User's Guide

Localization System StarGazer™

for Intelligent Robots

<Single ID Version>

www.hagisonic.com

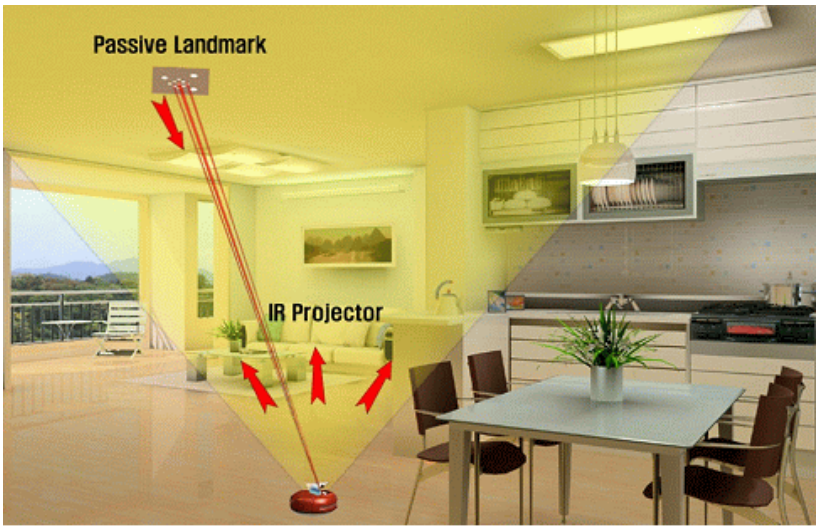
HAGISONIC CO.,LTD.

StarGazer™ User's Guide

Table of Contents

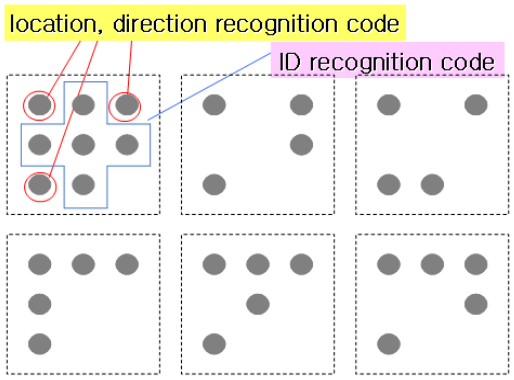
1. Product Overview

StarGazer™ is a unique sensor system for Indoor localization of intelligent mobile robots. It analyzes infrared ray image which is reflected from a passive landmark with an independent ID. The output of position and heading angle of a robot is given with very precise resolution and high speed. It is seldom affected by surroundings such as an infrared ray, a fluorescent light and sunshine.



Schematic showing localization principle by StarGazer™

StarGazer™



Landmarks

2. Parts List

① StarGazer™ Module (DSP Module, IRED Module, Support, Lens Hood) - 1set
② 3pin Connector with cables - 1ea, 7pin Connector with cables - 1ea
③ User's Manual (Download from website www.hagisonic.com.)
④ Sample Program with Visual C++ 6.0(Download from website www.hagisonic.com.)

3. Features and Specification

A. Landmark
- With IDs i.e. codes given by the combination of circles to reflect infrared rays.
- No battery or adapter for Landmark is required.
- Landmark Types by use
  1) HLD1: for *1.1 m ≤ Height ≤ 2.9 m*
     HLD1-S: 3 X 3 combination, total 31ea, for normal use
     HLD1-L: 4 X 4 combination, total 4,095ea, for larger spaces
  2) HLD2: for *2.9 m ≤ Height ≤ 4.5 m*
     HLD2-S: 3 X 3 combination, total 31ea, for normal use
     HLD2-L: 4 X 4 combination, total 4,095ea, for larger spaces
  3) HLD3: for *4.5 m ≤ Height ≤ 6.5 m*
     HLD3-S: 3 X 3 combination, total 31ea, for normal use
     HLD3-L: 4 X 4 combination, total 4,095ea, for larger spaces

※ 'Height' means the distance between a StarGazer between a landmark which is attached on ceiling.
※ Please refer to [12. Appendix C. The type of landmarks and how generate the number of ID]

B. Specification of StarGazer™

Hardware interface	UART(TTL 3.3V), 14400bps~115200bps
Size	50×50×28 mm less than
Communication Protocol	User protocol based on ASCII code
Measurement Time	10 times/sec
Localization Range (per a Landmark)	2.5~3m in diameter (for ceiling height 2.4m)
Repetitive Precision	2 cm
Heading Angle Resolution	1.0degree
Landmark Types (Classification for height range)	HLD1: 1.1 ≤ height ≤ 2.9 m HLD2: 2.9 ≤ height ≤ 4.5 m HLD3: 4.5 ≤ height ≤ 6.0 m
Landmark Types (Classification for total ID numbers)	HLDnS: 31 ea (for a normal space) HLDnL: 4,095 ea (for a larger space) (n=1,2,3; see the classification for height range)
Power Consumption	5 V: 300 mA, 12 V: 70 mA

C. Features and Performance

- It analyzes the image of the infrared ray which is reflected from a passive landmark with a unique ID.
- It is composed of an IR Projector part and an image processing unit.
- High resolution and high speed localization of position and heading angle.
- Landmark is used by being attached on ceiling.
- No need for any synchronization or communication between a robot and a landmark.
- The area that StarGazer covers is extended by only adding landmarks to ceiling.
- Each room can be distinguished easily each other by using landmarks with different IDs.
- Automatic measurement and calibration of distance between landmarks and ceiling height.
- No battery or power supply for landmark is needed.
- A little extra cost consumes when landmarks are attached additionally.
- Nearly not affected in environment such as lamp and sunlight.
- It works excellent localization function at night as well as in the day.
- World's best in resolution, convenience and cost-efficiency.

4. Connector Configuration

① Connector configuration for DSP Module

Cable Line Color	White	Black	White	Black	White	Red	Red
Function	Reserved	GND	SDIN	GND	SDOUT	VCC(5V)	VCC(5V)

② Connector configuration for IRED Module

Cable Line Color	Black	White	Yellow
Function	GND	Reserved	VCC(12V)

5. UART Configuration

The StarGazer supports UART communication as shown in Table 1

I/O Level	TTL 3.3V Output, 3.3V~5V Input
Baudrate	14400bps ~ 115200 bps
Data Bit	8bit
Stop Bit	1bit
Parity Bit	None
Flow Control	None

Table 1. UART Configuration

6. Communication Protocol

StarGazer calculates coordinates and heading angle using parameters in flash memory. The protocols, shown in Table 2 and Table 3, can be used to read or update the parameters.

A. Communication Protocol, Parameters, Commands

Table 2. Communication Protocol

Read	STX	@	Parameter/Command	ETX	
Write	STX	#	Parameter/Command	|Data	ETX
Return Value	STX	$	Parameter/Command	|Data	ETX
ACK	STX	!	Parameter/Command	|Data	ETX
Message	STX	*	Message	[|Data]	ETX

Notice : STX : '~', ETX : '`'

Table 3. Parameters and Commands

Parameter or Command	Version	Firmware Version
	IDNum	Number of ID(1-31, 1-4095)
	RefID	Reference ID(2-626, 2-28662)
	HeightFix	Mark Height Fix(Yes/No)
	MarkHeight	Height of Landmark(mm)
	MarkType	Mark Type(HLD1S/HLD1L/HLD2S/HLD2L/HLD3S/HLD3L)
	MarkMode	Landmark Mode(Alone/Map)
	BaudRate	UART Baudrate(14400~115200bps, default:115200bps)
	HeightCalc	Calculate Height of Landmark
	MapMode	Map Building Mode(Start/Stop)
	CalcStart	Calculation Start
	CalcStop	Calculation Stop
	SetEnd	Parameter Setting End
	Reset	Reset All Parameters

[Basic Command and Protocol]

~ : to mean the start of command sentence; STX(start of text) character.

` : to mean the end of command sentence; ETX(end of text) character.

@ : to mean command to read a following parameter; READ command

! : to follow automatically when READ or WRITE command completely executed; ACK(acknowledge) character. Response symbol sent from a StarGazer.

$: Response symbol to mean that data follow after the following parameter as response of READ command.
* : Symbol to indicate the message from StarGazer
| : Symbol to distinguish a command from data or to distinguish Parameter from data.

[Parameters for data]

- Parameters : Version, IDNum, RefID, MarkHeight, BaudRate

Version : Version of Firmware.
IDNum : A total number of landmarks to be assigned under Map Mode. Default value: 4
RefID : The number of reference ID under Map Mode; Default value: 2
MarkHeight : Distance from a StarGazer to a landmark; used when wanting to input manually the height; Default value: 2400 mm
BaudRate : Communication Speed for UART(14400bps~115200bps); Default value: 115200.

[Parameters for setting up modes]

- Parameters : HeightFix, MarkType, MarkMode

HeightFix : Select the option to use fixed ceiling height or automatic measurement (Yes or No).
- Yes : This option will calculate the coordinates by using the manually inputted ceiling height.(fixed ceiling height).
- No : This option will calculate the coordinates automatically all the time.(When StarGazer is used in different ceiling height). This option will reduce the precision slightly. This option can not be used with different landmark types. For example, HLD1-S or HLD1-L has 1.1m~2.9m range and this option only allows the different ceiling height within this range. When using HLD1-S(L) and HLD2-S(L), for instance, this option can not be used. This rule applies to all of our landmark models.

MarkType : To set up landmark type by use(HLD1S, HLD1L, HLD2S, HLD2L, HLD3S, HLD3L).
- HLD1 : 1.1 ≤ height ≤ 2.9 m
- HLD2 : 2.9 ≤ height ≤ 4.5 m
- HLD3: 4.5 ≤ height ≤ 6.0 m

HLDnS means landmark up to 31 IDs and HLDnL means landmark up to 4095 IDs. Default: HLD1S.

MarkMode : To determine whether landmarks are used independently under Alone Mode or not (dependently under Map Mode). There are Alone and Map. Default; Alone (if Map mode, then 'Map'.)

[Execution Commands]

- Commands : HeightCalc, MapMode, CalcStart, CalcStop, SetEnd, Reset

HeightCalc : Command to calculate automatically height between a StarGazer and a

landmark. It is enough to execute only once when installing.

MapMode : To determine whether map building mode is executed or not. There are Start and Stop. If action under Map Mode is required, you should set the parameter 'Start' and start Map Building. Default; Stop

CalcStart : Command to start calculation. After executing the command, the output of data including position and angle is obtained continuously.

CalcStop : Command to stop calculating.

SetEnd : Command to mean the completion of a serious of command sentences. Values for a serious of parameters given in preceding several commend sentences are operated only after 'SetEnd' command comes into practice.

Reset : Reset all parameters

Default reset values are as follows:

IDNum = 4
RefID = 2
MarkHeight = 2400
MarkType = HLD1S
MarkMode = Alone
BaudRate = 115200

※ Note: Execution command 'HeightCalc', 'CalcStart', 'CalcStop', 'Reset' are operated without 'SetEnd'.

[Message]

- Message from StarGazer during operation
- Commands: DeadZone, MAPID

DeadZone : The message indicates that there is no landmark detected.
Example: ~*DeadZone`

MAPID : a newly-mapped ID during a map-building process.
Example: ~*MAPID|id`

B. How to write data to parameters and the procedure

① Send a command to stop calculation. Ex. ~#CalcStop`

② Send a command sentence for the change of a parameter.
Ex. ~#MarkHeight|2200`

③ Wait a response message. In the response '#' is changed to '!'.
Ex. ~!MarkHeight|2200`

④ Send another command sentence for the change of another parameter and wait a response. Send other sentences in the same way.

⑤ Send the completion command 'SetEnd' after sending whole sentences for parameters. Ex. ~#SetEnd`

⑥ StarGazer responds with the message, ~!ParameterUpdate`, after receiving 'SetEnd'

and updating the values and strings for parameters to flash memories.

⑦ Finally, send a command to start calculating. And then, calculated data output is obtained. Ex. ~#CalcStart`

C. How to read data in parameters and the procedure

① Send a command to stop calculation. Ex. ~#CalcStop`

② Send a command sentence to read a parameter. Ex. Read the height of a landmark: ~@MarkHeight`

③ Wait a response message. In the response '@' is changed to '!'.
Ex. ~!MarkHeight`

④ Data are immediately received after the response message. If the data is value, the character '$' accompanies the message. Ex. If height is 2200 mm, response is ~$MarkHeight|2200`

⑤ Send the completion command 'SetEnd' after sending whole sentences.
Ex. ~#SetEnd`

⑥ Send a command to start calculating. Ex. ~#CalcStart`

D. Examples of Parameter Setting and Map-Building

1) Update a number of IDs to 8, and reference ID to 32

① ~#CalcStop` response message => ~!CalcStop`
② ~#IDNum|8` response message => ~!IDNum|8`
③ ~#RefID|32` response message => ~!RefID|32`
④ ~#SetEnd` response message => ~!SetEnd`
response message => ~!ParameterUpdate`
⑤ ~#CalcStart` response message => ~!CalcStart`

2) Calculate automatically the height of a landmark

① ~#CalcStop` response message => ~!CalcStop`
② ~#HeightCalc` response message => ~!HeightCalc`
③ The data received during calculating
~^Z2|+150.12|-33.12|+12.00|240.00` [Refer to 7. Format of Receiving Data]
④ The reponse received after the completion of calculation; ~!ParameterUpdate`
⑤ ~#CalcStart` response message => ~!CalcStart`

3) Start the Map-Building Process and the message

① ~#CalcStop` response message => ~!CalcStop`
② ~#MarkMode|Map` response message => ~!MarkMode|Map`
③ ~#MapMode|Start` response message => ~!MapMode|Start`
④ ~#CalcStart` response message => ~!CalcStart`

⑤ The data received during Map-Building process
~^F2|-165.74|-33.12|+12.00|240.00` [Refer to 7. Format of Receiving Data]
⑥ Move StarGazer around landmarks until mapping is completed.
⑦ Receive the Mapped ID Data
~*MAPID|32`
⑧ While all landmark mapping completed the StarGazer move.
⑨ After the completion of mapping the response message is accompanied by
~!ParameterUpdate`
⑩ Then, receiving data is as follows:
~^2I+58.48|-33.12|+12.00|240.00` [Refer to 7. Format of Receiving Data]

4) Update the baudrate for UART to 38400
① ~#CalcStop` response message => ~!CalcStop`
② ~#BaudRate|38400` response message => ~!BaudRate|38400`
③ ~#SetEnd` response message => ~!SetEnd`
(response message => ~!ParameterUpdate`)
※ Once a baudrate is changed, the message [ParameterUpdate] cannot be seen. But to get communication back on track, the baudrate of a windows application program or robot CPU should be changed.
④ ~#CalcStop` response message => ~!CalcStop`
(for the communication check)
⑤ ~#CalcStart` response message => ~!CalcStart`

E. Notice
① Though it can be possible to send or receive data without the command, 'stop calculation', in that case sometimes the command cannot operate because StarGazer is sending data successively. Therefore, it is strongly recommended to use the command 'stop calculation', prior to other command sentences.
② Sometimes, the command 'stop calculation' can be executed because of the same reason that a command is not executed though a command has been sent, the command should be sent repeatedly.
③ In order to communicate stably with StarGazer, minimum 30~50ms delay is required for every byte.
④ The program should be written to confirm the response message for each command.
⑤ When StarGazer updates a memory, several seconds, typically two or three seconds, is required. So, after a command such as [SetEnd] or [HeightCalc], StarGazer cannot operate. Note that [~!ParameterUpdate`] message is shown after the completion of a memory update.
⑥ StarGazer operates only over 1.1m height.

⑦ Map-Building should be programmed by the procedure to be shown in [6. D. 3) Start the Map-Building Process and the message]

7. Format of Received Data

The format of data received from StarGazer for the command ~#CalcStart` are as follows:

~	^	F I Z	Iiii|±aaaa.aa|±xxxx.xx|±yyyy.yy|zzzz.zz	`

^	Means the result data
F	Indicates the Map-Building Mode
I	Indicates the Map Mode
Z	Indicates the Height Calculation Mode
iiii	The number of an ID
±aaaa.aa	Value of Angle (degrees; -180°~+180°)
±xxxx.xx	Position on X axis (cm)
±yyyy.yy	Position on Y axis (cm)
zzzz.zz	Position on Z axis; Height of landmark (cm)

(Angle, X, and Y value are truncation to two decimal point)

Ex. ~^I+150.23|-33.12|+12.00|64`

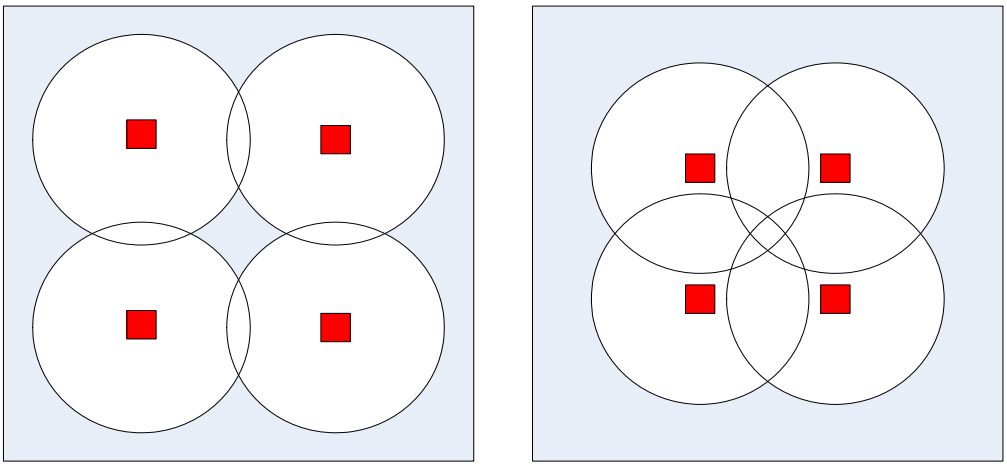
(~^I : Map Mode, +150.23:Angle, -33.12:X, +12,00:Y, 64 : IDNumber)

※ Map-building mode: a mode in the process of making a map by correlating several landmarks under a single coordinate system. In the process StarGazer is moved around under each landmark and correlation between landmarks is calculated.

※ Map mode: the mode to calculate the position and angle of StarGazer and send the data using the Map after the completion of Map-Building.

8. Guidance for Landmark Placement

The landmarks should be placed at 2 m intervals for the height of about 2.5 m in order that any dead zone may not occur.



(a) (b)

The placement of landmarks: (a) with dead zone and (b) without dead zone.

9. Alone Mode and Map Mode

In 'Alone Mode' a system operates under each independent coordinate system corresponding to each landmark.

In 'Map Mode' a system operates under one coordinate system defined by regarding the placement of a reference ID as an origin after map-building process.The landmarks should be placed at 2 m intervals for the height of about 2.5 m in order that any dead zone may not occur.

10. Map-Building Method

1) Map-building: to make a map under single coordinate system. The placement of a reference ID becomes an origin.
2) Set 'MarkMode' to 'Map' and 'MapMode' to 'start'.
3) If StarGazer detects a landmark, a position data accompanied by '~^F" is responded.
4) As the next step, move toward other nearest landmark and stop for about two seconds near halfway between two landmarks for the time to calculate the relation.
5) And then, move toward other landmark and stop near midway between another landmarks.
6) Proceed by the same way until whole landmarks are detected by StarGazer.
7) If the last landmark is found, the operating is stopped for a short time for data updating to flash memory.

8) Then, a response message, data message accompanied by '~I^' is given and map-building process ends.
9) Mode is automatically changed to 'Map Mode'.
※ For example and some details, refer to [6. D. 3) Start the Map-Building Process and the message]

11. Inquiries for Technical Support and Customer Service

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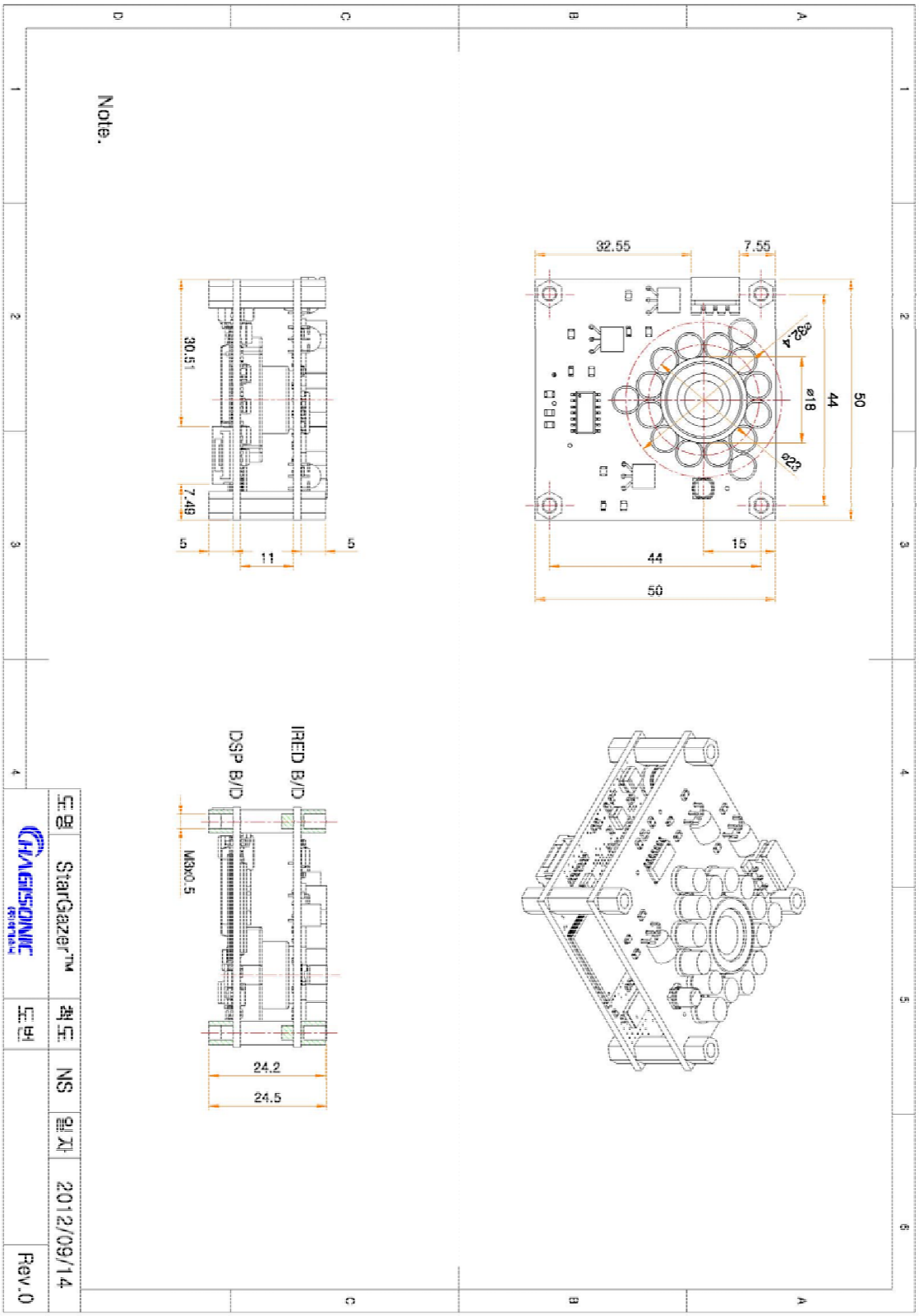
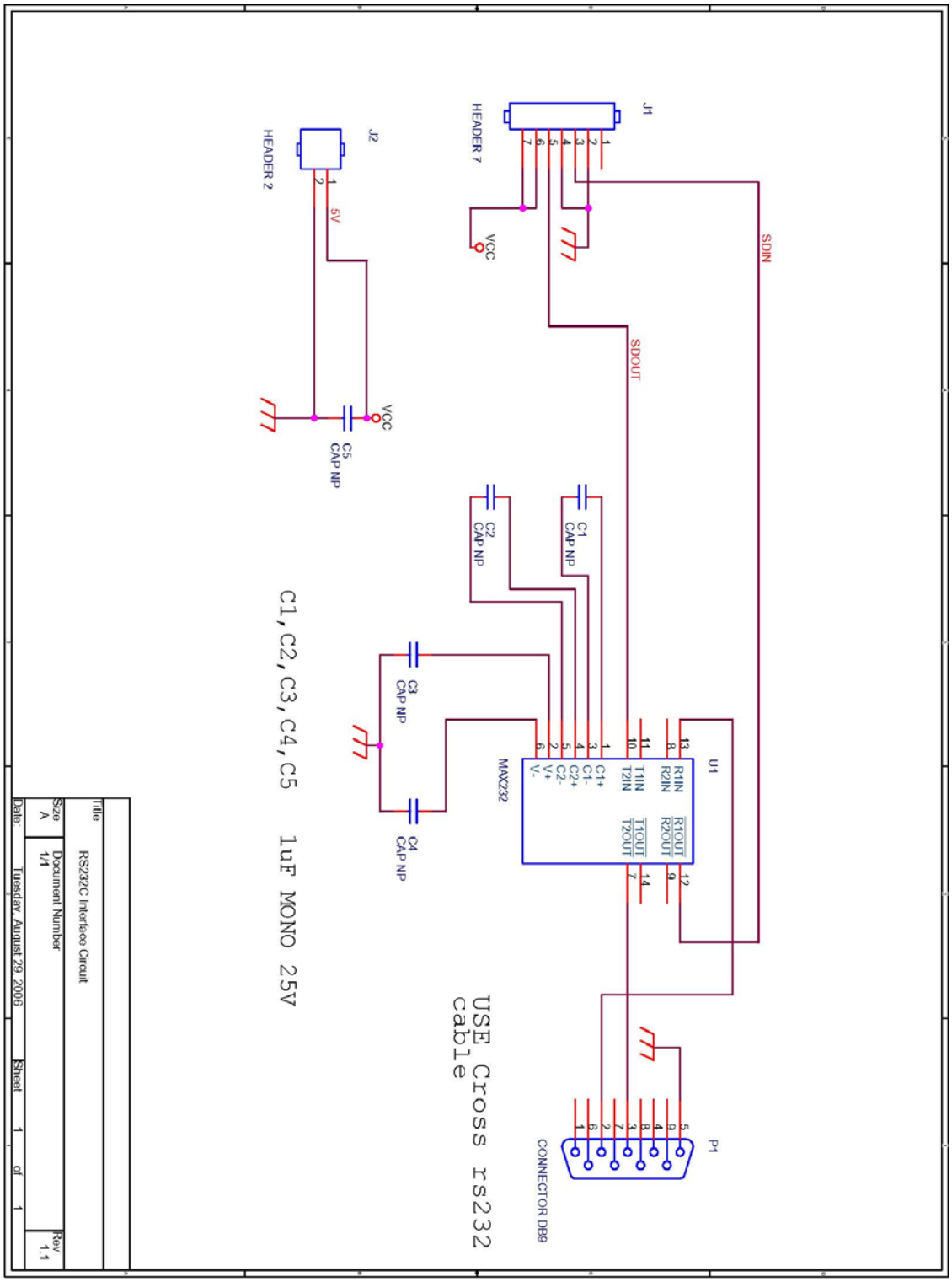
12. Appendix

A. Dimension of StarGazer™
B. RS232 Interface Circuit (for the communication between StarGazer and PC)
C. The types of landmarks and how to generate the number of ID.
D. Stargazer™ RS1.0 (for the communication between StarGazer and PC)
E. StarGazer Indicator™ (For displaying data from a StarGazer™)

A. Dimension of StarGazer™



B. RS232 Interface Circuit (for the communication between StarGazer™andPC)



C. Types of landmarks and how to generate the number of ID

(1) HLD1 landmarks are composed of the 3 X 3 combination of small circles. The total number is 31. The landmarks are used for general application such as at home.

(2) HLD2 landmarks are composed of the 4 X 4 combination of small circles. The total number is 4095. The landmarks are used for the application to very large area with several offices.

(3) Each line corresponds to an identified hexadecimal value.

(4) Fig.16-C-3 shows HL1 landmarks and corresponding decimal values.

※ '0x'in figures is the notation to mean hexadecimal.

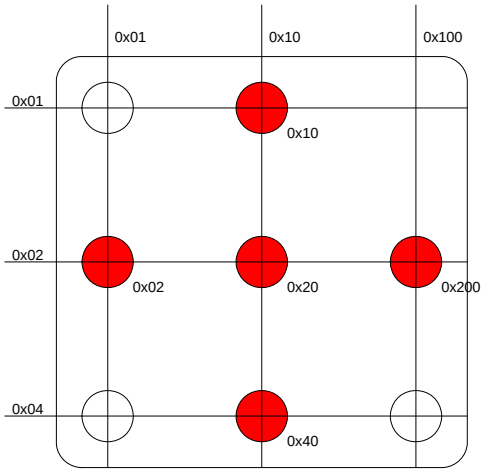


Fig.16-C-1. HLD1 landmark with hexadecimal values corresponding to each line.

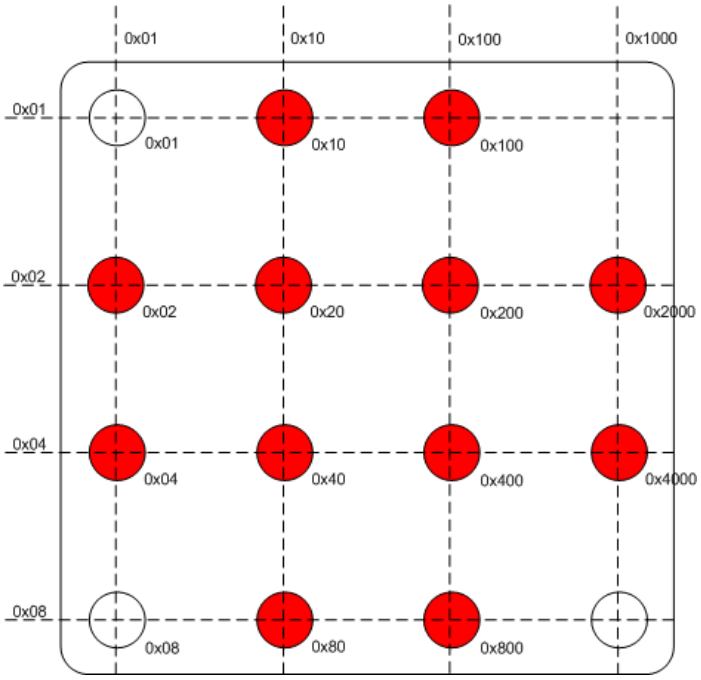
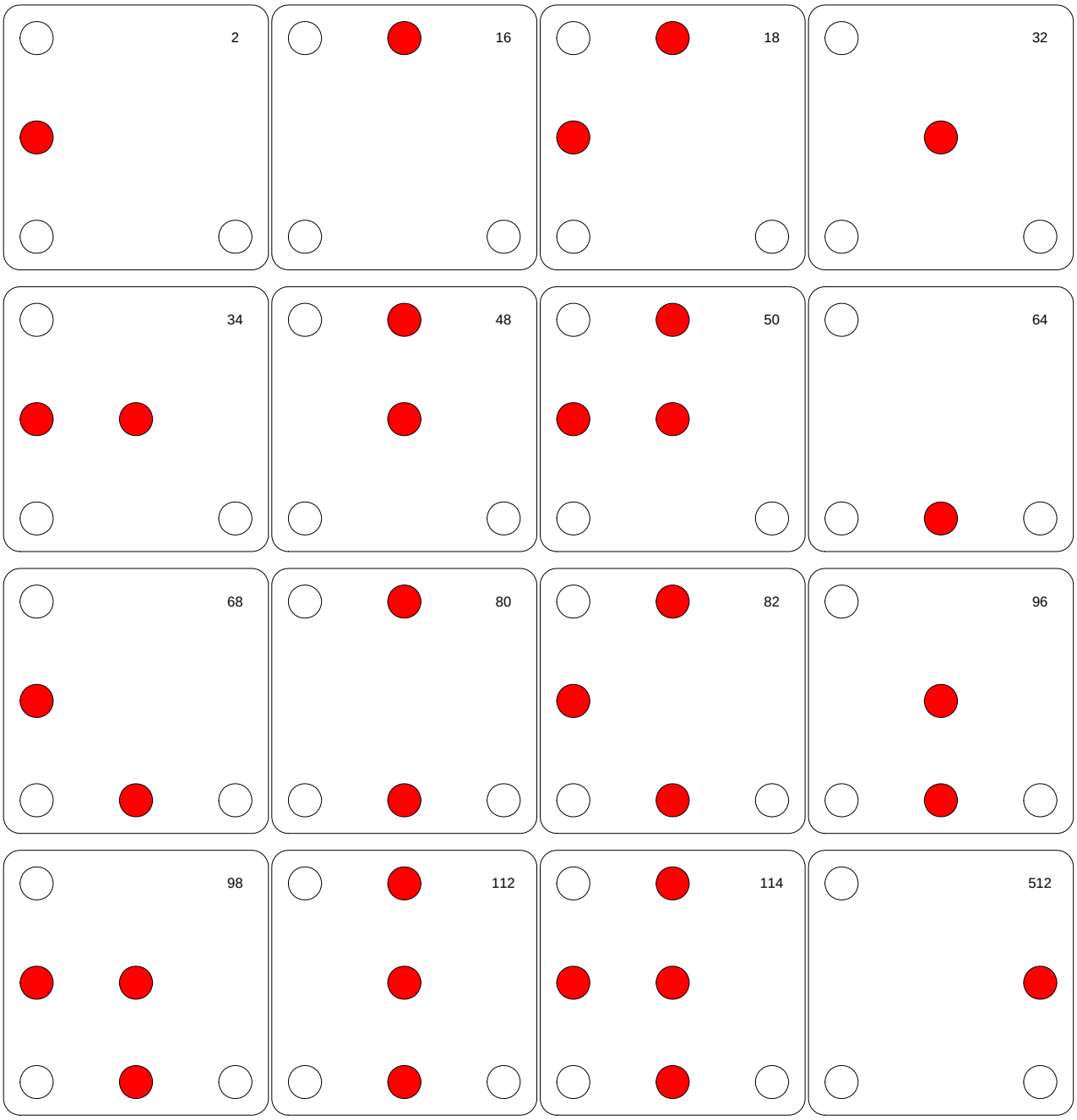


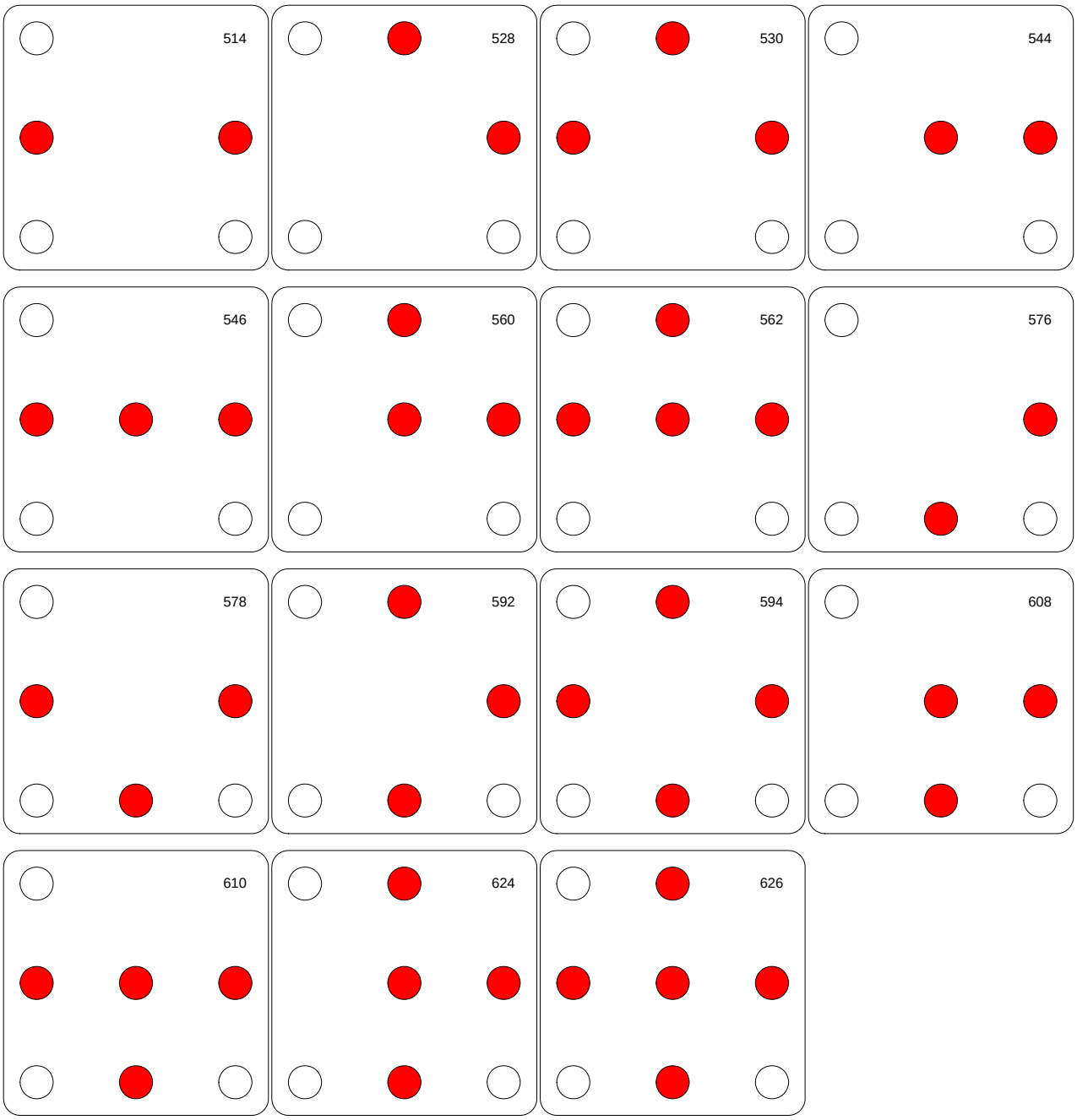
Fig.16-C-2. HLD2 landmark with hexadecimal values corresponding to each line.

Fig.16-C-3. Showing HLD1 landmarks and ID numbers.

No.	HEX	DEC
1	0x002	2
2	0x010	16
3	0x012	18
4	0x020	32
5	0x022	34
6	0x030	48
7	0x032	50
8	0x040	64
9	0x042	68
10	0x050	80
11	0x052	82
12	0x060	96
13	0x062	98
14	0x070	112
15	0x072	114
16	0x200	512
17	0x202	514
18	0x210	528
19	0x212	530
20	0x220	544
21	0x222	546
22	0x230	560
23	0x232	562
24	0x240	576
25	0x242	578
26	0x250	592
27	0x252	594
28	0x260	608
29	0x262	610
30	0x270	624
31	0x272	626

Fig.16-C-4. Type of the HLD1 landmark(decimal number inside the landmark means a ID number)




514
528
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624
626

D. StarGazer™ RS1.0 (for the communication between PC, Main Process and StarGazer)

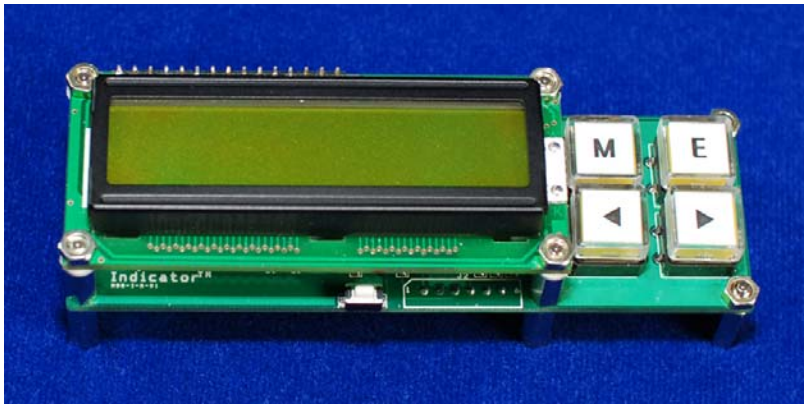
(a) StarGazer™ RS 1.0

- The user-friendly solution which easily outputs and controls data from StarGazer™, localization sensor, through standard serial wire / wireless communication in PCs, various systems, and robots
- The optimum localization system which is registered to Microsoft Robotics Studio.
- Application : Research in laboratory and development of the prototype of robots.

I/O Level	TTL 3.3V Output, 3.3V~5V Input
Size	62×56×50.8mm
Power	DC 12V
Baud Rate	115200 bps
Data Bit	8 Bit
Stop Bit	1 Bit
Parity Bit	None
Flow Control	None

※ Output : ~^I+150.23|-33.12|+12.00|64`

E. StarGazer Indicator™ (For displaying data from a StarGazer™)



(b) Stargazer™ Indicator

Initial	Name	Description
M	Menu	Menu Button: to move to other menu.
E	Enter	Selection Button : to select the menu. Also used to remove Buzzer sound.
▶	Right	Right Scroll Button After Menu button, users can scroll to the right. Also, users can select Buzzer sound.
◀	Left	Left Scroll Button After Menu button, users can scroll to the left.

1) Mode Number 1: Pure Communication data mode.
   - The output data of StarGazer™ is shown on the LCD without any filtration.
   - Users can see data by using the right or left scroll.
     Ex) ~*CMOS|Success` , ~*Dead zone`, ~^I+150.23|-33.12|+12.00|64`
2) Mode Number 2: Communication information.
   - The output data of StarGazer™ is filtered and is shown on the LCD in the order of ID, X, Y and Angle.
   - Users can see data by using the right or left scroll.
     Ex) ~^I+150.23|-33.12|+12.00|64`
3) Mode Number 3: System information.
   - Users can see the default communication setting of StarGazer™.
   - In addition, pressing button one more time allows users to set up Buzzer.

※ After Buzzer setup, please push the Enter button to finish the setting.