

# Mitsubishi Electric Industrial Robot

**CR800 series controller** 

# Robot Safety Option

# Instruction Manual 4F-SF002-01





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



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.)  $\rightarrow$ Enforcement of safety training



ON 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



■ 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



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



Establish a set signaling method to the related operators for starting work, and follow this method.  $\rightarrow$  Signaling of operation start



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.  $\rightarrow$ Indication of maintenance work in progress



Before starting work, inspect the robot, emergency stop switch and other related devices, etc., and confirm that there are no errors.  $\rightarrow$ 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.



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.



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.)



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.



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



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



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.

**AUTION** 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.



**G** 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.



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



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



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.

AUTION

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.



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.



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.



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



**/ARNING** 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.



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.



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.



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.

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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.

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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).)

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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).)



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.



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.

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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.



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 (FMG)"

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



Incorrect handling may result in imminent danger, leading to death or serious injury.

Incorrect handling may lead to death or serious injury.

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.
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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:

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)

Tab. 1	1-1:	Safety	monitoring	functions	overview
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# **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	
Robot controller	CR800-D	Ver. A1 or later	
	CR800-R	Ver. A1 or later	
	CR800-Q	Ver. A2 or later	
RT ToolBox3	3F-15C-WINE		Install the software to a personal
RT ToolBox3 mini	3F-14C-WINE		computer.
RT ToolBox3 Pro	3F-16D-WINE		The software is used to enable the safety monitoring function. (Separate purchase is required.)
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

	Item		Description	Remarks
Safety	STO function		The function electrically shuts off	IEC 60204-1
function			the driving energy to the motor of	Corresponds to
			the robot arm.	stop category 0
	SS1 function		The function to control and	IEC 60204-1
			decelerate the motor speeds of the	Corresponds to
			robot. After stopping, the robot	stop category 1
			transitions to the STO state.	
	SS2 function		The function to control and	IEC 60204-1
			decelerate the motor speeds of the	Corresponds to
			robot. After stopping, the robot	stop category 2
			transitions to the SOS state.	1 0 7
	SOS function		Without shutting off the driving	EN61800-5-2
			energy to the motors, this function	compliant
			monitors the robot so that it stavs	
			at rest.	
	SLS function		This is a function to monitor each	EN61800-5-2
			part of the robot arm so that their	compliant
			speeds do not exceed monitoring	
			speeds	
	SLP function		The function monitors specified	EN61800-5-2
	0		monitoring positions so that they	compliant
			do not go across position	
			monitoring planes.	
Safety	Standard		ISO10218-1(2011)	
performance	010110010		EN62061(2006)	
p 01.01.00			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	SIL 2 PL d/Category 3	
		SLS.SLP		
	Dangerous	STO	$PFH = 1.40 \times 10^{-8} [1/h]$	
	failure rate	SS1 SS2 SOS	$PFH = 3.42 \times 10^{-7} [1/h]$	
		SI S	$PEH = 3.42 \times 10^{-7} [1/h]$	
			$PEH = 2.42 \times 10^{-7} [1/h]$	
S of ot v	Dowor oupply	Voltago	$FFII = 3.42 \times 10 [1/11]$	
Salety		vollage	$24 \text{ V DC} \pm 5\%$	
extension	specifications	Maximum	Rippie 0.2 V (P-P)	
unit			300 MA	
		consumption		
	Structure (ID re		1030	
	Structure (IP 12	aung)		
	vveight			It must be kent
	Environment		U to 40°C	it must be kept
		temperature range		away from neat
				appliances and
		Deletive hours falls	45 to 75	Sources.
			40 IU / 5	Non-condensing
		vibration	During transportation: 34m/s <sup>2</sup> .	
		A turn a cur la cur -	During operation: 5 m/s <sup>2</sup> or less	
		Aunosphere	oil mist/dust	
			บแทบอินันนอเ	

	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 app	bearance	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.		2F-SFSDOCON
6	Termination resistor	1			2F-SFTM
7	Instruction manual	1	O CD-RO	M	BFP-A3543

# 2.1.2 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.	

#### Tab. 2-2 Customer-prepared items

# 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

No.	Connector	Function	Remarks
(1)	CJ31	Unavailable	
(2)	CJ32	Unavailable	
(3)	SDI1	Safety DI input connectors	Eight points for duplication.
(4)	SDI2	Safety DI input connectors	0 V common.
(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
(10)	SDO2	Safety relay output connector	Non-voltage contact output
(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

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

# 2.3 Installation and Connection



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.



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

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.



Please supply power to the safety extension unit before the robot controller. When the controller is turned on before the unit, H311(Remotel/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





#### 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.





### 2.3.4 Connector and cable



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.

No.	Connector	Accessories needed	Description		Recommended cable	
1	DCIN/DCOUT	2F-SFDCINCON				Conductor area: 0.5 to
			Manufacturer	Model	Qty.	1.42 mm²,
			TE Connectivity	2-178288-3	1	(20 to 16 AWG)
			TE Connectivity	1-175218-5	3	Sheath diameter: 1.8 to
						2.8 mm
						With shields
2	SDI1	2F-SFSDICON				Conductor area: 0.5 to
	SDI2		Manufacturer	Model	Qty.	1.42 mm²,
			TE Connectivity	175363-1	8	(20 to 16 AWG)
			TE Connectivity	175218-2	32	Sheath diameter: 1.8 to
			· · · · · ·		<u> </u>	2.8 mm
						With shields
3	SDO1	2F-SFSDOCON				Conductor area: 0.5 to
	SDO2		Manufacturer	Model	Qty.	1.42 mm²,
			TE Connectivity	178289-4	2	(20 to 16 AWG)
			TE Connectivity	175218-2	16	Sheath diameter: 1.8 to
			<u> </u>	•		2.8 mm
						With shields

#### Tab. 2-4 Connector and cable

# 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

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

Item	Specifications	Remarks
Output type	Non-voltage contact	Relay contact
000000000	output	
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

Tab. 3-2 Safety DO electrical specifications



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.

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

	Tab.	3-3:	DSI	Input	states
--	------	------	-----	-------	--------

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] $\rightarrow$ [Monitor] $\rightarrow$ [Signal] $\rightarrow$ [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: DSC	output states
---------------	---------------

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

(3) Exclusive input/output signals

DSI signal and DSO signal are assigned to exclusive input/output signals  $128 \sim 191$ . When the safety function is enabled and any exclusive input/output signals are assigned to  $128 \sim 191$ , 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	



Fig. 3-4 DCIN/DCOUT connector

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.

	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

#### Tab. 3-6 SDI1 and SDI2 pin assignment

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		



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		

Connector on the unit



SDO2 connector



Connector on the unit





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





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 Overvie	ew
--	----

Function		Functional description	See:	
Safety logic edit	Input Output	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. This allows outputting safety signals based on running states of the safety monitoring functions and AREA monitoring information. This is used for displaying safety	See: 4.4 Safety Logic Edit	
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.

0								
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.

### 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.







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.

Connecting RT ToolBox3	Connect RT ToolBox3 to the controller and put it in the online state.
Parameter configuration	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.
Parameter verification	Read each parameter and confirm that it is set correctly.
Turn ON the power supply again	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.)

	Basic Configuration 1:RC1 (Online)
	Enable / Disable the Safety Function Date of Modification Date of Modification Date of Modification 2017/03/06-18:11:06 Date of Modification Date of Mod
	Safety Parameters Protection
Operation Panel	
Program	Password must be set to use safety function.
5 Spline	Change Password
⊿ ■ Parameter	change rassificite
Parameter List	The Comment of Parameters
▷ 📋 Movement Parameter	
▷ 🝵 Program Parameter	
🗅 📋 Signal Parameter	
Communication Parameter	Set Comment
PLC Cooperation Parameter	The Output Number for Decoupy Made
△ 🖞 Safety parameter	The Output Number for Recovery Mode,
Basic Configuration	This Number Must be Set to Use Recovery Mode.
Bobot Model	-1 -1: Disable
E Safety Logic	
j = barcty cogic d sos	The Output Signal Number for #
> € as	Start: -1 End: -1 -1: Disable
v – C en p	
	Write



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.

Re	igister/Change Password	×			
	Safety	_			
	Please enter the password, and click OK.				
	Old password:				
	New Password:				
	Re-enter Password:				
	C Description of Available Characters				
	Please use 8 to 32 single-byte characters, which include numbers, A to Z, a to z for the password. Passwords are case-sensitive.				
	CNote				
	Keep passwords in a secure place, and never forget the registered password!				
	OK Cancel				

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.



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.

RT ToolBox3		×
Please enter the	e password.	
	ОК	Cancel

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  $[Online] \rightarrow [Parameter] \rightarrow [Basic Configuration] in Workspace.$ 

Workspace IX	Basic Configuration 1:RC1 (Online)	×
Workspace   ↓ ×     Image: Spline   Image: Spline     Image: Spline   <	Enable / Disable the Safety Function Enable © Disable Safety Parameters Protection Password must be set to use safety function Change Password The Comment of Parameters Set Comment The Output Number for Recovery Mode This Number Must be Set to Use Recovery Mode This Number Must be Set to Use Recovery Mode The Output Signal Number for #	Date of Modification 2017/03/06-18:11:06
Bedkup Wison I/O Simulator	Start: -1 End:	-1 -1: Disable Write

Fig. 4-5: Basic Configuration screen



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.



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.

Basic Configuration 1:RC	1 (Online)	_ = ×
Enable / Disable the Safety ( Enable Disable Safety Parameters Protection Password must be set to of Change Password The Comment of Parameter	Function Date of n use safety function.	Modification
Set Comment The Output Number for Red This Number Must be Set -1 -1: Disa	overy Mode. to Use Recovery Mode. ble	
The Output Signal Number 1 Start: -1	or #	-1: Disable Write

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.





1) Set the controller mode to MANUAL.

Set the [ENABLE] switch of the TB to ENABLE.

 Press [JOG] key and display JOG screen. While lightly holding the enable switch (three-position switch) press-and-hold the [RESET] key.

The [RESET] key is equivalent to the [CAUTION] key of R56/57TB. When using R56/57TB, use the [CAUTION] key for the operation.

The procedure above temporarily resets the error. While performing jog operation, press-and-hold the [RESET] key as well.



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:

Output 31						Output 16
(D)		(B)	•	(1)		(7)
C:	N	:OFF				
Basic Configura	tion 1:RC1	(Online)				- • ×
Enable / Disable th O Enable O Disable	ne Safety F	unction —	Date	of Modific 2017/0	ation )3/06-18:1	1:06
Safety Parameters Password must I	Protection	se safety fun	ction.			
Change Pass	word					
The Comment of	Parameters	-				
Set Comm	ent					
The Output Num	per for Reco	overy Mode.				
This Number Mu	st be Set t -1: Disab	o Use Recove le	ery Mode.			
The Output Signa	l Number fo	or #				
Start:	-1	End:		-1 .	1: Disable	
						Write

#### 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.





#### (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.







#### (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.

-				_
P	roperties		ų.	×
Ħ	Robot Informati	on		
Ħ	Robot arrangem	ent		
Ħ	Robot Model			
Ħ	Hand			
Ħ	Movement area			
Ħ	User-defined Are	ea		
Ħ	Free plane limit			
⊟	Safe monitoring			
	Display monitorin	[1]		
	1	True		-
1	2	False		
	3	False		
	4	False		
	5	False		
	6	False		
	7	False		
	8	False		
	Length	3000		
Ħ	Display monitorin	[]		
Ħ	Display AREA Inp	[1]		
	🖽 Arm model			
Ħ	Display tool mode	[1;2;3;4]		



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.







## 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] -> [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] -> [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

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

#### Tab. 4-2 Explanation of terminology

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.

i Safety Input 1:RC1 (Online)														
Input Sig	anal Set Op	eration Check						2017/03/06-18:11:06						
			SS	1 SS2	SLS1	SLS2	SLS3	SLSM	SLP1	SLP2	SLP3	SLPM		
	DSI1													
	DSI2				R									
	DSI3													
DSI	DSI4													
	DSI5													
	DSI6													
	DSI7													
	DSI8													
	AREA1													
AREA	AREA2													
	AREA3													
	· ·	AND	- 🗆											
LOGIC	-	- 🗆												
	× AND ×													
	AUTO													
MODE	MANUAL						Ø				Ø			
DSI Filter Time 10 [ms] Write														

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.

🗴 Safety	■ Safety Input 1:RC1 (Online) – □ ×													
Input Sig	gnal Set Op	eration Check						Date of Modification						
			SS1	SS2	SLS1	SLS2	SLS3	SLSM	SLP1	SLP2	SLP3	SLPM		
	DSI1													
	DSI2		-											
	DSI3								M					
DSI	DSI4				Γ				Γ					
	DSI5													
	DSI6													
	DSI7													
	DSI8													
	AREA1													
AREA	AREA2													
	AREA3													
	· ·	AND -												
LOGIC		AND -												
		AND *												
	AUTO		1											
MODE	MANUAL		-					M				R		
DSI Filter	DSI Filter Time 10 [ms]													

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.

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

#### Tab. 4-3: DSI Input states

(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.

■ Safety Input 1:RC1 (Online)															
Input Sig	gnal Set	Оре	eration C	heck						Date of	f Modific	ation —			
Toput cigo	alaat									2017/03/06-18:11:06					
Input signa	arset														
					SS1	SS2	SLS1	SLS2	SLS3	SLSM	SLP1	SLP2	SLP3	SLPM	
					_	_	_	_	_	_	_	_			
	DSI1				<u> </u>	<u> </u>	-	<u> </u>	<u></u>	<u></u>	<u> </u>	-	<u></u>	-	
	DSI2						-	<u> </u>	<u></u>	<u></u>	<u> </u>	<u></u>	<u></u>	-	
	0513				-	-			-			-		-	
DSI	DSI4				-										
	DSIS				-										
	DSIG				-	-						-			
	DSI7				-	-						-			
	ADEA1				1.4	1.4		-				-		-	
	AREAI						-								
AREA	AREA2														
					-	-	-	-	-	-	-	-		-	
	<u> </u>		AND	*	<u> </u>	<u> </u>							L4	14	
LOGIC AND				*											
		-	AND	-											
	AUTO														
MODE	MANUAL													M	
DSI Filter	Time	10	[ms]												
10/642													Write		

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.

Í	■ Safety Input 1:RC1 (Online)														
[	Input Sig	inal Set Op	eration	Check						Date of Modification					
							SLS1	SLS2	SLS3	SLSM	SLP1	SLP2	SLP3	SLPM	
L															
		DSI1			<u> </u>						<u> </u>				
		DSI2						<u> </u>			<u> </u>		<u> </u>	<u> </u>	
		DSI3			<u>–</u>						<u> </u>				
	DSI	DSI4			<u>–</u>						<u> </u>				
		DSI5			<u></u>						<u> </u>				
		DSI6									<u> </u>				
		DSI7	<u>–</u>						<u> </u>						
		DSI8			<u>L</u>						<u> </u>				
		AREA1									<u> </u>				
	AREA	AREA2									<u> </u>				
		AREA3													
		DSI1 *	AND	AREA1 *			R								
	LOGIC	-	AND	-											
IL		-	AND	-											
		AUTO													
	MODE	MANUAL													
[	DSI Filter Time 10 [ms]														

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.

🗴 Safety Input 1:RC1 (Online) — 🗆 🗸															
Input Si	gnal Set O	peration Check							Date of Modification2017/03/06-18:11:06						
							SLS2	SLS3	SLSM	SLP1	SLP2	SLP3	SLPM		
	DSI1														
	DSI2														
	DSI3														
DSI	DSI4														
	DSI5														
	DSI6	DSI6													
	DSI7	SI7													
	DSI8														
	AREA1														
AREA	AREA2														
	AREA3														
	-	AND	*												
LOGIC	-	AND	-												
	AUTO						Z			Z					
MODE	MANUAL								Ø						
DSI Filter	Time	10 [ms]											Write		

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.

Safety Output 1:RC1 (Online)															_	٢		
	Output Sig	gnal Set	Operation C	heck				ĺ	Date of	Modifica	ation	24.25						
0	)utput sign	nal set 😐						— (		2017,00	, 10 101							
					STO	SOS	SLS1	SLS2	SLS3	SLSM	SLP1	SLP2	SLP3	SLPM	AREA1	AREA2	AREA3	
			LOGIC															
		DSO1	OR -	Active														
		0501		Inactive														
		0000	OR 👻	Active														
	DC0	0502		Inactive														
	050			Active														
		DSO3		Inactive														
				Active														
		DSO4		Inactive														
l '	·																	
																	Write	

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).

Safety Output 1:RC1 (Online)																- • ×	
Output Signal Set Operation Check								ĺ	-Date of	Modifica	ation —						
Output signal set –								(		2017/03	3/10-15:2	24:25					
					STO	SOS	SLS1	SLS2	SLS3	SLSM	SLP1	SLP2	SLP3	SLPM	AREA1	AREA2	AREA3
			LOGIC														
		DSO1	OR -	Active													
		0301		Inactive													
		0502		Active		M											
		0302		Inactive													
	050	0000		Active													
		0503		Inactive													
				Active													
		DSO4		Inactive													
																	Write

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.

i Sa	afety	Output 1	RC1 (Online	e)													= ¤ ×
Output Signal Set Operation Check								ĺ	-Date of	Modifica	ation —						
Output signal set							(		2017/03	3/10-15:3	35:43						
					STO	SOS	SLS1	SLS2	SLS3	SLSM	SLP1	SLP2	SLP3	SLPM	AREA1	AREA2	AREA3
			LOGIC														
		DSO1		Active													
		0301		Inactive											Z		
		0502		Active													
	<u> </u>	0302		Inactive													
	30	0503		Active													
		0505		Inactive													
			00	Active													
		DSO4		Inactive													
																	Write

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.

Input S	ignal Set	Ор	eration Check						Date o	of Modifi 2017/	cation - 03/10-1	5:35:43	
				SS1	SS2	SLS1	SLS2	SLS3	SLSM	SLP1	SLP2	SLP3	SLPM
	DSI1	_											
	DSI2												
	DSI3					M							
DSI	DSI4					M	17						
	DSI5						17	1.3	17			1	
	DSI6												
	DSI7												
	DSI8												
	AREA1												
AREA	AREA2						<b>1</b>						
	AREA3												
			AND	-									
LOGIC	1	٣	AND	•									
			AND	•									
	AUTO									R			
MODE	MANUAL								M				

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.

∎ Sa	afety	Output 1	.:RC1 (Online	e)													_ 0 2
Output Signal Set		gnal Set	Operation (	Check				[	-Date of	Modifica	ation — 3/10-15::	35:43					
			LOGIC		STO	SOS	SLS 1	SLS2	SLS3	SLSM	SLP1	SLP2	SLP3	SLPM	AREA1	AREA2	AREA3
		DSO1	OR 🔻	Active Inactive													
		DSO2	OR 🔻	Active Inactive													
	50	DSO3	OR 🔻	Active Inactive													
		DSO4	OR 🔻	Active Inactive													
				·													Write

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.

· · · · · · · · · · · · · · · · · · ·
20-on operation TO monitoring 270 (Servo-on 1/STO).
gram does not gram is not
only.

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

#### (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.

SOS automatic resumption (Disabled by	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.
factory default.)	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.

Tab. 4-5: SOS automatio	c resumption mode
-------------------------	-------------------

#### (c) Operation restrictions

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

	SOS autorr resumption	natic disabled	SOS autor resumption	natic enabled
Operation	Available	Unavailable	Available	Unavailable
Servo-on	-		-	
Servo-off	~		~	
Program operation start		~	~	
JOG operation		~		~
Opening or closing hand	~		~	

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

- 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
- (ií) 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].

Setting item	Description	Default
Safe stop speed	This configures speed monitoring thresholds for	1.00 [deg./s] [mm/s]
	the SOS monitoring.	
Safe stopping	This configures allowable travel distances for the	1.00 [deg.] [mm]
distance	SOS monitoring.	
SOS automatic	This sets the SOS automatic resumption mode to	Disabled
resumption mode	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.	

Tab. 4-7. 303 Telateu parameters	Tab. 4-7	: SOS relate	ed parameters
----------------------------------	----------	--------------	---------------



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.





<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:





(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.

É SOS 1:RC	C1 (Online)					= ¤ ×
Safety Stop Fi	unction —		_ [	Date	e of Modificatio	D-15:35:43
Stop Speed			SOS Alle	wabl	e Amount of M	lovement
When each parameter This value	h axis speed b s, determined is used in SS1,	ecome less than these each axis has stopped. SS2, SOS.	Set the	tore	lance of SOS n	nonitoring.
J1:	1.01	[deg/s]	31	:	1.00	[deg]
J2 :	1.00	[deg/s]	32	:	1.00	[deg]
J3:	1.00	[deg/s, mm/s]	33	:	1.00	[deg, mm]
J4:	1.00	[deg/s]	34	:	1.00	[deg]
J5 :	1.00	[deg/s]	35	:	1.00	[deg]
J6 :	1.00	[deg/s]	Je	:	1.00	[deg]
J7:	0.00	[deg/s, mm/s]	76	:	1.00	[deg, mm]
J8 :	0.00	[deg/s, mm/s]	BC	:	1.00	[deg, mm]
Stop Restart When this restarts at O Enal O Disa	option is "Enat fter SOS becon ble ible	oled", the operation automatica ne inactive.	ally			Write

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.

			Dat	e of Modificatio	n
Safety Stop Fu	inction —			2017/03/1	0-15:35:43
Stop Speed			SOS Allowabl	e Amount of №	lovement
When each parameters This value i	n axis speed b s, determined is used in SS1,	ecome less than these each axis has stopped. , SS2, SOS.	Set the tore	lance of SOS r	nonitoring.
J1:	1.01	[deg/s]	J1:	1.00	[deg]
J2:	1.00	[deg/s]	J2 :	1.00	[deg]
J3:	1.00	[deg/s, mm/s]	J3 :	1.00	[deg, mm]
J4:	1.00	[deg/s]	J4:	1.00	[deg]
35:	1.00	[deg/s]	35 :	1.00	[deg]
J6 :	1.00	[deg/s]	J6 :	1.00	[deg]
J7:	0.00	[deg/s, mm/s]	37 :	1.00	[deg, mm]
J8 :	0.00	[deg/s, mm/s]	.: 8L	1.00	[deg, mm]
Stop Restart					
When this restarts af	option is "Enal ter SOS becor	bled", the operation automatica ne inactive.	lly		
🔿 Enab	ble				

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.

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

#### Tab. 4-8: SLS function start conditions



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.





#### (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.

	Monitoring items		Config mc	uration de	Setting range		
			Simple	Detail			
Orthogonal speed limit	Arm model	composite speed	1	1	0 mm/s to 100000 mm/s (0 to 250 mm/s for		
		+X speed		1	SLSM)		
	Mechanical I/F	-X speed		1			
		+Y speed		1			
		-Y speed		1			
		+Z speed		1			
		-Z speed		~			
Joint speed limit	Joint axes J1 to J6	J1 speed		✓	0% to 100%		
		J2 speed		1	(Configure a ratio to the		
		J3 speed		1	maximum speed.)		
		J4 speed		~			
		J5 speed		~			
		J6 speed		~			
	Additional axis	J7 speed		1			
	J7 to J8	J8 speed		1			

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

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

■ Speed 1:F	RC1 (Onlin	e)									• ×		
SLS Monitoring	speed			Date of Modification									
Setting Mode O Simple Mode							2017/03/10-15:35:43						
	0	Detail Mode											
XYZ Monitoring	g Speed –												
Comp	SLS 1	SLS2	SLS3	SLSM									
Speed :	100000.00	100000.00	100000.00	250.00	[mm/s]								
Deceleration R	Deceleration Response Time												
770 5-1					SLS 1	SLS2	SLS3	SLSM					
	liuzì						100.0000	100.0000	100.0000	100.0000	[%]		
										Write			
										Write			

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

Speed 1:RC1 (Online)															
SLS Monitorin	SLS Monitoring Speed							Date of Modification							
Setting Mode O Simple Mode						2017/03/10-15:35:43									
O Detail Mode															
XYZ Monitorin	ng Speed 🛛 🗕					Joint Monitoring Speed									
Came	SLS1	SLS2	SLS3	SLSM			SLS 1	SLS2	SLS3	SLSM					
Speed :	100000.00	100000.00	100000.00	250.00	[mm/s]	J1:	100.00	100.00	100.00	100.00	[%]				
Monitoring	g Speed for Ea	ach Direction				J2 :	100.00	100.00	100.00	100.00					
X+:	100000.00	100000.00	100000.00	250.00	[mm/s]	J3:	100.00	100.00	100.00	100.00					
X-:	100000.00	100000.00	100000.00	250.00		J4:	100.00	100.00	100.00	100.00					
Y+:	100000.00	100000.00	100000.00	250.00		35 :	100.00	100.00	100.00	100.00					
Y-:	100000.00	100000.00	100000.00	250.00		J6 :	100.00	100.00	100.00	100.00					
Z+:	100000.00	100000.00	100000.00	250.00		J7:	100.00	100.00	100.00	100.00					
Z-:	100000.00	100000.00	100000.00	250.00		J8 :	100.00	100.00	100.00	100.00					
Deceleration	Response Tim	ie	/			Speed Lir	nit OVRD								
							SLS1	SLS2	SLS3	SLSM					
	[ms]						100.0000	100.0000	100.0000	100.0000	[%]				
										Write					

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

a 🔽 Online	■ Speed 1:F	RC1 (Online										□ x
RV-7FR-D	SLS Monitoring Speed							Cate of Modification				
Program	Setting Mode O Simple Mode							2017/03/10-15:35:43				
5 Spline	<ul> <li>Detail Mode</li> </ul>											
Parameter	XYZ Monitoring Speed						Joint Monitoring Speed					
Parameter List		SLS1	SLS2	SLS3	SLSM			SLS1	SLS2	SLS3	SLSM	
b      b      Construction     Construction     Construction	Comp. Speed :	100000.00	100000.00	100000.00	250.00	5 mm (+1		100.00	100.00	100.00	100.00	Fax 2
▷	Speed I					[mm/s]	J1:	100.00	100.00	100.00	100.00	[%]
Communication Parameter	Monitoring	speed for Ea	Ch Direction				J2:	100.00	100.00	100.00	100.00	
PLC Cooperation Parameter	X+:	100000.00	100000.00	100000.00	250.00	[mm/s]	J3 :	100.00	100.00	100.00	100.00	
∠	X-:	100000.00	100000.00	100000.00	250.00		J4:	100.00	100.00	100.00	100.00	
Basic Configuration	Y+:	100000.00	100000.00	100000.00	250.00		J5 :	100.00	100.00	100.00	100.00	
	Y-:	100000.00	100000.00	100000.00	250.00		J6 :	100.00	100.00	100.00	100.00	
i SOS	Z+:	100000.00	100000.00	100000.00	250.00		J7:	100.00	100.00	100.00	100.00	
	Z-:	100000.00	100000.00	100000.00	250.00		J8 :	100.00	100.00	100.00	100.00	
📋 Speed	Deceleration Response Time						Speed Limit OVRD					
Operation Check	7	0 []						SLS1	SLS2	SLS3	SLSM	
⊿ ⊟ SLP & Plane		- [ms]						100.0000	100.0000	100.0000	100.0000	[%]
i Area											141.11	
Operation Check											Write	





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.



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.

⊿ 🔼	Online	Operation Check 1:RC1 (Onli	ne)					_	
	RV-7FR-D  Coperation Panel  Program  Solution	Please switch ON / OFF of each function to operate the robot and check whether it is monitored correctly.					Date of Modification2017/03/10-15:35:43		
2	Parameter     Parameter List     A Mexample Parameter	Detail mode ← Monitoring State of the SLS ←	_XYZ Monit	oring Speed [m	m/s]	Joint Mo	nitoring Speed ['	Reset	
	<ul> <li>Program Parameter</li> <li>Program Parameter</li> </ul>	SLS1 Inactive	Mor Comp.	nitoring Speed	Measure	Mo	nitoring Speed	Measure	
	▷	SLS2 Inactive	Speed :	1.000	17.000	12.	8.000	24.000	
	E Communication Parameter     E E PLC Cooperation Parameter	SLS3 Inactive SLSM Inactive	X+:	2.000	18.000	J3 :	10.000	26.000	
	Basic Configuration		X-:	3.000	19.000	J4:	11.000	27.000	
	☐ Robot Model	100 гест	Y+:	4.000	20.000	J5 :	12.000	28.000	
	SOS		Y-:	5.000	21.000	J6 :	13.000	29.000	
	⊿ É SLS		2+:	6.000	22.000	J7:	14.000	30.000	
	Speed		Z-:	7.000	23.000	J8:	15.000	31.000	

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.



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

A 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) SLP STO/SS1 SLP monitoring Robot position area Enabled SLP\_ command Disabled Enabled SLP\_monitoring Disabled SLP\_ error Error occurred No error SS1\_ command Enabled Disabled

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.

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).



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.

■ Plane 1:RC1 (Simulation)					_ 0	x	
Plane Setting Plane 1	•	Date of Modification					
Plane Monitoring	Monitoring Function To Apply the Plane		9:46				
O Disable	SLP1	Plane D	efinition — Set in the Bas	se coordinate s	system.	-	
	SLP2		Origin	+X axis	+Y axis		
Outside	SLP3	x:	0.00	0.00	0.00		
🔿 Inside (Robot Origin Side)	SLPM	Z :	0.00	0.00	0.00		
Monitoring Position		ļ	Teach	Teach	Teach		
Whole Arm and Tool							
O Tool Only					Write		

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.)







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.

■ Area 1:RC1 (Simulation)			_
Area Setting Area 1		Date of Modification	
Area Monitoring	Monitoring Function	2017/04/18-11:29:46	
O Enable	SLP1	Area Definition	
	SLP2	Set in the Base coordinate system.	
Safeguarded Space	SLP3	Diagonal 1 Diagonal 2	
○ Inside	SLPM	Y: 0.00 0.00	
Maritarian Daritian		Z: 0.00 0.00	
Monitoring Position		Teach Teach	
Whole Arm and Tool			
O Tool Only			Write

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 right, 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	0: Outputs no test pulses
means	1: Outputs test pulses
Default	0

# Emergency stop switches (2 contacts)



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
rub.	01.	LIOU	01	oluic	vanabico

State variable	Overview
M_DSI	Refers to the DSI Input state.
M_SfILogic	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_SIpPreStp	Refers to the SLP pre-stop status

# 5.2 State Variables

# <u>M DSI</u>

# [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.

# <u>M SfILogic</u>

[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 SfIArea

[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.

# <u>M SfSts</u>

[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)

Function	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) Msls = M\_SfSts(5) if Msls = 1 then M\_YDev(0) = 1 Endif 'The running state of STO is stored in Msto. (0: Disabled, 1: Enabled) 'The running state of SLS1 is stored in Msls. (0: Disabled, 1: Enabled)

'If SLS1 is enabled, sequencer output signal No.1 is turned on.

[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 SIpPreStp [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]

- The variable returns the present SLP pre-stop status.
   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.)

Error number	Error causes and solutions						
	Error message	Safety parameter error (xxxxx)					
	Cause	Detect errors in safety parameter value.					
H0230 *	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.					
	Error message	Parameter CRC error (xxxxx)					
H0231 *	Cause	Detect CRC errors in safety parameter.					
	Solution	Please check the safety parameters settings and write parameters.					
	Error message	Setting mismatch of safety func					
C0240	Cause	The safety function is disabled.					
00210	Solution	Although the safety logic is configured, the relevant safety functions are disabled. Delete the safety logic or enable the safety functions.					
	Error message	Fault in Safety Communication					
H0241 *	Cause	Detect a fault in safety communication.					
110241	Solution	Turn the power OFF and ON once. If the error recurs after that, contact the manufacturer.					
	Error message	Fault in Safety Data					
LI0242 *	Cause	Detect a fault in safety data.					
H0242	Solution	Turn the power OFF and ON once.					
	Solution	If the error recurs after that, contact the manufacturer.					
	Error message	Safety function unavailable (XXX)					
H0243	Cause	The Safety Function is not supported by this robot.					
	Solution	Disable the safety function.					
	Error message	Remotel/O unit config error					
H0311 *	Cause	The multiple Remotel/O units which do not support are connected.					
10011	Solution	If a safety extension unit is connected, turn off the robot and, after restarting the safety extension unit, turn on the robot again.					
	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.					
H220m	Error message	SLP (ROBOT position error:FB Plane)					
(The letter "m" is	Cause	SLP detected the robot position FB over the monitoring plane.					
a number for a	Solution	Please confirm the robot movement or related parameter setting.					
monitoring plane	Error message	SLP (ROBOT position error:CMD Area)					
or monitoring	Cause	SLP detected the robot position CMD over the monitoring area.					
area [1 to 8])	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.					
	Error message	Mismatch of Dual Safety Input					
	Cause	State of the redundant wiring do not match (Dual Safty Input)					
H222m * (The letter "m" is a DSI number. [1 to 8])	Solution	<ul> <li>DSI.</li> <li>DSI wiring</li> <li>Duplex signal ON/OFF states</li> <li>Timing of switching of ON/OFF states</li> <li>(The error occurs when the ON/OFF states of the duplex signals remain inconsistent for about 0.1 seconds.)</li> </ul>					
	Error message	Mismatch of Dual Safety Output					
110000 *	Cause	The duplex DSO states are not consistent.					
HZ23U ^	Solution	Turn the power OFF and ON once.					
	Error message	Mismatch of Dual Safety Output Feedback					
	Cause	State of Dual Safty Output and the feedback do not match.					
H2231 *		Turn the power OFF and ON once.					
	Solution	If the error recurs after that, contact the manufacturer.					

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

### 6 TROUBLESHOOTING

	i _						
	Error message	Extended safety unit's No. error					
H2261 *	Cause	The extended safety unit's station No. is illegal.					
	Solution	Set the extended safety unit's station No. to 2.					
	Error message	Cannot servo ON (SS1/STO active)					
H2270	Cause	The servo cannot be turned ON while SS1/STO is active.					
	Solution	Disable SS1 before turning the servo ON.					
	Error message	SS1 deceleration time exceeded					
L10000 *	Cause	The robot didn't stop within deceleration time from SS1 enabled.					
112200	Solution	Check operation instructions, terminal load, and stop speed (SFSPZERO) parameter of the robot.					
	Error message	SS2 deceleration time exceeded					
110004 *	Cause	The robot didn't stop within deceleration time from SS2 enabled.					
H2281 ^	0.1.1	Check operation instructions, terminal load, and stop speed (SFSPZERO)					
	Solution	parameter of the robot.					
	Error message	SOS (Position error)					
	Cause	Detect the change of position FB on SOS.					
		During the SOS monitoring, change in the position FB due to external force was					
	Solution	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					
H2282	Solution	Please check external force or related parameter settings					
	Error message	SOS (Position command error)					
		Detect the change of position CMD on SOS					
	Solution	Please confirm the robot movement or related parameter setting					
	Error mossago	SOS (Speed command error)					
		Detect CMD speed over an SOS					
	Solution	Detect GWD speed over on 505.					
	Error mossago	SI S ( Joint Speed Error)					
H220n		Shood manifer detected the speed over					
(The letter "n" is	Cause	The aread monitoring function detected a sneed eveneding the productormined					
an axis number		speed monitoring function detected a speed exceeding the predetermined					
	Solution	Speeu. Check the rebet movement or the menitering aread acting					
[1 (0 0])		Also, shock that the deceleration delay (parameter SLSDLY) is not too short					
<b>∐</b> 221n	Error mossago	Also, check that the deceleration delay (parameter SESDET) is not too short.					
(n shows the		Shood manifer detected the speed over					
direction where a	Cause						
nrohlem is		The speed monitoring function detected a speed exceeding the predetermined					
detected )		speed.					
1. Synthesized		Check the robot movement or the monitoring speed setting.					
speed	Solution	Also, check that the deceleration delay (parameter SLSDLY) is not too short.					
2 X+ 3 X-							
4: Y+ 5: Y-							
6' 7+ 7' 7-							
	Error message	SE (Process error)					
	Cause	The Safety Function is not normally executed					
		Reset the error by power-cycling the robot. If the same error recurs, contact the					
	Solution	manufacturer.					
H2370 *	Frror message	SE (Process Counter error)					
	Cause	The Safety Function of servo CPU is not normally executed					
		Reset the error by power-cycling the robot. If the same error recurs, contact the					
	Solution	manufacturer					
		manarataror.					

# 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 STO 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<sub>max</sub> : Maximum stopping distance
- V<sub>max</sub>: Maximum speed (Equivalent to the SLS monitoring speed when the SLS function is enabled)
- Tres : Reaction time (time from error detection to stop) (Approximately 7.1 msec)
- $T_{\text{max}}$  : Maximum stopping time (Differs from robot to robot, see chapter 7.2 )
- $\alpha$  : Safety factor (1 or more)



### <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.

<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.

Avio	Arm oxtonsion	Lood rate	Stopping time [s]	Stopping distance [deg]
AXIS	Annextension	LUau Tale	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 time means a duration that elapses from when the SS1 function starts to when the motor power supply is shut off. The angle means an operating angle during the time. 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	This is the degree of extension of the arm in relation to each
		extension	rotation axis. For details, see page 7-82.
М	%	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	Stopping time	This is the maximum duration that elapses from when the SS1
	(second)		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	This is the maximum distance that the robot moves from when the
		distance	SS1 function starts to when the robot stops.
			This is applicable to J3 axis of RH-FRH series.

- (2) The degree of extension of the robot arm
  - (a) RV-FR/RV-CR series



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

(b) RH-FRH series



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		Distanc	e mm
		М	W	D	Н	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

# RV-2FRB

Stopping time and stopping distance (emergency stop)

A	A	L a a d mata		Stopping time	[s]	Stop	ping distance	[deg]
Axis	Arm extension	Load rate	Ovrd 33%	Ovrd 66%	Ovrd 100%	Ovrd 33%	Ovrd 66%	Ovrd 100%
		M=100%	0.48	0.60	0.72	25.00	61.75	111.93
	1-1000/	M=66%	0.46	0.58	0.70	24.14	60.05	109.35
	L=100%	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
		M=100%	0.38	0.50	0.63	20.23	52.22	97.49
14	1-660/	M=66%	0.38	0.49	0.62	19.77	51.31	96.10
J1	L=00%	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
		M=100%	0.38	0.49	0.62	19.78	51.33	96.13
	1-220/	M=66%	0.36	0.47	0.60	18.78	49.32	93.09
	L-33%	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
		M=100%	0.53	0.65	0.78	13.82	33.52	59.96
	1-1000/	M=66%	0.51	0.63	0.75	13.14	32.16	57.91
	L=100%	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
10		M=66%	0.42	0.54	0.66	10.95	27.79	51.29
JZ		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
	1 00%	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
	L-33%	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
		M=100%	0.42	0.54	0.66	22.16	56.09	103.35
13		M=66%	0.40	0.52	0.64	20.86	53.49	99.40
55	-	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
		M=100%	0.39	0.51	0.63	30.81	79.27	147.64
14		M=66%	0.37	0.49	0.61	29.53	76.71	143.77
54	-	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
		M=100%	0.39	0.51	0.63	30.81	79.27	147.64
15		M=66%	0.37	0.49	0.61	29.53	76.71	143.77
55	-	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

Avio	Arm ovtension   Load rate		Stopping time [s]	Stopping distance [deg]
Axis Arm extension		Load rate	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	e and stoppind	distance	(emergency	v stop)
			\ = · · · = ·	,,

Avia			Stopping time [s]		Stopping distance [deg]			
AXIS	Arm extension	Load rate	Ovrd 33%	Ovrd 66%	Ovrd 100%	Ovrd 33%	Ovrd 66%	Ovrd 100%
		M=100%	0.77	0.85	0.93	27.50	60.48	100.20
	1-1000/	M=66%	0.72	0.80	0.88	25.84	57.17	95.20
	L=100%	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
		M=100%	0.60	0.68	0.77	21.78	49.04	82.87
14	1-000/	M=66%	0.57	0.65	0.73	20.62	46.73	79.37
J1	L=00%	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
		M=100%	0.51	0.59	0.67	18.47	42.42	72.84
	1-220/	M=66%	0.47	0.55	0.63	17.24	39.97	69.13
	L-33%	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
		M=100%	0.80	0.88	0.97	14.35	31.45	51.94
	1-100%	M=66%	0.76	0.84	0.93	13.66	30.06	49.82
	L-100%	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
12		M=66%	0.61	0.69	0.77	11.04	24.83	41.91
JZ		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
	1-220/	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
	L-33 /6	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
		M=100%	0.76	0.84	0.92	21.22	46.96	78.20
13		M=66%	0.72	0.80	0.89	20.16	44.85	75.00
55	-	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
		M=100%	0.53	0.61	0.69	37.83	86.44	147.79
и		M=66%	0.50	0.58	0.66	35.79	82.37	141.63
54	-	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
		M=100%	0.56	0.64	0.72	43.05	97.87	166.65
15		M=66%	0.50	0.58	0.66	39.05	89.86	154.51
55	-	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

Avia	Arm ovtonoion	Lood rate	Stopping time [s]	Stopping distance [deg]	
AXIS	Annextension	Load rate	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)

Avia	Arm ovtonoion	Lood rate	S	Stopping time	[s]	Stop	ping distance	e [deg]
AXIS	Annextension	Load rate	Ovrd 33%	Ovrd 66%	Ovrd 100%	Ovrd 33%	Ovrd 66%	Ovrd 100%
		M=100%	0.48	0.56	0.64	37.27	86.30	149.12
	1-1000/	M=66%	0.45	0.53	0.61	35.26	82.29	143.04
	L=100%	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
		M=100%	0.39	0.47	0.55	30.45	72.66	128.46
14	1-000/	M=66%	0.37	0.45	0.53	29.12	69.99	124.41
J1	L=00%	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
		M=100%	0.36	0.44	0.52	28.64	69.04	122.97
	1-220/	M=66%	0.33	0.41	0.49	26.57	64.90	116.70
	L=33%	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
		M=100%	0.46	0.54	0.62	35.57	82.72	143.41
	1-1000/	M=66%	0.43	0.51	0.59	33.88	79.50	138.76
	L=100%	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
10		M=66%	0.35	0.43	0.51	27.74	67.22	120.16
JZ		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
	1 000/	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
	L=33%	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
		M=100%	0.43	0.51	0.59	22.34	52.51	91.77
12		M=66%	0.40	0.48	0.56	21.07	49.97	87.93
33	-	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
		M=100%	0.38	0.46	0.54	36.26	86.64	153.30
14		M=66%	0.36	0.44	0.52	34.31	82.74	147.39
J4	-	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
		M=100%	0.38	0.46	0.55	41.98	100.25	177.31
15		M=66%	0.36	0.44	0.52	39.69	95.65	170.35
10	-	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

Axis Arm extension		Lood rate	Stopping time [s]	Stopping distance [deg]	
		Load rate	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 sto	time and stopping distance (emergency stop	Stopping time and	St
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	11 0	,	5	Stopping time	[s]	Stop	ning distance	[dea]
Axis	Arm extension	Load rate	Ovrd 33%	Ovrd 66%	Ovrd 100%	Ovrd 33%	Ovrd 66%	Ovrd 100%
		M=100%	0.49	0.57	0.65	35.50	81.98	141.34
	1 4000/	M=66%	0.46	0.54	0.62	33.74	78.45	135.99
	L=100%	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
		M=100%	0.39	0.47	0.55	28.87	68.72	121.25
14	1 000/	M=66%	0.38	0.45	0.54	27.67	66.32	117.61
JI	L=00%	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
		M=100%	0.36	0.44	0.52	26.79	64.55	114.93
	1-220/	M=66%	0.34	0.42	0.50	24.97	60.90	109.41
	L=33%	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
		M=100%	0.47	0.55	0.63	27.28	63.30	109.56
	1-1000/	M=66%	0.44	0.52	0.60	25.91	60.57	105.42
	L=100%	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
10		M=66%	0.36	0.44	0.52	21.07	50.88	90.74
JZ		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
	1 00%	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
	L-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
		M=100%	0.44	0.51	0.60	18.95	44.44	77.53
13		M=66%	0.41	0.49	0.57	17.95	42.44	74.51
55	-	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
		M=100%	0.40	0.48	0.56	37.77	89.65	157.87
14		M=66%	0.38	0.46	0.54	35.93	85.97	152.29
54	-	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
		M=100%	0.40	0.48	0.56	43.67	103.63	182.43
15		M=66%	0.38	0.46	0.54	41.49	99.27	175.83
55	-	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

Avia	Arm extension	Load rate	Stopping time [s]	Stopping distance [deg]	
7713		Load rate	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-7FR

Stopping time and stopping distance (emergency stop)

Avia	Avis Arm extension		5	Stopping time	[s]	Stopping distance [deg]		
AXIS	Annextension	Load rate	Ovrd 33%	Ovrd 66%	Ovrd 100%	Ovrd 33%	Ovrd 66%	Ovrd 100%
		M=100%	0.48	0.56	0.64	29.84	69.09	119.36
	1-100%	M=66%	0.45	0.53	0.61	28.31	66.03	114.74
	L=100%	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
		M=100%	0.40	0.48	0.56	25.21	59.82	105.33
14	1-660/	M=66%	0.38	0.46	0.54	23.86	57.13	101.25
J1	L=00%	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
		M=100%	0.40	0.48	0.56	25.21	59.82	105.33
	1-220/	M=66%	0.36	0.44	0.53	23.09	55.59	98.92
	L-33 /0	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
		M=100%	0.39	0.45	0.52	22.25	51.45	88.81
	1-100%	M=66%	0.37	0.45	0.52	24.21	57.35	100.82
	L=100%	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
		M=100%	0.32	0.40	0.47	21.52	52.35	93.87
12	1-66%	M=66%	0.30	0.38	0.46	21.65	53.76	97.78
JZ	L-00 %	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
	1-220/	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
	L-33 /0	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
		M=100%	0.48	0.55	0.62	30.96	69.82	118.12
13	_	M=66%	0.47	0.55	0.63	36.09	83.44	144.00
55	-	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
		M=100%	0.35	0.43	0.51	20.86	50.52	90.29
и		M=66%	0.33	0.41	0.49	19.66	48.14	86.68
J4	-	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
		M=100%	0.35	0.43	0.51	28.08	67.91	121.26
15		M=66%	0.33	0.41	0.49	26.42	64.60	116.24
30	-	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

Avia	Arm ovtonoion	Lood rate	Stopping time [s]	Stopping distance [deg]	
AXIS AI	Annextension	Load rate	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	

### RV-7FRL

Stopping time and stopping distance (emergency stop)

Avia			5	Stopping time	[s]	Stopping distance [deg]		
AXIS	Arm extension	Load rate	Ovrd 33%	Ovrd 66%	Ovrd 100%	Ovrd 33%	Ovrd 66%	Ovrd 100%
		M=100%	0.45	0.53	0.61	22.34	52.20	90.84
	1-1000/	M=66%	0.42	0.50	0.58	21.21	49.95	87.43
	L=100%	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
		M=100%	0.36	0.44	0.52	18.06	43.65	77.89
14	1-000/	M=66%	0.34	0.42	0.50	17.36	42.24	75.75
JI	L=00%	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
		M=100%	0.35	0.43	0.51	17.83	43.18	77.17
	1-220/	M=66%	0.33	0.41	0.49	16.63	40.78	73.54
	L=33%	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
		M=100%	0.43	0.51	0.59	24.00	56.32	98.32
	1-1000/	M=66%	0.41	0.49	0.57	22.81	53.93	94.69
	L=100%	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
10		M=66%	0.33	0.41	0.49	18.53	45.38	81.74
JZ		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
	1-220/	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
	L=33%	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
		M=100%	0.40	0.48	0.57	25.44	60.28	106.01
12		M=66%	0.38	0.46	0.54	24.10	57.61	101.97
33	-	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
		M=100%	0.37	0.45	0.53	22.01	52.82	93.78
14		M=66%	0.35	0.43	0.51	20.90	50.61	90.44
J4	-	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
		M=100%	0.37	0.45	0.54	29.58	70.92	125.82
15		M=66%	0.35	0.43	0.51	28.03	67.83	121.13
10	-	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

Avia	Arm ovtonoion	Lood rate	Stopping time [s]	Stopping distance [deg]	
AXIS AI	Annextension	Load rate	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	

# RV-7FRLL

Stopping time and stopping distance (emergency stop)

Avia	Arm ovtonoion	Lood rate	5	Stopping time	[s]	Stopping distance [deg]		
AXIS	Axis Arm extension	Load rate	Ovrd 33%	Ovrd 66%	Ovrd 100%	Ovrd 33%	Ovrd 66%	Ovrd 100%
		M=100%	0.63	0.75	0.87	34.66	81.90	143.73
	1-1000/	M=66%	0.60	0.72	0.84	33.21	79.01	139.35
	L=100%	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
		M=100%	0.57	0.69	0.81	31.61	75.80	134.50
14	1-000/	M=66%	0.54	0.66	0.78	29.85	72.29	129.18
J1	L=00%	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
		M=100%	0.57	0.69	0.81	31.56	75.71	134.35
	1-220/	M=66%	0.54	0.66	0.78	29.82	72.22	129.07
	L=33%	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
		M=100%	0.57	0.69	0.82	16.18	38.80	68.82
	1-1000/	M=66%	0.55	0.67	0.79	15.53	37.48	66.82
	L=100%	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
		M=100%	0.52	0.64	0.76	14.63	35.68	64.10
	1-660/	M=66%	0.49	0.61	0.73	13.81	34.05	61.63
JZ	L-00%	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
	1-220/	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
	L-33%	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
		M=100%	0.57	0.69	0.81	21.33	51.24	91.04
12		M=66%	0.53	0.65	0.78	20.20	48.98	87.61
33	-	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
		M=100%	0.48	0.60	0.73	31.49	77.69	140.66
14		M=66%	0.47	0.59	0.71	30.65	76.00	138.10
J4	-	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
		M=100%	0.48	0.60	0.73	37.79	93.22	168.79
15		M=66%	0.47	0.59	0.71	36.78	91.20	165.72
10	-	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

Avia	Arm ovtonoion	Lood rate	Stopping time [s]	Stopping distance [deg]	
Axis Annex	Annextension	Load rate	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	

### RV-13FR

Stopping time and stopping distance (emergency stop)

Avia			5	Stopping time	[s]	Stopping distance [deg]		
AXIS	Arm extension	Load rate	Ovrd 33%	Ovrd 66%	Ovrd 100%	Ovrd 33%	Ovrd 66%	Ovrd 100%
		M=100%	0.59	0.69	0.80	29.57	68.62	118.76
	1-1000/	M=66%	0.56	0.66	0.76	28.07	65.61	114.19
	L=100%	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
		M=100%	0.48	0.58	0.68	24.02	57.52	101.94
14	1-660/	M=66%	0.46	0.55	0.66	22.92	55.32	98.61
J1	L=00%	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
		M=100%	0.42	0.52	0.62	21.16	51.79	93.26
	1-220/	M=66%	0.39	0.49	0.59	19.93	49.33	89.53
	L-33%	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
		M=100%	0.54	0.64	0.74	21.81	51.27	89.62
	L -100%	M=66%	0.51	0.61	0.71	20.70	49.04	86.24
	L-100%	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
10		M=66%	0.40	0.50	0.61	16.55	40.74	73.67
JZ		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
	1 - 220/	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
	L-33%	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
		M=100%	0.48	0.58	0.68	26.05	62.28	110.28
13		M=66%	0.46	0.55	0.66	24.71	59.61	106.23
55	-	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
		M=100%	0.45	0.55	0.65	29.47	71.20	127.00
И		M=66%	0.43	0.53	0.63	28.34	68.92	123.55
54	-	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
		M=100%	0.45	0.55	0.65	29.47	71.20	127.00
15		M=66%	0.43	0.53	0.63	28.34	68.92	123.55
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

Avia		Lood rate	Stopping time [s]	Stopping distance [deg]	
AXIS AIIII	Annextension	Load rate	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-13FRL

Stopping time and stopping distance (emergency stop)

Assia	Avia Arm oxtonsion		5	Stopping time	[s]	Stopping distance [deg]		
Axis	Arm extension	Load rate	Ovrd 33%	Ovrd 66%	Ovrd 100%	Ovrd 33%	Ovrd 66%	Ovrd 100%
		M=100%	0.56	0.66	0.76	22.49	52.63	91.67
	1-1000/	M=66%	0.53	0.63	0.73	21.45	50.55	88.53
	L=100%	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
		M=100%	0.47	0.57	0.67	19.05	45.74	81.23
14	1-000/	M=66%	0.45	0.55	0.65	18.44	44.52	79.39
J1	L=00%	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
		M=100%	0.42	0.52	0.62	17.11	41.87	75.37
	1-220/	M=66%	0.41	0.51	0.61	16.73	41.11	74.22
	L=33%	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
		M=100%	0.57	0.67	0.77	16.16	37.68	65.45
	1-1000/	M=66%	0.54	0.64	0.75	15.39	36.13	63.11
	L=100%	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
10		M=66%	0.47	0.57	0.67	13.27	31.90	56.70
JZ		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
	1 00%	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
	L=33%	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
		M=100%	0.49	0.59	0.69	18.48	44.12	78.01
12		M=66%	0.47	0.57	0.67	17.89	42.94	76.23
33	-	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
		M=100%	0.45	0.55	0.65	29.42	71.09	126.83
14		M=66%	0.44	0.53	0.64	28.41	69.08	123.78
J4	-	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
		M=100%	0.45	0.55	0.65	29.42	71.09	126.83
15		M=66%	0.44	0.53	0.64	28.41	69.08	123.78
10	-	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

Avia		Lood rate	Stopping time [s]	Stopping distance [deg]	
AXIS AIIII	Annextension	Load rate	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-20FR

Stopping time and stopping distance (emergency stop)

A : -	A		Load rate Stoppi		[s]	Stopping distance [deg]		
AXIS	Arm extension	Load rate	Ovrd 33%	Ovrd 66%	Ovrd 100%	Ovrd 33%	Ovrd 66%	Ovrd 100%
		M=100%	0.75	0.87	0.99	14.04	32.41	55.87
	1 4000/	M=66%	0.70	0.82	0.94	13.20	30.72	53.31
	L=100%	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
		M=100%	0.66	0.78	0.90	12.52	29.36	51.24
14	1 -000/	M=66%	0.61	0.73	0.85	11.61	27.54	48.49
JI	L=00%	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
		M=100%	0.66	0.78	0.90	12.51	29.35	51.23
	1-220/	M=66%	0.61	0.73	0.85	11.61	27.54	48.48
	L-33%	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
		M=100%	0.65	0.76	0.89	12.19	28.70	50.25
	1-100%	M=66%	0.60	0.72	0.84	11.41	27.15	47.90
	L-100%	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
10		M=66%	0.52	0.63	0.76	9.82	23.97	43.08
JZ		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
	1 - 220/	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
	L-33%	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
		M=100%	0.69	0.81	0.94	13.09	30.52	53.00
13		M=66%	0.65	0.77	0.89	12.27	28.86	50.49
55	-	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
		M=100%	0.52	0.64	0.76	11.18	27.23	48.85
14		M=66%	0.49	0.61	0.73	10.55	25.97	46.93
54	-	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
		M=100%	0.52	0.64	0.76	11.27	27.45	49.24
15		M=66%	0.49	0.61	0.73	10.64	26.18	47.31
55	-	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

Avia	Arm ovtonoion	Lood rate	Stopping time [s]	Stopping distance [deg]
AXIS	Annextension	Load rate	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)

<b>A</b>	A	I a a d us to		Stopping time [s]		Stopping distance [deg]		
AXIS	Arm extension	Load rate	Ovrd 33%	Ovrd 66%	Ovrd 100%	Ovrd 33%	Ovrd 66%	Ovrd 100%
		M=100%	0.74	0.80	0.86	36.10	77.85	126.77
	1 1000/	M=66%	0.72	0.77	0.84	35.12	75.89	123.81
	L=100%	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
		M=100%	0.58	0.63	0.70	28.47	62.59	103.64
14		M=66%	0.52	0.58	0.64	25.99	57.63	96.13
JT	L=00%	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
		M=100%	0.51	0.57	0.63	25.30	56.24	94.02
	1-220/	M=66%	0.46	0.52	0.58	22.91	51.46	86.78
	L=33%	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
		M=100%	0.53	0.59	0.65	29.54	65.37	108.86
	1-100%	M=66%	0.49	0.55	0.61	27.36	61.01	102.26
	L=100%	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
		M=100%	0.44	0.50	0.56	24.38	55.05	93.22
12	1-669/	M=66%	0.40	0.46	0.52	22.28	50.86	86.88
JZ	L=66%	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
		M=100%	0.43	0.49	0.55	23.89	54.06	91.74
	1-220/	M=66%	0.38	0.44	0.50	21.59	49.47	84.77
	L-33%	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
		M=100%	0.49	0.55	0.61	30.62	68.29	114.49
12		M=66%	0.45	0.51	0.57	28.02	63.10	106.61
12	-	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
		M=100%	0.57	0.63	0.69	33.03	72.68	120.45
14		M=66%	0.56	0.62	0.68	32.44	71.51	118.67
J4	-	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
		M=100%	0.59	0.65	0.71	45.70	100.23	165.63
15		M=66%	0.58	0.64	0.70	44.60	98.02	162.28
cı	-	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

Axis	Arm oxtonsion	Load rate	Stopping time [s]	Stopping distance [deg]	
	Annextension	LUdu Tale	Ovrd 100%	Ovrd 100%	
J1	L=100%	M=100%	0.55	80.97	
J2	L=100%	M=100%	0.37	51.79	
13	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]		
7000			Ovrd 33%	Ovrd 66%	Ovrd 100%	Ovrd 33%	Ovrd 66%	J Ovrd 100%
		M=100%	0.26	0.28	0.31	13.86	30.52	50.61
	1-1000/	M=66%	0.24	0.28	0.31	15.82	35.68	60.36
	L=100%	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
		M=100%	0.26	0.28	0.31	13.86	30.52	50.61
14	1-669/	M=66%	0.24	0.27	0.31	15.54	35.11	59.50
JI	L=00%	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
		M=100%	0.26	0.28	0.31	13.86	30.52	50.61
	1-220/	M=66%	0.24	0.27	0.31	15.54	35.11	59.50
	L=33%	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
		M=100%	0.23	0.29	0.35	21.71	53.02	95.32
12		M=66%	0.23	0.29	0.36	25.36	64.55	119.39
52	-	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
		M=100%	0.26	0.34	0.42	51.61	131.39	243.05
13		M=66%	0.24	0.32	0.40	47.68	124.10	232.91
55	-	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
14		Load 2	0.33	0.35	0.38	52.24	111.53	180.00
J4	-	Load 1	0.31	0.36	0.42	110.40	255.63	441.69

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Axis	Avia	Arm ovtonoion	Lood rate	Stopping time [s]	Stopping distance [deg]
	Annextension	Load rate	Ovrd 100%	Ovrd 100%	
14	14	1-100%	M=100%	0.92	196.55
	JI	L-100%	M=33%	1.28	275.17
10	10	L=100%	M=100%	1.00	126.12
	JZ		M=33%	1.40	176.60
	10	-	M=100%	0.41	71.82
	73		M=33%	0.34	61.32
	14		Load 2	2.74	601.95
	J4	-	Load 1	1.45	667.04

# RH-6FRH

Stopping	time and	stopping	distance	(emergency stop)

11 0	11 0		<u> </u>	1 /				
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%
		M=100%	0.37	0.45	0.53	17.52	42.29	75.40
	L = 100%	M=66%	0.38	0.48	0.59	23.82	60.26	111.01
	L-100 %	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
		M=100%	0.34	0.42	0.50	16.37	39.99	71.92
11	1-66%	M=66%	0.36	0.46	0.57	22.49	57.60	106.98
JI	L=00%	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
		M=100%	0.32	0.40	0.49	15.53	38.32	69.38
	L=33%	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
		M=100%	0.26	0.33	0.40	21.67	53.48	96.84
12		M=66%	0.27	0.36	0.45	29.47	76.60	143.62
52	-	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
		M=100%	0.25	0.32	0.39	95.89	241.91	444.79
13		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
14		Load 2	0.33	0.36	0.39	49.79	107.14	174.13
J4	-	Load 1	0.31	0.37	0.43	104.53	246.80	432.85

Avia	Arm outoncion	Lood rate	Stopping time [s]	Stopping distance [deg]	
AXIS	Annextension	Load rate	Ovrd 100%	Ovrd 100%	
	1-100%	M=100%	0.53	71.40	
JI	L=100%	M=50%	0.65	95.48	
10	L=100%	M=100%	0.43	83.44	
JZ		M=50%	0.46	119.56	
10	-	M=100%	0.09	53.34	
33		M=50%	0.10	145.88	
14		Load 2	0.94	340.61	
J4	-	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]		
_			Ovrd 33%	Ovrd 66%	Ovrd 100%	Ovrd 33%	Ovrd 66%	Ovrd 100%
		M=100%	0.48	0.50	0.51	18.28	37.61	58.60
	1-100%	M=66%	0.42	0.44	0.46	22.86	47.82	75.71
	L=100%	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
		M=100%	0.48	0.50	0.51	18.28	37.61	58.60
14	1-660/	M=66%	0.42	0.44	0.46	22.86	47.82	75.71
JI	L=00%	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
		M=100%	0.47	0.50	0.54	18.94	40.59	65.72
12		M=66%	0.42	0.47	0.52	24.31	54.06	90.40
52	-	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
		M=100%	0.51	0.55	0.59	216.09	466.05	759.02
13		M=66%	0.43	0.47	0.52	191.96	421.11	696.11
55	-	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
14		Load 2	0.48	0.50	0.51	95.32	195.56	303.97
J4	-	Load 1	0.38	0.41	0.43	155.60	332.07	535.73

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Axis	Avia	Arm ovtonoion	Lood rate	Stopping time [s]	Stopping distance [deg]
	Annextension	Load rate	Ovrd 100%	Ovrd 100%	
14	14	1-100%	M=100%	0.62	24.55
	JT	L-100%	M=25%	0.59	38.17
10	10	L=100%	M=100%	0.66	57.68
	JZ		M=25%	1.26	109.27
	10	-	M=100%	0.68	269.73
	73		M=25%	0.19	150.08
	14		Load 2	1.95	281.87
	J4	-	Load 1	0.68	269.73
## RH-20FRH

Stopping time and stopping dista	ance (emergency stop)
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Axis	Arm extension	Load rate	Stopping time [s]			Stopping distance J1/J2/J4 axis [deg] .I3 axis [mm]		
			Ovrd 33%	Ovrd 66%	Ovrd 100%	Ovrd 33%	Ovrd 66%	Ovrd 100%
		M=100%	0.63	0.65	0.68	15.08	31.26	49.08
	1-100%	M=66%	0.55	0.59	0.62	19.30	40.92	65.62
	L-100%	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
		M=100%	0.63	0.65	0.68	15.08	31.26	49.08
14	1-660/	M=66%	0.55	0.59	0.62	19.30	40.92	65.62
JI	L=00%	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
		M=100%	0.54	0.56	0.59	20.96	43.69	68.96
10		M=66%	0.47	0.50	0.54	26.53	56.78	91.85
JZ	-	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
14		Load 2	0.67	0.67	0.68	29.79	60.21	92.21
J4	-	Load 1	0.62	0.66	0.69	128.44	270.25	430.32

## Stopping time and stopping distance (power off)

Avia		Lood rate	Stopping time [s]	Stopping distance [deg]
AXIS AITI EXTENSI	Annextension	Load rate	Ovrd 100%	Ovrd 100%
14 1 4000/		M=100%	0.92	36.82
JI L=I	L-100%	M=25%	0.88	57.26
J2	1-100%	M=100%	1.00	86.52
	L=100%	M=25%	1.89	163.90
12		M=100%	1.02	404.60
J3	-	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)

	11 0		<b>v</b> ,	• •				
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%
		M=100%	0.42	0.46	0.51	36.55	80.50	133.54
	L -100%	M=66%	0.40	0.45	0.50	40.91	91.91	155.01
	L-100%	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
		M=100%	0.38	0.43	0.47	33.84	75.08	125.32
11	1-66%	M=66%	0.37	0.42	0.47	38.10	86.29	146.49
JI	L-00%	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
	-	M=100%	0.38	0.42	0.47	35.21	78.23	130.72
12		M=66%	0.36	0.41	0.47	39.41	89.45	152.12
JZ		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
14		Load 2	0.22	0.26	0.31	93.78	222.25	390.89
J4	-	Load 1	0.22	0.28	0.34	124.52	310.71	567.03

### Stopping time and stopping distance (power off)

		•			
Axis Arm exte	Arm ovtonoion	Lood rate	Stopping time [s]	Stopping distance [deg]	
	Annextension	Loau rate	Ovrd 100%	Ovrd 100%	
J1 L=100%	M=100%	0.43	91.70		
	L=100%	M=33%	0.61	119.14	
		1-100%	M=100%	0.41	74.34
JZ	L=100%	M=33%	0.41	104.30	
	10	10	M=100%	0.21	78.40
J3	-	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]		
			Ovrd 33%	Ovrd 66%	Ovrd 100%	Ovrd 33%	Ovrd 66%	J Ovrd 100%
		M=100%	0.22	0.26	0.30	9.76	22.45	38.59
	1-1000/	M=66%	0.23	0.27	0.32	11.91	28.02	49.03
	L=100%	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
		M=100%	0.21	0.24	0.28	9.18	21.29	36.82
11	1-66%	M=66%	0.21	0.26	0.30	11.24	26.68	47.01
51	L-00%	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
	-	M=100%	0.24	0.28	0.32	22.23	51.66	89.52
12		M=66%	0.24	0.29	0.35	27.14	64.65	114.13
52		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)

		Lood rate	Stopping time [s]	Stopping distance [deg]	
AXIS AITT EXTENSION	Load rate	Ovrd 100%	Ovrd 100%		
11	1-100%	M=100%	0.22	22.12	
JI L=100%	M=33%	0.35	53.20		
J2 L=100%	1-100%	M=100%	0.19	41.02	
	M=33%	0.26	71.12		
12		M=100%	0.13	49.28	
73	-	M=33%	0.11	37.24	
J4	-	Load 1	0.16	177.24	

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