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WARNING

THE INSTALLATION SHALL BE MADE BY QUALIFIED INSTALLATION PERSONNEL AND SHOULD CONFORM TO ALL NATIONAL AND LOCAL CODES

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Hi5aSS230619FMEN6

Hi5a Controller Function Manual

SafeSpace

Functional Safety Manual for Safety Related Systems and SIL2 applications according IEC 61508 Standards

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1 Introduction

1.1. Overview

SafeSpace is an option with software and hardware components

SafeSpace module consists of hardware, software, and safety IO module. The hardware and software perform the function that communicate with the robot controller, calculate and supervise the robot's motion. SafeSpace transmits the status and results to a field safety controller via a safety IO module.

SafeSpace always monitors the robot's motion as position, speed. If the robot is over a limitation, SafeSpace makes the robot stop, immediately and safely. Therefore, SafeSpace can be used in industrial fields that have been removed fences for the safeguard.

1.2. Target Group and Safety Training

This manual is aimed at users with the following knowledge and skills:

- SafeSpace training
- Hyundai robot programming skills
- Advanced knowledge of the robot control system

All the personnel who intend to teach, operate or inspect the robot and SafeSpace must be trained in an approved robotic operation and safety training course before start-up. The safety training course includes the following details:

- Purpose and functions of SafeSapce and safety devices
- Safety procedure to handle the robot
- Performance of robot or the robot system and possible hazards
- Tasks associated with any specific robot applications
- Safety concepts, etc.

1.3. Representation of warning and notes

For the purpose of effective safety instructions, the following safety symbols are used in this manual.

Table 1-1 Safety Marking

Symbols		Descriptions
Warning		Warning
Mandatory		Mandatory

Prohibited		Prohibited

1.4. Terms used

The following abbreviations and expression are going to be used within the project.

Table 1-2 Terms in SafeSpace manual

Term	Description
Workspace	Workspace that the defined robot axes or the tools which is attached on the robot's end-effector. The axes or the tool must move within the limits of the workspace.
SLP	Safely-Limited Position
SLS	Safely-Limited Speed
SOS	Safe Operating Stop
STO	Safe Torque Off
OLP	Offline Language Programming
Stopping distance	The moving distance from triggered STO to standstill state. It is described in robot troubleshooting manual. It depends on robot type, position, speed, payload and so on.
Mastering Test	The mastering test is to evaluate the calibration condition of robot and external axes.
Cell area	Cell area is a kind of the cartesian working space in world coordinate system. The cell area could be modeled with X-Y plane vertexes and Z-direction height. The cell area is configured with 3 to 10 vertexes and it should be convex polygon
Cartesian space	Cartesian space could be defined working space or protected space for monitoring tool area
Joint space	Joint space could be defined working space or protected space for monitoring joint movement. Joint space could be configured up to 4 spaces and each space consists of 8 axis maximum.
Joint speed	Joint speed is limit value for monitoring each joint speed
Global parameters	Global parameters are TCP speed limitation for monitoring Cartesian speed

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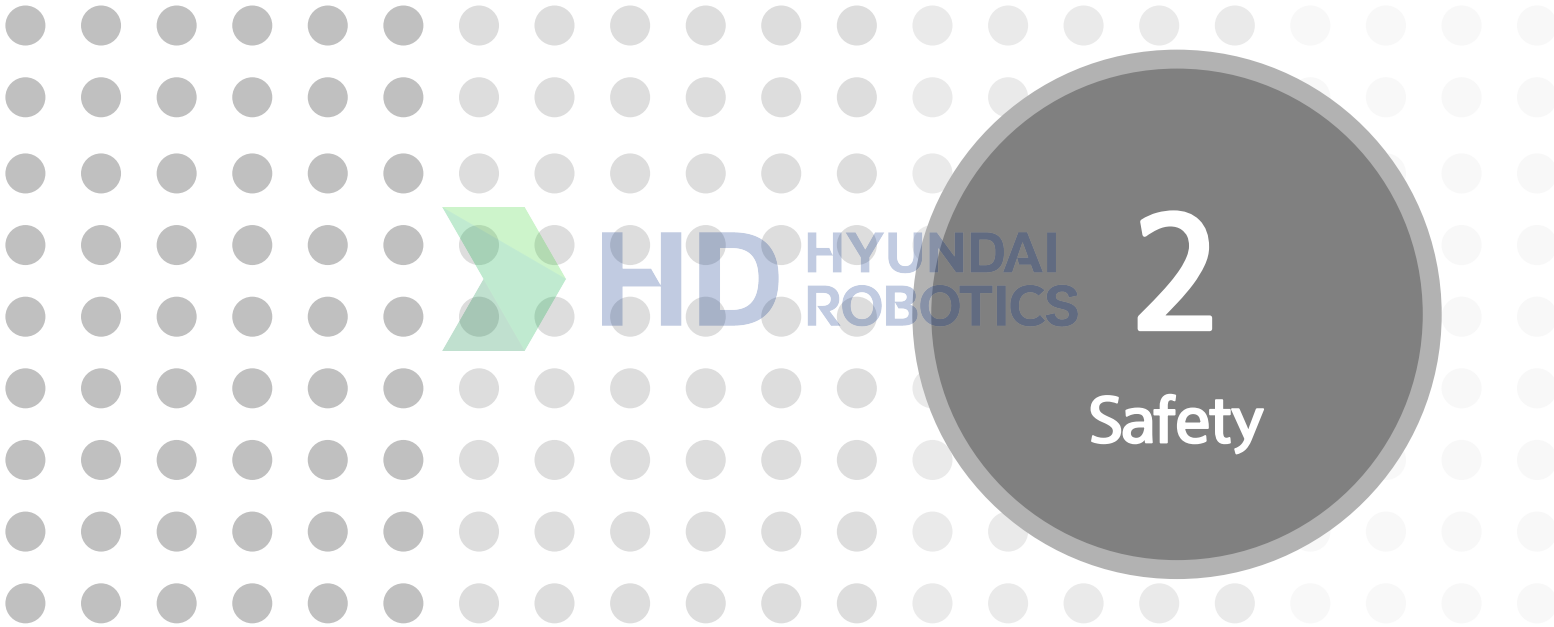
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2
Safety

2.1. Safety Functions and Safety Integrity

SafeSpace meets the requirements for PL=d (SIL 2), Cat. 3 in ISO 13849-1:2015, IEC 61508:2010. The safety function and PL (or SIL) for each as follows:

SF.1: SLP (Safely-limited position) function

The SLP function prevents the motor shaft from exceeding the specified position limit(s).
SLP meets the requirements for PL=d (SIL 2).

- SF.1.1 Cell area
- SF.1.2 Cartesian Space
- SF.1.3 Axis-specific Space

SF.2: SLS (Safely-limited speed) function

The SLS function prevents the motor from exceeding the specified speed limit.
SLS meets the requirements for PL=d (SIL 2).

- SF.2.1 Cartesian TCP velocity
- SF.2.2 Axis velocity
- SF.2.3 Reduced velocity mode

SF.3: SOS (Safe operating stop) function

The SOS function prevents the motor from deviating more than a defined amount from the stopped position. The PDS(SR) in the robot controller provides energy to the motor to enable it to resist external forces.
SOS meets the requirements for PL=d (SIL 2).

NOTE : This description of an operational stop function is based on implementation by means of a PDS(SR) in the robot controller without external (for example mechanical) brakes.

SF.4: STO (Safe torque off) function

Power, that can cause rotation or motion, is not applied to the motor. The PDS(SR) in the robot controller will not provide energy to the motor which can generate torque or force.
STO meets the requirements for PL=e (SIL 3).
For safe stop 1 (SS1), refer to clause 4.2.2.3 of IEC 61800-5-2.

SF.5: Physical Safety IO function to external safety related controllers

SafeSpace communicates to external safety related controllers via safety related device as safety remote IO. It transmits a violation alarm of velocity, area, stop, space, speed, etc. Also, It receives an emergency stop, tool selection, the activation of Cartesian, Joint space, etc.
Safety IO meets the requirements for PL=e (SIL 3), Cat.3.

2.2. Applied Standards

SafeSpace is designed as IEC 61508 series for functional safety, ISO 10218-1:2011 for industrial robot safety, and so on.

Table 2-1 Applied standards

Standard	Title
IEC 61800-5-1:2007	Adjustable speed electrical power drive systems -Part 5-1: Safety requirements - Electrical, thermal and energy
IEC 61800-5-2:2007	Adjustable speed electrical power drive systems -Part 5-2: Safety requirements - Functional
IEC 60204-1:2006/A1:2009	Safety of machinery - Electrical equipment of machines - Part 1: General requirements
IEC 62061:2005	Safety of machinery - Functional safety of safety-related electrical, electronic and programmable electronic control systems
ISO 13849-1:2015	Safety of machinery - Safety-related parts of control systems - Part 1: General principles for design
ISO 10218-1:2011	Robots and robotic devices - Safety requirements for industrial robots - Part 1: Robots
IEC 61508-1:2010	Functional safety of electrical/electronic/ programmable electronic safety-related systems. General requirements
IEC 61508-2:2010	Functional safety of electrical/electronic/ programmable electronic safety-related systems. Requirements for electrical/electronic/ programmable electronic safety-related systems
IEC 61508-3:2010	Functional safety of electrical/electronic/ programmable electronic safety-related systems. Software requirements
IEC 61508-6:2010	Functional safety of electrical/electronic/ programmable electronic safety related systems. Guidelines on the application of IEC 61508-2 and IEC 61508-3
IEC 61508-7:2010	Functional safety of electrical/electronic/ programmable electronic safety related systems. Overview of techniques and measures
IEC 61784-3:2010	Industrial communication networks. Profiles. Functional safety fieldbuses. General rules and profile definitions
IEC 61000-6-2:2005	Electromagnetic compatibility (EMC). Generic standards. Immunity for industrial environments

Standard	Title
IEC 61000-6-4:2007/A1:2011	Electromagnetic compatibility (EMC). Generic standards. Emission standard for industrial environments
IEC 61326-3-1:2008	Electrical equipment for measurement, control and laboratory use. EMC requirements. Immunity requirements for safety-related systems and for equipment intended to perform safety-related functions (functional safety). General industrial applications
SN 29500-1:2004 (SIEMENS NORM)	Expected values, general.

2.3. Safety Precautions

Working person safety is the primary safety consideration because it is very dangerous to enter the operating space of the robot during AUTO operation. Therefore, adequate safety precautions must be observed. Careful consideration must be made to ensure working person safety.

(a) Have the robot system working persons trained the robot education courses by HHI.

(b) When adjusting SafeSpace module, be sure to turn off the power of robot.

(c) In the first operation of the robot after installation of SafeSpace, the operation should be restricted to low speeds. Then, the speed should be gradually increased to check the functions of SafSpace.

(d) Be sure to confirm the stop movement and do not take the wrong connection.

(e) During operation, never enter the robot work area.

(f) A hazardous situation may arise when the robot or SafeSpace are kept with their power-on during maintenance operations, Therefore, for any maintenance operation, the robot and SafeSpace should be put into the power-off state. In case maintenance needs to be executed in the power-on state, the emergency stop button must be pressed.

(g) If it becomes necessary to enter the robot operation range while the power in on, press the emergency stop button on the operational panel, or the teaching pendent before entering the range. The maintenance personnel must indicate that maintenance work is in progress and be careful not to allow other people to operate the robot carelessly.

2.4. Response Time

Table 2-2 Measurement of response time(excluding time for detection)

Functions	Response time
STO	78.7us
SLP	149us
SLS	182us
SOS	107us
Fault	1.2ms

☞ The scan-time for all safety functions is 5ms.

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3 System Description

3.1. System configuration

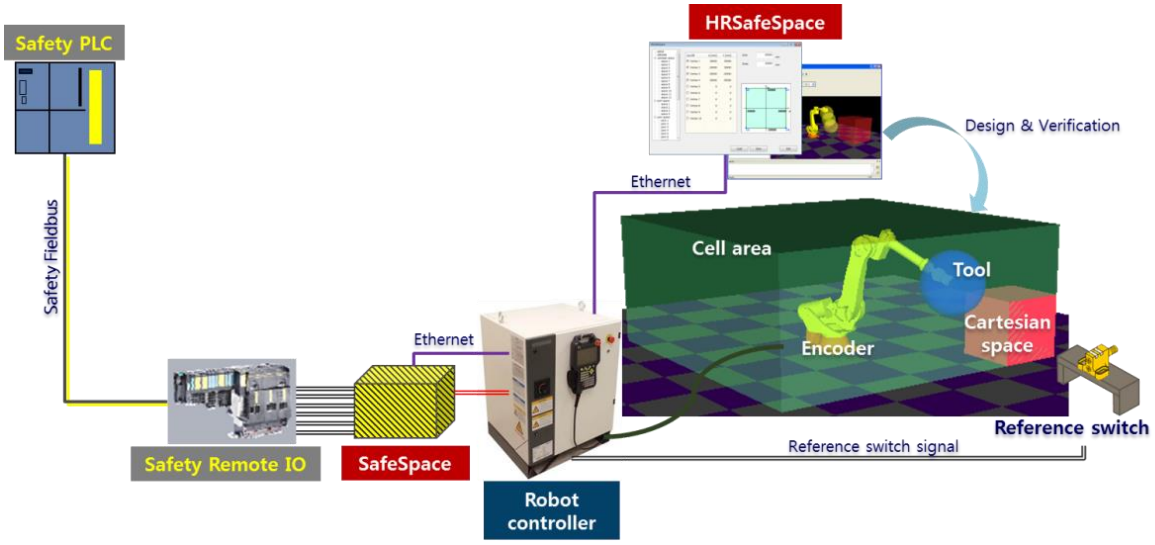


Figure 3.1 The system configuration of SafeSpace

Table 3-1 System Requirement for the SafeSpace Function

system	requirement	remark
Hardware	Hi5a robot controller SafeSpace	
Software	V40.13-00 (Main software) V1.00 (SafeSpace Software) V1.1.0 (HRSafeSpace)	
Consisting of Robot	Robot controller Teach Pendant Base Axis(Linear axis) Positioner (max two- axis) Jig (max two axis)	
Supported axes	Max. 8 axis	
Servo board (BD544)	1 ea. Which can be consisted with 4-7 axes robot, 1-2 add axes.	

3.2. Service life

The maximum permissible service life of safety-relevant hardware components is 10 years. Once this time has been reached, the safety-relevant hardware components must be exchanged.

3.3. Environmental Requirements

SafeSpace was designed for a lifetime more than 10 years and 10,000 switching cycles. For this lifetime, installation and operation conditions shall meet requirements as followings:

(a) SafeSpace module should be transported and installed by accurately following the procedures recommended by Hyundai Robotics. Wrong transportation or installation may cause the module to fall, be impacted and shake.

(b) The module shall be installed in a place that is no impact and shaking.

(c) The installation of the module should avoid such place which is directly exposed to the sun, extremely humid, contaminated by oil or chemicals, and containing a large amount of metal powder and explosive gas.

It shall be taken a special measure, considering thermodynamics of controller, if the module is installed near the heating elements or places exposed directly to the sun.

(d) It shall be taken a special measure if the module is installed in a place of abundant dust such as metal powder in the air.

(e) Grounding is very critical in preventing electric shock and malfunction caused by noise, and thus install as following instructions.

It shall be connected grounding line to the grounding bus-bar inside of the robot controller's panel.

3.4. Hardware

3.4.1. Dimension

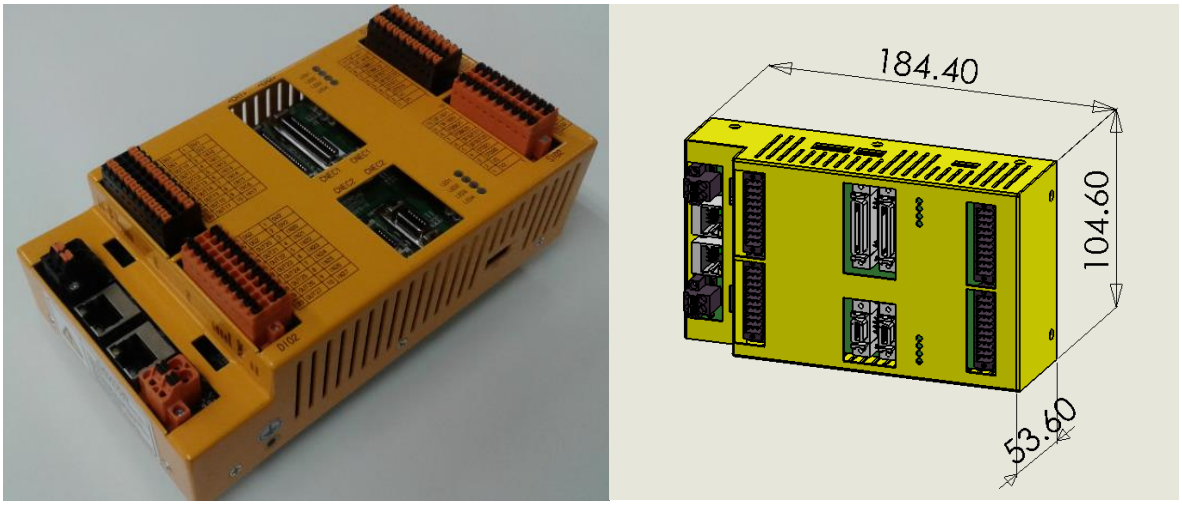


Figure 3.2 the external appearance of SafeSpace Module

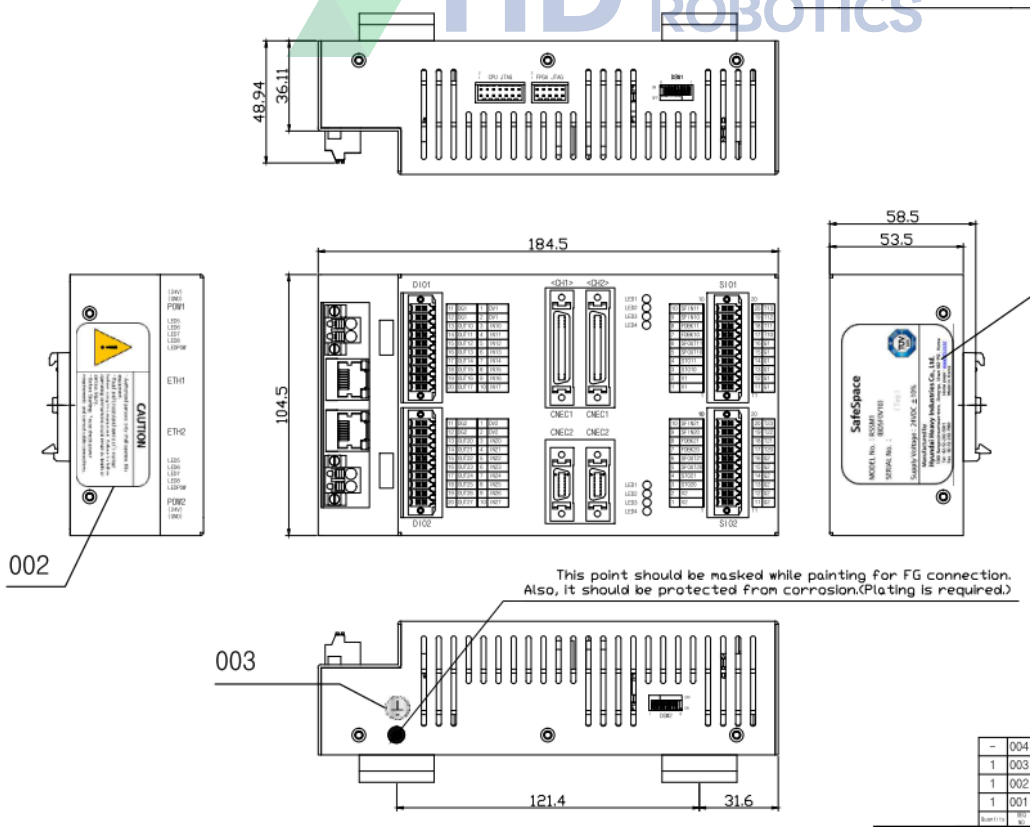


Figure 3.3 Dimensions of SafeSpace Module

3.4.2. Nameplate and Warning Marking

(1) Nameplate

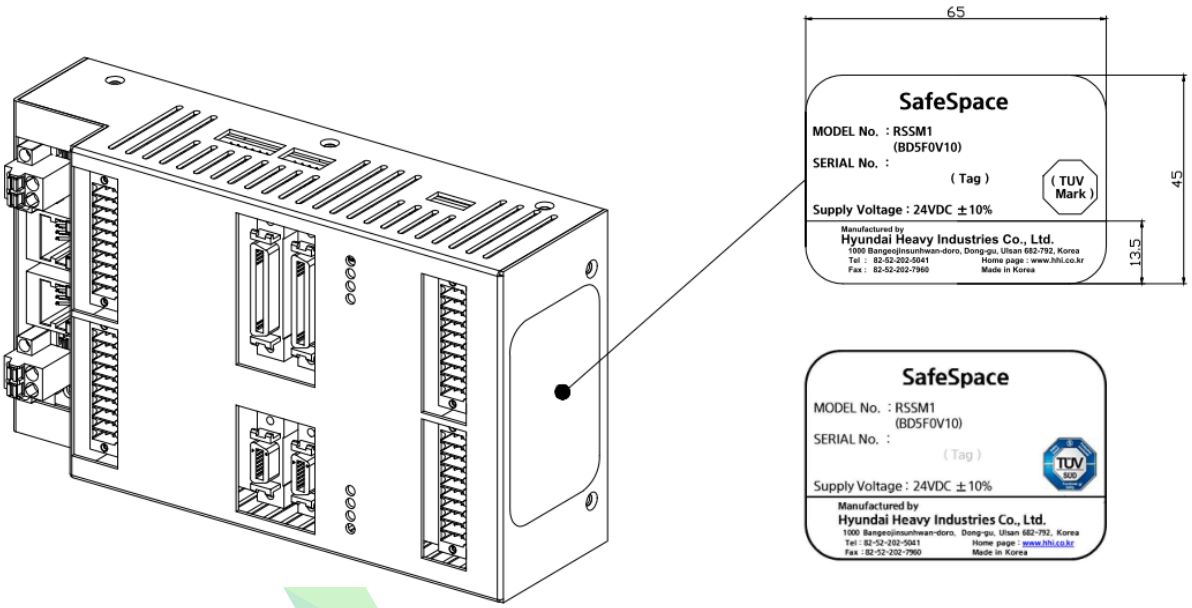


Figure 3.4 Nameplate of SafeSpace Module

(2) Warning Mark

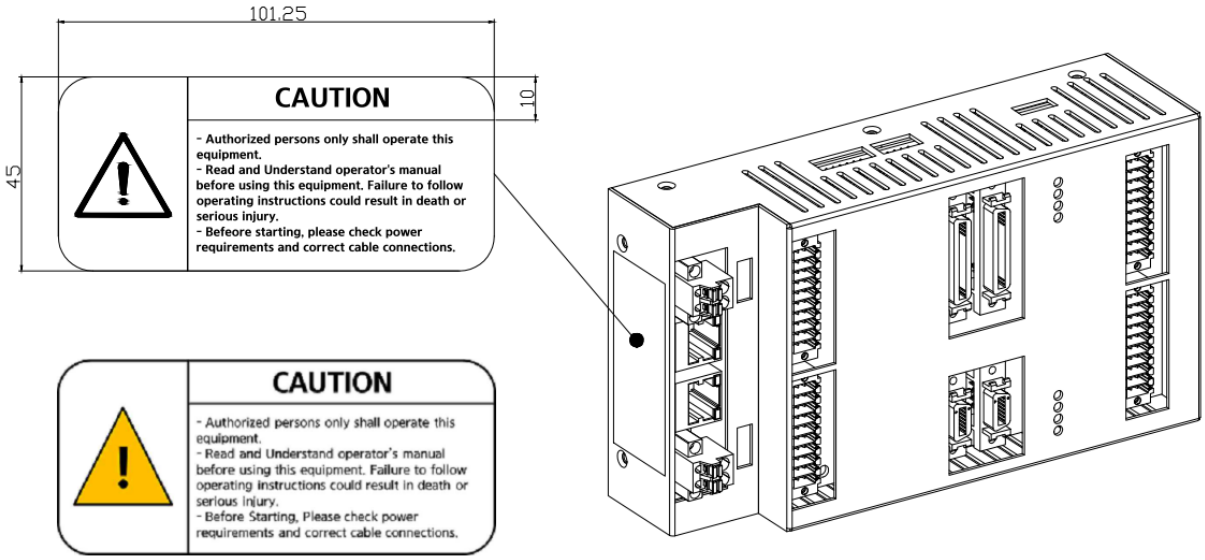


Figure 3.5 Warning Mark of SafeSpace Module

(3) Earth Marking

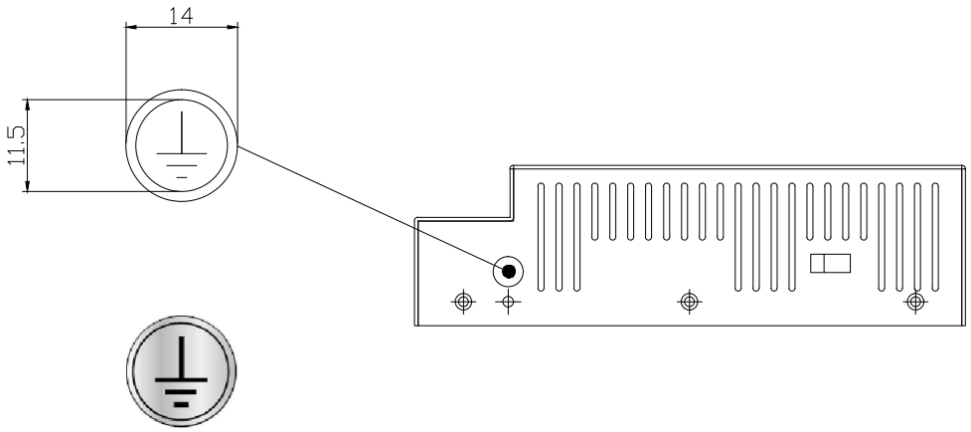


Figure 3.6 Earth Mark of SafeSpace Module

3.4.3. Hardware Functions

SafeSpace shall have the following hardware functions:

The safety integrity of SafeSpace is PL=d (SIL 2), Cat. 3., exceptionally STO function is PL=e (SIL 3), Cat. 3.

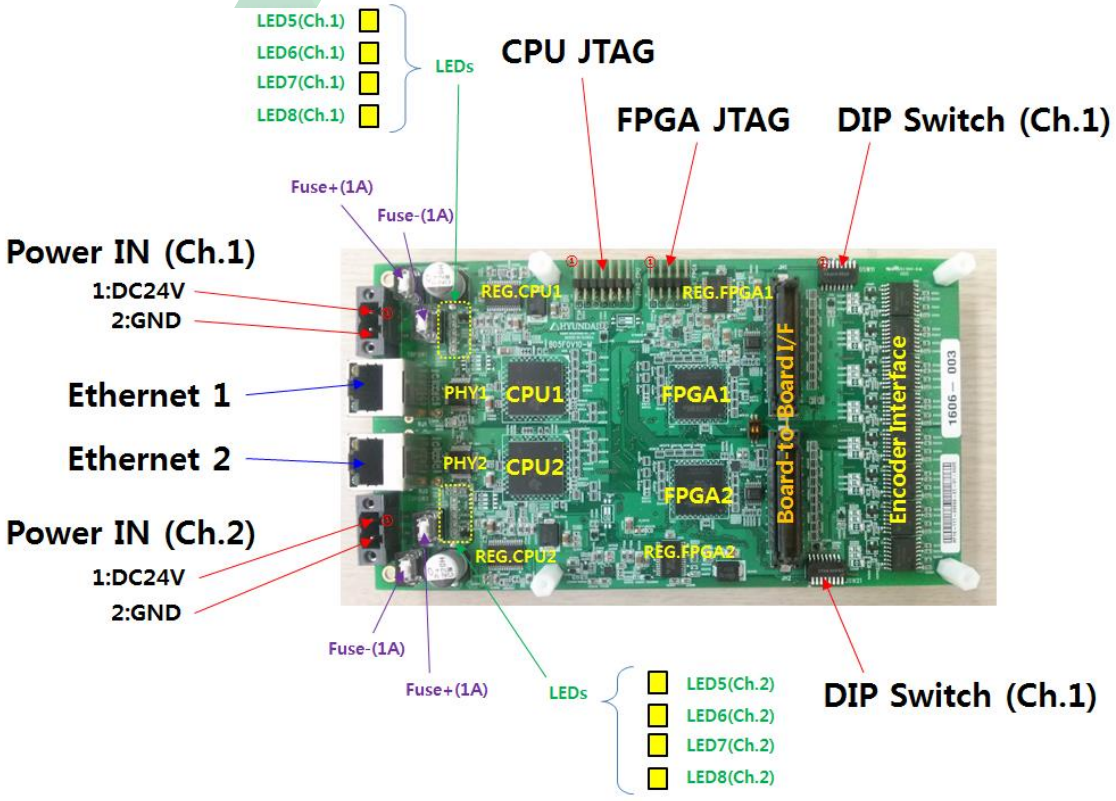


Figure 3.7 Internal Main Board in SafeSpace

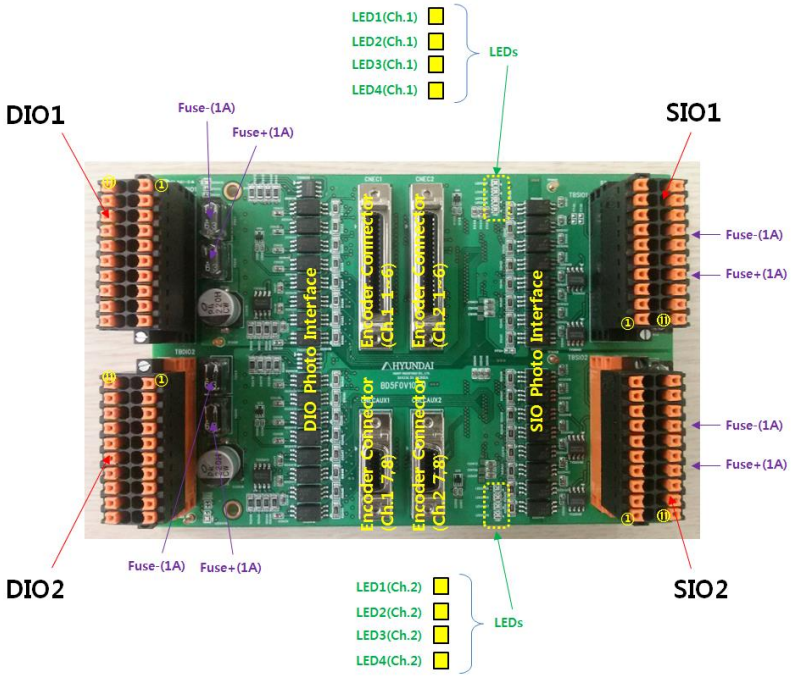


Figure 3.8 Internal Upper Board in SafeSpace

HF.1: Power Supply function

This function is to supply control powers in SafeSpace Module.
DC24V input is distributed to DC5V, DC3.3V, DC1.2V, DC2.5V by regulators with supervisor.

HF.2: Watchdog function

This function is to supervise a malfunction of CPUs. It uses the time-window-based watchdog pulse. If failed, CPU is reset, STO output of FPGA and STO buffer are shut down.

HF.3: Clock function

The clock is used in operation of the CPU, FPGA, Ethernet PHY. The clock source is from only one crystal oscillator. Using PLLs in the FPGA, this clock source is split various clocks for each component.

HF.4: CPU function

The CPU carries out safety-related functions and operates module.

HF.5: FPGA function

The FPGA consists in dual-port RAM for the channel interlock, serial-to-parallel data transformation part for acquiring a robot position, STO signal output for stopping the robot motion and shutting motors power down, general digital input/output part for interfacing an external safety PLC.

HF.6: Encoder I/F function (RS485)

The positions of a robot manipulator transfer to serial data by encoders in each axis. This serial data are transmitted to the robot controller via RS-485 line. This function of SafeSpace captures these data in middle and inputs to the FPGA for serial-to-parallel data transformation. That is to change RS-485 differential signals to single ended TTL logic signals.

HF.7: STO function and general purpose DIO

This function is to stop robot's motion and turn motors power off if faults occur. For this action, CPU or FPGA output digital signal to the robot controller. This result is monitored with test-pulsed monitoring signal.
Target safety integrity level of this function is PL=e (SIL 3), Cat. 3.

Additionally, there are digital inputs / outputs for general purpose. These are used to exchange IO data with an external safety PLC. Target safety integrity level of these is PL=d (SIL 2), Cat. 3.

HF.8: Temperature Sensor function

The temperature sensors are used to monitoring temperature in module. If over-heated, all functions are shut down and STO signal is outputted to the robot controller by CPU.

HF.9: Ethernet function

This function is non-safety and to interface between the robot controller and SafeSpace. The SafeSpace needs many setting values normally to operate it's functions. So the module receives these values from the robot controller and also transmits information via the Ethernet communication.
This part consists of EMAC module in CPU, Ethernet PHY, Ethernet transformer and connector.

At the initial start-up, the operation check and validation of the wiring for safety signals should be carried out, and then the wiring should be protected by the cable duct or etc.

3.5. Installation

3.5.1. Installation Requirements

Grounding is very critical in preventing electric shock and malfunction caused by noise. Thus It shall be connected grounding line to the grounding bus-bar inside of the robot controller's panel.

Power supply and IO connection should be isolated from other circuitry.
(Example, external safety IO module, power supplies for other devices, etc.)

At the start-up, the operation check and validation of the wiring for safety signals shall be carried out, and also the wiring should be protected by such as duct.

3.5.2. Installation Position

SafeSpace Module is installed in the robot controller as following figure. So operators cannot access to the module. Only authorized person can maintain the module with opening the controller.

① SafeSpace Module
② SMPS

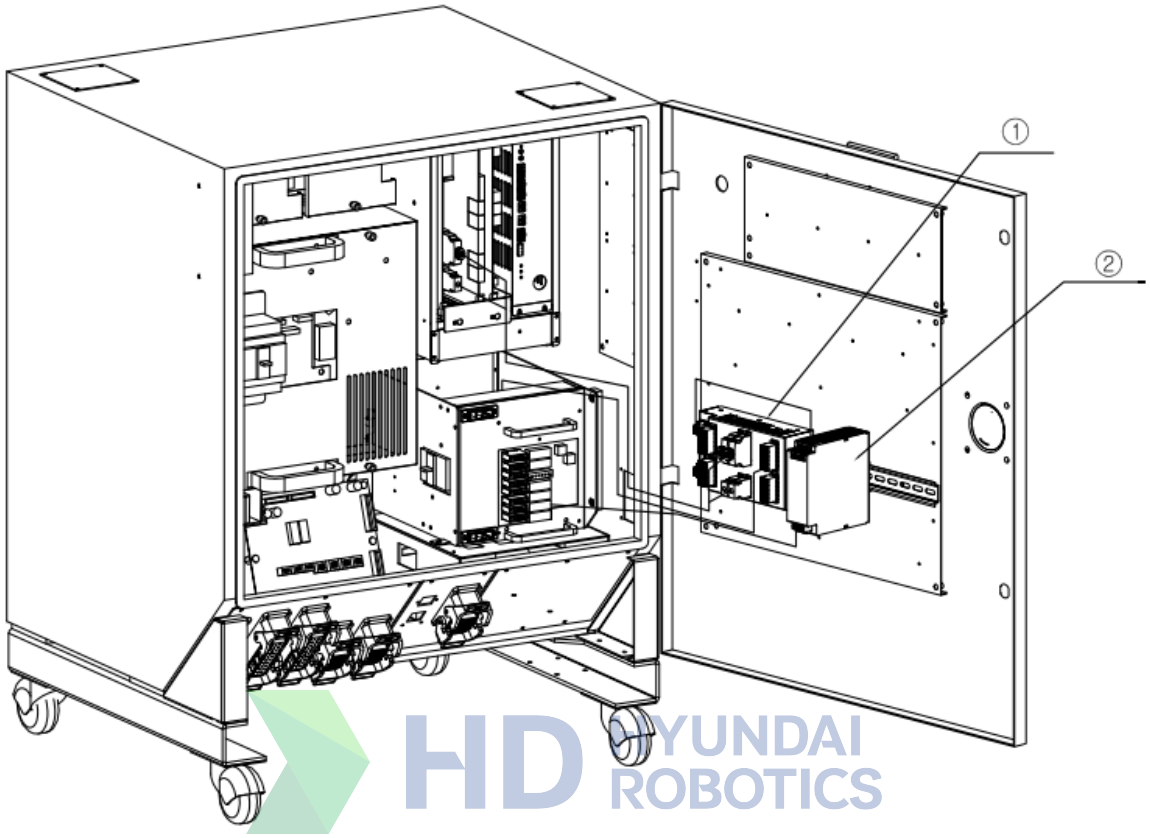


Figure 3.9 Installation of SafeSpace Module

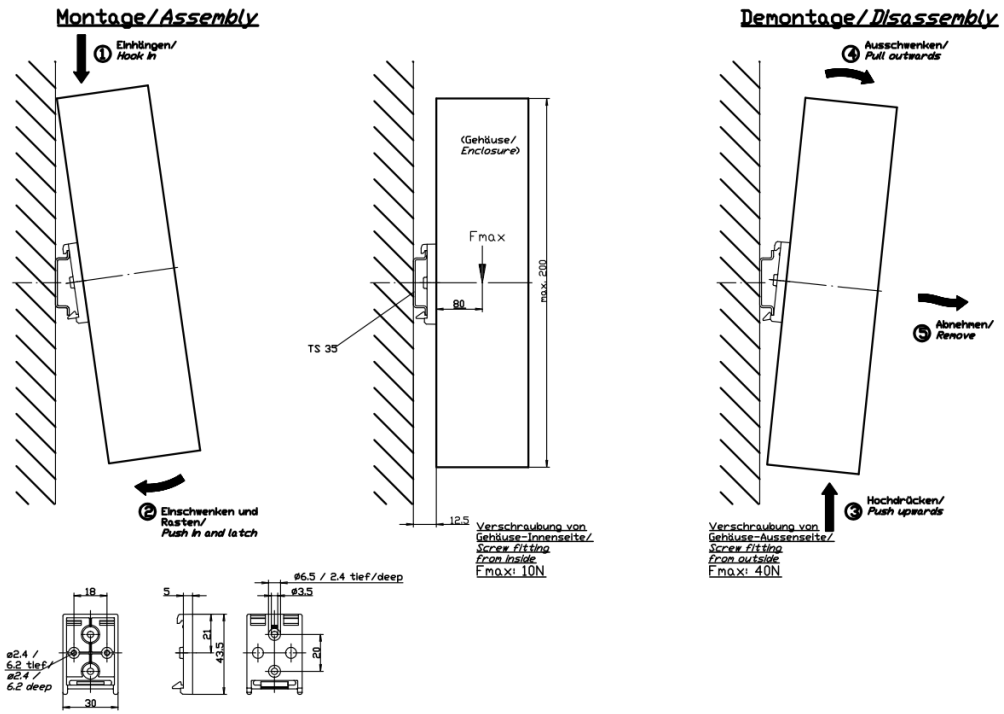


Figure 3.10 the way of the attachment on the wall

3.5.3. Power Connection and Specification

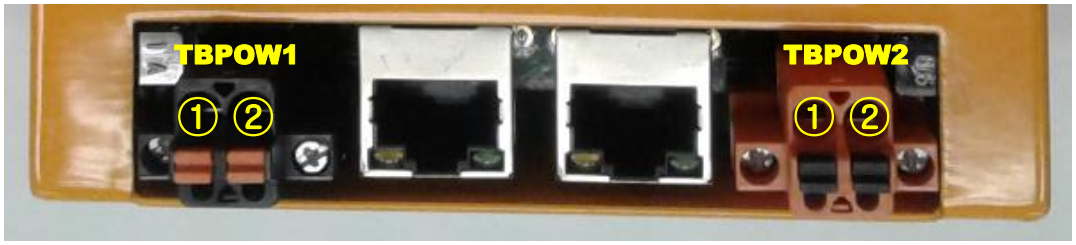


Figure 3.11 Power Connectors in SafeSpace

Table 3-2 Power port description

Usage	Terminal Block	Pin No.	Name	Description	Action
Power Input (Channel 1)	TBPOW1	1	POW1(+)	Power voltage input (ch.1) for SafeSpace	DC24V
		2	POW1(-)	Power ground input (ch.1) for SafeSpace	DC24V GND
Power Input (Channel 2)	TBPOW2	1	POW2(+)	Power voltage input (ch.2) for SafeSpace	DC24V
		2	POW2(-)	Power ground input (ch.2) for SafeSpace	DC24V GND

Input power shall be used DC24V / 40W that is general spec. as the table below.

Table 3-3 Power specification

Item	Specification	Remark
Ambient temperature	-40 ~ 85 ° C	
Nominal output voltage	24 V DC ±5 %	
Nominal output current	more than 1.7 A	
Residual ripple	〈 100 mV_{PP} (with nominal values)	
Output power	more than 40 W	
MTBF	〉 1,000,000 h (40° C)	
Standard	IEC 60950-1 (SELV)	

3.5.4. Ethernet connection between Hi5a and SafeSpace

It is required to connect Ethernet 1 of SafeSpace to CNETN1 or CNETN2 of BD511 board to use SafeSpace as shown in the following procedure.

1. Select the ethernet port of Hi5a to be connected to the SafeSpace module.

   ① Press the R.. button and enter the number 257

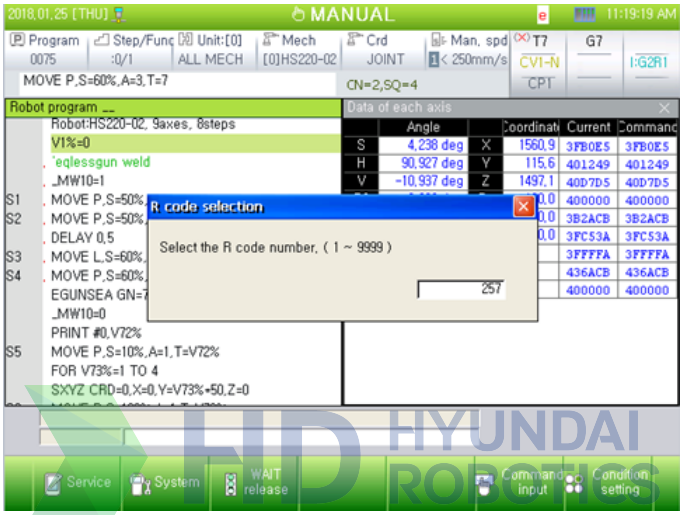


Figure 3.12 R code dialog box

   ② Choose EN0 or EN2 port of Hi5a controller.

   - EN0 corresponds to the CNETN1 connector on the BD511 board.
   - EN2 corresponds to the CNETN3 connector on the BD511 board.

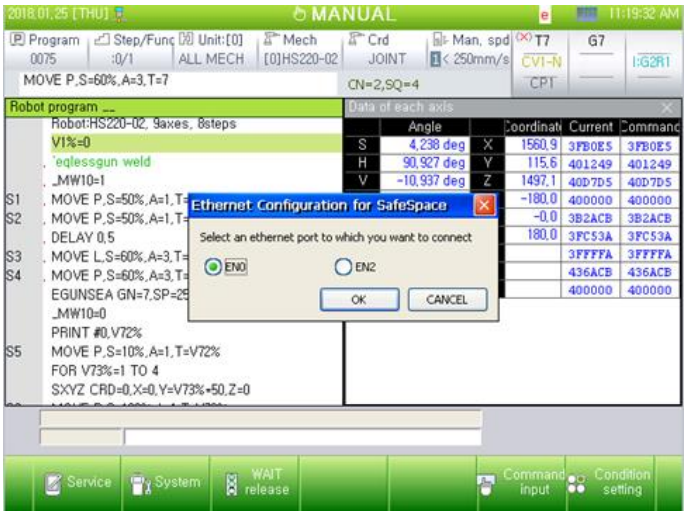


Figure 3.13 Ethernet port selection

2. Select the IP address of Hi5a controller in SafeSpace module side

① If the value of DIP switch of channel 1 is 0, then the default IP address 192.168.1.251 will be used for Hi5a controller. (All pins of DIP switch are OFF)

If the value of DIP switch of channel 1 isn't 0, then IP address 192.168.1.xxx will be used for Hi5a controller. (xxx is the value of DIP switch)

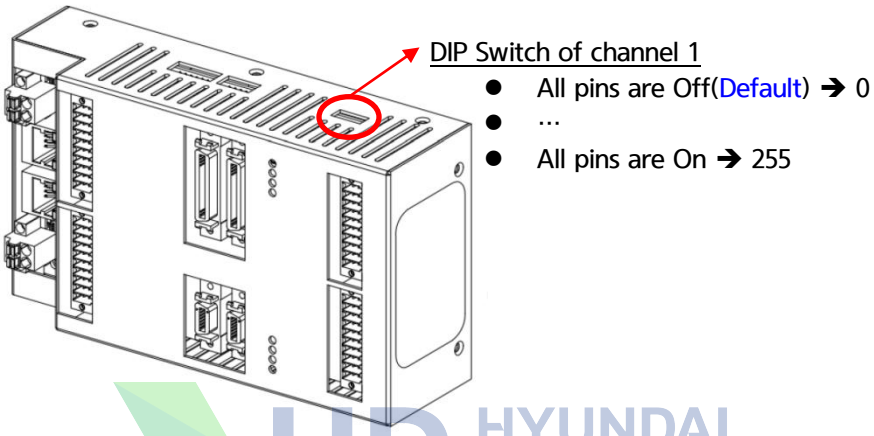


Figure 3.14 DIP switch of channel 1

※ The IP address of SafeSpace module is fixed at 192.168.1.45.
Please avoid using this IP address for Hi5a controller side.

3. Set the IP address of Hi5a controller side.

① Select 『[F2] System』 → 『2: Control parameter』 → 『9: Network』 → 『1: Environment setting』

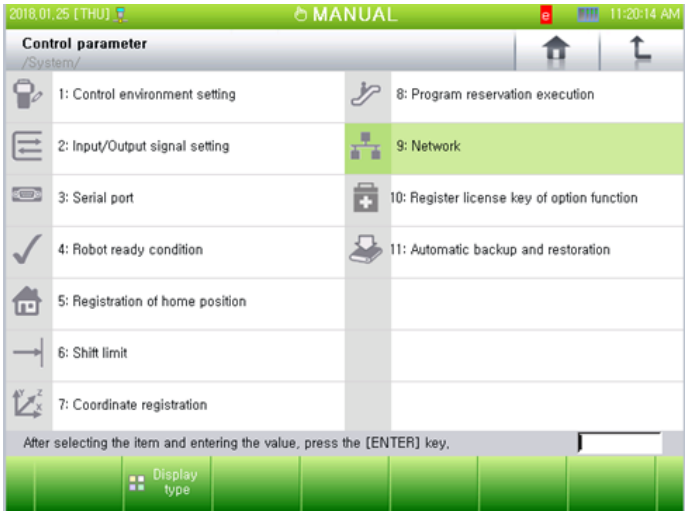


Figure 3.15 Network menu

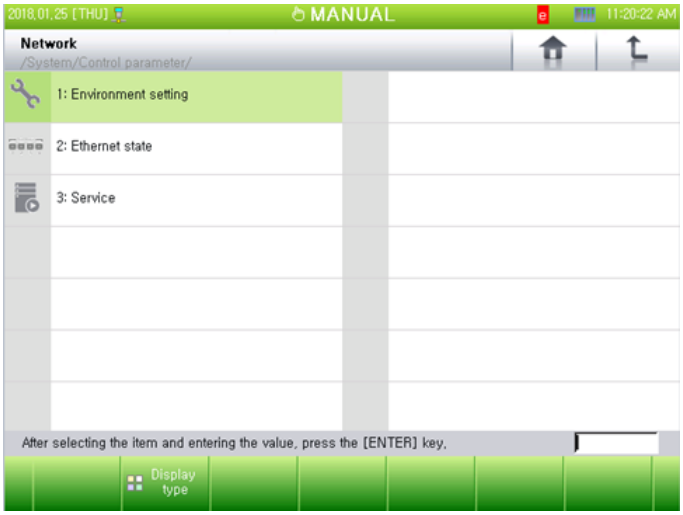


Figure 3.16 Environment setting menu

② Set up the IP address of EN2 or EN0.

Figure 3.17 IP address

4. Connect an Ethernet cable between Ethernet 1 of SafeSpace module and CNETN3 (EN2) or CNETN1(EN0) of BD511 main board. It is recommended to use STP(Shielded Twisted Pair) cable to enhance noise immunity.

① When the EN2 of Hi5a is used for SafeSpace interface

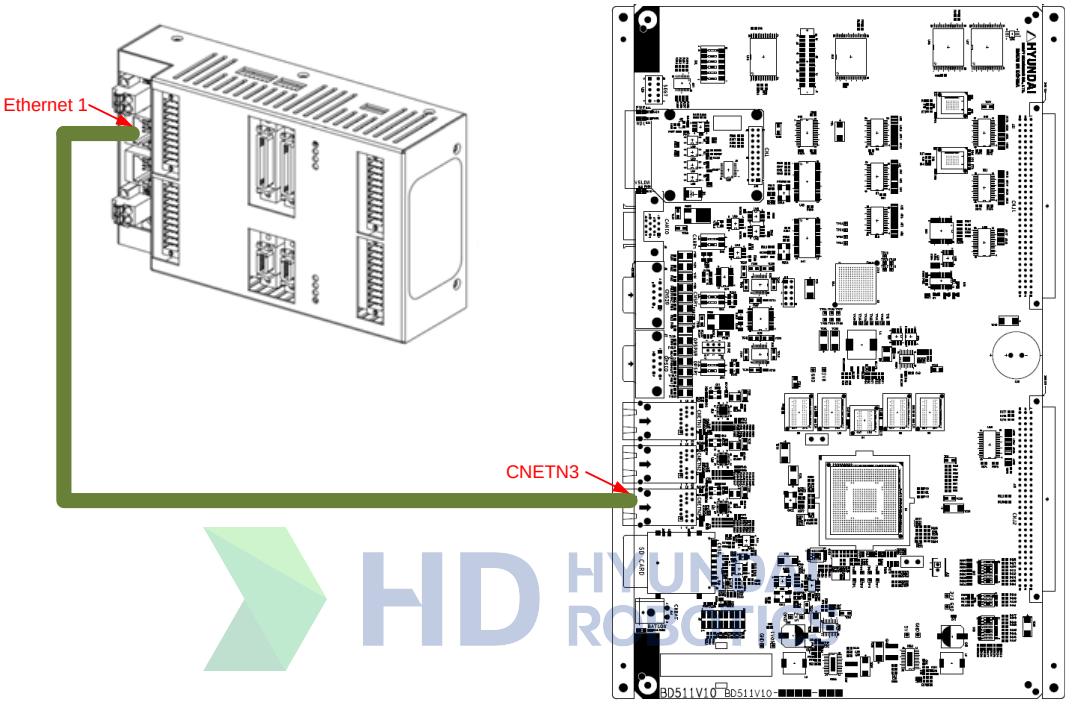


Figure 3.18 Ethernet cable connection for EN2

② When the EN0 of Hi5a is used for SafeSpace interface

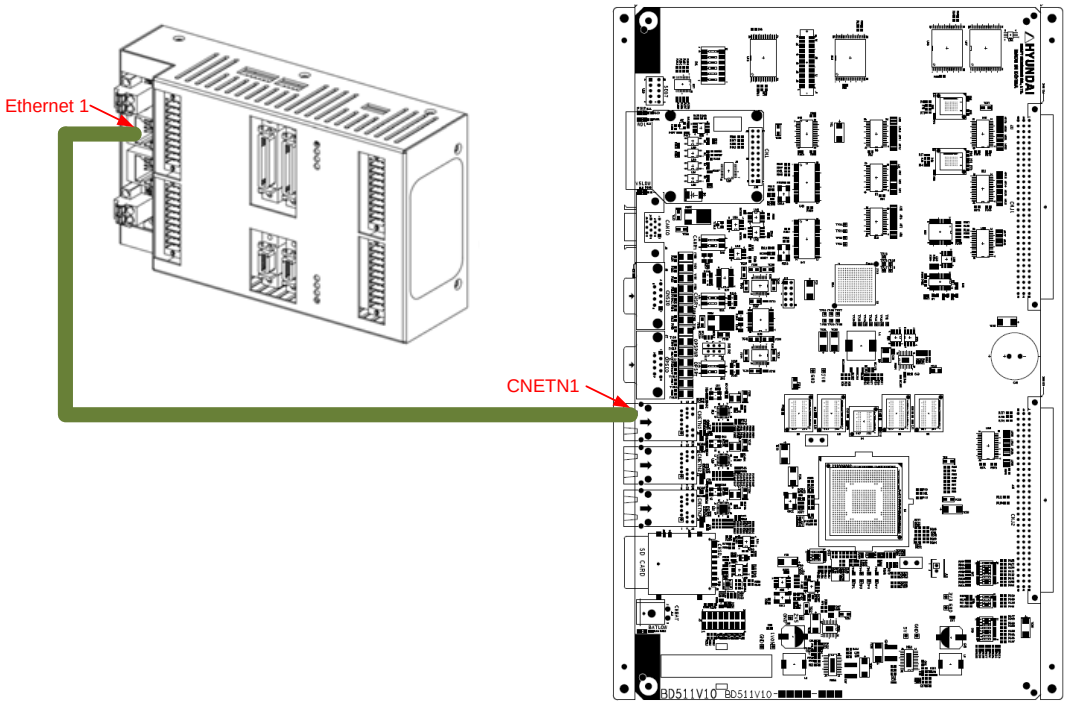


Figure 3.19 Ethernet cable connection for EN0

3.5.5. SIO/DIO Connection and Specification

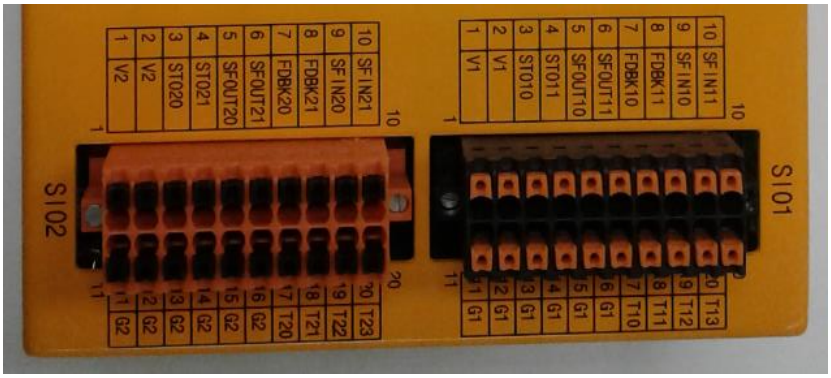


Figure 3.20 SIO Connectors in SafeSpace

Table 3-4 SIO port description

Usage	Terminal Block	Pin No.	Name	Description	Action
Safety Function (Channel 1)	TBSIO1	1	V1	Output voltage for SIO	DC24V
		2	V1	Output voltage for SIO	DC24V
		3	STO10	STO Output 0 (ch.1)	**(+) Sinking input type** ON : 24V, 10mA OFF : floating **(+) Sourcing output** ON : 24V, 120mA OFF : floating 〈current limit〉 800mA/full ports
		4	STO11	STO Output 1 (ch.1)	
		5	SFOUT10	Safety Function Output 0 (ch.1)	
		6	SFOUT11	Safety Function Output 1 (ch.1)	
		7	FDBK10	STO Feedback Input 0 (ch.1)	
		8	FDBK11	STO Feedback Input 1 (ch.1)	
		9	SFIN10	Safety Function Input 0 (ch.1)	
		10	SFIN11	Safety Function Input 1 (ch.1)	
		11	G1	Output ground for SIO	DC24V GND
		12	G1	Output ground for SIO	DC24V GDN
		13	G1	Output ground for SIO	DC24V GND
		14	G1	Output ground for SIO	DC24V GDN
		15	G1	Output ground for SIO	DC24V GND
		16	G1	Output ground for SIO	DC24V GDN
		17	T10	Test Pulse Output 0 (ch.1)	**(+) Sourcing pulse output** ON : 24V, 120mA OFF : floating
		18	T11	Test Pulse Output 1 (ch.1)	
		19	T12	Test Pulse Output 2 (ch.1)	
		20	T13	Test Pulse Output 3 (ch.1)	
Safety Function (Channel 2)	TBSIO2	1	V2	Output voltage for SIO	DC24V
		2	V2	Output voltage for SIO	DC24V
		3	STO20	STO Output 0 (ch.2)	**(+) Sinking input type** ON : 24V, 10mA OFF : floating **(+) Sourcing output** ON : 24V, 120mA
		4	STO21	STO Output 1 (ch.2)	
		5	SFOUT20	Safety Function Output 0 (ch.2)	
		6	SFOUT21	Safety Function Output 1	

Usage	Terminal Block	Pin No.	Name	Description	Action
				(ch.2)	OFF : floating 〈current limit〉 800mA/full ports
		7	FDBK20	STO Feedback Input 0 (ch.2)	
		8	FDBK21	STO Feedback Input 1 (ch.2)	
		9	SFIN20	Safety Function Input 0 (ch.2)	
		10	SFIN21	Safety Function Input 1 (ch.2)	
		11	G2	Output ground for SIO	DC24V GND
		12	G2	Output ground for SIO	DC24V GDN
		13	G2	Output ground for SIO	DC24V GND
		14	G2	Output ground for SIO	DC24V GDN
		15	G2	Output ground for SIO	DC24V GND
		16	G2	Output ground for SIO	DC24V GDN
		17	T20	Test Pulse Output 0 (ch.2)	**(+) Sourcing pulse output** ON : 24V, 120mA OFF : floating
		18	T21	Test Pulse Output 1 (ch.2)	
		19	T22	Test Pulse Output 2 (ch.2)	
		20	T23	Test Pulse Output 3 (ch.2)	

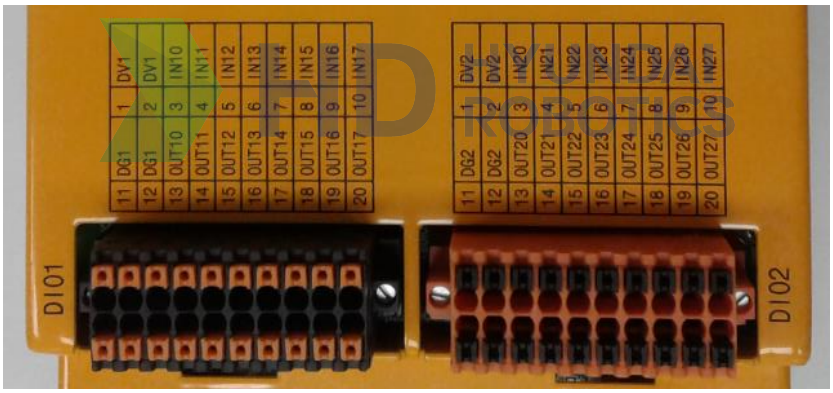


Figure 3.21 DIO Connectors in SafeSpace

Table 3-5 DIO port description

Usage	Terminal Block	Pin No.	Name	Description	Action
Remote IO connection (Channel 1)	TBDIO1	1	DV1	Output voltage for DIO	DC24V
		2	DV1	Output voltage for DIO	DC24V
		3	DIN10	Digital Input 0 (ch.1)	**(+) Sinking input type** ON : 24V, 10mA OFF : floating
		4	DIN11	Digital Input 1 (ch.1)	
		5	DIN12	Digital Input 2 (ch.1)	
		6	DIN13	Digital Input 3 (ch.1)	
		7	DIN14	Digital Input 4 (ch.1)	
		8	DIN15	Digital Input 5 (ch.1)	
		9	DIN16	Digital Input 6 (ch.1)	
		10	DIN17	Digital Input 7 (ch.1)	
		11	DG1	Output ground for DIO	DC24V GND

Usage	Terminal Block	Pin No.	Name	Description	Action
		12	DG1	Output ground for DIO	DC24V GDN
		13	DOUT10	Digital Output 0 (ch.1)	**(+) Sourcing output type** ON : 24V, 120mA OFF : floating 〈current limit〉 800mA/full ports
		14	DOUT11	Digital Output 1 (ch.1)	
		15	DOUT12	Digital Output 2 (ch.1)	
		16	DOUT13	Digital Output 3 (ch.1)	
		17	DOUT14	Digital Output 4 (ch.1)	
		18	DOUT15	Digital Output 5 (ch.1)	
		19	DOUT16	Digital Output 6 (ch.1)	
		20	DOUT17	Digital Output 7 (ch.1)	
Remote IO connection (Channel 2)	TBDIO2	1	DV2	Output voltage for DIO	DC24V
		2	DV2	Output voltage for DIO	DC24V
		3	DIN20	Digital Input 0 (ch.2)	**(+) Sinking input type** ON : 24V, 10mA OFF : floating
		4	DIN21	Digital Input 1 (ch.2)	
		5	DIN22	Digital Input 2 (ch.2)	
		6	DIN23	Digital Input 3 (ch.2)	
		7	DIN24	Digital Input 4 (ch.2)	
		8	DIN25	Digital Input 5 (ch.2)	
		9	DIN26	Digital Input 6 (ch.2)	
		10	DIN27	Digital Input 7 (ch.2)	
		11	DG2	Output ground for DIO	DC24V GND
		12	DG2	Output ground for DIO	DC24V GDN
		13	DOUT20	Digital Output 0 (ch.2)	**(+) Sourcing output type** ON : 24V, 120mA OFF : floating 〈current limit〉 800mA/full ports
		14	DOUT21	Digital Output 1 (ch.2)	
		15	DOUT22	Digital Output 2 (ch.2)	
		16	DOUT23	Digital Output 3 (ch.2)	
		17	DOUT24	Digital Output 4 (ch.2)	
		18	DOUT25	Digital Output 5 (ch.2)	
		19	DOUT26	Digital Output 6 (ch.2)	
		20	DOUT27	Digital Output 7 (ch.2)	

3.5.6. Examples of the Connection

The following figures show an example of the SafeSpace connection.

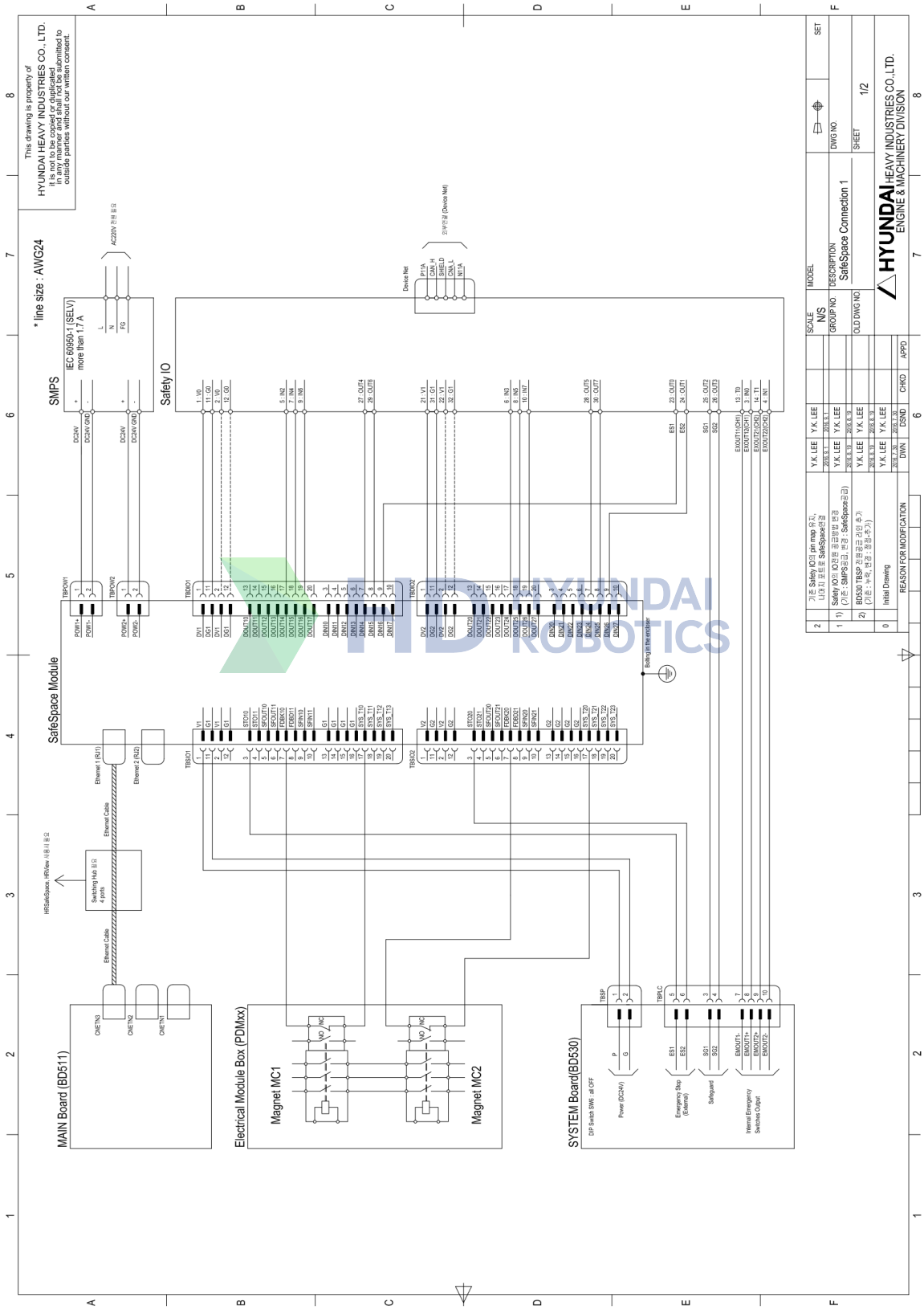


Figure 3.22 SafeSpace Connection (1/2)

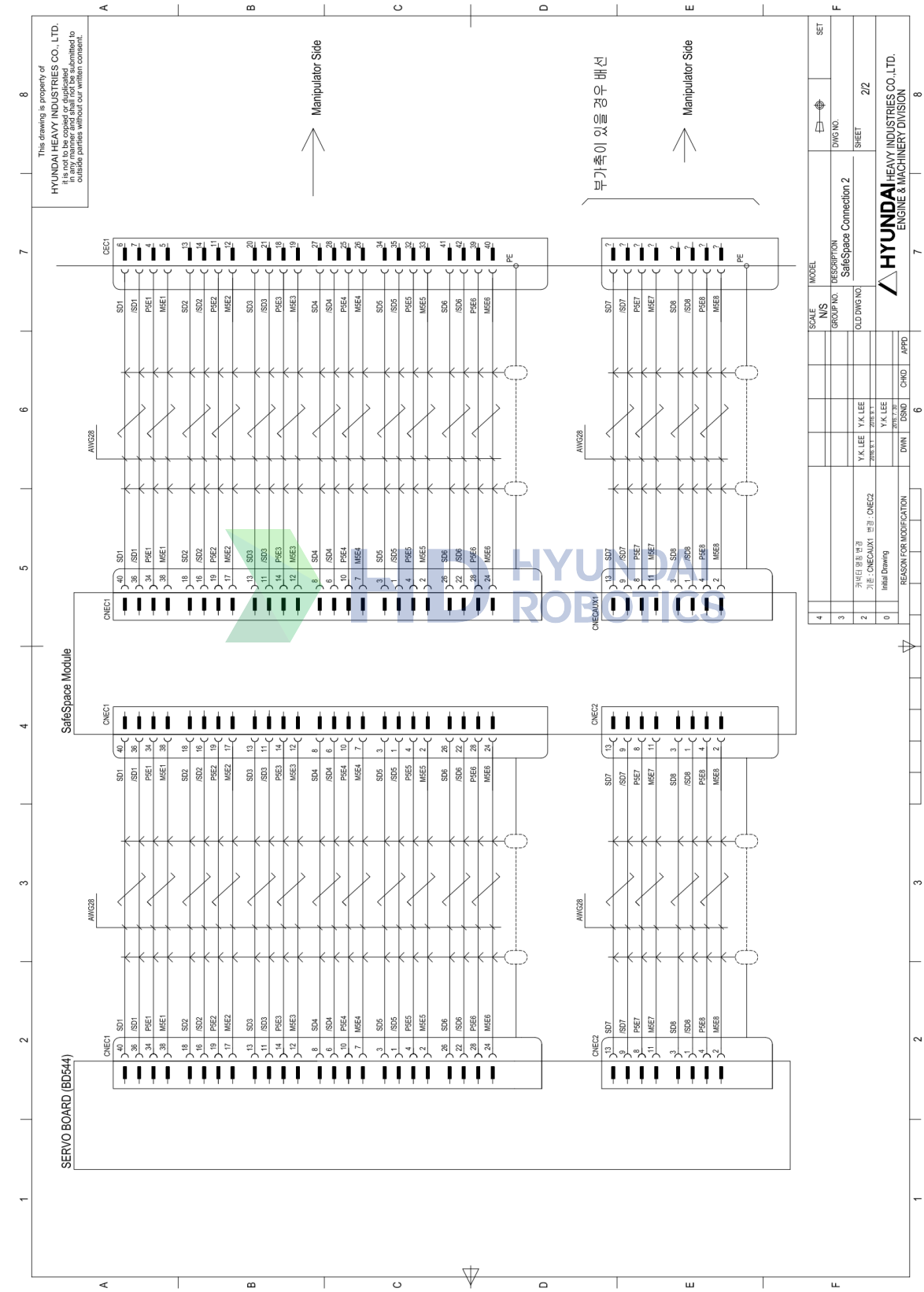

Manipulator Side
부가축이 있을 경우 배선
Manipulator Side
SafeSpace Module
SERVO BOARD (BD544)
CNEC1
CNEC2
CNEDAUX1
CEC1
AWG28
SafeSpace Connection 2
HYUNDAI HEAVY INDUSTRIES CO.,LTD.
ENGINE & MACHINERY DIVISION
Initial Drawing
REASON FOR MODIFICATION
HYUNDAI ROBOTICS

Figure 3.23 SafeSpace Connection (2/2)

3.5.7. Mastering test module

The sensor based mastering test needs mastering test module. The mastering test module consists of reference switch and activating tool.

The reference switch is inductive sensor and it can operate by an activating tool that is attached on robot flange or working tool. The sensor should be mounted an immovable structure. The mastering test module should not interfere with working equipment.

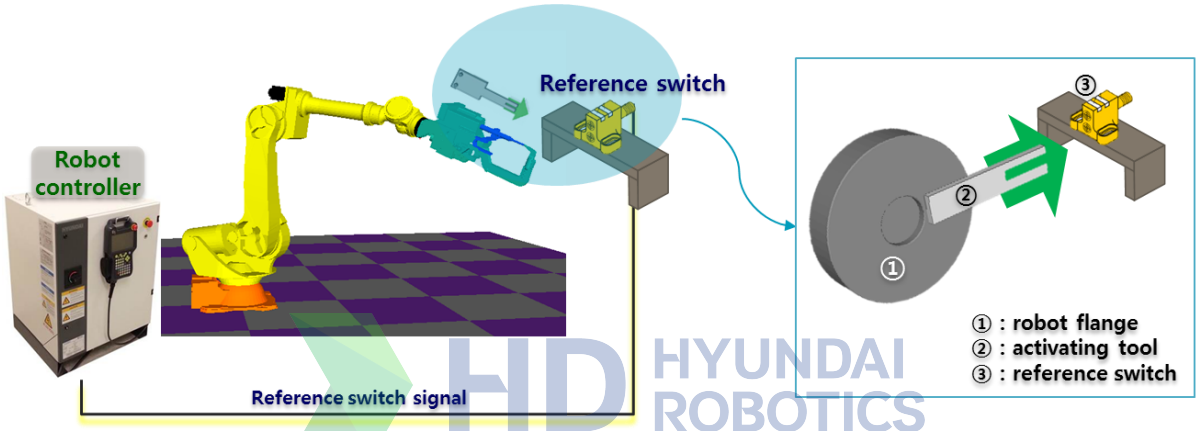
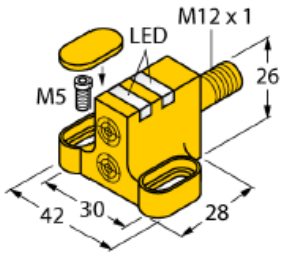
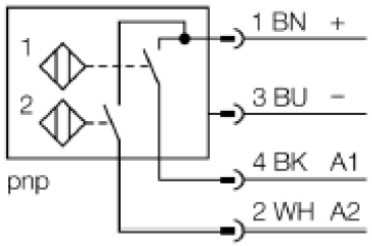


Figure 3.24 Installation of mastering test module

Table 3-6 specification of mastering test module

Reference switch	
Type	Inductive sensor
	
Operating voltage[V]	10 ~30 DC
Rated switching distance	4 mm
Ambient temperature[℃]	-25 ~ +70
Output	PNP, Dual sensor
Switching frequency	0.05kHz

wiring	
Activating tool	
	
Thickness	7 mm
material	mild steel

3.6. Operating Mode

Startup or power up – During power up all safety related outputs and communication interfaces are switched off.

Normal operation – In normal operation the safety functions and the integrity measures are cyclically executed.

Error modes – After failure detected an integrity measure is driven into the safe state.

Switch off or power off – During power off all safety related outputs and communication interfaces are switched off.

Configuration or modification mode – During work for a configuration or modification all safety related outputs and communication interfaces are switched off.

3.7. Indications and alarms

3.7.1. LED indication

(1) **Booting mode** (Power on self-test)

LED1~8 LEDs are blink in sequential order. (Two cycle)

(2) **Operating mode**

Table 3-7 LED indication

LED No.	Status	Meaning
LED1 (MOD)	Green On	- SafeSpace is under initialization state.
	Green blinking	- SafeSpace is running state. (Safety function is activated)
	Red On	- SafeSpace is fault state.
	Off	- Power off
LED2 (PARAM)	**Green On**	**- Safety parameters are initialized successfully.**
	Green blinking	- Safety parameters are not initialized yet. - SafeSpace is Off.
	Off	- SafeSpace module is not initialized yet. - Fault state
LED3 (CONFIG)	**Green On**	**- Robot information is initialized successfully.**
	Green blinking	- Robot information is not initialized yet. (Wait robot information from Hi5a robot controller)
	Off	- SafeSpace is Off. - SafeSpace module is not initialized yet. - Safety parameters are not initialized yet. - Fault state
LED4 (COMM)	**Green On**	- Encoder communication is open. - The cyclic communication with Hi5a controller is open.
	Green blinking	- Encoder communication is not open. - The cyclic communication with Hi5a controller is not open.
	Off	- SafeSpace is Off. - SafeSpace module is not initialized yet. - Safety parameters are not initialized yet. - Robot information is not initialized yet. - Fault state
LED5 (VIOLATION)	**Green blinking**	- There is no violation of the safety parameter.
	Red blinking	- SafeSpace detects a violation of the safety parameter.

LED No.	Status	Meaning
	Off	- Safety functions(SLS, SLP, SOS) are not activated.
LED6 (Ethernet)	**Green On**	- Ethernet communication is open
	Red On	- Ethernet communication is not open.
LED7 (STO)	**Green On**	- Emergency stop is not activated.
	Red On	- Emergency stop is activated. (STO is triggered)
LED8 (WD)	**Green On**	- Main watchdog of SafeSpace moduel is normal.
	Red On	- Main watchdog timer of SafeSpace moduel is expired.

3.8. Maintenance

For the safety of maintenance persons, pay attention to the following.

(1) A hazardous situation may arise when the robot or SafeSpace are kept with their power-on during maintenance operations, Therefore, for any maintenance operation, the robot and SafeSpace should be put into the power-off state. In case maintenance needs to be executed in the power-on state, the emergency stop button must be pressed.

(2) If it becomes necessary to enter the robot operation range while the power in on, press the emergency stop button on the operational panel, or the teaching pendent before entering the range. The maintenance personnel must indicate that maintenance work is in progress and be careful not to allow other people to operate the robot carelessly.

A hardware or software version-up in fields, shall be carried out by the qualified person.

If problems with safety product occur in fields, customers call the HHI's robot global service department and then HHI replaces the SafeSpace module.

- Internal functions of the SafeSpace require no maintenance activities. All internal functions are self-tested.

- Execute the test for EM-Stop of the robot controller every 6 months.
  ① Turn off the power of the SafeSpace. This will cause a EM-Stop of the robot controller.

② Verify that the robot is stopped.

- Execute the test for external safety-related components and wiring every 6 months; door switches, emergency stop devices and so on.

- The motor's encoder batteries need to be replaced periodically.
  ① Refer to the Clause "Battery Replacement" in the Manipulator Maintenance Manual. This manual has descripted types, manufacturers of the battery, and period, procedure of replacement, etc.
  ② Warning message : "W0104 (0 axis) Encoder battery voltage drop"

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4

SafeSpace functions

4.1. Robot monitoring function

4.1.1. Global parameters

Global parameters are TCP speed limitation for monitoring cartesian speed. These parameters are always monitored when the SafeSpace function is activated. If the TCP speed in world coordinate system exceeds limit value, STO will be triggered. Global parameters contain maximum TCP speed and reduced speed when reduced mode is activated.

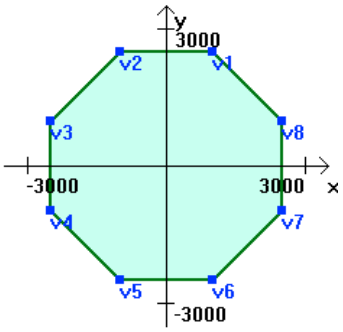
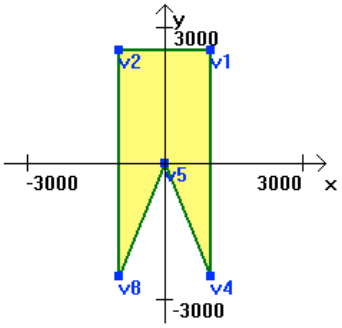
Table 4-1 Global parameters

Global parameters		
Parameter name	Parameter name	Parameter name
SafeSpace	SafeSpace	SafeSpace
Max. Global TCP speed	Max. Global TCP speed	Max. Global TCP speed
Reduced TCP speed (remote/auto mode)	Reduced TCP speed (remote/auto mode)	Reduced TCP speed (remote/auto mode)
Reduced TCP speed (manual mode)	Reduced TCP speed (manual mode)	Reduced TCP speed (manual mode)

It is important that speed limit is configured considering STO reaction time.
If it is not covered, they could cause collisions and injuries.

4.1.2. Cell area

Cell area is a kind of cartesian working space in world coordinate system. The cell area could be modeled with X-Y plane vertexes and Z-direction height. This area is configured with 3 to 10 vertexes and it should be convex polygon and considered stopping distance.

Example	
	
Convex polygon	Concave polygon(non-convex)

Robot monitoring function performs based on configured spaces and modeled tool. It is important that modeled spaces and tools contain each component overall and stopping distance also be included. If it is not covered, they could cause collisions and injuries.

If the sphere models of tool exceeds cell area, STO will be triggered. Tool area configuration is referred in chapter 3.2.7.

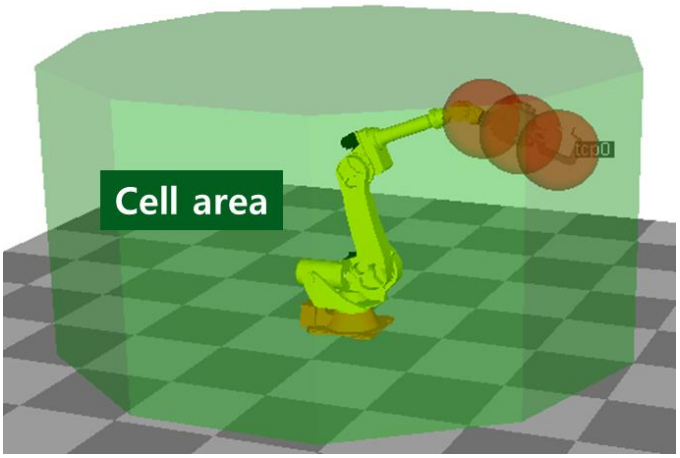


Figure 4.1 Cell area

Table 4-2 SafeCell area parameters

Cell area parameter(1 Cell, World coordinate system)			
Parameter name		Value	Description
Zmin		-30,000~ 30,000(mm)	Z coordinate value of bottom Default: -2,000
Zmax		-30,000~ 30,000(mm)	Z coordinate value of top Default: 5,000
properties: Corner 1~10 of the convex polygon			
On/Off		On/Off	Off= This corner is not activated On= This corner is activated Default: On(Corner 1~4), Off(Corner 5~10)
Coordinate value	X	-30,000~ 30,000(mm)	The X/Y coordinate values of the corner Default: 5,000(Corner 1,4), -5,000(Corner 2,3), 0(Corner 5~10)
	Y		

4.1.3. Cartesian spaces

Cartesian space could be defined working space or protected space for monitoring tool area. Working space means the limited space where the tool can move freely but cannot leave. Otherwise, protected space is the limited space where the tool cannot enter and move.
Cartesian space could be configured up to 12 spaces with position of origin and length in world coordinate system. Each space should be configured including stopping distance. Each space can be activated by parameter setting or Safety I/O.

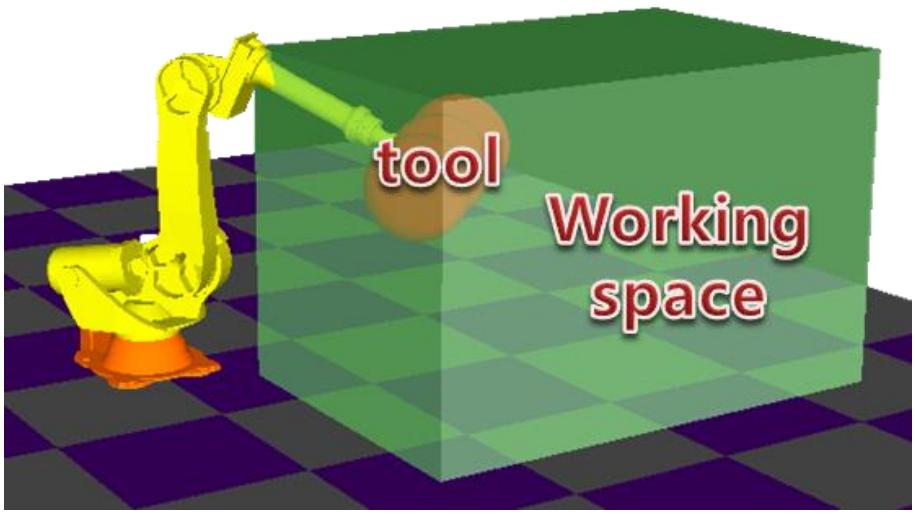


Figure 4.2 Cartesian working space

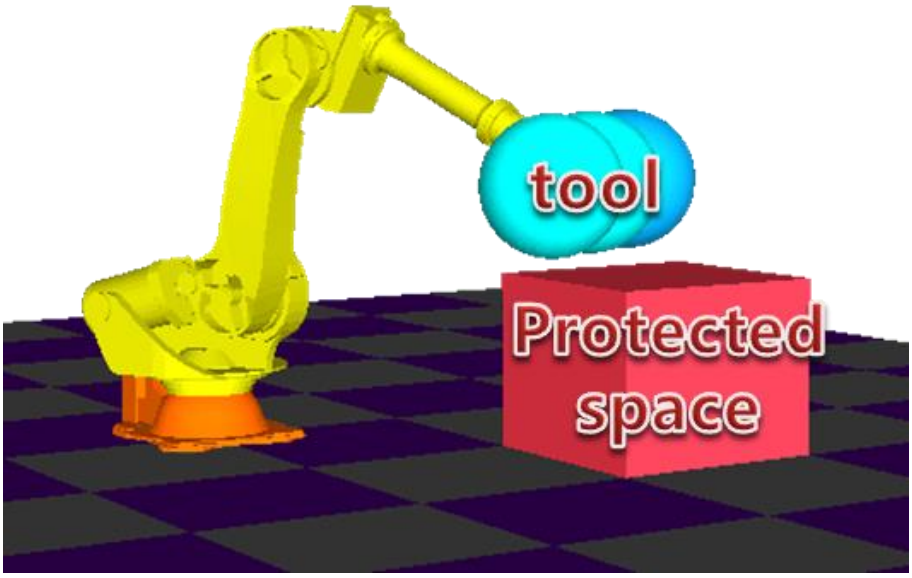


Figure 4.3 Cartesian protected space

TCP speed configured in cartesian spaces also be monitored. If the TCP speed exceeds limit value of activated space, STO will be triggered.
When the spheres of tool violate the cartesian space, the reaction will be according to configuration of stop at bound. If the stop at bound is on, STO will be triggered and robot will be stopped. If not, robot will not stop and send alarm to safety PLC.

Table 4-3 Cartesian space parameters

Cartesian space parameter: 12 Spaces			
Parameter name		Parameter name	Parameter name
Name		Name string	Max. 24charaters. Default="Cartesian Space n" ※ Used in the HRSafeSpace only. Name is not transferred to the SafeSpace from the robot controller.
Type		0,1	0=Working space(Default) 1=Protected space
Activation		0~2	0=Always Off(Default) 1=Always On 2=Safety I/O
TCP speed max.		1~30,000 (mm/s)	Limit of Cartesian TCP speed Default: 30,000
TCP speed monitoring		0,1	Monitor TCP speed when the tool is 0= inside of the space 1= outside of the space
Stop at bound		On/Off	Off=don't stop On =stop(default)
Properties			
Origin	X	-30,000~ 300,000 (mm)	The origin of the space Default: 0
	Y		
	Z		
	RX	RX,RZ: -180~180(°) RY:-90~90(°)	The direction of origin Default: 0
	RY		
	RZ		
Length	LX	60,000 (mm)	Lengh in X, Y, Z direction Default: 0
	LY		
	LZ		

Robot monitoring function performs based on configured spaces and modeled tool. It is important that modeled spaces and tools contain each component overall and stopping distance also be included. If it is not covered, they could cause collisions and injuries.

4.1.4. Joint space

Joint space could be defined working space or protected space for monitoring joint movement. Working space means the limited space where the joint can move freely but cannot leave. Otherwise, protected space is the limited space where the joint cannot enter and move.
Joint space could be configured up to 4 spaces and each space consists of 8 axis maximum. Each space should be configured including stopping distance. Spaces can be activated by parameter setting or Safety I/O.

Robot monitoring function performs based on configured spaces and modeled tool. It is important that modeled spaces and tools contain each component overall and stopping distance also be included. If it is not covered, they could cause collisions and injuries.

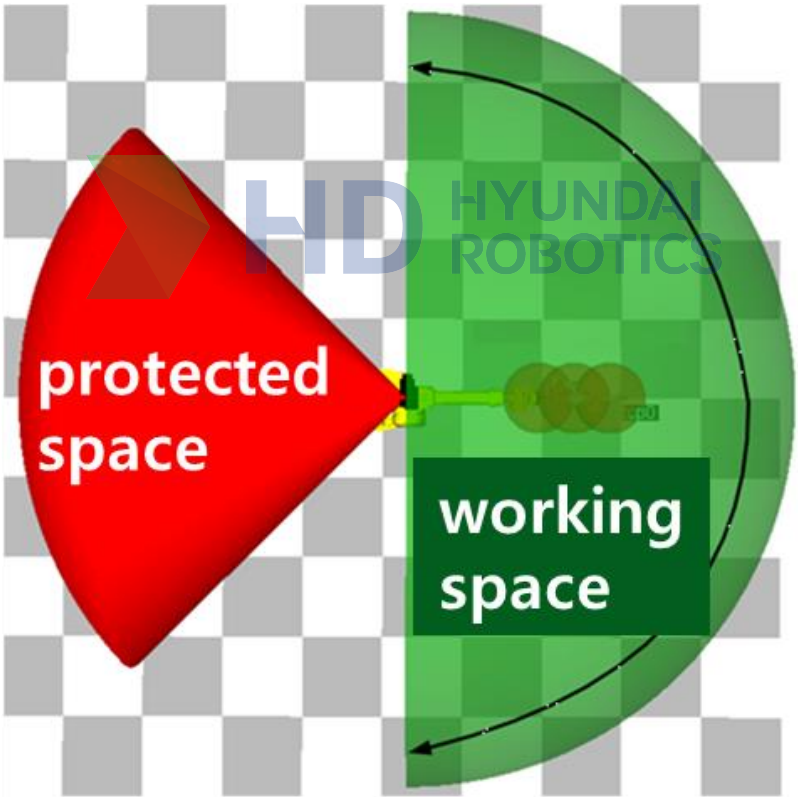


Figure 4.4 Joint spaces

TCP speed configured in joint spaces also be monitored. If the TCP speed exceeds limit value of activated space, STO will be triggered.
When the joint violate the cartesian space, the reaction will be according to configuration of stop at bound. If the stop at bound is on, STO will be triggered and robot will be stopped. If not, robot will not stop and send alarm to safety PLC.

Table 4-4 Joint space parameters

Joint space parameter: 4 Spaces		
Parameter name	Value	Description
Name	Name string	Max. 24charaters. Default="Joint Space n" ※ Used in the the HRSafeSpace only. Name is not transferred to the SafeSpace from the robot controller.
Type	0,1	0=Working space(Default) 1=Protected space
Activation	0~3	0=Always Off(Default) 1=Always On 2=Safety IO 3=Safety fieldbus
Max. TCP speed	1~30,000 (mm/s)	Limit of Cartesian TCP speed Default: 30,000
TCP speed monitoring	0,1	Monitor TCP speed when the tool is 0= inside of the space 1= outside of the space
Stop at bound	0,1	0=don't stop 1=stop(default)
Properties: Joint1~8		
Monitoring On/Off	On/Off	Activation of monitoring Off=This joint is not monitored(Default) On=This joint is monitored
Min	-360~360(°) or -30,000~ 30,000(mm)	Lower boundary of the joint space Default: -360
Max	-360~360(°) or -30,000~ 30,000(mm)	Upper boundary of the joint space Default: 360

The range of joint space should be considered Soft limit which is set in robot controller. If the range of working space is larger than Soft limit, the robot could be stopped in working space when the joint position is over the Soft limit range.

4.1.5. Joint speed

Joint speed is limit value for monitoring each joint speed. These parameters are monitored when the monitoring is activated. If the joint speed exceeds limit value, STO will be triggered. Joint speed parameters contain maximum speed and reduced speed when reduced mode is activated.

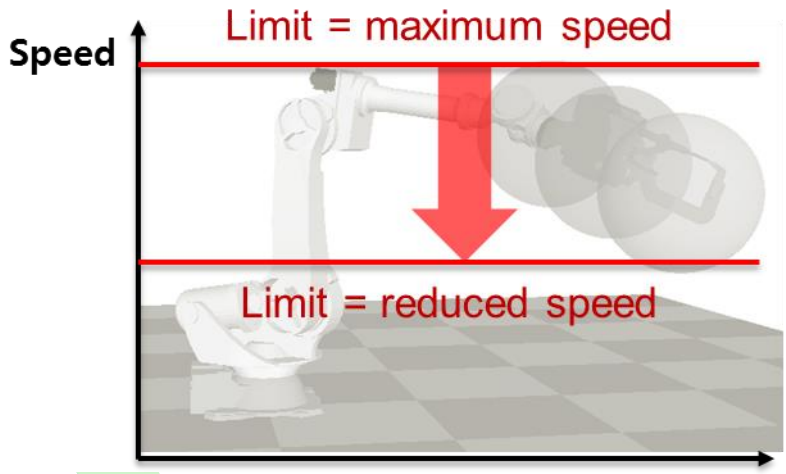


Figure 4.5 Joint speed

Table 4-5 Joint speed parameters

Joint speed parameter: 8 Joints		
Parameter name	Value	Description
Monitoring	On/Off	Off=Joint speed monitoring is deactivated On= Joint speed monitoring is activated Default: Off
Reduced speed (remote/auto mode)	1~5,000(° /s) or 1~10,000(mm/s)	Safe reduced speed in remote/auto mode. Default: 5,000(° /s) or 10,000 mm/s
Reduced speed (manual mode)	1~100(° /s) or 1~250(mm/s)	Safe reduced speed in manual mode Default: 100(° /s) or 250 mm/s
Maximum speed of rotation joint	1~5,000(° /s)	Maximum joint speed Default: 1,000
Maximum speed of translation joint	1~30,000(mm/s)	Maximum joint speed Default: 5,000

It is important that speed limit is configured considering STO reaction time.
If it is not covered, they could cause collisions and injuries.

4.1.6. SOS(Safe Operating Stop)

Safe operating stop parameters could be configured by 2 joint groups for monitoring stop state. Each joint could be selected activation and set tolerance of joint angle or distance.
If the SOS is activated, each axis will be monitored whether the joint moves or not. When the joint movement exceeds configured tolerance, STO will be triggered.

Table 4-6 Safe operating stop parameters

Safe Operating Stop parameter: 8 axes		
Parameter name	Value	Description
Monitoring in joint group1	On/Off	Off=This axis is included in group1 On=This axis isn't included in group1 Default: Off
Monitoring in joint group2	On/Off	Off=This axis is included in group2 On=This axis isn't included in group2 Default: Off
Joint tolerance	0.001~1(°) 0.003~3(mm)	Permitted joint tolerance of SOS. Default: 0.01

4.1.7. Tool

Tool could be configured up to 16 and it is modeled by several spheres. Each tool model consists of up to 6 spheres. Tool model is used for monitoring cell area and cartesian spaces. TCP is monitored by TCP speed limits. Only one tool could be activated through safety I/O signal.

TCP position should be configured based on robot flange coordinate system(Xf, Yf, Zf in Figure 3-7). Each tool's TCP position should be same with robot controller's tool data because robot monitoring function checks that SafeSpace's tool number and TCP position are same with robot controller's.

The spheres for tool modeling consist of center and radius. The sphere's center should be set based on robot flange coordinate system. These parameters are independent of the tool data set in robot controller. The radius must be large enough to cover the current tool size and stopping distance at maximum TCP speed.

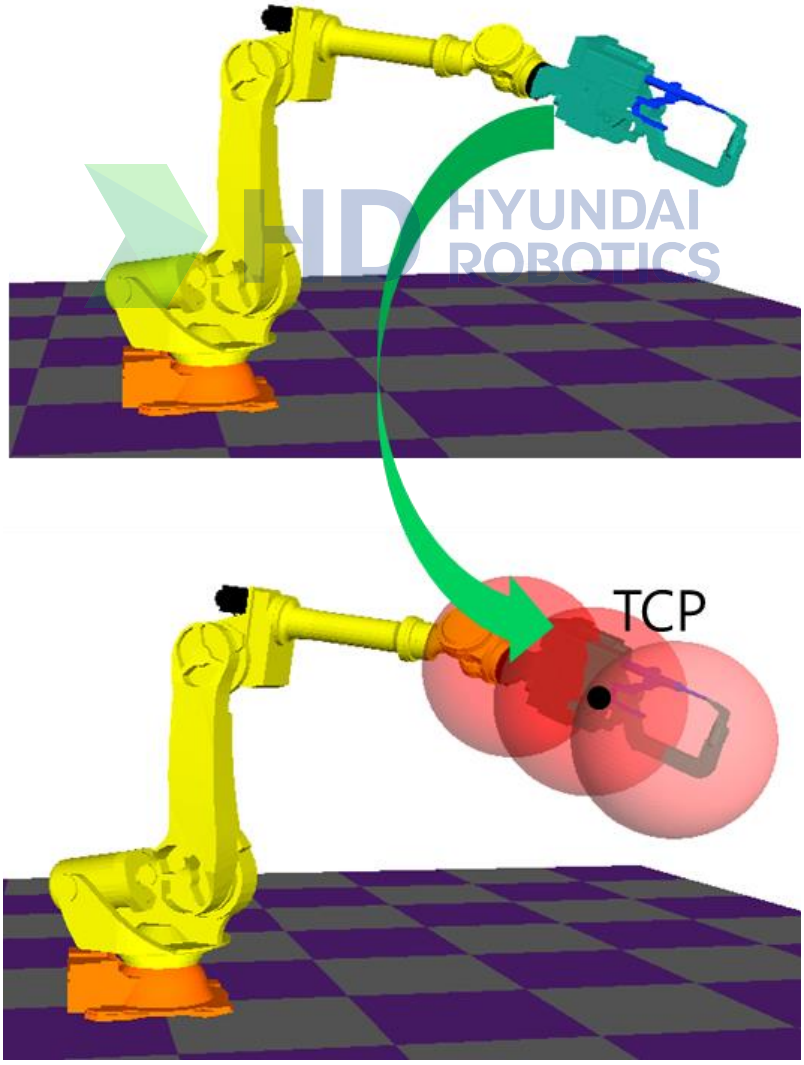


Figure 4.6 Tool modeling

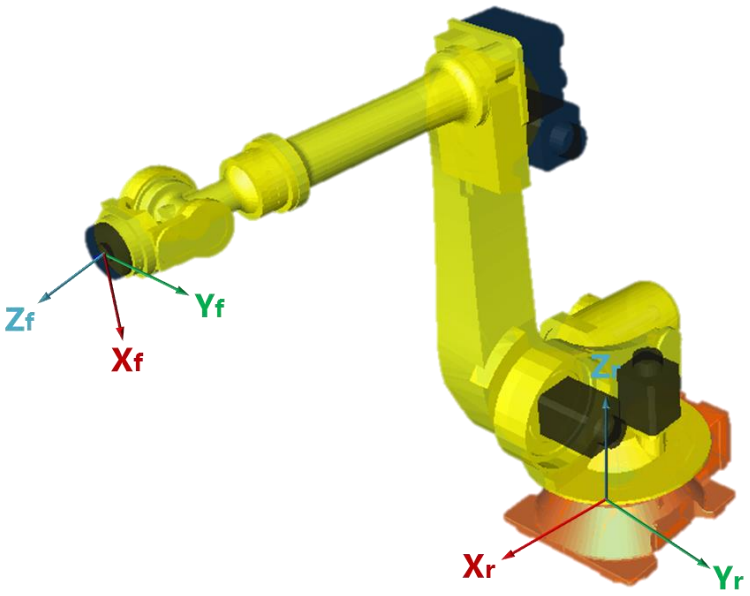


Figure 4.7 Robot flange coordinate system

Table 4-7 Tool parameters

Tool parameter: Tool 1~16			
Parameter name		Value	Description
Name		Name string	Max. 24charaters. Default="Joint Space n" ※ Used in the the HRSafeSpace only. Name is not transferred to the SafeSpace from the robot controller.
TCP	X	-10,000~ 10,000(mm)	XYZ coordinate values of TCP Default: 0
	Y		
	Z		
Properties: Sphere1~6			
On/Off		On/Off	Off=This sphere is not monitored On=This sphere is monitored Default: On(Sphere1), Off(Sphere2~6)
Center	X	XYZ coordinate values of a sphere's center in flange coordinate system. Default: 0	XYZ coordinate values of a sphere's center in flange coordinate system. Default: 0
	Y		
	Z		
Radius		0~10,000 (mm)	Radius of a sphere Default: 1,000(mm)

4.2. Release STO function

If the robot violates the safety parameters, the SafeSpace triggers STO and robot will be stop. The operator should check the robot and safety parameters. After that, the operator should release STO function and move the robot to safe area.

In SafeSpace monitoring menu, you can monitor the violation of configured spaces. Also you can release STO caused by violation and move the robot to safe area with manual mode. The status would be updated in real time.

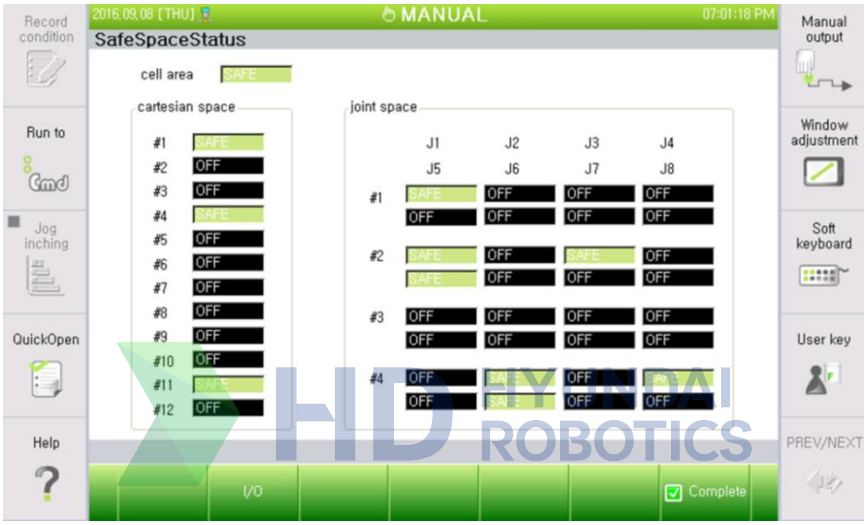


Figure 4.8 SafeSpace Status

When the STO triggered, the error messages would be occurred in teach pendant and expressed at I/O page in SafeSpace monitoring menu. You can check the reasons of STO and maintain the robot.
In I/O page, there are status and assignment of input/output signals.

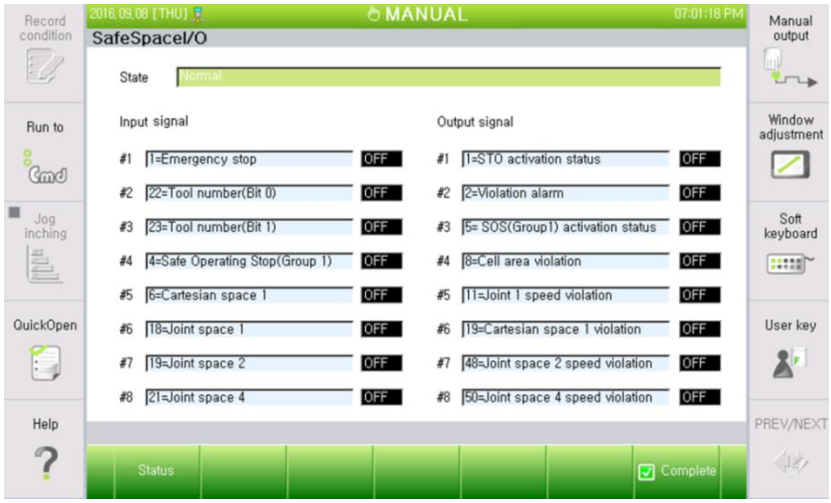


Figure 4.9 SafeSpace I/O

4.3. Mastering test function

The position of robot should have validity for reliable robot monitoring. The mastering test function helps to evaluate the condition of robot and external axes. When the deviation of reference position and current position is too large, robot controller occurred error and robot would be stopped. The operator should maintain the robot and calibrate it.

There are two types of mastering test.

Table 4-8 Mastering test types

	Sensorless mastering test (SLMT)	Sensor based mastering test (SBMT)
Reference position	Position of sharp object or marked equipment	Position of conductive sensor
Method	Manually performed by operator	Automatically performed by program
Verify	Safety user	Sensor signal

In mastering test menu, users have to select test type, test time and test position. These are common things to configure for SLMT and SBMT.

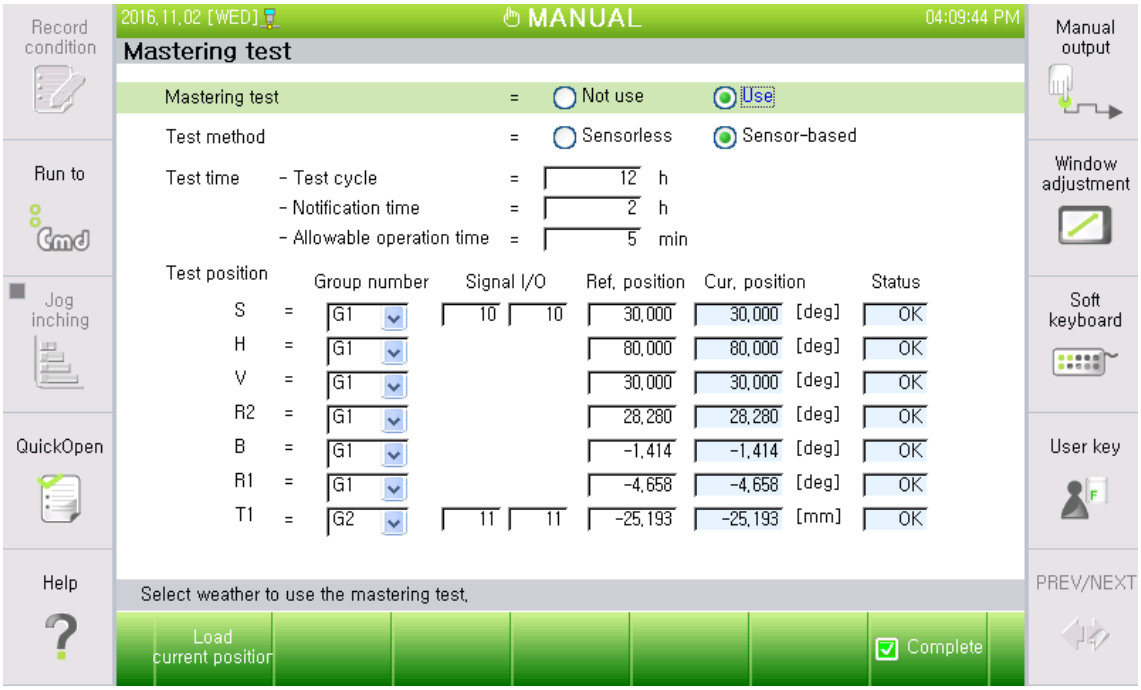


Figure 4.10 Mastering test menu

Table 4-9 Mastering test parameters

Mastering test	Select to use the mastering test	
Test type	Select one of types for test	
Test time	Test cycle time [h]	Period of test cycle(12h ~720h) Default: 12h
	Pre-alarm time [h]	Notify hours before the test stars (1h~11h) Default: 1h
	Max time limit [min]	Max time to move the robot since motor on when the robot stopped because of overtime (1min~60min) Default: 1min
Test position	Group	Groups number for mastering test (1~3)
	I/O signal	- input/output signal - only for using SBMT
	Reference Pos. [deg], [mm]	- Reference position to verify the deviation - jog and press F1 key, read current position for reference
	Current Pos. [deg],[mm]	Current position or each axis – ready only
	Status	Express of deviation between Current position and reference position -OK: position of joint is in the range -NG: position of joint is out of range

If you want to save the configured parameters, the SafeSpace password should be needed. Setting or changing parameters and performing SLMT should be protected by password. The password is set by HRSafeSpace.

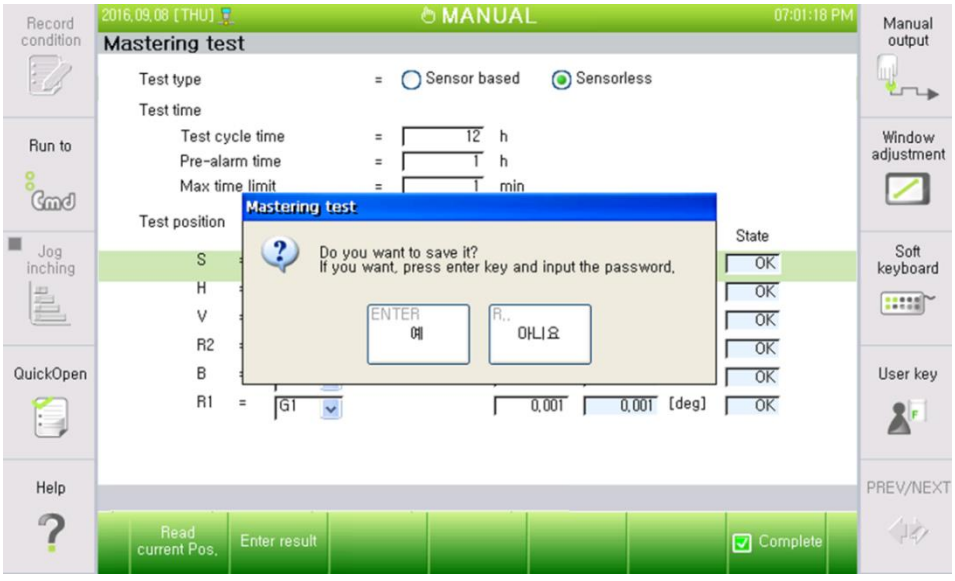


Figure 4.11 Enter the password for save parameters

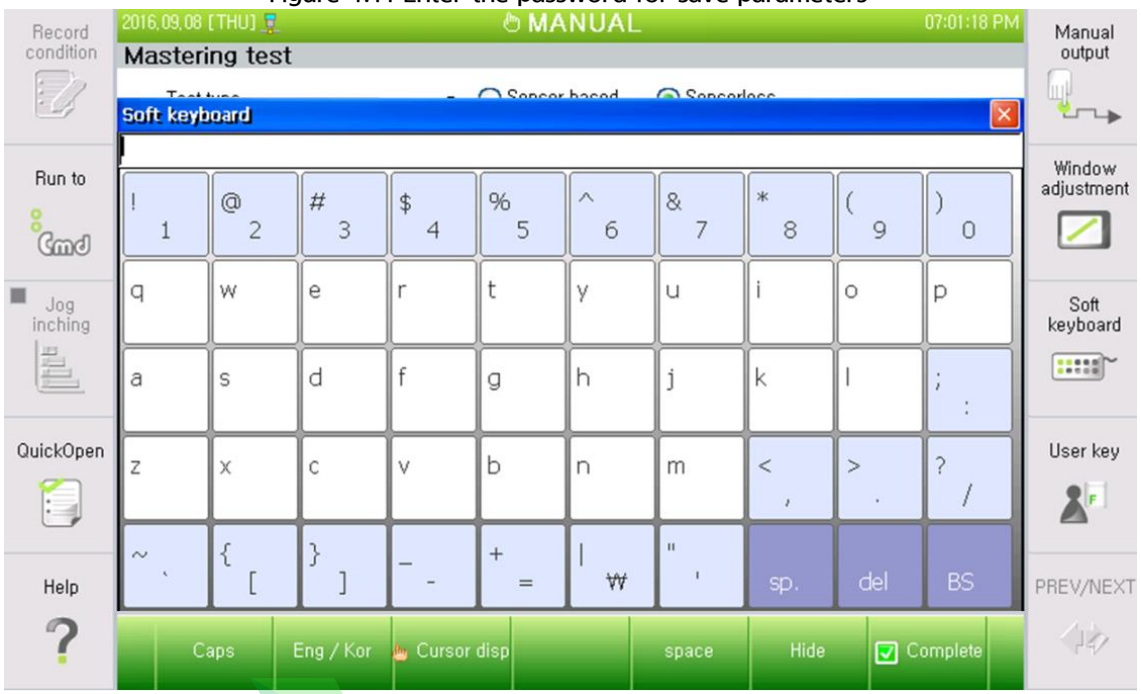


Figure 4.12 Soft keyboard for input password

4.3.1. Sensorless mastering test

If the test type is changed to Sensorless mastering test(SLMT), F2 key will be activated. After setting the mastering test parameters in mastering test menu, SLMT could be performed by [F2:Enter result] key.

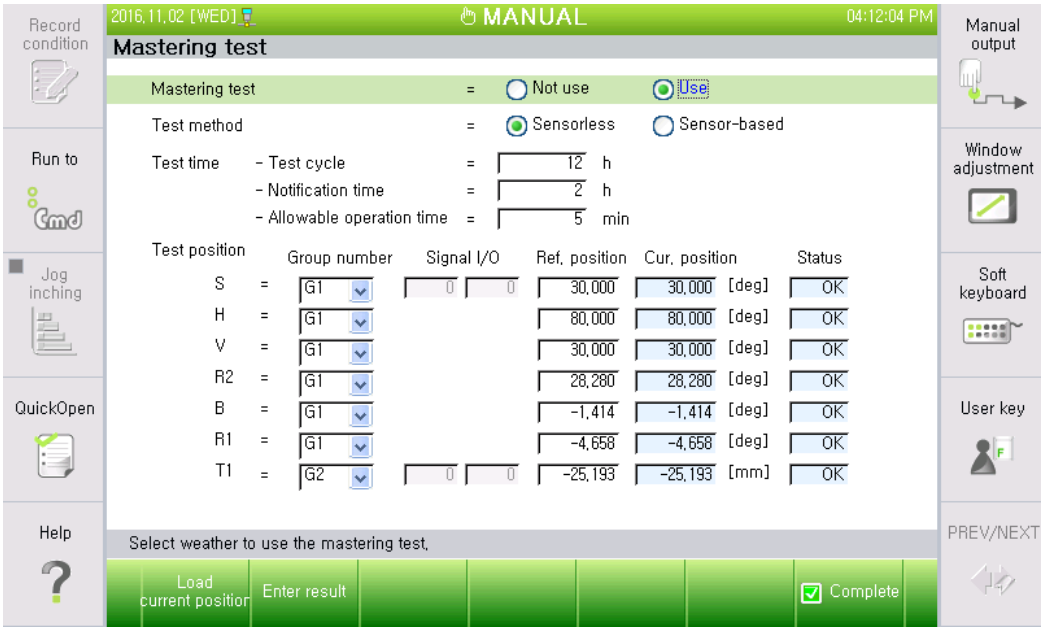


Figure 4.13 SLMT activated F2 key

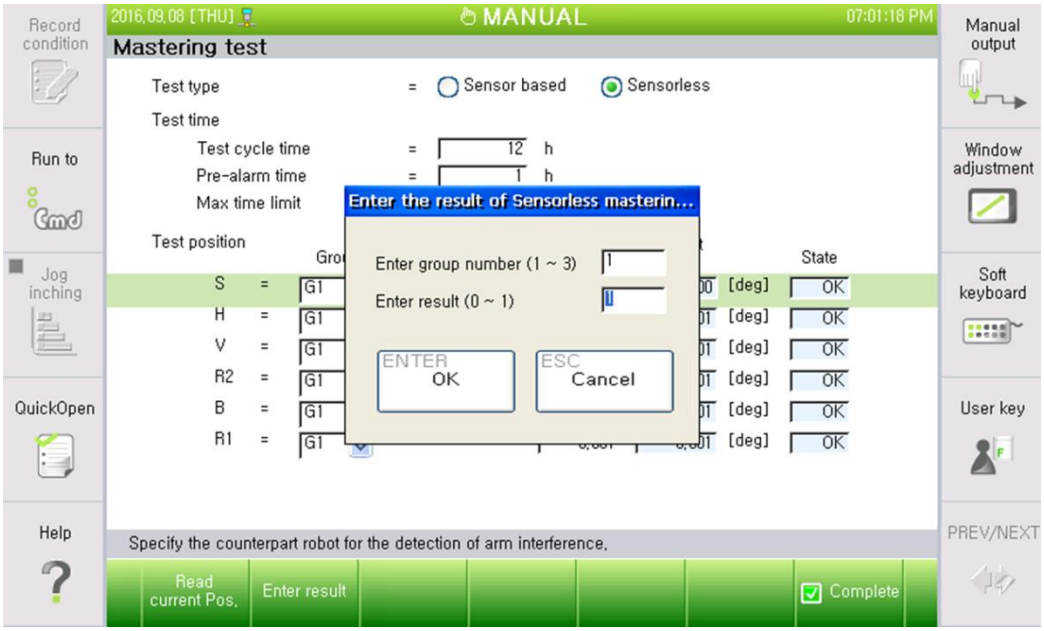


Figure 4.14 SLMT result

The user has to check that each state is OK at reference position and visually verify it. And then the user enters the group number and its result.

If the robot did not meet the sharp object at reference position or the user did not perform within test cycle time, STO will be triggered and the robot could move for max limited time.

4.3.2. Sensor based mastering test

After setting the mastering test parameters in mastering test menu, sensor based mastering test(SBMT) needs programming with function MSTtest and system variable _MSTRef, _MSTResult. The embedded PLC should be programmed for dual sensor input signal.

Table 4-10 Mastering test function and variable

MSTtest		
Explanation	This function defines make a branch according to condition.	
Syntax	MSTtest G=〈group No.〉 TEHN CALL 〈program No.〉	
Parameter	Group number	Groups number for mastering test (1~3)
	Program number	MST program number
Example	MSTtest G=1 THEN CALL 10	
_MSTRef		
Explanation	This variable means reference position which configured in mastering test menu.	
Syntax	_MSTRef〈group No.〉	

Example	P1=_MSTRef1
_MSTResult	
Explanation	This variable means the result of mastering test (0=fail, 1=pass)
Syntax	_MSTResult〈group No.〉
Example	V1%=_MSTResult1

Table 4-11 Mastering test programming

MST Program	
Explanation	- Teaching reference position and approach positions - Approach positions are moving to reference position to avoid collision - Reference position is the value configured in mastering test menu - Reference position should be assigned to Pose variable by using _MSTRef - Set the speed to move reference position should be slow enough for safety - Insert WAIT for decision of _MSTResult after arrived at reference position
Example	**P1=_MSTRef1** MOVE L, S=60%,A=1,T=1 : approach position **MOVE L, P1, S=5%,A=0,T=1 : Reference position** **WAIT 1=_MSTResult1, 10, S5** MOVE L, S=60%,A=1,T=1 END
Main Program	
Explanation	- Insert the function MSTtest in the main JOB program. - MSTtest will call MST program when the time meets from pre-alarm time to test cycle time
Example	MOVE L, S=60%,A=1,T=1 MOVE L, S=60%,A=1,T=1 MOVE L, S=60%,A=1,T=1 …… **MSTtest G=1 THEN CALL 10** END
	The number of groups is same with the number of MST programs.

If the robot controller did not receive sensor signal at reference position or MSTtest did not perform within test cycle time, STO will be triggered and the robot could move for max limited time.

4.3.3. Monitoring state of mastering test

The monitoring window displays mastering test state. It shows last execution date, residual time before test and progress of each mastering group.

It can be set by selecting 『[F1]: Service』 → 『1: Monitoring』 → 『25: Mastering test state』

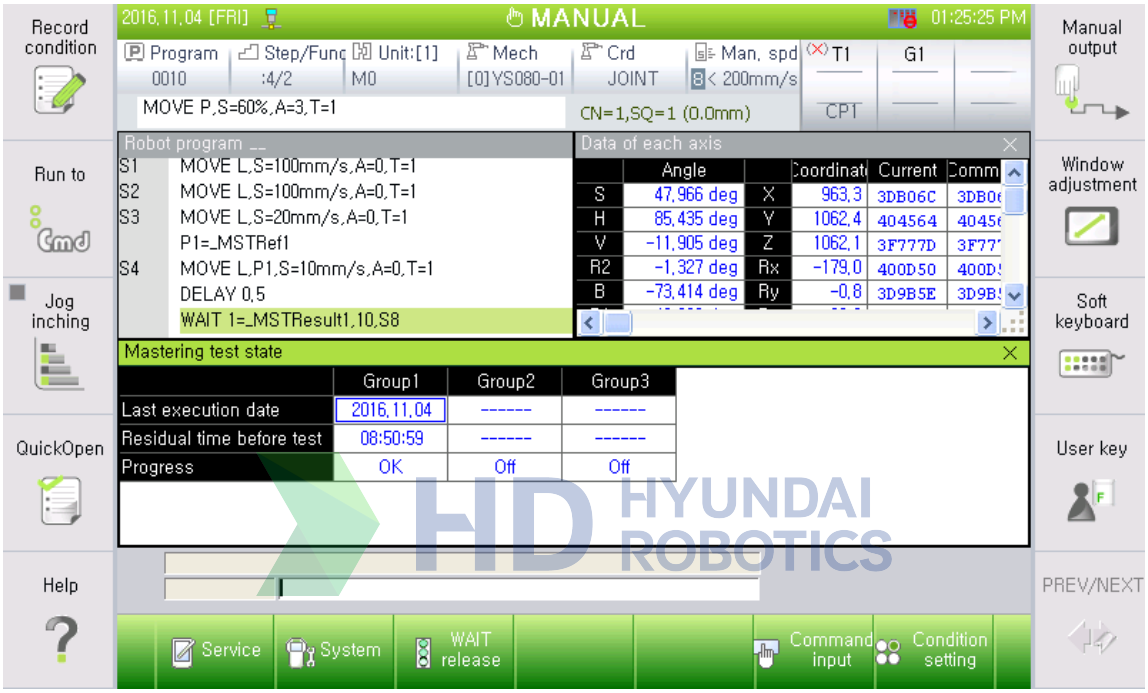


Figure 4.15 Monitoring mastering test state

The progress of mastering test has four cases.

- **Off**: not use SafeSpace or disable mastering test
- **Error**: result of mastering test was fail
- **OK**: result of mastering test was pass
- **Ready**: mastering test can be executed
- **Play**: mastering test is running
- **Time limit**: robot can move for mastering test after error state

5 Safety I/O signals

5. Safety I/O signals

Safety I/O could be assigned by using HRSafeSpace. Input and Output signals could be configured up to 8 respectively.

Table 5-1 Safety I/O parameters

Safety I/O parameter: 8 inputs/ouputs		
Parameter name	Value	Description
IN0~IN3		
Input signal allocation	0~25	Activation signal allocation 0=None 1=Emergency stop 2=Reference switch input 3=Reduced speed monitoring 4=Safe Operating Stop(Group 1) 5=Safe Operating Stop(Group 2) 6~17=Cartesian space1~12 18~21=Joint space1~4 22=Tool number(Bit 0) 23=Tool number(Bit 1) 24=Tool number(Bit 2) 25=Tool number(Bit 3)
IN4~IN7		
Input signal allocation	0~21	Activation signal allocation 0=None 1=Emergency stop 2=Reference switch input 3=Reduced speed monitoring 4=Safe Operating Stop(Group 1) 5=Safe Operating Stop(Group 2) 6~17=Cartesian space1~12 18~21=Joint space1~4 ※ Activation signals for tool number can't be allocated to the IN4~7.
OUT0~ OUT7		
Output signal allocation	0~50	Monitoring signal allocation 0=None 1=STO activation status 2=Violation alarm 3= SafeSpace activation status 4= Reduced speed activation status 5= SOS(Group1) activation status 6= SOS(Group2) activation status 7=Global TCP speed violation 8=Cell area violation 9=SOS(Group1) violation 10=SOS(Group2) violation 11~18=Joint speed violation(Joint1~8) 19~30=Cartesian space violation(Space1~12) 31~34=Joint space1~4 violation 35~46=Cartesian space speed violation(Space1~12) 47~50=Joint space speed violation

6

HRSafeSpace installation and start

Run the installer file, HRSafeSpace.msi. Follow the instructions while clicking the [Next >] button.

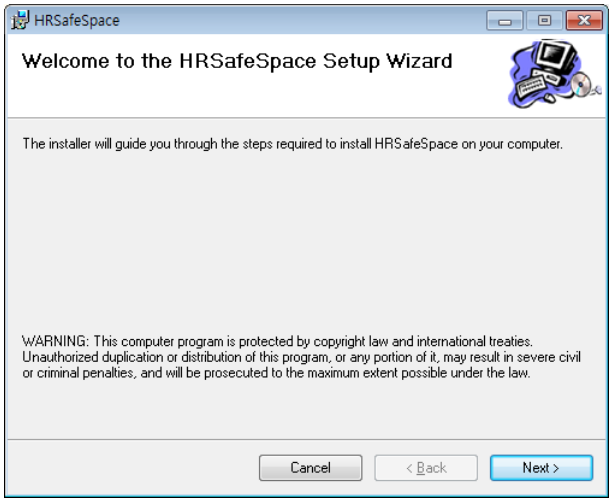


Figure 6.1 HRSafeSpace installation wizard

When the installation is completed, the icon of HRSafeSpace will be created on the wallpaper and the Windows START button. Double-click the icon on wallpaper or select HRSafeSpace. In Windows START button.

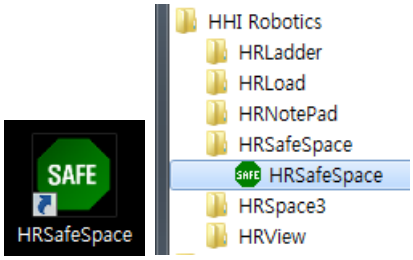


Figure 6.2 HRSafeSpace icon

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7

HRSafeSpace - Basic

7.1. Data Input

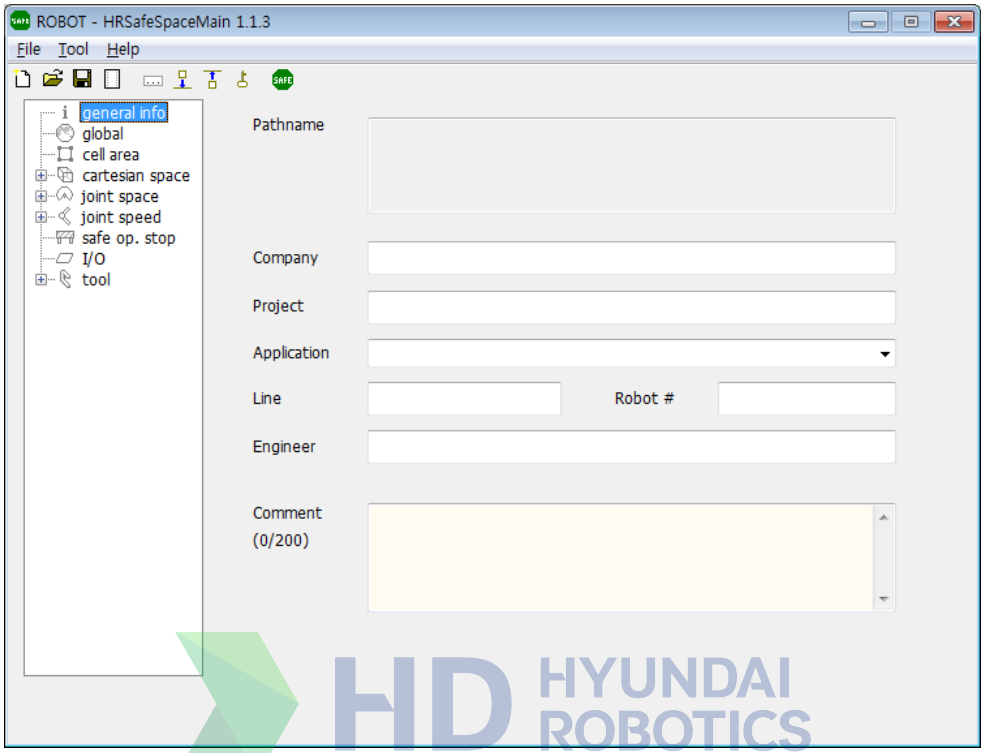

Figure 7.1 HRSafeSpace execution screen

When HRSafeSpace is started, the screen will be displayed as shown in Figure 3.1. On left-side, a tree-control is located for selection of group. HRSafeSpace provides with 9 groups of parameters. Amongst these, some groups have their sub-groups like below.

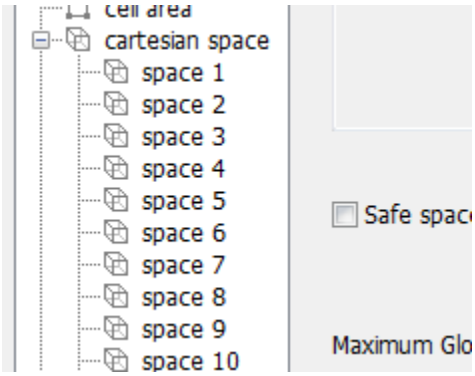

Figure 7.2 Some groups have their sub-groups

If you click a group or sub-group node, corresponding set-up page appears. At first, the pages are filled with default parameter values. Edit the parameters. If you click another node of tree-control, the edited values are applied to memory of HRSafeSpace

If you want to re-initialize the parameters as default value, select File – New menu, or click button.

7.2. Save, open data

When you complete editing parameters, save it by selecting File - Save menu or clicking button on the Toolbar.

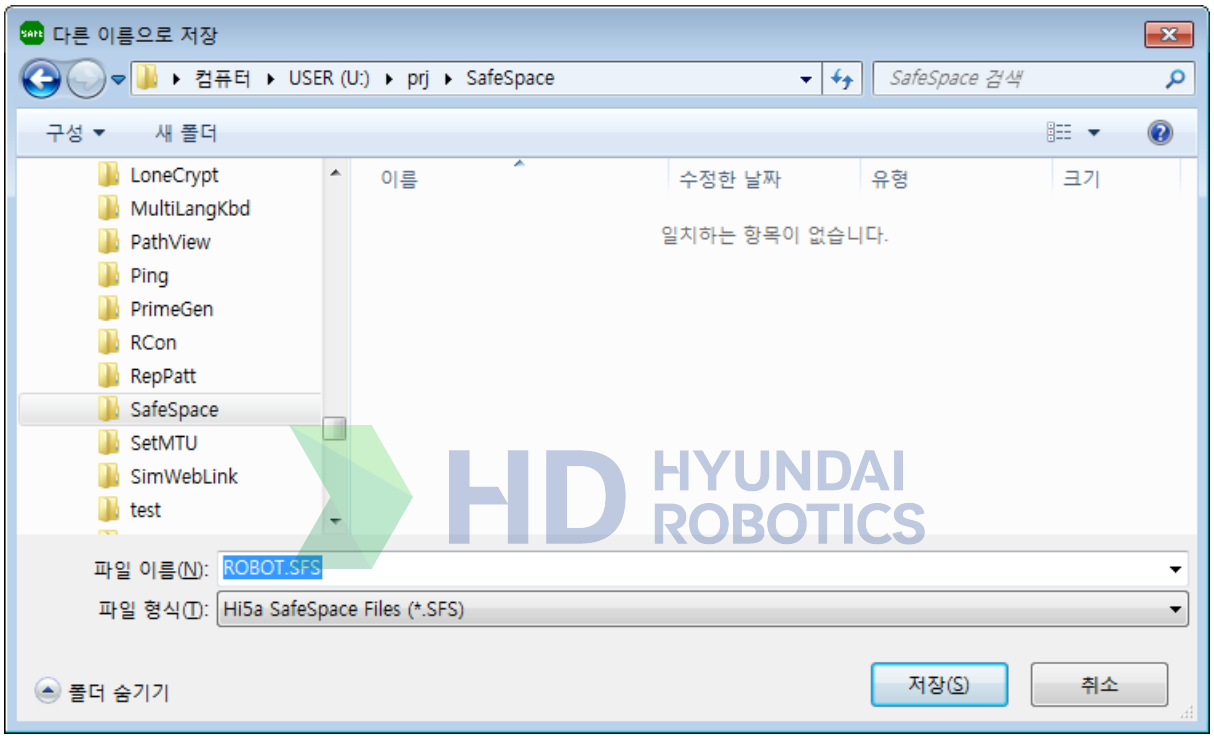

Figure 7.3 Save dialog-box

The default file-title is ROBOT and file-extension is .SFS. You may change the file-title as you wish, but when you download the SFS file, the file is saved as the standard name 'ROBOT.SFS' in the Hi5a robot controller.

And, you can load the saved file by selecting File – Open… menu or clicking button on the ToolBar.

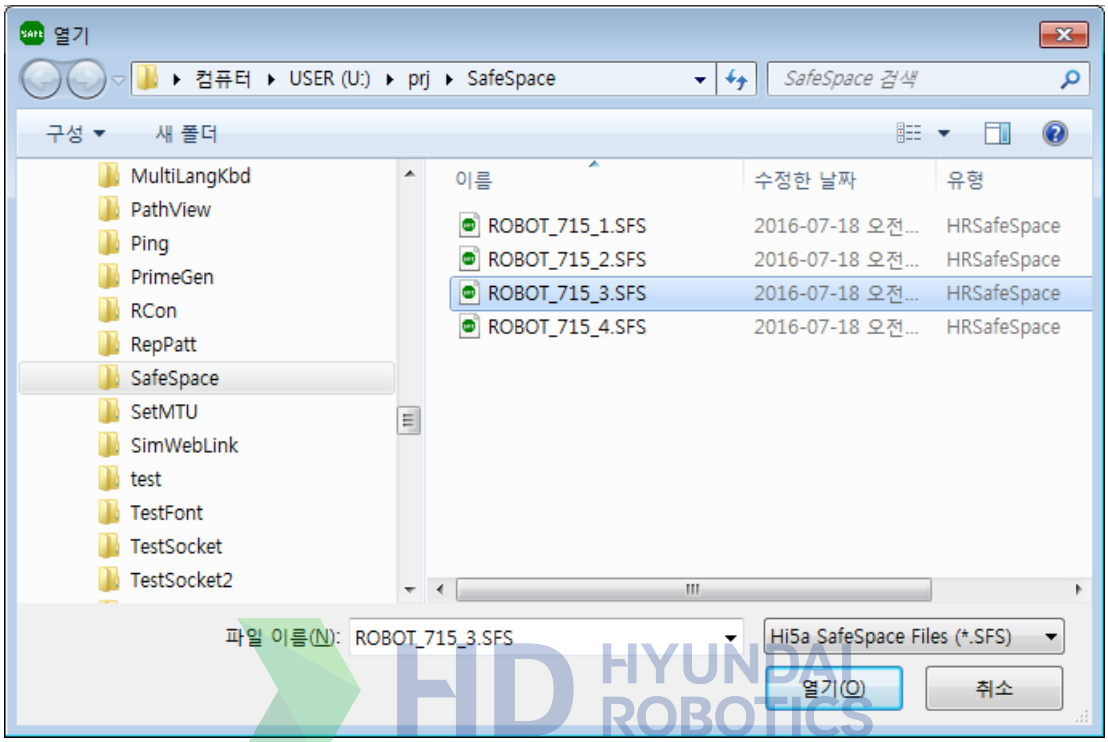

Figure 7.4 Open… dialog-box

The full path/filename is displayed in general info. group's page.

Figure 7.5 Full path/filename

7.3. Communication set-up

In order to download the SafeSpace parameter file to Hi5a robot controller, Ethernet communication between PC and Hi5a has to be connected. Select Tool – Set IP Address menu, or click button on ToolBar.

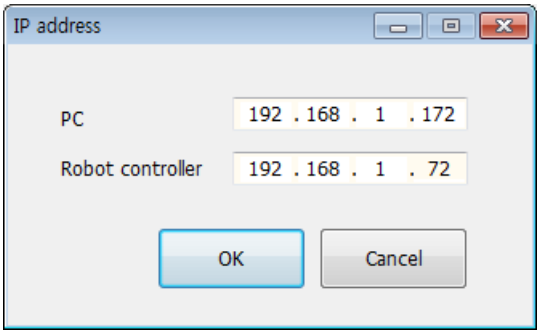

Figure 7.6 IP address set-up dialog-box

Input PC's IP address and Hi5a robot controller's IP address, and click OK.

7.4. Initializing Hi5a robot controller's password.

Only the authorized person is permitted to download the ROBOT.SFS file. So, if you want to use SafeSpace feature of some Hi5a robot controller, the Hi5a has to be initialized with SafeSpace password.

Select Tool – Change Password, or click button on ToolBar. If no one set a password since the Hi5a is system-initialized (formatted), below dialog-box appears. Set the SafeSpace password, and click Change button. The password is stored in the Hi5a controller.

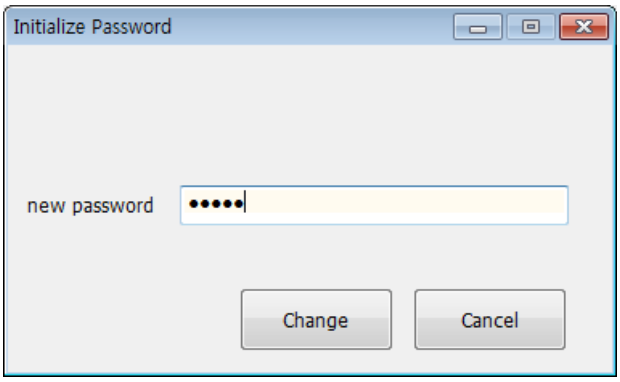

Figure 7.7 Initialize Password dialog-box

Once a password is initialized, if you want to change the password, select Tool – Change Password, or click button on ToolBar. You have to input correct old password, and input new password.

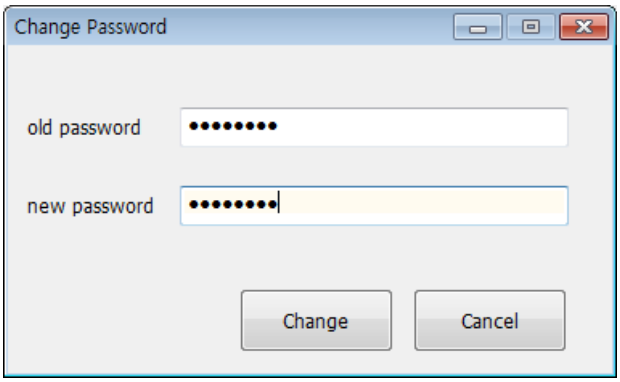

Figure 7.8 Change Password dialog-box

7.5. Downloading the parameter file

If the procedures of section 3.1 ~ 3.4 are completed, you can download the SafeSpace file to Hi5a robot controller. Select Tool – Download, or click button on ToolBar.

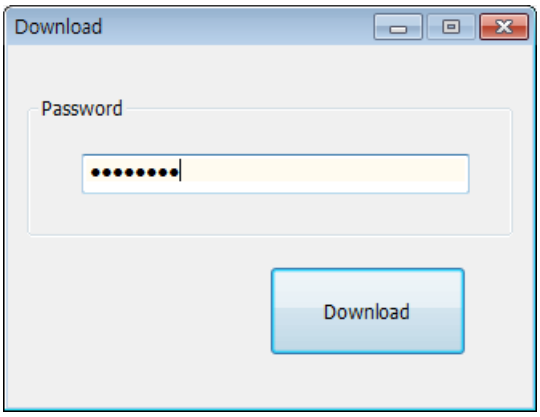

Figure 7.9 Download dialog-box

You have to input correct SafeSpace password. Click Download button. If the password is valid, 'Completed' message-box appears. Reboot the robot controller to apply the setting.

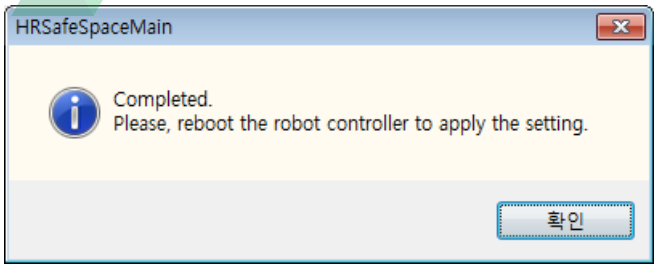

Figure 7.10 'Completed' dialog-box

Even though the password is incorrect, SafeSpace file is downloaded to the Hi5a, but the SafeSpace feature fails to be initialized, and below message-box appears.

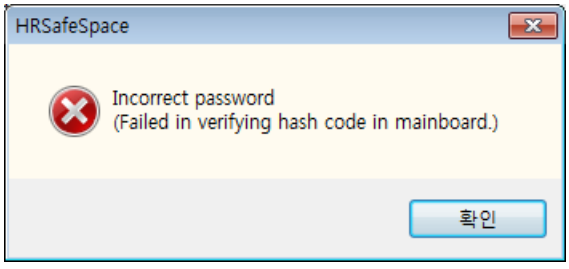

Figure 7.11 'Incorrect password' dialog-box

7.6. Uploading the parameter file

If the communication set-up (section 3.3) is completed, you can upload the SafeSpace file from Hi5a robot controller. Select Tool – Upload, or click button on ToolBar. Password is not needed for uploading.

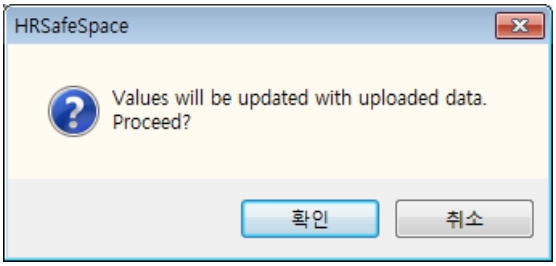

Figure 7.12 Message-box of upload proceeding

The uploaded file is stored in temporary folder of the PC, and the file data come to be loaded in dialog-box. So, if you click OK on the message-box to proceed, you will lose current data that you input on dialog-box.

If uploading is successful, 'Completed' message-box appears.

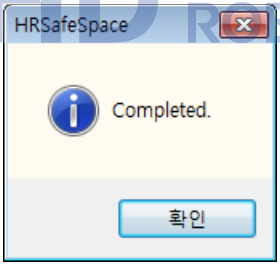

Figure 7.13 'Completed' dialog-box

7.7. 3D-visualizing with HRSpace

In general, a production-line cell or line including robots is planned with OLP (off-line programming) software. HRSpace is OLP simulation software for Hyundai robots.

The SafeSpace configuration you input can be visualized in 3D virtual workspace on HRSpace. This chapter explains how to do this visualization.

HRSpace version 3.73 or later have to prepared. If your HRSpace is older version, download the latest version and install it. And if you are unfamiliar with the usage of HRSpace, study how to use it. (In Home ribbon menu, click Manual button, to open the user manual of HRSpace.)

Because HRSpace invoke HRSafeSpace as a child process, HRSpace have to know the location of HRSafeSpace.exe file. Select Misc. – Preference ribbon menu..

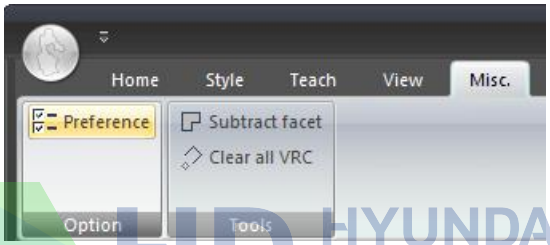

Figure 7.14 Misc. – Preference in ribbon menu

In General tab of the Preference property page, you can specify the path/filename of the installed HRSafeSpace.exe. If you installed HRSafeSpace at default path ({Program Files}/HHI Robotics/HRSafeSpace), you may leave this setting empty.

Figure 7.15 Specifying HRSafeSpace path/filename

Now HRSafeSpace has been bound to HRSpace. The detailed way to use is explained in the next chapter with an example.

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8

HRSafeSpace – Practice

Let's suppose we have designed a layout of robot spot-welding cell like below;

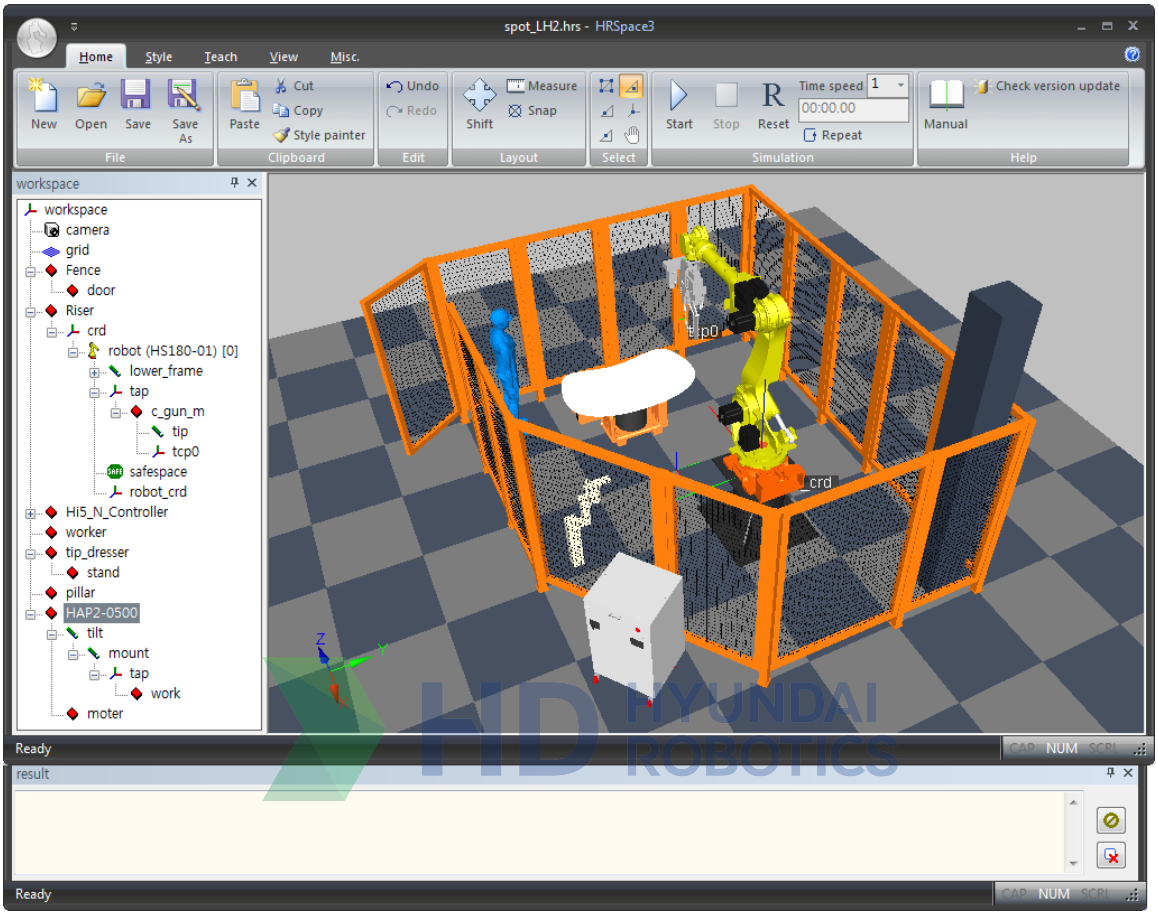

Figure 8.1 Example of robot spot-welding cell

There is one HS180-01 manipulator on a riser. A C-type spot welding gun is mounted on the robot flange, and the robot is mounted on a riser which height is 800mm. At the beginning of each work-cycle, a human worker installs a welding-workpiece on the positioner in front of the robot. The whole cell is surrounded by five-sided fence. Let's assume the robot's movement of Z-axis is limited to 0 ~ 3400mm because of ducts on ceiling, and there is a pillar inside of the fence.

We will configure the SafeSpace parameter by help of HRSpace visualization and then download the created ROBOT.SFS file into actual Hi5a robot controller.

8.1. Creating SafeSpace model in HRSpace

In order to bind the HRSafeSpace to this HRSpace project, you have to create a SafeSpace model as a child of the robot.

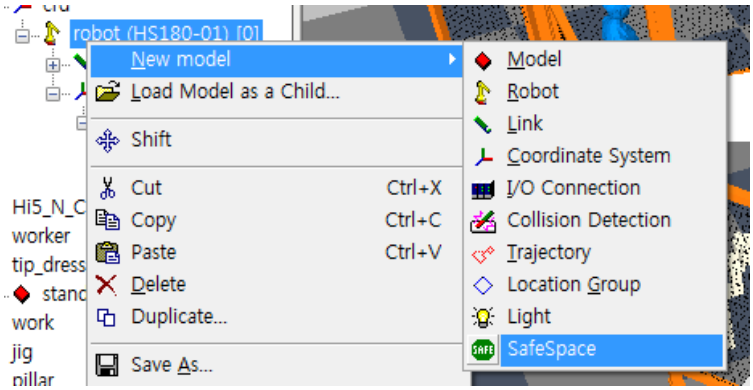

Figure 8.2 Creating a SafeSpace model as a child of the robot

Then, select the SafeSpace properties... pop-up menu. This menu just opens the HRSafeSpace software.

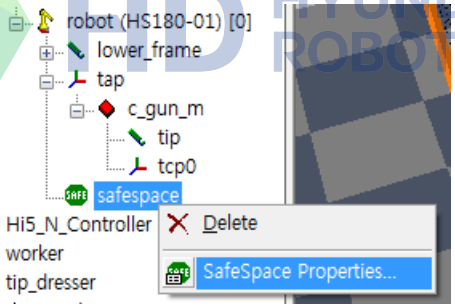

Figure 8.3 Opening SafeSpace Properties

You can see the path of ROBOT.SFS file is automatically set as the robot's VRC's folder. In this state, once you click save tool button, the ROBOT.SFS file is initially generated in VRC folder. Now, specify each group's parameters with HRSafeSpace.

8.2. Setting the parameters

8.2.1. General Info

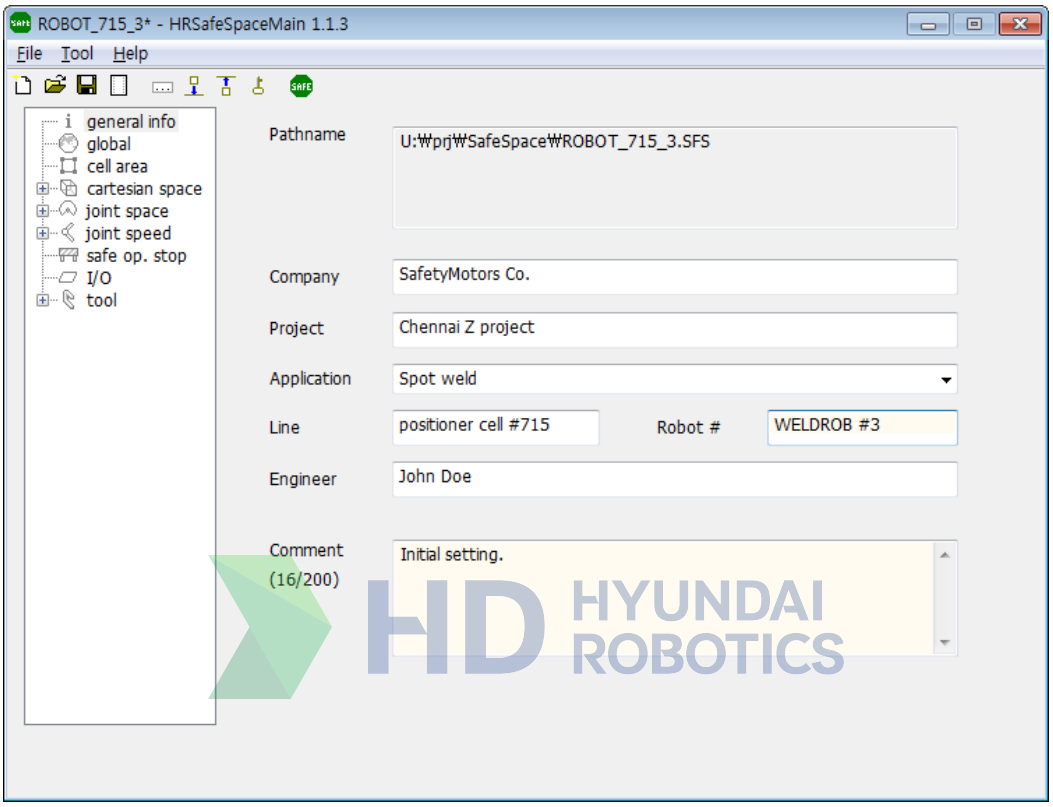

Figure 8.4 general info

First group is general information. This setting is only for human, so it doesn't affect the operation of SafeSpace. (If not needed, you can skip this setting.)

8.2.2. Global

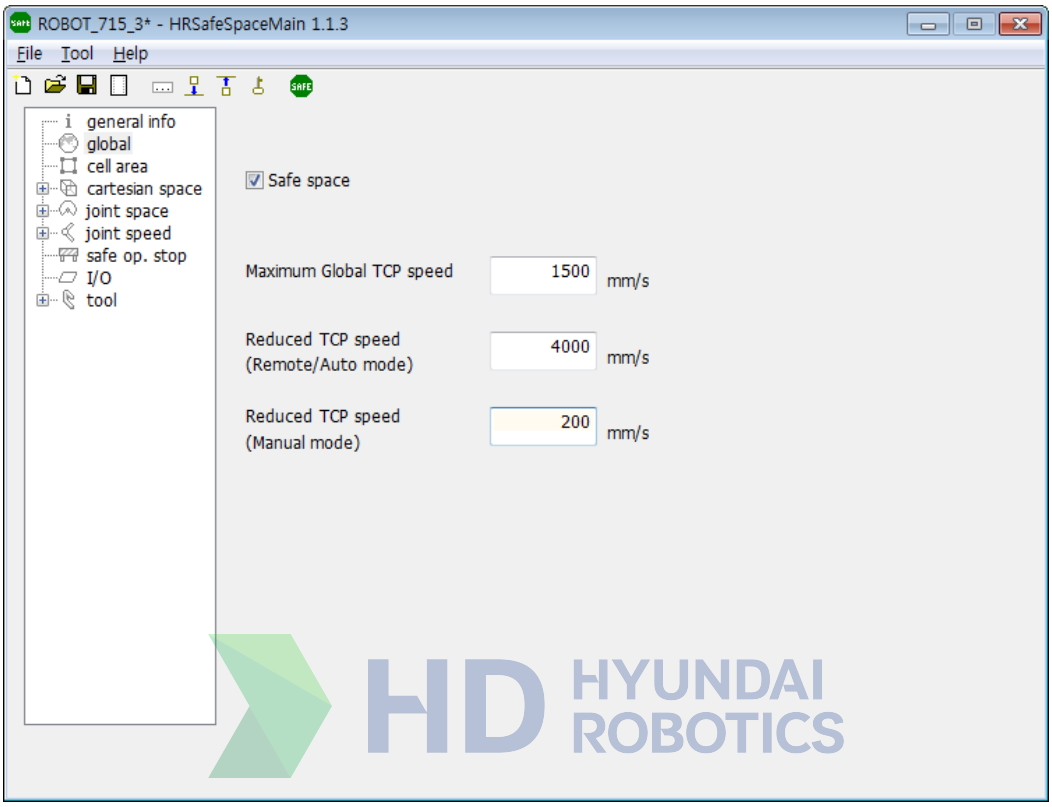

Figure 8.5 global setting

Check the Safe space check-box in global group to activate the SafeSpace. Limit the global and Remote/Auto mode TCP speed to 1500mm/s and Manual mode TCP speed to 250mm/s. Now You can see some default settings of SafeSpace are displayed as translucent primitive shape in 3D workspace.

8.2.3. Cell Area

Let's set the cell area. For easy setting, push View - orthographic view button, and click the button to move the camera. It would be helpful for intuitive view, to align the X, Y directions of HRSafeSpace's cell area 2D diagram and HRSpace's 3D view. (Note that it is robot coordinate system, not world coordinate system.) In HRSpace's 3D view, the cell area is expressed as cyan colored polyhedron.

Because the permitted Z area is 0 ~ 3400mm and the riser's height is 800mm, you have to set Zmin and Zmax as -800, 2600mm. And because the fence are is five-sided, input five vertices and set the Z area as 0 ~ 3200 mm as you planned. In the list control of cell area page, the order of vertices is not important. HRSafeSpace internally sort them automatically. Whenever you click save tool button of HRSafeSpace, your current setting is applied to the 3D workspace of HRSpace.

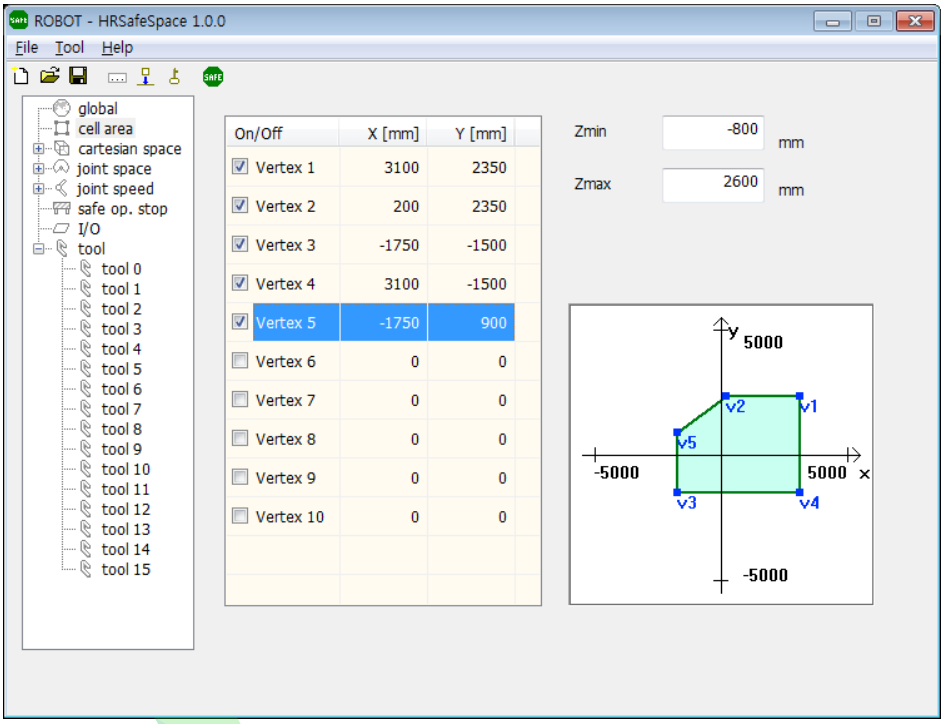

Figure 8.6 cell area setting

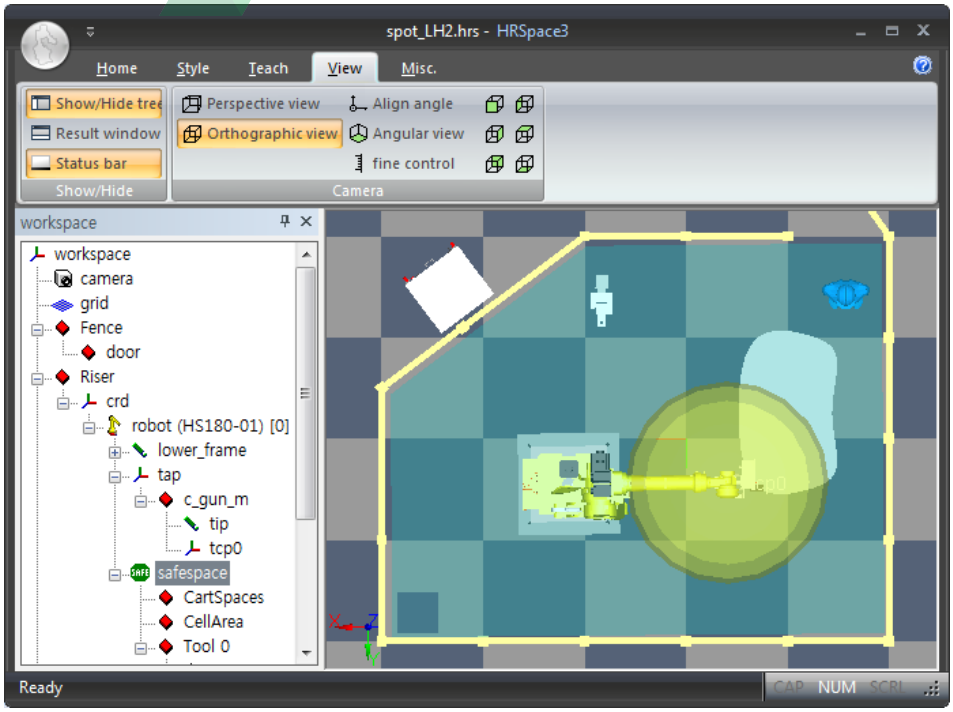

Figure 8.7 cell area in HRSpace 3D view (floor plan)

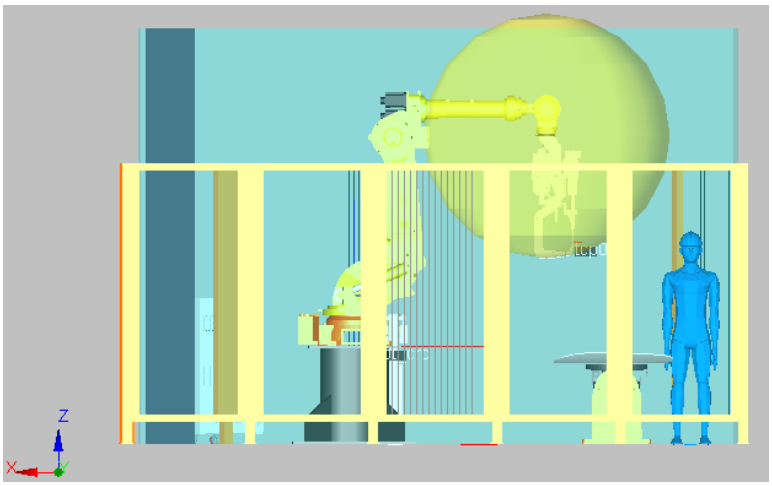

Figure 8.8 cell area in HRSpace 3D view (elevation)

8.2.4. Cartesian space

To prohibit the robot crash against the pillar in the fence, you will make it as protected space. Set the space 1 as below figure. We will use just global TCP speed limit, so ignore the setting of TPC speed setting of this page. And sometimes a human worker enters into the fence, make the space in front of the fence door the second protected space. Make it activated by Safety I/O. (activated by fence door or laser sensor)

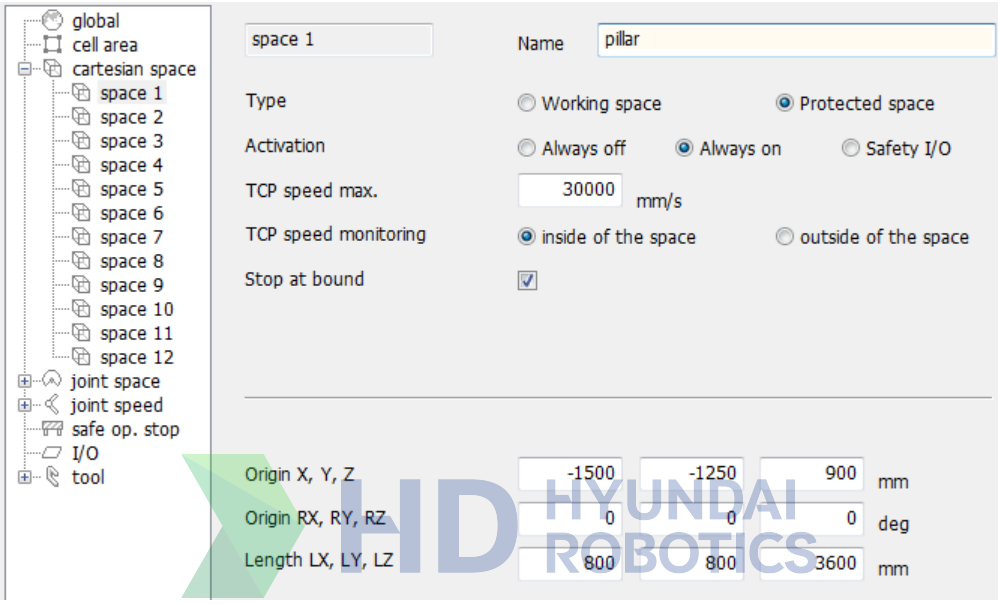

Figure 8.9 protected space - pillar

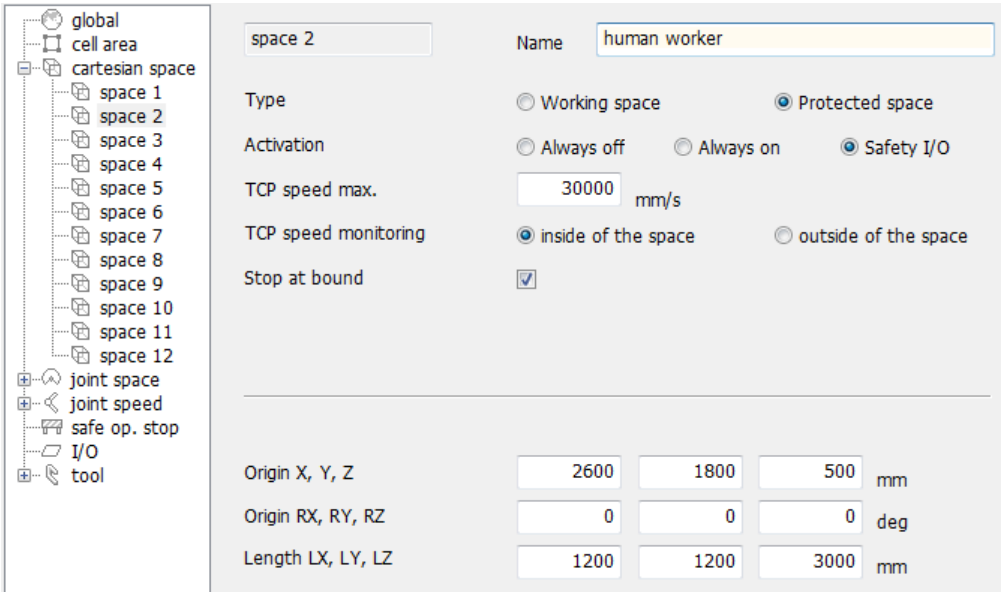

Figure 8.10 protected space – human worker

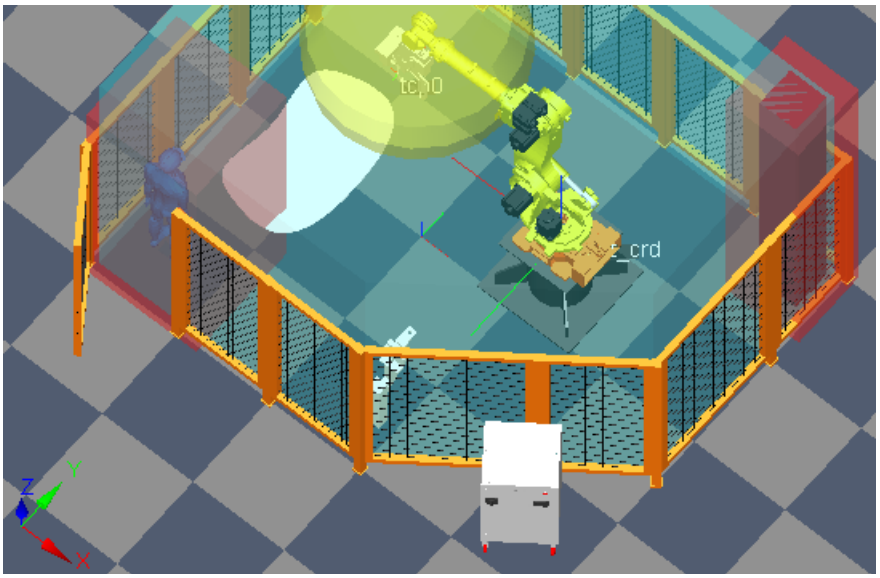

Figure 8.11 protected spaces in HRSpace 3D view

8.2.5. Tool

In this example, the spot welding gun is tool 0 (T0). It have to be wrapped by a set of spheres. When one or more of the sphere intersect with the protected area or outer side of cell area, SafeSpace will regard the situation as a collision. In this sample, we have set 3 spheres to wrap the T0 and robot wrist body. (Use tool coordinate system.)

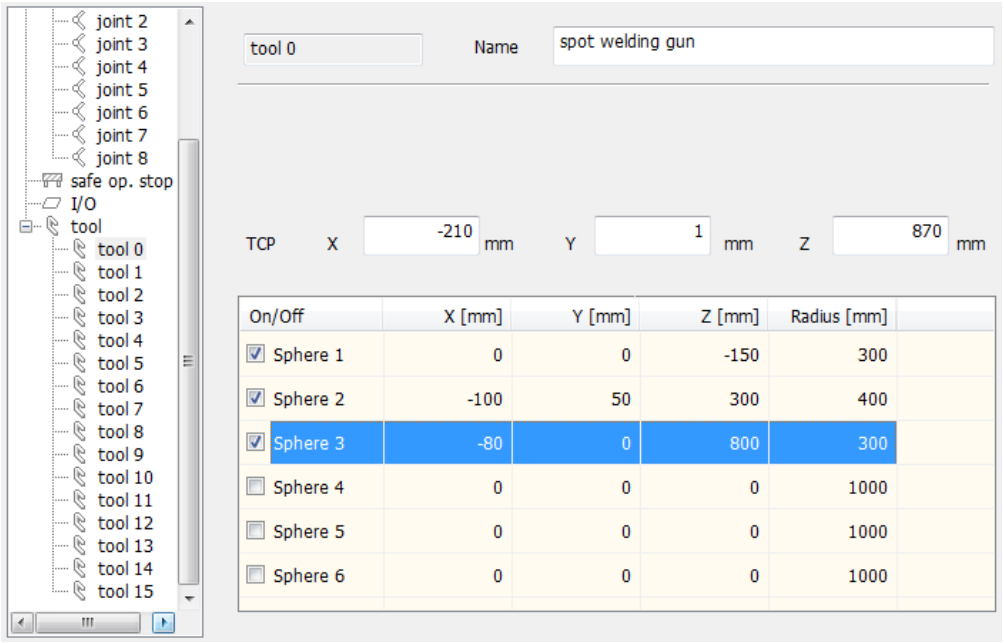

Figure 8.12 tool 0 setting

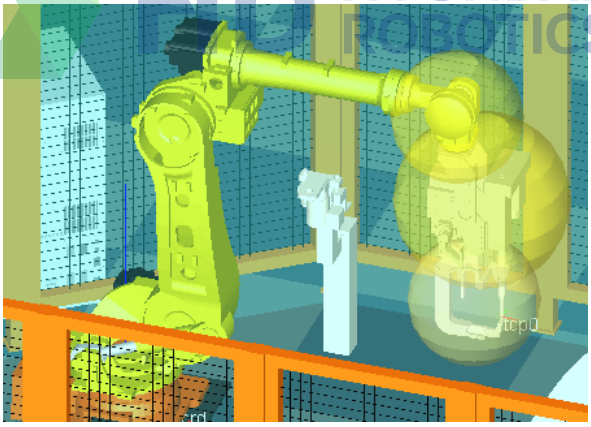

Figure 8.13 tool 0 spheres in HRSpace 3D view

8.2.6. Joint space

In this example, robot's role is doing spot-welding on the workpiece and intermittent tip-dressing. So, considering the layout of the workpiece and the tip-dresser, the robot's S-axis can be limited to -40 ~ +95 deg. Set the space 1 as the working space for S-axis. (The setting of joint space doesn't expressed on HRSpace 3D view.)

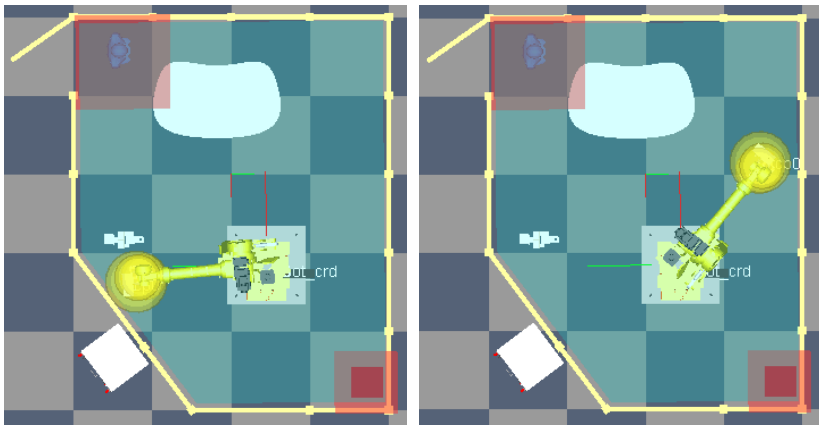

Figure 8.14 Robot poses when its S-axis value is +95 deg.(left) and -45 deg.(right)

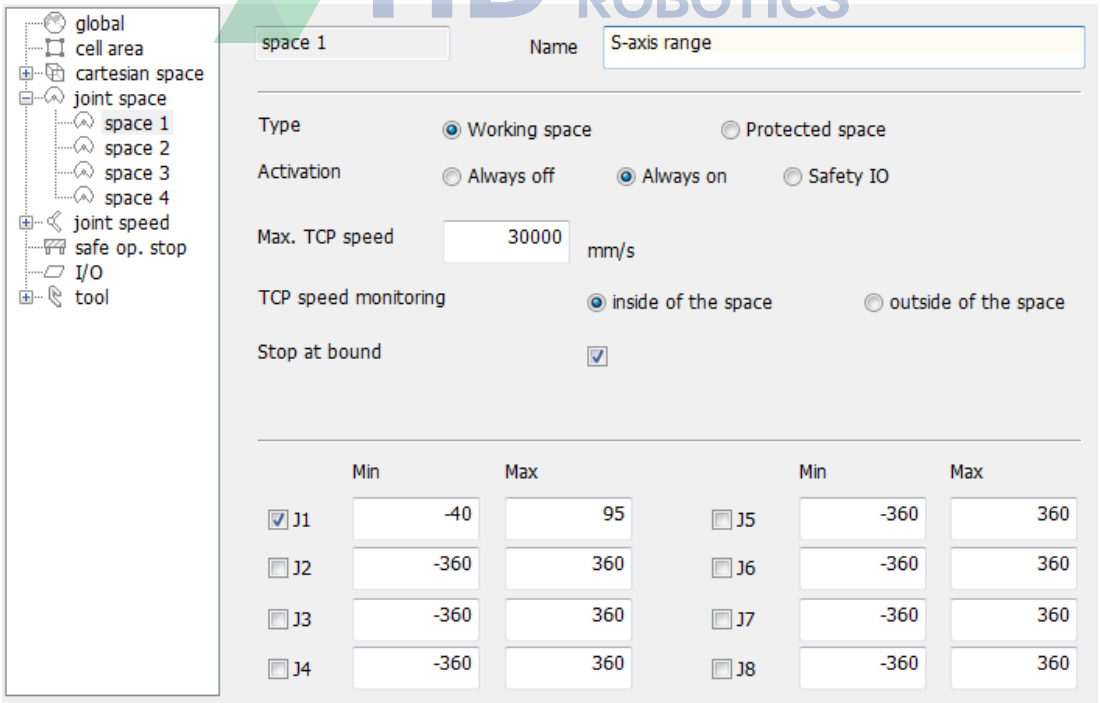

Figure 8.15 joint space setting

8.3. Print the report of setting

If you want to make the document of your setting, you can make an HTML file and print it.

Save the setting and select File – Report menu or click button on toolbar. Two files are generated in the folder in which the .SFS file is located.

- {filename}.htm : HRSafeSpace setting report file (HTML format)
- hrsafespace.css : HRSafeSpace setting report's style file (CSS format)

And the default web browser is launched to show the HTML report file.

(Major modern web browsers including Mozilla Firefox, Google Chrome, Apple Safari, Microsoft Internet Explorer, Edge will render the report well. But in case of old web-browser like Internet Explorer 8 or older won't show CellArea diagram properly.)

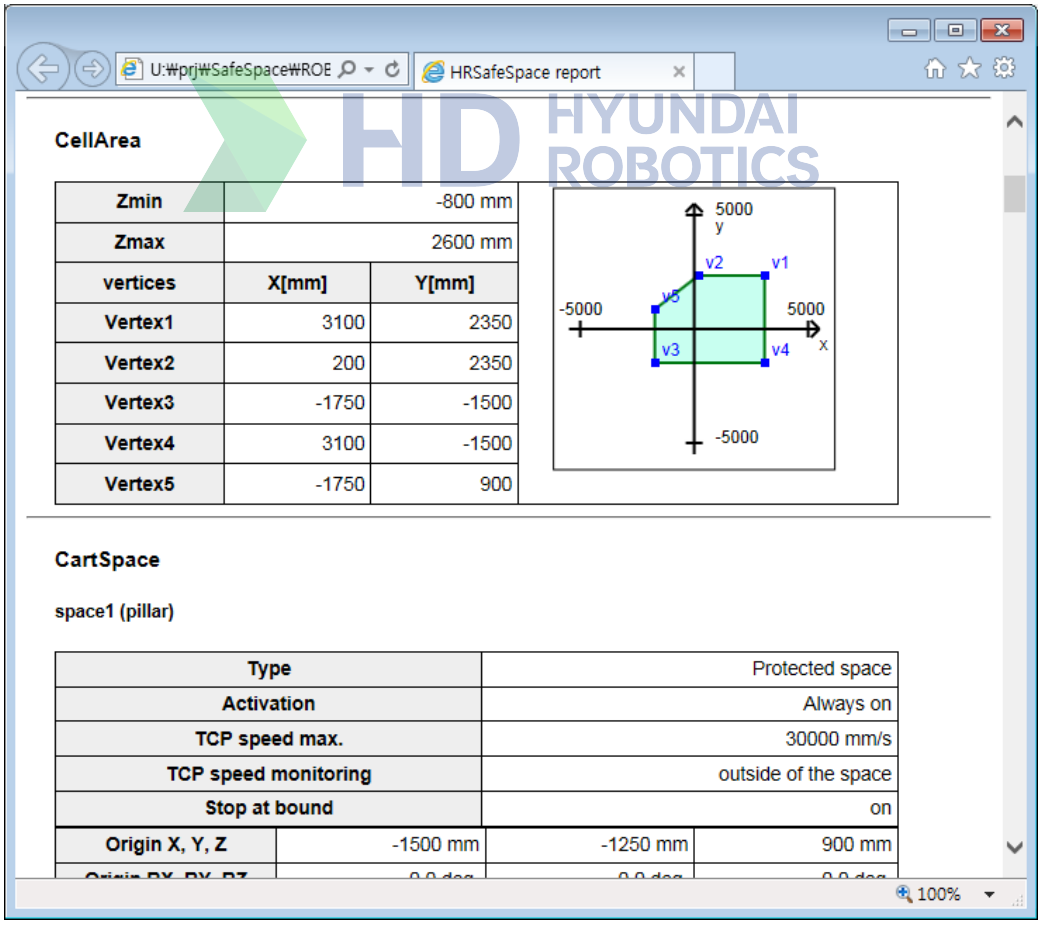

Figure 8.16 Report on Internet Explorer 11

If you are familiar with HTML and CSS (cascade style sheet) format, you can change the style of the report as you prefer by modifying hrsafespace.css file. Modify the file, update the web browser (e.g. in Chrome or Internet Explorer, press F5 key) and see if the style has changed as you want.

Once the hrsafespace.css file exists, it is not generated again by doing File – Report. So your modification on CSS file is not overwritten. If you want to initialize the CSS file into default setting, just delete the hrsafespace.css file and do File – Report again.

```
body {
        font-family: arial;
        font-size: 95%;
}
h4, h5 {
        text-indent: 20px;
}
table, th, td {
        font-size: 95%;
        margin-left:20px;
        border: 1px solid black;
        border-collapse: collapse;
        padding: 4px;
        width: 600px;
}
th {
        background-color: '#EEEEEE';
}
```

Figure 8.17 Hrsafespace.css

With web browser's print function, you can print out the report. If you have PDF print driver (installed with Adobe Acrobat), you can also make .PDF file with print function.

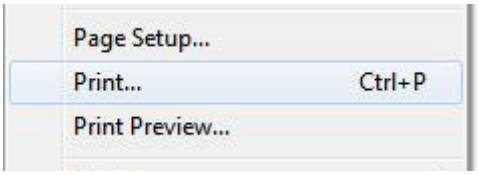

Figure 8.18 print menu of the Internet Explorer

HD
HYUNDAI
ROBOTICS

HYUNDAI ROBOTICS

9 Messages

Table 9-1 SafeSpace error messages

code	message	cause	remedy
E4001	FAULT_SafeSpace:CH_TYPE_DUPLICATED	SafeSpace Error	1. Reboot the robot controller 2. Change the SafeSpace module.
E4001	FAULT_SafeSpace:CH_TYPE_DUPLICATED	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change the SafeSpace module.
E4002	FAULT_SafeSpace:PG_FLOW_ERROR	SafeSpace Error	1. Reboot the robot controller. 2. Check the EtherNet cable between robot controller and SafeSpace. 3. If this error is stiil remained, change the SafeSpace module.
E4100	FAULT_SafeSpace:GET_PARAM_REQ_FAIL	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change the SafeSpace module.
E4101	FAULT_SafeSpace:GET_PARAM_RES_FAIL	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change the SafeSpace module.
E4102	FAULT_SafeSpace:GET_PARAM_CRC_ERROR	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change the SafeSpace module.
E4103	FAULT_SafeSpace:INV_SAFE_PARAM_SPACE_TYPE	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change the SafeSpace module.
E4104	FAULT_SafeSpace:INV_SAFE_PARAM_CELL_AREA	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change the SafeSpace module.
E4105	FAULT_SafeSpace:INV_SAFE_PARAM_JOINT_AREA	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change the SafeSpace module.
E4106	FAULT_SafeSpace:INV_SAFE_PARAM_DUP_IN_USAGE	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change the SafeSpace module.
E4107	FAULT_SafeSpace:INV_SAFE_PARAM_DUP_OUT_USAGE	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change

			the SafeSpace module.
E4201	FAULT_SafeSpace:GET_ROB_INFO_REQ_FAIL	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change the SafeSpace module.
E4202	FAULT_SafeSpace:GET_ROB_INFO_RES_FAIL	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change the SafeSpace module.
E4300	FAULT_SafeSpace:MON_ITEM_FAULT	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change the SafeSpace module.
E4301	FAULT_SafeSpace:DIAG_ERR_CMDrc_FBrc	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change the SafeSpace module.
E4302	FAULT_SafeSpace:DIGA_ERR_CMDrc_FBsafe	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change the SafeSpace module.
E4303	FAULT_SafeSpace:DIAG_ERR_TCPrc_TCPsafe	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change the SafeSpace module.
E4304	FAULT_SafeSpace:DIAG_ERR_iCMDrc_iFBdrive	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change the SafeSpace module.
E4305	FAULT_SafeSpace:DIAG_ERR_prevCMDrc_curCMDrc	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change the SafeSpace module.
E4400	FAULT_SafeSpace:DIAG_ERR_LOC_V1_2C_LOW_ERR	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change the SafeSpace module.
E4401	FAULT_SafeSpace:DIAG_ERR_LOC_V3_3C_LOW_ERR	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change the SafeSpace module.
E4402	FAULT_SafeSpace:DIAG_ERR_LOC_V3_3D_LOW_ERR	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change the SafeSpace module.
E4403	FAULT_SafeSpace:DIAG_ERR_L	SafeSpace Error	1. Reboot the robot controller.

	OC_V5D_LOW_ERR		2. If this error is stiil remained, change the SafeSpace module.
E4404	FAULT_SafeSpace:DIAG_ERR_LOC_V1_2F_LOW_ERR	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change the SafeSpace module.
E4405	FAULT_SafeSpace:DIAG_ERR_LOC_V2_5F_LOW_ERR	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change the SafeSpace module.
E4406	FAULT_SafeSpace:DIAG_ERR_LOC_V3_3F_LOW_ERR	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change the SafeSpace module.
E4407	FAULT_SafeSpace:DIAG_ERR_LOC_V24_LOW_ERR	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change the SafeSpace module.
E4408	FAULT_SafeSpace:DIAG_ERR_LOC_V3_3S_LOW_ERR	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change the SafeSpace module.
E4409	FAULT_SafeSpace:DIAG_ERR_CPU_6V_LOW_ERR	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change the SafeSpace module.
E4410	FAULT_SafeSpace:DIAG_ERR_TEMP_1_LOW_ERR	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change the SafeSpace module.
E4411	FAULT_SafeSpace:DIAG_ERR_TEMP_2_LOW_ERR	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change the SafeSpace module.
E4412	FAULT_SafeSpace:DIAG_ERR_REM_V1_2C_LOW_ERR	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change the SafeSpace module.
E4413	FAULT_SafeSpace:DIAG_ERR_REM_V3_3C_LOW_ERR	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change the SafeSpace module.
E4414	FAULT_SafeSpace:DIAG_ERR_REM_V3_3D_LOW_ERR	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change the SafeSpace module.

E4415	FAULT_SafeSpace:DIAG_ERR_REM_V5D_LOW_ERR	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change the SafeSpace module.
E4416	FAULT_SafeSpace:DIAG_ERR_REM_V1_2F_LOW_ERR	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change the SafeSpace module.
E4417	FAULT_SafeSpace:DIAG_ERR_REM_V2_5F_LOW_ERR	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change the SafeSpace module.
E4418	FAULT_SafeSpace:DIAG_ERR_REM_V3_3F_LOW_ERR	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change the SafeSpace module.
E4419	FAULT_SafeSpace:DIAG_ERR_REM_V24_LOW_ERR	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change the SafeSpace module.
E4420	FAULT_SafeSpace:DIAG_ERR_REM_V3_3S_LOW_ERR	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change the SafeSpace module.
E4421	FAULT_SafeSpace:DIAG_ERR_FPGA_6V_LOW_ERR	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change the SafeSpace module.
E4422	FAULT_SafeSpace:DIAG_ERR_TEMP_3_LOW_ERR	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change the SafeSpace module.
E4423	FAULT_SafeSpace:DIAG_ERR_TEMP_4_LOW_ERR	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change the SafeSpace module.
E4424	FAULT_SafeSpace:DIAG_ERR_LOC_V1_2C_HIGH_ERR	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change the SafeSpace module.
E4425	FAULT_SafeSpace:DIAG_ERR_LOC_V3_3C_HIGH_ERR	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change the SafeSpace module.
E4426	FAULT_SafeSpace:DIAG_ERR_LOC_V3_3D_HIGH_ERR	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change

			the SafeSpace module.
E4427	FAULT_SafeSpace:DIAG_ERR_LOC_V5D_HIGH_ERR	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change the SafeSpace module.
E4428	FAULT_SafeSpace:DIAG_ERR_LOC_V1_2F_HIGH_ERR	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change the SafeSpace module.
E4429	FAULT_SafeSpace:DIAG_ERR_LOC_V2_5F_HIGH_ERR	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change the SafeSpace module.
E4430	FAULT_SafeSpace:DIAG_ERR_LOC_V3_3F_HIGH_ERR	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change the SafeSpace module.
E4431	FAULT_SafeSpace:DIAG_ERR_LOC_V24_HIGH_ERR	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change the SafeSpace module.
E4432	FAULT_SafeSpace:DIAG_ERR_LOC_V3_3S_HIGH_ERR	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change the SafeSpace module.
E4433	FAULT_SafeSpace:DIAG_ERR_CPU_6V_HIGH_ERR	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change the SafeSpace module.
E4434	FAULT_SafeSpace:DIAG_ERR_TEMP_1_HIGH_ERR	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change the SafeSpace module.
E4435	FAULT_SafeSpace:DIAG_ERR_TEMP_2_HIGH_ERR	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change the SafeSpace module.
E4436	FAULT_SafeSpace:DIAG_ERR_REM_V1_2C_HIGH_ERR	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change the SafeSpace module.
E4437	FAULT_SafeSpace:DIAG_ERR_REM_V3_3C_HIGH_ERR	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change the SafeSpace module.
E4438	FAULT_SafeSpace:DIAG_ERR_	SafeSpace Error	1. Reboot the robot controller.

	REM_V3_3D_HIGH_ERR		2. If this error is stiil remained, change the SafeSpace module.
E4439	FAULT_SafeSpace:DIAG_ERR_REM_V5D_HIGH_ERR	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change the SafeSpace module.
E4440	FAULT_SafeSpace:DIAG_ERR_REM_V1_2F_HIGH_ERR	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change the SafeSpace module.
E4441	FAULT_SafeSpace:DIAG_ERR_REM_V2_5F_HIGH_ERR	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change the SafeSpace module.
E4442	FAULT_SafeSpace:DIAG_ERR_REM_V3_3F_HIGH_ERR	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change the SafeSpace module.
E4443	FAULT_SafeSpace:DIAG_ERR_REM_V24_HIGH_ERR	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change the SafeSpace module.
E4444	FAULT_SafeSpace:DIAG_ERR_REM_V3_3S_HIGH_ERR	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change the SafeSpace module.
E4445	FAULT_SafeSpace:DIAG_ERR_FPGA_6V_HIGH_ERR	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change the SafeSpace module.
E4446	FAULT_SafeSpace:DIAG_ERR_TEMP_3_HIGH_ERR	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change the SafeSpace module.
E4447	FAULT_SafeSpace:DIAG_ERR_TEMP_4_HIGH_ERR	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change the SafeSpace module.
E4448	FAULT_SafeSpace:DIAG_ERR_EMIF	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change the SafeSpace module.
E4449	FAULT_SafeSpace:DIAG_ERR_VIMRAMCRC	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change the SafeSpace module.

E4450	FAULT_SafeSpace:DIAG_ERR_FLASHCRC	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change the SafeSpace module.
E4451	FAULT_SafeSpace:DIAG_ERR_MARCHC	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change the SafeSpace module.
E4452	FAULT_SafeSpace:DIAG_ERR_SRAMECC	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change the SafeSpace module.
E4453	FAULT_SafeSpace:DIAG_ERR_FLASHECC	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change the SafeSpace module.
E4454	FAULT_SafeSpace:DIAG_ERR_SRAMADDR	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change the SafeSpace module.
E4455	FAULT_SafeSpace:DIAG_ERR_CCMR4F	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change the SafeSpace module.
E4456	FAULT_SafeSpace:DIAG_ERR_PSCON	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change the SafeSpace module.
E4457	FAULT_SafeSpace:DIAG_ERR_PLLSLIP	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change the SafeSpace module.
E4458	FAULT_SafeSpace:DIAG_ERR_CLKMON	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change the SafeSpace module.
E4459	FAULT_SafeSpace:DIAG_ERR_VIMRAMPRT	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change the SafeSpace module.
E4460	FAULT_SafeSpace:DIAG_ERR_UNDEFFAULT	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change the SafeSpace module.
E4461	FAULT_SafeSpace:DIAG_ERR_DABORT	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change

			the SafeSpace module.
E4462	FAULT_SafeSpace:DIAG_ERR_PREFABORT	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change the SafeSpace module.
E4463	FAULT_SafeSpace:DIAG_ERR_UNDEFINSTR	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change the SafeSpace module.
E4464	FAULT_SafeSpace:DIAG_ERR_DIO_INTFB	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change the SafeSpace module.
E4465	FAULT_SafeSpace:DIAG_ERR_DPRAMCOMP	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change the SafeSpace module.
E4466	FAULT_SafeSpace:DIAG_ERR_STOFB	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change the SafeSpace module.
E4467	FAULT_SafeSpace:DIAG_ERR_DIOFB	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change the SafeSpace module.
E4468	FAULT_SafeSpace:DIAG_ERR_INTERFPGA	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change the SafeSpace module.
E4469	FAULT_SafeSpace:DIAG_ERR_FPGAWDT	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change the SafeSpace module.
E4470	FAULT_SafeSpace:DIAG_ERR_FPGAWDTCL	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change the SafeSpace module.
E4471	FAULT_SafeSpace:DIAG_ERR_ENDRV	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change the SafeSpace module.
E4472	FAULT_SafeSpace:DIAG_ERR_WD_TIMEOUT	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change the SafeSpace module.
E4473	FAULT_SafeSpace:DIAG_ERR_	SafeSpace Error	1. Reboot the robot controller.

	CPUCLK		2. If this error is stiil remained, change the SafeSpace module.
E4474	FAULT_SafeSpace:DIAG_ERR_FPGACLK	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change the SafeSpace module.
E4500	FAULT_SafeSpace:SAFE_IN_DISREPANCY_TIME_OVER	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change the SafeSpace module.
E4501	FAULT_SafeSpace:SAFE_OUT_DISREPANCY_TIME_OVER	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change the SafeSpace module.
E4502	FAULT_SafeSpace:SAFE_STO_INT_FB_ERROR	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change the SafeSpace module.
E4503	FAULT_SafeSpace:SAFE_STO_PULSE_INT_FB_ERROR	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change the SafeSpace module.
E4504	FAULT_SafeSpace:SAFE_STO_PULSE_EXT_FB_ERROR	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change the SafeSpace module.
E4505	FAULT_SafeSpace:SAFE_STO_REM_EXT_FB_ERROR	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change the SafeSpace module.
E4506	FAULT_SafeSpace:SAFE_STO_EN_DRV_ERROR	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change the SafeSpace module.
E4600	FAULT_SafeSpace:ENC_DATA_UPDATE_ERROR	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change the SafeSpace module.
E4601	FAULT_SafeSpace:ENC_REM_WD_TIMEOUT	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change the SafeSpace module.
E4700	FAULT_SafeSpace:GET_ROB_CNTRL_INFO_REQ_FAIL	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change the SafeSpace module.

E4701	FAULT_SafeSpace:GET_ROB_CNTRL_INFO_RES_FAIL	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change the SafeSpace module.
E4702	FAULT_SafeSpace:ROB_REM_CNTRL_UPDATE_TIEMOUT	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change the SafeSpace module.
E4703	FAULT_SafeSpace:ROB_LOC_CNTRL_UPDATE_TIEMOUT	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change the SafeSpace module.
E4704	FAULT_SafeSpace:ROB_CNTRL_UPDATE_TIEMOUT	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change the SafeSpace module.
E4800	FAULT_SafeSpace:UDP_NOT_OPENED	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change the SafeSpace module.
E4900	FAULT_SafeSpace:CROSS_CHK_SEND_TIMEOUT	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change the SafeSpace module.
E4901	FAULT_SafeSpace:CROSS_CHK_RECV_TIMEOUT	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change the SafeSpace module.
E4902	FAULT_SafeSpace:CROSS_CHK_JOINT_POS_ERR	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change the SafeSpace module.
E4903	FAULT_SafeSpace:CROSS_CHK_JOINT_SPD_ERR	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change the SafeSpace module.
E4904	FAULT_SafeSpace:CROSS_CHK_TCP_POS_ERR	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change the SafeSpace module.
E4905	FAULT_SafeSpace:CROSS_CHK_TCP_SPD_ERR	SafeSpace Error	1. Reboot the robot controller. 2. If this error is stiil remained, change the SafeSpace module.

E5060	VIOLATION:SLS for Gloabal Parameter	SafeSpace detected violation of global parameter.	1. Release the STO in SafeSpace monitoring menu. 2. Reverify the Global parameters.
E5070	VIOLATION:SLP for Cell	SafeSpace detected violation of cell area.	1. Release the STO in SafeSpace monitoring menu. 2. Reverify the Cell parameters.
E5080	VIOLATION:SLP for Cartesian Space [%d]	SafeSpace detected violation of Cartesian space.	1. Release the STO in SafeSpace monitoring menu. 2. Move robot out of the violated space. 3. Reverify the Cartesian space parameters.
E5081	VIOLATION:SLS for Cartesian Space [%d]	SafeSpace detected violation of TCP speed configured in cartesian space parameters.	1. Release the STO in SafeSpace monitoring menu. 2. Reverify the parameters.
E5090	VIOLATION:SLP for Joint Space [%d]	SafeSpace detected violation of joint space.	1. Release the STO in SafeSpace monitoring menu. 2. Move robot out of the violated space. 3. Reverify the Joint space parameters.
E5091	VIOLATION:SLS for Joint Space [%d]	SafeSpace detected violation of TCP speed configured in joint space parameters.	1. Release the STO in SafeSpace monitoring menu. 2. Reverify the parameters.
E5100	VIOLATION:SLS for Speed of Joint[%d]	SafeSpace detected violation of joint speed.	1. Release the STO in SafeSpace monitoring menu. 2. Reverify the Joint speed parameters.

E5110	VIOLATION:SOS for Axis[%d] Group	SafeSpace detected violation of SOS.	1. Release the STO in SafeSpace monitoring menu. 2. Reverify the SOS parameters of check the robot and robot controller.
E5120	FAULT_SafeSpace:ServoErrFromRC	SafeSpace triggered STO because of error in robot controller.	1. Check the robot and robot controller. 2. Reboot the robot controller.
E5130	VIOLATION:ToolMisMatch	Tool number for SafeSpace is not same with tool number in robot controller.	Synchronize tool numbers.
E5402	SafeSapce failed to initialize	SafeSpace failed to initialize because robot controller failed to initialize.	Reboot the robot controller.
E5403	SafeSpace cannot support this configuration.	SafeSpace module can support DSP BD1.	1. Change the configuration of axis to disable and download ROBOT.SFS file again by HRSafeSpace. 2. Assign the additional axis to DSP BD1.
E5404	SafeSpace cannot support this configuration.	SafeSpace module cannot support the system which has the base axis assigned in DSP BD2.	Assign the base axis to DSP BD1.
E5405	SafeSpace file block is damaged.	SafeSpace setting file's memory block is damaged.	Delete ROBOT.SFS file, and download the backup file again.
E5406	SafeSpace file size exceeded the maximum.	SafeSpace file size exceeded the maximum.	SafeSpace file(ROBOT.SFS) must be edit/download with HRSafeSpace. (If the cause is unknown, contact our company for inquiries.)

E5409	SafeSpace hash code is unmatched.	SafeSpace setting file's hashcode signed by password is invalid.	SafeSpace file(ROBOT.SFS) must be edit/download with HRSafeSpace. (If the cause is unknown, contact our company for inquiries.)
E5412	SafeSpace setting XML file is failed to be loaded.	SafeSpace setting file's XML format is invalid.	SafeSpace file(ROBOT.SFS) must be edit/download with HRSafeSpace. (If the cause is unknown, contact our company for inquiries.)
E5413	SafeSpace setting XML file's root element is failed to be parsed.	SafeSpace setting file's XML root format is invalid.	SafeSpace file(ROBOT.SFS) must be edit/download with HRSafeSpace. (If the cause is unknown, contact our company for inquiries.)
E5414	SafeSpace setting file's structure is invalid.	SafeSpace setting file's XML format is valid, but the schema is invalid.	SafeSpace file(ROBOT.SFS) must be edit/download with HRSafeSpace. (If the cause is unknown, contact our company for inquiries.)
E5415	SafeSpace setting file's element is invalid.	SafeSpace setting file's some group cannot be found.	SafeSpace file(ROBOT.SFS) must be edit/download with HRSafeSpace. (If the cause is unknown, contact our company for inquiries.)
E5416	SafeSpace setting file's attribute is invalid.	SafeSpace setting file's some entries cannot be found.	SafeSpace file(ROBOT.SFS) must be edit/download with HRSafeSpace. (If the cause is unknown, contact our company for inquiries.)
E5420	SafeSpace setting file's value exceeded the range.	SafeSpace setting file's some values exceeded the range.	Using HRSafeSpace, check the exceeded values and correct them.
E5421	SafeSpace setting file's global group value exceeded the range.	SafeSpace setting file's global group value exceeded the range.	In HRSafeSpace's global page, check the exceeded values and correct them.
E5422	SafeSpace setting file's cell area group value exceeded the range.	SafeSpace setting file's cell area group value exceeded the range.	In HRSafeSpace's cell area page, check the exceeded values and correct them.

E5423	SafeSpace setting file's cart.space group value exceeded the range.	SafeSpace setting file's cartesian space group value exceeded the range.	In HRSafeSpace's cartesian space page, check the exceeded values and correct them.
E5424	SafeSpace setting file's joint space group value exceeded the range.	SafeSpace setting file's joint space group value exceeded the range.	In HRSafeSpace's joint space page, check the exceeded values and correct them.
E5425	SafeSpace setting file's joint speed group value exceeded the range.	SafeSpace setting file's joint speed group value exceeded the range.	In HRSafeSpace's joint speed page, check the exceeded values and correct them.
E5426	SafeSpace setting file's SOS group value exceeded the range.	SafeSpace setting file's safe operating stop group value exceeded the range.	In HRSafeSpace's safe operating stop page, check the exceeded values and correct them.
E5427	SafeSpace setting file's I/O group value exceeded the range.	SafeSpace setting file's I/O group value exceeded the range.	In HRSafeSpace's I/O page, check the exceeded values and correct them.
E5428	SafeSpace setting file's tool group value exceeded the range.	SafeSpace setting file's tool group value exceeded the range.	In HRSafeSpace's tool page, check the exceeded values and correct them.
E5452	Cannot execute the command of mastering test.	SafeSpace function is disabled.	Enable the SafeSpace function.
E5453	Group%d cannot execute mastering test.	This group did not set in mastering test.	Configure this group for mastering test.
E5454	The mastering test result of Group%d is abnormal.	The robot cannot reach the reference position.	After calibrating the robot, execute matering test again.

E5455	Mastering test timer of Group%d exceeded test cycle time.	Mastering test did not execute within the test cycle time.	Execute mastering test.

GRC: 477, Bundangsuseo-ro, Bundang-gu, Seongnam-si, Gyeonggi-do

Daegu: 50 Technosunhwan-ro 3-gil, Yuga-eup, Dalseong-gun, Daegu-si

Ulsan: Room 201-5, Automotive and Shipbuilding Engineering Hall, Maegoksaneop-ro 21, Buk-gu, Ulsan-si

Middle Region: Song-gok-gil 161, Yeomchi-eup, Asan-si, Chungcheongnam-do

Gwangju: Room 101, Building B, Pyeongdongsandan-ro 170-3, Gwangsan-gu, Gwangju-si

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