSOR)

I (49H)	I	String Characters	LF

.

(SENSOR → HOST)

I	I	String Characters	LF	0	0	P	LF	
Sensor Model			;	Sum	LF			
Laser illumination state			;	Sum	LF			
Motor Speed			;	Sum	LF			
Measurement Mode			;	Sum	LF			
Bit Rate for RS232C			;	Sum	LF			
Time Stamp			;	Sum	LF			
Sensor Diagnostic			;	Sum	LF	LF		

Example:
```
II [LF] 0 0 P [LF]
MODL: URG-04LX (Hokuyo Automatic Co., Ltd.);N [LF]
LASR: OFF; 7 [LF]
SCSP:Initial(600[rpm]) <-Default setting by user;A [LF]
MESM:IDLE;: [LF]
SBPS:19200[bps] <-Default setting by user;A [LF]
TIME:002AA9;f [LF]
STAT: Sensor works well.;8 [NL2]
```

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♦ Response to Invalid Commands ♦

Whenever sensor receives undefined commands or without valid parameters in it, the error status will have one of the following values.

● Error Status: A --- Unable to create transmission data or reply command internally.

B --- Buffer shortage or command repeated that is already processed

C --- Command with insufficient parameters 1

D --- Undefined Command 1

E --- Undefined Command 2

F --- Command with insufficient parameters 2.

G --- String Character in command exceeds 16 letters

H --- String Character has invalid letters.

0I --- Sensor is now in firmware update mode*.⚠1

*Firmware update mode:⚠1

Sensor will be sent to firmware update mode by special command before updating the new firmware. During this state motor and laser is stopped. When sensor is in firmware update mode it accepts only [VV-Command], [II-Command], [RS-Command] and [SCIPVer2.0 Changing Command]. It will send error status 0I to any other commands. To confirm the state user can send [II-Command] which will have the reply including term of "UDST:", for example "UDST:F/W update mode (CPU clock is 6MHz)".

If sensor goes to this state unintentionally, send [RS-Command] and restart the sensor. If sensor remains in this state even after the restart use firmware update tool and follow the instructions in the help.

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