MITSUBISHI ELECTRIC

Mitsubishi Electric Industrial Robot

CR800 series controller

Robot Safety Option Instruction Manual

4F-SF002-01

MELFA

BFP-A3531-C

⚠ Safety Precautions

Always read the following precautions and the separate "Safety Manual" before starting use of the robot to learn the required measures to be taken.

⚠CAUTION All teaching work must be carried out by an operator who has received special training.
(This also applies to maintenance work with the power source turned ON.)
→Enforcement of safety training

⚠CAUTION For teaching work, prepare a work plan related to the methods and procedures of operating the robot, and to the measures to be taken when an error occurs or when restarting. Carry out work following this plan.
(This also applies to maintenance work with the power source turned ON.)
→Preparation of work plan

⚠WARNING Prepare a device that allows operation to be stopped immediately during teaching work.
(This also applies to maintenance work with the power source turned ON.)
→Setting of emergency stop switch

⚠CAUTION During teaching work, place a sign indicating that teaching work is in progress on the start switch, etc.
(This also applies to maintenance work with the power source turned ON.)
→Indication of teaching work in progress

⚠DANGER Provide a fence or enclosure during operation to prevent contact of the operator and robot.
→Installation of safety fence

⚠CAUTION Establish a set signaling method to the related operators for starting work, and follow this method.
→Signaling of operation start

⚠CAUTION As a principle turn the power OFF during maintenance work. Place a sign indicating that maintenance work is in progress on the start switch, etc.
→Indication of maintenance work in progress

⚠CAUTION Before starting work, inspect the robot, emergency stop switch and other related devices, etc., and confirm that there are no errors.
→Inspection before starting work

The points of the precautions given in the separate "Safety Manual" are given below.
Refer to the actual "Safety Manual" for details.

DANGER When automatic operation of the robot is performed using multiple control devices (GOT, programmable controller, push-button switch), the interlocking of operation rights of the devices, etc. must be designed by the customer.

CAUTION Use the robot within the environment given in the specifications. Failure to do so could lead to faults or a drop of reliability.
(Temperature, humidity, atmosphere, noise environment, etc.)

CAUTION Transport the robot with the designated transportation posture. Transporting the robot in a non-designated posture could lead to personal injuries or faults from dropping.

CAUTION Always use the robot installed on a secure table. Use in an instable posture could lead to positional deviation and vibration.

CAUTION Wire the cable as far away from noise sources as possible. If placed near a noise source, positional deviation or malfunction could occur.

CAUTION Do not apply excessive force on the connector or excessively bend the cable. Failure to observe this could lead to contact defects or wire breakage.

CAUTION Make sure that the workpiece weight, including the hand, does not exceed the rated load or tolerable torque. Exceeding these values could lead to alarms or faults.

WARNING Securely install the hand and tool, and securely grasp the workpiece. Failure to observe this could lead to personal injuries or damage if the object comes off or flies off during operation.

WARNING Securely ground the robot and controller. Failure to observe this could lead to malfunctioning by noise or to electric shock accidents.

CAUTION Indicate the operation state during robot operation. Failure to indicate the state could lead to operators approaching the robot or to incorrect operation.

WARNING When carrying out teaching work in the robot's movement range, always secure the priority right for the robot control. Failure to observe this could lead to personal injuries or damage if the robot is started with external commands.

CAUTION Keep the jog speed as low as possible, and always watch the robot. Failure to do so could lead to interference with the workpiece or peripheral devices.

CAUTION After editing the program, always confirm the operation with step operation before starting automatic operation. Failure to do so could lead to interference with peripheral devices because of programming mistakes, etc.

CAUTION Make sure that if the safety fence entrance door is opened during automatic operation, the door is locked or that the robot will automatically stop. Failure to do so could lead to personal injuries.

CAUTION Never carry out modifications based on personal judgments, non-designated maintenance parts. Failure to observe this could lead to faults or failures.

WARNING When the robot arm has to be moved by hand from an external area, do not place hands or fingers in the openings. Failure to observe this could lead to hands or fingers catching depending on the posture.

CAUTION Do not stop the robot or apply emergency stop by turning the robot controller's main power OFF. If the robot controller main power is turned OFF during automatic operation, the robot accuracy could be adversely affected. Also a dropped or coasted robot arm could collide with peripheral devices.

CAUTION Do not turn OFF the robot controller's main power while rewriting the robot controller's internal information, such as a program and parameter. Turning OFF the robot controller's main power during automatic operation or program/parameter writing could break the internal information of the robot controller.

DANGER Do not connect the Handy GOT when using the GOT direct connection function of this product. Failure to observe this may result in property damage or bodily injury because the Handy GOT can automatically operate the robot regardless of whether the operation rights are enabled or not.

DANGER Do not connect the Handy GOT to a programmable controller when using an iQ Platform compatible product with the CR800-R /CR800-Q controller. Failure to observe this may result in property damage or bodily injury because the Handy GOT can automatically operate the robot regardless of whether the operation rights are enabled or not.

DANGER Do not remove the SSCNET III cable while power is supplied to the multiple CPU system or the servo amplifier. Do not look directly at light emitted from the tip of SSCNET III connectors or SSCNET III cables of the Motion CPU or the servo amplifier. Eye discomfort may be felt if exposed to the light.
(Reference: SSCNET III employs a Class 1 or equivalent light source as specified in JIS C 6802 and IEC60825-1 (domestic standards in Japan).)

DANGER Do not remove the SSCNET III cable while power is supplied to the controller. Do not look directly at light emitted from the tip of SSCNET III connectors or SSCNET III cables. Eye discomfort may be felt if exposed to the light.
(Reference: SSCNET III employs a Class 1 or equivalent light source as specified in JIS C 6802 and IEC60825-1 (domestic standards in Japan).)

DANGER Attach the cap to the SSCNET III connector after disconnecting the SSCNET III cable. If the cap is not attached, dirt or dust may adhere to the connector pins, resulting in deterioration connector properties, and leading to malfunction.

CAUTION Make sure there are no mistakes in the wiring. Connecting differently to the way specified in the manual can result in errors, such as the emergency stop not being released. In order to prevent errors occurring, please be sure to check that all functions (such as the teaching box emergency stop, customer emergency stop, and door switch) are working properly after the wiring setup is completed.

CAUTION Use the network equipments (personal computer, USB hub, LAN hub, etc.) confirmed by manufacturer. The thing unsuitable for the FA environment (related with conformity, temperature or noise) exists in the equipments connected to USB. When using network equipment, measures against the noise, such as measures against EMI and the addition of the ferrite core, may be necessary. Please fully confirm the operation by customer. Guarantee and maintenance of the equipment on the market (usual office automation equipment) cannot be performed.

CAUTION To maintain the safety of the robot system against unauthorized access from external devices via the network, take appropriate measures. To maintain the safety against unauthorized access via the Internet, take measures such as installing a firewall.

■ Revision history

Date of print	Manual No.	Details of revisions
2017-05-31	BFP-A3531	・ First print
2018-06-01	BFP-A3531-A	・ The CR800-Q controller was added. ・ Tables were corrected. (Stopping time and stopping distance (emergency stop), Stopping time and stopping distance (power off))
2019-10-31	BFP-A3531-B	・ Added RV-8CRL. ・ Added the length of the RIO cable. ・ Amended "4.6.1 Test pulse diagnosis (EMG)".
2020-04-24	BFP-A3531-C	・ Added information for the RH-3CRH and RH-6CRH. ・ Added information on functions that cannot be used in conjunction with the robot safety option. ・ Amended "4.2.5 Recovery mode". ・ Added the following error codes. H2240, C2250, H2260, H2320 ・ Added a solution to error H0241. ・ Revised chapter 7 "SAFE STOPPING DISTANCE".

■ Introduction

Thank you for purchasing an industrial robot from Mitsubishi Electric Corporation. The "robot safety option", used together with external devices such as a safety switch or light curtain, enhances the robot safety function.
Before using the "robot safety option", make sure to read and fully understand the contents of this manual.

The manual is intended for use on the assumption that you understand basic operations and functions of the Mitsubishi industrial robot. For the basic operation of the robot, refer to the separate "Instruction Manual/Detailed explanations of functions and operations".

■Symbols in this manual

Danger	Incorrect handling may result in imminent danger, leading to death or serious injury.
Warning	Incorrect handling may lead to death or serious injury.
Caution	Incorrect handling may result in property damage, or danger leading to impairment of the user.

- No part of this manual may be reproduced by any means or in any form, without prior consent from Mitsubishi.
- The details of this manual are subject to change without notice. We kindly ask for your understanding.
- Specification values are based on our standard test methods.
- An effort has been made to make full descriptions in this manual. However, if any discrepancies or unclear points are found, please contact your service provider.
- This document is original.
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- We omit ® and TM in this document.

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1. FUNCTIONS AND CONFIGURATION

1.1 Overview

This document explains how to use the safety monitoring functions with the robot safety option. As for the functions available in the standard robot controller and the operation method, refer to the instruction manual provided with the robot controller.

The robot safety option adds the safety monitoring functions to CR800 series controllers. The main functions are as follows:

Tab. 1-1: Safety monitoring functions overview

Function		Function Outline	See:
Safety logic edit	Input	This allows defining conditions to trigger the safety monitoring functions. Safety input signals from external sensors (area sensors, light curtains, etc.) and robot area information can be combined to configure the conditions to trigger the safety monitoring functions.	4.4 Safety Logic Edit
	Output	This allows outputting safety signals based on the safety monitoring functions and area information. This is used for displaying safety states or connecting other safety devices.	
Safe stop function 1	SS1 (STO)	This is a function to stop the robot safely. After stopping the robot, power off the motors.	4.5.3 Safe stop 1 (SS1)
Safe stop function 2	SS2 (SOS)	This is a function to stop the robot safely. While the motor control keeps working after the robot stops, this function monitors the robot so that it does not continue to operate.	4.5.4 Safe stop 2 (SS2)
Safely limited speed function	SLS	This is a function to monitor the robot arm and robot tools so that their speed does not exceed a specified limit. This can monitor the speeds both in XYZ coordinates and joint coordinates.	4.5.5 Safely limited speed function (SLS)
Safely limited position function	SLP	This is a function to monitor the position of the robot arm and robot tools so that they do not enter safeguarded spaces. Safeguarded spaces can be specified with planes and areas.	4.5.6 Safely limited position function (SLP)

1.2 System Configuration

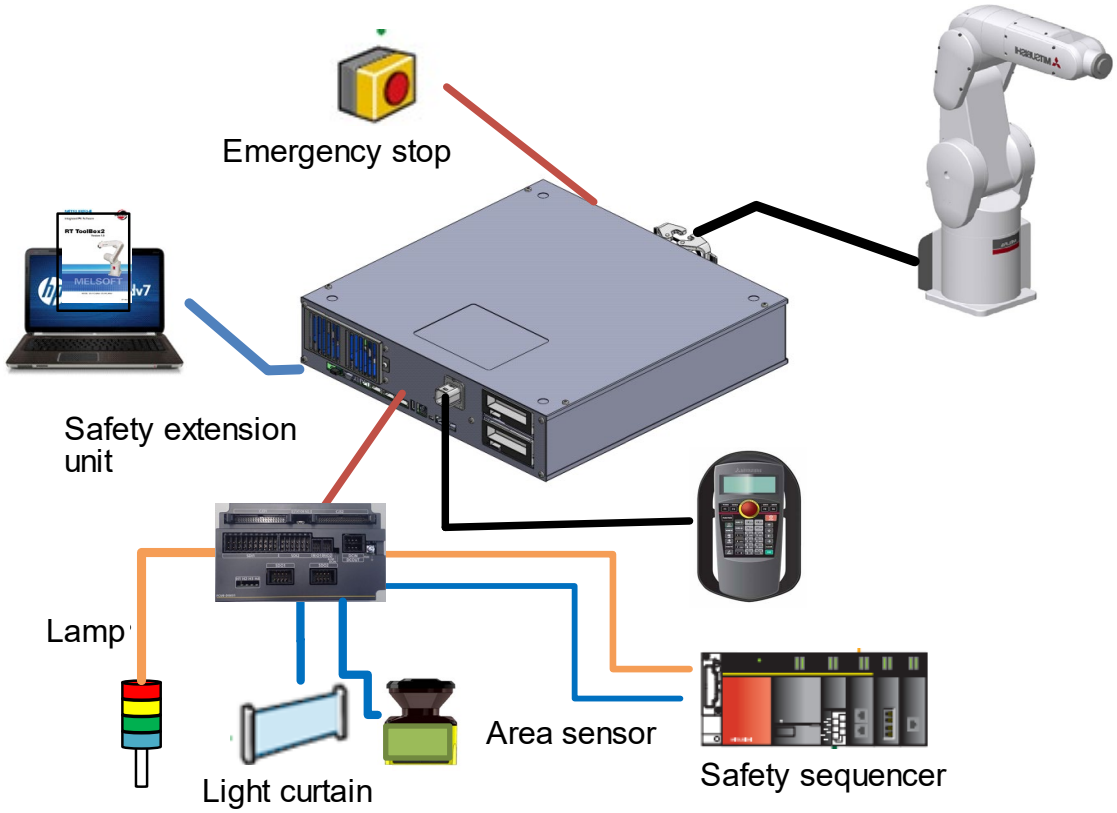


Fig. 1-1 System configuration

Tab. 1-2 System configuration

Item	Description		Remarks
Robot arm	Vertically articulated type RV-FR series	RV-2FRB,RV-2FRLB,RV-4FR,RV-4FRL, RV-4FRJL,RV-7FR,RV-7FRL,RV-7FRLL, RV-13FR,RV-13FRL,RV-20FR	Additional axes and user mechanisms are not included in the system.
	Vertically articulated type RV-CR series	RV-8CRL	
	SCARA type RH-FR series	RH-3FRH, RH-6FRH, RH-12FRH, RH-20FRH, RH-3FRHR, RH-1FRHR	
	SCARA type RH-CR series	RH-3CRH, RH-6CRH	
Robot controller	CR800-D	Ver. A1 or later	Ver. A5c or later for the RV-8CRL, and Ver. A5k or later for the RH-3CRH and RH-6CRH.
	CR800-R	Ver. A1 or later	
	CR800-Q	Ver. A2 or later	
RT ToolBox3	3F-15C-WINE		Install the software to a personal computer. The software is used to enable the safety monitoring function. (Separate purchase is required.) Ver. 1.61P or later for the RV-8CRL, and Ver. 1.70Y or later for the RH-3CRH and RH-6CRH.
RT ToolBox3 mini	3F-14C-WINE		
RT ToolBox3 Pro	3F-16D-WINE		
Robot safety option	4F-SF002-01		The option explained in this instruction manual.
External device	Light curtain, safety switch, etc.		To be prepared by the customer according to the system configuration.

1.3 Specifications

Tab. 1-3 Specifications

Item			Description	Remarks
Safety function	STO function		The function electrically shuts off the driving energy to the motor of the robot arm.	IEC 60204-1 Corresponds to stop category 0
	SS1 function		The function to control and decelerate the motor speeds of the robot. After stopping, the robot transitions to the STO state.	IEC 60204-1 Corresponds to stop category 1
	SS2 function		The function to control and decelerate the motor speeds of the robot. After stopping, the robot transitions to the SOS state.	IEC 60204-1 Corresponds to stop category 2
	SOS function		Without shutting off the driving energy to the motors, this function monitors the robot so that it stays at rest.	EN61800-5-2 compliant
	SLS function		This is a function to monitor each part of the robot arm so that their speeds do not exceed monitoring speeds.	EN61800-5-2 compliant
	SLP function		The function monitors specified monitoring positions so that they do not go across position monitoring planes.	EN61800-5-2 compliant
Safety performance	Standard		ISO10218-1(2011) EN62061(2006) ISO13849-1(2015) IEC61508 (2010) EN61800-5-1 (ES, EN for Drive) EN61800-5-2(Safety function Drive) IEC61326-3-1 (EMC for RS) EN60204-1	
	Performance	STO	SIL 3, PLe/Category 4 (Note 1)	
		SS1,SOS,SS2, SLS,SLP	SIL 2, PLd/Category 3	
	Dangerous failure rate	STO	PFH = 1.40×10^{-8} [1/h]	
		SS1, SS2, SOS	PFH = 3.42×10^{-7} [1/h]	
		SLS	PFH = 3.42×10^{-7} [1/h]	
		SLP	PFH = 3.42×10^{-7} [1/h]	
Safety extension unit	Power supply specifications	Voltage	24 V DC±5% Ripple 0.2 V (P-P)	
		Maximum consumption current	300 mA	
	Structure (IP rating)		IP20	
	Weight		0.8kg	
	Environment	Operating temperature range	0 to 40℃	It must be kept away from heat appliances and other heat sources.
		Relative humidity	45 to 75	Non-condensing
		Vibration	During transportation: 34m/s^2. During operation: 5 m/s^2 or less	
		Atmosphere	No corrosive gas / flammable gas / oil mist/dust	

		Installation environment	Indoors Place where no intense electromagnetic energy is generated No roughness or tilt on the installation surface	No direct sunlight. Do not install the unit on very rough surfaces.
	Input signal		Eight routes (duplex signal)	
	Output signal		Four routes (duplex signal)	

Note 1: Meeting SIL3 or PLe/Category 4 requires input diagnosis with test pulses.
See 4.6.1 Test pulse diagnosis (EMG).

1.4 Risk Assessment

To ensure safety, the user needs to assess all the risks and determine residual risks for the mechanical system as a whole. Companies or individuals who configure the system will accept full responsibility for installation and authorization of the safety system. Assessment for all risks and safety level certification are required for the equipment/system as a whole. The following shows residual risks related to the safety monitoring function of this product.

1.4.1 Residual Risk (Common)

(1) If the origin setting, parameter settings or programs of the robot are incorrect, unexpected operation may occur and safety cannot be ensured. Fully check whether operations are as intended.
(2) Until correct installation, wiring, and adjustment are achieved, safety cannot be ensured.
(3) Only a qualified person is given the authority to install, start, repair, adjust, etc. the equipment to which devices are installed. Installing or operating the equipment should be done by a trained engineer.
(4) For the safety monitoring function, perform the wiring separately from other signal wirings.
(5) Protect cables by appropriate means (installing inside the control panel, using a cable guard, etc.).
(6) It is recommended to use switches, relays, sensors, etc. conforming to safety standards. For using switches, relays, sensors, etc. not conforming to safety standards, sufficient verification of safety is necessary on the customer side.
(7) The safety function only works for the robot controller and the robot. The function covers no additional axes (additional robot axes, user mechanisms). When using an additional axis, the customer needs to ensure and assess the safety of the axis.
(8) To perform the initial test of the robot, power cycle it regularly. The initial test should be performed at least every six months.

1.4.2 Residual Risk (Specific to Each Function)

(1) STO function

This function interrupts transmission of power to the motor installed in the robot arm, and may bring variation to the posture of the robot arms due to mechanical factors, such as a timing belt break or brake wear, etc. of the robot arm. Periodic maintenance of the robot arm is required.

(2) SS1function

This function controls and decelerates the motor speed installed to a robot arm. The movement cannot be stopped immediately after deceleration is started.

(3) SS2 function

This function controls and decelerates the motor speed installed to a robot arm. The movement cannot be stopped immediately after deceleration is started.

(4) SOS function

This function monitors motors installed in the robot so that they stay at rest. Mechanical factors, such as break of timing belts of the robot, may bring variation to the posture of the robot. Periodic maintenance of the robot arm is required.

(5) SLS function

This function monitors the speed of each part of the robot arm and tools specified beforehand. Depending on the robot posture, some undefined parts may move at a speed higher than the monitoring speed.
This function is only enabled when the robot is in the servo-on state and therefore does not monitor the speed when the robot is in the servo-off state.

(6) SLP function

In the following cases, the monitoring position may go across a position monitoring plane or a position monitoring area. The following shows some concrete examples.

- When the position monitoring plane is applied, the robot position is beyond the plane.
- When the position monitoring plane is applied, the robot is moving near the plane at a high speed.
- The robot posture changes when the robot brake is released.

(7) Duplex input and output signal monitoring function

This function only monitors whether the duplexed input signals match each other, and does not detect malfunction or misconnection of the connected devices. The robot detects the mismatched signal when a signal mismatch for 0.1 seconds or more occurs.

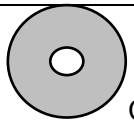
2. INSTALLATION

2.1 Product Components

2.1.1 Accessories

Please check to see if the package has all the necessary parts before use.

Tab. 2-1 List of items included in the package

Number	Item	Quantity	Outer appearance		Model
1	Safety extension unit	1			4F-SFUNIT
2	RIO cable (Cable length: 1 m)	1			2F-SFRIOCBL
3	DCIN connector set	1	 1 pcs.	 3 pcs.	2F-SFDCINCON
4	SDI connector set	1	 8 pcs.	 32 pcs.	2F-SFSDICON
5	SDO connector set	1	 2 pcs.	 16 pcs.	2F-SFSDOCON
6	Termination resistor	1			2F-SFTM
7	Instruction manual	1	 CD-ROM		BFP-A3543

2.1.2 Customer-prepared items

Tab. 2-2 Customer-prepared items

No.	Item	Quantity	Description	Remarks
1	24 V power supply	1	The power supply for the safety extension unit.	
2	24 V power cable	-	This is used to supply the safety extension unit with the 24 V power. Assemble the cable with the included DCIN connector set.	
3	Cable for SDI1 and SDI2 connectors	-	This is used to input the safety input signals to the safety extension unit. Assemble the cable with the included SDI connector set.	
4	Cable for SDO1 and SDO2 connectors	-	This is used to output the safety output signals from the safety extension unit. Assemble the cable with the included SDO connector set.	

2.2 Names of Each Part

The names of each part of the safety extension unit (4F-SFUNIT) are shown below:

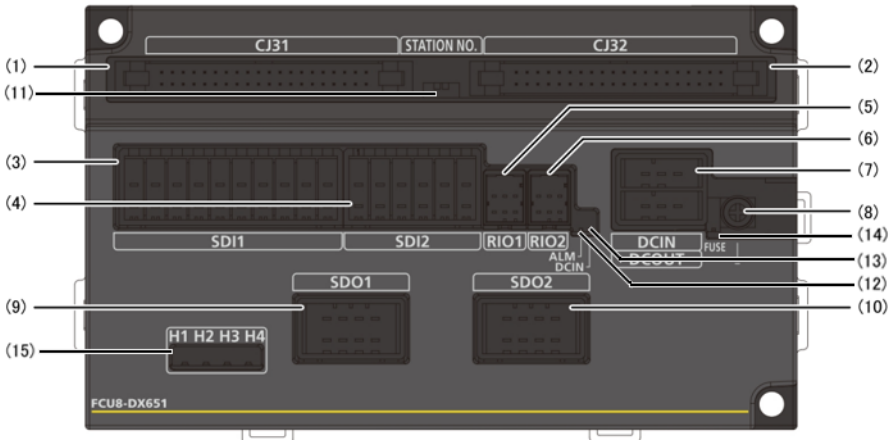


Fig. 2-1 Names of each part of the safety unit

Tab. 2-3 Names of each part of the safety extension unit

No.	Connector	Function	Remarks
(1)	CJ31	Unavailable	
(2)	CJ32	Unavailable	
(3)	SDI1	Safety DI input connectors	Eight points for duplication. 0 V common.
(4)	SDI2	Safety DI input connectors	
(5)	RIO1	Remote I/O communication ver. 2.0 connector	
(6)	RIO2	Remote I/O communication ver. 2.0 connector	
(7)	DCIN/DCOUT	24 V I/O connector	The power input to the safety I/O unit. DCOUT is unavailable.
(8)	FG	FG terminal	Use this terminal for grounding.
(9)	SDO1	Safety relay output connector	Four points for duplication Non-voltage contact output
(10)	SDO2	Safety relay output connector	
(11)	STATION NO.	Station number setting switch	This is set to station number 2 before shipping. Do not change the setting.
(12)	ALM LED	Remote I/O communication error check LED	On: Error Off: Normal
(13)	DCIN LED	24 V DC power check LED	On: Normal Off: Error
(14)	FUSE LED	Melted fuse check LED	On: Normal Off: Fuse melted
(15)	H1 LED ,H2 LED H3 LED, H4 LED	Welded relay check LED	On: Normal Off: Relay welded

2.3 Installation and Connection

Caution Make sure the power of the robot controller is turned OFF before fixing the safety extension unit, connecting the robot controller and the safety extension unit, or installing the connectors to the safety extension unit.

Caution Please pay attention to the orientation of insertion of the connectors. The connectors may be broken if they are forcibly inserted in an incorrect orientation.

Caution When an operator with static electricity installs/connects the product, the robot controller or the safety extension unit may be broken. Start the work after all static electricity is discharged.

Caution Please supply power to the safety extension unit before the robot controller. When the controller is turned on before the unit, H311(RemoteI/O unit config error) may occur. When this error occurs, turn off both of the unit and controller and supply power to the unit before the controller.

2.3.1 Fixing the safety extension unit

To fix the safety extension unit, use the hole marked with *1 in the external view **Fig. 2-2 External dimensions**. Alternatively, use DIN rails and fix it in a place free from vibration.

2.3.2 Safety extension unit external dimensions

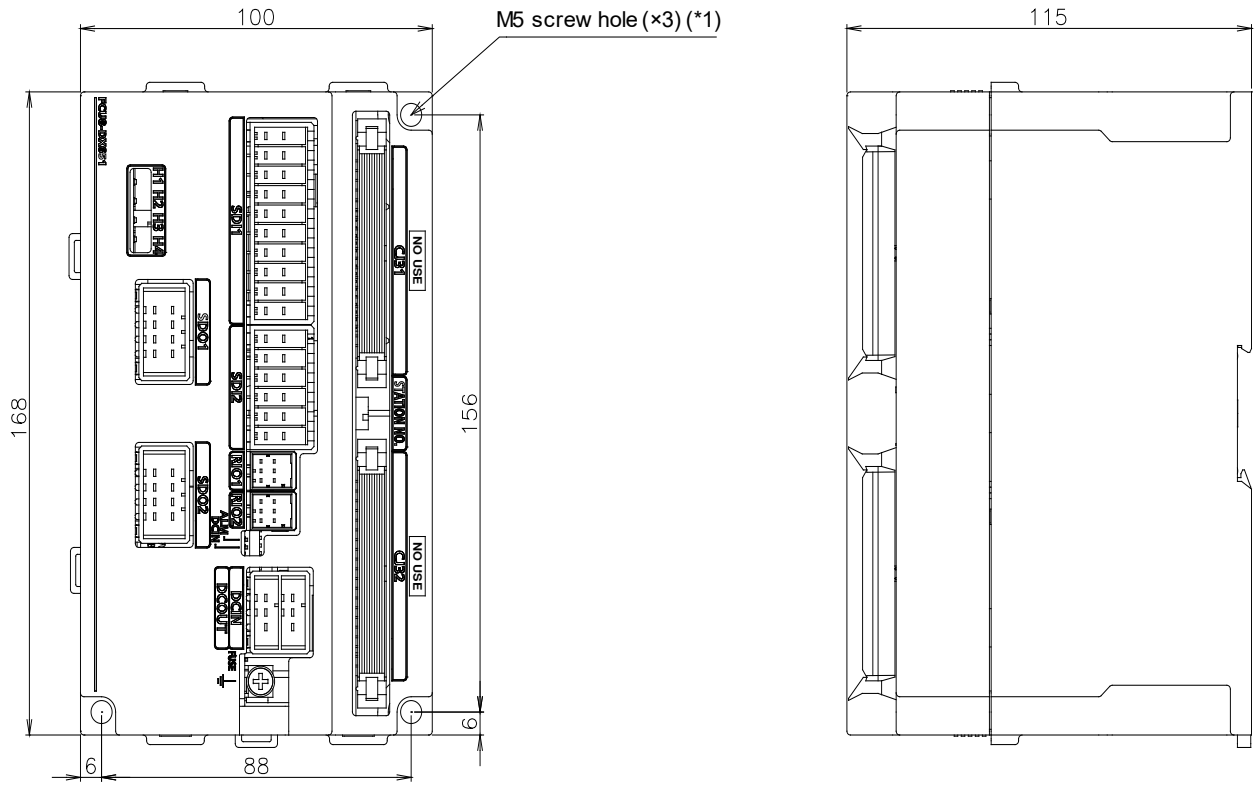


Fig. 2-2 External dimensions

2.3.3 Connecting with the robot controller

(1) Unit connection

By using the RIO cable (2F-SFRIOCBL) included in this product, connect the robot controller to the safety extension unit.

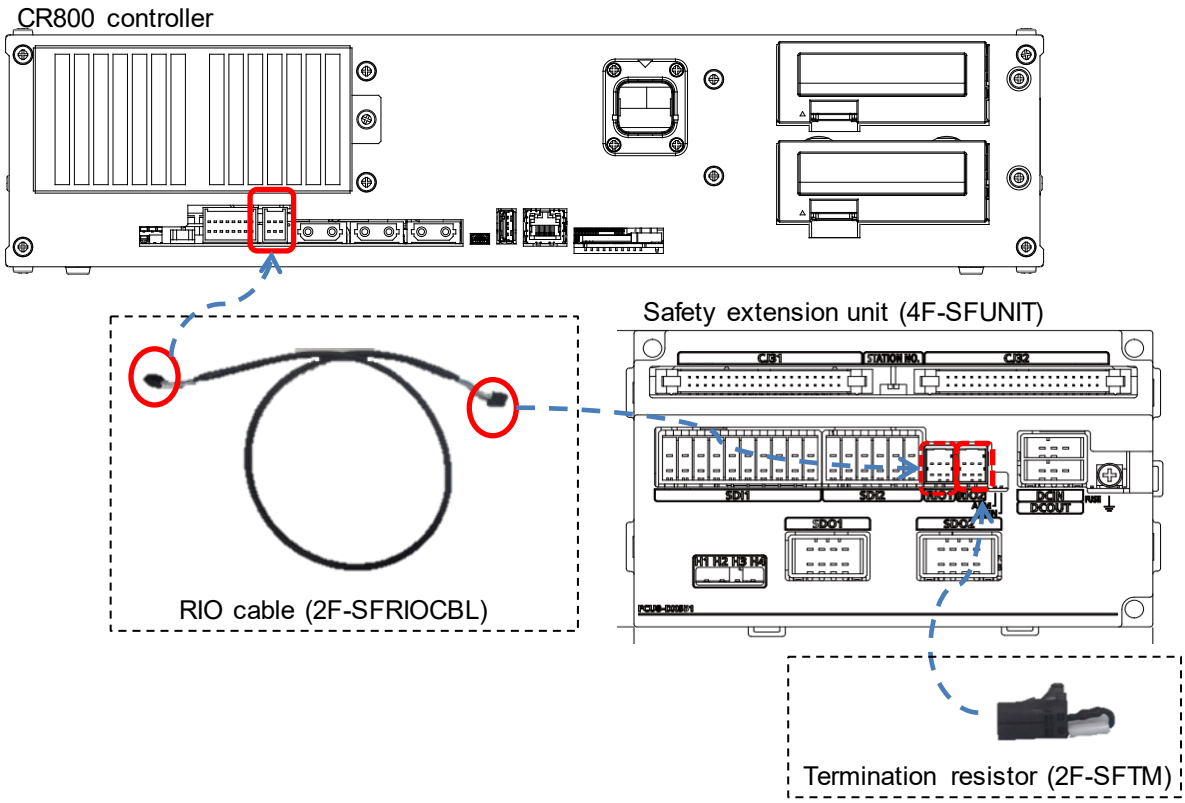


Fig. 2-3 Connection to the CR800 controller

(2) Station number

• Set the station number switch to station number 2. A wrong switch setting will cause error H2261.

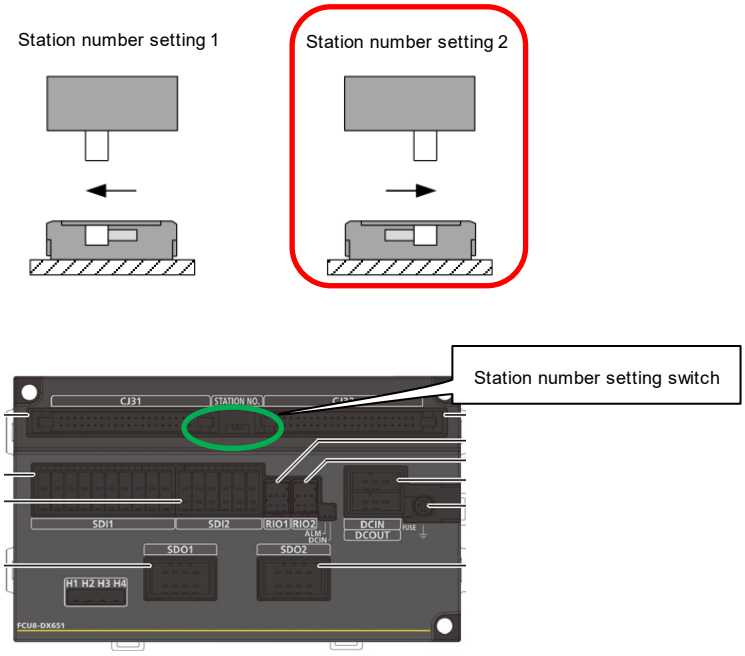


Fig. 2-4 Station number setting switch

2.3.4 Connector and cable

Caution Incorrect cable connection to a wiring connector may damage the robot or cause a malfunction. Take sufficient care when connecting the cables to a wiring connector.

To assemble the cables to connect to the DCIN, SDI1, SDI2, SDO1, and SDO2 connectors, use the included connector set.

Tab. 2-4 Connector and cable

<table>
<tr><th>No.</th><th>Connector</th><th>Accessories needed</th><th>Description</th><th>Recommended cable</th></tr>
<tr><td>1</td><td>DCIN/DCOUT</td><td>2F-SFDCINCON</td><td><table><tr><th>Manufacturer</th><th>Model</th><th>Qty.</th></tr><tr><td>TE Connectivity</td><td>2-178288-3</td><td>1</td></tr><tr><td>TE Connectivity</td><td>1-175218-5</td><td>3</td></tr></table></td><td>Conductor area: 0.5 to 1.42 mm^2,
(20 to 16 AWG)
Sheath diameter: 1.8 to 2.8 mm
With shields</td></tr>
<tr><td>2</td><td>SDI1
SDI2</td><td>2F-SFSDICON</td><td><table><tr><th>Manufacturer</th><th>Model</th><th>Qty.</th></tr><tr><td>TE Connectivity</td><td>175363-1</td><td>8</td></tr><tr><td>TE Connectivity</td><td>175218-2</td><td>32</td></tr></table></td><td>Conductor area: 0.5 to 1.42 mm^2,
(20 to 16 AWG)
Sheath diameter: 1.8 to 2.8 mm
With shields</td></tr>
<tr><td>3</td><td>SDO1
SDO2</td><td>2F-SFSDOCON</td><td><table><tr><th>Manufacturer</th><th>Model</th><th>Qty.</th></tr><tr><td>TE Connectivity</td><td>178289-4</td><td>2</td></tr><tr><td>TE Connectivity</td><td>175218-2</td><td>16</td></tr></table></td><td>Conductor area: 0.5 to 1.42 mm^2,
(20 to 16 AWG)
Sheath diameter: 1.8 to 2.8 mm
With shields</td></tr>
</table>

2.4 Check Items

Check the following items periodically.

(1) Make sure the connector is securely inserted to the safety extension unit.
(2) Make sure the electric wire has not come off from the wiring connector.
(3) Make sure no screws affixed to the safety extension unit are loose.
(4) Make sure the connectors connecting the robot controller and the safety extension unit are securely inserted.

2.5 Replacement Parts

No part requires regular replacement.

2.6 Maintenance

In the following cases, contact your service provider.

■ Relay failure
Maintenance due to a relay failure requires the replacement of the unit. (Note).
(Note) The relays are fixed onto the board, which makes it impossible to only replace a relay.

■ Melted fuse
When a melted fuse has turned off the melted fuse check LED, the unit needs replacing.

3. SIGNALS AND WIRING

3.1 Description of Signals

3.1.1 Electrical specifications

(1) Safety DI input specifications

Tab. 3-1 Safety DI electrical specifications

Item	Specifications	Remarks
Input type	0 V common	-
Input point	Eight points	16 points for duplication
Input voltage at external contact ON	18 V or more	-
Minimum current at external contact ON	6 mA or more	-
Input voltage at external contact OFF	3.8 V max.	-
Input current at external contact OFF	1 mA max.	-
Input resistor	5 kΩ	-
Allowable chattering time	1 ms max.	-
Input signal holding time	40 ms or more	40 ms is just a standard. The input signal is not recognized unless the time is held more than the entered DSI filter time.
Input circuit operation delay time	1 ms to 2 ms	-
Machine side contact capacity	30 V or more, 16 mA or more	-
Insulated/uninsulated	Uninsulated	-

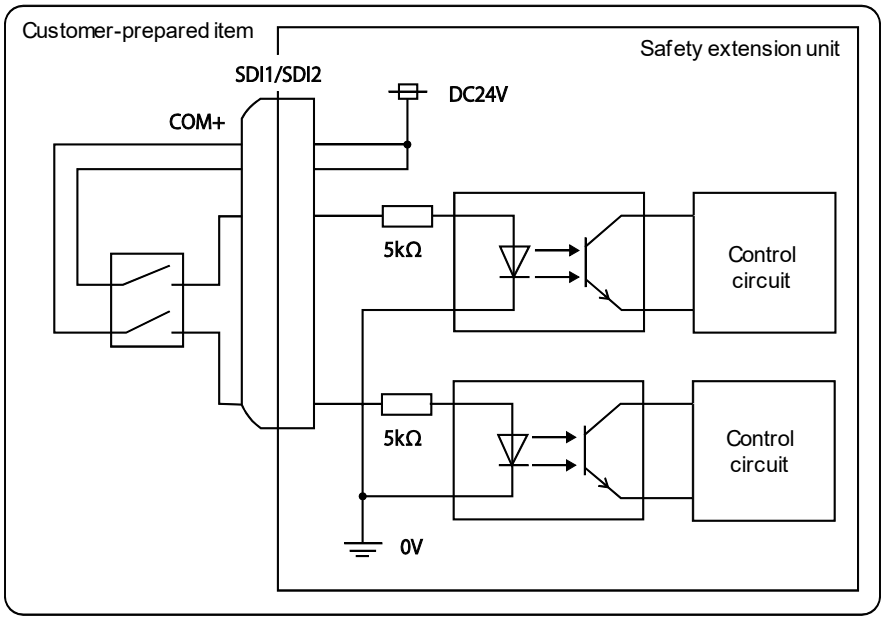


Fig. 3-1 Safety DI electrical specifications

(2) Safety DO output specifications

Tab. 3-2 Safety DO electrical specifications

Item	Specifications	Remarks
Output type	Non-voltage contact output	Relay contact
Output point	4 points	8 points for duplication
Maximum allowable contact voltage	250 V AC, 125 V DC	-
Maximum allowable contact current	6 A	-
Response time	8 ms max.	-
Restoration time	20 ms max.	-
Insulated/uninsulated	Insulated	Insulated by the relay

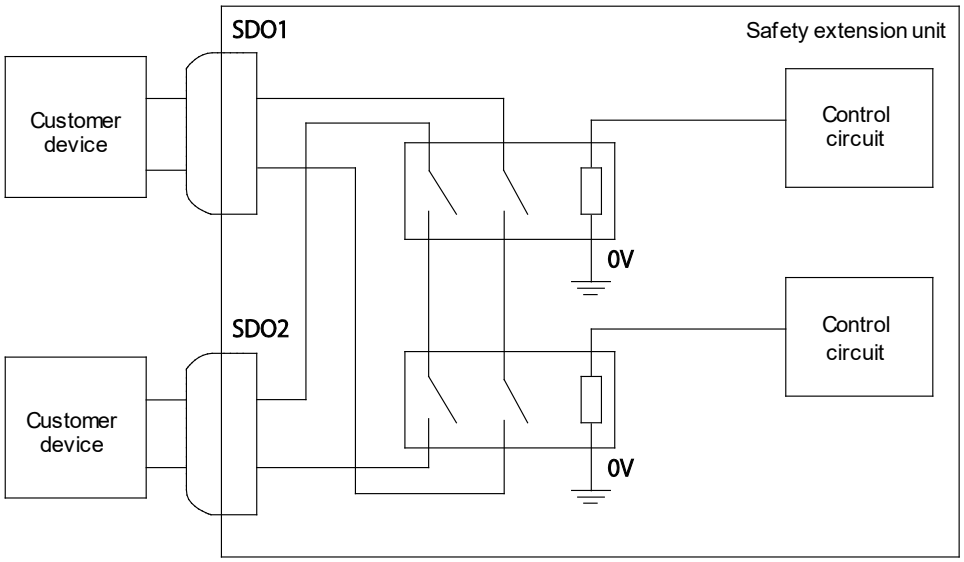


Fig. 3-2 Safety DO electrical specifications

3.1.2 Signal operation

(1) DSI signal

The DSI signals are used to switch items that the safety monitoring function monitors. Each of the signals is duplex and the states of the two input signals need to be identical to each other. If the states of the two input signals are different, an error occurs.
A 100-ms continuous discrepancy between DSI_A and DSI_B causes error H222* (DSI mismatch) and the SS1 function stops the robot.

Tab. 3-3: DSI Input states

		Signal input state		Remarks
		DSI_A	DSI_B	
DSI Input states	Enabled	OFF	OFF	-
		ON	OFF	A 100-ms continuous discrepancy between DSI_A and DSI_B will cause an error and start SS1.
		OFF	ON	
	Disabled	ON	ON	-

The DSI signal screen of RT ToolBox3 enables monitoring the input states of the DSI-A and DSI-B signals on it. Input the DSI signal individually from the peripheral devices and test to see if ON/OFF state of the signal or wiring is correct.
The DSI signal screen can be displayed by selecting [Online]→[Monitor]→[Signal]→[DSI signal] in Workspace.

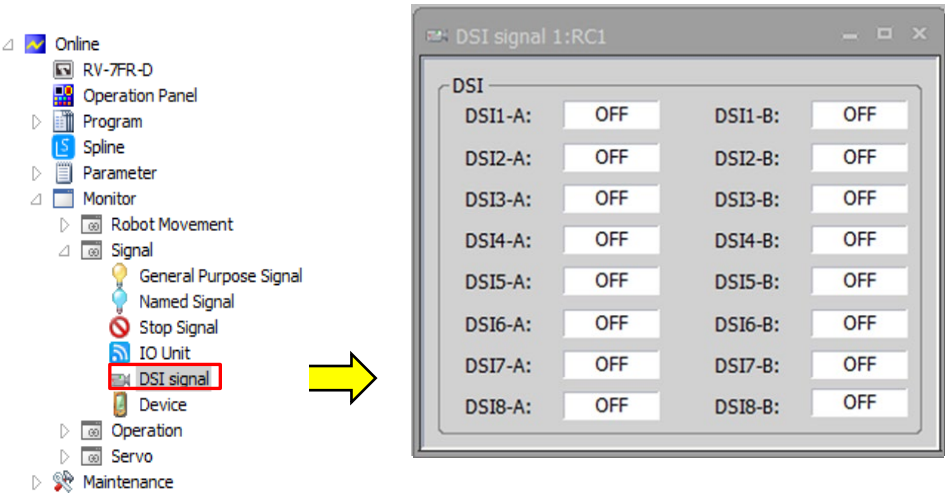


Fig. 3-3 DSI signal monitor

(2) DSO signal

The DSO signals are for outputting the state of the safety monitoring function. DSO1 to DSO4 can be assigned with output safety function and AREA signals. The outputs are duplex and a 100-ms continuous discrepancy between DSO_A and DSO_B signals causes error H.2230 (DSO mismatch) to be output and the SS1 function stops the robot.

Tab. 3-4: DSO output states

		Signal output state		Remarks
		DSO_A	DSO_B	
DSO output states	Enabled	ON	ON	-
	Disabled	OFF	OFF	-

(3) Exclusive input/output signals

DSI signal and DSO signal are assigned to exclusive input/output signals 128 ~ 191. When the safety function is enabled and any exclusive input/output signals are assigned to 128 ~ 191, L.6641(Duplicate setting (special IN)) and L.6650 (Duplicate setting (special OUT)) occur.

3.2 Connectors and Pin Assignment

Tab. 3-5 DCIN/DCOUT pin assignment

Terminal name	Signal name	Signal description	Remarks
A1	-	-	Unused (Note 1)
B1	DC24V	+24 V power supply (input)	
A2	-	-	Unused (Note 1)
B2	GND	0V	
A3	-	-	Unused (Note 1)
B3	FG	Frame ground	

Note 1: You can also use A1 as DC24V, A2 as GND, A3 as FG. In that case, do not connect the connector to B1, B2, B3.

Connector on the unit

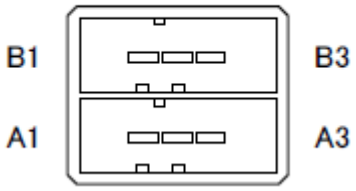
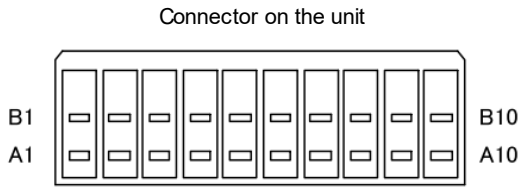


Fig. 3-4 DCIN/DCOUT connector

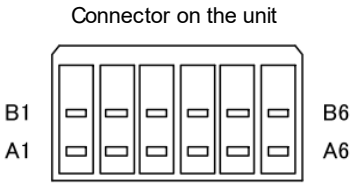
Tab. 3-6 SDI1 and SDI2 pin assignment

SDI1		
Terminal name	Signal name	Signal description
A1	DSI1A	Safety input 1A
B1	COM+	+24 V output
A2	DSI1B	Safety input 1B
B2	COM+	+24 V output
A3	DSI2A	Safety input 2A
B3	COM+	+24 V output
A4	DSI2B	Safety input 2B
B4	COM+	+24 V output
A5	DSI3A	Safety input 3A
B5	COM+	+24 V output
A6	DSI3B	Safety input 3B
B6	COM+	+24 V output
A7	DSI4A	Safety input 4A
B7	COM+	+24 V output
A8	DSI4B	Safety input 4B
B8	COM+	+24 V output
A9	DSI5A	Safety input 5A
B9	COM+	+24 V output
A10	DSI5B	Safety input 5B
B10	COM+	+24 V output

SDI2		
Terminal name	Signal name	Signal description
A1	DSI6A	Safety input 6A
B1	COM+	+24 V output
A2	DIS6B	Safety input 6B
B2	COM+	+24 V output
A3	DSI7A	Safety input 7A
B3	COM+	+24 V output
A4	DSI7B	Safety input 7B
B4	COM+	+24 V output
A5	DSI8A	Safety input 8A
B5	COM+	+24 V output
A6	DSI8B	Safety input 8B
B6	COM+	+24 V output



SDI1 connector



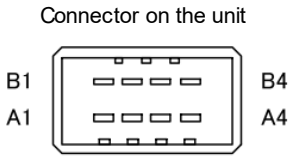
SDI2 connector

Fig. 3-5 SDI connector

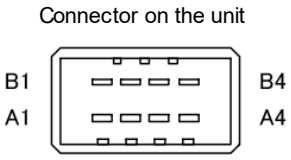
Tab. 3-7 SDO1 and SDO2 pin assignment

SDO1		
Terminal name	Signal name	Signal description
A1	DSO1A	Safety relay output 1A
B1	DSO1A	Safety relay output 1A
A2	DSO2A	Safety relay output 2A
B2	DSO2A	Safety relay output 2A
A3	DSO3A	Safety relay output 3A
B3	DSO3A	Safety relay output 3A
A4	DSO4A	Safety relay output 4A
B4	DSO4A	Safety relay output 4A

SDO2		
Terminal name	Signal name	Signal description
A1	DSO1B	Safety relay output 1B
B1	DSO1B	Safety relay output 1B
A2	DSO2B	Safety relay output 2B
B2	DSO2B	Safety relay output 2B
A3	DSO3B	Safety relay output 3B
B3	DSO3B	Safety relay output 3B
A4	DSO4B	Safety relay output 4B
B4	DSO4B	Safety relay output 4B



SDO1 connector



SDO2 connector

Fig. 3-6 SDO connector

3.3 Input Signal Connection Example

Fig. 3-7 shows a signal connection example. Devices to be connected depend on the user's system configuration.

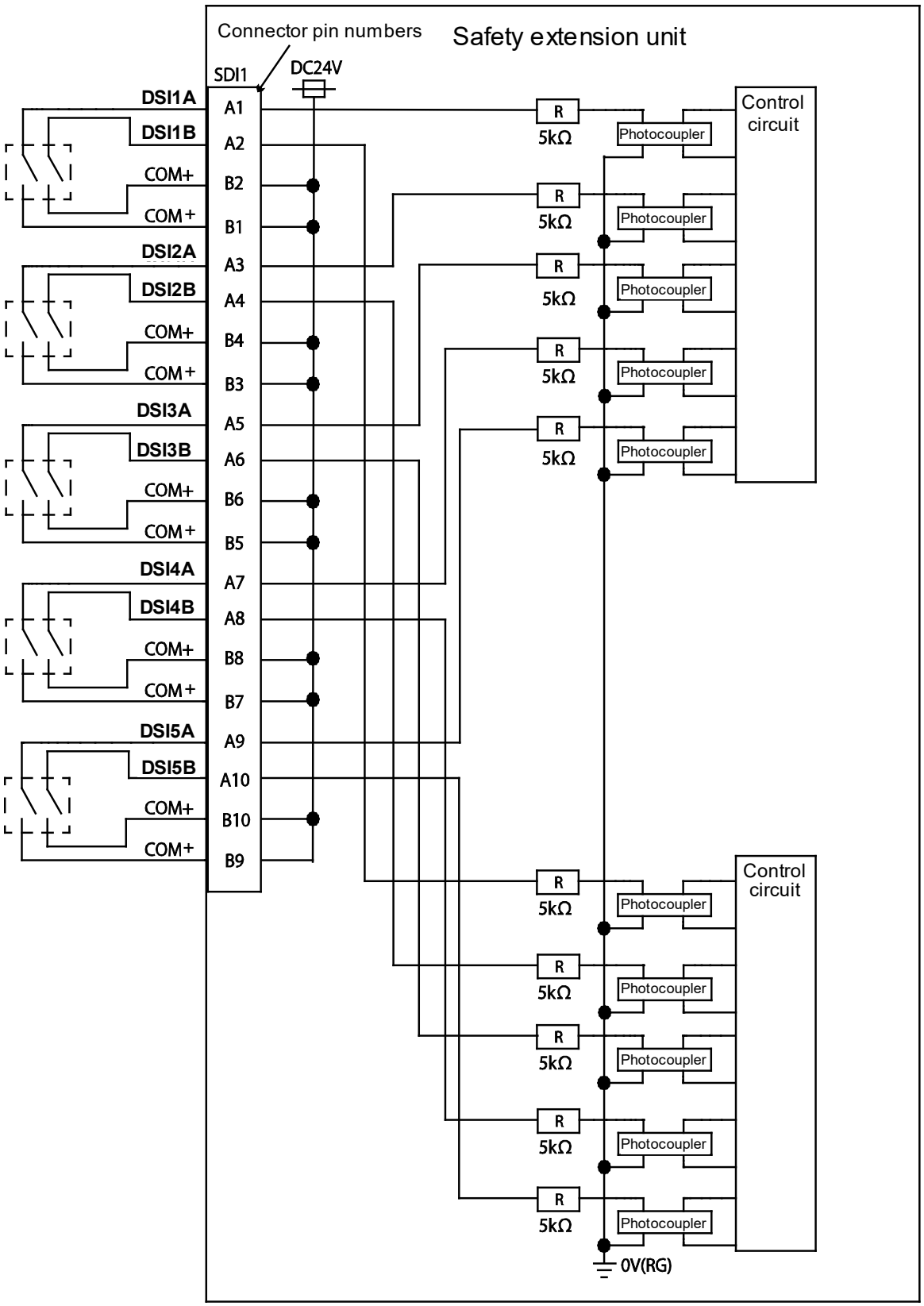


Fig. 3-7 Input signal connection example

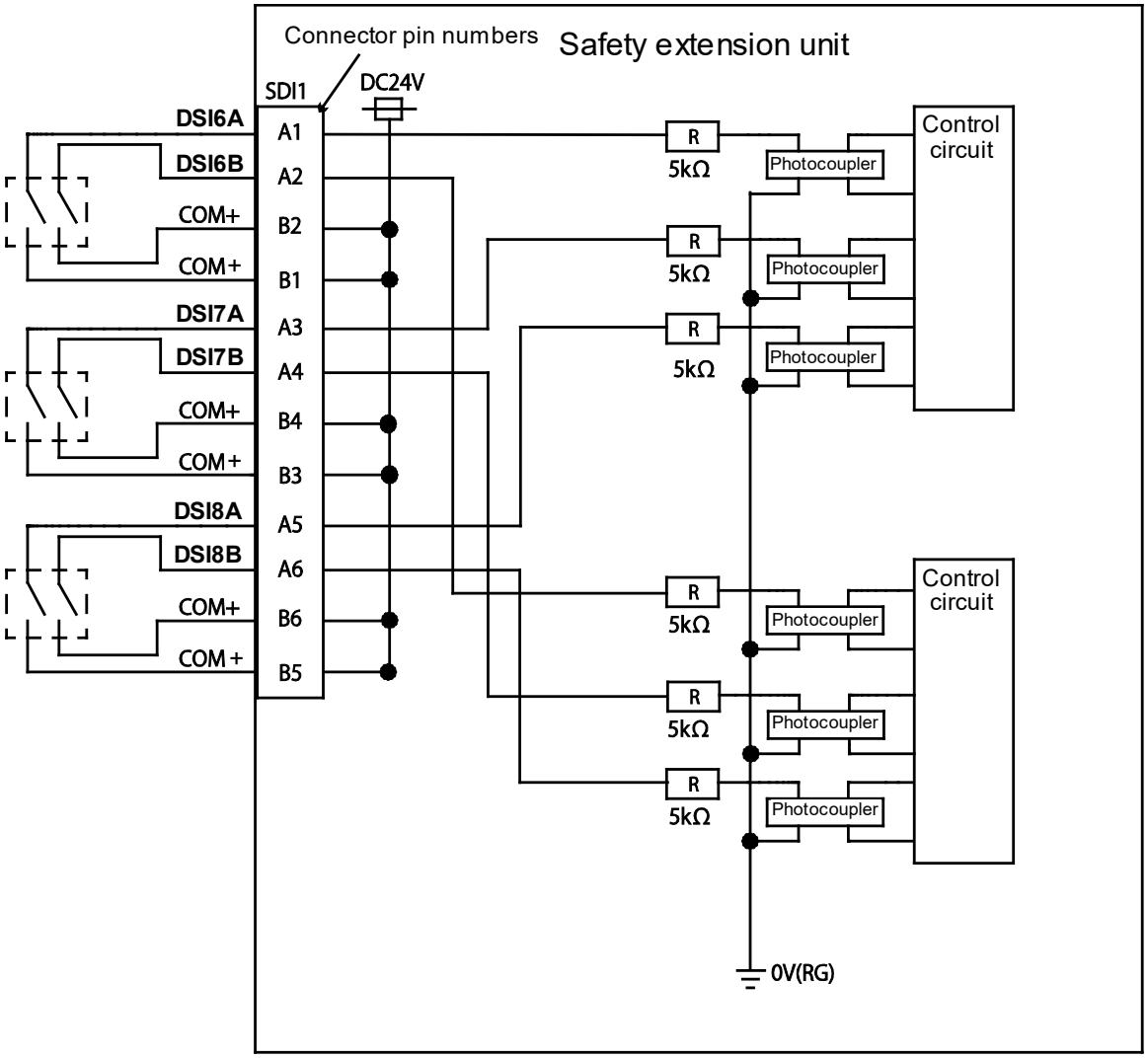


Fig. 3-8 Input signal connection example

<Safety DO connection example>

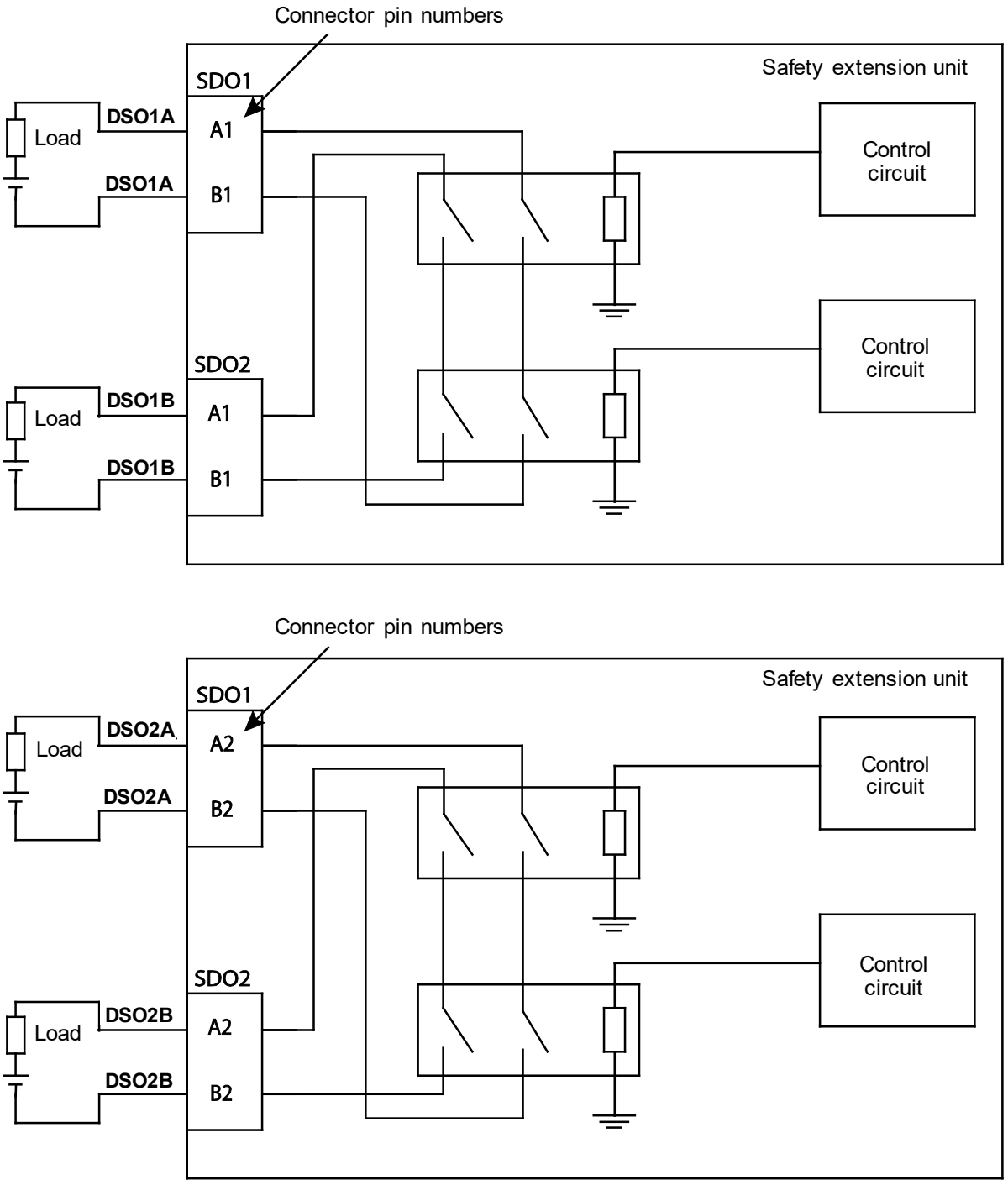


Fig. 3-9 Output signal connection example

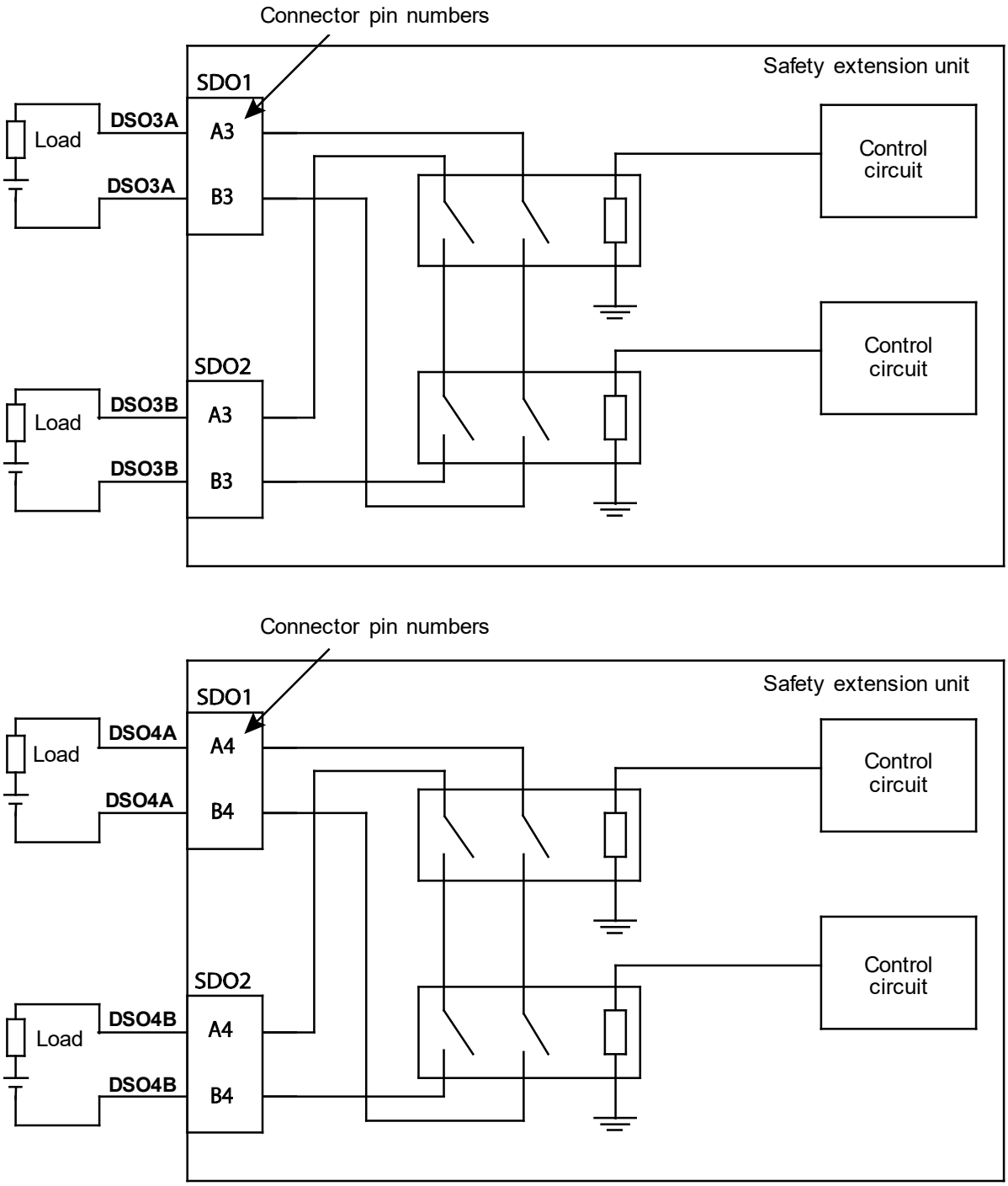


Fig. 3-10 Output signal connection example

3.4 Measures to Prevent Static Electricity and Noise

Use a shielded wire to avoid effects of noise. Perform wiring through the shortest path so that the cable length can become shorter. In case of malfunction, etc. due to noise or static electricity, ground the unit using the grounding terminals.

Static electricity may cause a malfunction. Do not touch the unit when you are statically charged. Take measures such as installing the safety extension unit in an enclosure.

4. SAFETY MONITORING FUNCTIONS

4.1 Safety Monitoring Functions Overview

The functions available on the robot safety option are shown below:

Tab. 4-1 Safety Monitoring Functions Overview

Function		Functional description	See:
Safety logic edit	Input	This allows defining conditions for the safety monitoring function to work. Safety input signals and the AREA information of the robot can be combined to configure the conditions to trigger the safety monitoring functions.	4.4 Safety Logic Edit
	Output	This allows outputting safety signals based on running states of the safety monitoring functions and AREA monitoring information. This is used for displaying safety states or connecting other safety devices.	
Safe torque off	STO	The function shuts off driving energy to the motors of the robot.	4.5.1 Safe torque off (STO)
Safe operating stop	SOS	Without shutting off the driving energy to the motors, this function monitors the robot so that it stays at rest.	4.5.2 Safe operating stop (SOS)
Safe stop function 1	SS1	This is a function to stop the robot safely. After stopping the robot, power off the motors.	4.5.3 Safe stop 1 (SS1)
Safe stop function 2	SS2	This is a function to stop the robot safely. While the motor control keeps working after the robot stops, this function monitors the robot so that it does not work.	4.5.4 Safe stop 2 (SS2)
Safely limited speed function	SLS	This is a function to monitor the robot arm and the tools so that their speeds do not exceed specified limits. • Speed monitoring in XYZ coordinates • Speed monitoring in joint coordinates	4.5.5 Safely limited speed function (SLS)
Safely limited position function	SLP	This is a function to monitor whether positions of the robot arm and the hand are in a safe area.	4.5.6 Safely limited position function (SLP)

4.1.1 Simulation

You can check operation of safety monitoring function with simulation on RT ToolBox3/RT ToolBox3 Pro.
(This simulation is not available on RT toolBox3 mini.)
Safety input (DSI) is assigned as following table. Switch DSI using Pseudo-input.

DSI	1	2	3	4	5	6	7	8
Signal No.	128	129	130	131	132	133	134	135

See “RT ToolBox3/RT ToolBox3 mini User’s Manual” for details on using simulation and pseudo-input.

■ Restrictions

The following functions and options cannot be used in conjunction with the robot safety option.

- Parallel I/O interface (2A-RZ361, 2A-RZ371) : Error H0311 (Remote I/O unit config error) occurs
- Controller CPU drive mode function : Error H0241 (Fault in Safety Communication) occurs
- Machine lock function : Error H0241 (Fault in Safety Communication) occurs
- Pseudo-input function : Error H2260 (No Safety extension unit) occurs

  * The pseudo-input function can be used in RT ToolBox3 simulations.

4.2 Startup and Basic Configuration

The safety monitoring function is disabled in the factory default setting. To use the safety monitoring function, it needs enabling and parameters for each monitoring function needs configuring. Changing the parameters for the safety monitoring functions requires RT ToolBox3, RT ToolBox3 mini, or RT ToolBox3 Pro separately.

4.2.1 Connecting RT ToolBox3

The safety monitoring function is configured in the online state by connecting RT ToolBox3 to the controller. For information on how to connect RT ToolBox3 to the controller, refer to "RT ToolBox3 / RT ToolBox3 mini Instruction manual" coming with RT ToolBox3.

4.2.2 Parameter configuration

Monitoring start conditions for the safety monitoring functions and the monitoring functions are configured through the editing screen for safety monitoring function parameters of RT ToolBox3.

(1) Editing screen for the safety monitoring function parameters
To open the editing screen for the safety monitoring function parameters, from Workspace, select [Online] -> [Parameter] -> [Safety parameter] and then select an applicable screen, which enables configuring and changing parameters concerning the safety monitoring function.

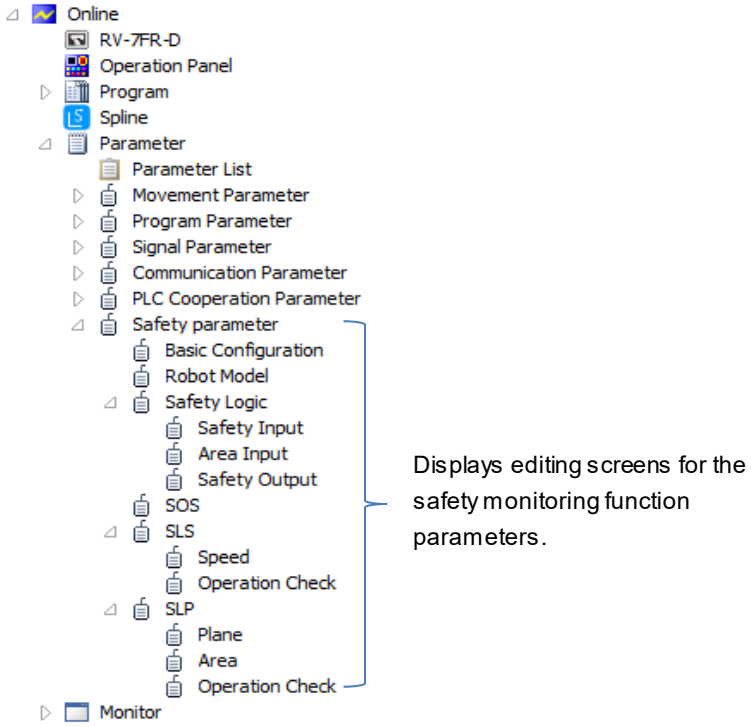
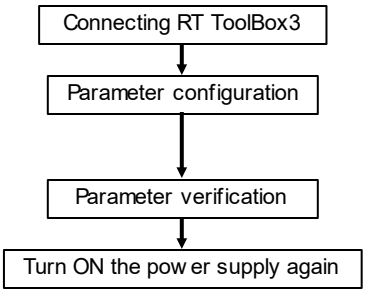


Fig. 4-1 Editing screen for the safety monitoring function parameters

Caution Parameters displayed on the editing screen for the safety monitoring function parameters can only be viewed or changed through this screen. The settings cannot be viewed or changed on the parameter list screen of RT ToolBox3 or the parameter editing screen of the teaching pendant (TB in short).

(2) Parameter setting procedure
Set the parameters in the following steps.



Connect RT ToolBox3 to the controller and put it in the online state.

Display the editing screen for the safety monitoring function parameters, and set each parameter.
Enter the password when you write the settings to the controller.

Read each parameter and confirm that it is set correctly.

The parameter settings take effect after the controller is power-cycled.

4.2.3 Password setting

Caution The password must be changed from the default setting in order to use the safety monitoring function.

The password is configured to prevent the safety monitoring function parameters from being changed inadvertently. The first thing to do when using the safety monitoring functions is to change the factory default password to new one.
(Viewing the parameter settings does not require the password.)

(1) Factory default password
The factory default password is "MELFASafetyPSWD". Unless the password is changed, error L7378 (Change password) occurs when a parameter change is attempted for a parameter related to the safety monitoring function, and the parameter cannot be changed.

(2) Password change
To change the password, open the Basic Configuration screen for the safety monitoring functions.
From Workspace, select [Online] -> [Parameter] -> [Safety parameter] -> [Basic Configuration].
(Robots incompatible with the safety monitoring function do not have [Safety parameter] in the [Movement Parameter] tree.)

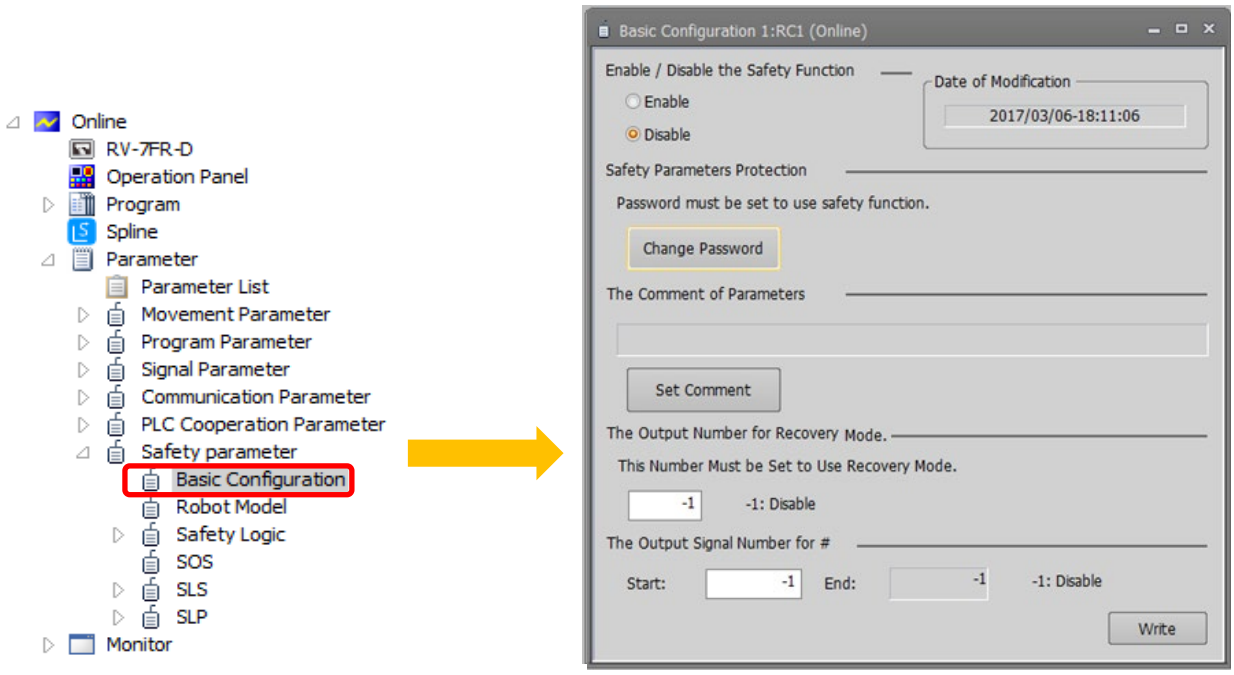


Fig. 4-2: Basic Configuration screen

Press the [Change Password] button on the bottom of the editing screen for parameters related to the safety monitoring function to display [Register/Change Password]. Change the password by entering a new and the current passwords.

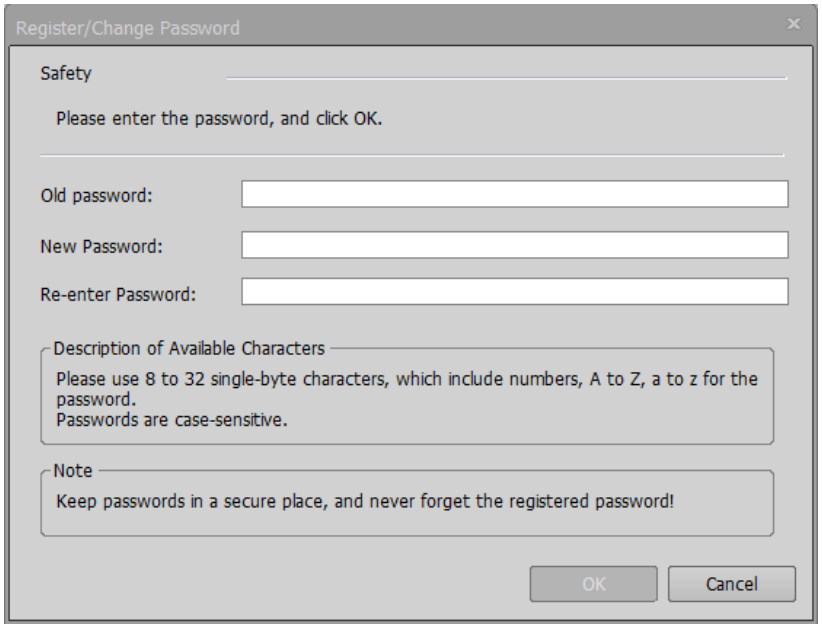


Fig. 4-3 Parameter change/registration screen

Use 8 to 32 single-byte characters for the password. Available characters are alphanumeric characters (0 to 9, A to Z, and a to z), and they are case-sensitive.

Caution If you forget the password, parameters related to the safety monitoring function cannot be changed. Take care to not forget the registered password. If you forget the password, you need to restore the factory settings by clearing the memory of the controller with the device reset operation. For the device reset operation, refer to "Instruction manual/Detailed explanations of functions and operations" provided with the robot.

Caution To prevent unintended change of parameters, keep passwords in a secure place so that it does not leak to any third parties.

(3) Entering password

When a parameter for the safety monitoring function is written, the password entry screen appears.

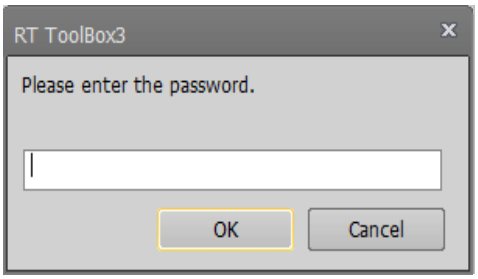


Fig. 4-4 Password input screen

Entering a correct password and pressing the [OK] button writes the parameter to the controller. If the password is incorrect, the parameter is not written. Instead, an error dialog is displayed and then the password entry screen appears again.

Password entry is only required when parameters are written for the first time after the editing screen for the safety monitoring function parameters is displayed. When the user continues writing parameters without closing the editing screen for the safety monitoring function parameters, the user does not have to enter the password again.

4.2.4 Enabling/disabling functions

To use the safety monitoring function, it needs to be enabled from the Basic Configuration screen for the safety monitoring function.
The Basic Configuration screen for the safety monitoring function parameters is displayed by selecting [Online]→[Parameter]→[Safety parameter]→[Basic Configuration] in Workspace.

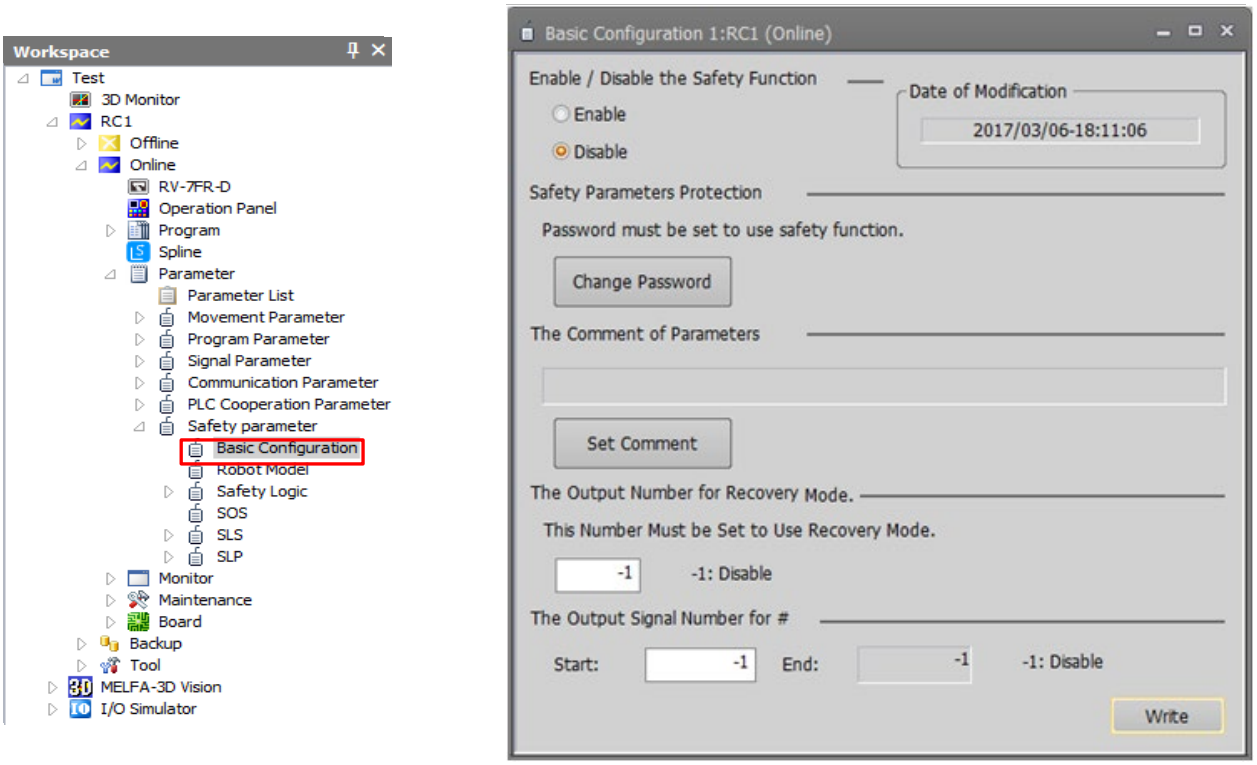


Fig. 4-5: Basic Configuration screen

Caution To enable the safety monitoring function, connect the safety extension unit beforehand. If the safety monitoring function is enabled without connecting the safety extension unit, error H2260 (No safety extension unit) occurs.

Caution When the origin of the robot is not configured, the safety monitoring functions cannot be activated even when the function is enabled. Configure the origin of the robot before enabling the safety monitoring functions.

4.2.5 Recovery mode

The recovery mode is a function to temporarily cancel the stop state activated by the SLP safety monitoring. To use this mode, a signal to indicate that the recovery mode is enabled must be assigned to the dedicated output. In The Output Number for Recovery Mode in the Basic Configuration screen, configure the output number.

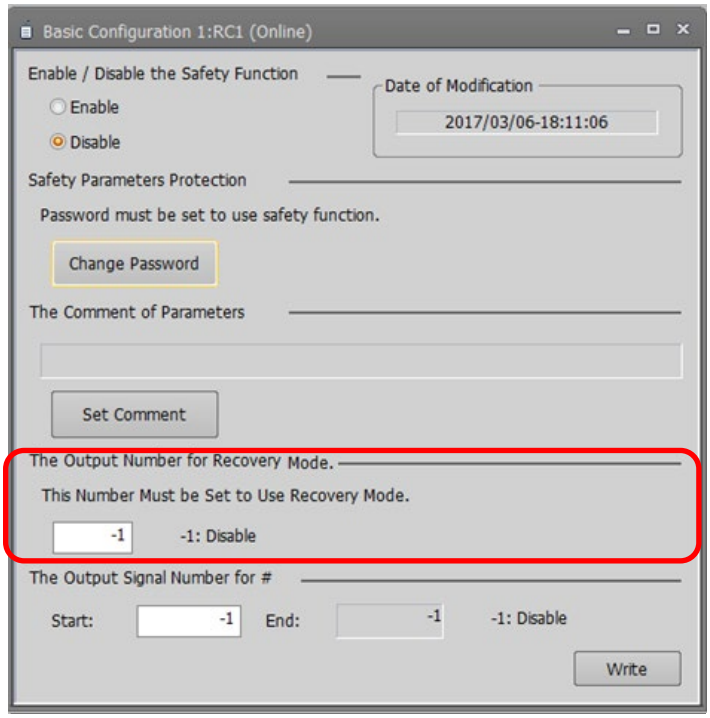
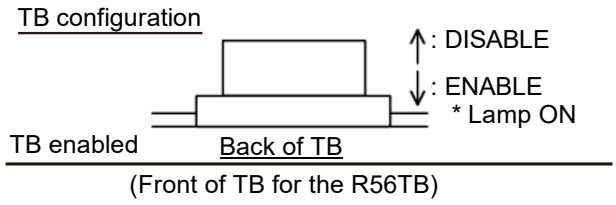


Fig. 4-6: Output Number for Recovery Mode setting screen

If the robot intrudes into a restricted area while SLP is enabled, resetting the error requires moving the robot outside the area. However, the servo-on operation cannot be performed while the error is occurring, which makes it impossible to operate the robot by the JOG operation.
In such a case, the recovery mode may be used. The recovery mode enables a temporary reset of the error and operation of the robot with the TB.

<When R32TB is used>



1) Change the controller mode to MANUAL.
2) Set the Enable switch of the teaching pendant to ENABLE.
3) Press the [JOG] key to display the JOG screen. When using the force sensor function, recovery mode can be used by accessing the Force sense function screen from the JOG screen.
4) Lightly hold the Enable switch (3-position switch).
5) For the R32TB, press and hold the [RESET] key. For the R56TB, press and hold the [CAUTION] key.
6) Press the [SERVO] key to turn the servo on.
7) Move the robot using Jog operation.

The procedure above temporarily resets the error.
Recovery mode can be disabled using any of the following methods:

① Releasing the [RESET] key or the [CAUTION] key.
② Setting the Enable switch of the teaching pendant to DISABLE and changing the controller mode to AUTOMATIC.
③ Displaying the JOG screen or a screen unrelated to the force sense function. (This method will only work for the R32TB.)

Errors will still occur after recovery mode is disabled if they have not been resolved.
Press and hold the [RESET] key or [CAUTION] key when moving the robot in Jog operation mode.

Caution During the recovery mode, the SLP function generates no errors even if the robot intrudes into the restricted area. Take care not to let the robot interfere with peripheral devices. Also, during the recovery mode, the safety monitoring functions are stopped temporarily. Configure a safety system in such a way that the dedicated output signal enables recognizing the recovery mode is active. The recovery mode disables the robot from stopping at an operating area boundary. Take care not to move the robot toward the outside of the operating area.

4.2.6 Parameter CRC output number

(1) Overview

A CRC can be calculated from the parameter file storing the parameter settings for the safety monitoring functions and sent out on dedicated output signals. Monitoring the signals enables peripheral devices to detect a change in the safety monitoring function parameters.

(2) When is a CRC calculated?

A CRC of the parameter file is calculated:

- Immediately after the controller is powered on
- After a safety monitoring function parameter is changed and it is written in the controller

* Even if the safety monitoring functions are disabled, a CRC is calculated and sent to the dedicated output signals.
* When the parameter file is written to the controller with the RT ToolBox3 restoration function, a CRC is calculated when the controller is power-cycled. The CRC becomes the same as one calculated when the written parameter file is backed up.

(3) Dedicated output signals

A CRC of the parameter file is output to the dedicated output signals configured in the Basic Configuration screen. The output signal width is fixed to 16 bits.

Example)

- Parameter CRC output number: The start number = 16, the end number = 31
- CRC value: DB17 (Hexadecimal)

In the above case, the signals are output as follows:

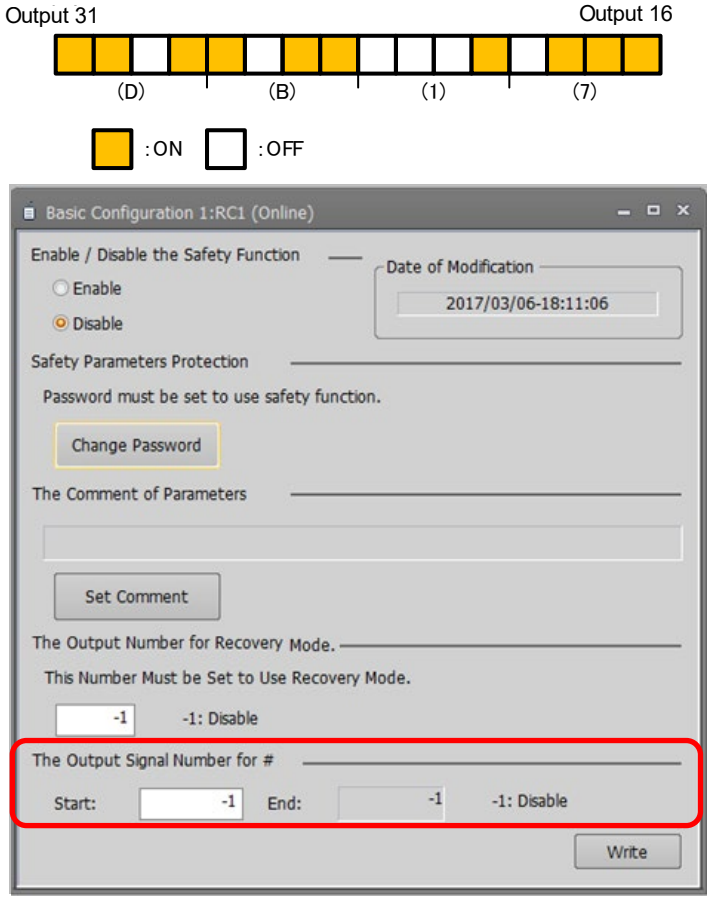


Fig. 4-7: Parameter file CRC output number

4.3 Defining 3D Models

This chapter talks about defining shape models for the robot and the robot tools used for the safety monitoring. The shape models defined in this chapter are used for judgment in the safely limited speed function, safely limited position function, and Area Input.

4.3.1 3D Monitor

The 3D Monitor screen of RT ToolBox3 enables viewing shape models of the robot and tools and the area settings used for the safely limited position function and AREA Input.

(1) Displaying the 3D Monitor
Double-clicking [3D Monitor] in Workspace opens the 3D Monitor screen.

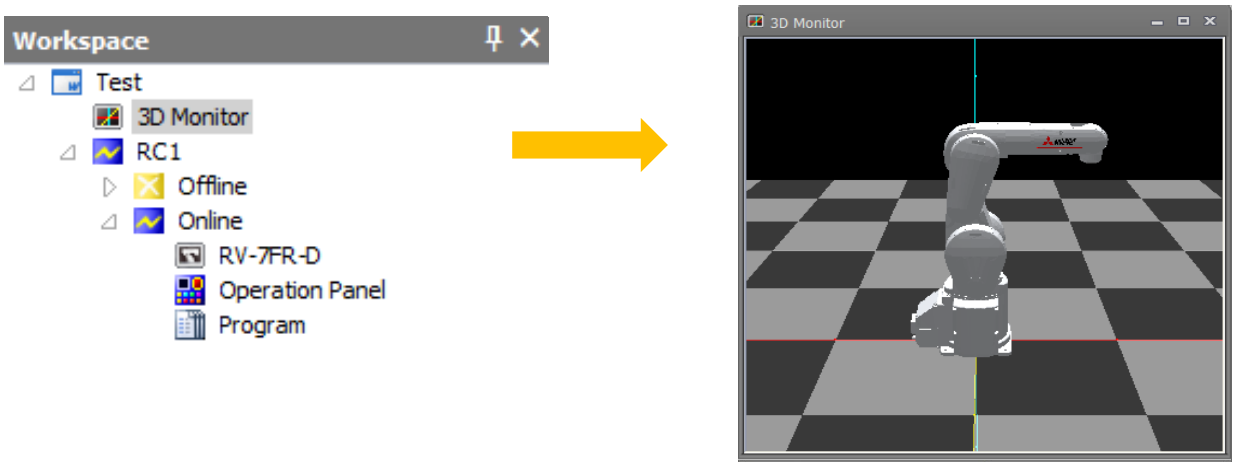


Fig. 4-8: Displaying the 3D Monitor

(2) Layout tree
Selecting a project name (RC1 in the example below) from the layout tree displays information on the robot in Properties.

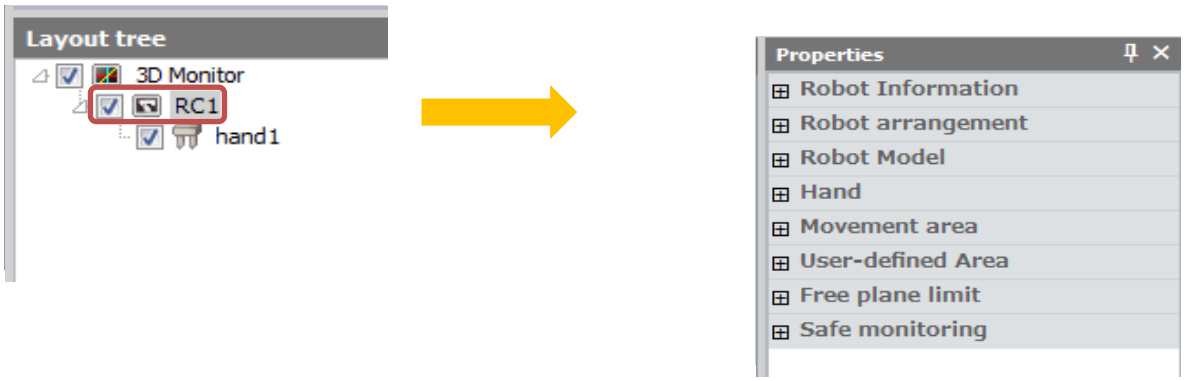


Fig. 4-9: Layout tree

(3) Properties

[Safe monitoring] in Properties enables viewing the relevant settings.

(a) Arm model

Selecting [AREA Input] -> [Arm model] in Properties and setting Display to True displays a shape model of the robot used for the safety monitoring function in the 3D Monitor screen.

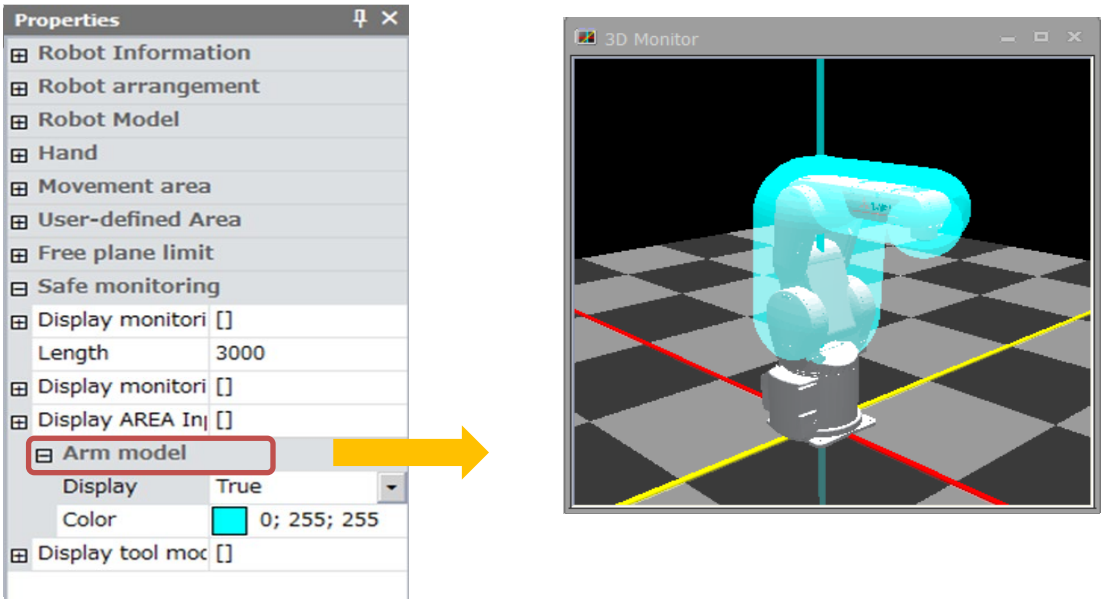


Fig. 4-10: Arm model

(b) Tool model

Selecting [Display tool model] in Properties and setting the items of 1 through 4 to True displays a tool model used for the safety monitoring function in the 3D Monitor screen.

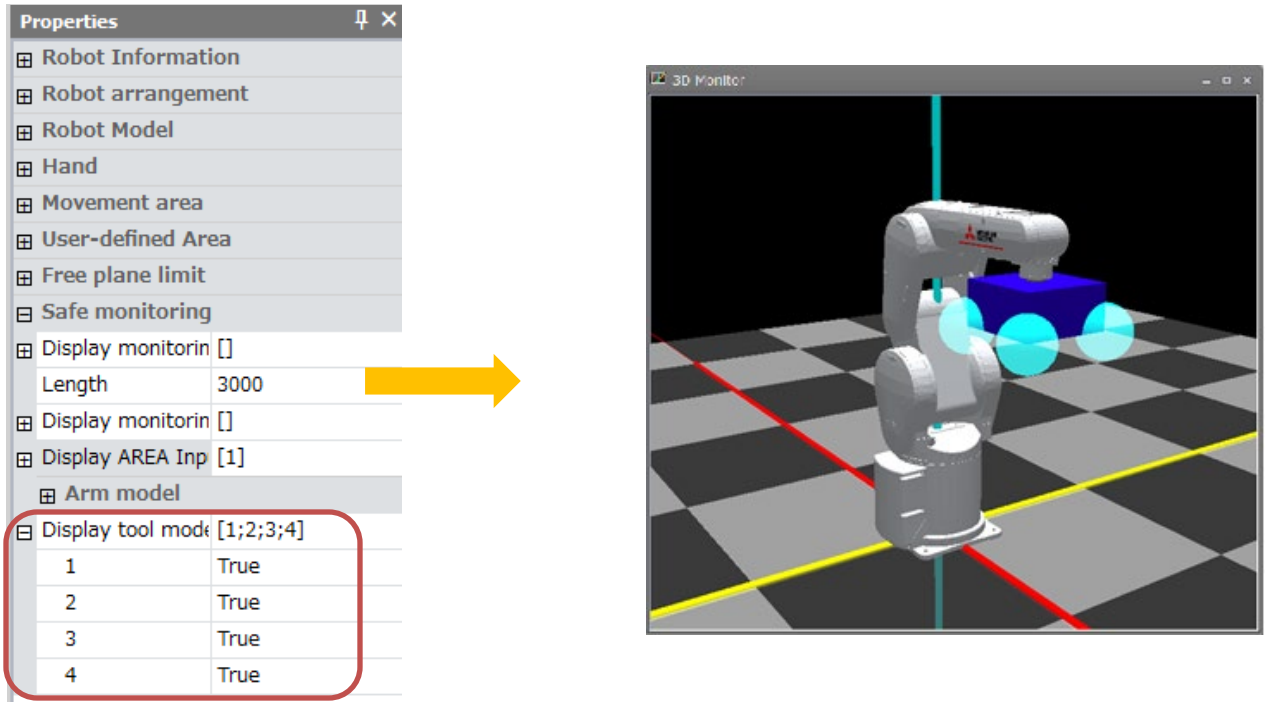


Fig. 4-11: Tool model

(c) Safety monitoring plane

Selecting [Display monitoring plane] in Properties and changing the items of 1 through 8 from False to True displays the selected safety monitoring planes in the 3D Monitor screen.

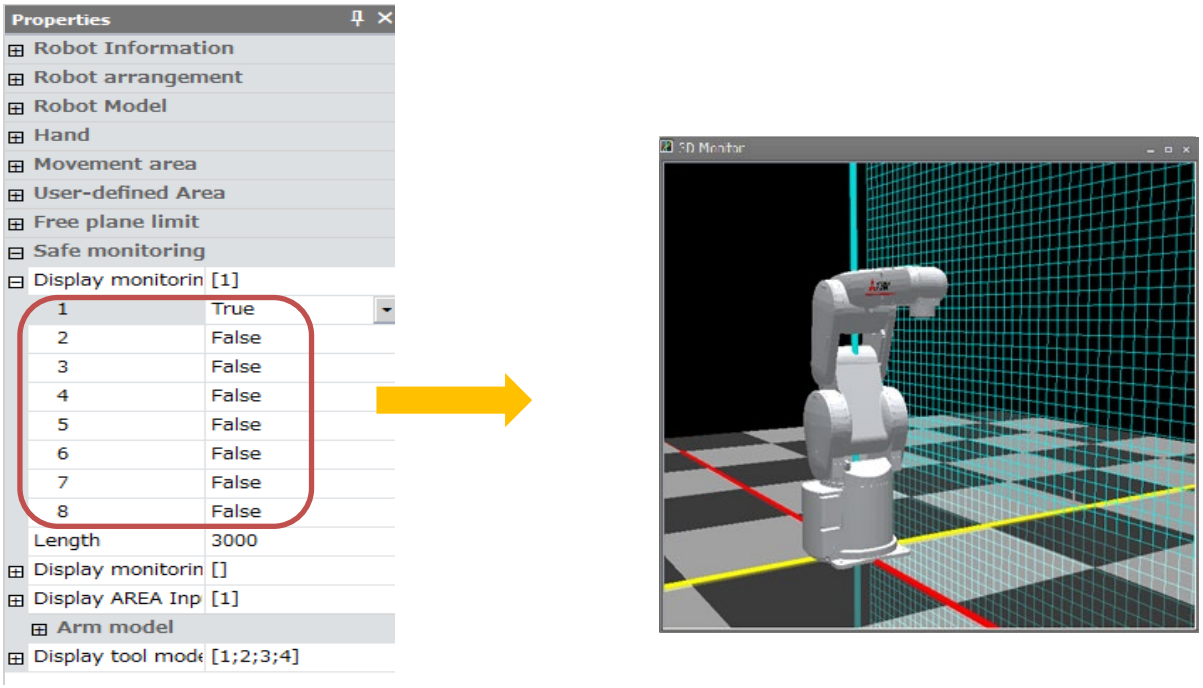


Fig. 4-12: Safety monitoring plane

(d) Safety monitoring area

Selecting [Display monitoring area] in Properties and setting the items of 1 through 8 to True displays the selected safety monitoring areas 1 to 8 in the 3D Monitor screen.

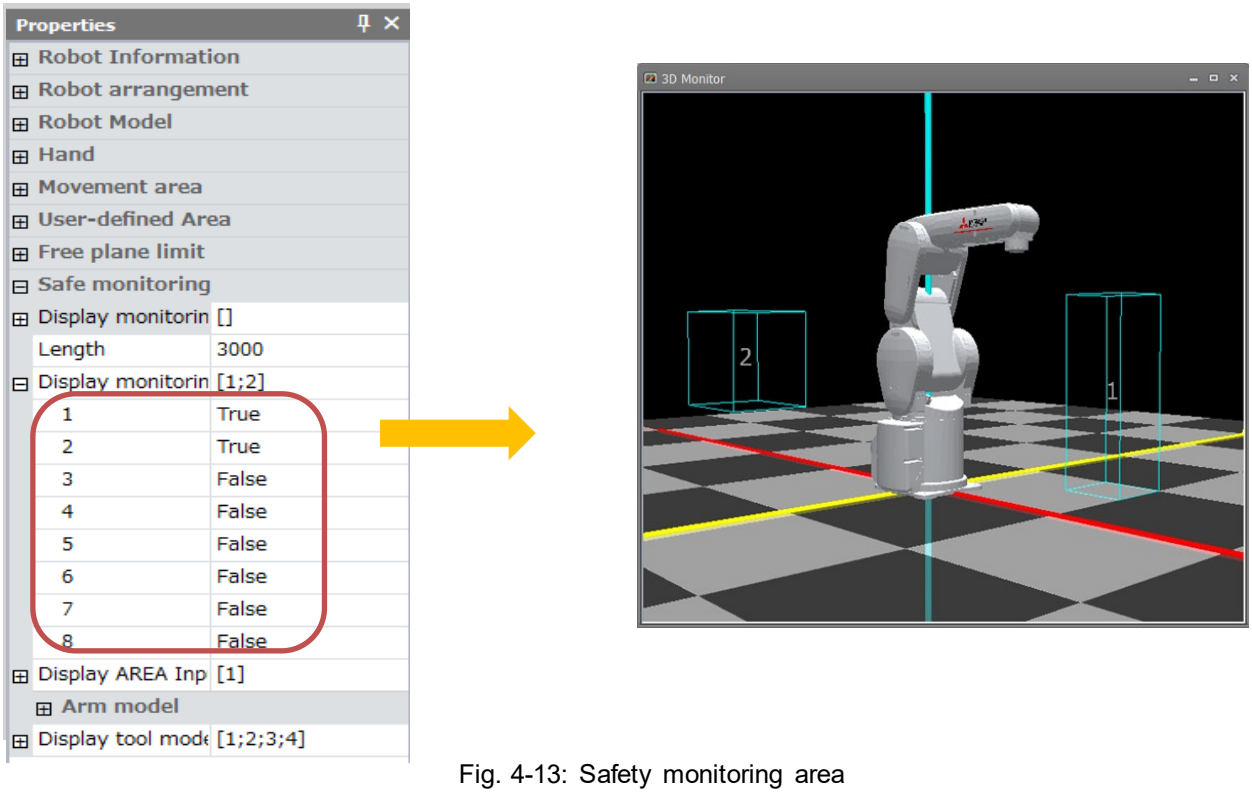


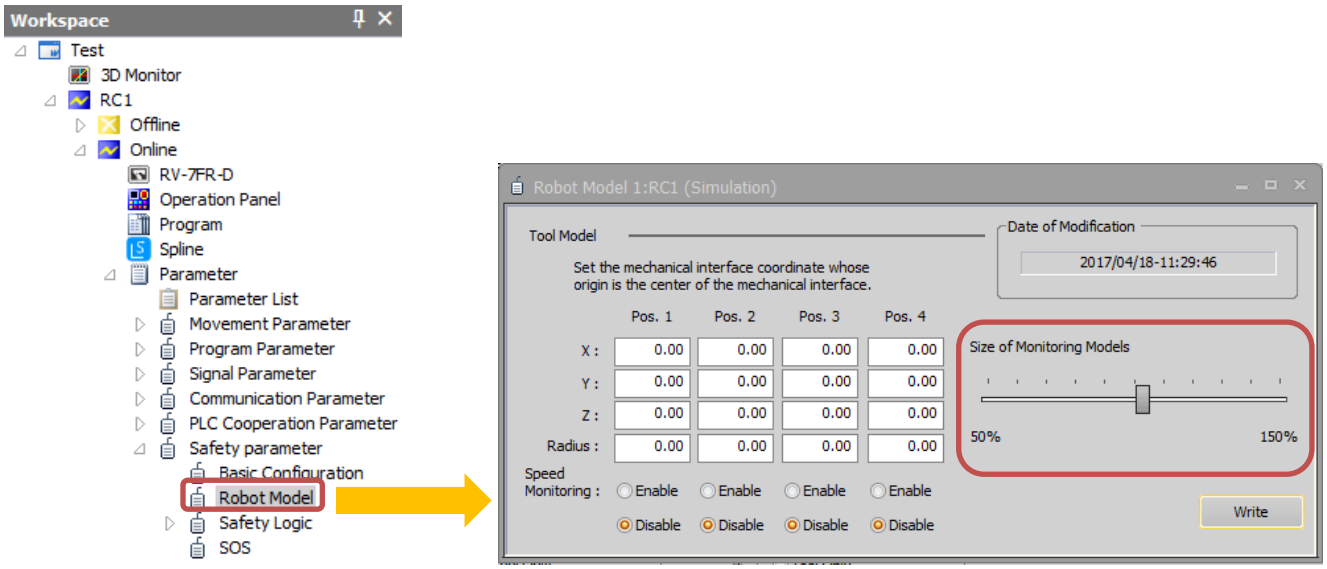
Fig. 4-13: Safety monitoring area

4.3.2 Arm model

The shape of the robot arm has been modeled with sphere models and cylinder models and the robot model is used for judging the speed and area of the robot.
The model can be used as it is in the initial condition. However, when cables, solenoid valves, or etc. are attached to the robot arm, resize the model as necessary.

(1) Changing monitoring models

To change monitoring models, open the Robot Model screen from Workspace by selecting [Online] -> [Parameter] -> [Safety parameter] -> [Robot Model].
Moving the slider bar resizes the monitoring model.



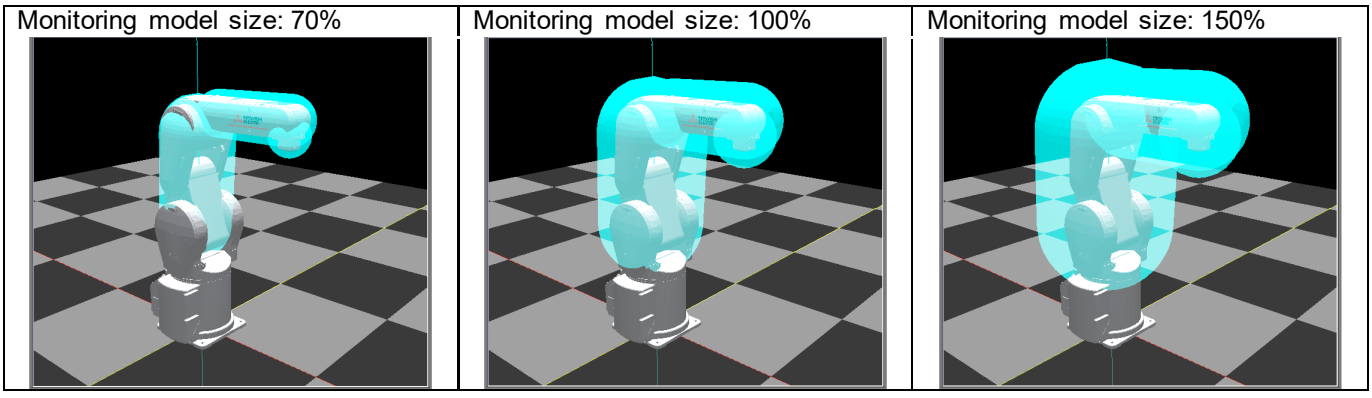


Fig. 4-14: Changing monitoring models

4.3.3 Tool model

The shape of a robot tool is defined with up to four sphere models. Resize the model as necessary.

(1) Changing monitoring models

To change monitoring models, open the Robot Model screen from Workspace by selecting [Online] -> [Parameter] -> [Safety parameter] -> [Robot Model].

In Pos. 1 to Pos. 4 of Tool model, enter the coordinates of the central point and the radius of a sphere model. They need configuring in the mechanical interface coordinate system.

<Mechanical interface coordinate system>

A coordinate system with its origin at the center of a flange is called the mechanical interface coordinate system. For details on the mechanical interface coordinate system, refer to the separate "Instruction Manual/Detailed Explanations of Functions and Operations" (“About tool coordinate system [mechanical interface coordinate system]” and “Standard Tool Coordinates”).

(2) Enabling or disabling monitoring models

Entering a value larger than 0 in Radius enables the tool model position monitoring.

The [Enable] and [Disable] buttons for each position configures the speed monitoring.

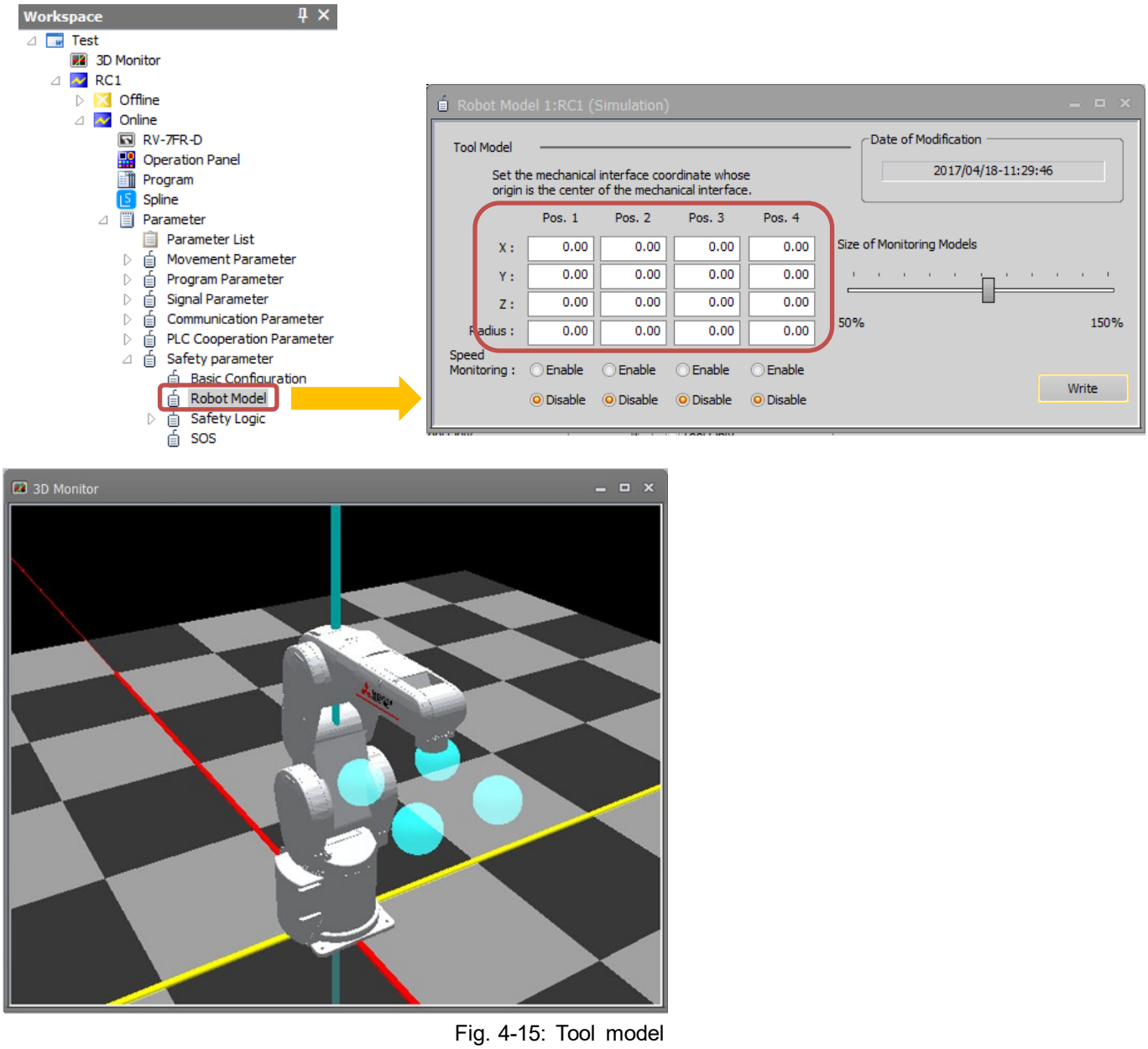


Fig. 4-15: Tool model

After configuring the parameters, check that the settings are correct with 3D Monitor.

4.4 Safety Logic Edit

4.4.1 Safety input settings

The safety logic edit function enables configuring conditions to start the safety monitoring function. Associating input states of DSI Input, Area Input, Logic Input, and Mode Input with safety monitoring functions to start enables switching safety monitoring items according to the input states.
(For details on DSI Input, Area Input, Logic Input, and Mode Input, see the next sub-section.)

To configuring the settings, open the Safety Input screen from Workspace by selecting [Online] -> [Parameter] -> [Safety parameter] -> [Safety Logic] -> [Safety Input].

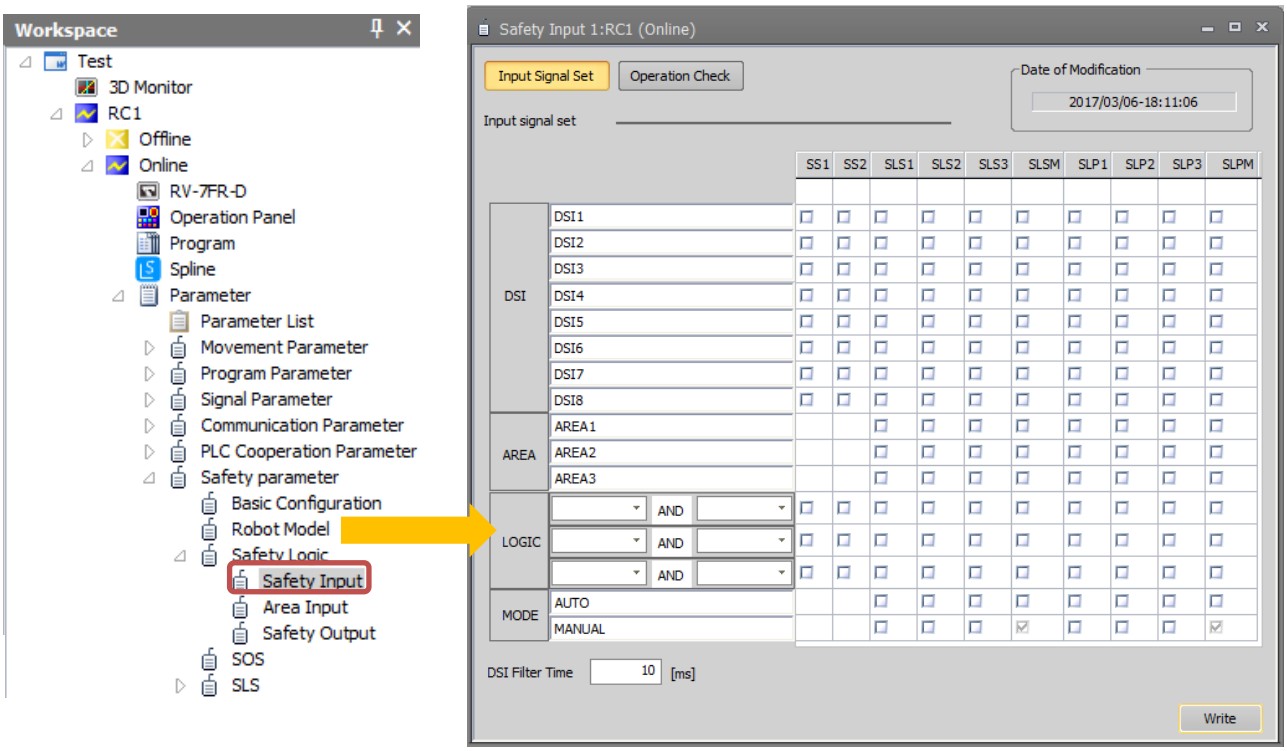


Fig. 4-16: Safety monitoring logic configuration screen

Tab. 4-2 Explanation of terminology

Category	String	Description	See:
Safety input state	DSIn (n = 1 to 8)	DSI Input states	(1)DSI Input
	AREAn (n = 1 to 3)	Area Input states	(2)Area Input
	LOGIC	This outputs results of AND operation of DSIn inputs and AREAn inputs.	(3)Logic Input
	MODE	Mode key switch states	(4)Mode Input
Safety monitoring command	SS1	SS1 command: Starts the SS1 function	-
	SS2	SS2 command: Starts the SS2 function	-
	SLSn (n = 1 to 3)	SLSn command: Controls the start and end of SLSn functions	-
	SLSM	SLSM command: Controls the start and end of SLSM functions	-
	SLPn (n = 1 to 3)	SLPn command: Controls the start and end of SLPn functions	-
	SLPM	SLPM command: Controls the start and end of SLPM functions	-

The matrix in the Safety Input screen has rows representing safety inputs (DSI, AREA, LOGIC, MODE). The columns represent safety monitoring start commands for each safety function (SS1, SS2, SLS1, SLS2, SLS3, SLSM, SLP1, SLP2, SLP3, SLPM).
Checking intersections of the rows and columns defines safety functions started when the individual safety inputs are enabled.

Example 1: To start the safely limited speed function 1 (SLS1) when DSI2 is enabled, check the intersection of DSI2 and SLS1 as shown in Fig 4-17.

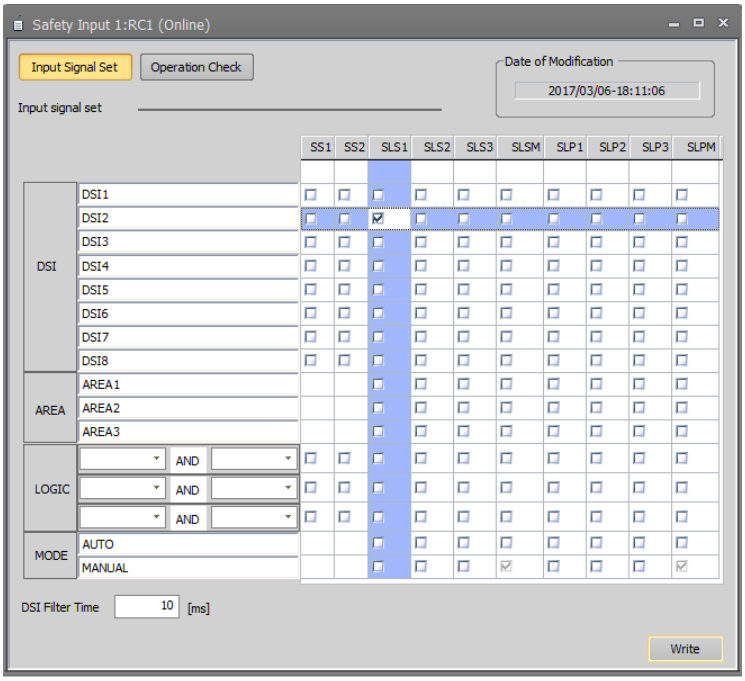


Fig 4-17: Example 1 of safety logic (safety input) configuration

Also, one safety input can start multiple safety functions.

Example 2: Enabling DSI3 starts SLS1, SLS2, and SLP1 and enabling DSI4 starts SLS3.

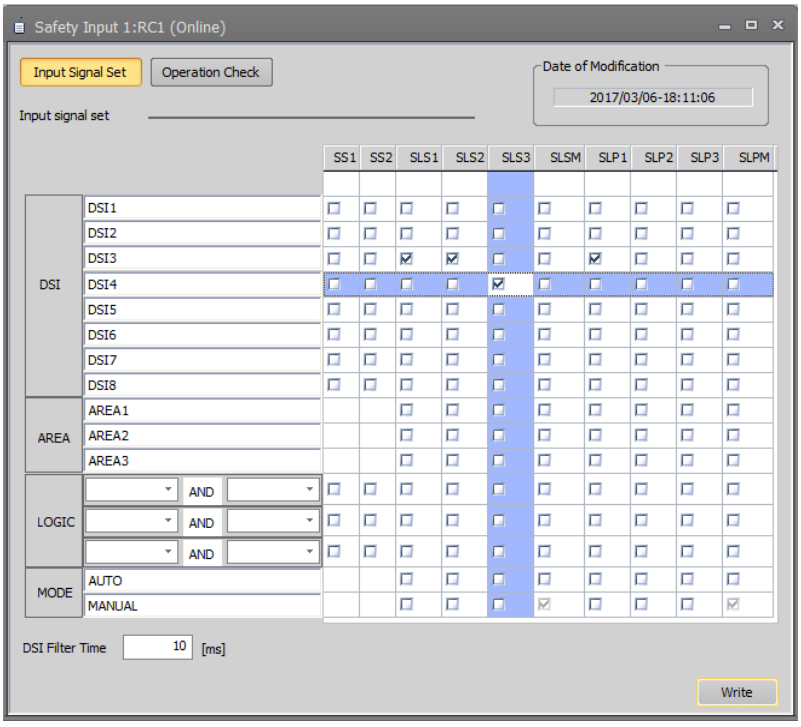


Fig 4-18: Example 2 of safety logic (safety input) configuration

(1) DSI Input

(a) Overview

The DSI Input switches between the enabled state and disabled state depending on states of the duplex signals input into the SDI1 and SDI2 connectors of the safety extension unit. Input of up to eight points is supported.Tab. 4-3 shows the relation of the DSI Input to DSInA and DSInB.

Tab. 4-3: DSI Input states

		DSI_A	DSI_B	Remarks
DSIn input states (n = 1 to 8)	Enabled	OFF	OFF	-
		ON	OFF	A 100-ms continuous discrepancy between DSI_A and DSI_B will cause error H222: (DSI mismatch) and start SS1.
		OFF	ON	
	Disabled	ON	ON	-

(b) Timing diagram

① Normal operation

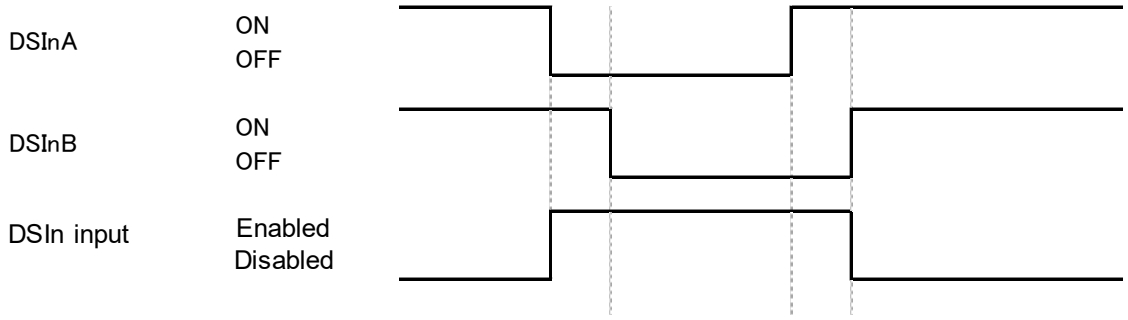


Fig. 4-19: DSIn timing diagram

② When a discrepancy between DSInA and DSInB is detected

If a discrepancy between DSInA and DSInB (n = 1 to 8) continues for 100 ms, error H222* (DSI mismatch) occurs.

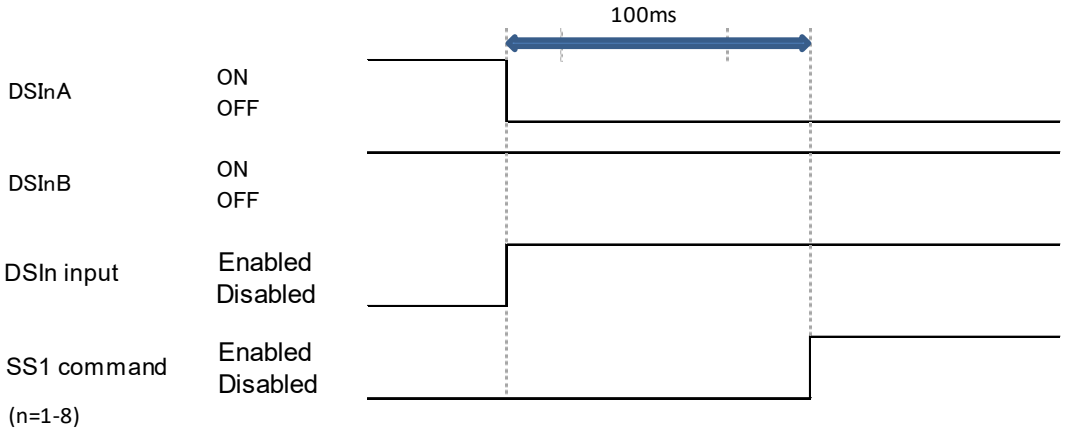
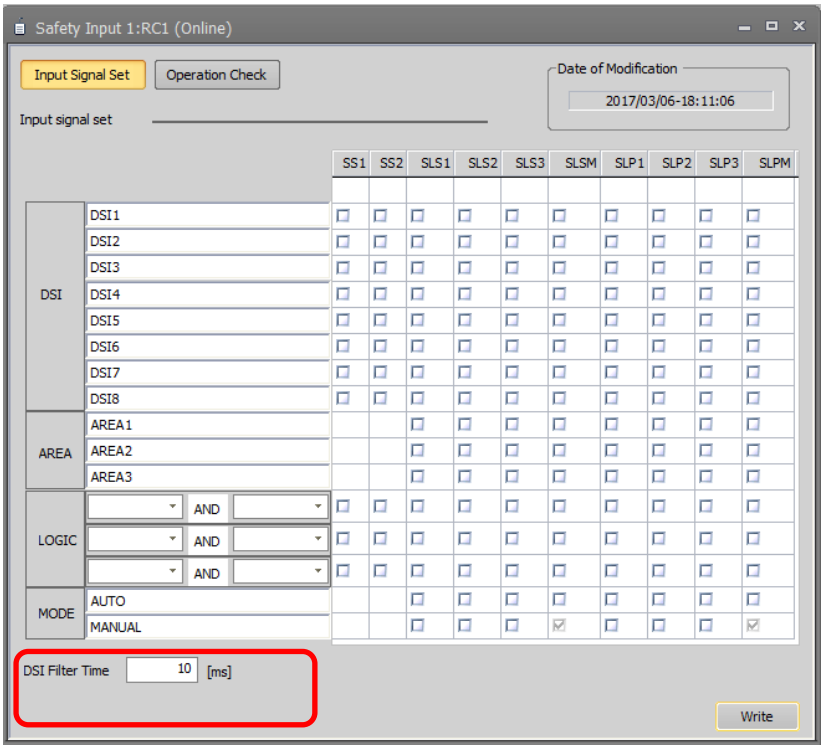


Fig. 4-20: DSIn timing diagram

(c) DSI filter configuration

The DSI signal filtering can prevent wrong detection caused by chattering in the DSInA or DSInB signals or by test pulses from input devices.

Enter a filter time in [DSI Filter Time] in the Safety Input screen.



Parameter	Description	Default
DSI Filter Time	A filter time for the DSI signals are entered. The larger the setting is, the stronger the noise resistance becomes but the more the signal input detection is delayed. [Unit]: ms [Setting range]: 0 to 100	10ms

Fig. 4-21: DSI filter configuration

The DSI filter time and DSI1 input (enabled/disabled) are shown in the following diagram:

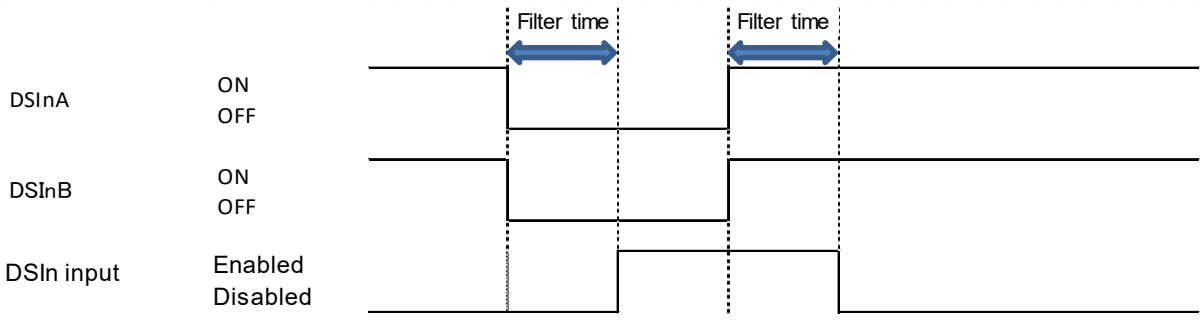


Fig. 4-22: Timing diagram of the DSI filter time and DSI1 input

(2)Area Input

(a) Overview

AREA Input is a state that is enabled (or disabled) when the robot intrudes into or moves outside an area that is specified beforehand. Configuration of up to three areas is supported.

The relation of the positions of the arm model and tool model, which are defined in Chapter 4.3 , to an area specified in this sub-section is monitored in real time, which switches AREA Input between the enabled and disabled states.

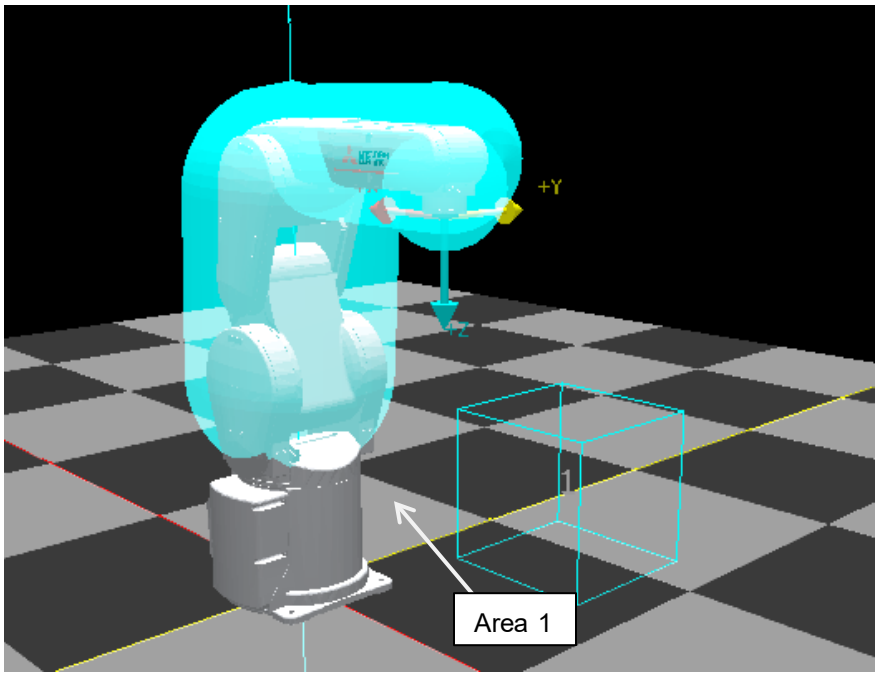


Fig. 4-23: Area input

(b) Timing diagram

Intrusion of a monitoring position of the robot into a specified area enables the AREAn input.

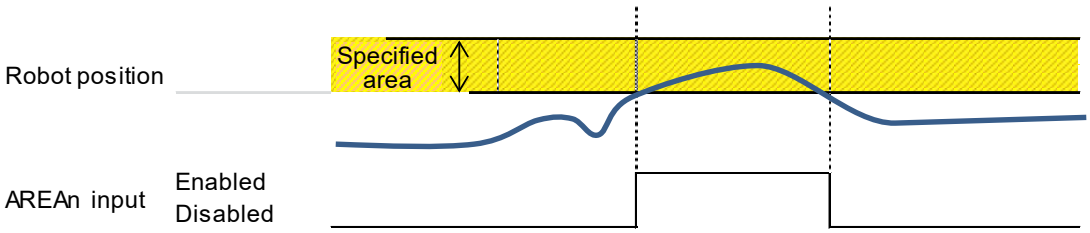


Fig. 4-24: AREA Input timing diagram

(c) Configuring Area Input monitoring conditions

Areas for area signals is configured in the Area Input screen.

Selecting [Online] -> [Parameter] -> [Safety parameter] -> [Safety Logic] -> [Safety Input] -> [Area Input] from Workspace displays the Area Input screen.

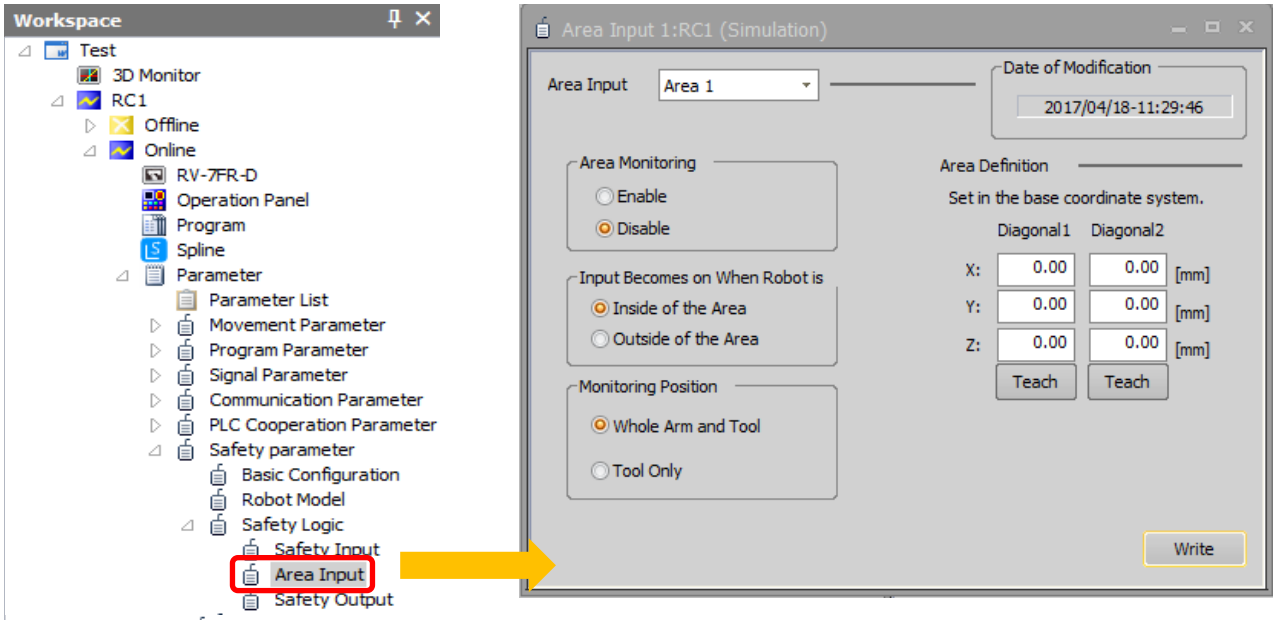


Fig. 4-25: Area Input

1) Area Input

Configuration of up to three types of area input conditions is supported. From the pull-down menu of Area Input, select an area to configure. (Area 1 to 3)

2) Area Monitoring

This sets the area monitoring to Enable or Disable. Selecting Disable results in no area judgment processing performed, always disabling Area Input.

3) Input Becomes on When Robot is

• To enable Area Input when a monitoring position of the robot intrudes into the area, select [Inside of the Area].

• To enable Area Input when a monitoring position of the robot moves out of the area, select Outside of the Area.

Both settings enable Area Input when a monitoring position of the robot comes into contact with the area.

4) Monitoring Position

This specifies a monitoring position of the robot subject to the judgment of whether it is inside or outside of the monitored area.

5) Area Definition

This specifies the monitored area. The area is defined as a cuboid parallel to a coordinate system formed from two points diagonal to each other. It is specified by the base coordinates system.

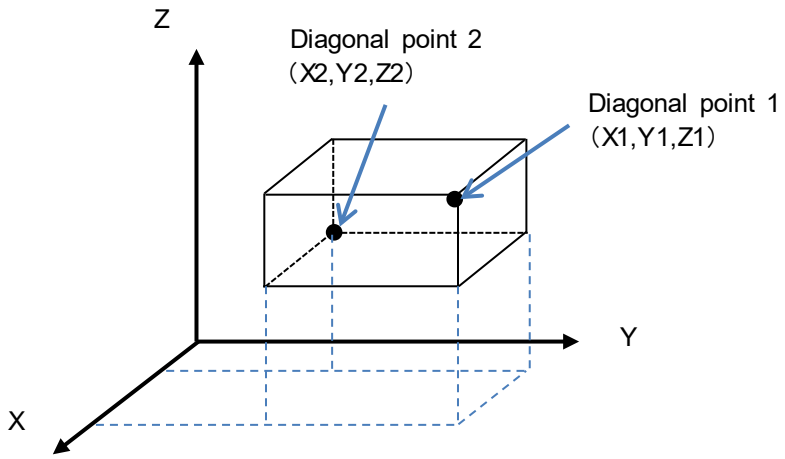


Fig. 4-26: Area Input area Definition

(d) How to view the Area Input state

State variable M_SflArea enables obtaining the Area Input state.

The Operation Check screen for the safety input also enables viewing it.

(3) Logic Input

(a) Overview

Logic Input is a state enabled based on a combination of DSIn inputs (n = 1 to 8) and AREAm inputs (m = 1 to 3).

It enables the AND condition of DSI and AREA to start the safety functions.

From Workspace, select [Online] -> [Parameter] -> [Safety parameter] -> [Safety Logic] -> [Safety Input] and open the Safety Input screen, which enables configuring of LOGIC (circled in red in the figure below).

The following is an example for inputting the SLS1 command when both DSI1 and AREA1 are enabled.

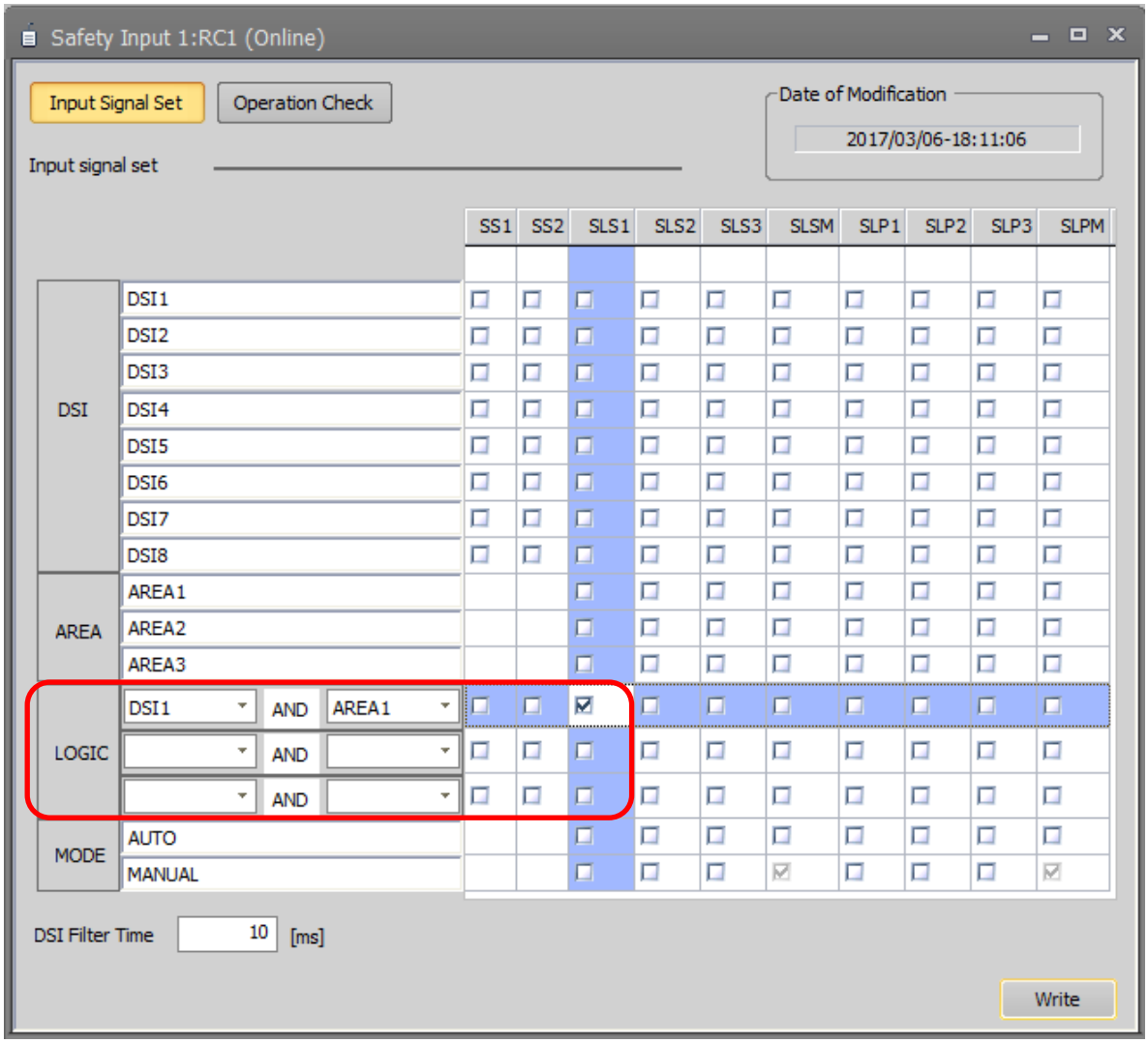


Fig. 4-27: Logic Input

(b) How to view the Logic Input state

State variable M_Logic enables obtaining the Logic Input state.

The Operation Check screen for the safety input also enables viewing it.

(4) Mode Input

Mode Input is input that works based on the mode key state (MANUAL or AUTO) of the robot controller. It enables switching automatically the safety monitoring functions based on the mode key state.

Configure the safety monitoring functions to always enable in the Auto mode or Manual mode regardless of DSI Input, Area Input, or Logic Input.

The Manual mode always enables SLSM and SLPM.

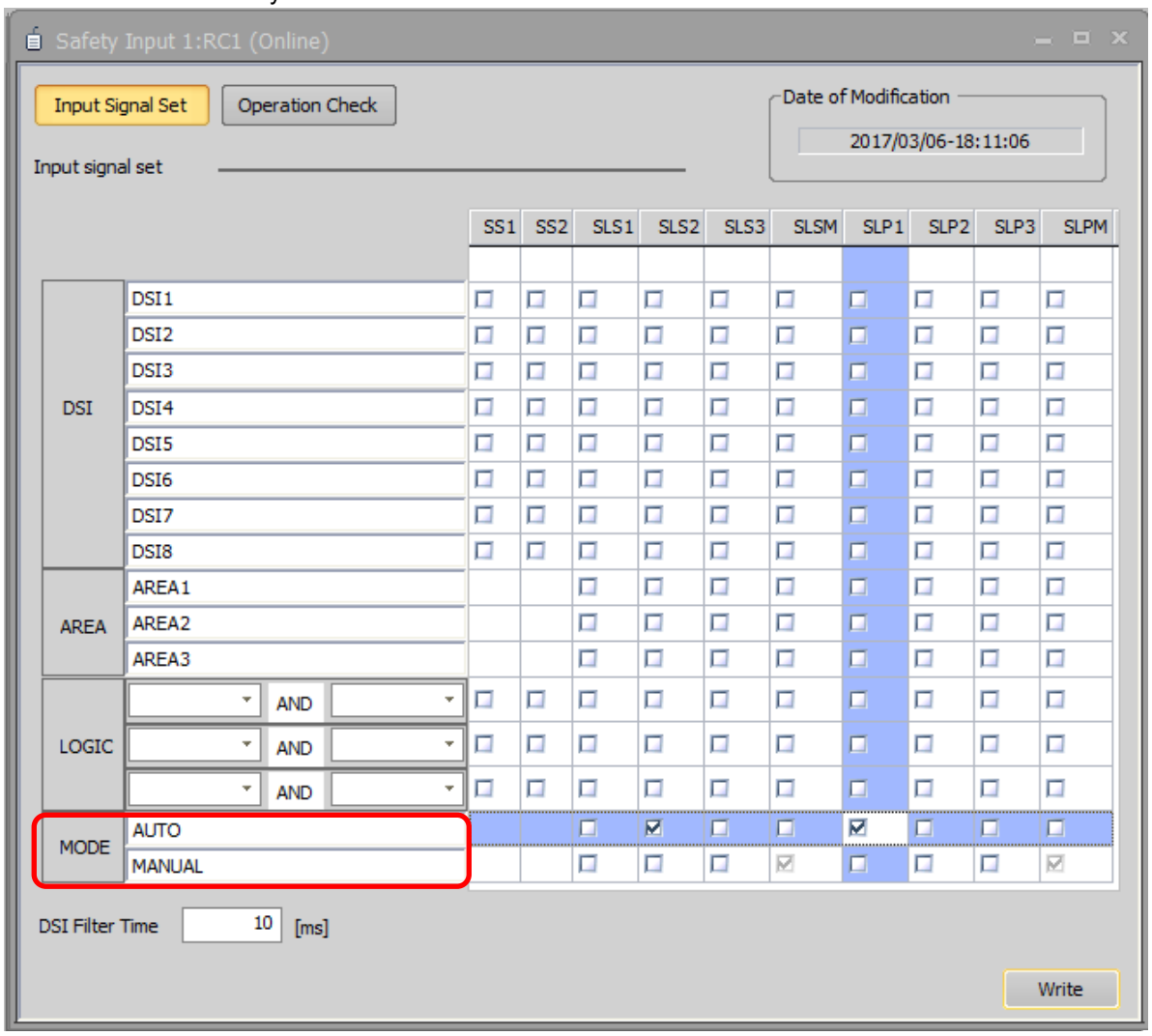


Fig. 4-28: Mode Input

The configuration above is an example for enabling the SLS2 and the SLP1 commands in the AUTO mode and also enabling the SLSM and SLPM commands in the MANUAL mode.

4.4.2 Safety output configuration

This enables assigning the Enable and Disable states of the safety monitoring states (STO, SOS, SLS*, SLP*) and Area states to DSO1 to DSO4 of the safety extension unit.
The configuration is used for displaying safety monitoring states or connecting other safety devices.

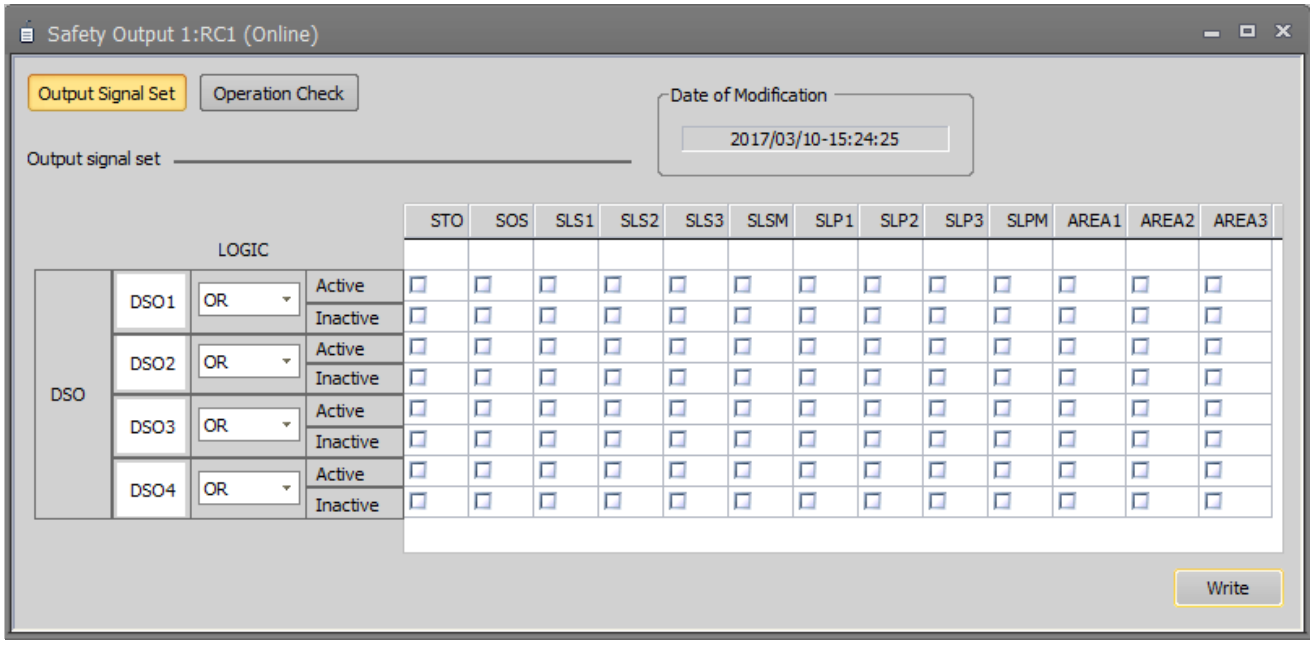


Fig. 4-29: Safety output configuration

The matrix in the Safety Output screen has rows representing the safety outputs (DSO1 to DSO4), safety monitoring states (SS1, SS2, SLS1, SLS2, SLS3, SLSM, SLP1, SLP2, SLP3, SLPM) for the safety functions, and Area Input (AREA1 to AREA3). The columns represent target safety functions and Area Inputs.
Checking intersections of the rows and columns defines safety signals output when the individual safety monitoring states and Area Inputs become Enable or Disable.

Example 1) To turn on DSO2 when SOS is enabled, check the intersection of DSO2 and SOS (at Enable).

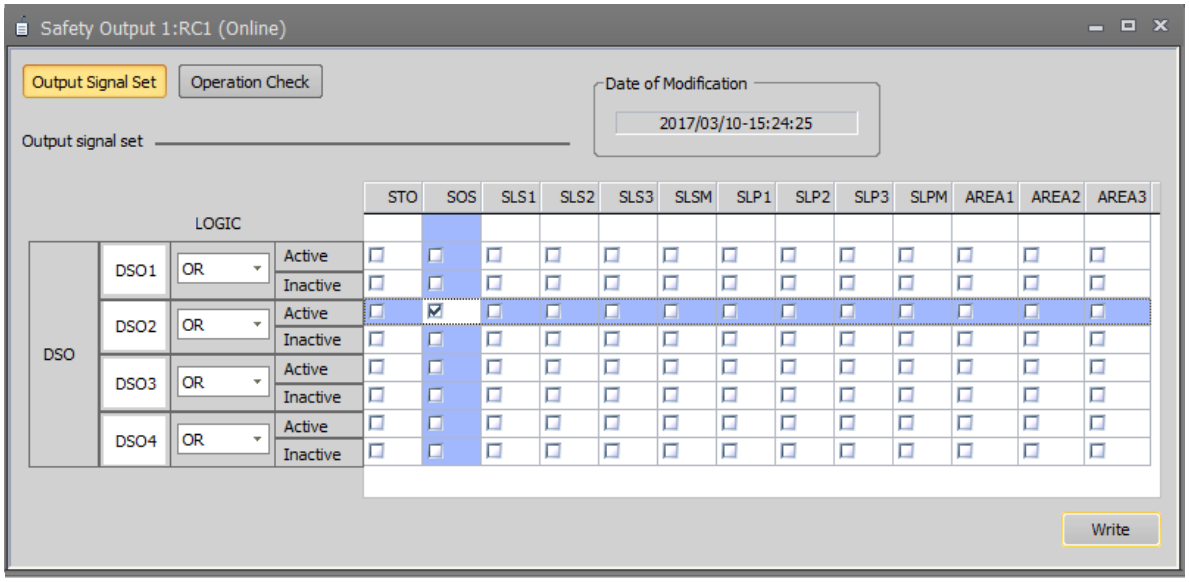


Fig. 4-30: Example of safety output configuration

LOGIC enables the AND and OR conditions of Enable and Disable of multiple safety monitoring states to control turning on or off the DSO_ signals.

Example 2) The following configuration is for outputting DSO1 when SLS1 is enabled and AREA1 disabled.

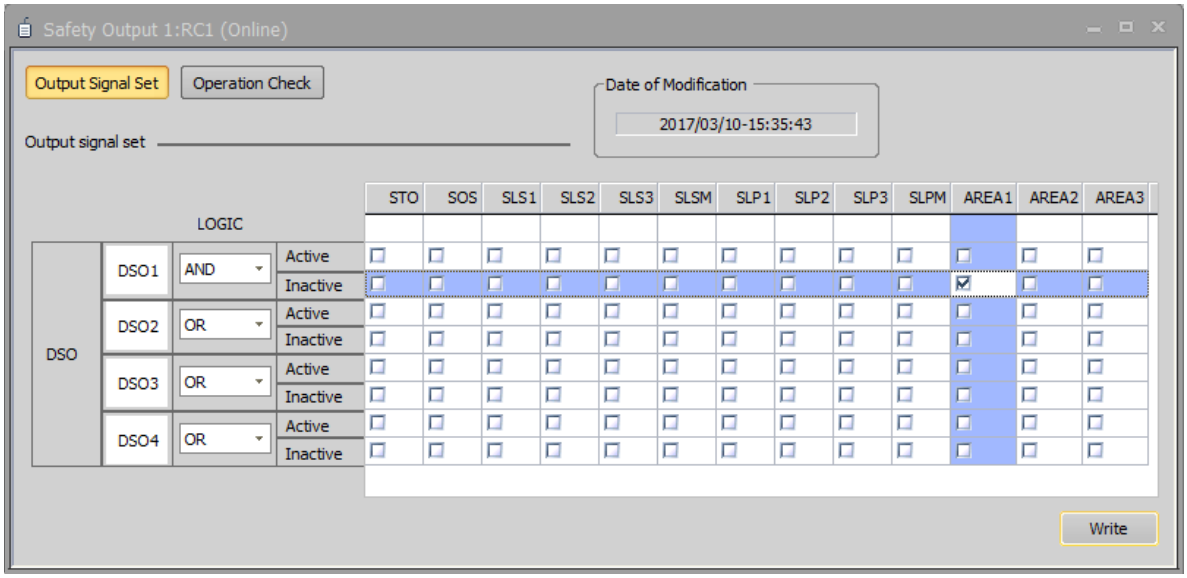


Fig. 4-31: Example of safety output configuration

4.4.3 Checking operation of the safety inputs and outputs

After configuring the safety inputs and outputs, be sure to check that they operate as intended.

(1) How to check operation of the safety inputs

From Workspace, select [Online] -> [Parameter] -> [Safety parameter] -> [Safety Logic] -> [Safety Input] to open the Safety Input screen. Pressing the Operation Check button in this screen enables checking current states of the safety inputs and safety monitoring.

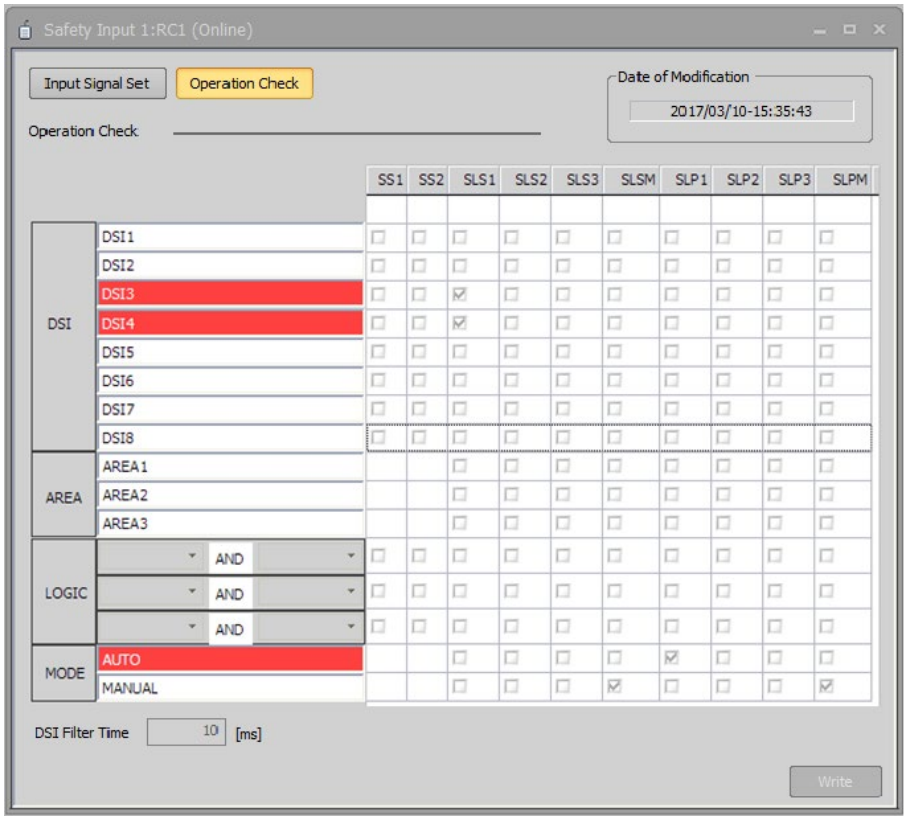


Fig. 4-32: Checking operation of the safety input

(2) How to check operation of the safety outputs

From Workspace, select [Online] -> [Parameter] -> [Safety parameter] -> [Safety Logic] -> [Safety Output] to open the Safety Output screen. Pressing the Operation Check button in this screen enables checking current states of the safety inputs and current states of safety monitoring.

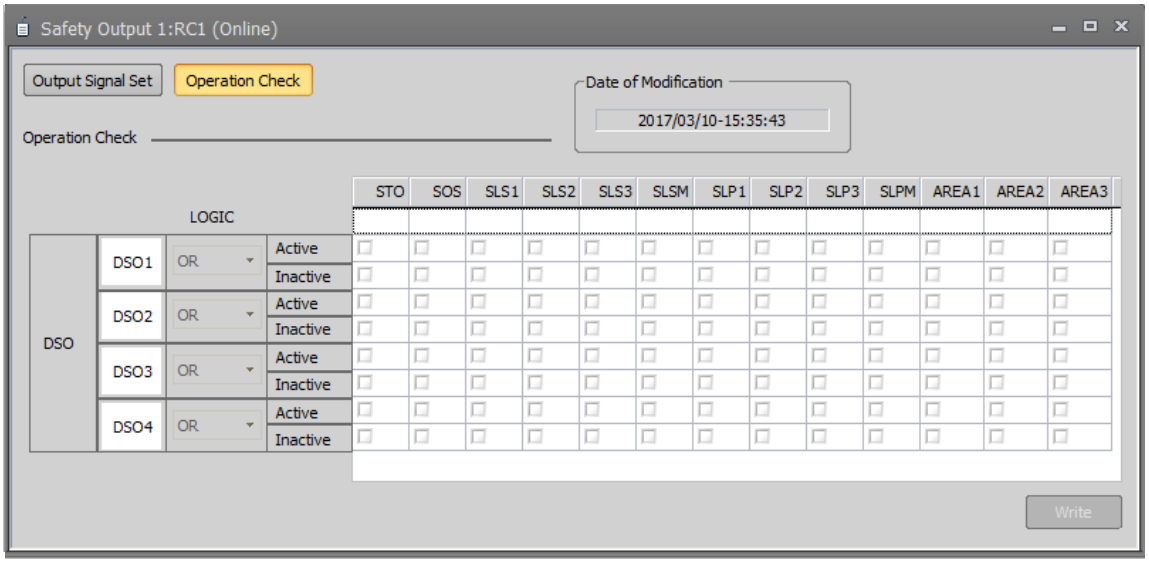


Fig. 4-33: Checking operation of the safety output

4.5 Safety Monitoring Functions

This chapter provides the functional overview and configuration method of the safety monitoring function.

4.5.1 Safe torque off (STO)

(1) Overview

This function electrically shuts off the motor driving energy according to input signals from external devices. It corresponds to stop category 0 of IEC60204-1.

(2) Operation sequence

(a) STO start conditions

<SS1 command or emergency stop>

To trigger the STO function, input the SS1 command or the emergency stop signal. Inputting the SS1 command or the emergency stop signal causes the robot to start decelerating and, after the robot stops safely, the STO function starts. For details on the sequence, see chapter 4.5.3 .

(No external signal can directly start the STO function.)

<When an error occurs>

The STO function is triggered if:

- The robot fails to stop within a deceleration monitoring period while SS1 is running.
- The robot fails to stop within a deceleration monitoring period while SS2 is running
- An internal error occurs which hinders the robot control
- Communication with the safety extension unit fails

(b) Program operation state

Program operation suspends during the STO monitoring. To resume, it is necessary to cancel all the SS1 start conditions and then perform program start operation.

(c) Operation restrictions

Operation restrictions during SS1/STO monitoring are shown in following table.

Tab. 4-4: Operation restrictions during SS1/STO monitoring

Operation	Available	Unavailable	Remarks
Servo-on		✓	Performing the servo-on operation during the SS1/STO monitoring causes error H2270 (Servo-on prohibited during SS1/STO).
Program operation start		✓	The ALWAYS program does not stop. The ERROR program is not performed.
JOG operation		✓	
Opening or closing hand	✓		For the TB operation only.

(3) Configuring monitoring conditions

There are no parameters concerning the STO function.

4.5.2 Safe operating stop (SOS)

(1) Overview

This is a function to keep shifts of the robot from the stop position within a specified value. This function provides the motors with driving energy necessary to keep the stop state.
Change in the position or speed during the SOS monitoring causes error H2282 (SOS position error, SOS speed error).

(2) Operation sequence

(a) SOS function start conditions

<SS2 command>

To trigger the SOS function, input the SS2 command. Inputting the SS2 command causes the robot to start decelerating, and after the robot stops safely, the SOS function starts. For details on the sequence, see chapter 4.5.4 . (No external signal can directly start the SOS function.)

(b) Program operation state

The SOS automatic resumption configuration enables changing the program operation state during the SOS monitoring.

Tab. 4-5: SOS automatic resumption mode

SOS automatic resumption (Disabled by factory default.)	Disabled	Enabling the SS2 command during a program operation suspends the operation and causes no program start operation to be accepted. Resuming the program requires disabling the SS2 command and then performing program start operation.
	Enabled	Enabling the SS2 command during a program operation suspends the operation once a command concerning the robot movement is performed. Disabling the SS2 command automatically resumes the program operation.

(c) Operation restrictions

Operation restrictions during the SOS monitoring are shown in Table Tab. 4-6.

Tab. 4-6: Operation restrictions during the SOS monitoring

	SOS automatic resumption disabled		SOS automatic resumption enabled	
Operation	Available	Unavailable	Available	Unavailable
Servo-on	-		-	
Servo-off	✔		✔	
Program operation start		✔	✔	
JOG operation		✔		✔
Opening or closing hand	✔		✔	

- Turning off servos during the SOS monitoring disables the SOS monitoring.
- When the SS2 command is enabled, turning on the servos again resumes the SOS monitoring.

(d) When the robot moves during the SOS monitoring

When one of the following items exceeds the allowable range during the SOS monitoring, the SS1 function stops the robot.

(i) Joint position command
(ii) Joint position FB
(iii) Joint speed command
(iv) Joint speed FB

For (i) and (ii), the values are recorded at the beginning of the SOS monitoring and the judgments are made based on the differences between the values and the current ones.

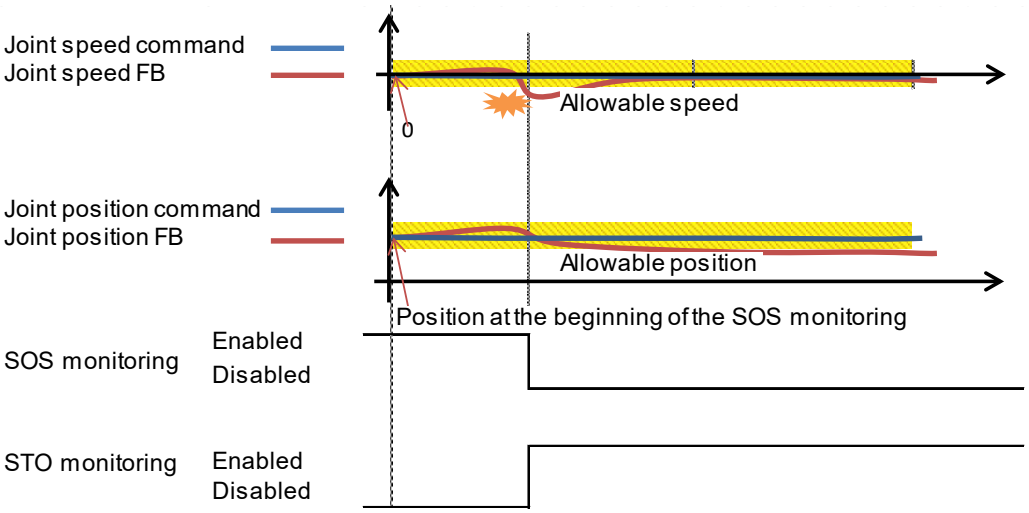


Fig. 4-34: When the robot moves during the SOS monitoring

(e) When servos are turned off during the SOS monitoring

Turning off servos when the SS2 command is enabled disables the SS2 monitoring and the SOS monitoring. Turning on the servos again with the SS2 command enabled will enable the SOS monitoring 200 ms after the servos are turned on.

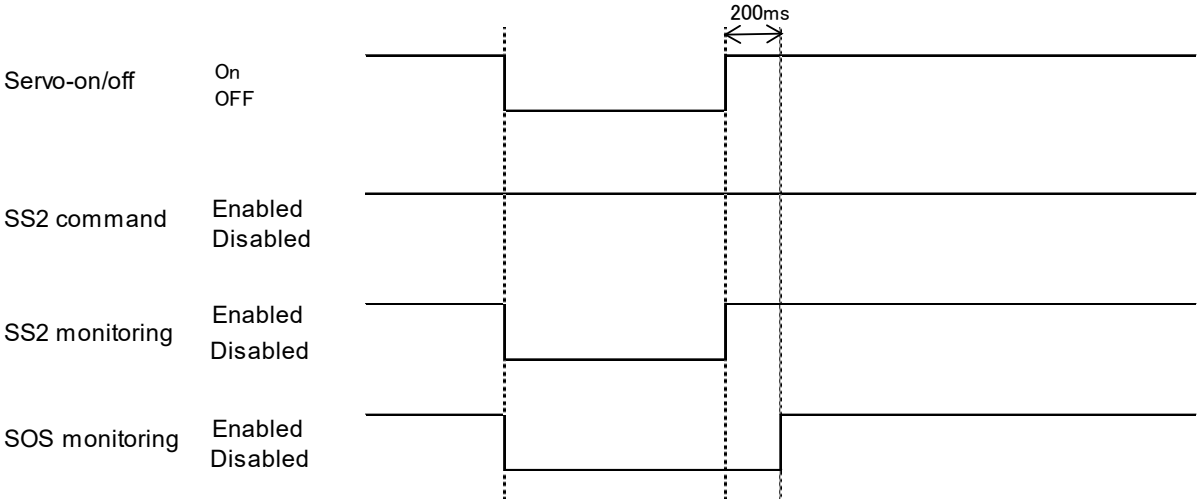


Fig. 4-35: When servos are turned off during the SOS monitoring

Configuring monitoring conditions

Parameters related to the SOS function can be configured in the SOS screen, which can be opened by going to Workspace and selecting [Online] -> [Parameter] -> [Safety parameter] -> [SOS].

Tab. 4-7: SOS related parameters

Setting item	Description	Default
Safe stop speed	This configures speed monitoring thresholds for the SOS monitoring.	1.00 [deg./s] [mm/s]
Safe stopping distance	This configures allowable travel distances for the SOS monitoring.	1.00 [deg.] [mm]
SOS automatic resumption mode	This sets the SOS automatic resumption mode to Enable or Disable. Selecting Enable leads the program to automatically resume when the SOS monitoring is disabled. For details, refer to Tab. 4-5: SOS automatic resumption mode.	Disabled

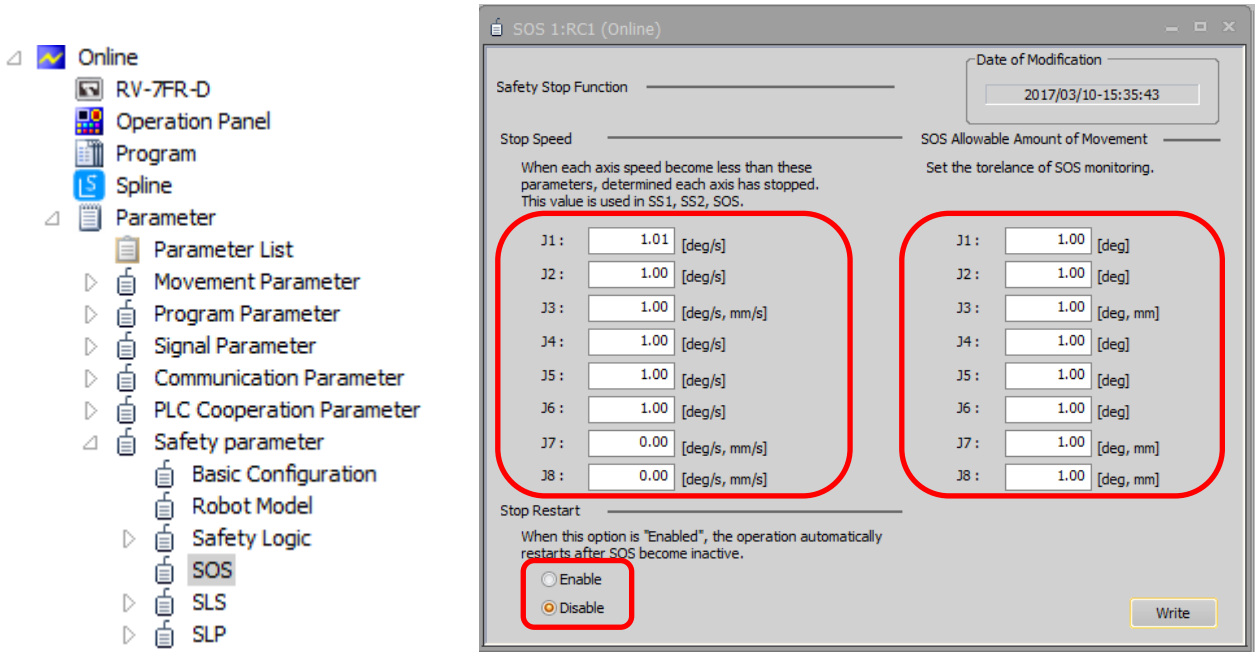


Fig. 4-36: Configuring monitoring conditions

4.5.3 Safe stop 1 (SS1)

(1) Overview

The SS1 command input starts deceleration and, after the motors of all the axes decelerate below specified speeds or a specified time elapses, motor driving power is turned off (STO is started). (This function corresponds to stop category 1 of IEC60204-1.)
Failure in deceleration within a specified maximum delay causes error H2280 (SS1 deceleration timeout).

(2) Operation sequence

(a) SS1 command (Normal operation)

The operation sequence of the SS1 function is as follows. The SS1 function is triggered when one of the following situations occurs during the robot operation.

- The SS1 command is entered.
- The emergency stop is input.
- An H level error occurs.

When the SS1 function is triggered, the deceleration starts at a specified deceleration rate. After the speed command becomes zero, the brakes are locked and STO shuts off the power supply to the servo motors. Canceling the trigger conditions restores the normal operation state.

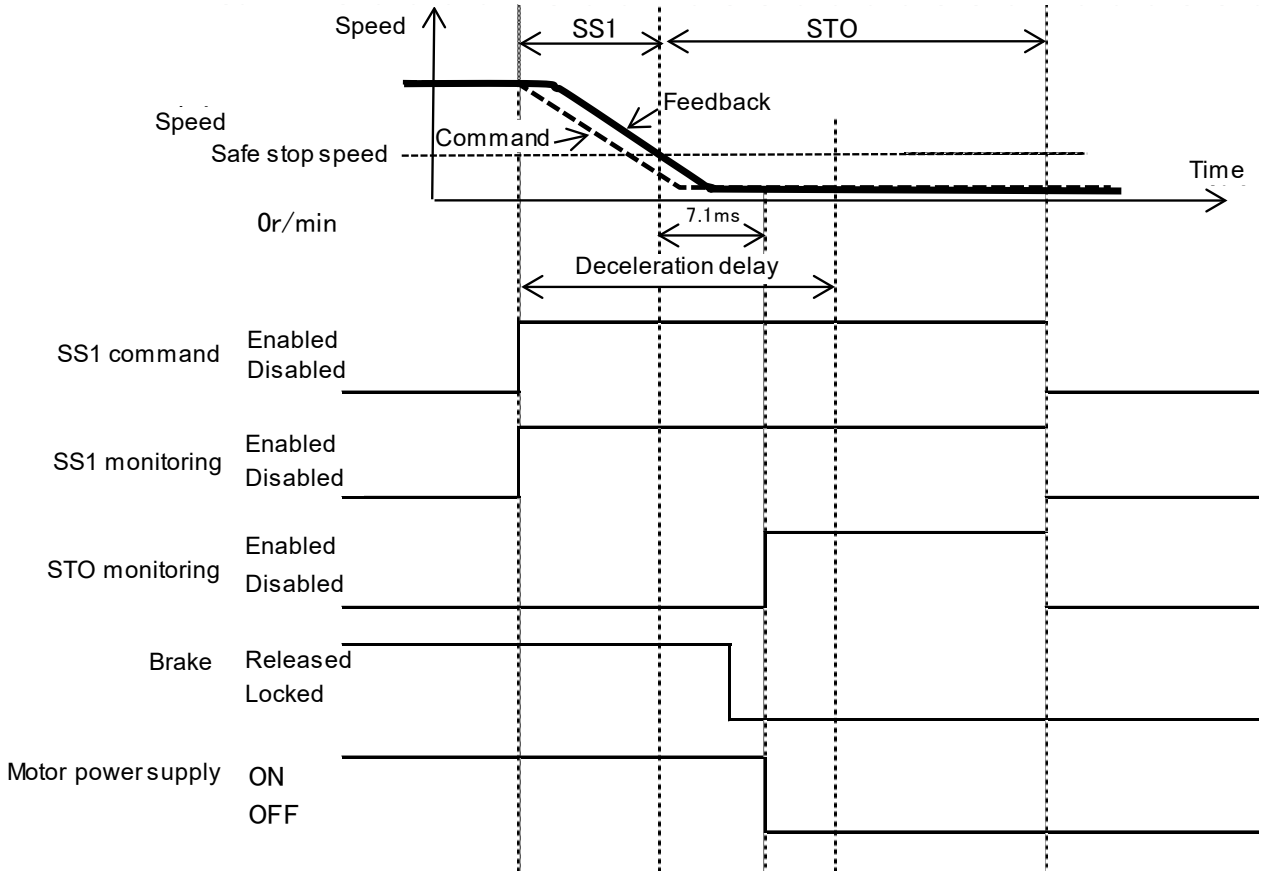


Fig. 4-37: SS1 command (Normal operation)

<Program operation state>

Program operation suspends during the SS1 or STO monitoring. To resume it, it is necessary to cancel all the SS1 start conditions and then perform the program start operation.

(b) When deceleration fails with SS1 enabled

Elapsed time from when the SS1 command is enabled is measured. If the motors fail to stop by the time the SS1 deceleration monitoring time elapses, error H2280 occurs. The operation sequence is shown below:

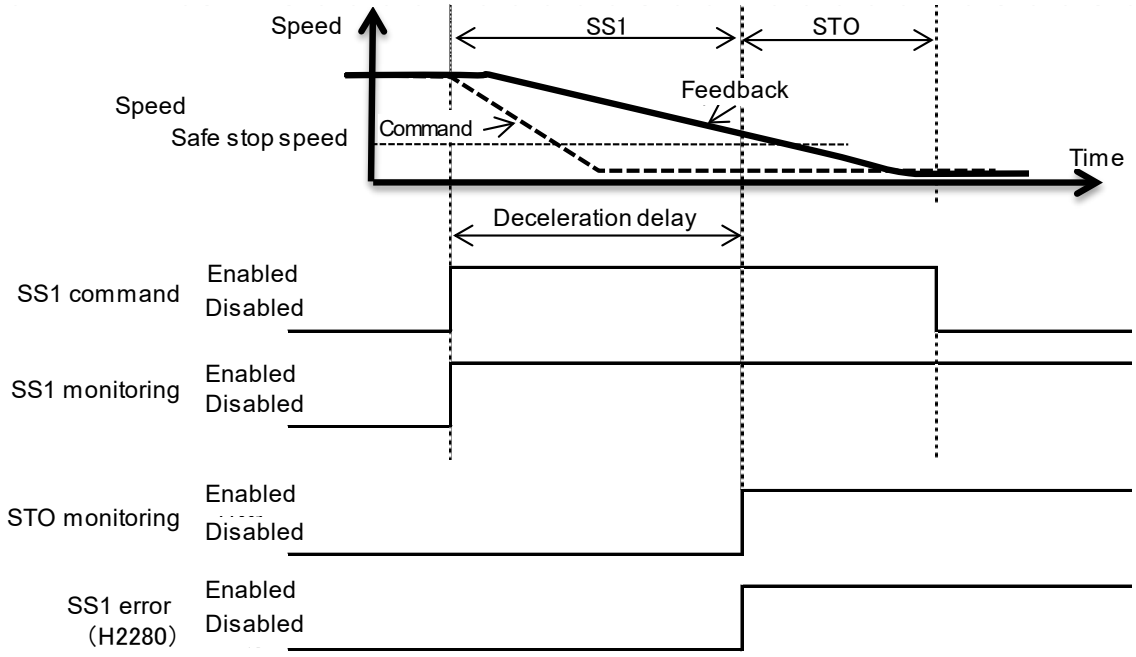


Fig. 4-38: When deceleration fails with SS1 enabled

(c) When the SS1 command is canceled with SS1 enabled before the STO monitoring state becomes active

Once the SS1 command is enabled, the SS1 monitoring cannot be canceled until the STO monitoring state becomes active (the deceleration and stop operation cannot be canceled). After the STO monitoring state becomes active, the SS1 monitoring is canceled.

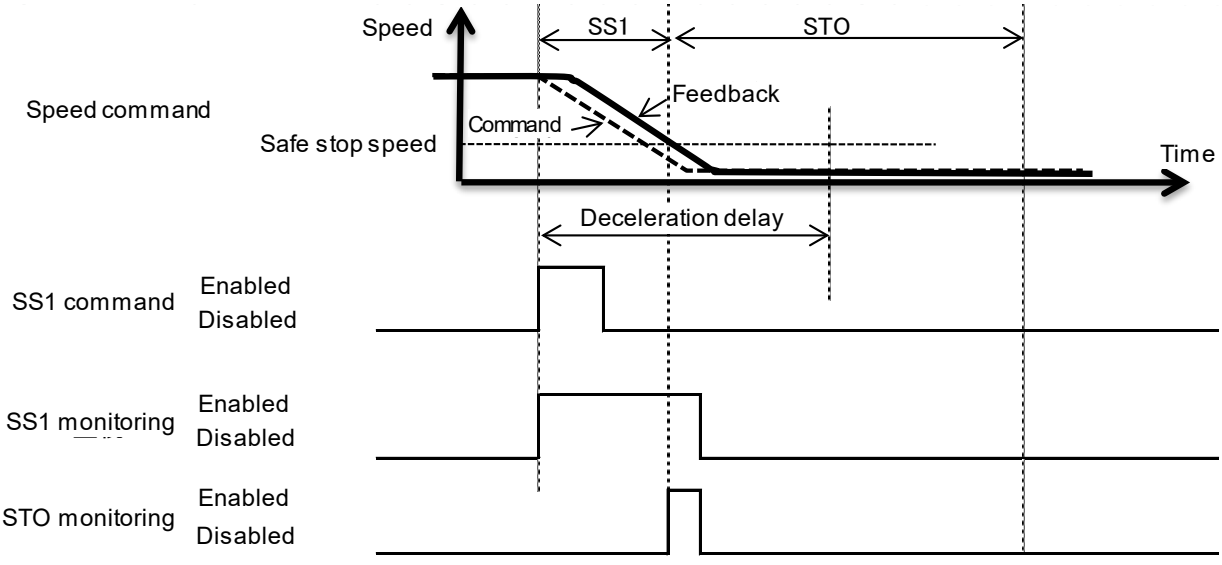


Fig. 4-39: When the SS1 command is canceled with SS1 enabled before the STO monitoring state becomes active

(d) When the origin has not been configured

When the origin has not been configured, inputting the SS1 command (emergency stop, error) activates the STO monitoring state immediately.

(3) Configuring monitoring conditions

(a) Safe stop speed

In Workspace, open the SOS screen by selecting [Online] -> [Parameter] -> [Safety parameter] -> [SOS]. Then, in the Stop Speed items, enter speeds at which the motors are judged to have stopped. These settings are shared by the SS1, SS2, and SOS functions.

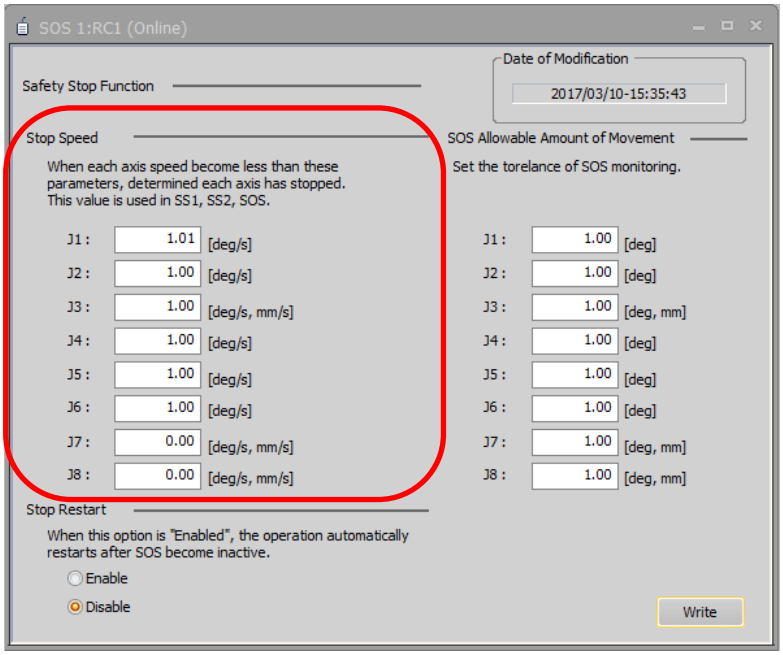


Fig. 4-40: Safe stop speed

(b) Deceleration monitoring time

Deceleration monitoring time differs from model to model. Deceleration monitoring time cannot be changed.

4.5.4 Safe stop 2 (SS2)

(1) Overview

The SS2 command input starts deceleration and, after the motors of all the axes decelerate below specified speeds, SOS is started. (This function corresponds to stop category 2 of IEC60204-1.)
Failure in deceleration within a specified maximum delay causes error H2281 (SS2 deceleration timeout).

(2) Operation sequence

(a) SS2 command (Normal operation)

The operation sequence of the SS2 function is as follows. Enabling the SS2 command while the robot is in operation starts the SS2 function. The triggered SS2 starts deceleration at a specified deceleration rate. After the speed command reaches the safety speed, SOS starts position monitoring with servo-on state kept. Disabling the SS2 command restores the normal operation state.

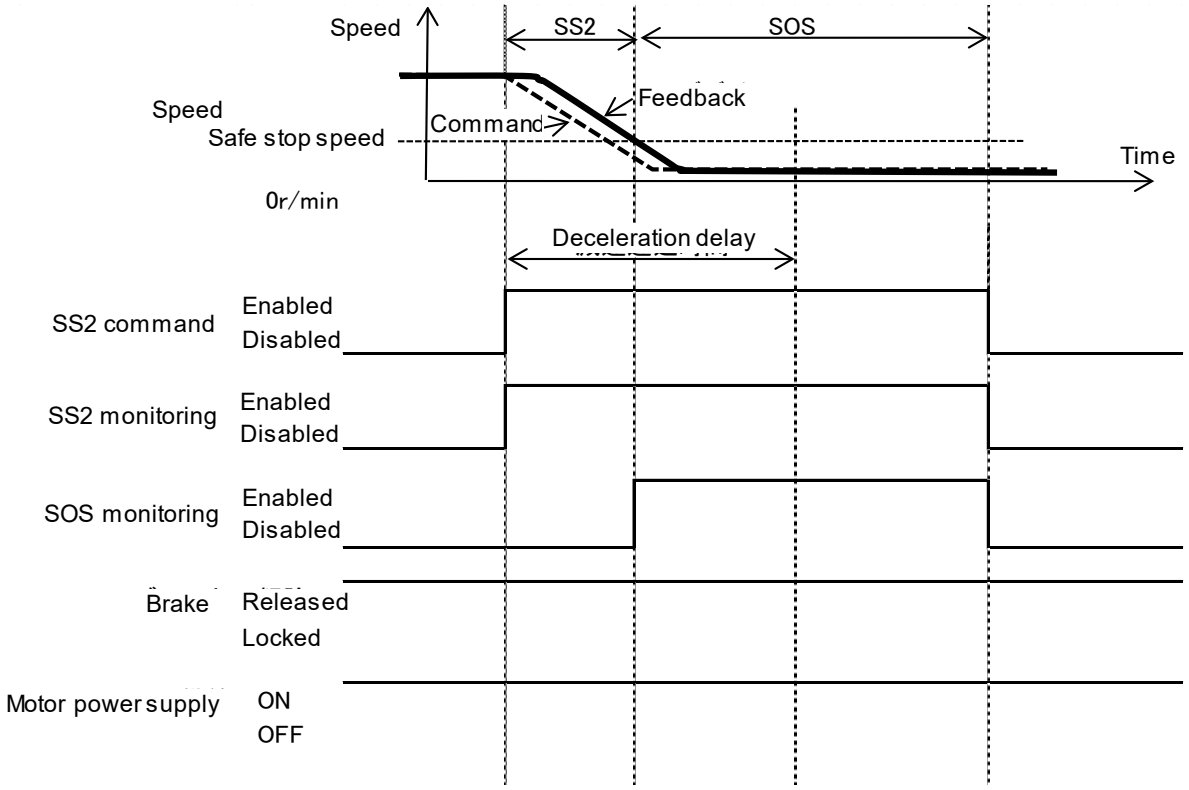


Fig. 4-41: SS2 command (Normal operation)

(b) When the motors fail to decelerate within monitoring time with SS2 enabled

Time is measured after the SS2 command is enabled. If the motors fail to stop by the time the SS2 deceleration monitoring time elapses, error H2281 occurs and STO shuts off the driving power. The operation sequence is shown below:

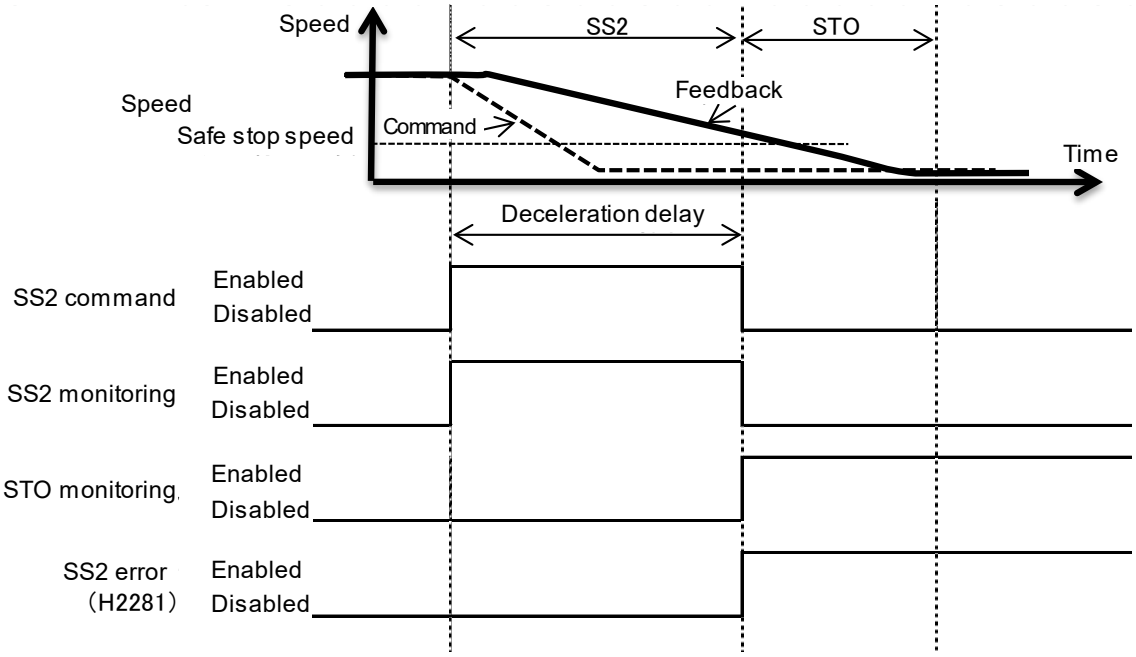


Fig. 4-42: When the motors fail to decelerate within monitoring time with SS2 enabled

(c) When the SS2 command is disabled before the motors stop with SS2 enabled

Once the SS2 command is enabled, the SS2 monitoring cannot be canceled until the SOS monitoring state becomes active (the deceleration and stop operation cannot be canceled). After the SOS state becomes active, the SS2 monitoring is canceled.

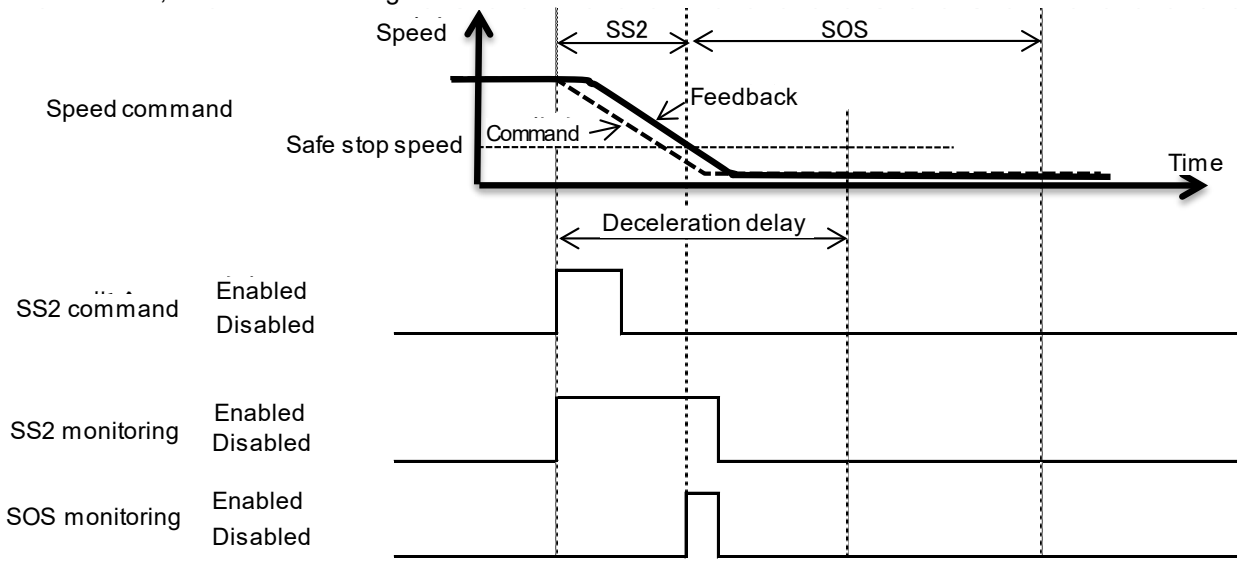


Fig. 4-43: When the SS2 command is disabled before the motors stop with SS2 enabled

(3) Configuring monitoring conditions

(a) Safe stop speed

From Online, open the SOS screen by selecting [Parameter] -> [Safety parameter] -> [SOS]. Then, in the Stop Speed items, enter speeds at which the motors are judged to have stopped. These settings are shared by the SS1, SS2, and SOS functions.

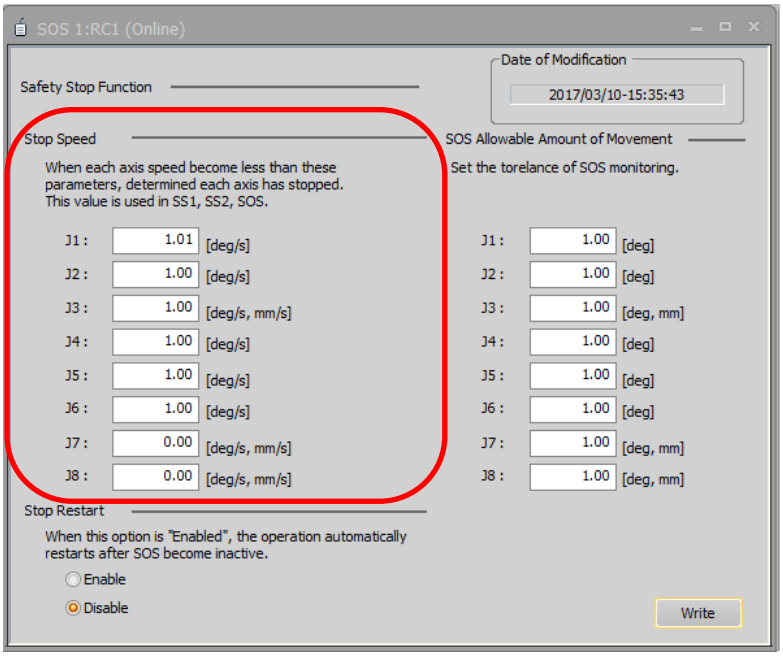


Fig. 4-44: Safe stop speed

(b) Deceleration monitoring time

Deceleration monitoring time differs from model to model. Deceleration monitoring time cannot be changed.

4.5.5 Safely limited speed function (SLS)

(1) Overview

This is a function to monitor the robot and the robot tool speeds so that they are under specified speed limits. When they are above a speed limit, the SS1 function stops the robot.
Configuration of up to four different types (SLS1, SLS2, SLS3, SLSM) of speed monitoring conditions are supported. During SLS monitoring, the devices move at speeds specified in Speed Limit OVRD.

(2) Operation sequence

(a) SLS_ function basic operation

Enabling the SLS_ command starts the SLS function. The moment the SLS_ command is enabled, deceleration starts at rates specified in Speed Limit OVRD and, after the deceleration monitoring time elapses, the speed monitoring (SLS monitoring) starts.

Tab. 4-8: SLS function start conditions

Function	Functional condition	Description
SLS1	SLS1 command input	When the signal assigned to the SLS1 command is input
SLS2	SLS2 command input	When the signal assigned to the SLS2 command is input
SLS3	SLS3 command input	When the signal assigned to the SLS3 command is input
SLSM	SLSM command input	When the signal assigned to the SLSM command is input

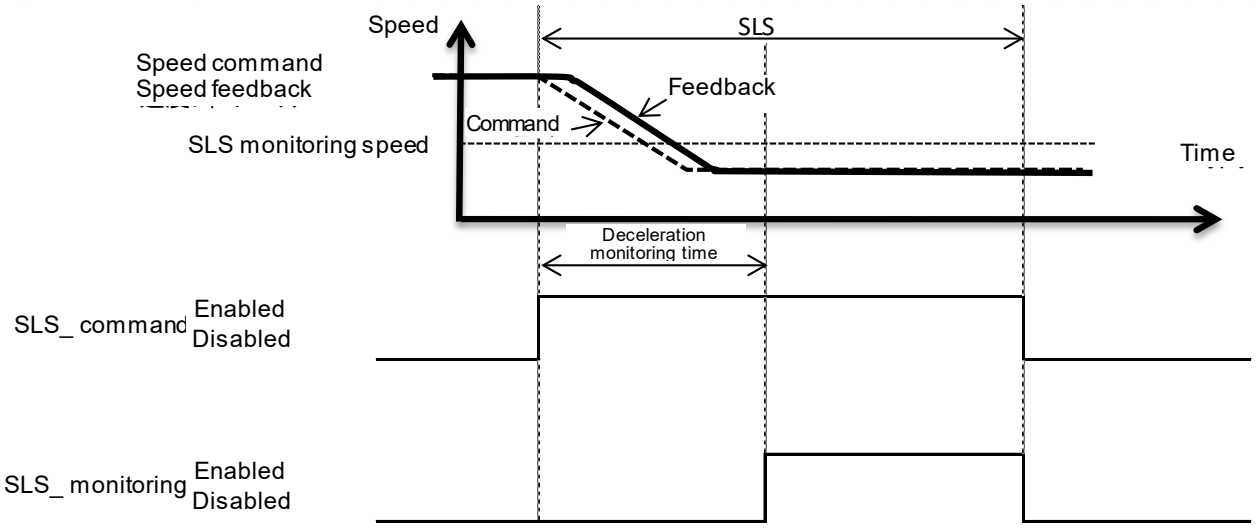


Fig. 4-45: SLS_ function basic operation

(b) When a specified speed limit is exceeded during the SLS_ monitoring

Detection of a speed command or speed feedback exceeding the monitoring speed during the SLS_ monitoring causes error 230* (Abnormal SLS joint speed) or error 231* (Abnormal SLS orthogonal speed). The operation sequence is shown in the figure below:

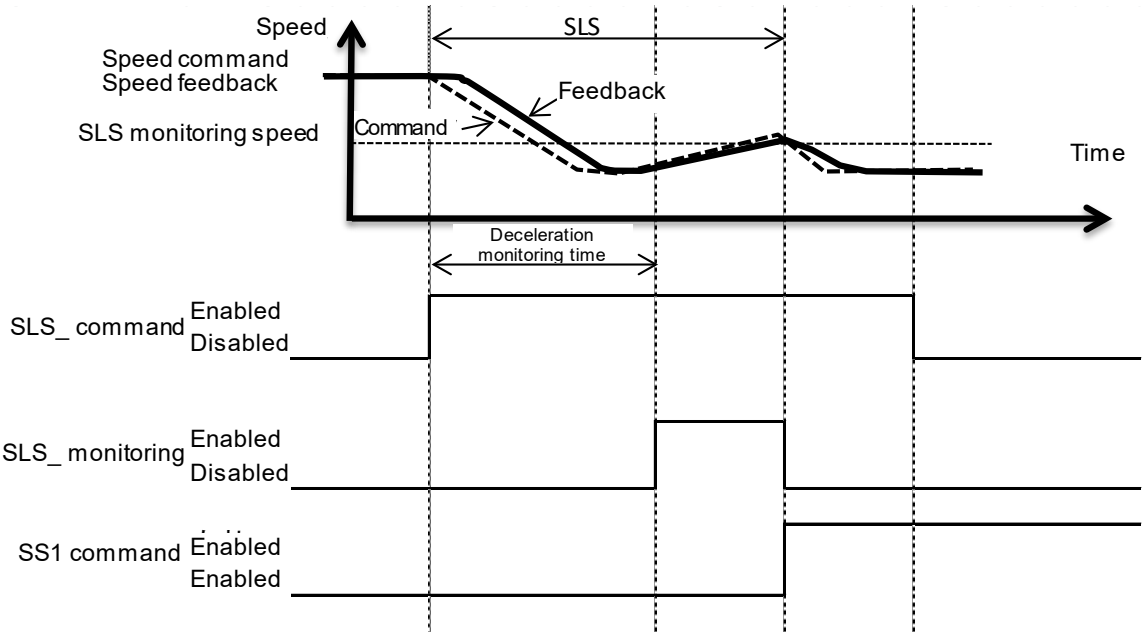


Fig. 4-46: When a specified speed limit is exceeded during the SLS_ monitoring

(c) When the devices fail to decelerate within a specified time with SLS enabled

With SLS enabled, if the SLS monitoring speed limit is exceeded or the devices fail to decelerate to the monitoring speed within the SLS deceleration time, error H230* (Abnormal SLS joint speed) or error H231* (Abnormal SLS orthogonal speed) occurs and the SS1 function stops the devices.

The errors occur when the limit overrides are too large or the deceleration monitoring time is too short.

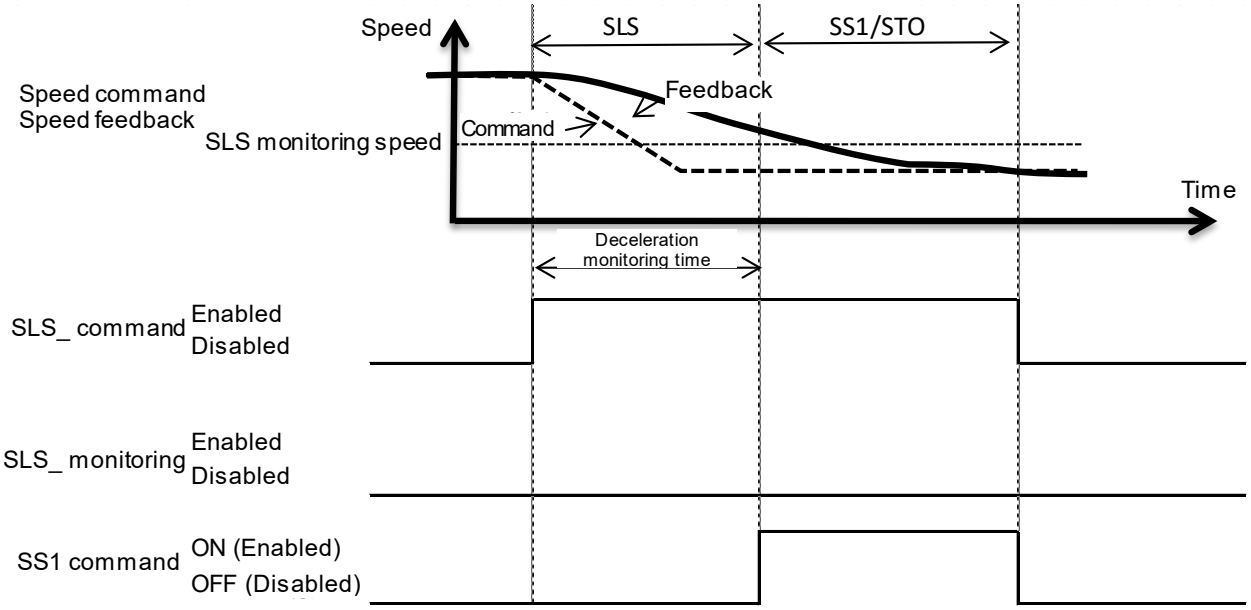


Fig. 4-47: When the devices fail to decelerate within a specified time with SLS enabled

(d) Operation with the servos on or off

When the servos are off, the SLS monitoring is disabled. The SLS monitoring is enabled 200 ms after the servos are turned on.

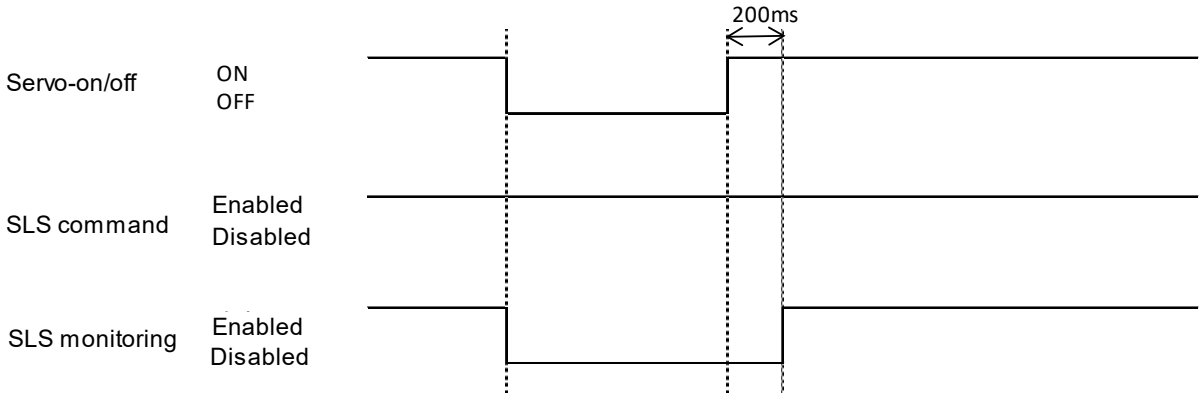


Fig. 4-48: Operation with the servos on or off

(e) When multiple SLS commands are input simultaneously

When multiple SLS commands are input simultaneously, the monitoring is performed based on all the enabled monitoring speeds.

The limit override applicable in this case is the smallest one of the values for the SLS functions.

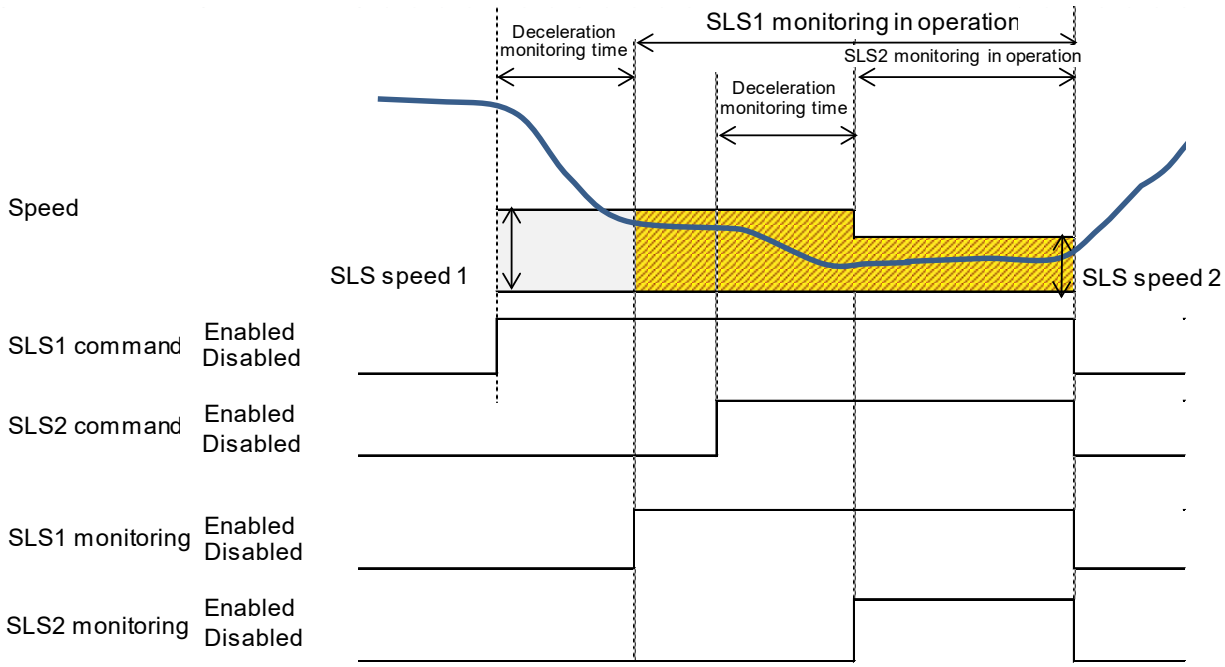


Fig. 4-49: When multiple SLS commands are input simultaneously

(3) Configuring monitoring conditions

(a) Speed monitoring position

Positions subject to robot speed monitoring are defined with an arm model and tool models. For configuration of an arm model and tool models, see 4.3 Defining 3D Models4.2.5 . Positions subject to monitoring on an arm model are A1, A2, and the origin of the mechanical interface coordinates in the figure below. Positions subject to monitoring on tool models are T1, T2, T3, and T4 in the figure below.

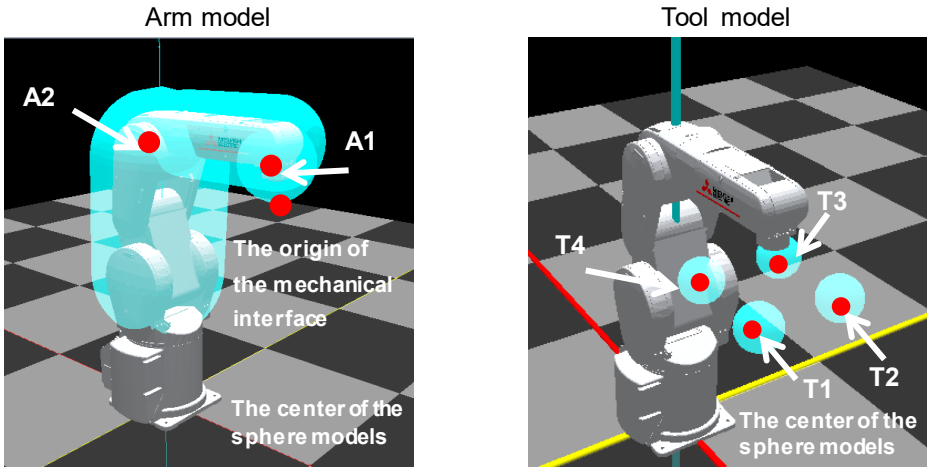


Fig. 4-50: Speed monitoring position

(b) Monitoring speed limits

There are two modes available for configuration of the SLS monitoring speeds: Simple Mode and Detail Mode. Detail Mode enables detailed configuration of allowable speeds. Besides synthesized speeds, it allows monitoring of speeds of X, Y, Z components and joint angular speeds.

Tab. 4-9: Items available for monitoring in each SLS mode

	Monitoring items		Configuration mode		Setting range
			Simple	Detail	
Orthogonal speed limit	Arm model	composite speed	✓	✓	0 mm/s to 100000 mm/s (0 to 250 mm/s for SLSM)
	Tool model	+X speed		✓	
		-X speed		✓	
	Mechanical I/F	+Y speed		✓	
		-Y speed		✓	
		+Z speed		✓	
		-Z speed		✓	
Joint speed limit	Joint axes J1 to J6	J1 speed		✓	0% to 100% (Configure a ratio to the maximum speed.)
		J2 speed		✓	
		J3 speed		✓	
		J4 speed		✓	
		J5 speed		✓	
		J6 speed		✓	
	Additional axis J7 to J8	J7 speed		✓	
		J8 speed		✓	

From Workspace of RT ToolBox3, open the Speed screen by selecting [Online] -> [Parameter] -> [Safety] -> [SLS] -> [Speed] and configure the speed limits.

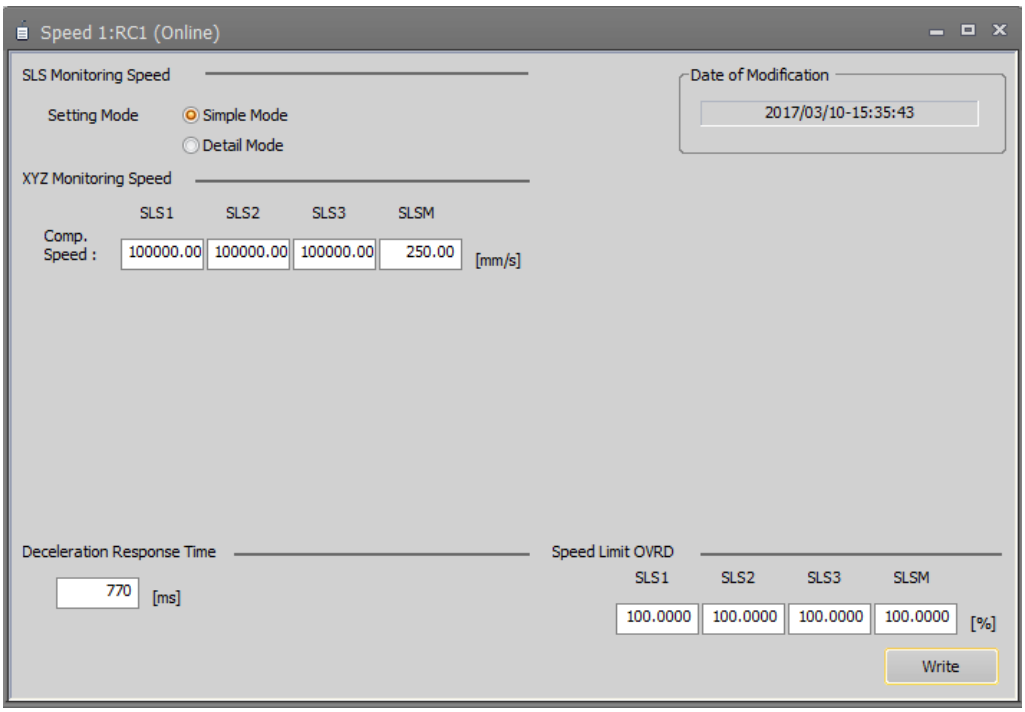


Fig. 4-51: Simple mode of monitoring speed limits

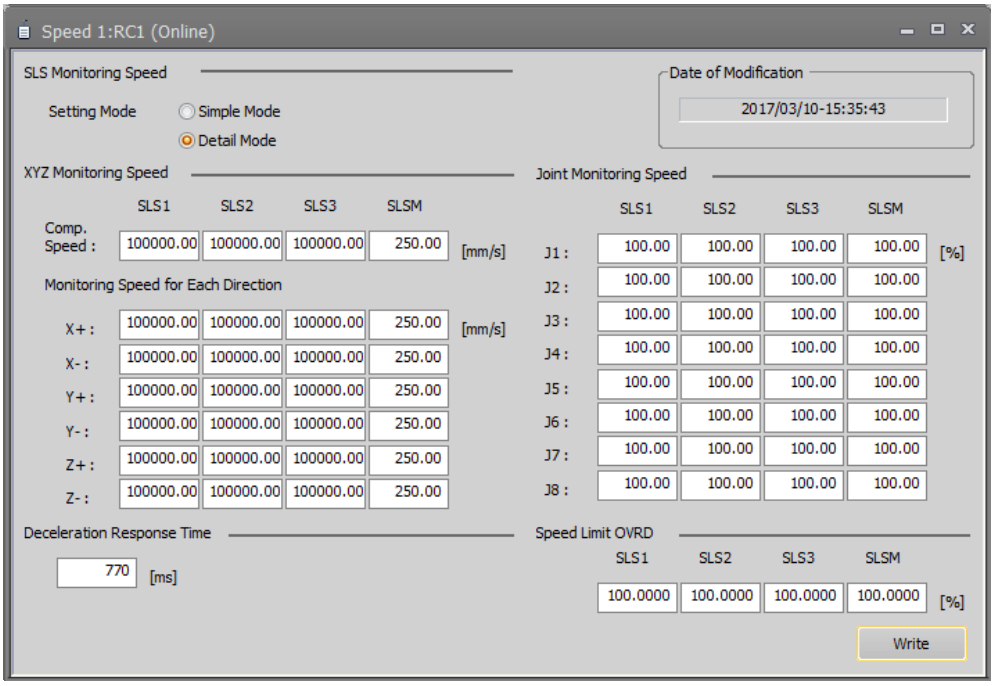


Fig. 4-52: Detail mode of monitoring speed limits

(c) Restricting the movement speed

The speed monitoring restricts the speed of movements made based on the interpolation command with Speed Limit OVRD specified beforehand. However, if a speed to which Speed Limit OVRD is applied exceeds the monitoring speed, error H230* (Abnormal SLS joint speed) or error H231* (Abnormal SLS orthogonal speed) occurs and the SS1 function stops the robot. To avoid errors in such cases, review the settings for the monitoring speed and Speed Limit OVRD or the speed settings of the robot program (Spd command, override, etc.).

A movement speed to which Speed Limit OVRD is applied is as follows:

Robot movement speed = Commanded speed specified in the program, etc. × Speed Limit OVRD (%) / 100

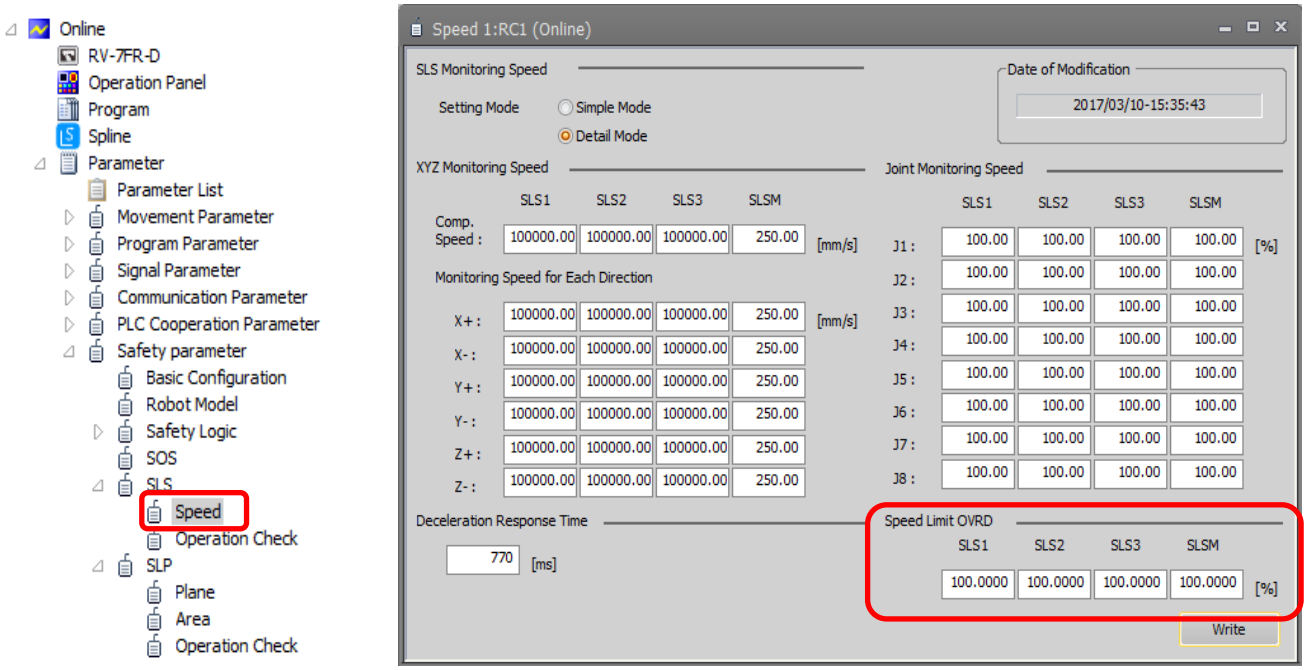


Fig. 4-53: Restricting the movement speed

Caution Restriction on the commanded speed by Speed Limit OVRD is effective for the speed of movements made by the interpolation command. The restriction is not effective for the correction speed generated by the compliance control, force sense control, or tracking function. While these functions are executed, an error may occur depending on the settings for operation or monitoring speed.

Caution Speed Limit OVRD is not effective for the movement speed under real-time external control (Mxt command). Correct the commanded position according to the monitoring speed on the commanded position generation side.

(d) Deceleration monitoring time

This field is for configuring wait time from when the SLS command is enabled to when monitoring starts. When a speed is above an allowable speed after the wait time elapses, an error occurs.

(4) Operation check

The following shows how to check that the monitoring speed is configured correctly.

① How to check the SLS monitoring state

From Workspace, open the Operation Check screen by selecting [Online] -> [Parameter] -> [Safety Parameter] -> [SLS] -> [Operation Check] and check the SLS monitoring state and speed measurement values.

The measurement value fields hold the maximum values of speed feedback for individual monitoring positions. The reset button clears the maximum values.

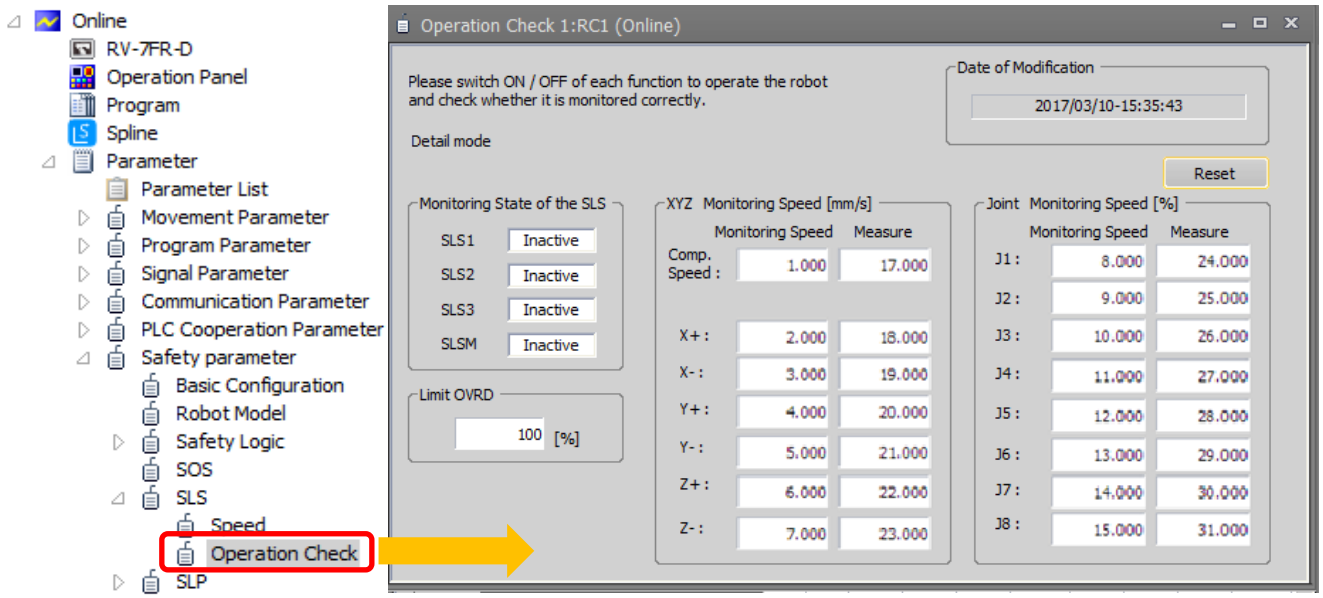


Fig. 4-54: How to check the SLS monitoring state

4.5.6 Safely limited position function (SLP)

(1) Overview

This function defines safeguarded spaces around the robot that restrict intrusion of the robot into them and monitors the robot arm and tools so that they do not enter the areas. If the robot gets close to a safeguarded space during operation, the robot stops. When a monitoring position goes across a position monitoring plane into a restricted area, error H220m (m is a plane or area number) occurs and the SS1 function stops the robot.

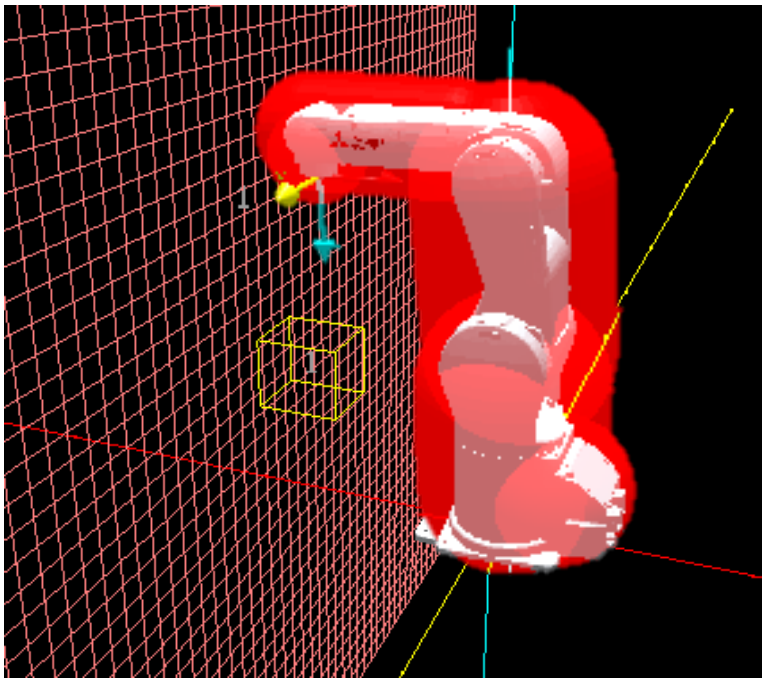


Fig. 4-55: Safely limited position function

(2) Operation sequence

(a) SLP_ function basic operation

Enabling a SLP_ command (SLP1, SLP2, SLP3, or SLPM command) triggers the SLP function.

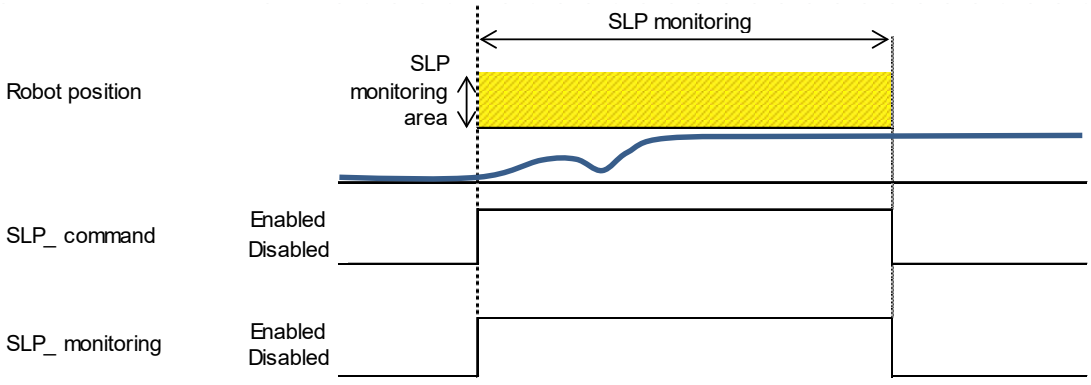


Fig. 4-56: SLP_ function basic operation

(b) Description of position monitoring

The enabled SLP monitoring function monitors an arm model and tool models according to predefined monitoring settings so that the models do not go into the restricted area applied at the time.

(c) Stop position prediction function

This function predicts whether the robot enters a monitoring area while it is run by the interpolation command or jog operation. If it judges that a predicted position will enter the restricted area, the function stops the robot. When the robot stops near the position monitoring plane, it behaves as follows:

① When the robot is run by the interpolation command

The automatic program operation maintains the RUN state. The robot operation suspends and the execution stops at the line of the interpolation command, but the state does not transition to STOP. If the target position monitoring plane does not exist in the vicinity due to the monitoring mode change to disable the target position monitoring plane, the SLP prior stop state is reset and the operation resumes.

Furthermore, when the automatic operation enters the STOP state due to a stop input or error occurrence, the SLP prior stop state is also canceled.

Caution Changing monitoring modes may resume the robot operation. Take sufficient care when changing monitoring modes.

② When the robot is run by the jog operation

A buzzer goes off from the teaching pendant to notify that the position monitoring plane is close, and the robot stops. If the function detects that any one of the monitoring positions has gone across the plane, error H220 m (m is a plane number) occurs and the robot stops by turning off the servos. The position monitoring is performed for the position command and the position feedback. The error message of error H220m changes according to the detected position.

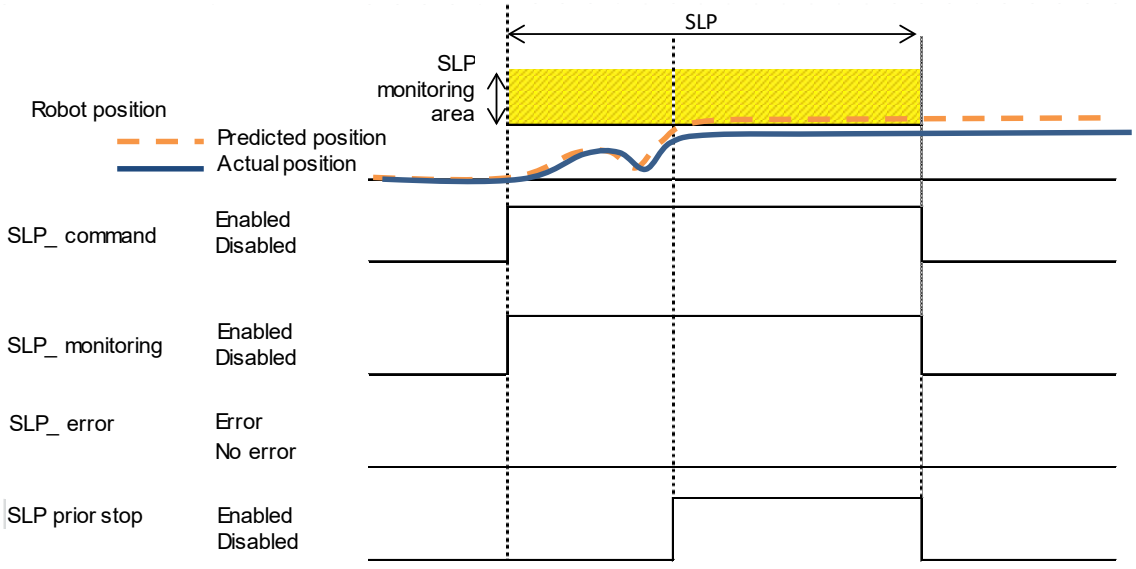


Fig. 4-57: Stop position prediction function

Caution The function to stop the movement near the position monitoring plane works for operation commands concerning the interpolation command or the jog operation. The function does not work for correction commands of the compliance control, force sense control, or tracking function.

Therefore, stopping operation commands near the position monitoring plane while these functions are running may not prevent the robot from reaching the position monitoring plane due to correction commands, causing an error.

(d) When intrusion into an SLP restricted area is detected

Intrusion of one of the following items into an SLP restricted area causes error H220* (SLP robot position error) and SS1 stops the robot.

(i) Position command (Whole arm and tools)
(ii) Position FB (Whole arm and tools)

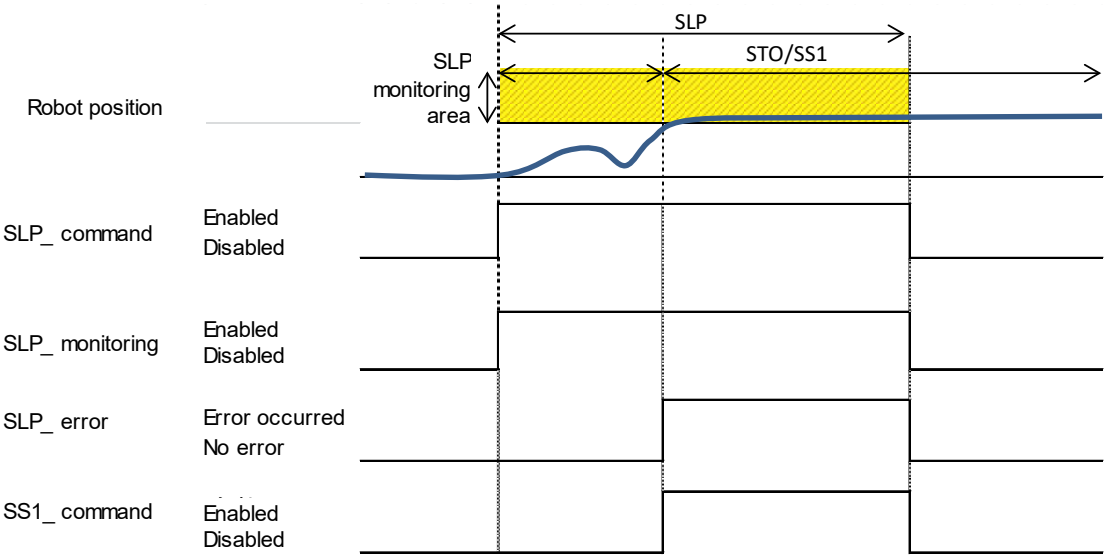


Fig. 4-58: When intrusion into an SLP restricted area is detected

(e) When the robot is run by the jog operation

A buzzer goes off from the teaching pendant to notify that a safety monitoring plane and safety monitoring area are close, and the robot stops. If the function detects that any one of the monitoring positions has gone across the plane, error H220* occurs and the robot stops by turning off the servos.

Caution

The function to stop the movement near the position monitoring plane does not work for the spline interpolation command (MvSpl, EMvSpl commands) or the real-time external control (Mxt command).

Caution

When no errors are found, if the brake release operation allows the robot to go across the position monitoring plane, error H220m occurs and the brake is applied at the same time. While an error is occurring, the brake is not applied even if another error occurs while the brake is released.

(3) Configuring monitoring conditions

(a) Arm model and tool model

Monitoring targets can be configured as a sphere model or cylinder model fixed to the robot or hand. Change in an arm model can only be made to the size. For tool models, free configuration of up to four sphere models is supported. For configuration of robot monitoring positions and hand monitoring positions, see 4.3 Defining 3D Models.

(b) Safety monitoring plane

SLP monitoring planes for position monitoring can be configured. Definition of up to eight planes is supported.

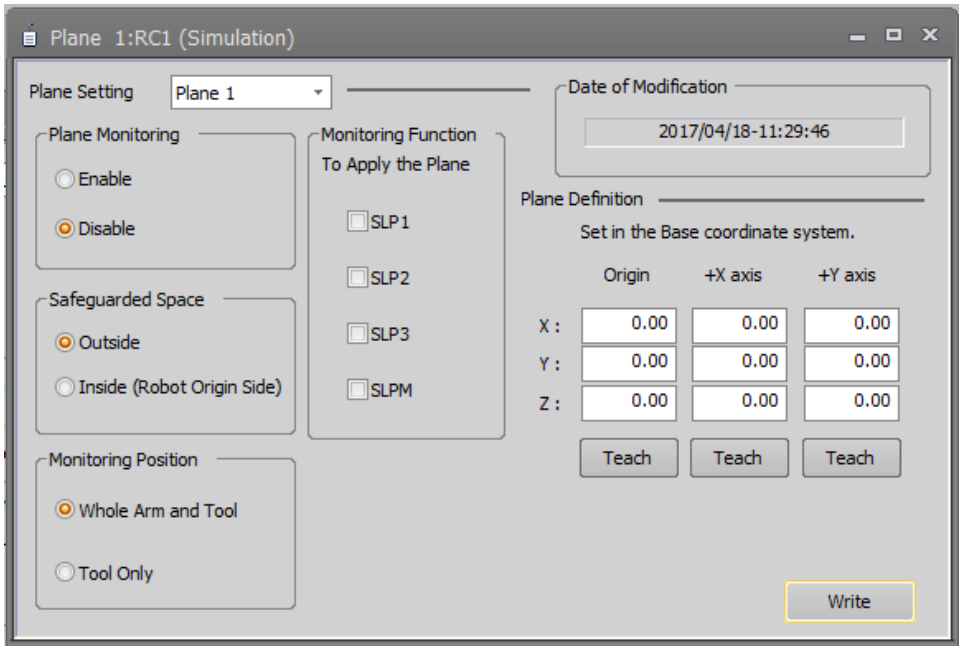


Fig. 4-59: Safety monitoring plane

① Plane Setting

This enables selecting a monitoring plane to be configured or changed from the pull-down menu. (Plane 1 to Plane 8)

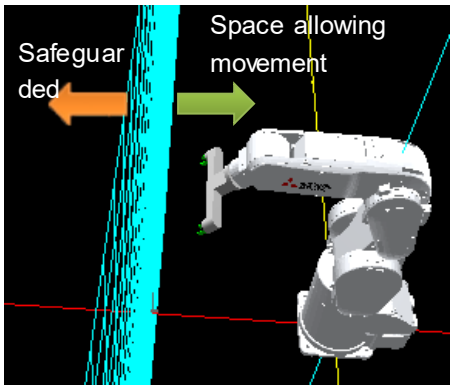
② Plane Monitoring

This sets the plane monitoring to Enable or Disable. Only the planes set to Enable are monitored.

③ Safeguarded Space

This specifies the side of a monitoring plane on which the safeguarded space (that allows no movement) is placed. To set the safeguarded space on the opposite side of the origin of the robot, select Outside. To set the safeguarded space on the side of the origin of the robot, select Inside. (See the figure below.)

[Outside setting]



[Inside setting]

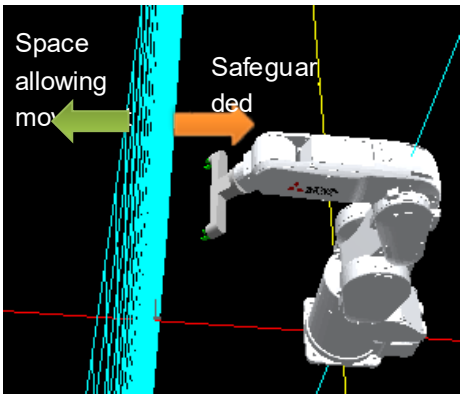


Fig. 4-60: Safeguarded space setting

④ Monitoring Position

This enables selecting a monitoring position of the robot subject to position monitoring.
Selecting [Whole Arm and Tool] enables the position monitoring that uses an arm model and tool models defined in 4.3 Defining 3D Models.
Selecting [Tool Only] enables the position monitoring that only monitors tool models.

⑤ Monitoring Function To Apply the Plane

This enables selecting monitoring functions (SLP1, SLP2, SLP3, SLPM) to which the monitoring plane is applied. Multiple functions can be selected.

⑥ Plane Definition

As shown in the right figure, configure X, Y, Z coordinates of the three points (origin, +X axis position, +Y axis direction) on the defined plane in the base coordinate system.
The plane is defined in the base coordinate system. Therefore, the base conversion does not change the relative position of the robot to the position monitoring plane.

<Base coordinate system>
The base coordinate system is a coordinate system based on the robot installation surface. The center of the robot installation position (base data) in the world coordinate system can be changed by using parameter MEXBS or executing the Base command. By default, the world coordinate system and the base coordinate system are placed at the same position.

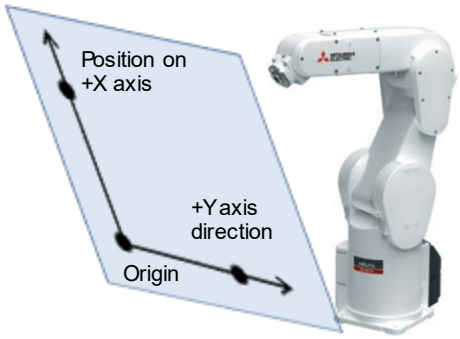


Fig. 4-61: Plane Definition

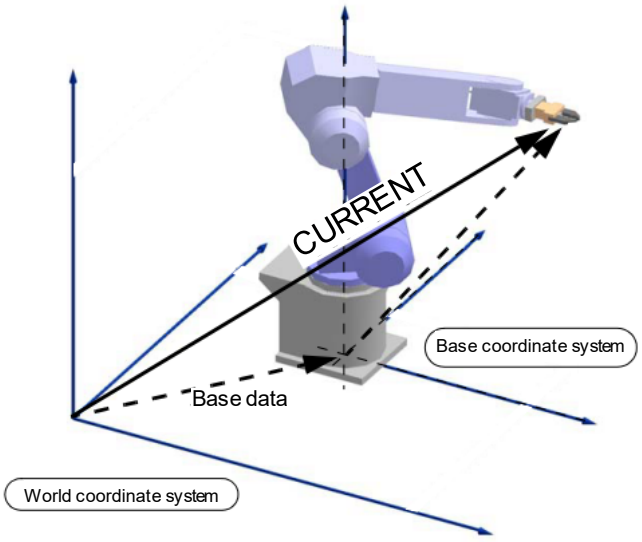


Fig. 4-62: Base coordinate system

(c) Safety monitoring area

This enables configuring safety monitoring areas. Definition of up to eight areas is supported.

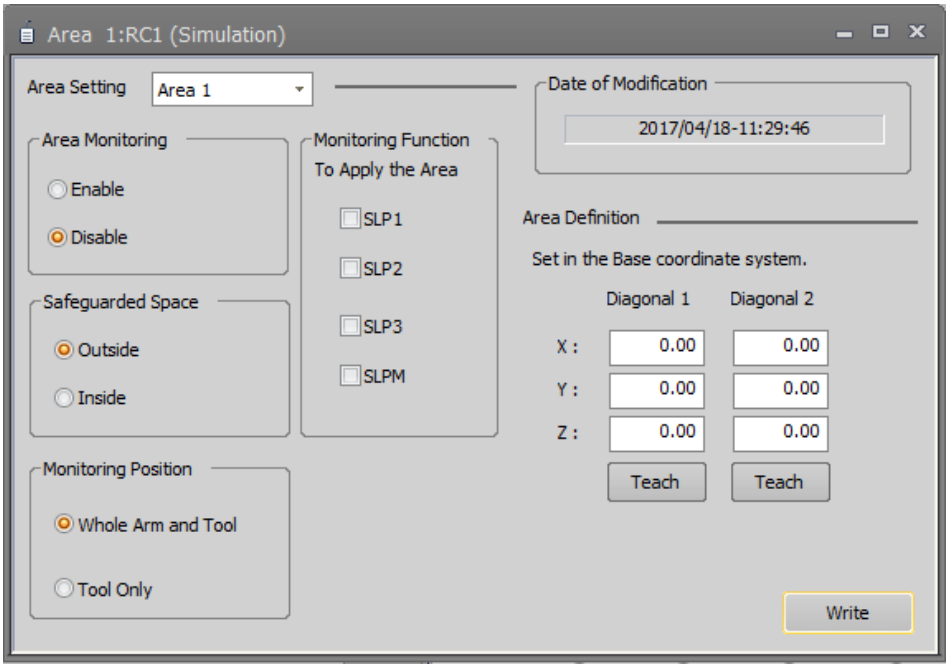


Fig. 4-63: Safety monitoring area

① Area Setting

Definition of up to eight areas is supported. Select a monitoring area (Area 1 to Area 8) to be changed or edited from the pull-down menu.

② Area Monitoring

This sets the area monitoring to Enable or Disable. Only the areas set to Enable are monitored.

③ Safeguarded Space

This specifies whether the safeguarded area (into which the robot cannot intrude) is inside or outside the area.

④ Monitoring Position

This enables selecting a monitoring position of the robot subject to position monitoring.

⑤ Monitoring Function To Apply the Area

This enables selecting monitoring functions (SLP1, SLP2, SLP3, SLPM) to which the monitoring area is applied. Multiple functions can be selected.

⑥ Area Definition

This configures the monitoring area. As shown in the figure in the rignt, the area is defined as a cuboid parallel to a coordinate system formed from two points diagonal to each other. In the same way as a plane area, configure the coordinates of the diagonal points in the base coordinate system.

The area is defined in the base coordinate system. Therefore, the base conversion does not change the relative position of the robot to the position monitoring plane.

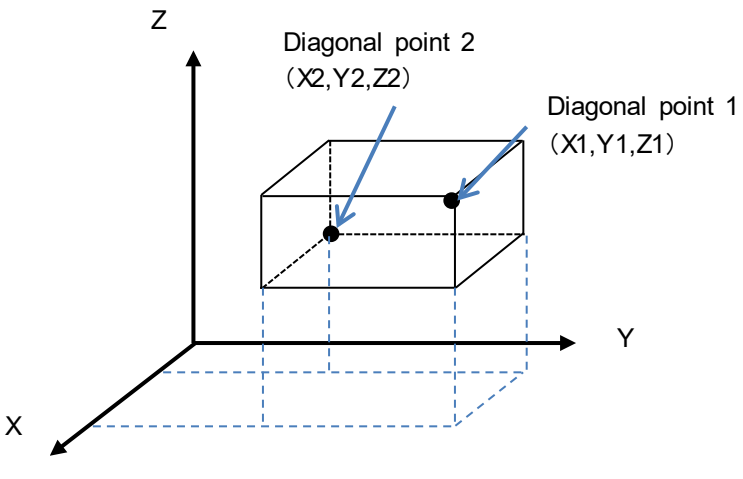


Fig. 4-64: Area Definition

(4) Operation check

Be sure to check that the monitoring conditions for the SLP function are configured correctly. The following describes how to check that.

① How to check monitoring plane switching

Open the Operation Check screen by selecting [Online] -> [Parameter] -> [Safety Parameter] -> [SLS] -> [Operation Check]. In this screen, check that the SLP monitoring states (SLP1, SLP2, SLP3, SLPM) and the states of planes and areas applicable at the time are as intended.

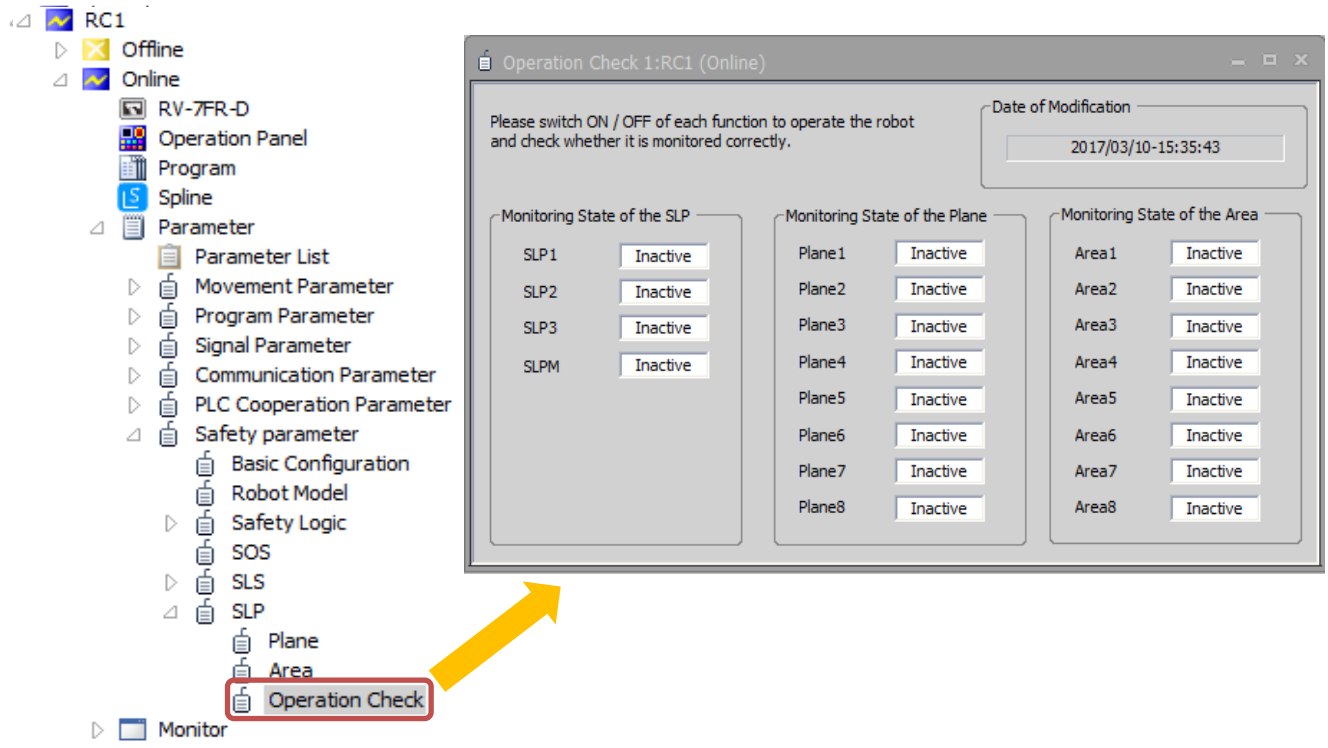


Fig. 4-65: Operation check

② How to check monitoring model definitions

In 3D Monitor, check that the settings for the arm model, tool models, monitoring planes, and monitoring areas are configured as intended. For details on 3D Monitor, see chapter 4.3.1 .

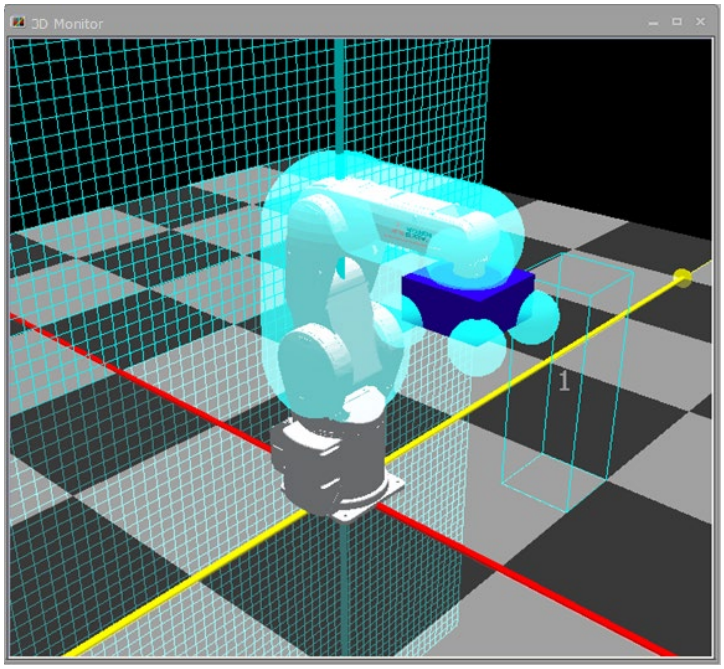


Fig. 4-66: How to check monitoring model definitions

4.6 Safety Diagnosis Function

4.6.1 Test pulse diagnosis (EMG)

This function enables diagnosis of external wiring by pulse signals output from the emergency stop ports (EXTEMG11, EXTEMG21). Changing parameter TPOEMG allows EXTEMG11 and EXTEMG21 to output off-pulses regularly. The width of output pulses is always approximately 20 ms. Checking regularly the test pulses inside the robot controller enables confirming the correct operation of the emergency stop lines. When an emergency stop signal triggers the SS1 function, use of this safety diagnosis function satisfies SIL3 and PLe/Category 4.

When using this function, connect emergency stop switches by seeing Fig. 4-68.

Make sure to prevent test pulses of this function from causing faulty operation of peripheral devices.

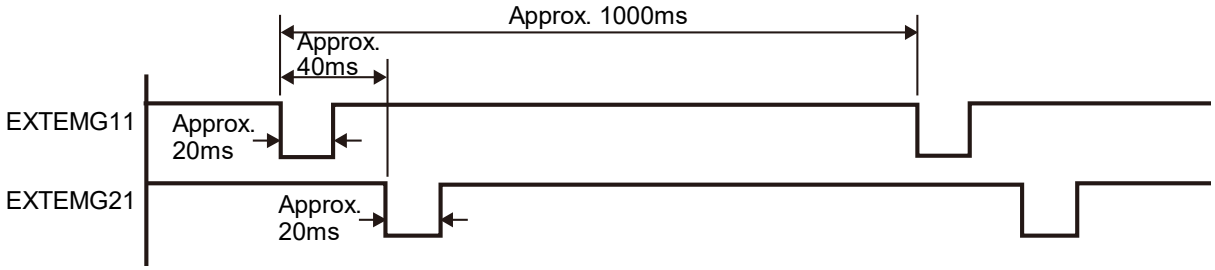


Fig. 4-67: Test pulse diagnosis

Tab. 4-10: Test pulse diagnosis

Item	Description
Parameter name	TPOEMG
Function	This enables configuring the pulse output function for outputting test pulse signals from emergency stop ports (EXTEMG11, EXTEMG21).
What parameter settings means	0: Outputs no test pulses 1: Outputs test pulses
Default	0

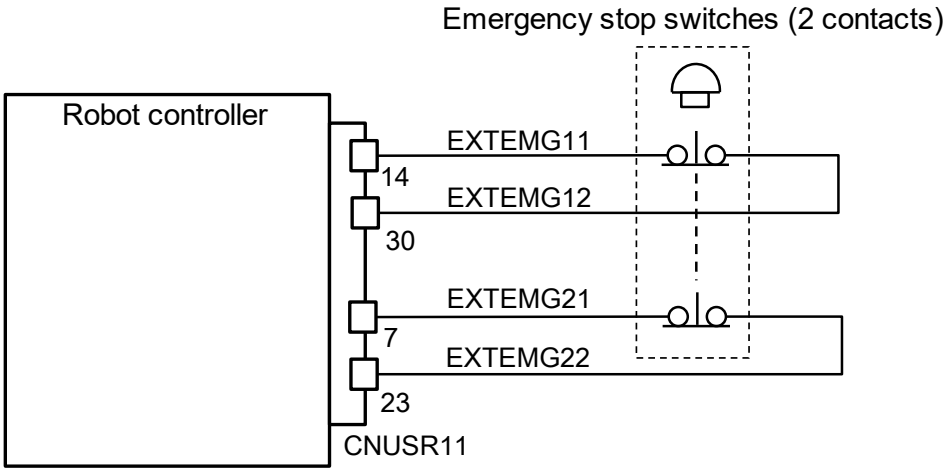


Fig. 4-68: How to wire emergency stop lines

5. STATE VARIABLE

States variable for the safety monitoring function are shown below:

5.1 List of State Variables

Tab. 5-1: List of state variables

State variable	Overview
M_DSI	Refers to the DSI Input state.
M_SflLogic	Refers to the Logic Input state.
M_SflArea	Refers to the Area Input state.
M_SfSts	Refers to the running state of the safety monitoring.
M_DSO	Refers to the DSO output state.
M_SlpPreStp	Refers to the SLP pre-stop status

5.2 State Variables

M_DSI

[Function]

Regarding DSI for functional safety, this refers to the current value.
DSI Input enabled: 1
DSI Input disabled: 0

[Format]

Example) <Numerical variable> = M_DSI(<DSI number>)

[Terminology]

<Numerical variable> This specifies where to store the DSI state.
<DSI number> This specifies a number for DSI whose state to be obtained.
Setting range: 1 to 8

[Reference Program]

```
M1 = M_DSI(1)        'The state of DSI1 is stored in M1.
```

[Explanation]

(1) Regarding DSI for functional safety, this refers to the current state.
(2) The value changes after the DSI filer setting time elapses following change in the input signals DSIn_A and DSIn_B.
(3) Assigning a value other than 1 to 8 to <DSI number> causes the L.3880 error on execution.

M_SflLogic

[Function]

Regarding functional safety input Logic, this returns the current value. (n = 1 to 3)
Logic Input state Enabled:1,
Logic Input state Disabled:0

[Format]

Example) <Numerical variable> = M_SflLogic(<Logic number>)

[Terminology]

<Numerical variable> This specifies where to store the LOGICn input state.
<Logic number> This specifies a number for LOGIC whose state to be obtained.
• Setting range: 1 to 3

[Reference Program]

```
M1 = M_SflLogic(1)      'The state of LOGIC1 is stored in M1.
```

[Explanation]

(1) This refers to the state of Logic Input for functional safety.
(2) Assigning a value other than 1 to 3 to <LOGIC number> causes the L.3880 error on execution.

M_SflArea

[Function]

This refers to the Area Input state.
(Enabled:1, Disabled: 0)

[Format]

Example) <Numerical variable> = M_SflArea(<Area number>)

[Terminology]

<Numerical variable> This specifies where to store the AREAn input state.
<Area number> This specifies a number for Area whose state to be obtained.
• Setting range: 1 to 3

[Reference Program]

```
M1 = M_SflArea(1)       'The value of Area1 is stored in M1.
```

[Explanation]

(1) This refers to the Area Input state.
(2) Assigning a value other than 1 to 3 to <Area number> causes the L.3880 error on execution.

M_SfSts

[Function]

This refers to the running state of the safety monitoring functions.
(1: Enabled, 0: Disabled)

[Format]

Example) <Numerical variable> = M_SfSts(<Function number>)

[Terminology]

<Numerical variable> This refers to the running state of a safety monitoring function corresponding to the function number.

<Function number> This specifies a number for a function whose running state is to be obtained. (Setting range: 1 to 12)

Tab. 5-2: List of function number

Function number	Function
1	STO
2	SOS
3	SS1
4	SS2
5	SLS1
6	SLS2
7	SLS3
8	SLSM
9	SLP1
10	SLP2
11	SLP3
12	SLPM

[Reference Program]

```
Msto = M_SfSts(1)      'The running state of STO is stored in Msto. (0: Disabled, 1: Enabled)
MsIs = M_SfSts(5)      'The running state of SLS1 is stored in MsIs. (0: Disabled, 1: Enabled)
if MsIs = 1 then
    M_YDev(0) = 1      'If SLS1 is enabled, sequencer output signal No.1 is turned on.
Endif
```

[Explanation]

(1) This variable refers to the current running state of a specified safety monitoring function.

M_DSO

[Function]

Regarding DSO for functional safety, this refers to the current value.
DSO Output enabled: 1
DSO Output disabled: 0

[Format]

Example) <Numerical variable> = M_DSO(<DSO number>)

[Terminology]

<Numerical variable> This specifies where to store the DSO state.
<DSO number> This specifies a number for DSO whose state to be obtained.
Setting range: 1 to 4

[Reference Program]

```
M1 = M_DSO(1)      'The state of DSO1 is stored in M1.
```

[Explanation]

(1) Regarding DSO for functional safety, this refers to the current state.
(2) Assigning a value other than 1 to 4 to <DSO number> causes the L.3880 error on execution.

M_SlpPreStp

[Function]

The variable returns the present SLP pre-stop status.

[Format]

Example) <Numerical variables>=M_SlpPreStp

[Terminology]

<Numerical variable>	The current SLP pre-stop status is returned. Not in pre-stop status: 0 During pre-stop: 1 to 8 (number of the applicable position monitoring plane) 101 to 108 (100 + number of the applicable position monitoring area)

[Reference Program]

```
M_Outb(100) = M_SlpPreStp   'The variable outputs the present SLP pre-stop status from the output signal
                            100 using 8-bit data.
```

[Explanation]

(1) The variable returns the present SLP pre-stop status.
(2) While the robot is stopped in the SLP pre-stop status, the number (1 to 8) of the applicable position monitoring plane or the number (101 to 108) of the applicable position monitoring area +100 is returned. Otherwise, 0 is returned.
(3) When the robot is stopped by multiple planes and areas, the smallest number is returned.
(4) When the position monitoring (SLP function) is disabled, 0 is always returned.
(5) The variable is read-only.

6. TROUBLESHOOTING

6.1 Error List for the Safety Monitoring Functions

Errors related to the safety monitoring functions are listed below.
For details about the errors not listed, refer to "Instruction manual/ Troubleshooting" coming with the robot. (Errors whose error number is suffixed with * requires resetting the power supply.)

Tab. 6-1 Error list for the safety monitoring functions

Error number	Error causes and solutions	
H0230 *	Error message	Safety parameter error (xxxxx)
	Cause	Detect errors in safety parameter value.
	Solution	There is something wrong with a safety function parameter setting. Check the parameter setting shown in (xxxxx) of the error message, and set it to an appropriate value.
H0231 *	Error message	Parameter CRC error (xxxxx)
	Cause	Detect CRC errors in safety parameter.
	Solution	Please check the safety parameters settings and write parameters.
C0240	Error message	Setting mismatch of safety func
	Cause	The safety function is disabled.
	Solution	Although the safety logic is configured, the relevant safety functions are disabled. Delete the safety logic or enable the safety functions.
H0241 *	Error message	Fault in Safety Communication
	Cause	Detect a fault in safety communication.
	Solution	Turn the power OFF and ON once. If the error recurs after that, contact the manufacturer. This error also occurs when the machine lock function and controller CPU drive mode are used. Disable the function/mode, then cycle the power of the robot controller.
H0242 *	Error message	Fault in Safety Data
	Cause	Detect a fault in safety data.
	Solution	Turn the power OFF and ON once. If the error recurs after that, contact the manufacturer.
H0243	Error message	Safety function unavailable (XXX)
	Cause	The Safety Function is not supported by this robot.
	Solution	Disable the safety function.
H0311 *	Error message	Remote I/O unit config error
	Cause	The multiple Remote I/O units which do not support are connected.
	Solution	If a safety extension unit is connected, turn off the robot and, after restarting the safety extension unit, turn on the robot again.
H220m (The letter "m" is a number for a monitoring plane or monitoring area [1 to 8])	Error message	SLP (ROBOT position error:CMD Plane)
	Cause	SLP detected the robot position CMD over the monitoring plane.
	Solution	Please confirm the robot movement or related parameter setting.
	Error message	SLP (ROBOT position error:FB Plane)
	Cause	SLP detected the robot position FB over the monitoring plane.
	Solution	Please confirm the robot movement or related parameter setting.
	Error message	SLP (ROBOT position error:CMD Area)
	Cause	SLP detected the robot position CMD over the monitoring area.
	Solution	Please confirm the robot movement or related parameter setting.
	Error message	SLP (ROBOT position error:FB Area)
	Cause	SLP detected the robot position FB over the monitoring area.
	Solution	Please confirm the robot movement or related parameter setting.
H222m * (The letter "m" is a DSI number. [1 to 8])	Error message	Mismatch of Dual Safety Input
	Cause	State of the redundant wiring do not match (Dual Safty Input)
	Solution	The duplex DSI signal ON/OFF states are not consistent. Check the following for the DSI. • DSI wiring • Duplex signal ON/OFF states • Timing of switching of ON/OFF states (The error occurs when the ON/OFF states of the duplex signals remain inconsistent for about 0.1 seconds.)
H2230 *	Error message	Mismatch of Dual Safety Output
	Cause	The duplex DSO states are not consistent.
	Solution	Turn the power OFF and ON once. If the error recurs after that, contact the manufacturer.

H2231 *	Error message	Mismatch of Dual Safety Output Feedback
	Cause	State of Dual Safty Output and the feedback do not match.
	Solution	Turn the power OFF and ON once. If the error recurs after that, contact the manufacturer.
H2240 *	Error message	Origin data change
	Cause	The origin data is changed during execution of the position monitoring function.
	Solution	The origin is set while position monitoring is being executed. This error occurs if the origin position data is changed while position monitoring is being executed. Cycle the power of the robot controller, then reset the error.
C2250	Error message	Safety function execution disabled (No origin setting)
	Cause	The safety function cannot be executed because the origin is not set.
	Solution	If the origin is not set, the safety monitoring functions will not work. Configure the origin settings.
H2260 *	Error message	Safety Unit communication error
	Cause	Extended Safety Unit communication failed
	Solution	In order to use the safety monitoring functions, the Safety extension unit must be connected to the robot controller. Connect the Safety extension unit to the robot controller. If the error occurs even when the Safety extension unit is connected, check that the Safety extension unit is powered on. Or check whether pseudo-input mode has been enabled. If none of these solutions rectify the problem, the Safety extension unit may be faulty. Contact Mitsubishi Electric.
H2261 *	Error message	Extended safety unit's No. error
	Cause	The extended safety unit's station No. is illegal.
	Solution	Set the extended safety unit's station No. to 2.
H2270	Error message	Cannot servo ON (SS1/STO active)
	Cause	The servo cannot be turned ON while SS1/STO is active.
	Solution	Disable SS1 before turning the servo ON.
H2280 *	Error message	SS1 deceleration time exceeded
	Cause	The robot didn't stop within deceleration time from SS1 enabled.
	Solution	Check operation instructions, terminal load, and stop speed (SFSPZERO) parameter of the robot.
H2281 *	Error message	SS2 deceleration time exceeded
	Cause	The robot didn't stop within deceleration time from SS2 enabled.
	Solution	Check operation instructions, terminal load, and stop speed (SFSPZERO) parameter of the robot.
H2282	Error message	SOS (Position error)
	Cause	Detect the change of position FB on SOS.
	Solution	During the SOS monitoring, change in the position FB due to external force was detected. Remove the external force factor or assess risks and adjust parameter SOSTLRNC to extend the allowable range of the SOS monitoring.
	Error message	SOS (Speed error)
	Cause	Detect FB speed over on SOS.
	Solution	Please check external force or related parameter settings.
	Error message	SOS (Position command error)
	Cause	Detect the change of position CMD on SOS.
	Solution	Please confirm the robot movement or related parameter setting.
	Error message	SOS (Speed command error)
	Cause	Detect CMD speed over on SOS.
	Solution	Please confirm the robot movement or related parameter setting.
H230n (The letter "n" is an axis number. [1 to 8])	Error message	SLS (Joint Speed Error)
	Cause	Speed monitor detected the speed over.
	Solution	The speed monitoring function detected a speed exceeding the predetermined speed. Check the robot movement or the monitoring speed setting. Also, check that the deceleration delay (parameter SLSDLY) is not too short.
H231n (n shows the direction where a problem is detected.) 1: Synthesized speed 2: X+, 3: X- 4: Y+, 5: Y- 6: Z+, 7: Z-	Error message	SLS (XYZ Speed Error)
	Cause	Speed monitor detected the speed over.
	Solution	The speed monitoring function detected a speed exceeding the predetermined speed. Check the robot movement or the monitoring speed setting. Also, check that the deceleration delay (parameter SLSDLY) is not too short.

H2320	Error message	SF robot control error
	Cause	The robot motion command and the feedback are inconsistent.
	Solution	The robot's position command and feedback position do not match. Check the movement of the robot, the load on the hand, and whether the robot is interfering with any peripheral devices.
H2370 *	Error message	SF (Process error)
	Cause	The Safety Function is not normally executed.
	Solution	Reset the error by power-cycling the robot. If the same error recurs, contact the manufacturer.
	Error message	SF (Process Counter error)
	Cause	The Safety Function of servo CPU is not normally executed.
	Solution	Reset the error by power-cycling the robot. If the same error recurs, contact the manufacturer.

6.2 Errors Whose Specification Is Changed by Safety Monitoring Functions

The specification of the following errors changes when the safety monitoring function is enabled.

(1) To reset the following errors while the safety monitoring function is enabled, reset the power supply.

Tab. 6-2 Errors whose specification is changed by safety monitoring functions

Error number	Error message
H0039	Faulty wiring (Door Switch)
H0046	Faulty wiring (Mode sel. switch)
H0049	Faulty Line (T/B Enable Switch)
H0051	Faulty wiring (External EMG)
H0061	Faulty line (O/P EMG)
H0071	Faulty line (T/B EMG)
H0074	Faulty line (T/B Enable/Disable)
H1680	Cannot servo ON (timeout)
H1681	Unexpected servo OFF
H1682	Servo ON Timeout(Safety relay)
H1683	Servo ON Timeout.(Contactor)

7. SAFE STOPPING DISTANCE

The concept of the maximum stopping distance of the robot is described below.

7.1 How to Calculate a Stopping Distance

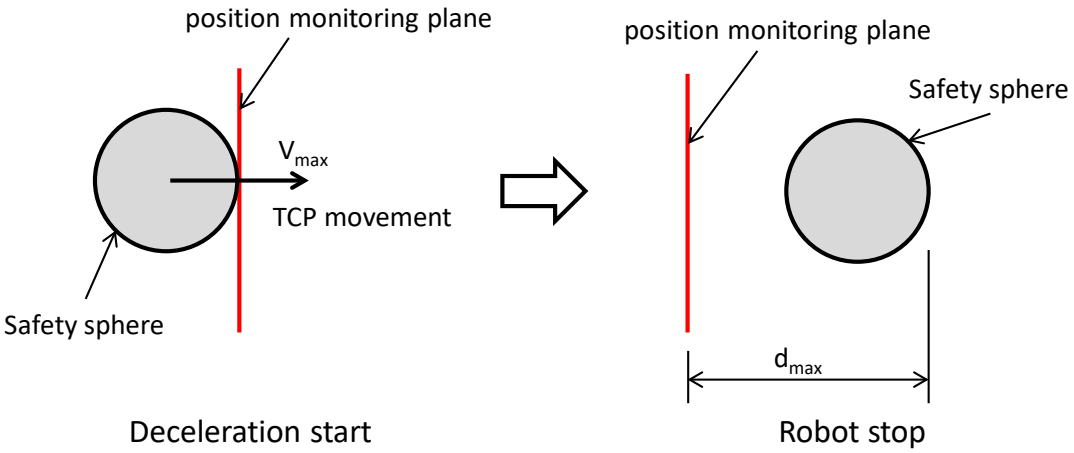
Assuming that the power supply to the robot controller is shut off during operation or that an error triggers the SS1 function, the maximum stopping distance in the worst scenario can be approximated by the following formula.
(Assume that the robot has brakes on all the axes.)

$$d_{\max} = (V_{\max} \times T_{res}) + (0.5 \times V_{\max} \times T_{\max} \times \alpha)$$

d_{max} : Maximum stopping distance
V_{max} : Maximum speed (Equivalent to the SLS monitoring speed when the SLS function is enabled)
T_{res} : Reaction time (time from error detection to stop) (Approximately 7.1 msec)
T_{max} : Maximum stopping time (Differs from robot to robot, see chapter 7.2)
α : Safety factor (1 or more)

Caution

The stopping time is affected by how the robot system is configured, the condition of the robot, and its posture. Therefore, the stopping distance calculated from this formula is approximate.
Use measurements from the system you are using to acquire an accurate stopping distance.



<Maximum speed>
When the safely limited speed function (SLS) is enabled, detection of a speed exceeding the SLS monitoring speed causes the SS1 function to immediately stops the robot. Therefore, the SLS monitoring speed can be considered equivalent to the maximum speed. Thus, reducing the SLS monitoring speed enables shortening the maximum stopping distance when power supply shut-off or an internal error shuts off the driving energy.
When Advanced Mode of the SLS function is configured, each of the X, Y, Z components are monitored for their speed, which enables restricting the maximum stopping distances for each of the X, Y, Z components. For example, if there is a safeguarded space in +X direction and the other directions are covered with safety fences, reducing the SLS speed only in +X direction enables ensuring safety and minimizing impact on tact time.

<Reaction time>
The delay between when an error detection enables the SS1 command and when deceleration starts is approximately 7.1 ms.
Using the DSI input of the Safety extension unit to stop the robot will have an effect on the DSI filter time specified in the DSI filter settings. For further information, refer to "(c) DSI filter configuration".
The initial value is 10 ms, therefore there will be a delay of 10 ms until the DSI input is enabled for the input signal.
If an error occurs in the reading of the DSI input, there may be a delay of up to 72 ms before the signal is read.

<Maximum stopping time>
The maximum stopping time differs from robot to robot. (see chapter 7.2)
(Example) In case of the table on the right, the maximum stopping time is the stopping time of J1 or 0.29 seconds, which results in the maximum stopping time of the robot being 0.29 seconds.

Axis	Arm extension	Load rate	Stopping time [s]	Stopping distance [deg]
			Ovrd 100%	Ovrd 100%
J1	L=100%	M=100%	0.29	58.80
J2	L=100%	M=100%	0.26	42.48
J3	L=100%	M=100%	0.24	28.80
J4	-	M=100%	0.20	49.80
J5	-	M=100%	0.23	61.56
J6	-	Load 1	0.14	66.48

7.2 Maximum Stopping Time and Maximum Operating Angle

The maximum stopping time and maximum operating angle indicate the time elapsed from when the SS1 function starts to when the robot stops. With low movement speed, which makes deceleration time short, operation will require a shorter elapsed time and smaller operating angle than those shown here. Improper use of the robot can result in a longer maximum elapsed time and a higher maximum movement speed than the values shown here.

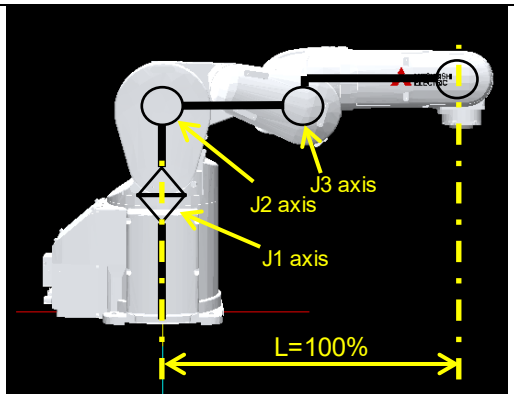
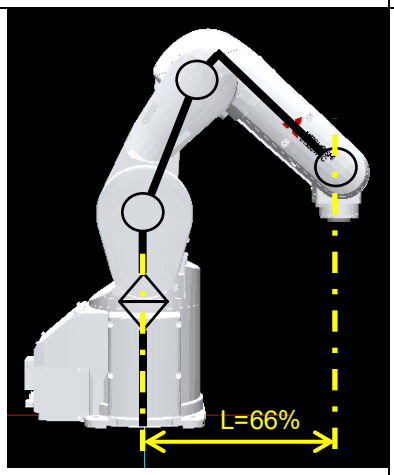
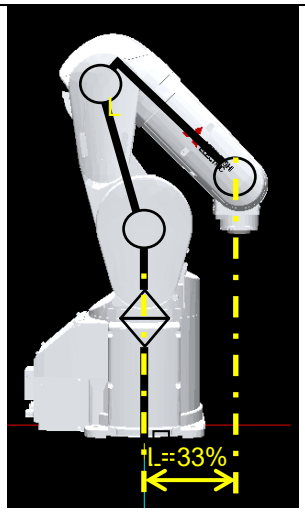
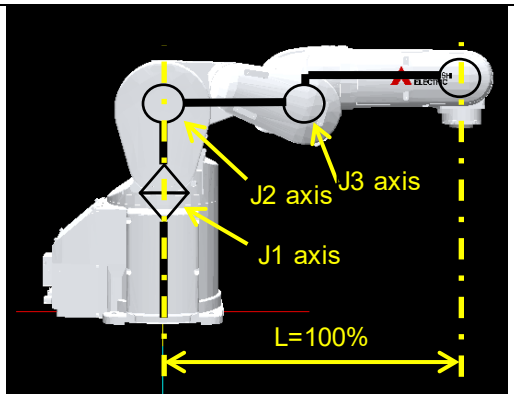
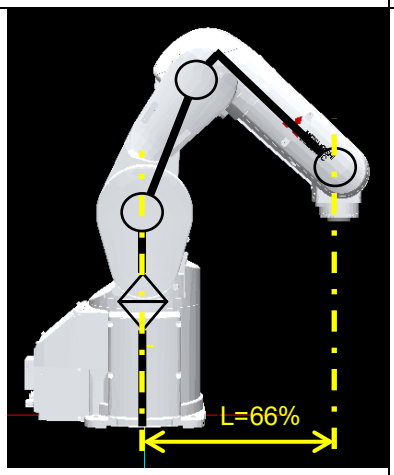
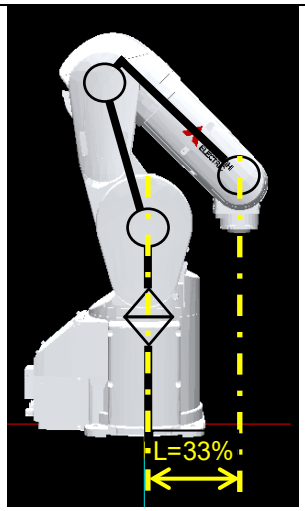
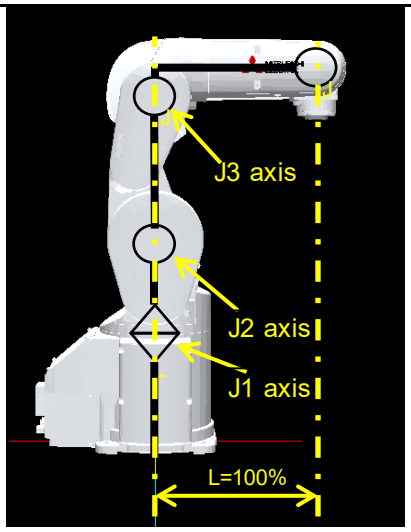
(1) What symbols mean

The following shows meanings of symbols used in this chapter.

String	Unit	Description	Description
L	mm	Degree of arm extension	This is the degree of extension of the arm in relation to each rotation axis. For details, see page 7-84.
M	%	Load ratio	This is the ratio of a load on the robot to the maximum load. Take for an example a robot with a maximum load of 4 kg. If M = 66%, the load on the robot is 2.64 kg.
OVRD	%	Robot override	This is an override for the robot speed.
t	s (second)	Stopping time	This is the maximum duration that elapses from when the SS1 function starts to when the motor power supply is shut off.
deg	°(degree)	Stopping angle	This is the maximum angle that the robot moves from when the SS1 function starts to when the robot stops.
d	mm	Stopping distance	This is the maximum distance that the robot moves from when the SS1 function starts to when the robot stops. This is applicable to the J3 axes of RH-FRH and RH-CRH series robots.

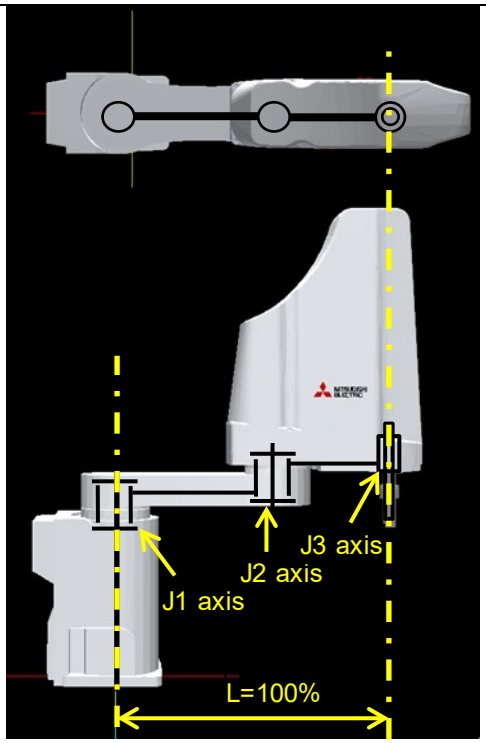
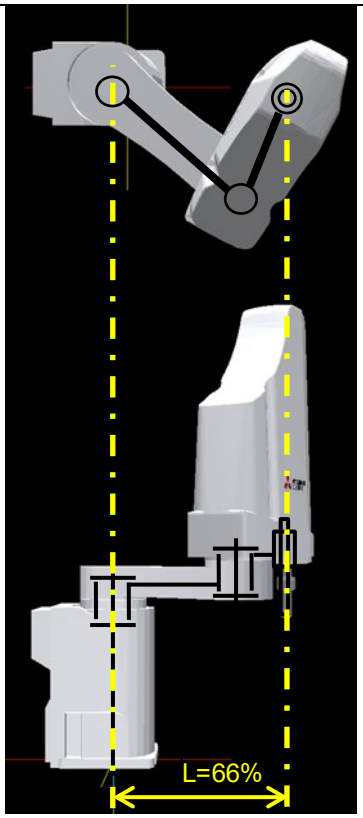
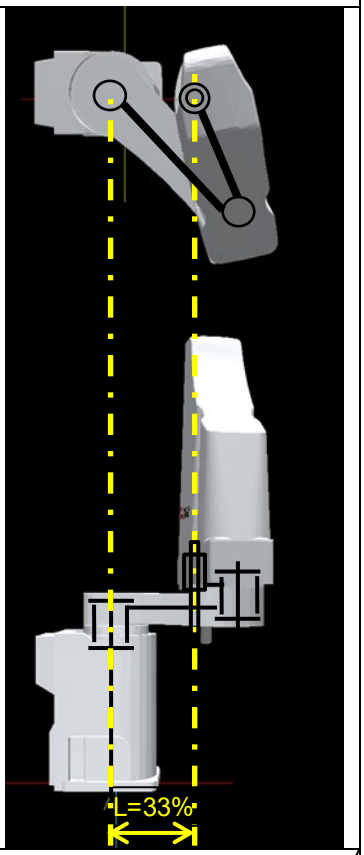
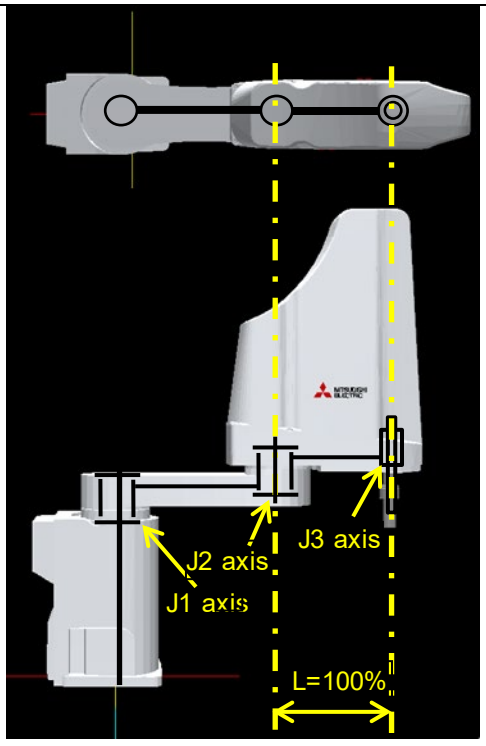
(2) The degree of extension of the robot arm

(a) RV-FR/RV-CR series

Axis	L=100%	L=66%	L=33%
J1			
J2			
J3			

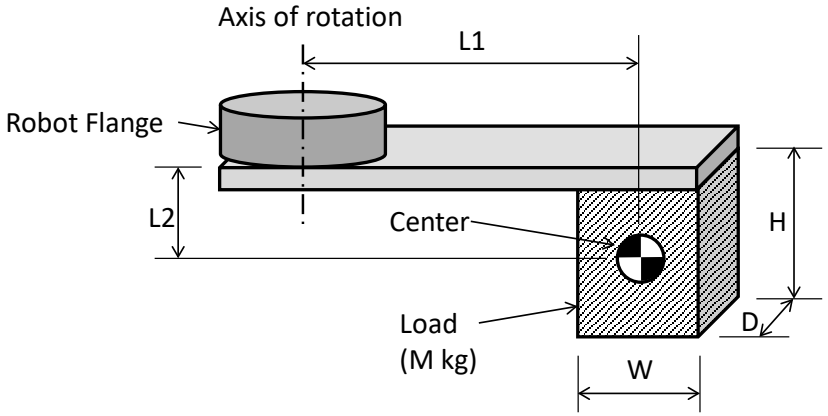
Note) The robot in the figure is RV-4FR.

(b) RH-FRH/RH-CRH series

Axis	L=100%	L=66%	L=33%
J1			
J2			

Note) The robot in the figure is RH-6FRH.

(3)Load dimension for J6 axis in RV series/J4 axis in RH series



Robot model	Load type	Mass kg	Size mm			Distance mm	
		M	W	D	H	L1	L2
RV-2FRB	Load 1	2	70	70	50	100	45
RV-2FRLB	Load 1	2	70	70	50	100	45
RV-4FR	Load 1	4	78	78	90	100	95
RV-4FRL	Load 1	4	78	78	90	100	95
RV-4FRJL	Load 1	4	78	78	90	100	95
RV-7FR	Load 1	7	95	95	95	100	170
RV-7FRL	Load 1	7	95	95	95	100	170
RV-7FRLL	Load 1	7	95	95	95	100	170
RV-13FR	Load 1	12	120	120	105	96	124
RV-13FRL	Load 1	12	120	120	105	96	124
RV-20FR	Load 1	15	160	160	78	73	189
RV-8CRL	Load 1	7	95	95	95	100	165
RH-3FRH	Load 1	1	72	72	42	71	13
	Load 2	3	82	82	61	142	22
RH-6FRH	Load 1	3	82	82	61	60	23
	Load 2	6	104	104	74	140	29
RH-12FRH	Load 1	3	125	80	33	108	19
	Load 2	12	165	165	54	158	29
RH-20FRH	Load 1	5	125	125	34	133	19
	Load 2	20	165	165	91	233	52
RH-3FRHR	Load 1	1	180	60	9	50	-5
	Load 2	3	82	82	61	77	37
RH-1FRHR	Load 1	1	72	72	42	71	13
RH-3CRH	Load 1	1	85	85	52	58	12
	Load 2	3	115	115	58	131	23
RH-6CRH	Load 1	2	93	93	52	54	13
	Load 2	6	138	138	45	133	36

RV-2FRB

Stopping time and stopping distance (emergency stop)

Axis	Arm extension	Load rate	Stopping time [s]			Stopping distance [deg]		
			Ovrd 33%	Ovrd 66%	Ovrd 100%	Ovrd 33%	Ovrd 66%	Ovrd 100%
J1	L=100%	M=100%	0.48	0.60	0.72	25.00	61.75	111.93
		M=66%	0.46	0.58	0.70	24.14	60.05	109.35
		M=33%	0.43	0.55	0.67	22.49	56.75	104.35
		M=0%	0.39	0.51	0.63	20.65	53.07	98.77
	L=66%	M=100%	0.38	0.50	0.63	20.23	52.22	97.49
		M=66%	0.38	0.49	0.62	19.77	51.31	96.10
		M=33%	0.35	0.47	0.59	18.63	49.02	92.63
		M=0%	0.33	0.45	0.57	17.35	46.46	88.75
	L=33%	M=100%	0.38	0.49	0.62	19.78	51.33	96.13
		M=66%	0.36	0.47	0.60	18.78	49.32	93.09
		M=33%	0.32	0.44	0.57	17.24	46.24	88.41
		M=0%	0.31	0.43	0.55	16.37	44.51	85.80
J2	L=100%	M=100%	0.53	0.65	0.78	13.82	33.52	59.96
		M=66%	0.51	0.63	0.75	13.14	32.16	57.91
		M=33%	0.48	0.59	0.72	12.38	30.63	55.59
		M=0%	0.44	0.56	0.68	11.52	28.93	53.01
	L=66%	M=100%	0.44	0.56	0.68	11.44	28.75	52.74
		M=66%	0.42	0.54	0.66	10.95	27.79	51.29
		M=33%	0.40	0.52	0.64	10.44	26.77	49.74
		M=0%	0.37	0.49	0.62	9.87	25.62	48.00
	L=33%	M=100%	0.43	0.55	0.67	11.21	28.30	52.06
		M=66%	0.40	0.52	0.64	10.46	26.80	49.78
		M=33%	0.37	0.49	0.61	9.75	25.37	47.63
		M=0%	0.36	0.47	0.60	9.38	24.65	46.52
J3	-	M=100%	0.42	0.54	0.66	22.16	56.09	103.35
		M=66%	0.40	0.52	0.64	20.86	53.49	99.40
		M=33%	0.37	0.49	0.61	19.37	50.50	94.88
		M=0%	0.33	0.45	0.57	17.65	47.05	89.65
J4	-	M=100%	0.39	0.51	0.63	30.81	79.27	147.64
		M=66%	0.37	0.49	0.61	29.53	76.71	143.77
		M=33%	0.35	0.47	0.60	28.06	73.76	139.29
		M=0%	0.33	0.45	0.57	26.43	70.51	134.37
J5	-	M=100%	0.39	0.51	0.63	30.81	79.27	147.64
		M=66%	0.37	0.49	0.61	29.53	76.71	143.77
		M=33%	0.35	0.47	0.60	28.06	73.76	139.29
		M=0%	0.33	0.45	0.57	26.43	70.51	134.37
J6	-	Load 1	0.39	0.51	0.63	49.30	126.83	236.23

Stopping time and stopping distance (power off)

Axis	Arm extension	Load rate	Stopping time [s]	Stopping distance [deg]
			Ovrd 100%	Ovrd 100%
J1	L=100%	M=100%	1.41	108.08
J2	L=100%	M=100%	0.38	24.78
J3	L=100%	M=100%	0.45	49.42
J4	-	M=100%	0.40	100.38
J5	-	M=100%	0.38	104.16
J6	-	Load 1	0.52	215.32

RV-2FRLB

Stopping time and stopping distance (emergency stop)

Axis	Arm extension	Load rate	Stopping time [s]			Stopping distance [deg]		
			Ovrd 33%	Ovrd 66%	Ovrd 100%	Ovrd 33%	Ovrd 66%	Ovrd 100%
J1	L=100%	M=100%	0.77	0.85	0.93	27.50	60.48	100.20
		M=66%	0.72	0.80	0.88	25.84	57.17	95.20
		M=33%	0.67	0.75	0.83	24.16	53.82	90.11
		M=0%	0.62	0.70	0.78	22.31	50.12	84.50
	L=66%	M=100%	0.60	0.68	0.77	21.78	49.04	82.87
		M=66%	0.57	0.65	0.73	20.62	46.73	79.37
		M=33%	0.54	0.62	0.70	19.46	44.41	75.85
		M=0%	0.50	0.58	0.66	18.17	41.84	71.96
	L=33%	M=100%	0.51	0.59	0.67	18.47	42.42	72.84
		M=66%	0.47	0.55	0.63	17.24	39.97	69.13
		M=33%	0.44	0.52	0.60	15.97	37.43	65.28
		M=0%	0.40	0.48	0.56	14.78	35.04	61.66
J2	L=100%	M=100%	0.80	0.88	0.97	14.35	31.45	51.94
		M=66%	0.76	0.84	0.93	13.66	30.06	49.82
		M=33%	0.72	0.80	0.88	12.92	28.59	47.61
		M=0%	0.68	0.76	0.84	12.12	26.99	45.18
	L=66%	M=100%	0.64	0.72	0.80	11.50	25.74	43.28
		M=66%	0.61	0.69	0.77	11.04	24.83	41.91
		M=33%	0.59	0.67	0.75	10.57	23.89	40.48
		M=0%	0.56	0.64	0.72	10.06	22.85	38.91
	L=33%	M=100%	0.54	0.62	0.70	9.84	22.43	38.26
		M=66%	0.52	0.60	0.68	9.36	21.45	36.79
		M=33%	0.49	0.56	0.65	8.83	20.40	35.19
		M=0%	0.46	0.54	0.62	8.36	19.46	33.76
J3	-	M=100%	0.76	0.84	0.92	21.22	46.96	78.20
		M=66%	0.72	0.80	0.89	20.16	44.85	75.00
		M=33%	0.68	0.76	0.84	19.05	42.61	71.62
		M=0%	0.63	0.71	0.80	17.80	40.13	67.85
J4	-	M=100%	0.53	0.61	0.69	37.83	86.44	147.79
		M=66%	0.50	0.58	0.66	35.79	82.37	141.63
		M=33%	0.47	0.55	0.63	33.67	78.13	135.20
		M=0%	0.44	0.52	0.60	31.37	73.52	128.23
J5	-	M=100%	0.56	0.64	0.72	43.05	97.87	166.65
		M=66%	0.50	0.58	0.66	39.05	89.86	154.51
		M=33%	0.47	0.55	0.63	36.73	85.23	147.50
		M=0%	0.44	0.52	0.60	34.22	80.21	139.88
J6	-	Load 1	0.53	0.61	0.69	66.03	150.87	257.97

Stopping time and stopping distance (power off)

Axis	Arm extension	Load rate	Stopping time [s]	Stopping distance [deg]
			Ovrd 100%	Ovrd 100%
J1	L=100%	M=100%	1.41	108.08
J2	L=100%	M=100%	0.38	24.78
J3	L=100%	M=100%	0.45	49.42
J4	-	M=100%	0.40	100.38
J5	-	M=100%	0.38	104.16
J6	-	Load 1	0.52	215.32

RV-4FR

Stopping time and stopping distance (emergency stop)

Axis	Arm extension	Load rate	Stopping time [s]			Stopping distance [deg]		
			Ovrd 33%	Ovrd 66%	Ovrd 100%	Ovrd 33%	Ovrd 66%	Ovrd 100%
J1	L=100%	M=100%	0.48	0.56	0.64	37.27	86.30	149.12
		M=66%	0.45	0.53	0.61	35.26	82.29	143.04
		M=33%	0.42	0.50	0.58	33.17	78.11	136.70
		M=0%	0.39	0.47	0.55	30.91	73.58	129.84
	L=66%	M=100%	0.39	0.47	0.55	30.45	72.66	128.46
		M=66%	0.37	0.45	0.53	29.12	69.99	124.41
		M=33%	0.35	0.43	0.51	27.73	67.23	120.22
		M=0%	0.33	0.41	0.49	26.24	64.25	115.71
	L=33%	M=100%	0.36	0.44	0.52	28.64	69.04	122.97
		M=66%	0.33	0.41	0.49	26.57	64.90	116.70
		M=33%	0.30	0.38	0.46	24.30	60.37	109.83
		M=0%	0.27	0.35	0.43	22.11	55.99	103.19
J2	L=100%	M=100%	0.46	0.54	0.62	35.57	82.72	143.41
		M=66%	0.43	0.51	0.59	33.88	79.50	138.76
		M=33%	0.41	0.48	0.57	31.85	75.42	132.58
		M=0%	0.38	0.45	0.54	29.63	70.98	125.86
	L=66%	M=100%	0.37	0.45	0.53	29.02	69.78	124.03
		M=66%	0.35	0.43	0.51	27.74	67.22	120.16
		M=33%	0.33	0.41	0.49	26.41	64.56	116.12
		M=0%	0.31	0.39	0.47	24.97	61.67	111.75
	L=33%	M=100%	0.34	0.42	0.50	27.21	66.16	118.55
		M=66%	0.32	0.39	0.48	25.20	62.13	112.45
		M=33%	0.29	0.37	0.45	22.99	57.71	105.74
		M=0%	0.26	0.34	0.42	20.84	53.42	99.25
J3	-	M=100%	0.43	0.51	0.59	22.34	52.51	91.77
		M=66%	0.40	0.48	0.56	21.07	49.97	87.93
		M=33%	0.38	0.45	0.54	19.73	47.29	83.87
		M=0%	0.35	0.42	0.51	18.26	44.34	79.39
J4	-	M=100%	0.38	0.46	0.54	36.26	86.64	153.30
		M=66%	0.36	0.44	0.52	34.31	82.74	147.39
		M=33%	0.34	0.42	0.50	32.45	79.02	141.76
		M=0%	0.32	0.40	0.48	30.47	75.04	135.74
J5	-	M=100%	0.38	0.46	0.55	41.98	100.25	177.31
		M=66%	0.36	0.44	0.52	39.69	95.65	170.35
		M=33%	0.34	0.42	0.50	37.44	91.17	163.55
		M=0%	0.32	0.40	0.48	35.15	86.58	156.60
J6	-	Load 1	0.38	0.46	0.54	48.07	114.95	203.55

Stopping time and stopping distance (power off)

Axis	Arm extension	Load rate	Stopping time [s]	Stopping distance [deg]
			Ovrd 100%	Ovrd 100%
J1	L=100%	M=100%	0.33	68.60
J2	L=100%	M=100%	0.30	49.56
J3	L=100%	M=100%	0.27	33.60
J4	-	M=100%	0.24	58.10
J5	-	M=100%	0.26	71.82
J6	-	Load 1	0.17	77.56

RV-4FRL

Stopping time and stopping distance (emergency stop)

Axis	Arm extension	Load rate	Stopping time [s]			Stopping distance [deg]		
			Ovrd 33%	Ovrd 66%	Ovrd 100%	Ovrd 33%	Ovrd 66%	Ovrd 100%
J1	L=100%	M=100%	0.49	0.57	0.65	35.50	81.98	141.34
		M=66%	0.46	0.54	0.62	33.74	78.45	135.99
		M=33%	0.44	0.52	0.60	31.91	74.80	130.47
		M=0%	0.41	0.49	0.57	29.96	70.89	124.54
	L=66%	M=100%	0.39	0.47	0.55	28.87	68.72	121.25
		M=66%	0.38	0.45	0.54	27.67	66.32	117.61
		M=33%	0.36	0.44	0.52	26.43	63.84	113.85
		M=0%	0.34	0.42	0.50	25.11	61.19	109.85
	L=33%	M=100%	0.36	0.44	0.52	26.79	64.55	114.93
		M=66%	0.34	0.42	0.50	24.97	60.90	109.41
		M=33%	0.31	0.39	0.47	23.00	56.97	103.45
		M=0%	0.28	0.36	0.44	21.22	53.42	98.07
J2	L=100%	M=100%	0.47	0.55	0.63	27.28	63.30	109.56
		M=66%	0.44	0.52	0.60	25.91	60.57	105.42
		M=33%	0.42	0.50	0.58	24.50	57.74	101.14
		M=0%	0.39	0.47	0.55	22.98	54.69	96.52
	L=66%	M=100%	0.37	0.45	0.53	21.99	52.72	93.52
		M=66%	0.36	0.44	0.52	21.07	50.88	90.74
		M=33%	0.34	0.42	0.50	20.12	48.99	87.87
		M=0%	0.32	0.40	0.48	19.10	46.95	84.79
	L=33%	M=100%	0.34	0.42	0.50	20.35	49.46	88.62
		M=66%	0.32	0.40	0.48	18.93	46.63	84.33
		M=33%	0.29	0.37	0.45	17.40	43.57	79.69
		M=0%	0.27	0.34	0.43	16.02	40.81	75.51
J3	-	M=100%	0.44	0.51	0.60	18.95	44.44	77.53
		M=66%	0.41	0.49	0.57	17.95	42.44	74.51
		M=33%	0.39	0.47	0.55	16.92	40.36	71.36
		M=0%	0.34	0.42	0.50	14.95	36.44	65.41
J4	-	M=100%	0.40	0.48	0.56	37.77	89.65	157.87
		M=66%	0.38	0.46	0.54	35.93	85.97	152.29
		M=33%	0.36	0.44	0.52	34.14	82.39	146.87
		M=0%	0.34	0.42	0.50	32.30	78.71	141.30
J5	-	M=100%	0.40	0.48	0.56	43.67	103.63	182.43
		M=66%	0.38	0.46	0.54	41.49	99.27	175.83
		M=33%	0.36	0.44	0.52	39.39	95.06	169.45
		M=0%	0.34	0.42	0.50	37.26	90.81	163.01
J6	-	Load 1	0.40	0.48	0.56	50.02	118.86	209.47

Stopping time and stopping distance (power off)

Axis	Arm extension	Load rate	Stopping time [s]	Stopping distance [deg]
			Ovrd 100%	Ovrd 100%
J1	L=100%	M=100%	0.33	68.60
J2	L=100%	M=100%	0.30	49.56
J3	L=100%	M=100%	0.27	33.60
J4	-	M=100%	0.24	58.10
J5	-	M=100%	0.26	71.82
J6	-	Load 1	0.17	77.56

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Stopping time and stopping distance (emergency stop)

Axis	Arm extension	Load rate	Stopping time [s]			Stopping distance [deg]		
			Ovrd 33%	Ovrd 66%	Ovrd 100%	Ovrd 33%	Ovrd 66%	Ovrd 100%
J1	L=100%	M=100%	0.48	0.56	0.64	29.84	69.09	119.36
		M=66%	0.45	0.53	0.61	28.31	66.03	114.74
		M=33%	0.43	0.50	0.59	26.70	62.81	109.86
		M=0%	0.40	0.47	0.56	24.93	59.27	104.49
	L=66%	M=100%	0.40	0.48	0.56	25.21	59.82	105.33
		M=66%	0.38	0.46	0.54	23.86	57.13	101.25
		M=33%	0.36	0.44	0.52	22.87	55.14	98.23
		M=0%	0.34	0.42	0.50	21.78	52.98	94.95
	L=33%	M=100%	0.40	0.48	0.56	25.21	59.82	105.33
		M=66%	0.36	0.44	0.53	23.09	55.59	98.92
		M=33%	0.33	0.41	0.49	21.24	51.90	93.32
		M=0%	0.31	0.39	0.47	19.60	48.61	88.35
J2	L=100%	M=100%	0.39	0.45	0.52	22.25	51.45	88.81
		M=66%	0.37	0.45	0.52	24.21	57.35	100.82
		M=33%	0.35	0.43	0.51	24.87	60.20	107.54
		M=0%	0.32	0.40	0.48	22.98	56.43	101.85
	L=66%	M=100%	0.32	0.40	0.47	21.52	52.35	93.87
		M=66%	0.30	0.38	0.46	21.65	53.76	97.78
		M=33%	0.29	0.37	0.45	20.60	51.66	94.60
		M=0%	0.27	0.35	0.43	19.48	49.42	91.23
	L=33%	M=100%	0.32	0.40	0.48	22.85	55.98	100.86
		M=66%	0.29	0.37	0.45	20.80	52.05	95.19
		M=33%	0.26	0.34	0.42	18.80	48.05	89.13
		M=0%	0.23	0.31	0.39	17.05	44.57	83.88
J3	-	M=100%	0.48	0.55	0.62	30.96	69.82	118.12
		M=66%	0.47	0.55	0.63	36.09	83.44	144.00
		M=33%	0.45	0.53	0.61	35.07	81.89	142.42
		M=0%	0.42	0.50	0.58	32.89	77.54	135.83
J4	-	M=100%	0.35	0.43	0.51	20.86	50.52	90.29
		M=66%	0.33	0.41	0.49	19.66	48.14	86.68
		M=33%	0.31	0.39	0.47	18.49	45.78	83.12
		M=0%	0.29	0.37	0.45	17.27	43.36	79.44
J5	-	M=100%	0.35	0.43	0.51	28.08	67.91	121.26
		M=66%	0.33	0.41	0.49	26.42	64.60	116.24
		M=33%	0.31	0.39	0.47	24.69	61.13	110.99
		M=0%	0.29	0.37	0.45	23.07	57.89	106.08
J6	-	Load 1	0.35	0.43	0.51	44.09	107.00	191.49

Stopping time and stopping distance (power off)

Axis	Arm extension	Load rate	Stopping time [s]	Stopping distance [deg]
			Ovrd 100%	Ovrd 100%
J1	L=100%	M=100%	0.36	48.58
J2	L=100%	M=100%	0.54	62.30
J3	L=100%	M=100%	0.38	57.40
J4	-	M=100%	0.29	38.92
J5	-	M=100%	0.40	27.30
J6	-	Load 1	0.18	36.12

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Stopping time and stopping distance (emergency stop)

Axis	Arm extension	Load rate	Stopping time [s]			Stopping distance [deg]		
			Ovrd 33%	Ovrd 66%	Ovrd 100%	Ovrd 33%	Ovrd 66%	Ovrd 100%
J1	L=100%	M=100%	0.45	0.53	0.61	22.34	52.20	90.84
		M=66%	0.42	0.50	0.58	21.21	49.95	87.43
		M=33%	0.40	0.48	0.56	20.04	47.60	83.88
		M=0%	0.37	0.45	0.53	18.77	45.06	80.03
	L=66%	M=100%	0.36	0.44	0.52	18.06	43.65	77.89
		M=66%	0.34	0.42	0.50	17.36	42.24	75.75
		M=33%	0.33	0.41	0.49	16.63	40.79	73.55
		M=0%	0.31	0.39	0.47	15.85	39.23	71.19
	L=33%	M=100%	0.35	0.43	0.51	17.83	43.18	77.17
		M=66%	0.33	0.41	0.49	16.63	40.78	73.54
		M=33%	0.30	0.38	0.46	15.34	38.20	69.63
		M=0%	0.28	0.36	0.44	14.29	36.11	66.47
J2	L=100%	M=100%	0.43	0.51	0.59	24.00	56.32	98.32
		M=66%	0.41	0.49	0.57	22.81	53.93	94.69
		M=33%	0.38	0.46	0.54	21.56	51.43	90.91
		M=0%	0.36	0.44	0.52	20.20	48.73	86.81
	L=66%	M=100%	0.34	0.42	0.50	19.26	46.84	83.95
		M=66%	0.33	0.41	0.49	18.53	45.38	81.74
		M=33%	0.31	0.39	0.47	17.78	43.87	79.45
		M=0%	0.30	0.38	0.46	16.97	42.25	77.00
	L=33%	M=100%	0.34	0.42	0.50	19.00	46.32	83.16
		M=66%	0.31	0.39	0.47	17.72	43.75	79.28
		M=33%	0.29	0.36	0.45	16.34	40.99	75.10
		M=0%	0.26	0.34	0.43	15.24	38.79	71.76
J3	-	M=100%	0.40	0.48	0.57	25.44	60.28	106.01
		M=66%	0.38	0.46	0.54	24.10	57.61	101.97
		M=33%	0.36	0.44	0.52	22.70	54.81	97.73
		M=0%	0.33	0.41	0.49	21.17	51.75	93.08
J4	-	M=100%	0.37	0.45	0.53	22.01	52.82	93.78
		M=66%	0.35	0.43	0.51	20.90	50.61	90.44
		M=33%	0.33	0.41	0.49	19.89	48.58	87.36
		M=0%	0.31	0.39	0.47	18.80	46.41	84.07
J5	-	M=100%	0.37	0.45	0.54	29.58	70.92	125.82
		M=66%	0.35	0.43	0.51	28.03	67.83	121.13
		M=33%	0.33	0.41	0.49	26.56	64.88	116.66
		M=0%	0.31	0.39	0.47	25.11	61.97	112.26
J6	-	Load 1	0.37	0.45	0.53	46.69	112.20	199.38

Stopping time and stopping distance (power off)

Axis	Arm extension	Load rate	Stopping time [s]	Stopping distance [deg]
			Ovrd 100%	Ovrd 100%
J1	L=100%	M=100%	0.36	48.58
J2	L=100%	M=100%	0.54	62.30
J3	L=100%	M=100%	0.38	57.40
J4	-	M=100%	0.29	38.92
J5	-	M=100%	0.40	27.30
J6	-	Load 1	0.18	36.12

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Stopping time and stopping distance (emergency stop)

Axis	Arm extension	Load rate	Stopping time [s]			Stopping distance [deg]		
			Ovrd 33%	Ovrd 66%	Ovrd 100%	Ovrd 33%	Ovrd 66%	Ovrd 100%
J1	L=100%	M=100%	0.63	0.75	0.87	34.66	81.90	143.73
		M=66%	0.60	0.72	0.84	33.21	79.01	139.35
		M=33%	0.58	0.69	0.82	31.75	76.08	134.91
		M=0%	0.55	0.67	0.79	30.21	73.01	130.27
	L=66%	M=100%	0.57	0.69	0.81	31.61	75.80	134.50
		M=66%	0.54	0.66	0.78	29.85	72.29	129.18
		M=33%	0.51	0.62	0.75	28.03	68.64	123.64
		M=0%	0.47	0.59	0.71	26.04	64.66	117.62
	L=33%	M=100%	0.57	0.69	0.81	31.56	75.71	134.35
		M=66%	0.54	0.66	0.78	29.82	72.22	129.07
		M=33%	0.50	0.62	0.75	28.00	68.59	123.57
		M=0%	0.47	0.59	0.71	26.03	64.65	117.61
J2	L=100%	M=100%	0.57	0.69	0.82	16.18	38.80	68.82
		M=66%	0.55	0.67	0.79	15.53	37.48	66.82
		M=33%	0.52	0.64	0.77	14.86	36.14	64.79
		M=0%	0.50	0.62	0.74	14.15	34.73	62.66
	L=66%	M=100%	0.52	0.64	0.76	14.63	35.68	64.10
		M=66%	0.49	0.61	0.73	13.81	34.05	61.63
		M=33%	0.45	0.57	0.70	12.95	32.34	59.04
		M=0%	0.42	0.54	0.66	12.02	30.46	56.19
	L=33%	M=100%	0.52	0.63	0.76	14.60	35.63	64.03
		M=66%	0.49	0.60	0.73	13.79	34.01	61.57
		M=33%	0.45	0.57	0.70	12.94	32.32	59.00
		M=0%	0.42	0.54	0.66	12.02	30.46	56.19
J3	-	M=100%	0.57	0.69	0.81	21.33	51.24	91.04
		M=66%	0.53	0.65	0.78	20.20	48.98	87.61
		M=33%	0.50	0.62	0.74	19.02	46.63	84.05
		M=0%	0.47	0.59	0.71	17.75	44.09	80.20
J4	-	M=100%	0.48	0.60	0.73	31.49	77.69	140.66
		M=66%	0.47	0.59	0.71	30.65	76.00	138.10
		M=33%	0.46	0.58	0.70	29.79	74.29	135.50
		M=0%	0.44	0.56	0.68	28.90	72.49	132.79
J5	-	M=100%	0.48	0.60	0.73	37.79	93.22	168.79
		M=66%	0.47	0.59	0.71	36.78	91.20	165.72
		M=33%	0.46	0.58	0.70	35.75	89.14	162.61
		M=0%	0.44	0.56	0.68	34.68	86.99	159.35
J6	-	Load 1	0.48	0.60	0.73	60.47	149.16	270.06

Stopping time and stopping distance (power off)

Axis	Arm extension	Load rate	Stopping time [s]	Stopping distance [deg]
			Ovrd 100%	Ovrd 100%
J1	L=100%	M=100%	0.71	61.34
J2	L=100%	M=100%	0.84	39.74
J3	L=100%	M=100%	0.85	74.59
J4	-	M=100%	0.79	120.24
J5	-	M=100%	0.91	135.36
J6	-	Load 1	0.18	37.15

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Stopping time and stopping distance (emergency stop)

Axis	Arm extension	Load rate	Stopping time [s]			Stopping distance [deg]		
			Ovrd 33%	Ovrd 66%	Ovrd 100%	Ovrd 33%	Ovrd 66%	Ovrd 100%
J1	L=100%	M=100%	0.59	0.69	0.80	29.57	68.62	118.76
		M=66%	0.56	0.66	0.76	28.07	65.61	114.19
		M=33%	0.53	0.63	0.73	26.51	62.49	109.47
		M=0%	0.50	0.59	0.70	24.84	59.15	104.42
	L=66%	M=100%	0.48	0.58	0.68	24.02	57.52	101.94
		M=66%	0.46	0.55	0.66	22.92	55.32	98.61
		M=33%	0.43	0.53	0.63	21.79	53.06	95.18
		M=0%	0.41	0.51	0.61	20.58	50.64	91.51
	L=33%	M=100%	0.42	0.52	0.62	21.16	51.79	93.26
		M=66%	0.39	0.49	0.59	19.93	49.33	89.53
		M=33%	0.38	0.48	0.58	19.26	47.99	87.50
		M=0%	0.37	0.47	0.57	18.71	46.89	85.84
J2	L=100%	M=100%	0.54	0.64	0.74	21.81	51.27	89.62
		M=66%	0.51	0.61	0.71	20.70	49.04	86.24
		M=33%	0.48	0.58	0.68	19.54	46.73	82.73
		M=0%	0.45	0.55	0.65	18.30	44.24	78.96
	L=66%	M=100%	0.42	0.52	0.63	17.33	42.31	76.04
		M=66%	0.40	0.50	0.61	16.55	40.74	73.67
		M=33%	0.38	0.48	0.58	15.74	39.12	71.20
		M=0%	0.36	0.46	0.56	14.86	37.37	68.55
	L=33%	M=100%	0.37	0.46	0.57	15.02	37.69	69.04
		M=66%	0.34	0.44	0.54	14.13	35.91	66.34
		M=33%	0.33	0.43	0.53	13.69	35.03	65.01
		M=0%	0.32	0.42	0.52	13.35	34.35	63.98
J3	-	M=100%	0.48	0.58	0.68	26.05	62.28	110.28
		M=66%	0.46	0.55	0.66	24.71	59.61	106.23
		M=33%	0.43	0.53	0.63	23.52	57.24	102.64
		M=0%	0.41	0.51	0.61	22.48	55.15	99.47
J4	-	M=100%	0.45	0.55	0.65	29.47	71.20	127.00
		M=66%	0.43	0.53	0.63	28.34	68.92	123.55
		M=33%	0.41	0.51	0.62	27.16	66.57	119.99
		M=0%	0.39	0.49	0.60	25.90	64.05	116.18
J5	-	M=100%	0.45	0.55	0.65	29.47	71.20	127.00
		M=66%	0.43	0.53	0.63	28.34	68.92	123.55
		M=33%	0.41	0.51	0.62	27.16	66.57	119.99
		M=0%	0.39	0.49	0.60	25.90	64.05	116.18
J6	-	Load 1	0.45	0.55	0.65	56.59	136.70	243.84

Stopping time and stopping distance (power off)

Axis	Arm extension	Load rate	Stopping time [s]	Stopping distance [deg]
			Ovrd 100%	Ovrd 100%
J1	L=100%	M=100%	0.69	59.69
J2	L=100%	M=100%	0.81	38.66
J3	L=100%	M=100%	0.82	72.50
J4	-	M=100%	0.77	116.94
J5	-	M=100%	0.89	131.61
J6	-	Load 1	0.29	106.75

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Stopping time and stopping distance (emergency stop)

Axis	Arm extension	Load rate	Stopping time [s]			Stopping distance [deg]		
			Ovrd 33%	Ovrd 66%	Ovrd 100%	Ovrd 33%	Ovrd 66%	Ovrd 100%
J1	L=100%	M=100%	0.56	0.66	0.76	22.49	52.63	91.67
		M=66%	0.53	0.63	0.73	21.45	50.55	88.53
		M=33%	0.50	0.60	0.71	20.39	48.43	85.32
		M=0%	0.48	0.57	0.68	19.27	46.19	81.92
	L=66%	M=100%	0.47	0.57	0.67	19.05	45.74	81.23
		M=66%	0.45	0.55	0.65	18.44	44.52	79.39
		M=33%	0.44	0.54	0.64	17.83	43.31	77.55
		M=0%	0.42	0.52	0.62	17.21	42.07	75.68
	L=33%	M=100%	0.42	0.52	0.62	17.11	41.87	75.37
		M=66%	0.41	0.51	0.61	16.73	41.11	74.22
		M=33%	0.40	0.50	0.60	16.36	40.37	73.10
		M=0%	0.39	0.49	0.59	15.99	39.62	71.96
J2	L=100%	M=100%	0.57	0.67	0.77	16.16	37.68	65.45
		M=66%	0.54	0.64	0.75	15.39	36.13	63.11
		M=33%	0.52	0.61	0.72	14.59	34.54	60.70
		M=0%	0.48	0.58	0.69	13.75	32.86	58.15
	L=66%	M=100%	0.48	0.58	0.68	13.75	32.85	58.13
		M=66%	0.47	0.57	0.67	13.27	31.90	56.70
		M=33%	0.45	0.55	0.65	12.80	30.95	55.26
		M=0%	0.43	0.53	0.63	12.31	29.97	53.78
	L=33%	M=100%	0.43	0.53	0.63	12.39	30.14	54.03
		M=66%	0.42	0.52	0.62	12.08	29.51	53.08
		M=33%	0.41	0.51	0.61	11.77	28.89	52.14
		M=0%	0.40	0.50	0.60	11.45	28.25	51.17
J3	-	M=100%	0.49	0.59	0.69	18.48	44.12	78.01
		M=66%	0.47	0.57	0.67	17.89	42.94	76.23
		M=33%	0.45	0.55	0.66	17.29	41.74	74.41
		M=0%	0.44	0.54	0.64	16.66	40.47	72.48
J4	-	M=100%	0.45	0.55	0.65	29.42	71.09	126.83
		M=66%	0.44	0.53	0.64	28.41	69.08	123.78
		M=33%	0.42	0.52	0.62	27.38	67.02	120.66
		M=0%	0.40	0.50	0.60	26.29	64.84	117.37
J5	-	M=100%	0.45	0.55	0.65	29.42	71.09	126.83
		M=66%	0.44	0.53	0.64	28.41	69.08	123.78
		M=33%	0.42	0.52	0.62	27.38	67.02	120.66
		M=0%	0.40	0.50	0.60	26.29	64.84	117.37
J6	-	Load 1	0.45	0.55	0.65	56.48	136.49	243.52

Stopping time and stopping distance (power off)

Axis	Arm extension	Load rate	Stopping time [s]	Stopping distance [deg]
			Ovrd 100%	Ovrd 100%
J1	L=100%	M=100%	0.69	59.69
J2	L=100%	M=100%	0.81	38.66
J3	L=100%	M=100%	0.82	72.50
J4	-	M=100%	0.77	116.94
J5	-	M=100%	0.89	131.61
J6	-	Load 1	0.29	106.75

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Stopping time and stopping distance (emergency stop)

Axis	Arm extension	Load rate	Stopping time [s]			Stopping distance [deg]		
			Ovrd 33%	Ovrd 66%	Ovrd 100%	Ovrd 33%	Ovrd 66%	Ovrd 100%
J1	L=100%	M=100%	0.75	0.87	0.99	14.04	32.41	55.87
		M=66%	0.70	0.82	0.94	13.20	30.72	53.31
		M=33%	0.65	0.77	0.89	12.30	28.92	50.58
		M=0%	0.60	0.71	0.84	11.30	26.92	47.54
	L=66%	M=100%	0.66	0.78	0.90	12.52	29.36	51.24
		M=66%	0.61	0.73	0.85	11.61	27.54	48.49
		M=33%	0.56	0.68	0.80	10.62	25.56	45.48
		M=0%	0.50	0.62	0.74	9.55	23.42	42.24
	L=33%	M=100%	0.66	0.78	0.90	12.51	29.35	51.23
		M=66%	0.61	0.73	0.85	11.61	27.54	48.48
		M=33%	0.56	0.68	0.80	10.61	25.56	45.48
		M=0%	0.49	0.61	0.74	9.45	23.23	41.96
J2	L=100%	M=100%	0.65	0.76	0.89	12.19	28.70	50.25
		M=66%	0.60	0.72	0.84	11.41	27.15	47.90
		M=33%	0.56	0.68	0.80	10.58	25.49	45.38
		M=0%	0.51	0.62	0.75	9.66	23.64	42.57
	L=66%	M=100%	0.56	0.68	0.80	10.66	25.65	45.62
		M=66%	0.52	0.63	0.76	9.82	23.97	43.08
		M=33%	0.46	0.58	0.71	8.90	22.13	40.29
		M=0%	0.41	0.53	0.65	7.91	20.14	37.27
	L=33%	M=100%	0.56	0.68	0.80	10.66	25.64	45.61
		M=66%	0.52	0.63	0.76	9.82	23.97	43.07
		M=33%	0.46	0.58	0.71	8.90	22.13	40.28
		M=0%	0.40	0.52	0.65	7.81	19.95	36.99
J3	-	M=100%	0.69	0.81	0.94	13.09	30.52	53.00
		M=66%	0.65	0.77	0.89	12.27	28.86	50.49
		M=33%	0.60	0.72	0.84	11.38	27.08	47.79
		M=0%	0.54	0.66	0.79	10.36	25.05	44.72
J4	-	M=100%	0.52	0.64	0.76	11.18	27.23	48.85
		M=66%	0.49	0.61	0.73	10.55	25.97	46.93
		M=33%	0.46	0.58	0.70	9.88	24.62	44.89
		M=0%	0.42	0.54	0.66	9.13	23.12	42.61
J5	-	M=100%	0.52	0.64	0.76	11.27	27.45	49.24
		M=66%	0.49	0.61	0.73	10.64	26.18	47.31
		M=33%	0.46	0.58	0.70	9.96	24.82	45.25
		M=0%	0.42	0.54	0.66	9.20	23.30	42.96
J6	-	Load 1	0.52	0.64	0.76	32.47	79.06	141.82

Stopping time and stopping distance (power off)

Axis	Arm extension	Load rate	Stopping time [s]	Stopping distance [deg]
			Ovrd 100%	Ovrd 100%
J1	L=100%	M=100%	0.69	59.69
J2	L=100%	M=100%	0.81	38.66
J3	L=100%	M=100%	0.82	72.50
J4	-	M=100%	0.77	116.94
J5	-	M=100%	0.89	131.61
J6	-	Load 1	0.29	106.75

RV-8CRL

Stopping time and stopping distance (emergency stop)

Axis	Arm extension	Load rate	Stopping time [s]			Stopping distance [deg]		
			Ovrd 33%	Ovrd 66%	Ovrd 100%	Ovrd 33%	Ovrd 66%	Ovrd 100%
J1	L=100%	M=100%	0.74	0.80	0.86	36.10	77.85	126.77
		M=66%	0.72	0.77	0.84	35.12	75.89	123.81
		M=33%	0.66	0.72	0.79	32.72	71.09	116.52
		M=0%	0.65	0.77	0.89	33.46	78.68	137.58
	L=66%	M=100%	0.58	0.63	0.70	28.47	62.59	103.64
		M=66%	0.52	0.58	0.64	25.99	57.63	96.13
		M=33%	0.47	0.53	0.59	23.36	52.37	88.15
		M=0%	0.41	0.47	0.53	20.46	46.56	79.36
	L=33%	M=100%	0.51	0.57	0.63	25.30	56.24	94.02
		M=66%	0.46	0.52	0.58	22.91	51.46	86.78
		M=33%	0.40	0.46	0.52	20.28	46.21	78.82
		M=0%	0.38	0.43	0.50	18.96	43.57	74.83
J2	L=100%	M=100%	0.53	0.59	0.65	29.54	65.37	108.86
		M=66%	0.49	0.55	0.61	27.36	61.01	102.26
		M=33%	0.45	0.51	0.57	25.05	56.39	95.26
		M=0%	0.40	0.46	0.52	22.49	51.27	87.50
	L=66%	M=100%	0.44	0.50	0.56	24.38	55.05	93.22
		M=66%	0.40	0.46	0.52	22.28	50.86	86.88
		M=33%	0.37	0.43	0.49	20.64	47.57	81.89
		M=0%	0.33	0.39	0.45	18.86	44.01	76.51
	L=33%	M=100%	0.43	0.49	0.55	23.89	54.06	91.74
		M=66%	0.38	0.44	0.50	21.59	49.47	84.77
		M=33%	0.34	0.39	0.46	19.04	44.38	77.07
		M=0%	0.31	0.37	0.44	17.93	42.16	73.70
J3	-	M=100%	0.49	0.55	0.61	30.62	68.29	114.49
		M=66%	0.45	0.51	0.57	28.02	63.10	106.61
		M=33%	0.40	0.46	0.52	25.21	57.47	98.09
		M=0%	0.35	0.41	0.47	21.98	51.01	88.30
J4	-	M=100%	0.57	0.63	0.69	33.03	72.68	120.45
		M=66%	0.56	0.62	0.68	32.44	71.51	118.67
		M=33%	0.52	0.58	0.64	30.33	67.28	112.27
		M=0%	0.47	0.53	0.59	27.67	61.96	104.21
J5	-	M=100%	0.59	0.65	0.71	45.70	100.23	165.63
		M=66%	0.58	0.64	0.70	44.60	98.02	162.28
		M=33%	0.53	0.59	0.65	41.06	90.94	151.56
		M=0%	0.47	0.53	0.59	36.90	82.62	138.94
J6	-	Load 1	0.55	0.61	0.67	68.13	150.37	249.87

Stopping time and stopping distance (power off)

Axis	Arm extension	Load rate	Stopping time [s]	Stopping distance [deg]
			Ovrd 100%	Ovrd 100%
J1	L=100%	M=100%	0.55	80.97
J2	L=100%	M=100%	0.37	51.79
J3	L=100%	M=100%	0.24	33.57
J4	-	M=100%	0.16	25.62
J5	-	M=100%	0.13	13.46
J6	-	Load 1	0.06	8.48

RH-3FRH

Stopping time and stopping distance (emergency stop)

Axis	Arm extension	Load rate	Stopping time [s]			Stopping distance J1/J2/J4 axis [deg] J3 axis [mm]		
			Ovrd 33%	Ovrd 66%	Ovrd 100%	Ovrd 33%	Ovrd 66%	Ovrd 100%
J1	L=100%	M=100%	0.26	0.28	0.31	13.86	30.52	50.61
		M=66%	0.24	0.28	0.31	15.82	35.68	60.36
		M=33%	0.24	0.28	0.32	18.04	41.58	71.56
		M=0%	0.22	0.26	0.30	17.18	39.84	68.93
	L=66%	M=100%	0.26	0.28	0.31	13.86	30.52	50.61
		M=66%	0.24	0.27	0.31	15.54	35.11	59.50
		M=33%	0.22	0.26	0.30	16.90	39.29	68.10
		M=0%	0.21	0.25	0.29	16.23	37.94	66.06
	L=33%	M=100%	0.26	0.28	0.31	13.86	30.52	50.61
		M=66%	0.24	0.27	0.31	15.54	35.11	59.50
		M=33%	0.21	0.25	0.29	16.51	38.50	66.90
		M=0%	0.21	0.24	0.29	15.88	37.25	65.01
J2	-	M=100%	0.23	0.29	0.35	21.71	53.02	95.32
		M=66%	0.23	0.29	0.36	25.36	64.55	119.39
		M=33%	0.23	0.30	0.39	29.65	78.12	147.75
		M=0%	0.21	0.29	0.37	28.24	75.30	143.47
J3	-	M=100%	0.26	0.34	0.42	51.61	131.39	243.05
		M=66%	0.24	0.32	0.40	47.68	124.10	232.91
		M=33%	0.22	0.30	0.38	43.89	116.53	221.44
		M=0%	0.22	0.30	0.38	44.86	118.48	224.39
J4	-	Load 2	0.33	0.35	0.38	52.24	111.53	180.00
		Load 1	0.31	0.36	0.42	110.40	255.63	441.69

Stopping time and stopping distance (power off)

Axis	Arm extension	Load rate	Stopping time [s]	Stopping distance [deg]
			Ovrd 100%	Ovrd 100%
J1	L=100%	M=100%	0.92	196.55
		M=33%	1.28	275.17
J2	L=100%	M=100%	1.00	126.12
		M=33%	1.40	176.60
J3	-	M=100%	0.41	71.82
		M=33%	0.34	61.32
J4	-	Load 2	2.74	601.95
		Load 1	1.45	667.04

RH-6FRH

Stopping time and stopping distance (emergency stop)

Axis	Arm extension	Load rate	Stopping time [s]			Stopping distance J1/J2/J4 axis [deg] J3 axis [mm]		
			Ovrd 33%	Ovrd 66%	Ovrd 100%	Ovrd 33%	Ovrd 66%	Ovrd 100%
J1	L=100%	M=100%	0.37	0.45	0.53	17.52	42.29	75.40
		M=66%	0.38	0.48	0.59	23.82	60.26	111.01
		M=33%	0.38	0.49	0.62	26.38	68.45	128.19
		M=0%	0.36	0.48	0.60	25.32	66.31	124.96
	L=66%	M=100%	0.34	0.42	0.50	16.37	39.99	71.92
		M=66%	0.36	0.46	0.57	22.49	57.60	106.98
		M=33%	0.36	0.48	0.60	25.13	65.94	124.40
		M=0%	0.34	0.46	0.59	24.32	64.33	121.95
	L=33%	M=100%	0.32	0.40	0.49	15.53	38.32	69.38
		M=66%	0.34	0.45	0.56	21.56	55.73	104.15
		M=33%	0.35	0.46	0.59	24.40	64.48	122.18
		M=0%	0.34	0.46	0.58	23.93	63.54	120.75
J2	-	M=100%	0.26	0.33	0.40	21.67	53.48	96.84
		M=66%	0.27	0.36	0.45	29.47	76.60	143.62
		M=33%	0.27	0.37	0.47	32.38	86.65	165.46
		M=0%	0.25	0.35	0.45	30.63	83.15	160.15
J3	-	M=100%	0.25	0.32	0.39	95.89	241.91	444.79
		M=66%	0.23	0.31	0.39	96.81	250.11	467.14
		M=33%	0.22	0.30	0.38	95.41	253.54	482.08
		M=0%	0.23	0.30	0.39	98.83	260.38	492.44
J4	-	Load 2	0.33	0.36	0.39	49.79	107.14	174.13
		Load 1	0.31	0.37	0.43	104.53	246.80	432.85

Stopping time and stopping distance (power off)

Axis	Arm extension	Load rate	Stopping time [s]	Stopping distance [deg]
			Ovrd 100%	Ovrd 100%
J1	L=100%	M=100%	0.53	71.40
		M=50%	0.65	95.48
J2	L=100%	M=100%	0.43	83.44
		M=50%	0.46	119.56
J3	-	M=100%	0.09	53.34
		M=50%	0.10	145.88
J4	-	Load 2	0.94	340.61
		Load 1	0.50	377.44

RH-12FRH

Stopping time and stopping distance (emergency stop)

Axis	Arm extension	Load rate	Stopping time [s]			Stopping distance J1/J2/J4 axis [deg] J3 axis [mm]		
			Ovrd 33%	Ovrd 66%	Ovrd 100%	Ovrd 33%	Ovrd 66%	Ovrd 100%
J1	L=100%	M=100%	0.48	0.50	0.51	18.28	37.61	58.60
		M=66%	0.42	0.44	0.46	22.86	47.82	75.71
		M=33%	0.35	0.38	0.40	24.63	52.72	85.28
		M=0%	0.32	0.35	0.38	23.82	51.49	84.01
	L=66%	M=100%	0.48	0.50	0.51	18.28	37.61	58.60
		M=66%	0.42	0.44	0.46	22.86	47.82	75.71
		M=33%	0.35	0.37	0.40	24.46	52.37	84.75
		M=0%	0.29	0.31	0.34	21.51	46.85	76.99
	L=33%	M=100%	0.48	0.50	0.51	18.28	37.61	58.60
		M=66%	0.42	0.44	0.46	22.86	47.82	75.71
		M=33%	0.35	0.37	0.40	24.46	52.37	84.75
		M=0%	0.26	0.29	0.32	19.79	43.42	71.79
J2	-	M=100%	0.47	0.50	0.54	18.94	40.59	65.72
		M=66%	0.42	0.47	0.52	24.31	54.06	90.40
		M=33%	0.36	0.42	0.49	27.07	63.14	109.73
		M=0%	0.34	0.40	0.47	26.72	63.44	111.73
J3	-	M=100%	0.51	0.55	0.59	216.09	466.05	759.02
		M=66%	0.43	0.47	0.52	191.96	421.11	696.11
		M=33%	0.33	0.37	0.42	156.10	352.91	598.29
		M=0%	0.29	0.33	0.38	142.90	329.70	568.10
J4	-	Load 2	0.48	0.50	0.51	95.32	195.56	303.97
		Load 1	0.38	0.41	0.43	155.60	332.07	535.73

Stopping time and stopping distance (power off)

Axis	Arm extension	Load rate	Stopping time [s]	Stopping distance [deg]
			Ovrd 100%	Ovrd 100%
J1	L=100%	M=100%	0.62	24.55
		M=25%	0.59	38.17
J2	L=100%	M=100%	0.66	57.68
		M=25%	1.26	109.27
J3	-	M=100%	0.68	269.73
		M=25%	0.19	150.08
J4	-	Load 2	1.95	281.87
		Load 1	0.68	269.73

RH-20FRH

Stopping time and stopping distance (emergency stop)

Axis	Arm extension	Load rate	Stopping time [s]			Stopping distance J1/J2/J4 axis [deg] J3 axis [mm]		
			Ovrd 33%	Ovrd 66%	Ovrd 100%	Ovrd 33%	Ovrd 66%	Ovrd 100%
J1	L=100%	M=100%	0.63	0.65	0.68	15.08	31.26	49.08
		M=66%	0.55	0.59	0.62	19.30	40.92	65.62
		M=33%	0.45	0.50	0.54	20.84	45.62	75.26
		M=0%	0.37	0.42	0.47	18.29	40.97	68.94
	L=66%	M=100%	0.63	0.65	0.68	15.08	31.26	49.08
		M=66%	0.55	0.59	0.62	19.30	40.92	65.62
		M=33%	0.45	0.50	0.54	20.84	45.62	75.26
		M=0%	0.34	0.38	0.43	16.67	37.73	64.02
	L=33%	M=100%	0.63	0.65	0.68	15.08	31.26	49.08
		M=66%	0.55	0.59	0.62	19.30	40.92	65.62
		M=33%	0.45	0.50	0.54	20.84	45.62	75.26
		M=0%	0.31	0.36	0.41	15.46	35.30	60.35
J2	-	M=100%	0.54	0.56	0.59	20.96	43.69	68.96
		M=66%	0.47	0.50	0.54	26.53	56.78	91.85
		M=33%	0.37	0.42	0.47	27.97	62.26	104.22
		M=0%	0.30	0.34	0.39	23.83	54.71	93.92
J3	-	M=100%	0.58	0.62	0.66	202.66	432.13	696.62
		M=66%	0.49	0.53	0.58	183.42	397.15	649.07
		M=33%	0.38	0.42	0.47	149.09	331.43	554.08
		M=0%	0.28	0.33	0.38	121.69	281.01	484.52
J4	-	Load 2	0.67	0.67	0.68	29.79	60.21	92.21
		Load 1	0.62	0.66	0.69	128.44	270.25	430.32

Stopping time and stopping distance (power off)

Axis	Arm extension	Load rate	Stopping time [s]	Stopping distance [deg]
			Ovrd 100%	Ovrd 100%
J1	L=100%	M=100%	0.92	36.82
		M=25%	0.88	57.26
J2	L=100%	M=100%	1.00	86.52
		M=25%	1.89	163.90
J3	-	M=100%	1.02	404.60
		M=25%	0.21	182.00
J4	-	Load 2	2.74	422.80
		Load 1	1.02	404.60

RH-3FRHR

Stopping time and stopping distance (emergency stop)

Axis	Arm extension	Load rate	Stopping time [s]			Stopping distance J1/J2/J4 axis [deg] J3 axis [mm]		
			Ovrd 33%	Ovrd 66%	Ovrd 100%	Ovrd 33%	Ovrd 66%	Ovrd 100%
J1	L=100%	M=100%	0.42	0.46	0.51	36.55	80.50	133.54
		M=66%	0.40	0.45	0.50	40.91	91.91	155.01
		M=33%	0.38	0.44	0.50	44.64	102.46	175.81
		M=0%	0.35	0.41	0.47	41.41	95.99	166.01
	L=66%	M=100%	0.38	0.43	0.47	33.84	75.08	125.32
		M=66%	0.37	0.42	0.47	38.10	86.29	146.49
		M=33%	0.35	0.41	0.47	41.86	96.89	167.36
		M=0%	0.33	0.39	0.45	39.10	91.38	159.01
	L=33%	M=100%	0.36	0.41	0.45	32.07	71.56	119.98
		M=66%	0.35	0.40	0.45	35.98	82.05	140.05
		M=33%	0.34	0.39	0.46	39.81	92.79	161.15
		M=0%	0.31	0.37	0.43	37.46	88.09	154.03
J2	-	M=100%	0.38	0.42	0.47	35.21	78.23	130.72
		M=66%	0.36	0.41	0.47	39.41	89.45	152.12
		M=33%	0.34	0.40	0.46	42.83	99.54	172.48
		M=0%	0.31	0.37	0.43	39.13	92.14	161.27
J3	-	M=100%	0.30	0.34	0.39	61.49	140.53	240.32
		M=66%	0.28	0.33	0.38	63.65	148.89	259.30
		M=33%	0.25	0.30	0.35	59.33	141.80	250.98
		M=0%	0.20	0.26	0.32	56.24	141.89	260.88
J4	-	Load 2	0.22	0.26	0.31	93.78	222.25	390.89
		Load 1	0.22	0.28	0.34	124.52	310.71	567.03

Stopping time and stopping distance (power off)

Axis	Arm extension	Load rate	Stopping time [s]	Stopping distance [deg]
			Ovrd 100%	Ovrd 100%
J1	L=100%	M=100%	0.43	91.70
		M=33%	0.61	119.14
J2	L=100%	M=100%	0.41	74.34
		M=33%	0.41	104.30
J3	-	M=100%	0.21	78.40
		M=33%	0.22	73.78
J4	-	Load 2	0.78	418.60
		Load 1	0.92	915.32

RH-1FRHR

Stopping time and stopping distance (emergency stop)

Axis	Arm extension	Load rate	Stopping time [s]			Stopping distance J1/J2/J4 axis [deg] J3 axis [mm]		
			Ovrd 33%	Ovrd 66%	Ovrd 100%	Ovrd 33%	Ovrd 66%	Ovrd 100%
J1	L=100%	M=100%	0.22	0.26	0.30	9.76	22.45	38.59
		M=66%	0.23	0.27	0.32	11.91	28.02	49.03
		M=33%	0.23	0.28	0.33	14.11	33.95	60.39
		M=0%	0.23	0.28	0.33	13.91	33.55	59.78
	L=66%	M=100%	0.21	0.24	0.28	9.18	21.29	36.82
		M=66%	0.21	0.26	0.30	11.24	26.68	47.01
		M=33%	0.22	0.27	0.32	13.36	32.46	58.13
		M=0%	0.21	0.26	0.32	13.20	32.14	57.64
	L=33%	M=100%	0.20	0.24	0.27	8.84	20.61	35.79
		M=66%	0.20	0.25	0.29	10.85	25.91	45.84
		M=33%	0.21	0.26	0.31	12.94	31.61	56.84
		M=0%	0.21	0.26	0.31	12.80	31.33	56.43
J2	-	M=100%	0.24	0.28	0.32	22.23	51.66	89.52
		M=66%	0.24	0.29	0.35	27.14	64.65	114.13
		M=33%	0.25	0.31	0.37	32.18	78.48	140.94
		M=0%	0.24	0.30	0.37	31.91	77.93	140.10
J3	-	M=100%	0.19	0.25	0.31	27.10	69.20	128.25
		M=66%	0.19	0.25	0.31	26.69	68.38	127.01
		M=33%	0.19	0.25	0.31	26.51	68.02	126.46
		M=0%	0.18	0.24	0.31	26.33	67.65	125.91
J4	-	Load 1	0.17	0.20	0.24	56.51	134.20	236.38

Stopping time and stopping distance (power off)

Axis	Arm extension	Load rate	Stopping time [s]	Stopping distance [deg]
			Ovrd 100%	Ovrd 100%
J1	L=100%	M=100%	0.22	22.12
		M=33%	0.35	53.20
J2	L=100%	M=100%	0.19	41.02
		M=33%	0.26	71.12
J3	-	M=100%	0.13	49.28
		M=33%	0.11	37.24
J4	-	Load 1	0.16	177.24

RH-3CRH

Stopping time and stopping distance (emergency stop)

Axis	Arm extension	Load rate	Stopping time [s]			Stopping distance J1/J2/J4 axis [deg] J3 axis [mm]		
			Ovrd 33%	Ovrd 66%	Ovrd 100%	Ovrd 33%	Ovrd 66%	Ovrd 100%
J1	L=100%	M=100%	0.45	0.61	0.78	46.48	125.62	241.34
		M=66%	0.46	0.66	0.87	57.88	162.80	320.10
		M=33%	0.44	0.63	0.84	54.69	156.43	310.46
		M=0%	0.41	0.61	0.81	51.78	150.61	301.64
	L=66%	M=100%	0.39	0.55	0.72	40.94	114.55	224.57
		M=66%	0.41	0.61	0.82	51.94	150.92	302.11
		M=33%	0.39	0.59	0.80	49.54	146.13	294.84
		M=0%	0.46	0.66	0.86	57.51	162.07	319.00
	L=33%	M=100%	0.35	0.52	0.69	37.18	107.04	213.18
		M=66%	0.38	0.58	0.78	47.97	142.98	290.08
		M=33%	0.36	0.56	0.77	46.17	139.38	284.62
		M=0%	0.44	0.64	0.84	54.81	156.67	310.82
J2	-	M=100%	0.41	0.58	0.75	43.45	119.58	232.18
		M=66%	0.43	0.63	0.83	54.25	155.55	309.12
		M=33%	0.41	0.61	0.81	51.51	150.07	300.82
		M=0%	0.39	0.59	0.79	49.17	145.38	293.71
J3	-	M=100%	0.44	0.64	0.84	85.96	245.11	485.61
		M=66%	0.43	0.62	0.83	83.14	239.46	477.05
		M=33%	0.41	0.61	0.81	79.92	233.03	467.31
		M=0%	0.39	0.59	0.79	76.48	226.14	456.88
J4	-	Load 2	0.60	0.67	0.74	95.80	212.86	355.68
		Load 1	0.47	0.60	0.74	143.95	364.97	673.29

Stopping time and stopping distance (power off)

Axis	Arm extension	Load rate	Stopping time [s]	Stopping distance J1/J2/J4 axis [deg] J3 axis [mm]
			Ovrd 100%	Ovrd 100%
J1	L=100%	M=100%	0.61	170.70
J2	-	M=100%	0.57	174.28
J3	-	M=100%	0.27	168.38
J4	-	Load 2	0.63	208.89

RH-6CRH

Stopping time and stopping distance (emergency stop)

Axis	Arm extension	Load rate	Stopping time [s]			Stopping distance J1/J2/J4 axis [deg] J3 axis [mm]		
			Ovrd 33%	Ovrd 66%	Ovrd 100%	Ovrd 33%	Ovrd 66%	Ovrd 100%
J1	L=100%	M=100%	0.47	0.50	0.53	16.98	36.02	57.79
		M=66%	0.44	0.49	0.53	24.44	53.57	88.50
		M=33%	0.42	0.48	0.54	30.53	69.30	117.85
		M=0%	0.35	0.41	0.47	25.66	59.56	103.10
	L=66%	M=100%	0.33	0.36	0.39	12.25	26.55	43.45
		M=66%	0.32	0.37	0.41	18.02	40.74	69.05
		M=33%	0.31	0.37	0.43	23.06	54.36	95.21
		M=0%	0.28	0.34	0.40	21.29	50.82	89.85
	L=33%	M=100%	0.35	0.37	0.41	12.80	27.65	45.11
		M=66%	0.34	0.39	0.43	19.08	42.84	72.24
		M=33%	0.33	0.39	0.45	24.82	57.87	100.53
		M=0%	0.29	0.35	0.41	21.59	51.40	90.74
J2	-	M=100%	0.40	0.43	0.46	25.33	54.20	87.62
		M=66%	0.38	0.43	0.47	36.51	81.06	135.38
		M=33%	0.36	0.42	0.48	45.59	105.30	181.57
		M=0%	0.32	0.38	0.44	40.90	95.91	167.36
J3	-	M=100%	0.42	0.48	0.54	81.20	183.96	312.39
		M=66%	0.39	0.45	0.51	74.38	170.31	291.71
		M=33%	0.35	0.41	0.47	67.32	156.20	270.32
		M=0%	0.30	0.36	0.42	58.40	138.36	243.29
J4	-	Load 2	0.55	0.56	0.57	51.49	105.32	163.24
		Load 1	0.30	0.34	0.38	104.38	233.24	391.63

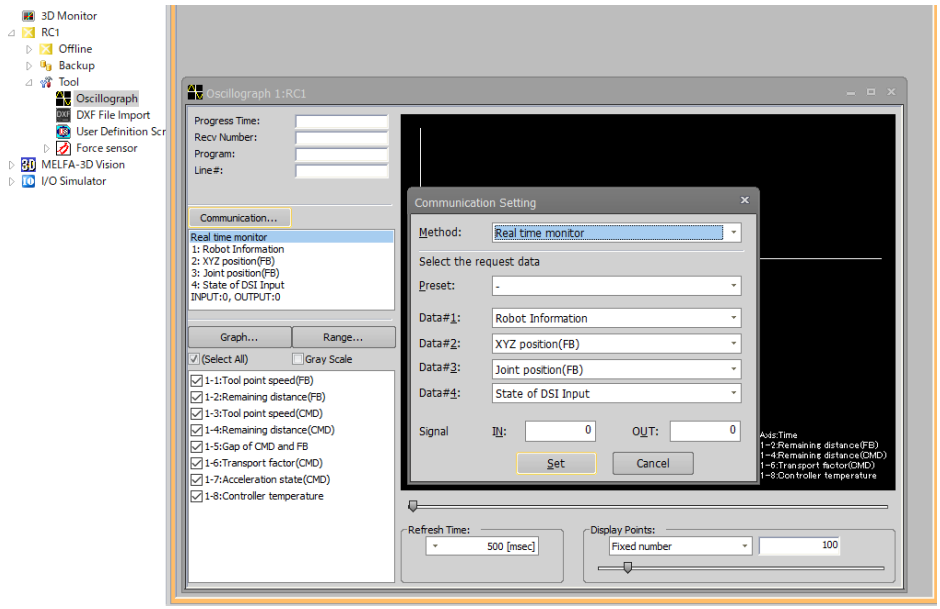
Stopping time and stopping distance (power off)

Axis	Arm extension	Load rate	Stopping time [s]	Stopping distance J1/J2/J4 axis [deg] J3 axis [mm]
			Ovrd 100%	Ovrd 100%
J1	L=100%	M=100%	0.37	39.21
J2	-	M=100%	0.34	58.92
J3	-	M=100%	0.44	185.80
J4	-	Load 2	0.48	108.94

7.3 Calculating stopping distance and stopping time

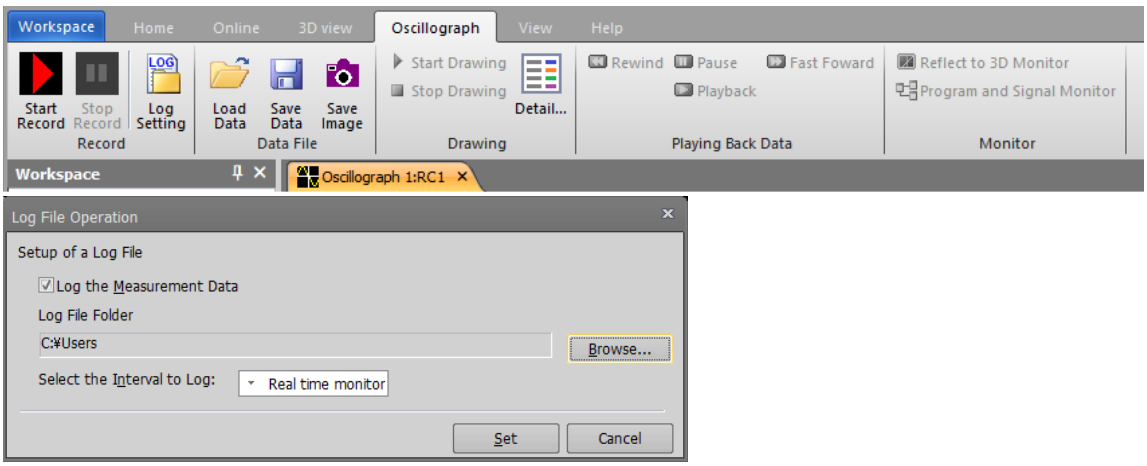
This section explains how to calculate stopping distance and stopping time with RT ToolBox3.
Calculating the stopping distance and time based on actual peripheral devices (such as hands) and the program that will be used will provide more accurate results. For information on how to use RT ToolBox3 or how to configure the advanced settings, refer to the RT ToolBox3 or RT ToolBox3 mini Instruction Manual.

① Configure the log settings of the oscillograph function.
Connect the robot controller to RT ToolBox3 via Ethernet, set the controller to Online mode, then select Tool → Oscillograph. Configure the communication settings as follows:
・Method: Real time monitor
・Data No.1 to 4: Robot Information / XYZ position (FB) / Joint position (FB) / State of DSI Input



Note that Real time monitor cannot be selected when the robot controller is connected to RT ToolBox3 via USB.
If some of the data that has been received is lost, we recommend connecting the robot controller and computer directly (not via a network hub), using a high-performance computer, or not using this software while any other application is open.

② Create the robot log.
Open [Log Setting] from the menu bar, then check the Log the Measurement Data check box. Select [Real time monitor] in the [Select the Interval to Log] drop down box, then choose a folder to save the log file in. Select [Start Record] to start logging data. Select [Stop Record] to stop logging data.



③ Log data.

Operate the robot and start data logging.

Next, input the stop signal. Finish data logging after the robot has stopped. A simple way to input the stop signal, is to input it from the emergency stop switch (EMS Switch) connected to the emergency stop input of the robot controller. If a teaching pendant is connected, the emergency stop switch on the teaching pendant can also be used. The robot can also be stopped by connecting a signal, which acts as a trigger, to the DSI input of the Safety extension unit. When using this method, SS1 must be assigned to the relevant DSI input in the safety input settings under Safety logic in RT ToolBox3.

Caution

Using the DSI input of the Safety extension unit to stop the robot will have an effect on the DSI filter time specified in the DSI filter settings. For further information, refer to "(c) DSI filter configuration".

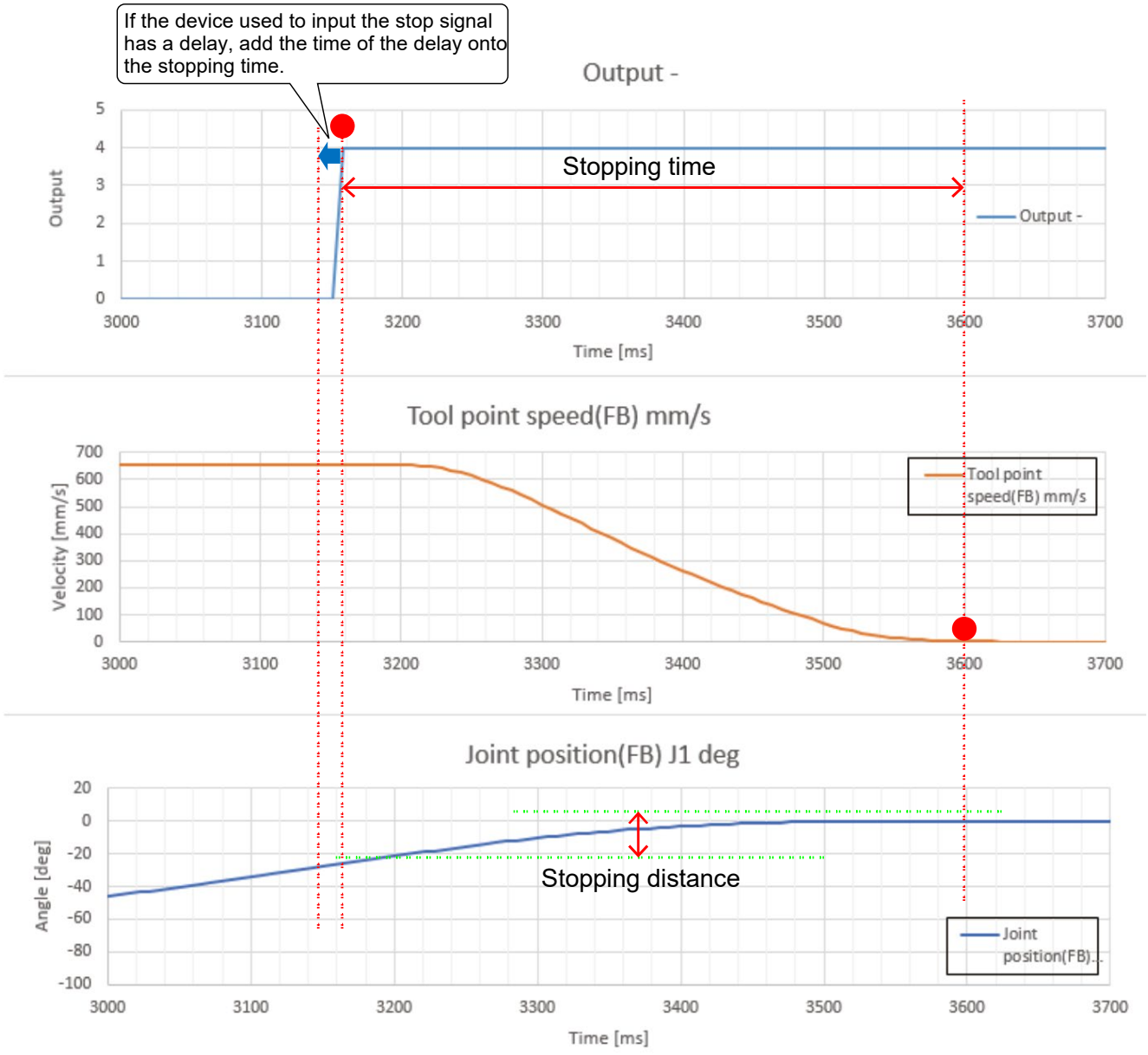
The initial value is 10 ms, therefore there will be a delay of 10 ms until the DSI input is enabled for the input signal.

④ Interpret the stopping distance and stopping time.

The logged data will be saved as a file in the folder you have specified. The current date and time will be used as the file name (e.g. "LOGYYYYMMDD-hhmmss.csv"). The first three rows in the CSV file contain information such as column titles and units of measurement. Data sampled at intervals is contained in the rows from the fourth row onwards. Check the values in the Output column. This number has been changed from a 32-bit binary value (assigned to the general-purpose output signal) to a decimal value. If the output signal of "ERRRESET" is set to "2", the value will increase to four (2^2 = 4) when an error occurs. When the emergency stop signal is input, the robot will enter an error state. By checking the time when bit 2 changes to "4" in the output column, you can see when the stop signal was input.

The CSV file can be used to check the time that the robot stopped. The "Tool point speed (FB)" column in the file shows the speed of the tool control point. Look for where the speed decreases to zero after the stop signal has been input.

The stopping time is the time from when the stop signal is input to when the speed becomes zero. By checking the XYZ position (FB) data or Joint position (FB) data at the times when the stop signal was input and at the time the robot stopped, it is possible to find the stopping distance of the tool center point within the XYZ coordinate system and the stopping distance (angle) of individual axes. Refer to the graphs on the following page which show an example of the stopping distance of the J1 axis. If there is a delay when the stop signal is input, consider the time that the signal was output as earlier than what is shown in the graph.



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