



Mitsubishi Electric Industrial Robot

CR800 series controller

Robot Safety Option

Instruction Manual

4F-SF003-05

Safety Precautions

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

**CAUTION**

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

**CAUTION**

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

**CAUTION**

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

**WARNING**

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

**CAUTION**

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

**CAUTION**

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

**DANGER**

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

**DANGER**

Do not connect the Handy GOT to a programmable controller when using an iQ Platform compatible product with the CR800-R /CR800-Q/CR860-R/CR860-Q controller. Failure to observe this may result in property damage or bodily injury because the Handy GOT can automatically operate the robot regardless of whether the operation rights are enabled or not.

**DANGER**

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

**DANGER**

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

**DANGER**

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

**CAUTION**

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

**CAUTION**

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

**CAUTION**

To maintain the security (confidentiality, integrity, and availability) of the Robot and the system against unauthorized access, DoS^{*1} attacks, computer viruses, and other cyberattacks from unreliable networks and devices via network, take appropriate measures such as firewalls, virtual private networks (VPNs), and antivirus solutions. Mitsubishi Electric shall have no responsibility or liability for any problems involving Robot trouble and system trouble by unauthorized access, DoS attacks, computer viruses, and other cyberattacks.

^{*1} DoS: A denial-of-service (DoS) attack disrupts services by overloading systems or exploiting vulnerabilities, resulting in a denial-of-service (DoS) state.



Précautions de sécurité

Veillez toujours lire les précautions suivantes et le « Manuel de sécurité » avant d'utiliser le robot afin de connaître les mesures à prendre.



ATTENTION Toutes les tâches de formation doivent être réalisées par un opérateur ayant reçu une formation appropriée.
(Cela s'applique également aux tâches de maintenance réalisées avec l'alimentation allumée.)
→Application de la formation à la sécurité



ATTENTION Pour les tâches de formation, préparez un plan de travail associé aux méthodes et aux procédures de fonctionnement du robot, et aux mesures à prendre en cas d'erreur ou lors du redémarrage. Effectuez la tâche en suivant ce plan.
(Cela s'applique également aux tâches de maintenance réalisées avec l'alimentation allumée.)
→Préparation du plan de travail



AVERTISSEMENT Préparez un appareil permettant de suspendre immédiatement le fonctionnement lors des tâches de formation.
(Cela s'applique également aux tâches de maintenance réalisées avec l'alimentation allumée.)
→Réglage de l'interrupteur d'arrêt d'urgence



ATTENTION Lors des tâches de formation, placez un panneau indiquant qu'une tâche de formation est en cours sur l'interrupteur de démarrage, etc.
(Cela s'applique également aux tâches de maintenance réalisées avec l'alimentation allumée.)
→Indication qu'une tâche de formation est en cours



DANGER Installez une barrière ou une cloison lors du fonctionnement afin d'éviter tout contact entre l'opérateur et le robot.
→Installation de la barrière de sécurité



ATTENTION Définissez une méthode de signalisation précise pour les opérateurs concernés avant de commencer une tâche, et suivez cette méthode.
→Signalisation du démarrage du fonctionnement



ATTENTION De manière générale, arrêtez l'alimentation lors des tâches de maintenance. Placez un panneau indiquant qu'une tâche de maintenance est en cours sur l'interrupteur de démarrage, etc.
→Indication qu'une tâche de maintenance est en cours

**ATTENTION**

Avant de démarrer une tâche, inspectez le robot, l'interrupteur d'arrêt d'urgence, les autres appareils liés, etc., et vérifiez qu'il n'y a pas d'erreur.

→Inspection avant de démarrer une tâche

Les précautions indiquées dans le « Manuel de sécurité » sont rappelées ci-dessous.
Pour plus d'informations, consultez le « Manuel de sécurité ».



DANGER

Lorsque le robot fonctionne en mode automatique à l'aide de plusieurs dispositifs de commande (GOT, contrôleur programmable, interrupteur à bouton-poussoir), le client est responsable de la définition des droits d'utilisation des appareils, etc.



ATTENTION

Utilisez le robot dans les conditions indiquées dans les spécifications. Le non-respect de cette consigne peut entraîner des dysfonctionnements ou une baisse de la fiabilité.
(Température, humidité, atmosphère, environnement exposé aux interférences, etc.)



ATTENTION

Transportez le robot dans la position de transport indiquée. Transporter le robot dans une position inappropriée peut entraîner des blessures corporelles ou des dysfonctionnements causés par une chute.



ATTENTION

Utilisez toujours le robot installé sur une table stable. Utiliser le robot dans une position instable peut entraîner un décalage de la position et des vibrations.



ATTENTION

Placez les câbles le plus loin possible des sources d'interférences. Si les câbles sont placés près d'une source d'interférences, un décalage de la position ou des dysfonctionnements peuvent survenir.



ATTENTION

N'appliquez pas de force excessive sur le connecteur et ne tordez pas excessivement le câble.
Le non-respect de cette consigne peut entraîner des défauts de contact ou une rupture du câble.



ATTENTION

Assurez-vous que le poids de la pièce, main comprise, ne dépasse pas la charge nominale ou le couple admissible.
Dans le cas contraire, des erreurs ou des défauts peuvent survenir.



AVERTISSEMENT

Mettez en place la main et l'outil de manière sécurisée, puis saisissez la pièce en toute sécurité. Le non-respect de cette consigne peut entraîner des dommages physiques ou matériels si l'objet se détache ou tombe lors du fonctionnement.



AVERTISSEMENT

Reliez le robot et le contrôleur à la terre de manière sécurisée. Le non-respect de cette consigne peut entraîner des dysfonctionnements dus aux interférences ou des chocs électriques.



ATTENTION Indiquez l'état de fonctionnement du robot lors de son fonctionnement. Le non-respect de cette consigne peut entraîner un risque d'approche du robot par les opérateurs ou des dysfonctionnements.



AVERTISSEMENT Lorsque vous réalisez une tâche de formation dans le rayon de déplacement du robot, accordez toujours la priorité au contrôle du robot. Le non-respect de cette consigne peut entraîner des dommages physiques ou matériels si le robot est démarré à l'aide de commandes externes.



ATTENTION Définissez la vitesse la plus basse possible, et regardez toujours le robot. Le non-respect de cette consigne peut entraîner des interférences avec la pièce ou les appareils périphériques.



ATTENTION Une fois le programme modifié, vérifiez toujours le fonctionnement en mode pas à pas avant de lancer le mode automatique. Le non-respect de cette consigne peut entraîner des interférences avec les appareils périphériques en raison d'erreurs de programmation, etc.



ATTENTION Veillez à ce que, si la porte de la barrière de sécurité est ouverte lors du fonctionnement automatique, celle-ci se verrouille ou que le robot s'arrête automatiquement. Le non-respect de cette consigne peut entraîner des dommages physiques.



ATTENTION N'effectuez jamais de modifications basées sur des appréciations personnelles et n'utilisez pas de pièces de rechange autres que celles indiquées. Le non-respect de cette consigne peut entraîner des défauts ou des dysfonctionnements.



AVERTISSEMENT Lorsque le bras robotisé doit être déplacé manuellement depuis une zone périphérique, ne placez pas vos mains ou vos doigts dans les ouvertures. Le non-respect de cette consigne peut entraîner des blessures aux mains ou aux doigts, en fonction de la position.



ATTENTION N'arrêtez pas le robot et n'utilisez pas l'arrêt d'urgence en coupant l'alimentation principale du contrôleur du robot. Si l'alimentation principale du contrôleur du robot est coupée lors du fonctionnement en mode automatique, la précision du robot peut être altérée. Un bras robotisé en mouvement ou qui tomberait peut entrer en collision avec des appareils périphériques.

**ATTENTION**

N'arrêtez pas l'alimentation principale du contrôleur du robot lors de la réécriture des informations internes du contrôleur du robot, telles qu'un programme et des paramètres. Arrêter l'alimentation principale du contrôleur du robot lors du fonctionnement automatique ou de l'écriture du programme/des paramètres peut endommager les informations internes du contrôleur du robot.

**DANGER**

Ne connectez pas Handy GOT lors de l'utilisation de la fonction de connexion directe GOT de ce produit. Le non-respect de cette consigne peut entraîner des dégâts matériels ou des dommages corporels, car Handy GOT peut faire fonctionner le robot automatiquement, que les droits de fonctionnement soient activés ou non.

**DANGER**

Ne connectez pas Handy GOT à un contrôleur programmable lors de l'utilisation d'un produit compatible iQ Platform avec le contrôleur CR800-R/CR800-Q/CR860-R/CR860-Q. Le non-respect de cette consigne peut entraîner des dégâts matériels ou des dommages corporels, car Handy GOT peut faire fonctionner le robot automatiquement, que les droits de fonctionnement soient activés ou non.

**DANGER**

Ne retirez pas le câble SSCNET III lorsque le système à plusieurs CPU ou l'amplificateur servo sont sous tension. Ne regardez pas directement la lumière émise par l'extrémité des connecteurs SSCNET III ou des câbles SSCNET III du CPU Motion ou de l'amplificateur servo. Le non-respect de cette consigne pourrait entraîner une gêne oculaire. (Référence : SSCNET III utilise une source lumineuse de classe 1 ou équivalente, conformément aux normes JIS C 6802 et IEC60825-1 [normes nationales japonaises])

**DANGER**

Ne retirez pas le câble SSCNET III lorsque le contrôleur est sous tension. Ne regardez pas directement la lumière émise par l'extrémité des connecteurs SSCNET III ou des câbles SSCNET III. Le non-respect de cette consigne pourrait entraîner une gêne oculaire. (Référence : SSCNET III utilise une source lumineuse de classe 1 ou équivalente, conformément aux normes JIS C 6802 et IEC60825-1 [normes nationales japonaises])

**DANGER**

Remettez le capuchon sur le connecteur SSCNET III une fois le câble SSCNET III débranché. Dans le cas contraire, de la saleté ou de la poussière peuvent s'incruster dans les broches du connecteur, ce qui peut détériorer les propriétés du connecteur et entraîner un dysfonctionnement.

**ATTENTION**

Assurez-vous que le câblage soit correct. Un raccordement différent de celui indiqué dans le manuel peut entraîner des erreurs, comme le non-déclenchement de l'arrêt d'urgence. Afin d'éviter toute erreur, veuillez vérifier que toutes les fonctions (telles que l'arrêt d'urgence du module de formation, l'arrêt d'urgence client, et l'interrupteur de la trappe) fonctionnent correctement une fois le câblage terminé.

**ATTENTION**

Utilisez les équipements réseau (ordinateur personnel, port USB, port LAN, etc.) recommandés par le fabricant. Les équipements connectés par USB présentent des caractéristiques incompatibles avec l'environnement FA (en matière de conformité, de température ou d'interférences). Lors de l'utilisation d'équipements réseau, des mesures de réduction des interférences, telles que des mesures contre les interférences électromagnétiques et l'ajout d'un noyau en ferrite, peuvent s'avérer nécessaires.

Veuillez demander au client de vérifier l'intégralité du fonctionnement. La prise en charge de la garantie et de la maintenance des équipements disponibles sur le marché (équipements de bureautique courants) ne peut être assurée.

**ATTENTION**

Pour assurer la sécurité (confidentialité, intégrité et disponibilité) du robot et du système contre les accès non autorisés, les attaques DoS*1, les virus informatiques et autres cyberattaques provenant de réseaux et d'appareils non fiables via le réseau, prenez les mesures appropriées telles que la mise en place de pare-feu, de réseaux privés virtuels (VPN) et d'antivirus.

La responsabilité de Mitsubishi Electric ne saurait être engagée en cas de problèmes liés au robot ou au système causés par un accès non autorisé, par des attaques par déni de service, par des virus informatiques ou par d'autres cyberattaques.

*1 DoS : une attaque par déni de service (DoS) perturbe les services en surchargeant les systèmes ou en exploitant leurs vulnérabilités, ce qui entraîne un état de déni de service (DoS).

■ Revision history

[illegible]

■ 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".

In this manual, the CR800 series indicates the CR800 and CR860 controllers.

The CR800 controller indicates the CR800-D, CR800-Q, or CR800-R controller.

The CR860 controller indicates the CR860-D, CR860-Q, or CR860-R controller.

■ Symbols in this manual

Before using this product, please read this manual and the relevant manuals carefully and pay full attention to safety to handle the product correctly.

The precautions given in this manual are concerned with this product only. For the safety precautions of the robot system, refer to the user's manual for the peripheral equipment used.

In this manual, the safety precautions are classified into three levels: "DANGER", "WARNING", and "CAUTION".



Danger

Precaution indicating cases where there is a risk of operator fatality or serious injury if handling is mistaken. Always observe these precautions to safely use the robot.



Warning

Precaution indicating cases where the operator could be subject to fatalities or serious injuries if handling is mistaken. Always observe these precautions to safely use the robot.



Caution

Precaution indicating cases where operator could be subject to injury or physical damage could occur if handling is mistaken. Always observe these precautions to safely use the robot.

Under some circumstances, failure to observe the precautions given under "CAUTION" may lead to serious consequences.

Observe the precautions of all the levels because they are important for personal and system safety.

Make sure that the end users read this manual and then keep the manual in a safe place for future reference.

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

1. FUNCTIONS AND CONFIGURATION	1-1
1.1 Overview	1-1
1.2 System Configuration	1-2
1.3 Specifications	1-5
1.4 Risk Assessment	1-8
1.4.1 Residual Risk (Common)	1-8
1.4.2 Residual Risk (Specific to Each Function)	1-8
2. INSTALLATION	2-10
2.1 Product Components	2-10
2.1.1 Accessories	2-10
2.1.2 Items to be prepared by customer	2-11
2.2 Part Names	2-15
2.3 Installation and Connection	2-16
2.3.1 Fixing the safety extension unit	2-16
2.3.2 Safety extension unit external dimensions	2-17
2.3.3 Connecting with the robot controller	2-18
2.3.4 Connector and cable	2-21
2.4 Check Items	2-22
2.5 Replacement Parts	2-22
2.6 Maintenance	2-22
3. SIGNALS AND WIRING	3-23
3.1 Description of Signals	3-23
3.1.1 Electrical specifications	3-23
3.1.2 Signal operation	3-26
3.2 Connector Wiring	3-27
3.3 Connectors and Pin Assignment	3-29
3.4 Input Signal Connection Example	3-31
3.5 Measures to Prevent Static Electricity and Noise	3-33
4. SAFETY MONITORING FUNCTIONS	4-34
4.1 Safety Monitoring Functions Overview	4-34
4.1.1 Simulation	4-34
4.2 Startup and Basic Configuration	4-35
4.2.1 Connecting RT ToolBox3	4-35
4.2.2 Parameter configuration	4-35
4.2.3 Password setting	4-36
4.2.4 Enabling/disabling functions	4-38
4.2.5 Recovery mode	4-39
4.2.6 Parameter CRC output number	4-40
4.3 Defining 3D Models	4-42
4.3.1 3D Monitor	4-42
4.3.2 Arm model	4-45
4.3.3 Tool model	4-46
4.4 Safety Logic Edit	4-48
4.4.1 Safety input settings	4-48
4.4.2 Safety output configuration	4-57
4.4.3 Checking operation of the safety inputs and outputs	4-59
4.5 Safety Monitoring Functions	4-60
4.5.1 Safe torque off (STO)	4-60
4.5.2 Safe operating stop (SOS)	4-61
4.5.3 Safe stop 1 (SS1)	4-64
4.5.4 Safe stop 2 (SS2)	4-70
4.5.5 Safely-limited speed function (SLS)	4-73

4.5.6 Safely-limited position function (SLP)	4-81
4.6 Safety Diagnosis Function	4-90
4.6.1 Test pulse diagnosis (EMG).....	4-90
4.6.2 Safety diagnosis function.....	4-91
5. STATE VARIABLE	5-92
5.1 List of State Variables.....	5-92
5.2 State Variables.....	5-92
6. TROUBLESHOOTING	6-97
6.1 Error List for the Safety Monitoring Functions.....	6-97
6.2 Errors Whose Specification Is Changed by Safety Monitoring Functions	6-100
7. SAFE STOPPING DISTANCE.....	7-101
7.1 How to Calculate a Stopping Distance	7-101
7.2 Maximum Stopping Time and Maximum Operating Angle	7-102
7.3 Calculating stopping distance and stopping time.....	7-131
8. APPENDIX	8-134
8.1 Appendix 1: Selection Conditions for 24VDC Stabilized Power Supply	8-134
8.2 Appendix 2: How to Install the Safety Extension Unit	8-135
8.3 Appendix 3: How to Install the Stabilized Power Supply for the Safety Extension Unit	8-137
8.4 Appendix 4: EMC installation guideline.....	8-139
8.4.1 Outlines	8-139
8.4.2 EMC directive.....	8-139
8.4.3 EMC measures.....	8-139
8.4.4 Component parts for EMC measures	8-140

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 expands the safety monitoring function for the CR800 series controller. The main functions are shown below.

Tab. 1-1: Safety monitoring functions overview

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

1.2 System Configuration

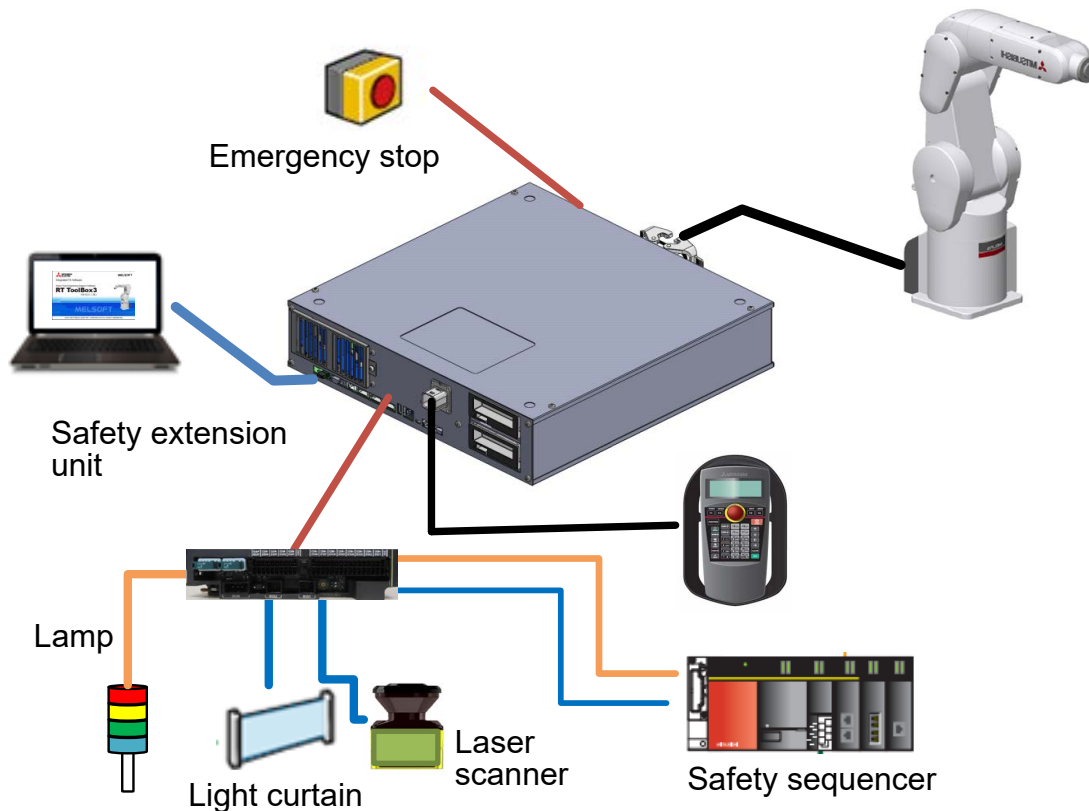


Fig. 1-1 System configuration example

Tab. 1-2 System configuration

Item	Description		Remarks
Robot arm	Vertical articulated robot 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, RV-35FR, RV-50FR, RV-80FR	Additional axes and user mechanisms are not included in the system.
	Vertical articulated robot RV-CR series	RV-8CRL, RV-12CRL	
	SCARA robot RH-FRH series	RH-3FRH, RH-6FRH, RH-12FRH, RH-20FRH, RH-3FRHR, RH-1FRHR	
	SCARA robot RH-CRH series	RH-3CRH, RH-6CRH, RH-10CRH, RH-20CRH	
Robot controller	CR800 series	CR800-D	For supported versions, refer to Tab. 1-3.
		CR800-R	
		CR800-Q	
		CR860-D	
		CR860-R	
		CR860-Q	
RT ToolBox3	3F-15C-WINE		Install the software to a personal computer. The software is used to enable the safety monitoring function. (Separate purchase is required.) For supported versions, refer to Tab. 1-3.
RT ToolBox3 mini	3F-14C-WINE		
RT ToolBox3 Pro	3F-16D-WINE		
Robot safety option	4F-SF003-05		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.

The following table lists the versions of the robot controller and RT ToolBox3 when the robot safety option is used. Note that the supported version differs depending on the robot arm.

Tab. 1-3 Supported version

Robot arm		Robot controller version		RT ToolBox3 version
Vertical articulated robot RV-FR series	RV-2FRB	CR800-D	Ver. A5c or later, HW Ver. * or later	Ver. 1.00A or later
		CR800-R		
		CR800-Q		
	RV-2FRLB	CR800-D	Ver. A5c or later, HW Ver. * or later	Ver. 1.00A or later
		CR800-R		
		CR800-Q		
	RV-4FR	CR800-D	Ver. A5c or later, HW Ver. * or later	Ver. 1.00A or later
		CR800-R		
		CR800-Q		
	RV-4FRL	CR800-D	Ver. A5c or later, HW Ver. * or later	Ver. 1.00A or later
		CR800-R		
		CR800-Q		
	RV-4FRJL	CR800-D	Ver. A5c or later, HW Ver. * or later	Ver. 1.00A or later
		CR800-R		
		CR800-Q		
	RV-7FR	CR800-D	Ver. A5c or later, HW Ver. * or later	Ver. 1.00A or later
		CR800-R		
		CR800-Q		
	RV-7FRL	CR800-D	Ver. A5c or later, HW Ver. * or later	Ver. 1.00A or later
		CR800-R		
		CR800-Q		
	RV-7FRLL	CR800-D	Ver. A5c or later, HW Ver. * or later	Ver. 1.00A or later
		CR800-R		
		CR800-Q		
	RV-13FR	CR800-D	Ver. A5c or later, HW Ver. * or later	Ver. 1.00A or later
		CR800-R		
		CR800-Q		
	RV-13FRL	CR800-D	Ver. A5c or later, HW Ver. * or later	Ver. 1.00A or later
		CR800-R		
		CR800-Q		
	RV-20FR	CR800-D	Ver. A5c or later, HW Ver. * or later	Ver. 1.00A or later
		CR800-R		
		CR800-Q		
	RV-35FR	CR860-D	Ver. D1 or later, HW Ver. * or later	Ver. 2.30G or later
		CR860-R		
		CR860-Q		
	RV-50FR	CR860-D	Ver. D1 or later, HW Ver. * or later	Ver. 2.30G or later
		CR860-R		
		CR860-Q		
	RV-80FR	CR860-D	Ver. D1 or later, HW Ver. * or later	Ver. 2.30G or later
		CR860-R		
		CR860-Q		
Vertical articulated robot RV-CR series	RV-8CRL	CR800-D	Ver. A5c or later, HW Ver. * or later	Ver. 1.61P or later
	RV-12CRL	CR800-D	Ver. D1 or later, HW Ver. A or later	Ver. 2.40S or later

1 FUNCTIONS AND CONFIGURATION

Robot arm		Robot controller version		RT ToolBox3 version
SCARA robot RH-FRH series	RH-3FRH	CR800-D	Ver. A5c or later, HW Ver. * or later	Ver. 1.00A or later
		CR800-R		
		CR800-Q		
	RH-6FRH	CR800-D	Ver. A5c or later, HW Ver. * or later	Ver. 1.00A or later
		CR800-R		
		CR800-Q		
	RH-12FRH	CR800-D	Ver. A5c or later, HW Ver. * or later	Ver. 1.00A or later
		CR800-R		
		CR800-Q		
	RH-20FRH	CR800-D	Ver. A5c or later, HW Ver. * or later	Ver. 1.00A or later
		CR800-R		
		CR800-Q		
	RH-3FRHR	CR800-D	Ver. A5c or later, HW Ver. * or later	Ver. 1.00A or later
		CR800-R		
		CR800-Q		
	RH-1FRHR	CR800-D	Ver. A5c or later, HW Ver. * or later	Ver. 1.00A or later
		CR800-R		
SCARA robot RH-CRH series	RH-3CRH	CR800-D	Ver. A5k or later, HW Ver. * or later	Ver. 1.70Y or later
	RH-6CRH	CR800-D	Ver. A5k or later, HW Ver. * or later	Ver. 1.70Y or later
	RH-10CRH	CR800-D	Ver. D3 or later, HW Ver. A or later	Ver. 2.50C or later
	RH-20CRH	CR800-D	Ver. D3 or later, HW Ver. A or later	Ver. 2.50C or later

1.3 Specifications

Tab. 1-4 Specifications

Item			Description	Remarks
Safety function	STO function		The function electrically shuts off the driving energy to the motor of the robot arm. The driving energy to the motor is shut off, which means that safety is ensured.	IEC 60204-1:2016 Corresponds to stop category 0
	SS1 function		The function to control and decelerate the motor speeds of the robot. After stopping, the robot transitions to the STO state.	IEC 60204-1:2016 Corresponds to stop category 1
	SS2 function		The function to control and decelerate the motor speeds of the robot. After stopping, the robot transitions to the SOS state.	IEC 60204-1:2016 Corresponds to stop category 2
	SOS function		Without shutting off the driving energy to the motors, this function monitors the robot so that it stays at rest.	EN 61800-5-2:2017 compliant
	SLS function		This is a function to monitor each part of the robot arm so that their speeds do not exceed monitoring speeds.	EN 61800-5-2:2017 compliant
	SLP function		The function monitors specified monitoring positions so that they do not go across position monitoring planes.	EN 61800-5-2:2017 compliant
Safety performance	Standard		EN ISO 10218-1:2011 EN ISO 13849-1:2015 IEC 61508-1:2010 IEC 61508-2:2010 IEC 61508-3:2010 EN 61800-5-1:2007/A1:2017 EN 61800-5-2:2017 IEC 61326-3-1:2017 EN 60204-1: 2018 EN 61000-6-7:2015	-
	Classification		Type B	-
Safety extension unit	Power supply specifications	Voltage	24 V DC±5% Ripple 0.2 V (P-P)	-
		Maximum consumption current (Note 1)	300 mA	The value not including the external load current of the output (DO)
	Structure (IP rating)		IP20	-
	Weight		0.4kg	-
	Environment	Operating temperature range	0 to 40°C	It must be kept away from heat appliances and other heat sources.
		Relative humidity	0 to 58°C	Non-condensing
		Vibration	During transportation: 34m/s ² . During operation: 5 m/s ² or less	-
		Atmosphere	No corrosive gas / flammable gas / oil mist/dust	-

Item			Description	Remarks
Safety extension unit	Environment	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: Refer to 8.1 Appendix 1: Selection Conditions for 24VDC Stabilized Power Supply.



Caution

Do not use the JRC command when any of the safety functions are enabled.

If the JRC command is used when the safety extension unit is connected and a safety function is enabled, there may be deviation from the monitoring position of the safety process. Position monitoring (SLP) and speed monitoring (SLS) may not be performed correctly either.

- Applicable models: MELFA FR series and MELFA CR series (not applicable to the MELFA ASSISTA series as it cannot use the JRC command)
- Applicable software versions: Ver. A1 or later

The following table shows the safety performance of the CR800 controller.

Function	Item	Description	Remarks
STO	Safety Level	SIL 3 (IEC 61508:2010)	Performance when: • External emergency stop input when the test pulse diagnosis settings are enabled (Note 1)
		Category 4, PL e (EN ISO 13849-1:2015)	
	Mean time to dangerous failure (MTTFd)	MTTFd ≥ 100 years	
	Diagnostic coverage (DC)	DC = 99%	
	Probability of dangerous failure per hour (PFH) (Note 2)	PFH = 1.40×10^{-8} [1/hour]	
	Hardware Fault Tolerance	1	
	Mission time	20 years	
	Diagnostic test interval	1000ms	
	Systematic capability	SC3	Performance when: • External emergency stop input when the test pulse diagnosis settings are disabled (factory settings) • Door switch input • Mode selector switch input • Safety extension unit's safety input (Note 3)
	Safety Level	SIL 2 (IEC 61508:2010)	
		Category 3, PL d (EN ISO 13849-1:2015)	
	Mean time to dangerous failure (MTTFd)	MTTFd ≥ 100 years	
	Diagnostic coverage (DC)	DC = 90%	
	Probability of dangerous failure per hour (PFH) (Note 2)	PFH = 1.57×10^{-8} [1/hour]	
	Hardware Fault Tolerance	1	
	Mission time	20 years	
	Diagnostic test interval	1000ms	
	Systematic capability	SC2	
SS1, SS2, SOS, SLS, SLP	Safety Level	SIL 2 (IEC 61508:2010)	(Note 3)
		Category 3, PL d (EN ISO 13849-1:2015)	
	Mean time to dangerous failure (MTTFd)	MTTFd = 24 years	
	Diagnostic coverage (DC)	DC = 90%	
	Probability of dangerous failure per hour (PFH) (Note 2)	PFH = 3.42×10^{-7} [1/hour]	
	Hardware Fault Tolerance	1	
	Mission time	20 years	
	Diagnostic test interval	1000ms	
	Systematic capability	SC2	

Note 1: To use this product at a performance level of SIL 3, Category 4, PL e, refer to “4.6.1 Test pulse diagnosis (EMG)”.

Note 2: The robot controller PFH or PFHd (Probability of Dangerous Failure per Hour).

Note 3: For systems using the I/O signals of the safety extension unit, add the PFH value in the table below.

Safety performance of the safety extension unit complies with PL d/Category 3.

MTTFd [year]	DC [%]	PFH [1/hour]
256	90	1.76×10^{-8}

The following table shows the safety performance of the CR860 controller.

Function	Item	Description	Remarks
STO	Safety Level	SIL 3 (IEC 61508:2010)	Performance when: • External emergency stop input when the test pulse diagnosis settings are enabled (Note 1)
		Category 4, PL e (EN ISO 13849-1:2015)	
	Mean time to dangerous failure (MTTFd)	MTTFd $\geq$ 100 years	
	Diagnostic coverage (DC)	DC = 99%	
	Probability of dangerous failure per hour (PFH) (Note 2)	PFH = 1.60×10^{-8} [1/hour]	
	Hardware Fault Tolerance	1	
	Mission time	20 years	
	Diagnostic test interval	1000ms	
	Systematic capability	SC3	
	Safety Level	SIL 2 (IEC 61508:2010)	Performance when: • External emergency stop input when the test pulse diagnosis settings are disabled (factory settings) • Door switch input • Enabling device input • Safety extension unit's safety input (Note 3)
		Category 3, PL d (EN ISO 13849-1:2015)	
	Mean time to dangerous failure (MTTFd)	MTTFd $\geq$ 100 years	
	Diagnostic coverage (DC)	DC = 96%	
	Probability of dangerous failure per hour (PFH) (Note 2)	PFH = 2.24×10^{-8} [1/hour]	
	Hardware Fault Tolerance	1	
	Mission time	20 years	
	Diagnostic test interval	1000ms	
	Systematic capability	SC2	
SS1, SS2, SOS, SLS, SLP	Safety Level	SIL 2 (IEC 61508:2010)	(Note 3)
		Category 3, PL d (EN ISO 13849-1:2015)	
	Mean time to dangerous failure (MTTFd)	MTTFd $\geq$ 100 years	
	Diagnostic coverage (DC)	DC = 95%	
	Probability of dangerous failure per hour (PFH) (Note 2)	PFH = 5.58×10^{-7} [1/hour]	
	Hardware Fault Tolerance	1	
	Mission time	20 years	
	Diagnostic test interval	1000ms	
	Systematic capability	SC2	

Note 1: To use this product at a performance level of SIL 3, Category 4, PL e, refer to “4.6.1 Test pulse diagnosis (EMG)”.

Note 2: The robot controller PFH or PFHd (Probability of Dangerous Failure per Hour).

Note 3: For systems using the I/O signals of the safety extension unit, add the PFH value in the table below.

Safety performance of the safety extension unit complies with PL d/Category 3.

MTTFd [year]	DC [%]	PFH [1/hour]
256	90	1.76×10^{-8}

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. Depending on the posture of the robot, the arm may droop if the axis does not have a brake.

(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.

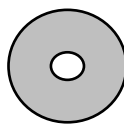
2. INSTALLATION

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	Model	Quantity	Outer appearance		Remarks
1	Safety extension unit	4F-SFUNIT2	1			If using it with the CR860, install the unit inside the CR860. (See chapter 2.3.1)
2	RIO cable (Cable length: 5 m)	2F-SFRIOCBL05	1			-
3	DCIN connector set	2F-SFDCINCON	1	 Connector: 1pcs.	 Pin: 3 pcs.	For primary power wires
4	Terminator cap	2F-SFTM	1			For connection to the RIO2 socket
5	Instruction manual	BFP-A3764	1	 CD-ROM		BFP-A3764

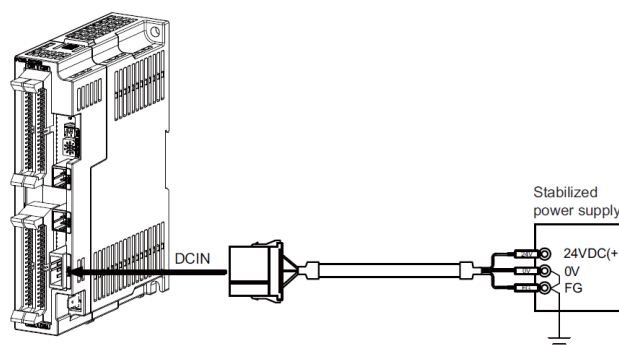
2.1.2 Items to be prepared by customer

Items to be prepared by customer for the CR800 series controller

Tab. 2-2 Items to be prepared by customer for the CR800 series controller

No.	Item	Quantity	Description	Remarks
1	24 V power supply	1	The power supply for the safety extension unit.	Refer to 8.1 Appendix 1: Selection Conditions for 24VDC Stabilized Power Supply.
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	FG cable	1	Make a cable that connects to the frame ground.	-
4	Safety extension unit installation metal plate	1	Fabricate a metal plate to install the safety extension unit inside the CR860. When the unit is used with the CR800, no fabrication is required.	Refer to 8.2 Appendix 2: How to Install the Safety Extension Unit.
5	24 V power supply installation metal plate	1	A metal plate to install the 24 V power supply inside the CR860. Fabricate it when installing the 24 V power supply inside the CR860. When installing the 24 V power supply outside the CR860, no fabrication is required.	Refer to 8.3 Appendix 3: How to Install the Stabilized Power Supply for the Safety Extension Unit.
6	Fixing screw	-	A screw to fix the safety extension unit, installation metal plate, etc. Prepare screws by referring to the information described in this manual.	-

■ Connected to 24V power supply



Connectors/cables: Table 2-5 Connectors and cables

Connector Pin Assignment: Table 3-5 DCIN pin assignment

Fig. 2-1 Power supply connection

• Supplementary explanation when using this product with the CR860

When installing the 24V power supply of the safety extension unit outside the CR860

- 1) Pull the 24V power supply cable through the cable entrance (Note 1), and connect the cable to the safety extension unit as shown in Fig. 2-1 Power supply connection.

Note 1: Refer to the method of wiring cables through the cable entrance described in the "CR860 Controller Instruction Manual/Controller setup, basic operation, and maintenance".

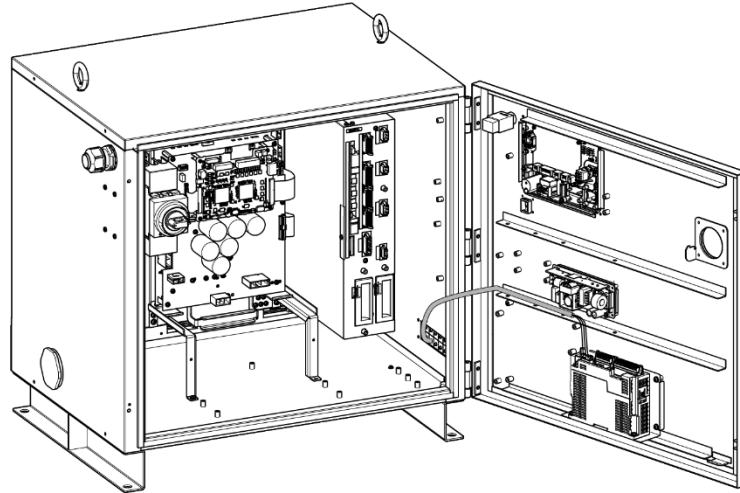


Fig. 2-2 Power supply connection when installing the 24V power supply outside the CR860

When installing the power supply of the safety extension unit inside the CR860

- 1) A space is provided next to the safety extension unit for the installation of the 24V power supply. Install the 24V power supply using an installation metal plate supplied by customer.

To prevent interference with mechanical parts, ensure that the height is within 51mm. (Note 1)

Note 1): Refer to 8.3 Appendix 3: How to Install the Stabilized Power Supply for the Safety Extension Unit.

- 2) Pull a cable that is used to connect the input side of the 24V power supply through the cable entrance (Note 2), and connect the cable to the input side of the 24V power supply.

Note 2): Refer to the method of wiring cables through the cable entrance described in the "CR860 Controller Instruction Manual/Controller setup, basic operation, and maintenance".

- 3) Connect the 24V power supply cable to the safety extension unit as shown in Fig. 2-1 Power supply connection.

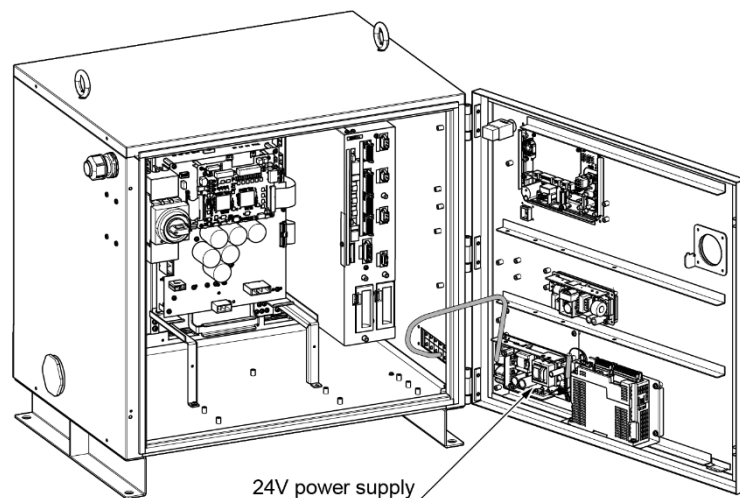


Fig. 2-3 Power supply connection when installing the 24V power supply inside the CR860

•Wiring precautions

When wiring this product inside the controller, fix the cable using the studs and the ribs of the door.

When wiring the product inside the door, ensure enough cable length for the opening and closing sections. Otherwise, excessive force may be applied to the cable when the door is opened or closed, causing the cable to be cut or disconnected.

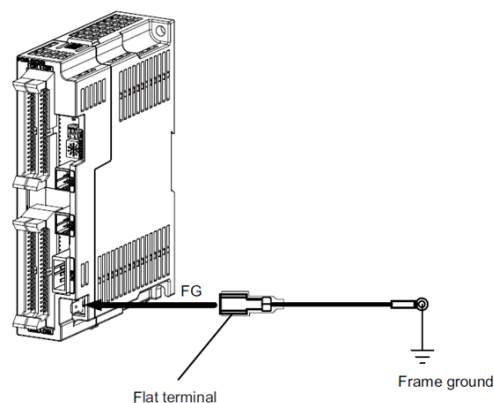
■Connection to Frame ground

Fig. 2-4 FG wire connection

Tab. 2-3 Frame ground connector

Manufacturer	Name	Type
TE Connectivity	Flat terminal	175021-1/175023-1
TE Connectivity	Protection conver	174817-2

• Supplementary explanation when using this product with the CR860

Connect the grounding plate located inside the controller and the FG cable of the safety extension unit. Fix the FG cable using the studs inside the controller as shown in the figure below.

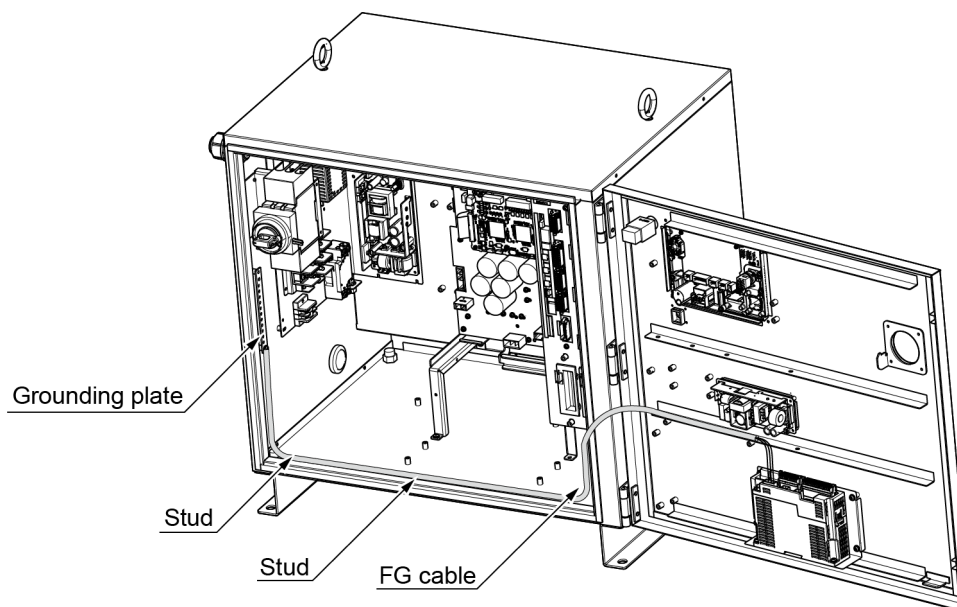


Fig. 2-5 FG wire connection

Tab. 2-4 Frame ground connector

Manufacturer	Name	Type
TE Connectivity	Flat terminal	175021-1/175023-1
TE Connectivity	Protection conver	174817-2

•Wiring precautions

When wiring this product inside the controller, fix the cable using the studs and the ribs of the door.

When wiring the product inside the door, ensure enough cable length for the opening and closing sections. Otherwise, excessive force may be applied to the cable when the door is opened or closed, causing the cable to be cut or disconnected.

2.2 Part Names

The names of each part of the safety extension unit (4F-SFUNIT2) are shown below:

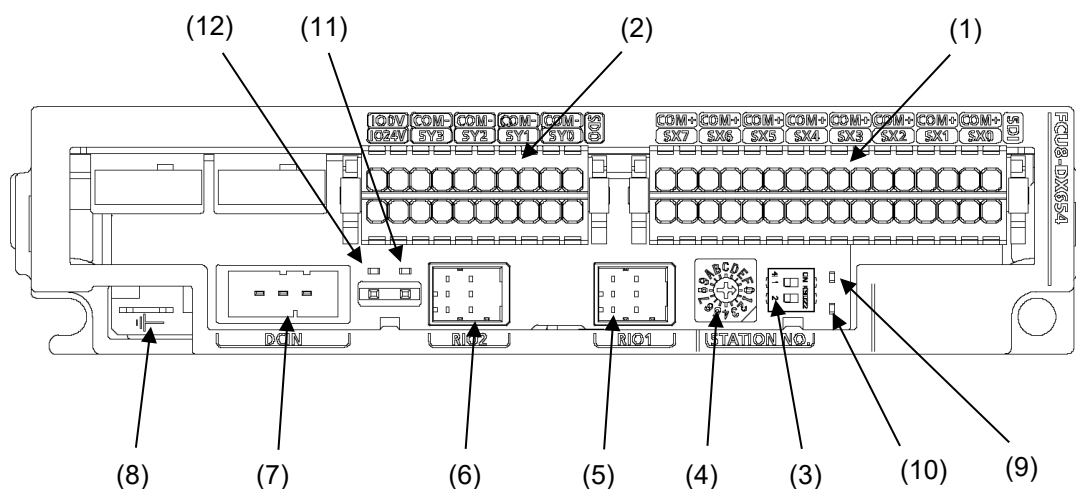


Fig. 2-6 Names of each part of the safety unit

Tab. 2-5 Names of each part of the safety extension unit

No	Connector	Function	Remarks
(1)	DSI	Safety DI input connectors	-
(2)	DSO	Safety DI input connectors	-
(3)	STATION No.	Station No. group setting switch	Cannot be changed from the factory setting.
(4)		Station No. setting switch	
(5)	RIO1	Remot I/O 2.0 communication	-
(6)	RIO2	Remot I/O 2.0 communication	-
(7)	DCIN	24 VDC input	For power input to the safety I/O unit
(8)	FG	FG terminal	Use this terminal for grounding.
(9)	RIOVER	RIO communication status(Green)	On: Normal Off: Error
(10)	ALM	Remote I/O communication error check LED	On: Error Off: Normal
(11)	FUSE	Melted fuse check LED	On: Normal Off: Fuse melted
(12)	24VDCIN	Energization status of 24VDC input of DCIN connector(Green)	On: Normal Off: Error

2.3 Installation and Connection



Caution

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



Caution

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



Caution

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



Caution

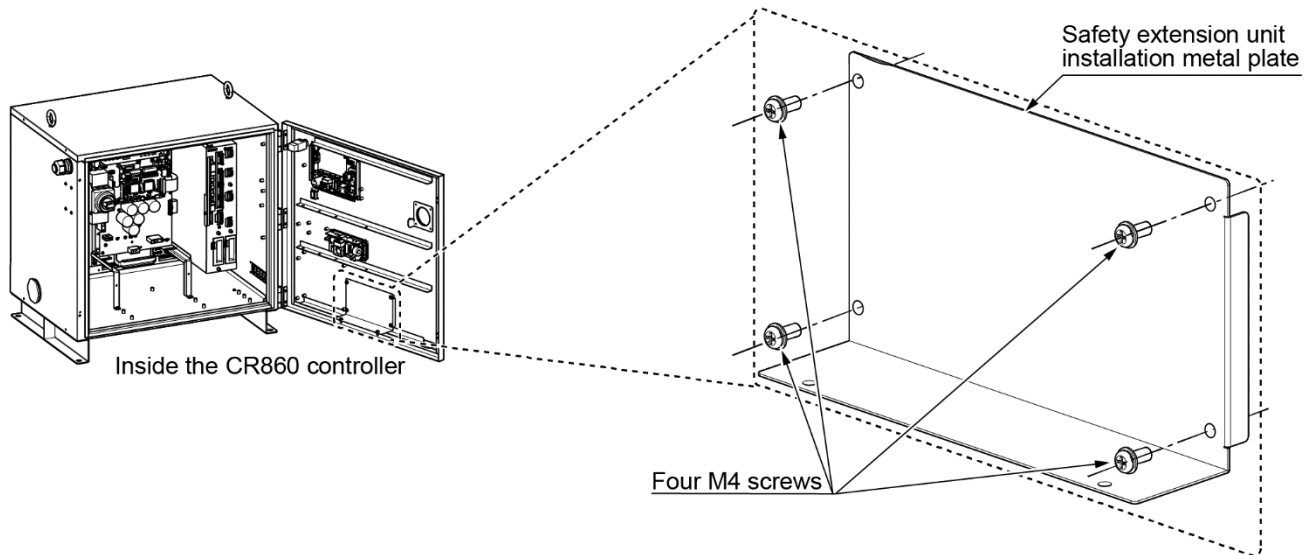
Please supply power to the safety extension unit before the robot controller. When the controller is turned on before the unit, H311(Remotel/O unit config error) may occur. When this error occurs, turn off both of the unit and controller and supply power to the unit before the controller.

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. 2-4 External dimensions. Alternatively, use DIN rails and fix it in a place free from vibration.

If using the safety extension unit in the CR860, fabricate a metal plate to install the unit, and fix the metal plate and unit inside the CR860 controller using the following steps: For details, refer to "8.2 Appendix 2: How to Install the Safety Extension Unit".

- 1) Install the safety extension unit installation metal plate to the controller door section with M4 screws.



- 2) Fix the safety extension unit to the metal plate using M5 screws.

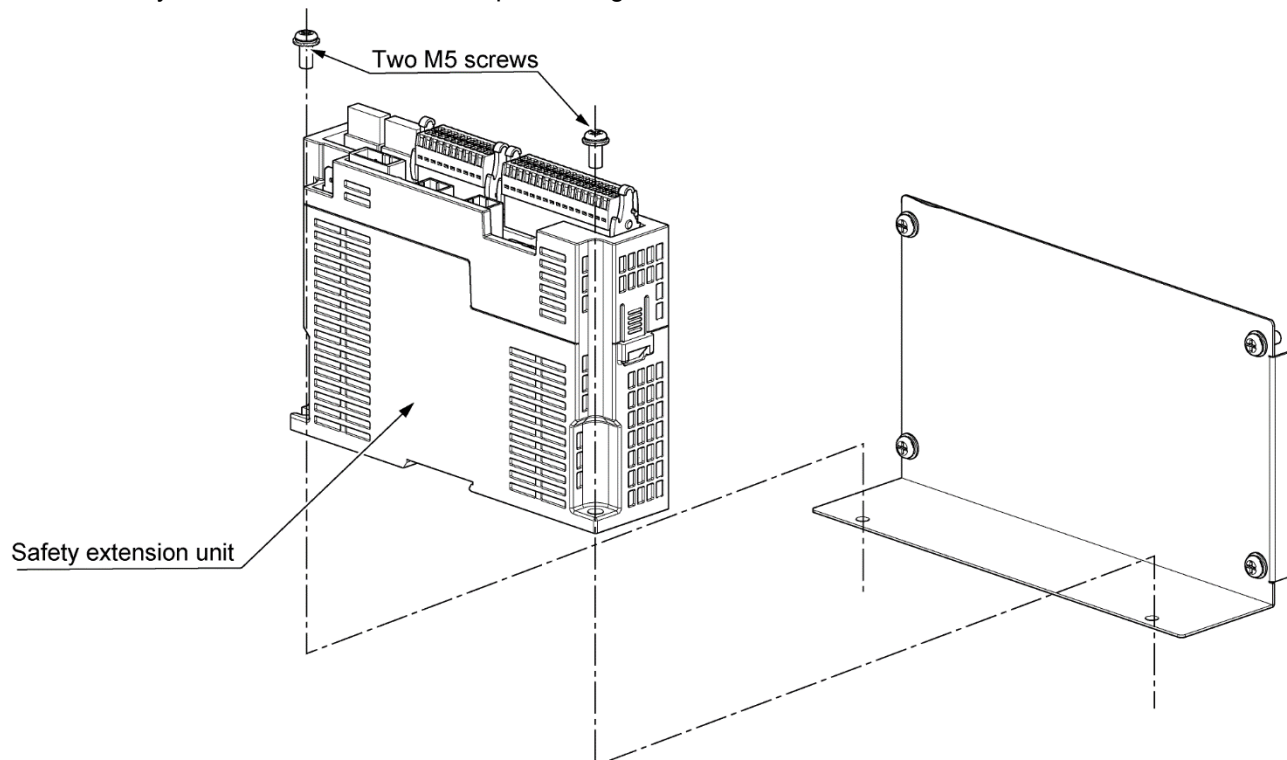


Fig. 2-7 Installing the unit inside the CR860 controller

2.3.2 Safety extension unit external dimensions

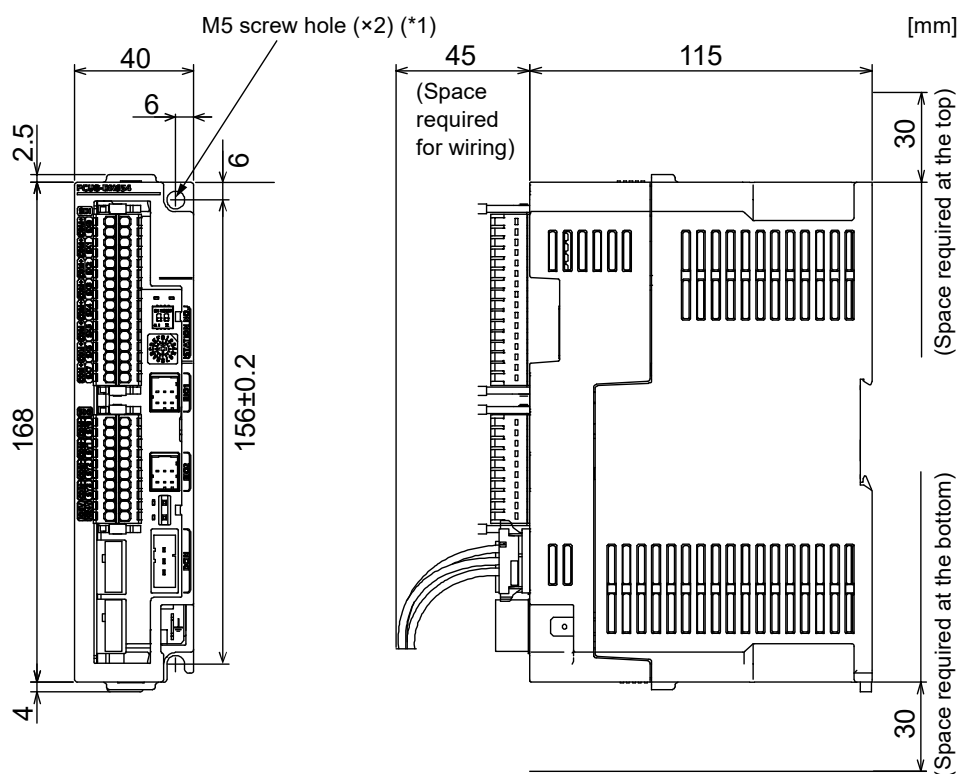


Fig. 2-8 External dimensions

2.3.3 Connecting with the robot controller

(1) Unit connection (CR800 controller)

Connect the safety extension unit to the robot controller using the following steps.

- 1) Use the RIO cable (2F-SFRIOCBL05) to connect the safety extension unit to the robot controller.
- 2) Connect the terminator cap (2F-SFTM) to the RIO2 socket of the safety extension unit.

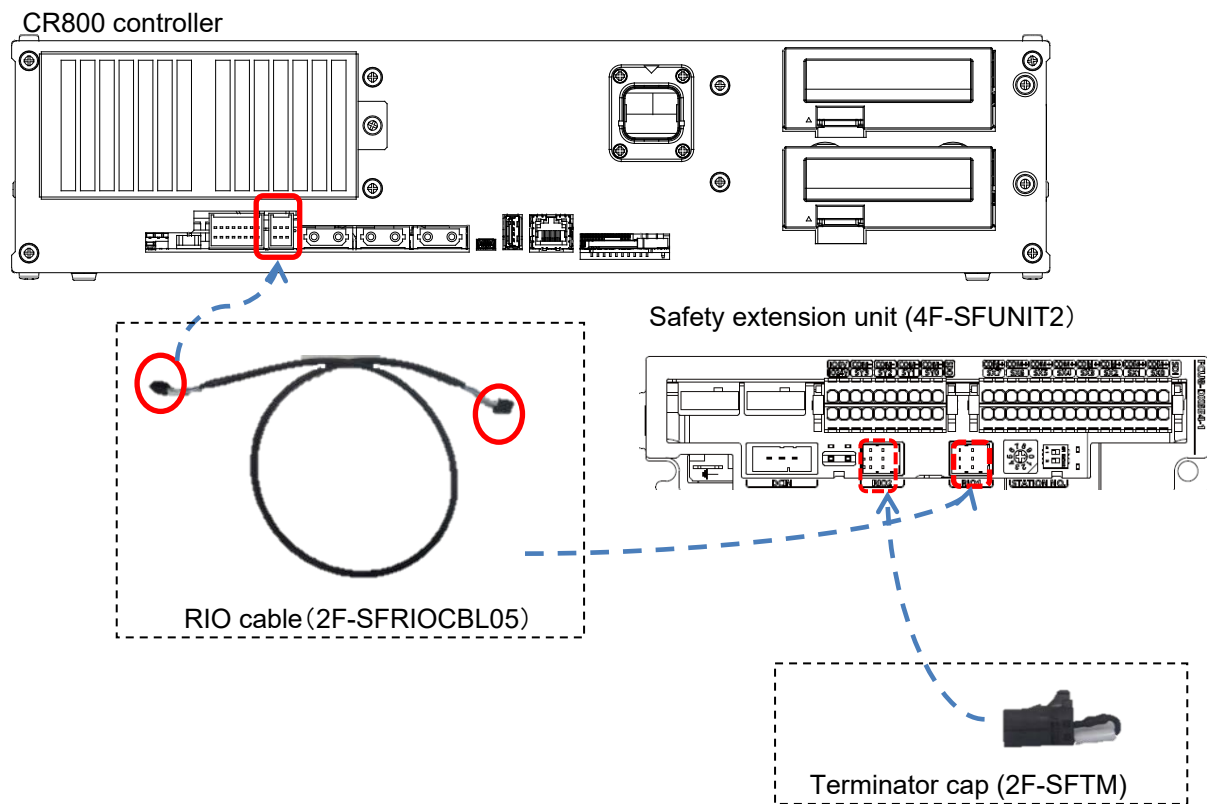


Fig. 2-9 Connection to the CR800 controller

(2) Unit connection (CR860 controller)

Connect the safety extension unit to the robot controller using the following steps.

- 1) Use the RIO cable (2F-SFRIOCBL05) to connect the safety extension unit to the robot controller.
- 2) Connect the terminator cap (2F-SFTM) to the RIO2 socket of the safety extension unit.
- 3) Locate the excess RIO cable in a space under the R800CPU module.

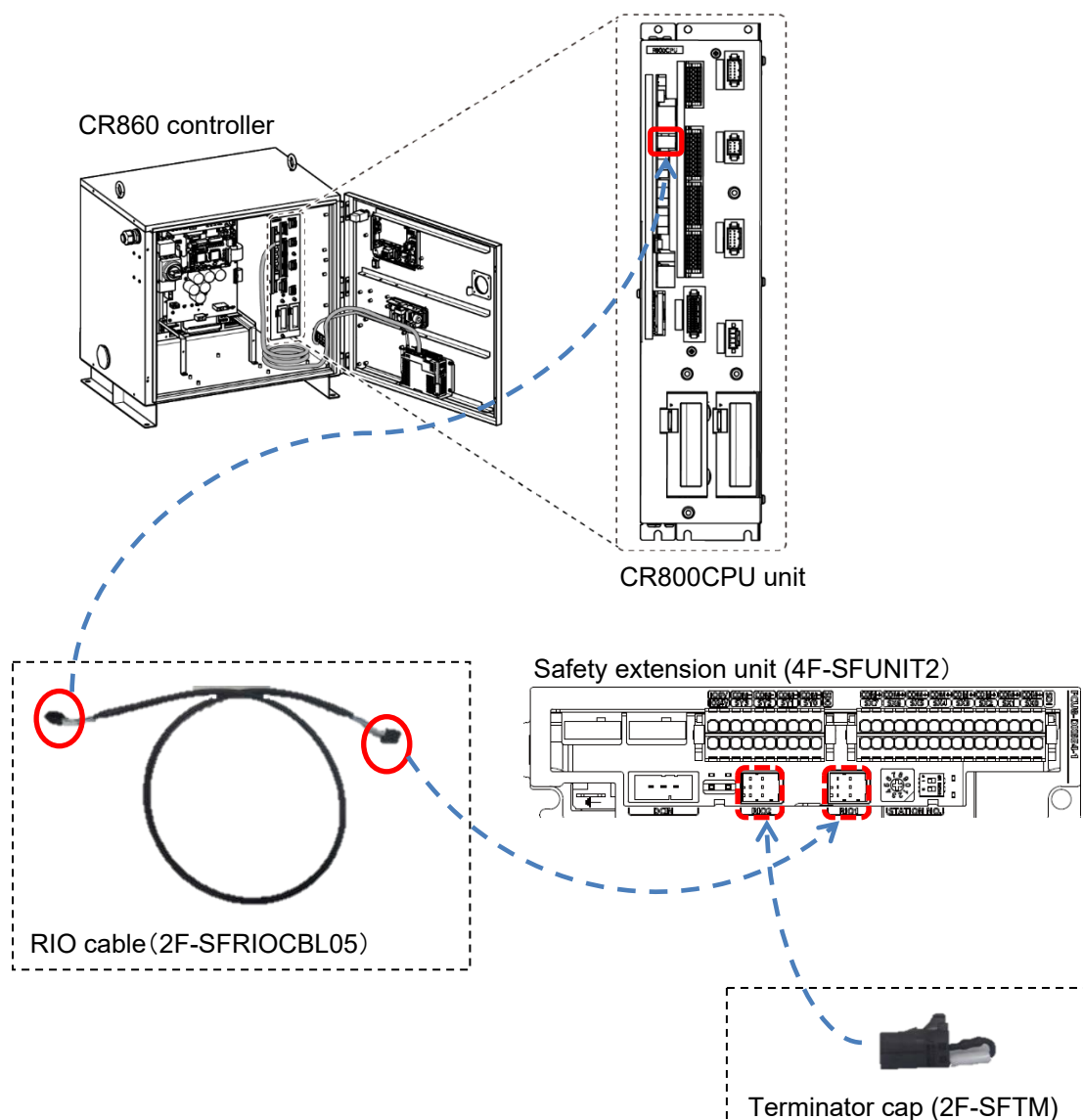


Fig. 2-10 Connection to the CR860 controller

(3) Station number

- Set 【Station Number Group Settings Switch】 to OFF for both 1 and 2.
- Set 【Station No. Setting Switch】 to Station No. 4.

If the switch is incorrectly set, an error H2261 occurs.

STATION No. (Station No. group setting switch)



STATION No. (Station No. setting switch)

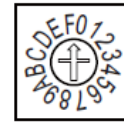
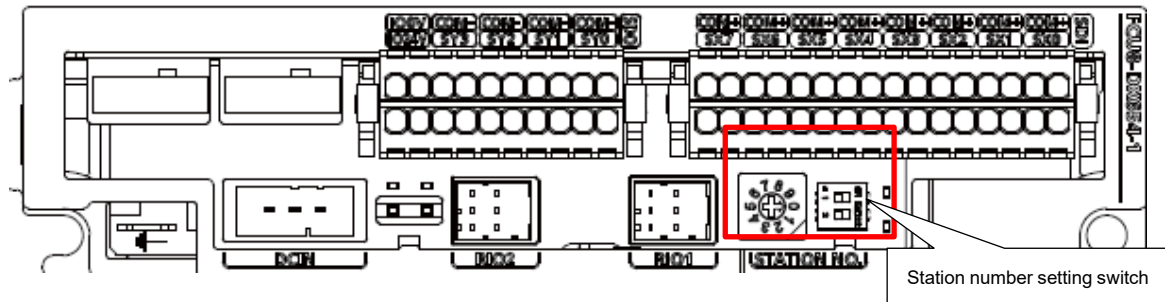


Fig. 2-11 Station number setting switch

2.3.4 Connector and cable



Caution

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

To assemble the cables to connect to the DCIN connectors, use the included connector set.

Tab. 2-6 Connector and cable

No.	Connector	Accessories needed	Description			Recommended cable
1	DCIN	2F-SFDCINCON	Manufacturer	Model	Qty.	Conductor area: 0.5 to 1.42 mm ² , (20 to 16 AWG) Sheath diameter: 1.8 to 2.8 mm With shields
			TE Connectivity	Connector 2-178288-3	1	
			TE Connectivity	Contact 1-175218-5	3	

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

Spare parts that are required/recommended for maintenance are indicated below.

Only purchase parts directly from specified vendors or the Mitsubishi Electric Service Department.

No.	Name	Type	Qty.	Manufacture	Supplier
1	Control unit protection fuse (5A)	LM50	1	Daito Communication Apparatus Co., Ltd.	Mitsubishi Electric System & Service Co., Ltd.
2	I/O protection fuse (6.3A)	MP63	1	Daito Communication Apparatus Co., Ltd.	Mitsubishi Electric System & Service Co., Ltd.

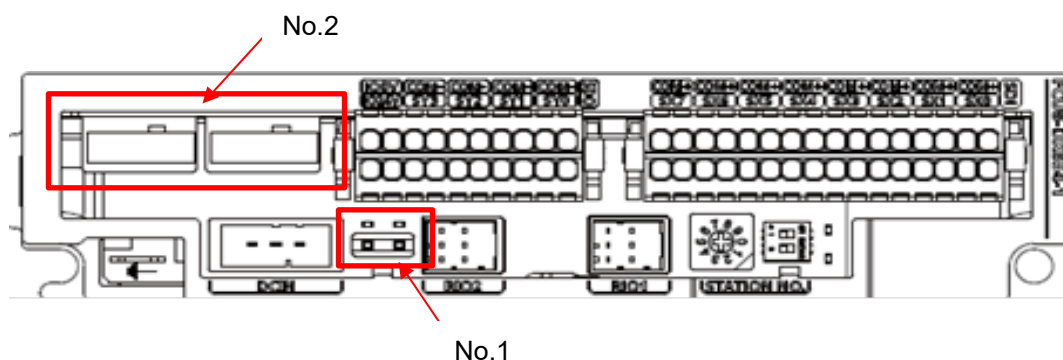


Fig. 2-12 Fuse position

3. SIGNALS AND WIRING

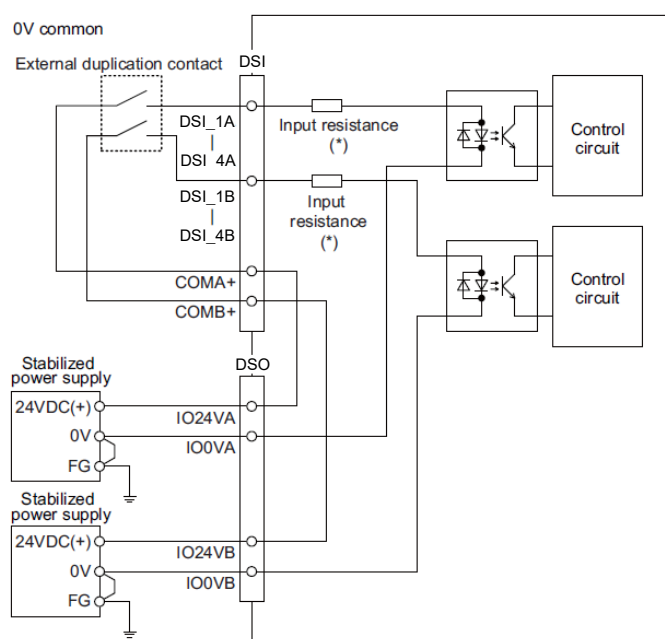
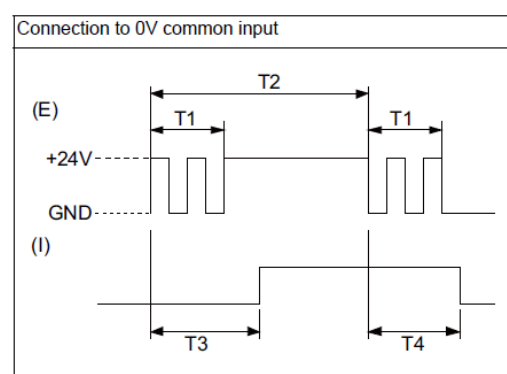
3.1 Description of Signals

3.1.1 Electrical specifications

(1) Safety DI input specifications

Tab. 3-1 Safety DI electrical specifications

Item	Specifications	Remarks
Input voltage at external contact ON	18 V to 25.2 V	-
Input current at external contact ON	3 mA or more	-
Input voltage at external contact OFF	3.8 V max.	-
Input current at external contact OFF	0.7 mA or less.	-
Input resistor	5 k Ω	-
Tolerable chattering time (T1)	3 ms	-
Input signal holding time (T2)	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(T3, T4)	3 ms to 16 ms	-
Machine side contact capacity	30 V or more, 16 mA or more	-



(E) : External signal, (I):Internal signal

Fig. 3-1 Safety DI electrical specifications

(2) Safety DO output specifications

Tab. 3-2 Safety DO electrical specifications

Item	Specifications	Remarks
Output type	Source	-
Output point	4 points	16 points for duplication
common control	Non	-
Common input voltage	24V+5%/-10%	-
Output Current	2A max	Up to 4A per point of common Up to 8A for the entire unit
Output voltage when ON	21.6V or more	-
Output voltage when OFF	2.0V or lower	-
Output delay time	400us	-

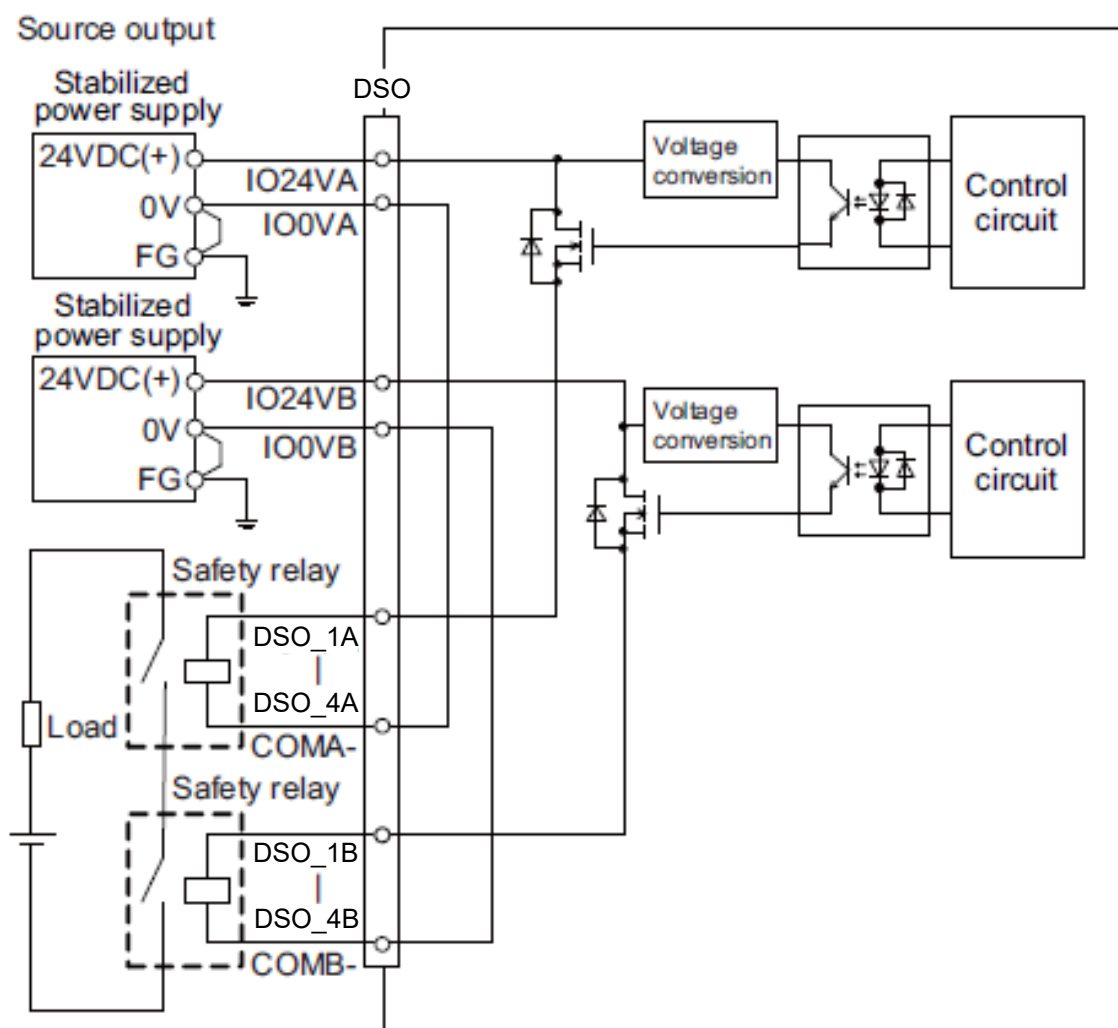


Fig. 3-2 Safety DO electrical specifications

(Note 1) When using an inductive load such as a relay, always connect a diode (voltage resistance 100V or more, twice or more the load current) in parallel to the load.

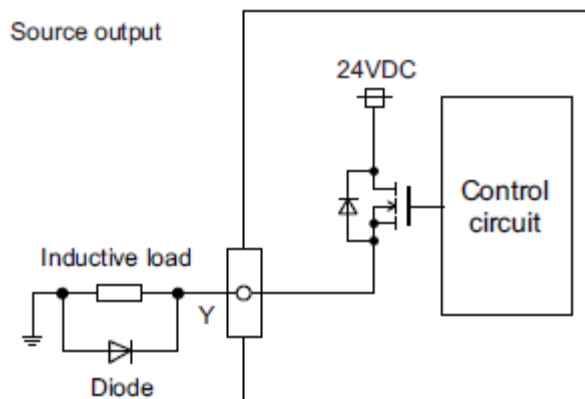


Fig. 3-3 Output signal connection example

(Note 2) When the rush current exceeds the maximum output current, always connect a protective resistor ($R=150\Omega$) serially to the load to suppress rush currents. Make sure that the current is less than the maximum output current including the momentary current.

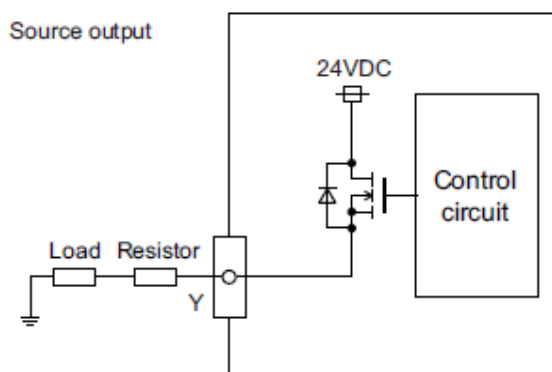


Fig. 3-4 Output signal connection example



Caution

1. When using an induction load, such as a relay, a diode must be connected in parallel to the load to suppress counter-electromotive force.
2. If the in-rush current exceeds the maximum output current, a protective resistor must be connected in series with the load to limit the in-rush current.

3.1.2 Signal operation

(1) DSI signal

The DSI signals are used to switch items that the safety monitoring function monitors. Each of the signals is duplex and the states of the two input signals need to be identical to each other. If the states of the two input signals are different, an error occurs.

A 100-ms continuous discrepancy between DSI_A and DSI_B causes error H222* (DSI mismatch) and the SS1 function stops the robot.

Tab. 3-3: DSI Input states

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

The DSI signal screen of RT ToolBox3 enables monitoring the input states of the DSI-A and DSI-B signals on it. Input the DSI signal individually from the peripheral devices and test to see if ON/OFF state of the signal or wiring is correct.

The DSI signal screen can be displayed by selecting [Online]→[Monitor]→[Signal]→[DSI signal] in Workspace.

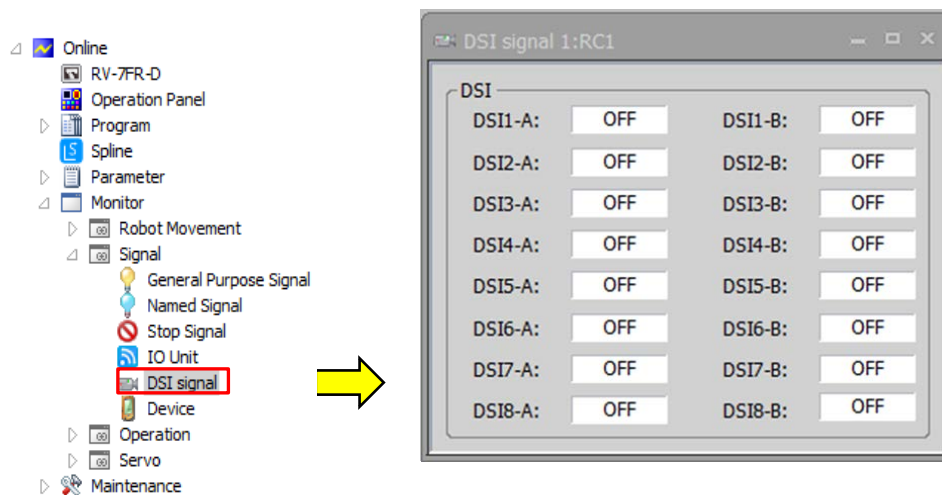


Fig. 3-5 DSI signal monitor

(2) DSO signal

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

Tab. 3-4: DSO output states

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

(3) Exclusive input/output signals

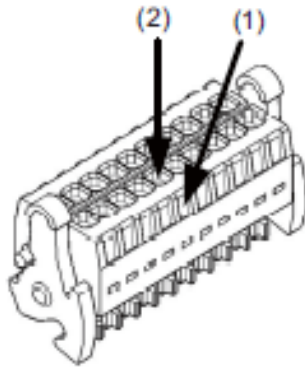
DSI signal and DSO signal are assigned to exclusive input/output signals 128 ~ 191. When the safety function is enabled and any exclusive input/output signals are assigned to 128 ~ 191, L.6641(Duplicate setting (special IN))

and L.6650 (Duplicate setting (special OUT)) occur.

3.2 Connector Wiring

[Mounting the wire]

- (1) Insert a slotted screwdriver (blade width: 2.5mm).
- (2) Insert the wire and then pull the screwdriver out.

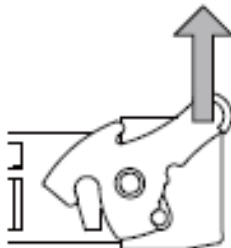


[Mounting the connector]

- (1) Push the connector to the lock lever position.



- (2) Push the right and left lock levers up simultaneously.

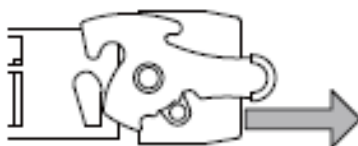


[Removing the connector]

- (1) Push the right and left lock levers down simultaneously.



- (2) Release the lock and pull the connector out.



If using the safety extension unit with the CR860, fix the cable using the studs or ribs inside the controller as shown in the figure below.

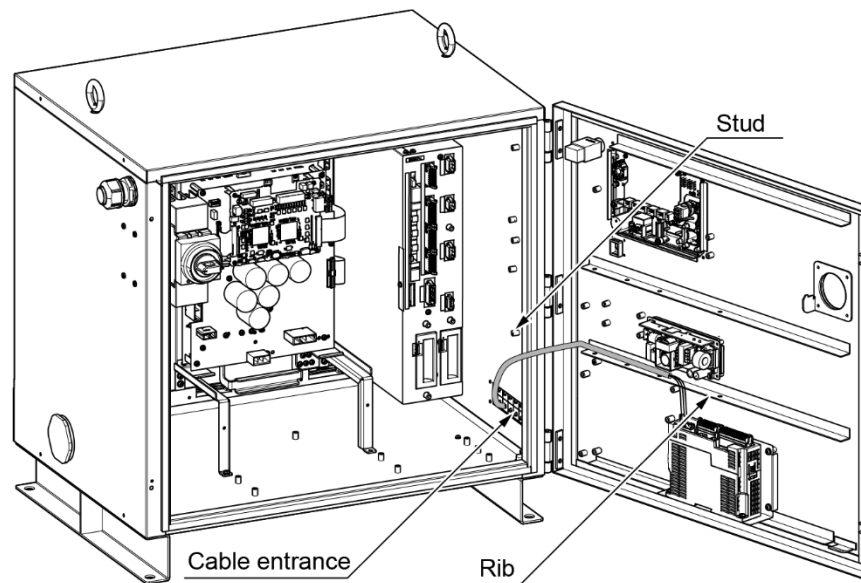


Fig. 3-6 Wiring inside the CR860 controller

When wiring cables to the outside of the controller, use the cable entrance on the side of the controller. For information on how to wire the cable through the cable entrance, refer to the following manual: "CR860 Controller Instruction Manual/Controller setup, basic operation, and maintenance"

3.3 Connectors and Pin Assignment

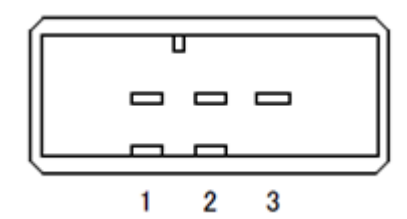


Fig. 3-7 DCIN connector

Tab. 3-5 DCIN pin assignment

Terminal name	Signal name	Signal description	Remarks
1	DC24V	+24 V power supply (input)	-
2	GND	0V	-
3	FG	Frame ground	-

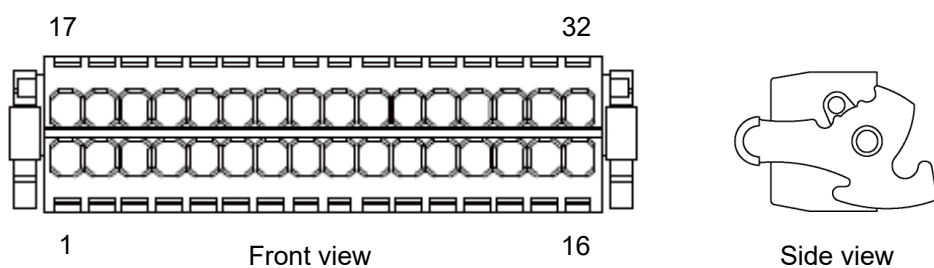


Fig. 3-8 DSI connector on the unit

Tab. 3-6 DSI pin assignment

DSI					
Terminal name	Signal name	Signal description	Terminal name	Signal name	Signal description
1	DSI_1A	Safety input	17	COMA+	+24 V output
2	DSI_1B	Safety input	18	COMB+	+24 V output
3	DSI_2A	Safety input	19	COMA+	+24 V output
4	DSI_2B	Safety input	20	COMB+	+24 V output
5	DSI_3A	Safety input	21	COMA+	+24 V output
6	DSI_3B	Safety input	22	COMB+	+24 V output
7	DSI_4A	Safety input	23	COMA+	+24 V output
8	DSI_4B	Safety input	24	COMB+	+24 V output
9	DSI_5A	Safety input	25	COMA+	+24 V output
10	DSI_5B	Safety input	26	COMB+	+24 V output
11	DSI_6A	Safety input	27	COMA+	+24 V output
12	DSI_6B	Safety input	28	COMB+	+24 V output
13	DSI_7A	Safety input	29	COMA+	+24 V output
14	DSI_7B	Safety input	30	COMB+	+24 V output
15	DSI_8A	Safety input	21	COMA+	+24 V output
16	DSI_8B	Safety input	32	COMB+	+24 V output

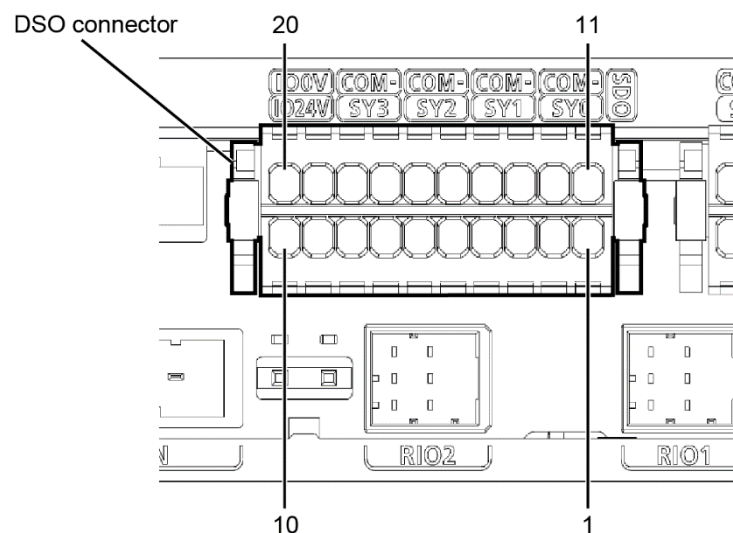


Fig. 3-9 DSO connector (when connected to the safety extension unit)

Tab. 3-7 DSO pin assignment

DSO					
Terminal name	Signal name	Signal description	Terminal name	Signal name	Signal description
1	DSO_1A	Safety relay output	11	COMA-	+24 V output 1A
2	DSO_1B	Safety relay output	12	COMB-	+24 V output 1B
3	DSO_2A	Safety relay output	13	COMA-	+24 V output 2A
4	DSO_2B	Safety relay output	14	COMB-	+24 V output 2B
5	DSO_3A	Safety relay output	15	COMA-	+24 V output 3A
6	DSO_3B	Safety relay output	16	COMB-	+24 V output 3B
7	DSO_4A	Safety relay output	17	COMA-	+24 V output 4A
8	DSO_4B	Safety relay output	18	COMB-	+24 V output 4B
9	IO24VA	24 V input(COMA)	19	IO0VA	External power supply +24 V ground
10	IO24VB	24 V input(COMB)	20	IO0VB	External power supply +24 V ground

3.4 Input Signal Connection Example

Fig. 3-9 shows a signal connection example. Devices to be connected depend on the user's system configuration.

<Safety DI connection example>

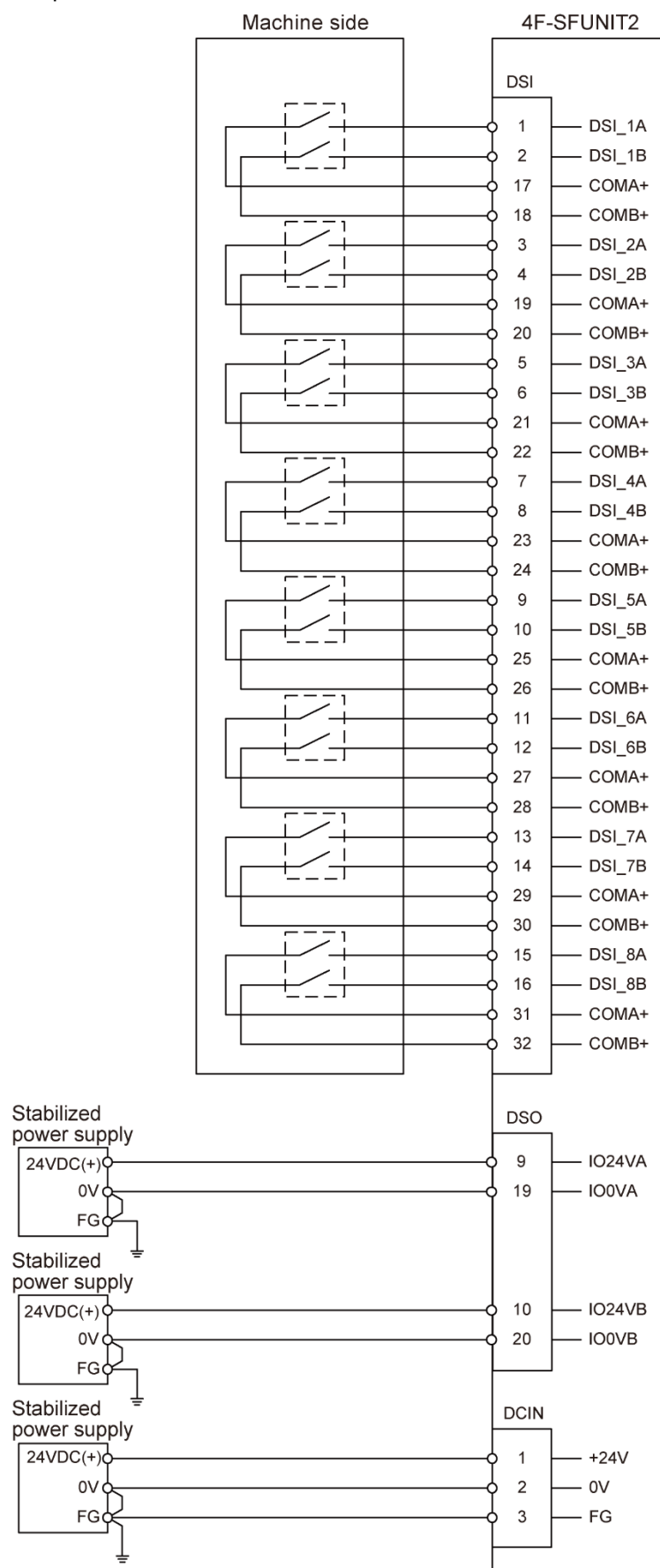


Fig. 3-10 Input signal connection example

<Safety DO connection example>

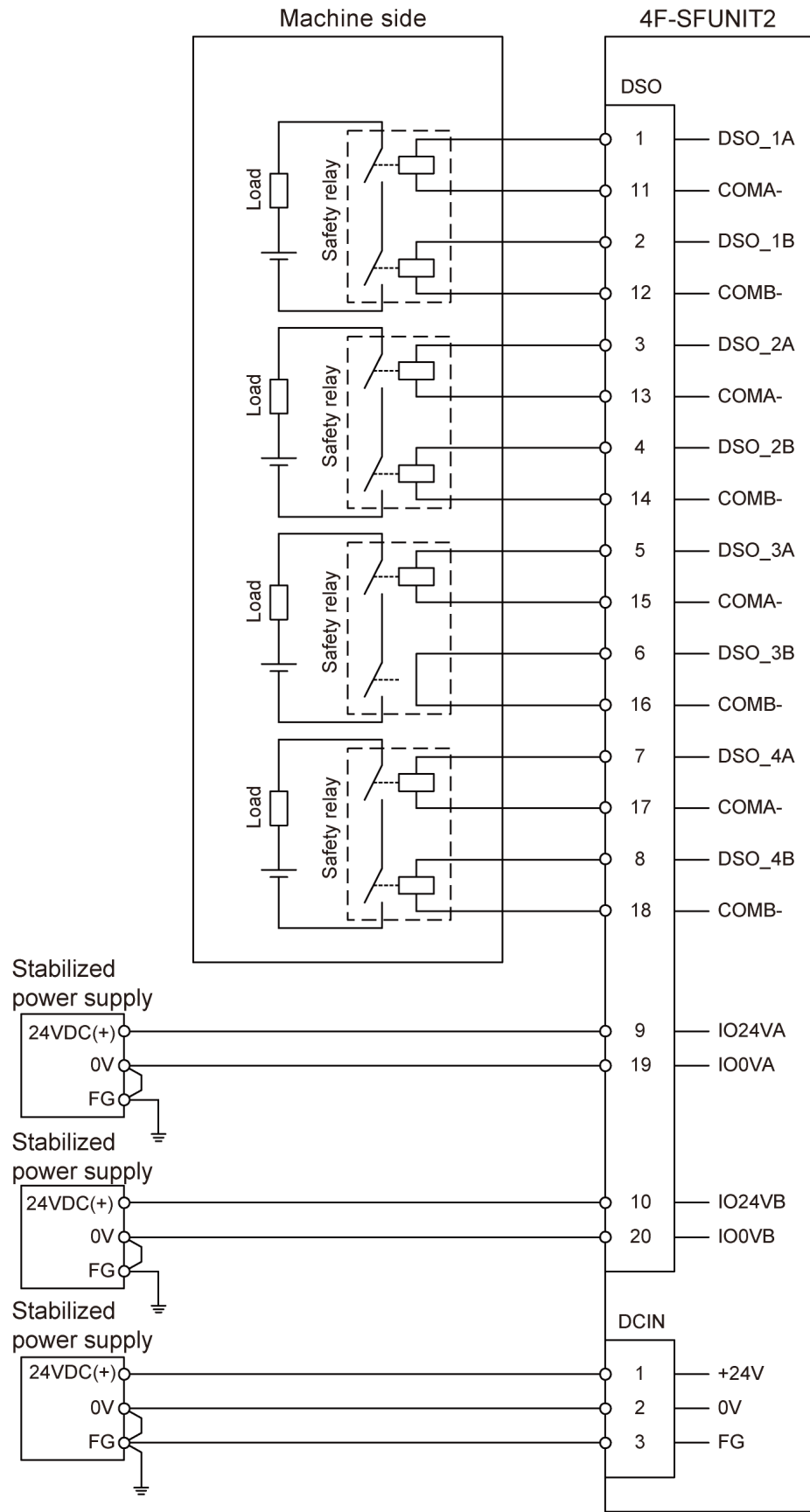


Fig. 3-11 Output signal connection example

3.5 Measures to Prevent Static Electricity and Noise

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

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

4. SAFETY MONITORING FUNCTIONS

4.1 Safety Monitoring Functions Overview

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

Tab. 4-1 Safety Monitoring Functions Overview

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

■ Restrictions

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

- Parallel I/O interface (2A-RZ361, 2A-RZ371)
- Controller CPU drive mode function
- Machine lock function
- Pseudo-input function
 - * The pseudo-input function can be used in RT ToolBox3 simulations.
- CPU standalone mode function

4.1.1 Simulation

You can check operation of safety monitoring function with simulation on RT ToolBox3/RT ToolBox3 Pro.
(This simulation is not available on RT toolBox3 mini.)

Safety input (DSI) is assigned as following table. Switch DSI using Pseudo-input.

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

See "RT ToolBox3/RT ToolBox3 mini User's Manual" for details on using simulation and pseudo-input.

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] -> [Safety option] and then select an applicable screen, which enables configuring and changing parameters concerning the safety monitoring function.

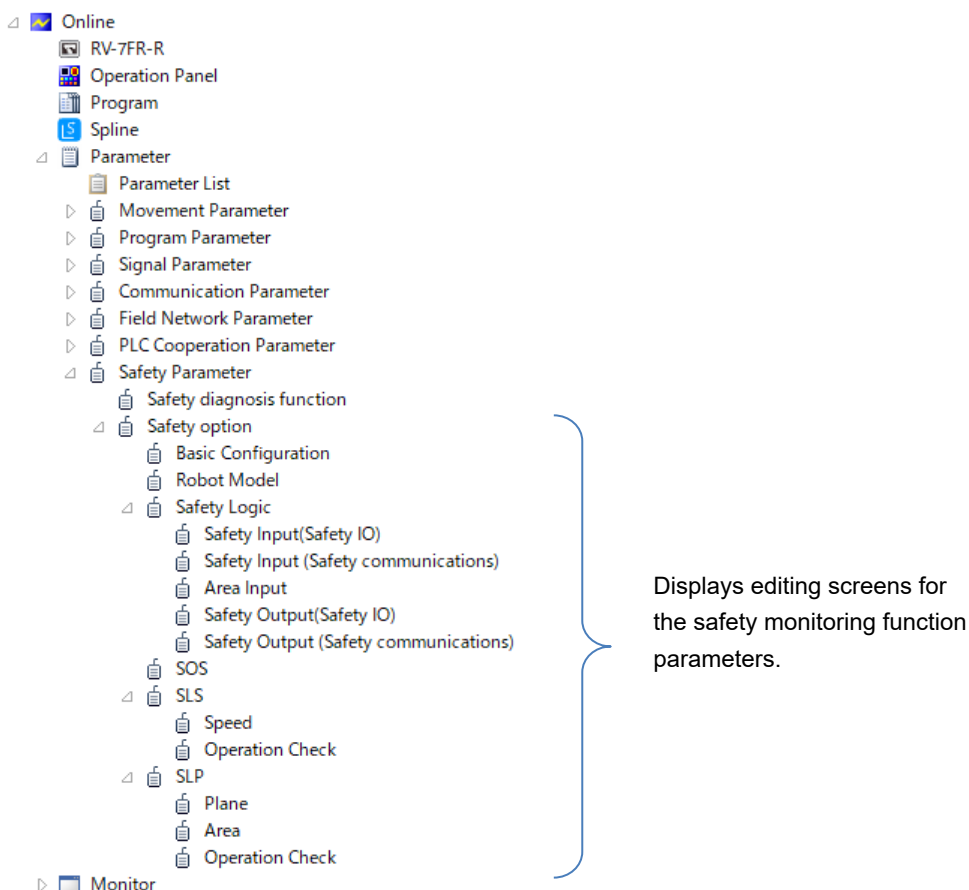


Fig. 4-1 Editing screen for the safety monitoring function parameters

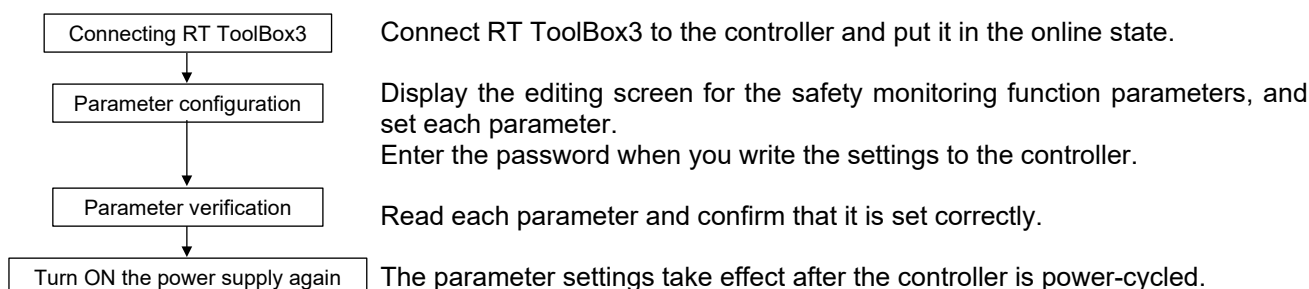


Caution

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

(2) Parameter setting procedure

Set the parameters in the following steps.



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] -> [Safety option] -> [Basic Configuration].

(Robots incompatible with the safety monitoring function do not have [Safety Parameter] in the [Movement Parameter] tree.)

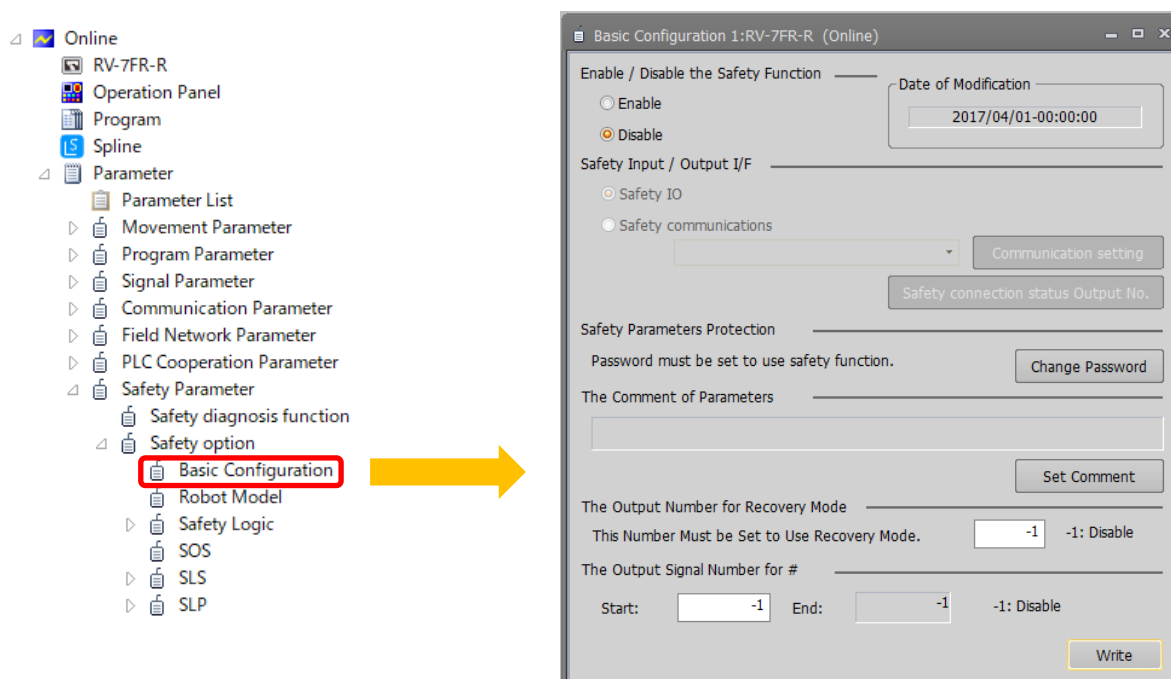
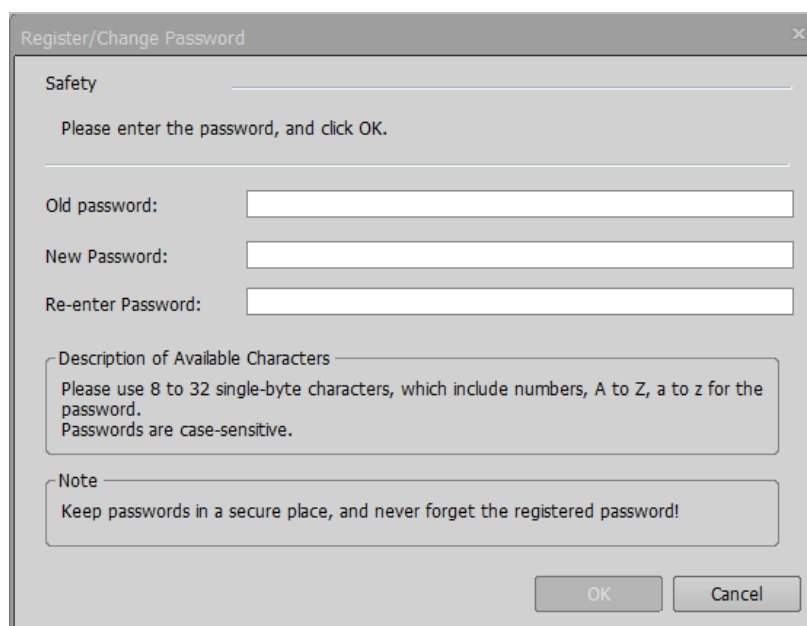


Fig. 4-2: Basic Configuration screen

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



The dialog box is titled "Register/Change Password" and has a close button (X) in the top right corner. It contains the following elements:

- A "Safety" label followed by a horizontal line.
- Instructional text: "Please enter the password, and click OK."
- Three input fields labeled "Old password:", "New Password:", and "Re-enter Password:".
- A section titled "Description of Available Characters" containing the text: "Please use 8 to 32 single-byte characters, which include numbers, A to Z, a to z for the password. Passwords are case-sensitive."
- A "Note" section containing the text: "Keep passwords in a secure place, and never forget the registered password!"
- Two buttons at the bottom right: "OK" and "Cancel".

Fig. 4-3 Register/Change Password screen

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



Caution

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

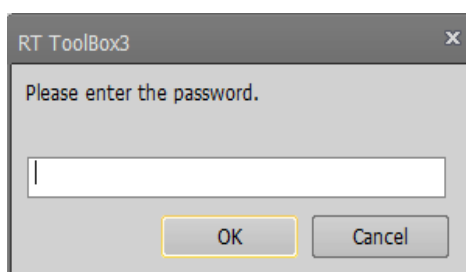


Caution

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

(3) Entering password

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



The screen is titled "RT ToolBox3" and has a close button (X) in the top right corner. It contains the following elements:

- Instructional text: "Please enter the password."
- A single-line password input field.
- Two buttons at the bottom: "OK" and "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]→[Parameter]→[Safety Parameter]→[Safety option]→[Basic Configuration] in Workspace.

Select "Enable" under "Enable / Disable the Safety Function" (for RT ToolBox3 Ver. 1.90U or later).

Select "Safety IO" under "Safety Input / Output I/F".

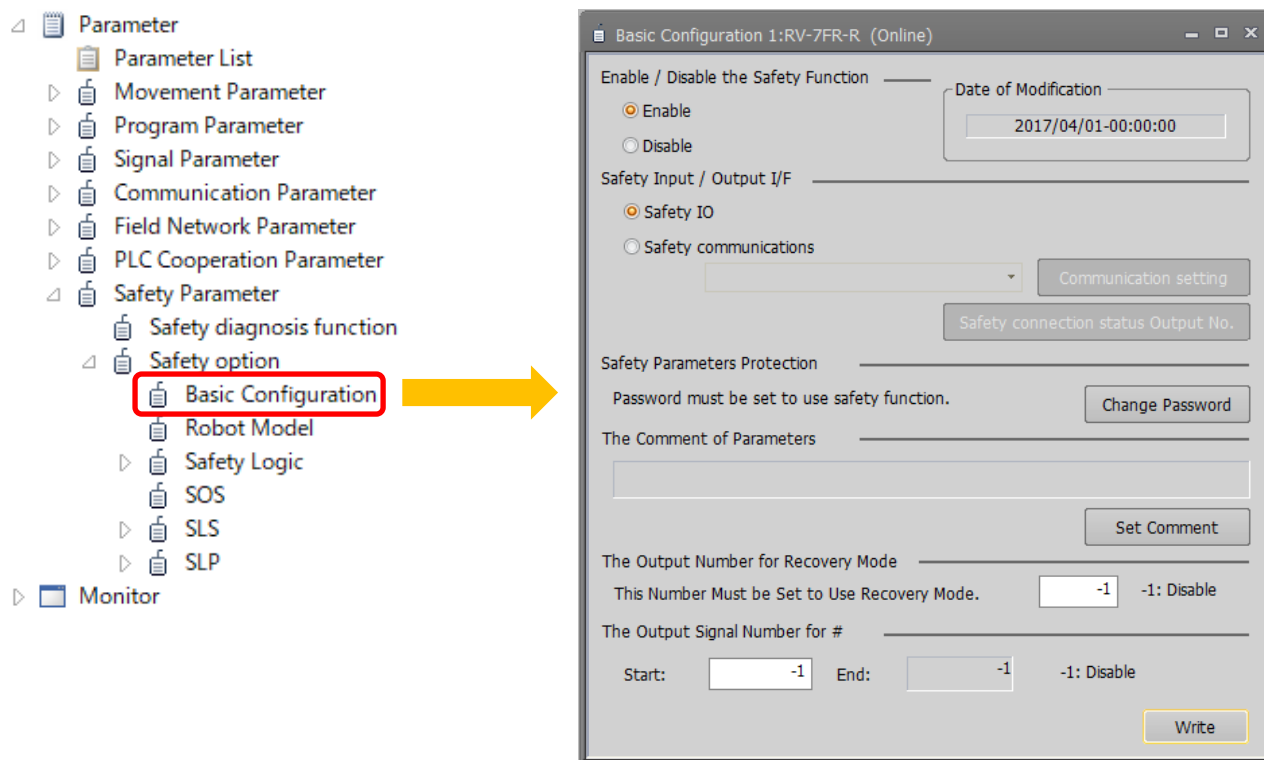


Fig. 4-5: Basic Configuration screen



Caution

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



Caution

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

4.2.5 Recovery mode

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

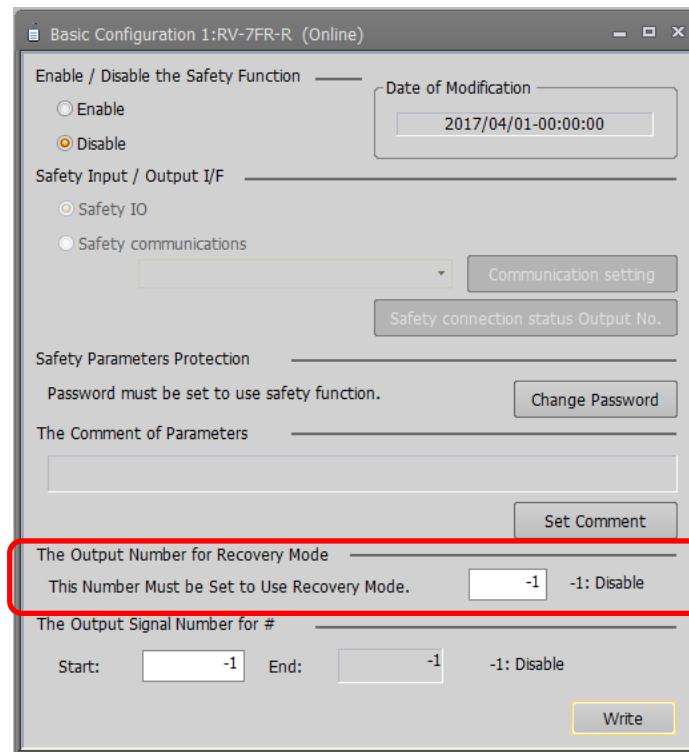
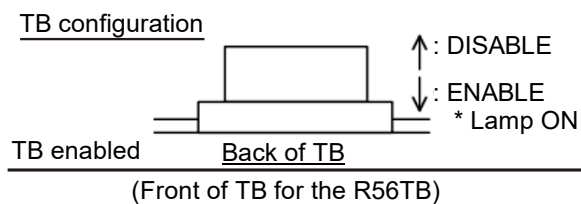


Fig. 4-6: Output Number for Recovery Mode setting screen

If the robot intrudes into a restricted area while SLP is enabled, resetting the error requires moving the robot outside the area. However, the servo-on operation cannot be performed while the error is occurring, which makes it impossible to operate the robot by the JOG operation.

In such a case, the recovery mode may be used. The recovery mode enables a temporary reset of the error and operation of the robot with the TB.

<When R32TB is used>



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

The procedure above temporarily resets the error.

Recovery mode can be disabled using any of the following methods:

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

Errors will still occur after recovery mode is disabled if they have not been resolved.

Press and hold the [RESET] key or [CAUTION] key when moving the robot in Jog operation mode.



Caution

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

4.2.6 Parameter CRC output number

(1) Overview

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

(2) When is a CRC calculated?

A CRC of the parameter file is calculated:

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

* Even if the safety monitoring functions are disabled, a CRC is calculated and sent to the dedicated output signals.

* When the parameter file is written to the controller with the RT ToolBox3 restoration function, a CRC is calculated when the controller is power-cycled. The CRC becomes the same as one calculated when the written parameter file is backed up.

(3) Dedicated output signals

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

Example)

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

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

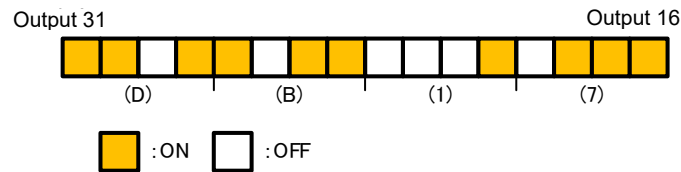
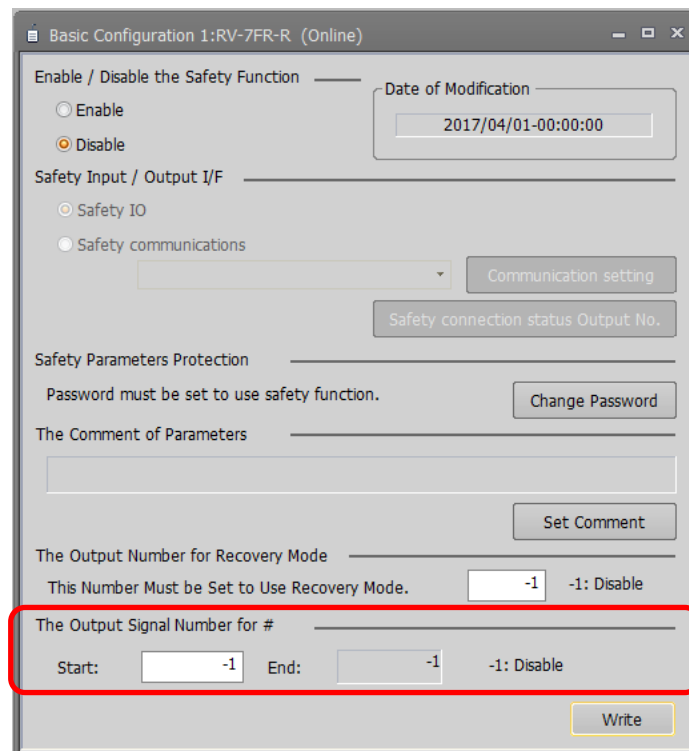


Fig. 4-7: Parameter file CRC output number

4.3 Defining 3D Models

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

4.3.1 3D Monitor

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

(1) Displaying the 3D Monitor

Double-clicking [3D Monitor] in Workspace opens the 3D Monitor screen.

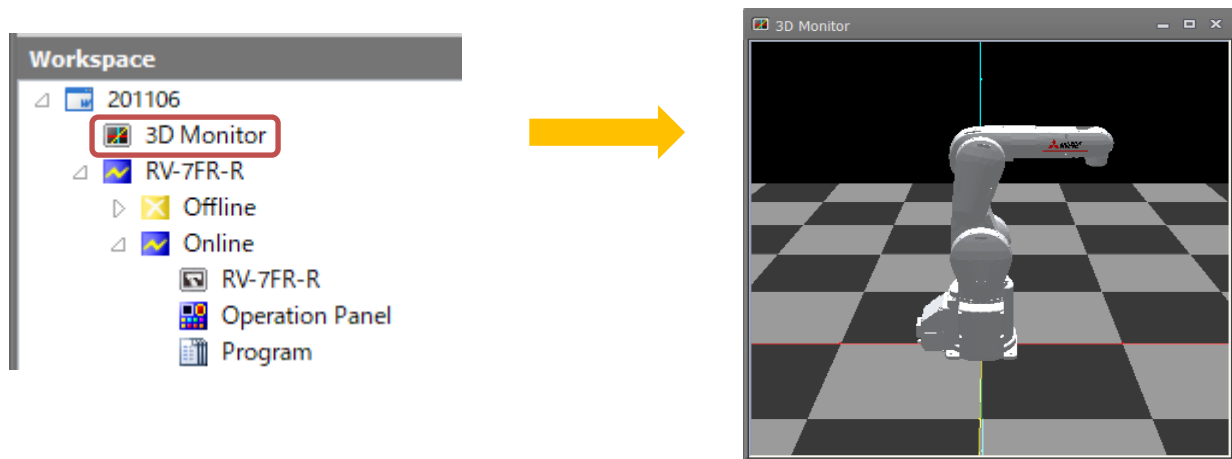


Fig. 4-8: Displaying the 3D Monitor

(2) Layout tree

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

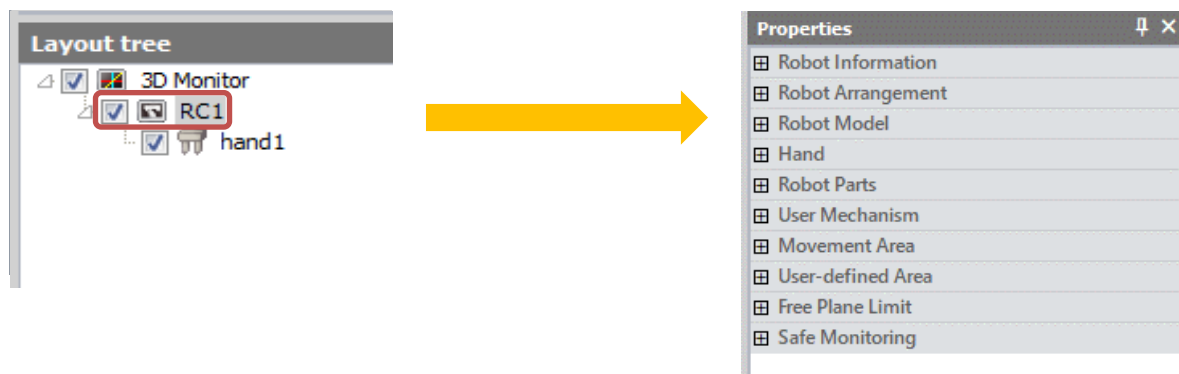


Fig. 4-9: Layout tree

(3) Properties

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

(a) Arm model

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

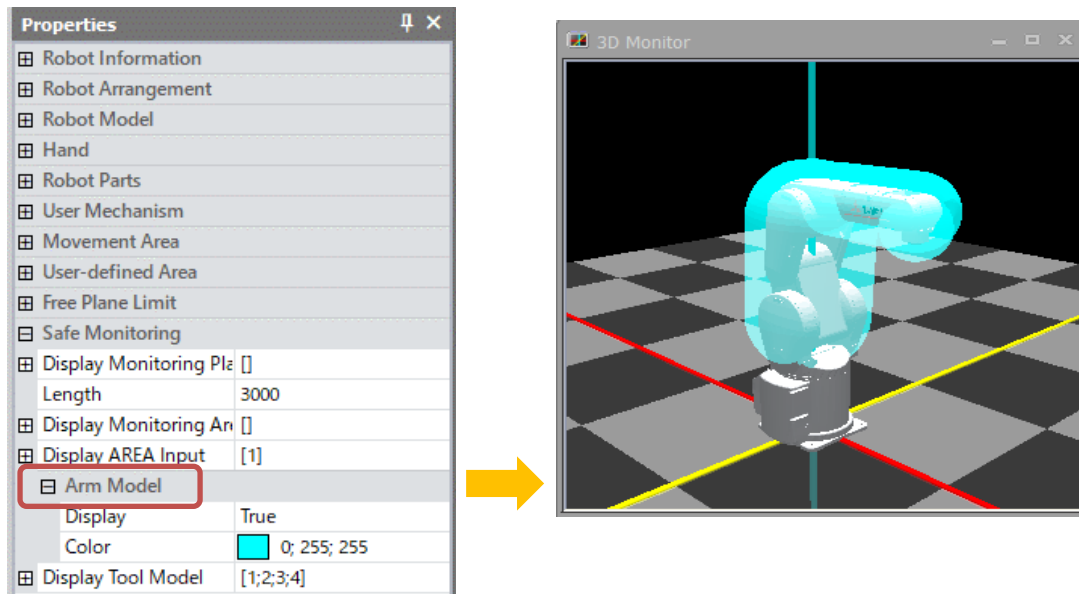


Fig. 4-10: Arm model

(b) Tool model

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

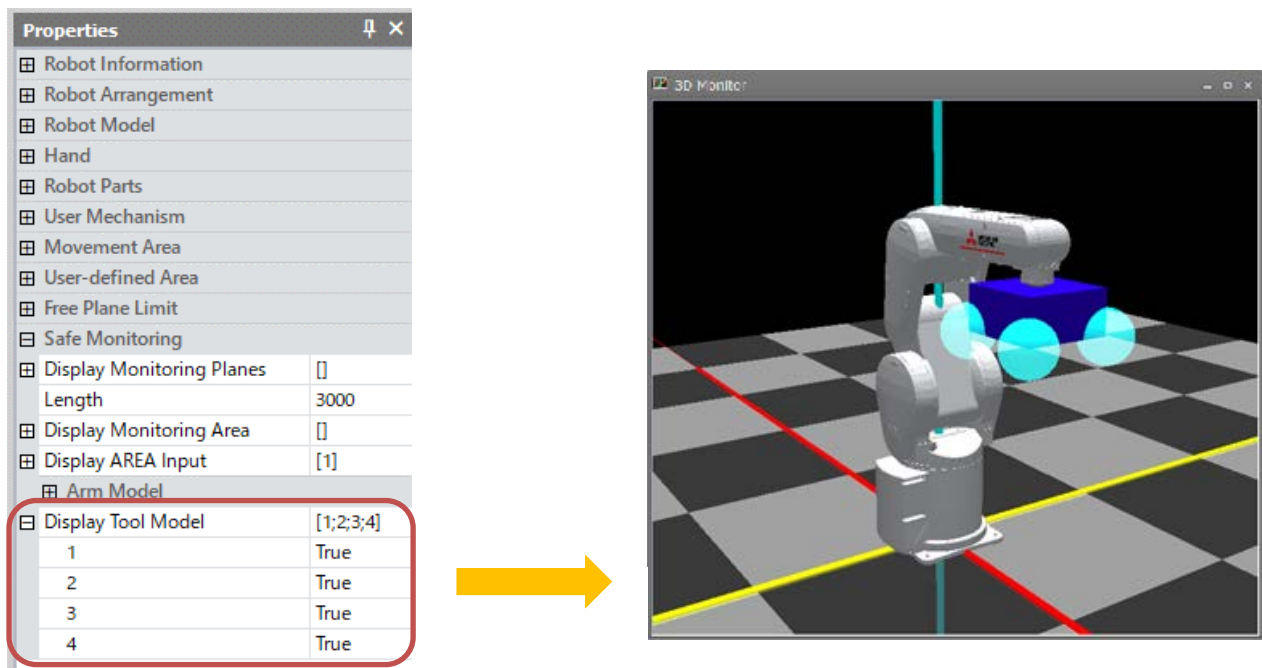


Fig. 4-11: Tool model

(c) Safety monitoring plane

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

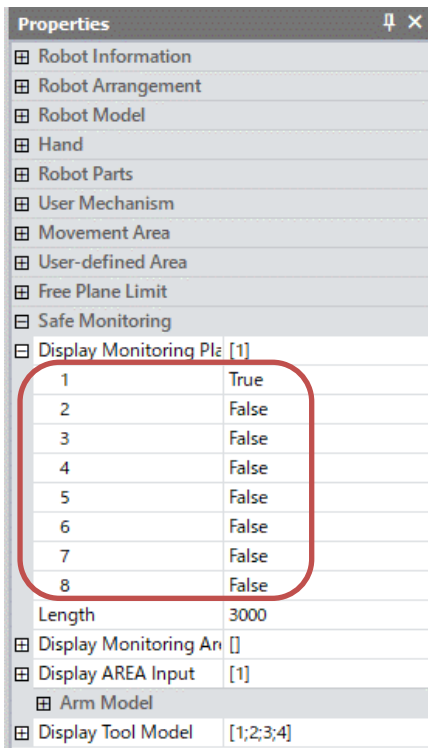
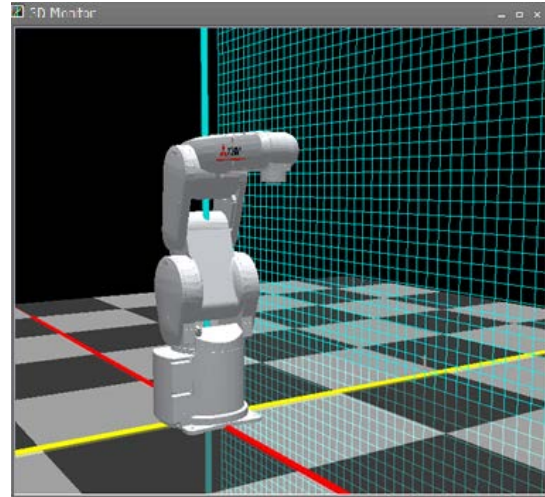


Fig. 4-12: Safety monitoring plane

(d) Safety monitoring area

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

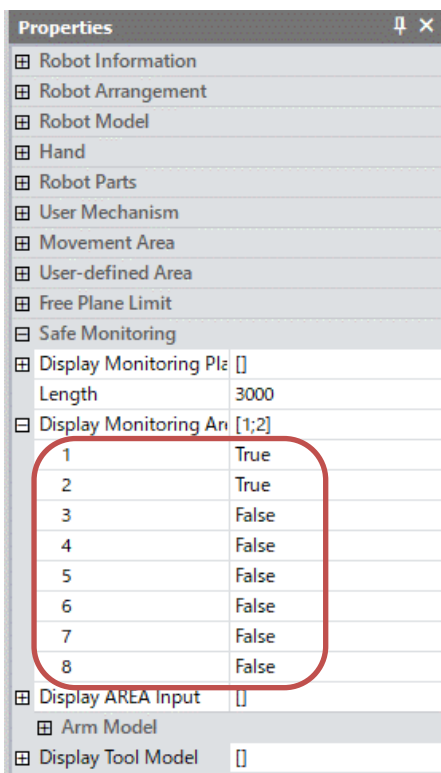
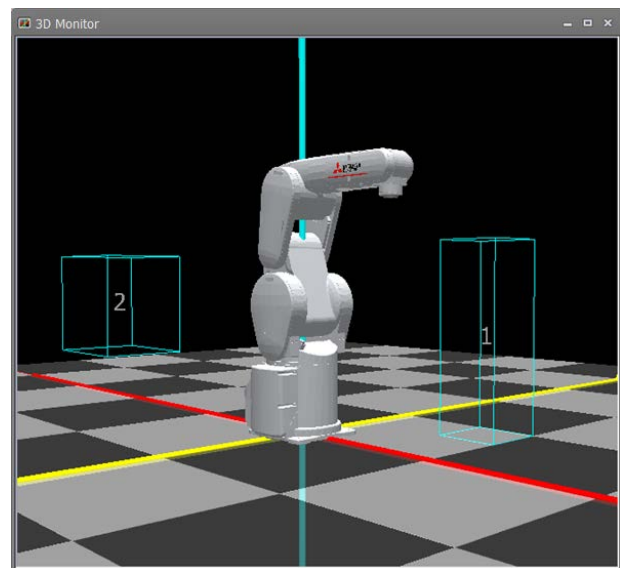


Fig. 4-13: Safety monitoring area

4.3.2 Arm model

The shape of the robot arm has been modeled with sphere models and cylinder models and the robot model is used for judging the speed and area of the robot.

The model can be used as it is in the initial condition. However, when cables, solenoid valves, or etc. are attached to the robot arm, resize the model as necessary.

(1) Changing monitoring models

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

Moving the slider bar resizes the monitoring model.

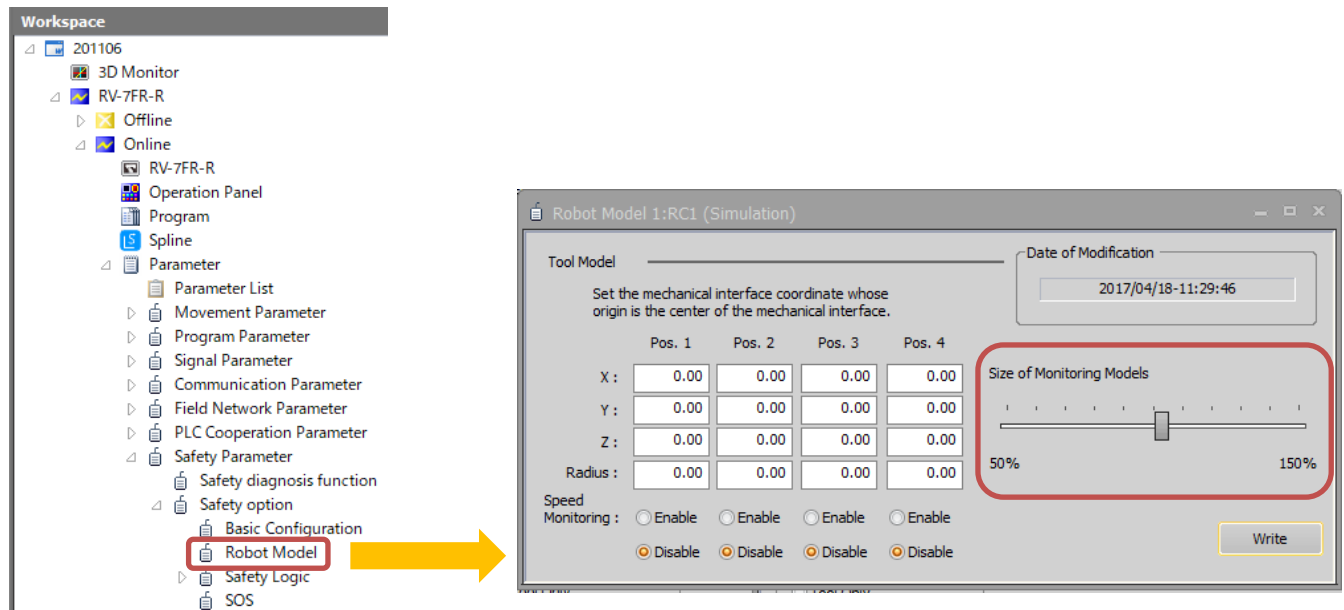
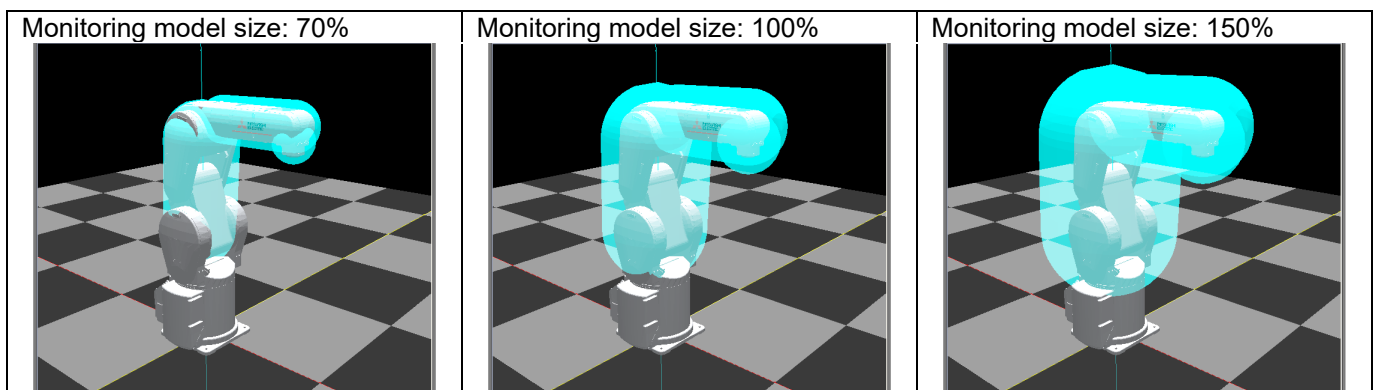


Fig. 4-14: Changing monitoring models

4.3.3 Tool model

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

(1) Changing monitoring models

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



Caution

When using the safely-limited speed function (SLS), set the center point of the tool monitoring model to the position where the maximum speed is reached when the robot moves.

(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.

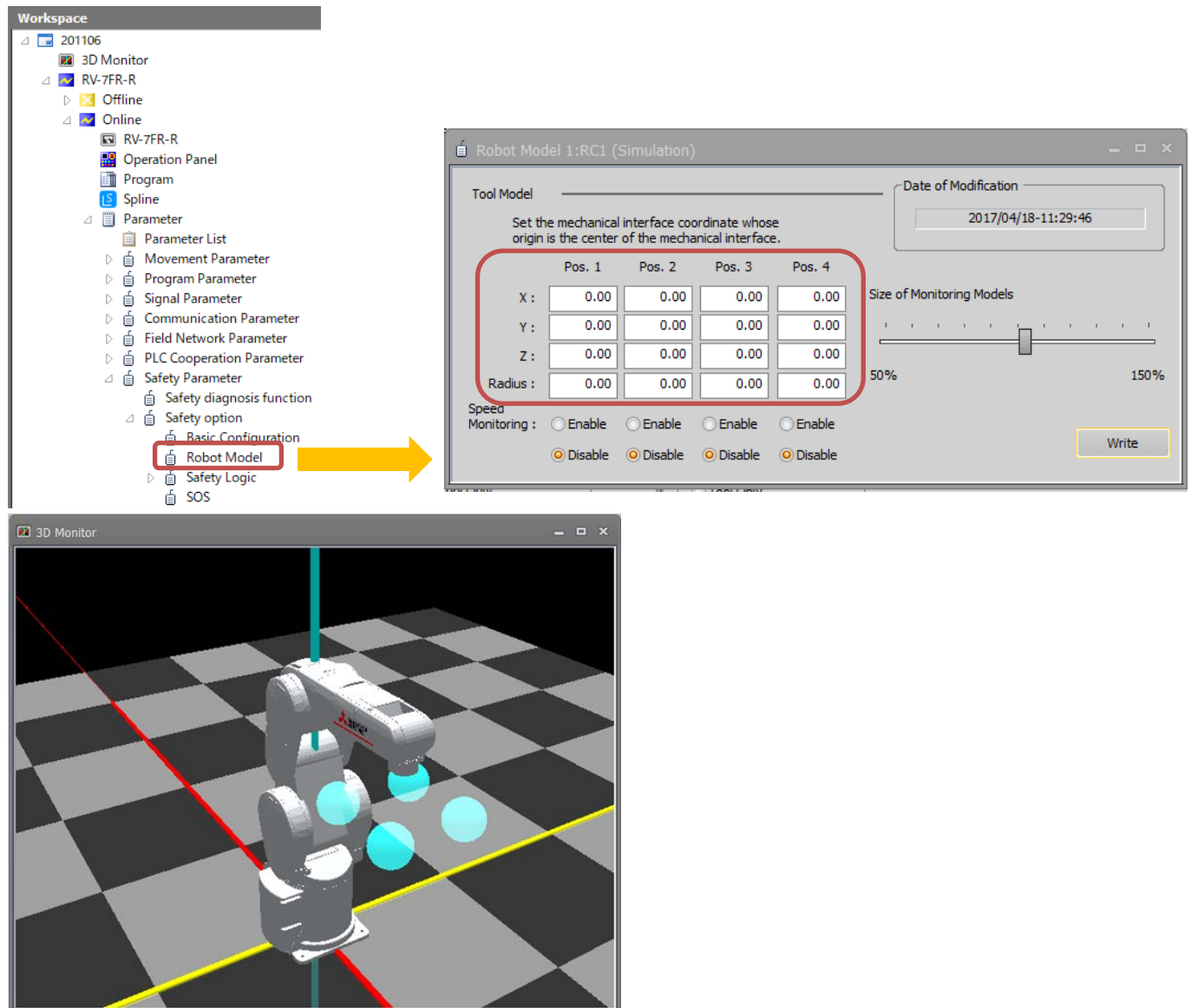


Fig. 4-15: Tool model

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.

(Details on DSI Input, Area Input, Logic Input, and Mode Input are provided in this section.)

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

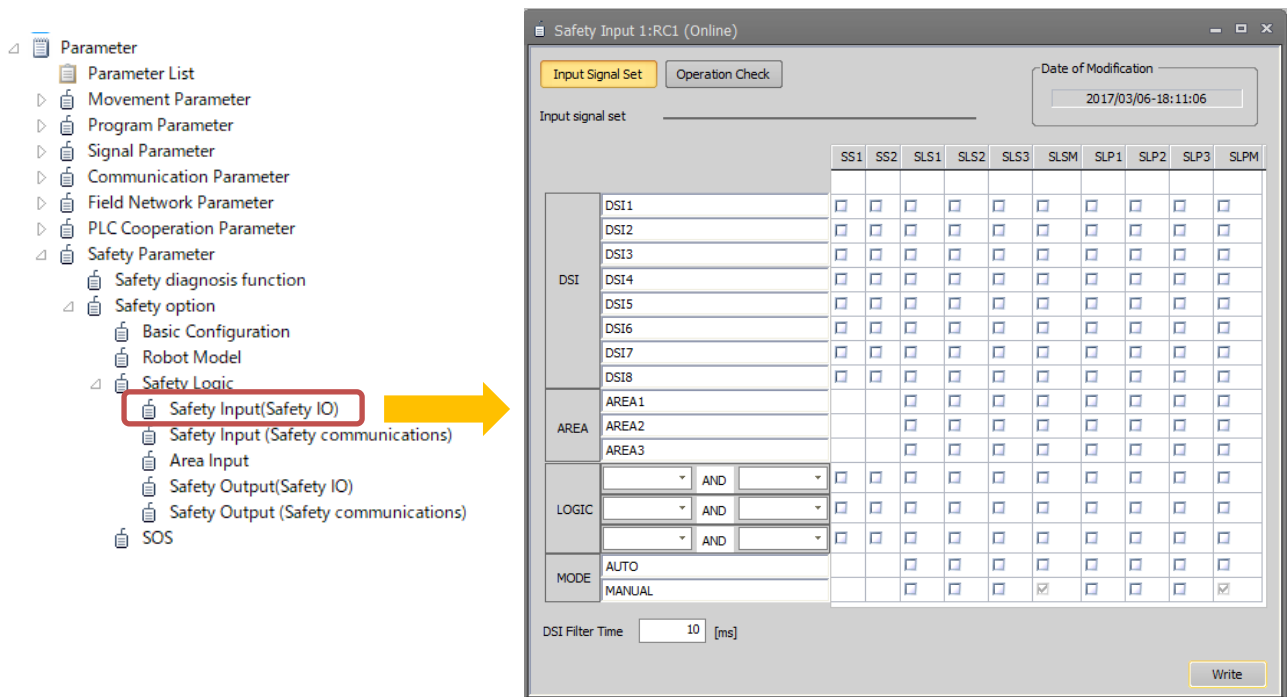


Fig. 4-16: Safety monitoring logic configuration screen

Tab. 4-2 Explanation of terminology

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

The matrix in the Safety Input screen has rows representing safety inputs (DSI, AREA, LOGIC, MODE). The columns represent safety monitoring start commands for each safety function (SS1, SS2, SLS1, SLS2, SLS3, SLSM, SLP1, SLP2, SLP3, SLP4).

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.

The screenshot shows the 'Safety Input 1:RC1 (Online)' window. The 'Input Signal Set' tab is active. The matrix shows the following configuration for Example 1:

	SS1	SS2	SLS1	SLS2	SLS3	SLSM	SLP1	SLP2	SLP3	SLP4
DSI1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
DSI2	☐	☐	☒	☐	☐	☐	☐	☐	☐	☐
DSI3	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
DSI4	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
DSI5	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
DSI6	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
DSI7	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
DSI8	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
AREA1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
AREA2	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
AREA3	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
LOGIC	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
MODE	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

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.

The screenshot shows the 'Safety Input 1:RC1 (Online)' window. The 'Input Signal Set' tab is active. The matrix shows the following configuration for Example 2:

	SS1	SS2	SLS1	SLS2	SLS3	SLSM	SLP1	SLP2	SLP3	SLP4
DSI1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
DSI2	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
DSI3	☐	☐	☒	☒	☐	☐	☒	☐	☐	☐
DSI4	☐	☐	☐	☐	☒	☐	☐	☐	☐	☐
DSI5	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
DSI6	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
DSI7	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
DSI8	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
AREA1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
AREA2	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
AREA3	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
LOGIC	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
MODE	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

DSI Filter Time: 10 [ms]

Write

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

(1) DSI Input

(a) Overview

The DSI input is enabled or disabled depending on the states of redundant signals input to the DSI connector of the safety extension unit. Input of up to eight points is supported. Tab. 4-3 shows the relation of the DSI Input to DSInA and DSInB.

Tab. 4-3: DSI Input states

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

(b) Timing diagram

① Normal operation

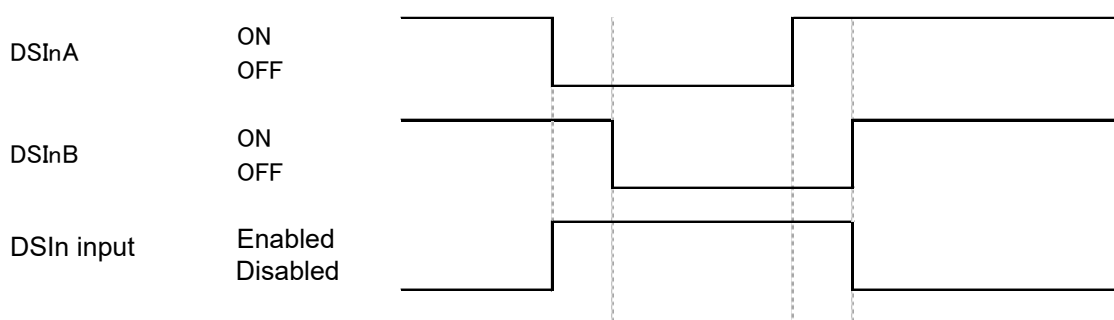


Fig. 4-19: DSIn timing diagram

② When a discrepancy between DSInA and DSInB is detected

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

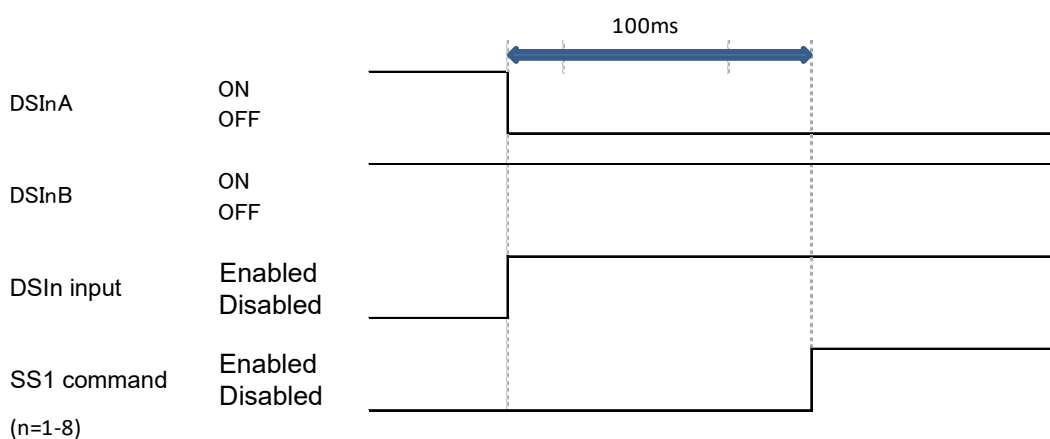


Fig. 4-20: DSIn timing diagram

(c) DSI filter configuration

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

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

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

Fig. 4-21: DSI filter configuration

The DSI filter time and DSIn1 input (enabled/disabled) are shown in the following diagram:

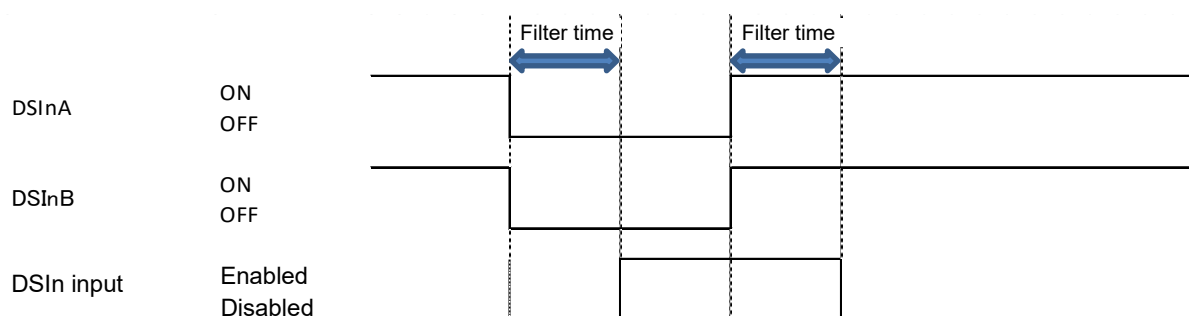


Fig. 4-22: Timing diagram of the DSI filter time and DSIn1 input

(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.

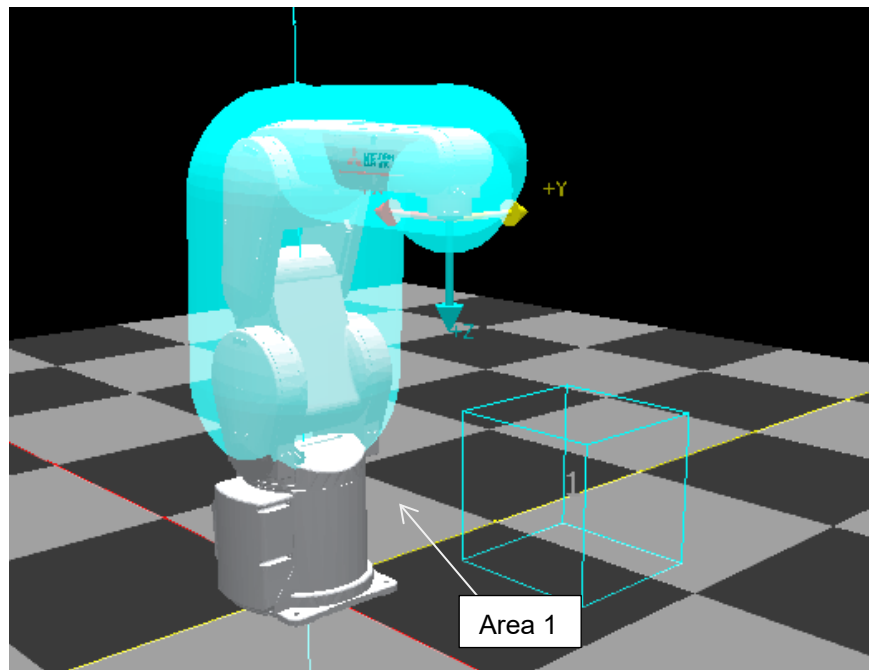


Fig. 4-23: Area input

(b) Timing diagram

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

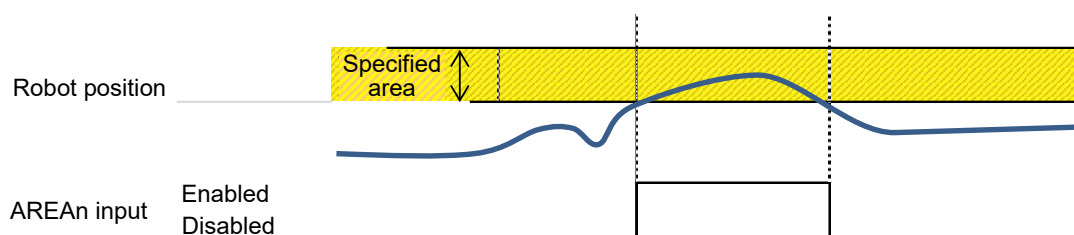


Fig. 4-24: AREA Input timing diagram

(c) Configuring Area Input monitoring conditions

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

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

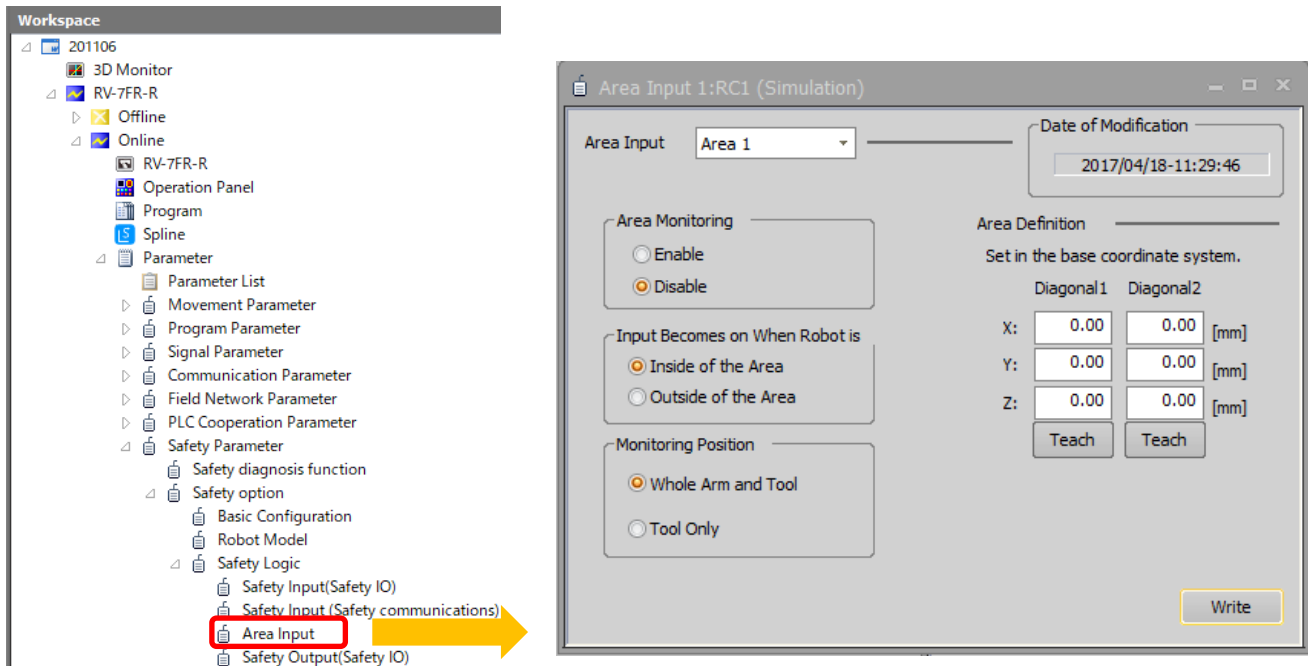


Fig. 4-25: Area Input

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.

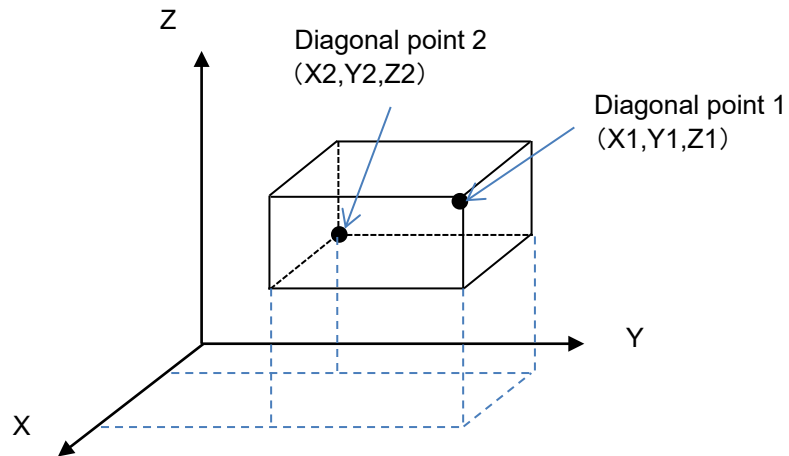


Fig. 4-26: Area Input area Definition

(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 DSI_n inputs (n = 1 to 8) and AREA_m 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 option] -> [Safety Logic] -> [Safety Input (Safety IO)] 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.

Safety Input 1:RC1 (Online)

Input Signal Set Operation Check Date of Modification: 2017/03/06-18:11:06

Input signal set

		SS1	SS2	SLS1	SLS2	SLS3	SLSM	SLP1	SLP2	SLP3	SLPM
DSI	DSI1	☐	☐	☒	☐	☐	☐	☐	☐	☐	☐
	DSI2	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	DSI3	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	DSI4	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	DSI5	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	DSI6	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	DSI7	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	DSI8	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
AREA	AREA1	☐	☐	☒	☐	☐	☐	☐	☐	☐	☐
	AREA2	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	AREA3	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
LOGIC	DSI1 AND AREA1	☐	☐	☒	☐	☐	☐	☐	☐	☐	☐
		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
MODE	AUTO	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	MANUAL	☐	☐	☐	☐	☒	☐	☐	☐	☒	

DSI Filter Time: 10 [ms]

Write

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 selector switch state (MANUAL or AUTO) of the robot controller. It enables switching automatically the safety monitoring functions based on the mode selector switch state. Configure the safety monitoring functions to always enable in the AUTO mode or MANUAL mode regardless of DSI Input, Area Input, or Logic Input. The MANUAL mode always enables SLSM and SLPM.

Safety Input 1:RC1 (Online)

Input Signal Set Operation Check Date of Modification: 2017/03/06-18:11:06

Input signal set

		SS1	SS2	SLS1	SLS2	SLS3	SLSM	SLP1	SLP2	SLP3	SLPM
DSI	DSI1	☐	☐	☐	☐	☐	☐	☒	☐	☐	☐
	DSI2	☐	☐	☐	☐	☐	☐	☒	☐	☐	☐
	DSI3	☐	☐	☐	☐	☐	☐	☒	☐	☐	☐
	DSI4	☐	☐	☐	☐	☐	☐	☒	☐	☐	☐
	DSI5	☐	☐	☐	☐	☐	☐	☒	☐	☐	☐
	DSI6	☐	☐	☐	☐	☐	☐	☒	☐	☐	☐
	DSI7	☐	☐	☐	☐	☐	☐	☒	☐	☐	☐
	DSI8	☐	☐	☐	☐	☐	☐	☒	☐	☐	☐
AREA	AREA1	☐	☐	☐	☐	☐	☐	☒	☐	☐	☐
	AREA2	☐	☐	☐	☐	☐	☐	☒	☐	☐	☐
	AREA3	☐	☐	☐	☐	☐	☐	☒	☐	☐	☐
LOGIC	<input type="text"/> AND <input type="text"/>	☐	☐	☐	☐	☐	☐	☒	☐	☐	☐
	<input type="text"/> AND <input type="text"/>	☐	☐	☐	☐	☐	☐	☒	☐	☐	☐
	<input type="text"/> AND <input type="text"/>	☐	☐	☐	☐	☐	☐	☒	☐	☐	☐
MODE	AUTO	☐	☐	☐	☒	☐	☐	☒	☐	☐	☐
	MANUAL	☐	☐	☐	☐	☒	☒	☐	☐	☐	☒

DSI Filter Time: 10 [ms]

Write

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, SS1, SS2, 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.

The screenshot shows the 'Safety Output(Safety IO) 1:RV-7FR-R (Online)' window. It features a 'Date of Modification' field set to '2020/11/26-16:01:01'. Below this is a table for configuring safety outputs. The table has columns for safety monitoring states (STO, SOS, SS1, SS2, SLS1, SLS2, SLS3, SLSM, SLP1, SLP2, SLP3, SLP4) and Area Inputs (AREA1, AREA2, AREA3). The rows represent DSO1 to DSO4, each with a 'LOGIC' dropdown (set to 'OR') and 'Active'/'Inactive' checkboxes. A 'Write' button is at the bottom right.

		STO	SOS	SS1	SS2	SLS1	SLS2	SLS3	SLSM	SLP1	SLP2	SLP3	SLP4	AREA1	AREA2	AREA3
DSO	DSO1	OR	Active	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
		OR	Inactive	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	DSO2	OR	Active	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
		OR	Inactive	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	DSO3	OR	Active	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
		OR	Inactive	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	DSO4	OR	Active	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
		OR	Inactive	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

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, SLP4) 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).

The screenshot shows the same 'Safety Output(Safety IO) 1:RV-7FR-R (Online)' window. In this example, the intersection of DSO2 and SOS is checked, indicating that DSO2 will be turned on when SOS is enabled. The 'Active' checkbox for DSO2 is checked, and the 'SOS' column for DSO2 is highlighted with a blue background.

		STO	SOS	SS1	SS2	SLS1	SLS2	SLS3	SLSM	SLP1	SLP2	SLP3	SLP4	AREA1	AREA2	AREA3
DSO	DSO1	OR	Active	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
		OR	Inactive	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	DSO2	OR	Active	☒	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
		OR	Inactive	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	DSO3	OR	Active	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
		OR	Inactive	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	DSO4	OR	Active	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
		OR	Inactive	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

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.

Safety Output(Safety IO) 1:RV-7FR-R (Online)

Output Signal Set Operation Check Date of Modification: 2020/11/26-16:01:01

LOGIC			STO	SOS	SS1	SS2	SLS1	SLS2	SLS3	SLSM	SLP1	SLP2	SLP3	SLP4	AREA1	AREA2	AREA3
DSO	DSO1	OR	☐	☐	☐	☐	☒	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
		AND	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	DSO2	OR	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☒	☐	☐
		AND	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	DSO3	OR	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
		AND	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	DSO4	OR	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
		AND	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Write

Fig. 4-31: Example of safety output configuration



Caution

Output settings for safety monitoring states SS1 and SS2 are supported by RT ToolBox3 Ver. 1.90U or later. To assign SS1 and SS2 to DSO outputs, use RT ToolBox3 Ver. 1.90U or later.



Caution

When SS1 and SS2 are assigned to DSO outputs, pressing [Write] on the Safety Output screen in RT ToolBox3 Ver. 1.82L or earlier will delete the assignments.



Caution

Precautions when using the CR860 controller
For CR860 controllers with software versions other than D1 or later, safety output is used to display status and is not a safety signal. Do not use it to control safety devices.

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 option] -> [Safety Logic] -> [Safety Input (Safety IO)] 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.

Safety Input 1:RC1 (Online)

Input Signal Set Operation Check

Date of Modification: 2017/03/10-15:35:43

Operation Check: _____

		SS1	SS2	SLS1	SLS2	SLS3	SLSM	SLP1	SLP2	SLP3	SLP4
DSI	DSI1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	DSI2	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	DSI3	☐	☐	☒	☐	☐	☐	☐	☐	☐	☐
	DSI4	☐	☐	☒	☐	☐	☐	☐	☐	☐	☐
	DSI5	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	DSI6	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	DSI7	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	DSI8	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
AREA	AREA1	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	AREA2	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	AREA3	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
LOGIC	AND	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	AND	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	AND	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
MODE	AUTO	☐	☐	☐	☐	☐	☒	☐	☐	☐	☐
	MANUAL	☐	☐	☐	☐	☐	☒	☐	☐	☐	☒

DSI Filter Time: 10 [ms]

Write

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 option] -> [Safety Logic] -> [Safety Output (Safety IO)] 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.

Safety Output(Safety IO) 1:RV-7FR-R (Online)

Output Signal Set Operation Check

Date of Modification: 2020/11/26-16:01:01

Operation Check: _____

			STO	SOS	SS1	SS2	SLS1	SLS2	SLS3	SLSM	SLP1	SLP2	SLP3	SLP4	AREA1	AREA2	AREA3
DSO	DSO1	OR	Active	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
		Inactive	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	DSO2	OR	Active	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
		Inactive	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	DSO3	OR	Active	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
		Inactive	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	DSO4	OR	Active	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
		Inactive	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

DSO Filter Time: 10 [ms]

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. (This function corresponds to stop category 0 of IEC 60204-1.)

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

(b) Program operation state

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

(c) Operation restrictions

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

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

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

(3) Configuring monitoring conditions

There are no parameters concerning the STO function.

4.5.2 Safe operating stop (SOS)

(1) Overview

This is a function to keep shifts of the robot from the stop position within a specified value. This function provides the motors with driving energy necessary to keep the stop state.

Change in the position or speed during the SOS monitoring causes error H2282 (SOS position error, SOS speed error).

(2) Operation sequence

(a) SOS function start conditions

<SS2 command>

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

(b) Program operation state

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

Tab. 4-5: SOS automatic resumption mode

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

(c) Operation restrictions

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

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

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

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

(d) When the robot moves during the SOS monitoring

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

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

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

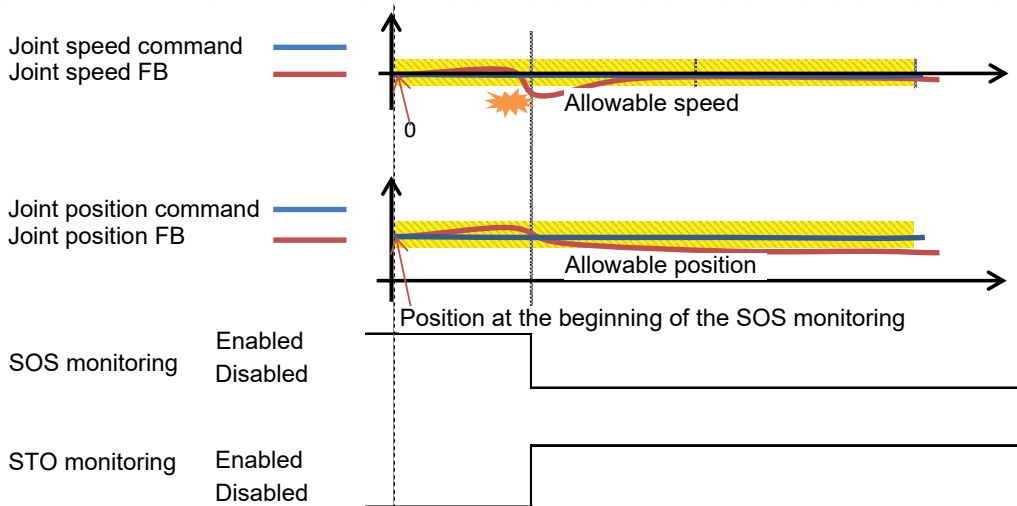


Fig. 4-34: When the robot moves during the SOS monitoring

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

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

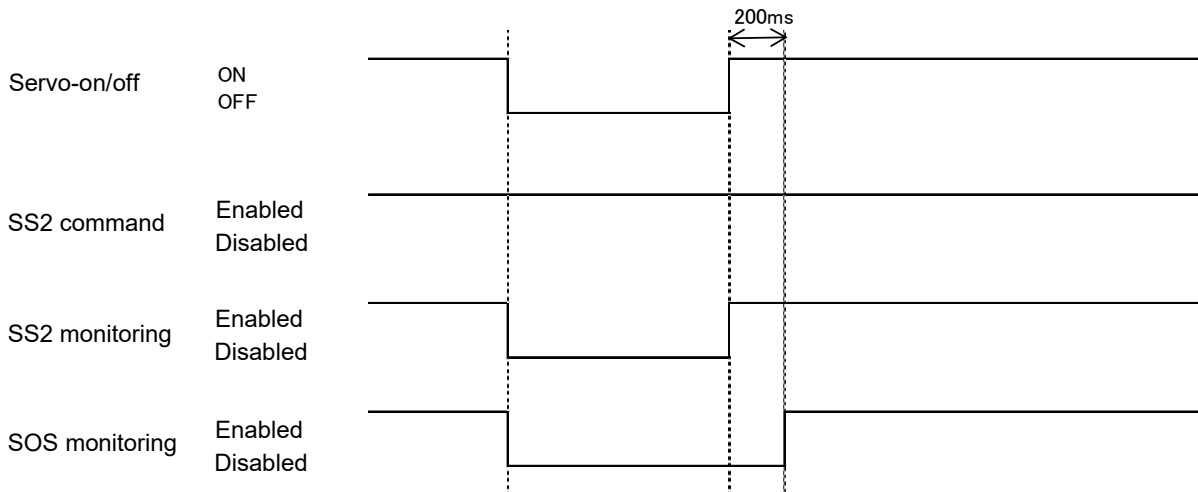


Fig. 4-35: When servos are turned off during the SOS monitoring

(3) 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] -> [Safety option] -> [SOS].

Tab. 4-7: SOS related parameters

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

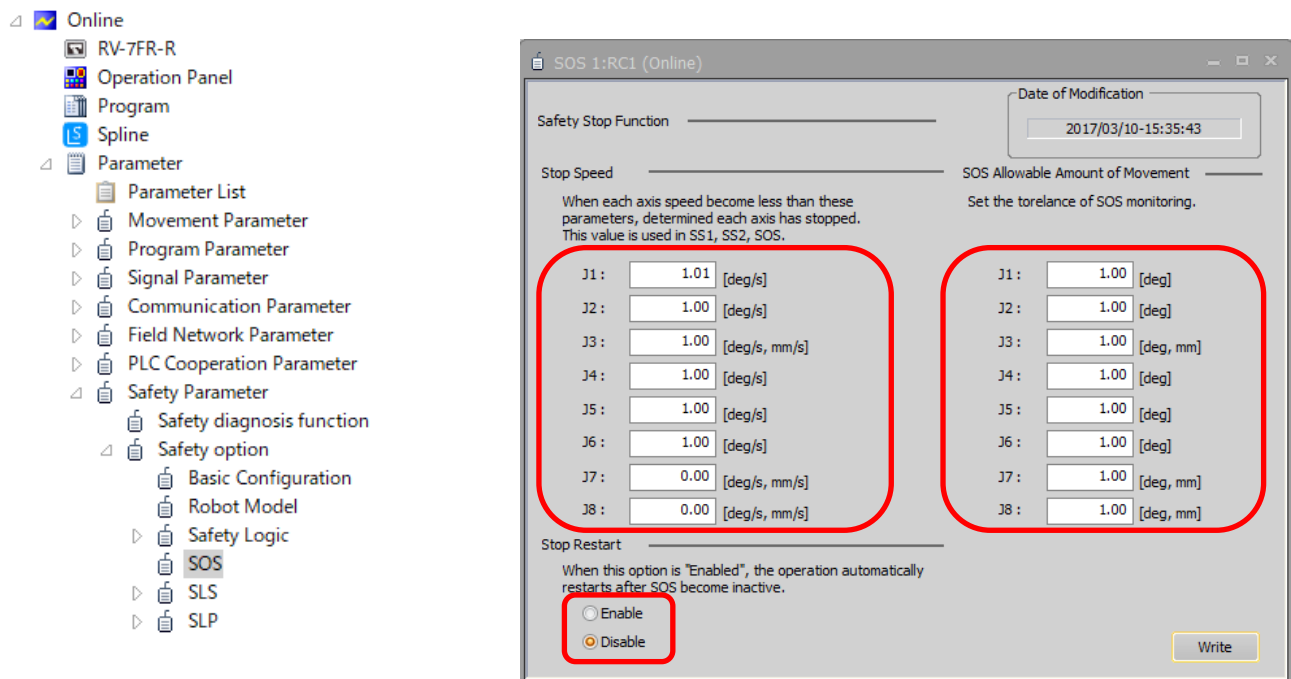


Fig. 4-36: Configuring monitoring conditions

4.5.3 Safe stop 1 (SS1)

(1) Overview

The SS1 command input starts deceleration and, after the motors of all the axes are decreased to a speed at or 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 IEC 60204-1.)

Failure in deceleration within a deceleration monitoring time 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.

For CR800 controllers with software version D1 or later, the SS1 function will operate even under the following circumstances:

- When the 3-position enable switch on the back of the T/B is released or firmly pressed down in MANUAL mode.

For CR860 controllers with software version D1 or later, the SS1 function will operate even under the following circumstances:

- When the 3-position enable switch on the back of the T/B is released or firmly pressed down in MANUAL mode while the door switch input is on (door closed).
- When the 3-position enable switch on the back of the T/B or enabling device are released or firmly pressed down (individually or simultaneously) in MANUAL mode while the door switch input is off (door open).

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

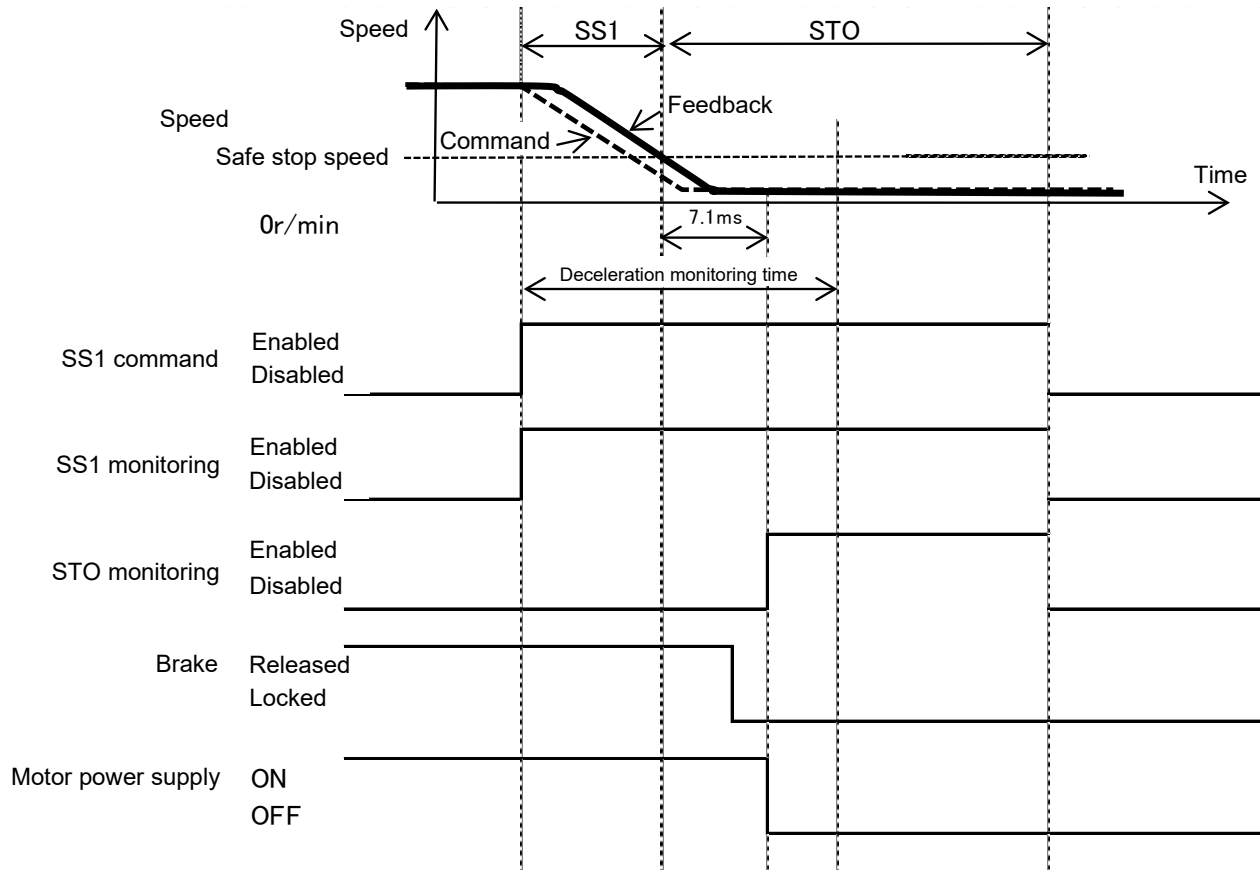


Fig. 4-37: SS1 command (Normal operation)

<Program operation state>

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

(b) When deceleration fails with SS1 enabled

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

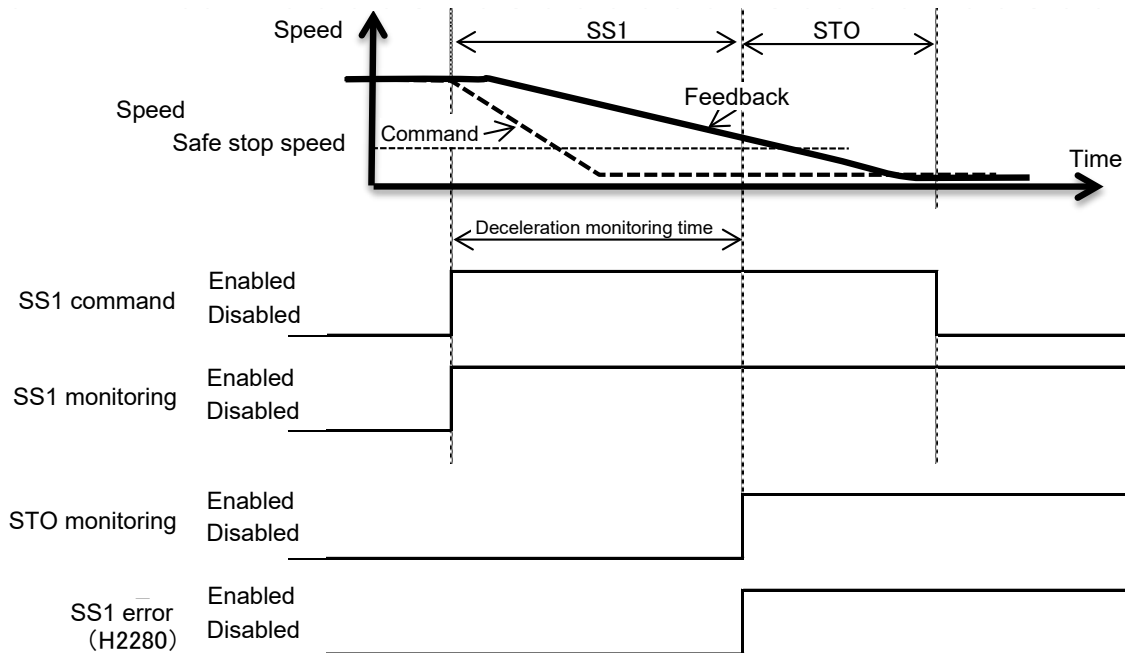


Fig. 4-38: When deceleration fails with SS1 enabled

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

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

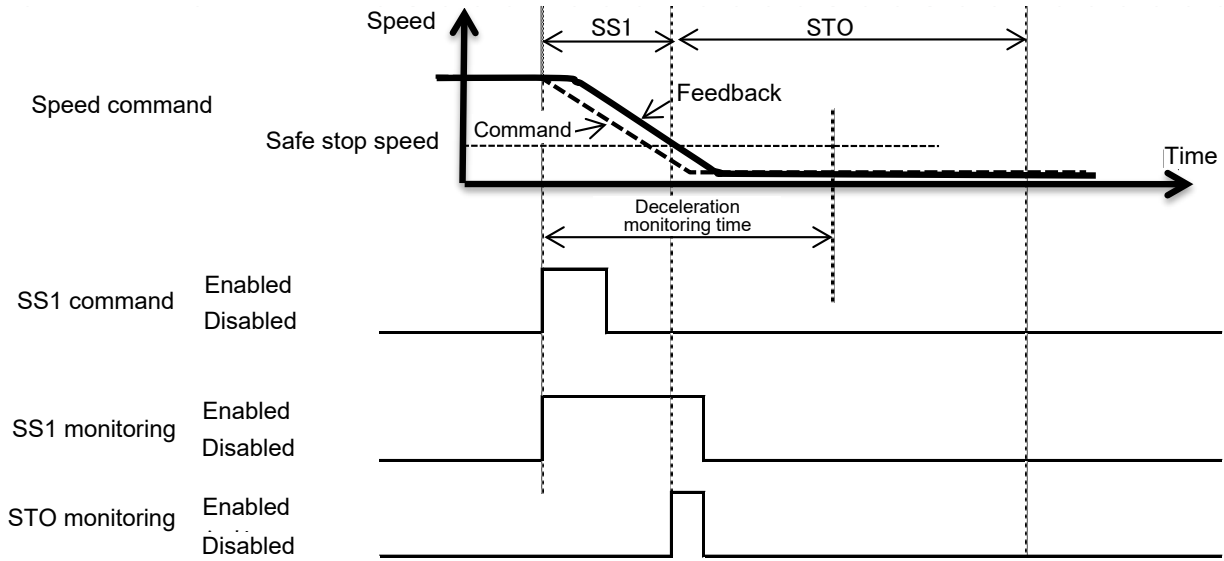


Fig. 4-39: When the SS1 command is canceled with SS1 enabled before the STO monitoring state becomes active

(d) When the origin has not been configured

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

(3) Configuring monitoring conditions

(a) Safe stop speed

In Workspace, open the SOS screen by selecting [Online] -> [Parameter] -> [Safety Parameter] -> [Safety option] -> [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.

SOS 1:RC1 (Online)

Date of Modification: 2017/03/10-15:35:43

Safety Stop Function

Stop Speed

When each axis speed become less than these parameters, determined each axis has stopped. This value is used in SS1, SS2, SOS.

J1 :	1.01	[deg/s]
J2 :	1.00	[deg/s]
J3 :	1.00	[deg/s, mm/s]
J4 :	1.00	[deg/s]
J5 :	1.00	[deg/s]
J6 :	1.00	[deg/s]
J7 :	0.00	[deg/s, mm/s]
J8 :	0.00	[deg/s, mm/s]

SOS Allowable Amount of Movement

Set the tolerance of SOS monitoring.

J1 :	1.00	[deg]
J2 :	1.00	[deg]
J3 :	1.00	[deg, mm]
J4 :	1.00	[deg]
J5 :	1.00	[deg]
J6 :	1.00	[deg]
J7 :	1.00	[deg, mm]
J8 :	1.00	[deg, mm]

Stop Restart

When this option is "Enabled", the operation automatically restarts after SOS become inactive.

☐ Enable

☒ Disable

Write

Fig. 4-40: Safe stop speed

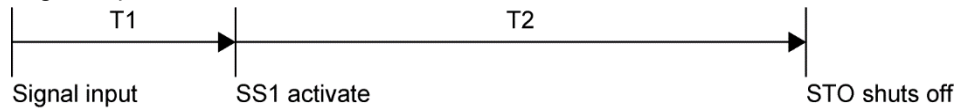
(b) Deceleration monitoring time

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

Model	SS1 deceleration monitoring time [ms]
RV-2FRB	847.1
RV-2FRLB	1237.1
RV-4FR	1137.1
RV-4FRL	1137.1
RV-4FRJL	1137.1
RV-7FR	1357.1
RV-7FRL	1357.1
RV-7FRLl	1027.1
RV-13FR	1257.1
RV-13FRL	1377.1
RV-20FR	1467.1
RV-35FR	2667.1
RV-50FR	2667.1
RV-80FR	3987.1
RV-8CRL	2587.1
RV-12CRL	3147.1
RH-3FRH	1117.1
RH-6FRH	1117.1
RH-12FRH	1597.1
RH-20FRH	2557.1
RH-3FRHR	1137.1
RH-1FRHR	1537.1
RH-3CRH	1857.1
RH-6CRH	1857.1
RH-10CRH	2937.1
RH-20CRH	2557.1

(c) Time performance

The time from signal input to STO shuts off when deceleration fails with SS1 enabled is as follow.



T1: The time from signal input to SS1 activation including:

T1-1: SS1 reaction time: 7.1ms

T1-2: Input signal filter

DSI: DSI Filter Time (refer to (c) DSI filter configuration.)

External emergency stop input: 7.1ms

Emergency stop switch (Operation panel) (Note 1): 7.1ms

Emergency stop switch (T/B): 7.1ms

Door switch input: 32.1ms

Enabling device input (Note 1): 32.1ms

Mode selector (Note 1): 32.1ms

Mode selector switch input (Note 2): 32.1ms

3-position enable switch: 32.1ms

Note 1) These switches are only set for the CR860 controller.

Note 2) This switch is only set for the CR800 controller.

T2: The time from SS1 activation to STO shuts off including:

T2-1: SS1 deceleration monitoring time

T2-2: STO reaction time: 7.1ms

The time from signal input of robot controller to STO shuts off

= <T1-1> + <T1-2> + <T2-1> + <T2-2>

4.5.4 Safe stop 2 (SS2)

(1) Overview

The SS2 command input starts deceleration and, after the motors of all the axes are decreased to a speed at or below the safe stop speed, SOS is started. (This function corresponds to stop category 2 of IEC 60204-1.)

Failure in deceleration within a deceleration monitoring time 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.

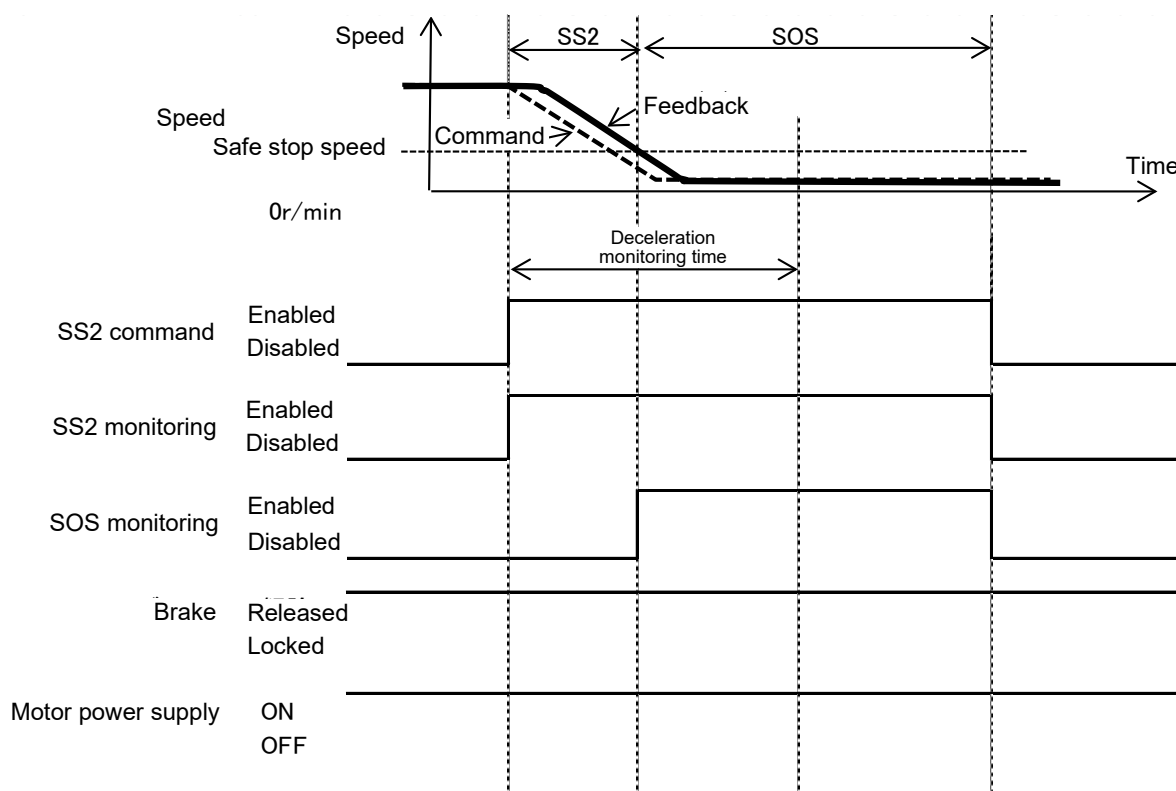


Fig. 4-41: SS2 command (Normal operation)

(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:

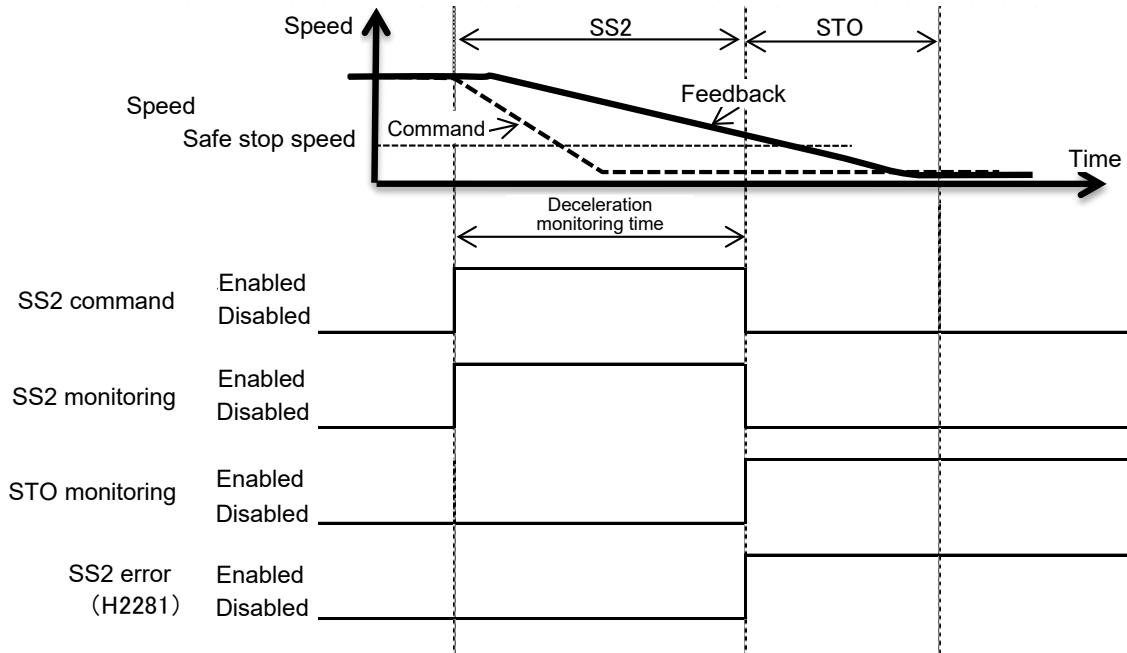


Fig. 4-42: When the motors fail to decelerate within monitoring time with SS2 enabled

(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.

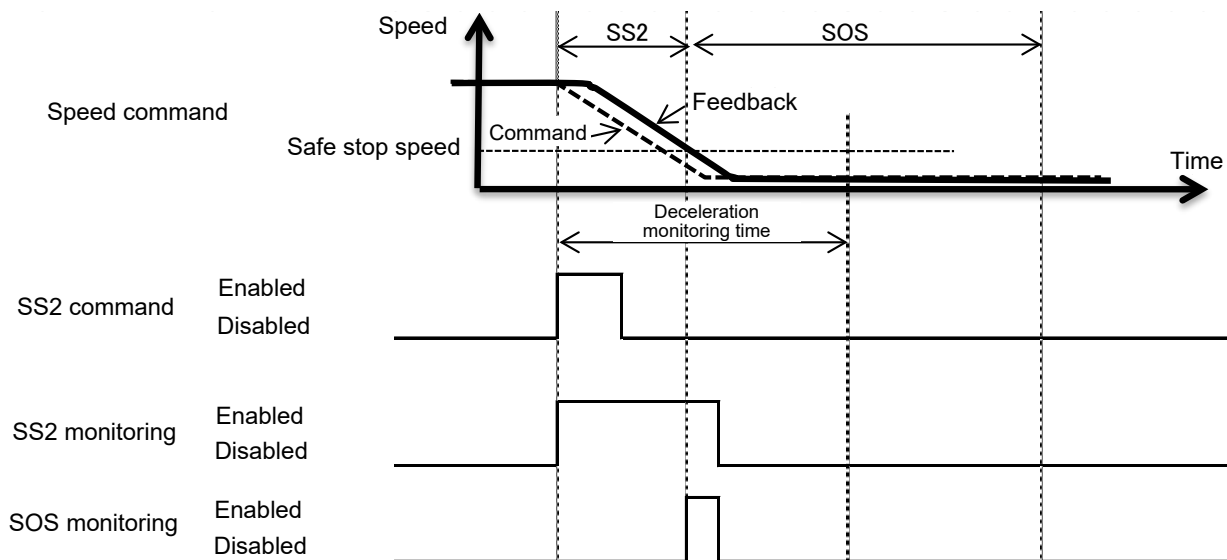


Fig. 4-43: When the SS2 command is disabled before the motors stop with SS2 enabled

(3) Configuring monitoring conditions

(a) Safe stop speed

From Online, open the SOS screen by selecting [Parameter] -> [Safety Parameter] -> [Safety option] -> [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.

SOS 1:RC1 (Online)

Date of Modification: 2017/03/10-15:35:43

Safety Stop Function

Stop Speed

When each axis speed become less than these parameters, determined each axis has stopped. This value is used in SS1, SS2, SOS.

J1 :	1.01	[deg/s]
J2 :	1.00	[deg/s]
J3 :	1.00	[deg/s, mm/s]
J4 :	1.00	[deg/s]
J5 :	1.00	[deg/s]
J6 :	1.00	[deg/s]
J7 :	0.00	[deg/s, mm/s]
J8 :	0.00	[deg/s, mm/s]

SOS Allowable Amount of Movement

Set the tolerance of SOS monitoring.

J1 :	1.00	[deg]
J2 :	1.00	[deg]
J3 :	1.00	[deg, mm]
J4 :	1.00	[deg]
J5 :	1.00	[deg]
J6 :	1.00	[deg]
J7 :	1.00	[deg, mm]
J8 :	1.00	[deg, mm]

Stop Restart

When this option is "Enabled", the operation automatically restarts after SOS become inactive.

☐ Enable

☒ Disable

Write

Fig. 4-44: Safe stop speed

(b) Deceleration monitoring time

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

4.5.5 Safely-limited speed function (SLS)

(1) Overview

This is a function to monitor the robot and the robot tool speeds so that they are under specified speed limits. When they are above a speed limit, the SS1 function stops the robot.

Configuration of up to four different types (SLS1, SLS2, SLS3, SLSM) of speed monitoring conditions are supported. During SLS monitoring, the devices move at speeds specified in Speed Limit OVRD.

(2) Operation sequence

(a) SLS_function basic operation

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

Tab. 4-8: SLS function start conditions

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

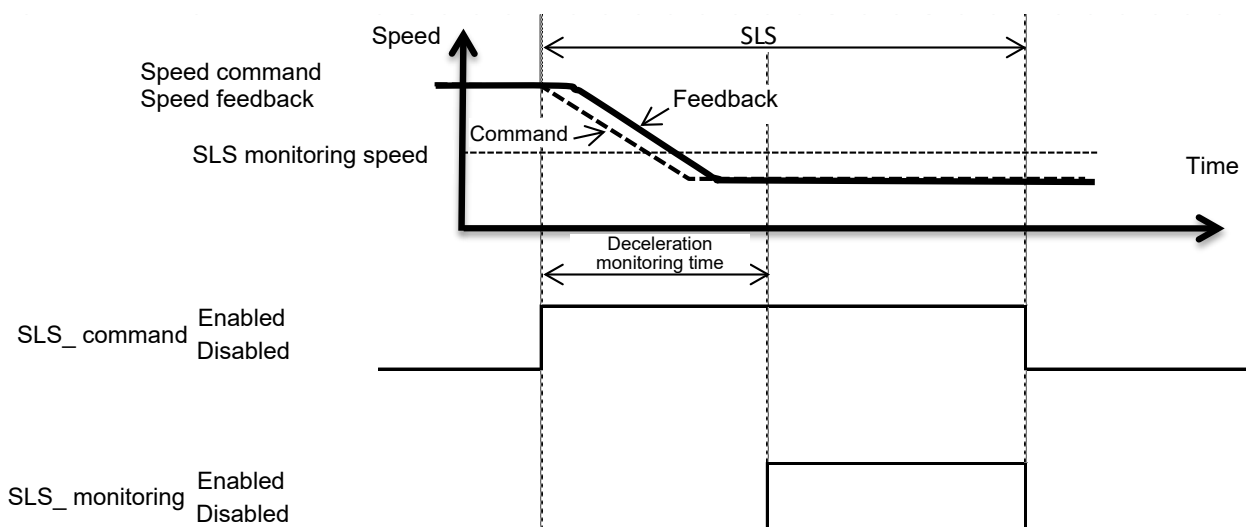


Fig. 4-45: SLS_function basic operation

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

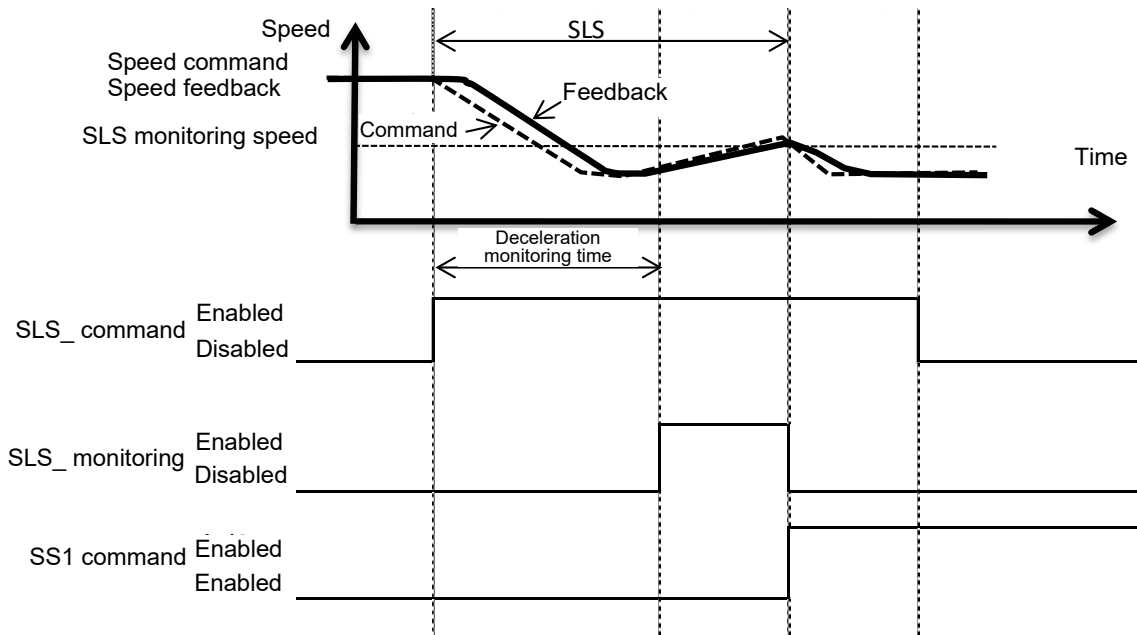


Fig. 4-46: When a specified speed limit is exceeded during the SLS_monitoring

(c) When the devices fail to decelerate within a specified time with SLS enabled
With SLS enabled, if the SLS monitoring speed limit is exceeded or the devices fail to decelerate to the monitoring speed within the SLS deceleration time, error H230* (Abnormal SLS joint speed) or error H231* (Abnormal SLS orthogonal speed) occurs and the SS1 function stops the devices. The errors occur when the limit overrides are too large or the deceleration monitoring time is too short.

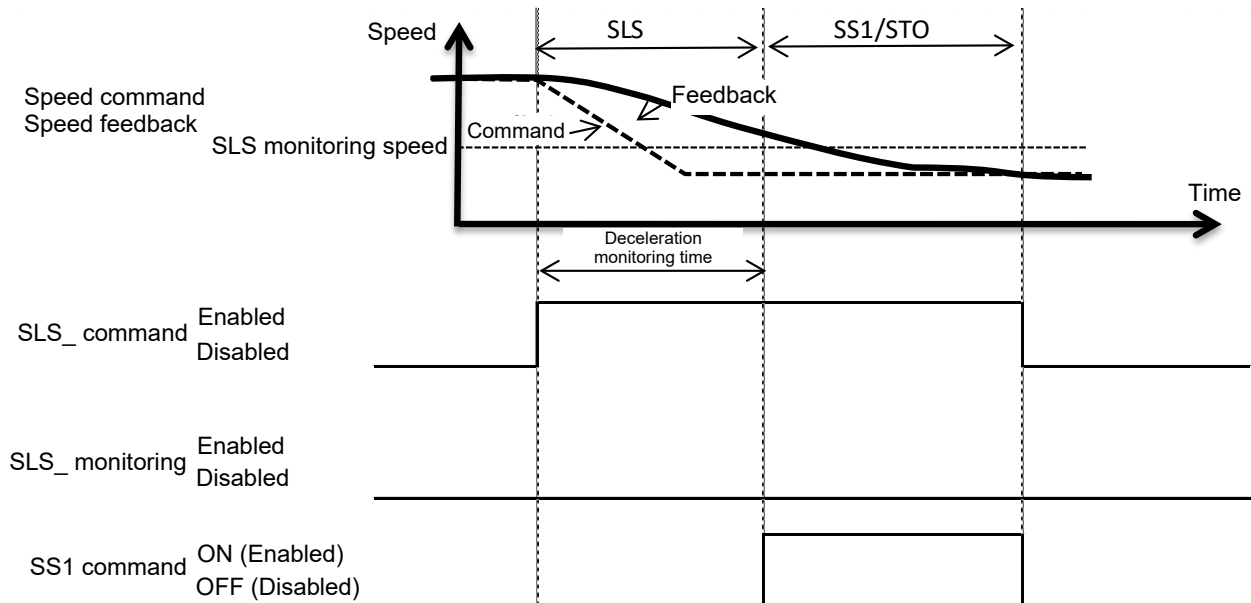


Fig. 4-47: When the devices fail to decelerate within a specified time with SLS enabled

(d) Operation with the servos on or off

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

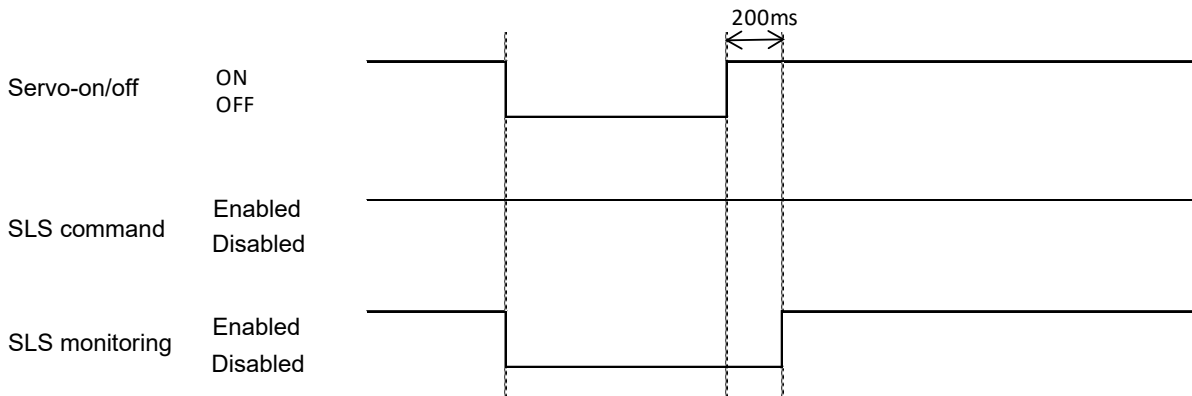


Fig. 4-48: Operation with the servos on or off

(e) When multiple SLS commands are input simultaneously

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

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

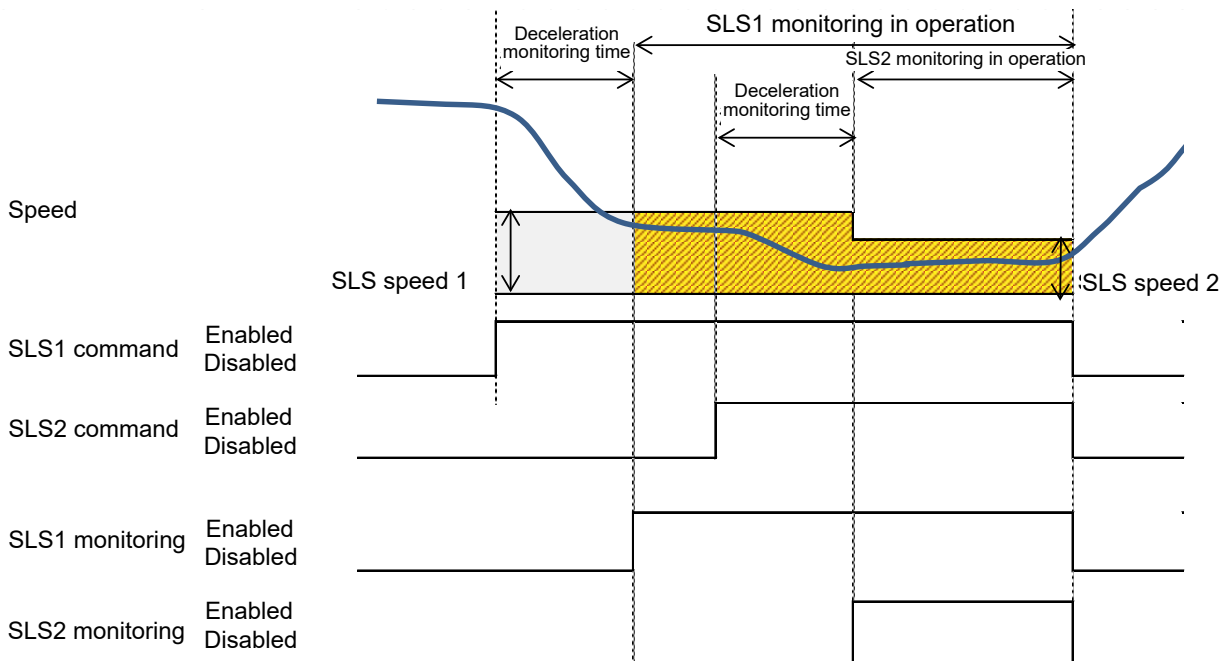


Fig. 4-49: When multiple SLS commands are input simultaneously

(3) Configuring monitoring conditions

(a) Speed monitoring position

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

Set the speed monitoring position at the point where the maximum speed can be monitored when the robot moves.

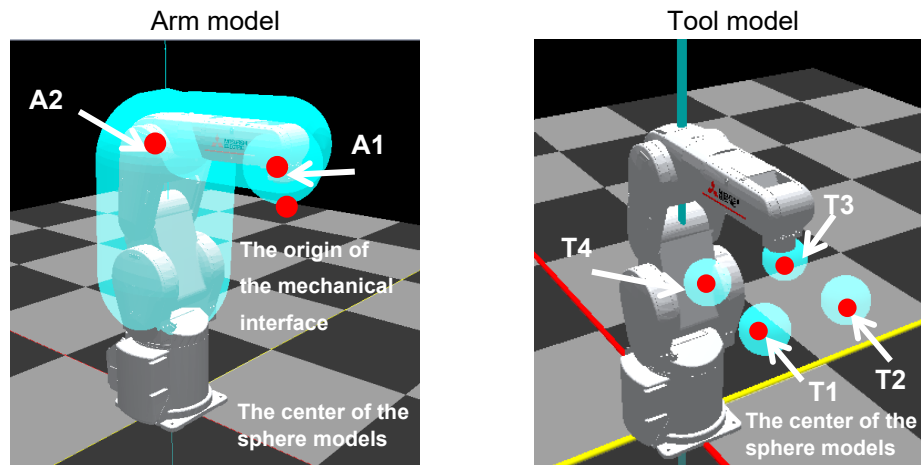


Fig. 4-50: Speed monitoring position

(b) Monitoring speed limits

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

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

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

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

The screenshot shows the 'Speed 1:RC1 (Online)' window. Under 'SLS Monitoring Speed', 'Simple Mode' is selected. The 'Date of Modification' is 2017/03/10-15:35:43. Under 'XYZ Monitoring Speed', there are four input fields for SLS1, SLS2, SLS3, and SLSM, all set to 100000.00, 100000.00, 100000.00, and 250.00 respectively, with a unit of [mm/s]. At the bottom, 'Deceleration Response Time' is set to 770 [ms]. 'Speed Limit OVRD' has four input fields for SLS1, SLS2, SLS3, and SLSM, all set to 100.0000, with a unit of [%]. A 'Write' button is at the bottom right.

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

Speed 1:RC1 (Online)

SLS Monitoring Speed

Setting Mode: ☐ Simple Mode ☒ Detail Mode

Date of Modification: 2017/03/10-15:35:43

XYZ Monitoring Speed

	SLS1	SLS2	SLS3	SLSM	
Comp. Speed :	100000.00	100000.00	100000.00	250.00	[mm/s]
Monitoring Speed for Each Direction					
X+ :	100000.00	100000.00	100000.00	250.00	[mm/s]
X- :	100000.00	100000.00	100000.00	250.00	
Y+ :	100000.00	100000.00	100000.00	250.00	
Y- :	100000.00	100000.00	100000.00	250.00	
Z+ :	100000.00	100000.00	100000.00	250.00	
Z- :	100000.00	100000.00	100000.00	250.00	

Deceleration Response Time: 770 [ms]

Joint Monitoring Speed

	SLS1	SLS2	SLS3	SLSM	
J1 :	100.00	100.00	100.00	100.00	[%]
J2 :	100.00	100.00	100.00	100.00	
J3 :	100.00	100.00	100.00	100.00	
J4 :	100.00	100.00	100.00	100.00	
J5 :	100.00	100.00	100.00	100.00	
J6 :	100.00	100.00	100.00	100.00	
J7 :	100.00	100.00	100.00	100.00	
J8 :	100.00	100.00	100.00	100.00	

Speed Limit OVRD

SLS1	SLS2	SLS3	SLSM	
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:

$$\text{Robot movement speed} = \text{Commanded speed specified in the program, etc.} \times \text{Speed Limit OVRD (\%)} / 100$$

Speed 1:RC1 (Online)

SLS Monitoring Speed

Setting Mode: ☐ Simple Mode ☒ Detail Mode

Date of Modification: 2017/03/10-15:35:43

XYZ Monitoring Speed

	SLS1	SLS2	SLS3	SLSM	
Comp. Speed :	100000.00	100000.00	100000.00	250.00	[mm/s]
Monitoring Speed for Each Direction					
X+ :	100000.00	100000.00	100000.00	250.00	[mm/s]
X- :	100000.00	100000.00	100000.00	250.00	
Y+ :	100000.00	100000.00	100000.00	250.00	
Y- :	100000.00	100000.00	100000.00	250.00	
Z+ :	100000.00	100000.00	100000.00	250.00	
Z- :	100000.00	100000.00	100000.00	250.00	

Deceleration Response Time: 770 [ms]

Joint Monitoring Speed

	SLS1	SLS2	SLS3	SLSM	
J1 :	100.00	100.00	100.00	100.00	[%]
J2 :	100.00	100.00	100.00	100.00	
J3 :	100.00	100.00	100.00	100.00	
J4 :	100.00	100.00	100.00	100.00	
J5 :	100.00	100.00	100.00	100.00	
J6 :	100.00	100.00	100.00	100.00	
J7 :	100.00	100.00	100.00	100.00	
J8 :	100.00	100.00	100.00	100.00	

Speed Limit OVRD

SLS1	SLS2	SLS3	SLSM	
100.0000	100.0000	100.0000	100.0000	[%]

Write

Fig. 4-53: Restricting the movement speed

**Caution**

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

**Caution**

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

(d) Deceleration monitoring time

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

(4) Operation check

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

(a) How to check the SLS monitoring state

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

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

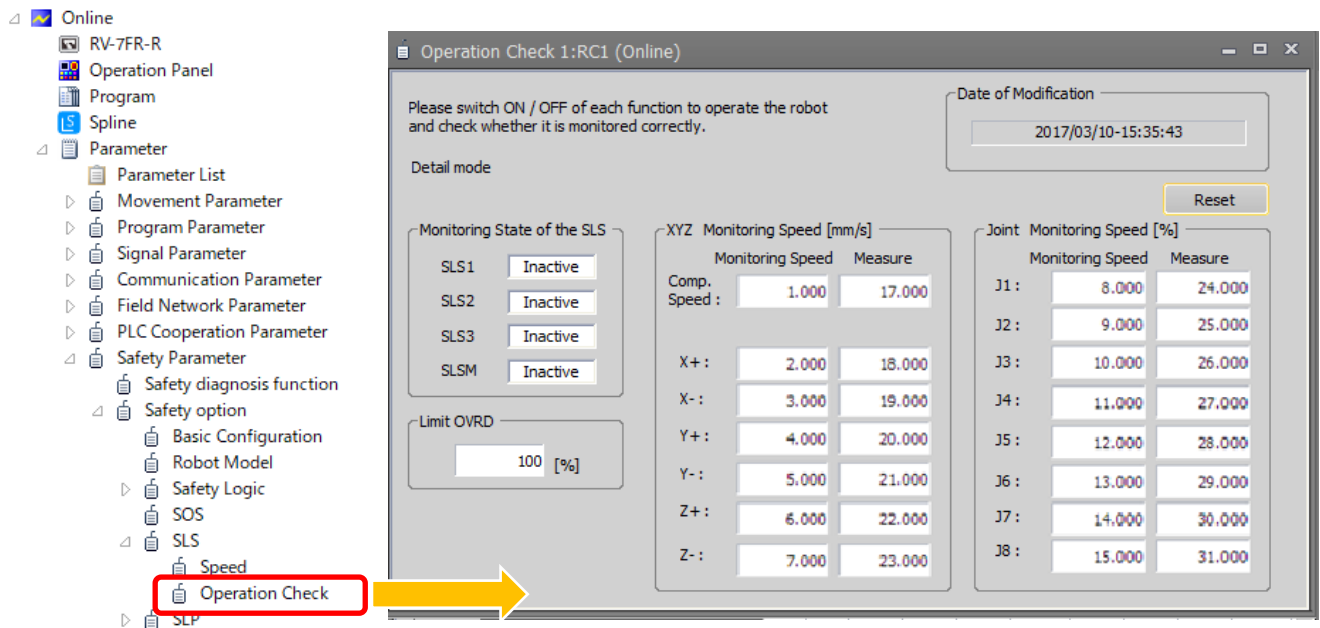


Fig. 4-54: How to check the SLS monitoring state

4.5.6 Safely-limited position function (SLP)

(1) Overview

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

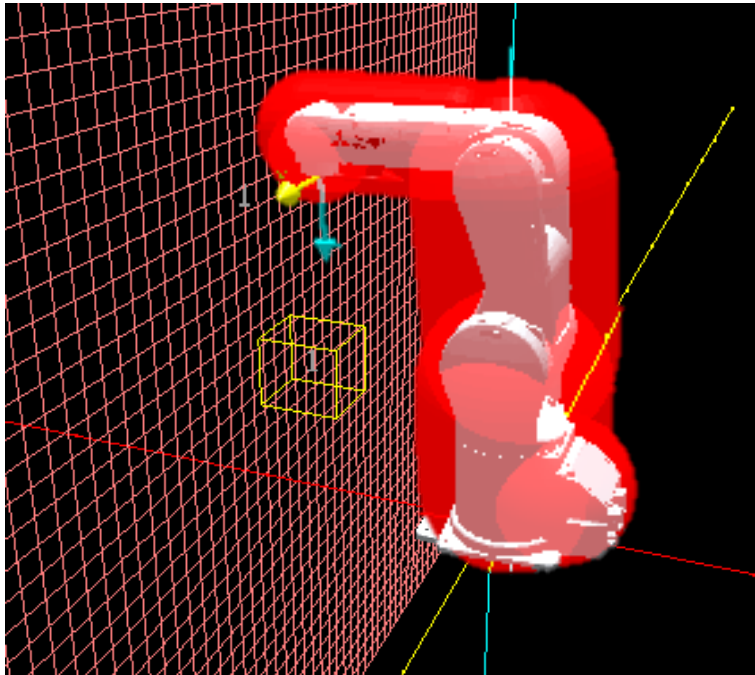


Fig. 4-55: Safely-limited position function



Caution

This function does not guarantee that the robot arm and tools will not enter the safeguarded spaces.

(2) Operation sequence

(a) SLP_function basic operation

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

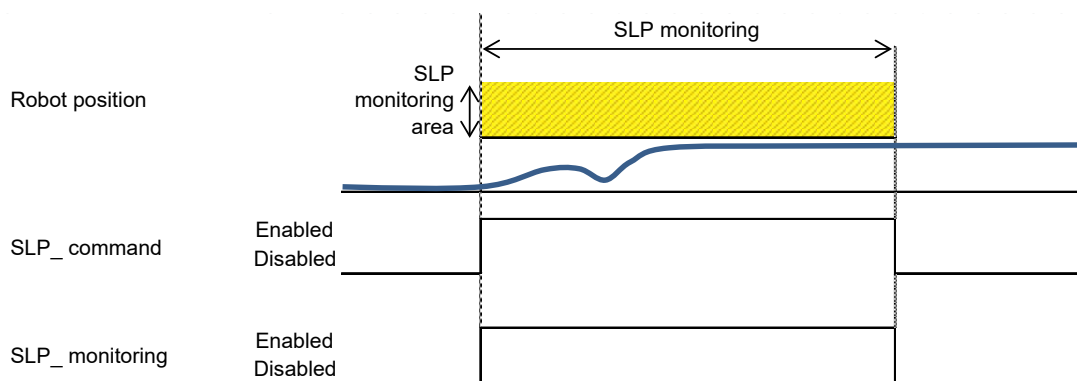


Fig. 4-56: SLP_function basic operation

(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 safeguarded spaces while it is run by the interpolation command or jog operation. If it judges that a predicted position will enter a safeguarded space, the function stops the robot. When the robot stops near the position monitoring plane, it behaves as follows:

① When the robot is run by the interpolation command

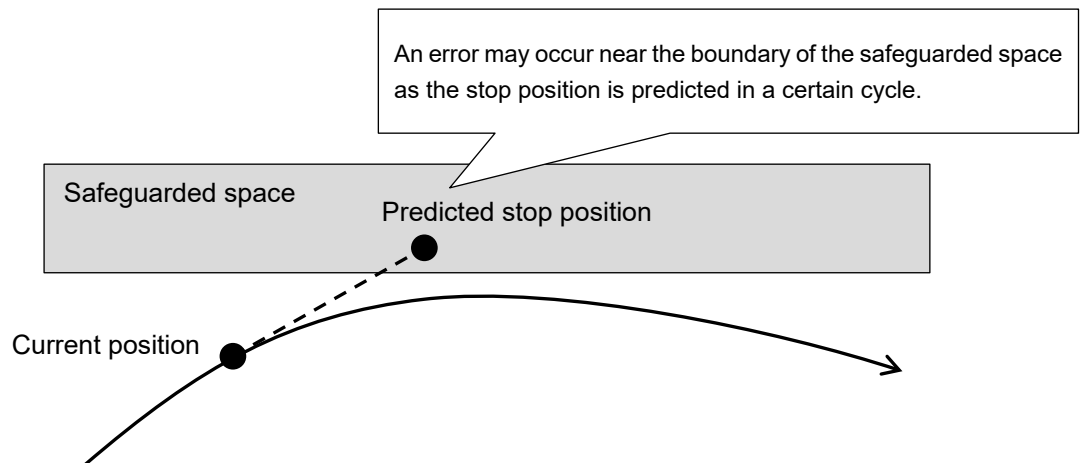
The automatic program operation maintains the RUN state. The robot operation suspends and the execution stops at the line of the interpolation command, but the state does not transition to STOP. If the target position monitoring plane does not exist in the vicinity due to the monitoring mode change to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

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



Caution

- Changing monitoring modes may resume the robot operation. Take sufficient care when changing monitoring modes.
- In the SLP prior stop state, errors are shown for "Monitoring State of the Plane" and "Monitoring State of the Area" in the [Operation Check] window of RT ToolBox3. (Refer to Fig. 4-66.)
- As shown in the following figure, an error may occur when a position passes near the boundary of the safeguarded space (especially during continuous path operation). If an error occurs, set the path away from the safeguarded space or lower the speed.



② When the robot is run by the jog operation

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

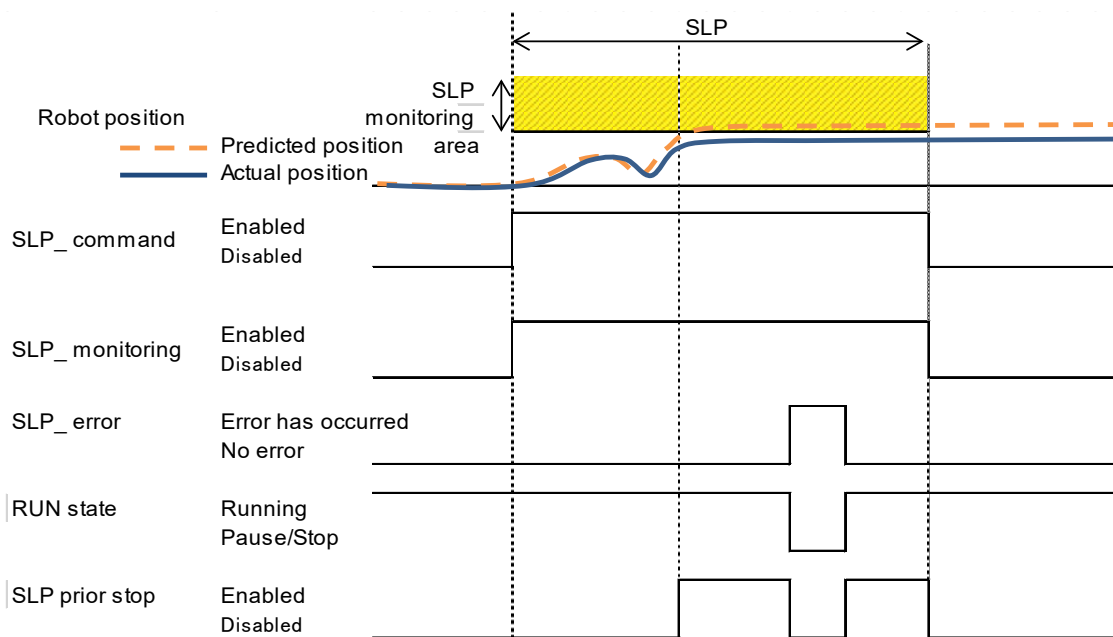


Fig. 4-57: Stop position prediction function

**Caution**

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

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

③ When error H220m occurs in the SLP prior stop state

Depending on the monitoring position settings or how the robot is moving, a monitoring position may enter a safeguarded space in the SLP prior stop state, causing error H220m. Setting a margin between the predicted stop position and the safeguarded space prevents error H220m from occurring. Use SPPFMG parameter to set the margin.

Table 4-10: Margin between the predicted stop position and the safeguarded space

Item	Description
Parameter name	SPPFMG
Function	Set a margin between the predicted stop position and the safeguarded space to prevent error H220m from occurring in the SLP prior stop state.
What parameter settings means	Margin (distance) between the predicted stop position and the safeguarded space
Setting range	0.00 to 1000.00 (unit: mm)
Default	0.00

When the margin is set using SPPFMG parameter, the robot will stop before entering the safeguarded space (SLP prior stop) according to the setting value. A monitoring position will not enter the safeguarded space and thus error H220m will not occur.

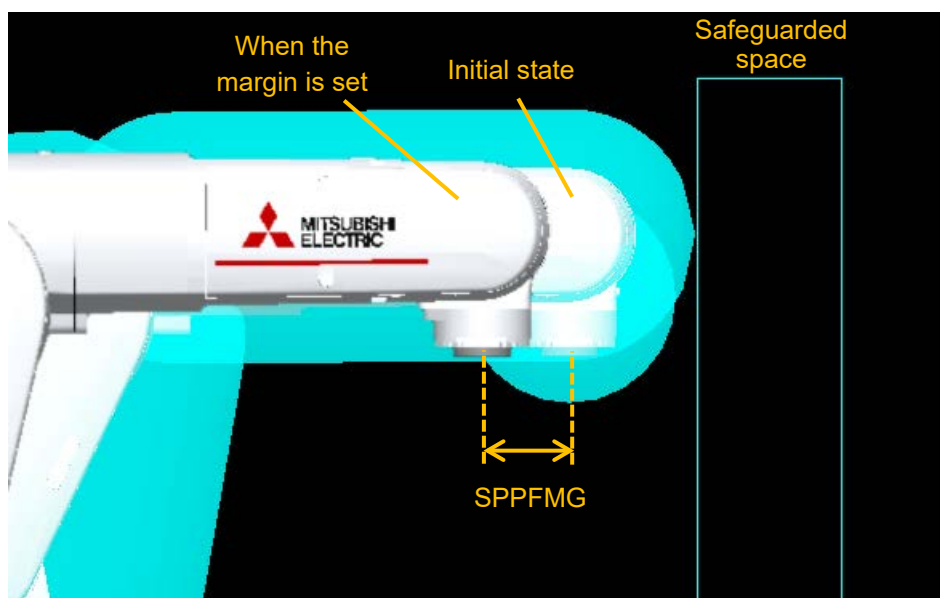


Fig. 4-58: SLP prior stop when the margin is set

SPPFMG parameter is available with software version of each device shown in the following table.

Table 4-11: Software version that supports SPPFMG parameter

Device	Compatible version
Controller	Ver. C2 or later
RT ToolBox3/RT ToolBox3 Pro (simulation function)	Ver. 1.90U or later

**Caution**

When a large value (for example, a value larger than the distance between the current position and the safeguarded space) is set in SPPFMG parameter, the robot will enter the SLP prior stop state immediately after the robot starts moving and its movement is restricted. Set SPPFMG parameter appropriately.

Check state variable M_SlpPreStp to see whether the robot is in the SLP prior stop state.

**Caution**

When the simulation function of RT ToolBox3 or RT ToolBox3 Pro is used, setting SPPFMG parameter to a value larger than the distance between the robot position at the start of the simulation and the safeguarded space will cause error H220m at startup of the simulation. In this case, change the SPPFMG parameter setting or the SLP monitoring settings.

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

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

(i) Position command (Whole arm and tools)

(ii) Position FB (Whole arm and tools)

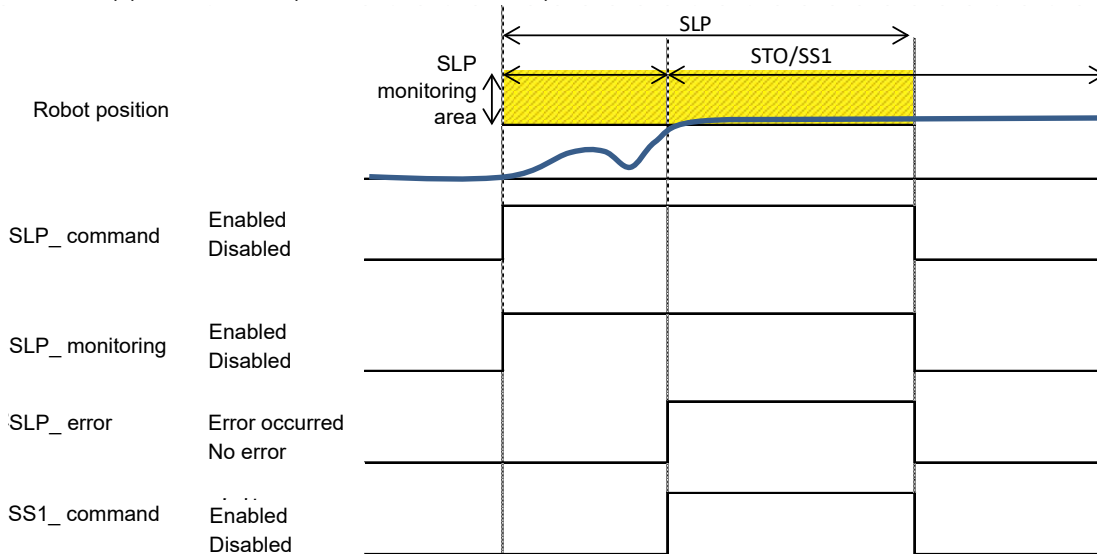


Fig. 4-59: When intrusion into an SLP restricted area is detected

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

The robot stops when it detects that it is close to the safety monitoring plane or safety monitoring area. If the function detects that any one of the monitoring positions has gone across the plane, error H220* occurs and the robot stops by turning off the servos.

**Caution**

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

**Caution**

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

(3) Configuring monitoring conditions

(a) Arm model and tool model

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

(b) Safety monitoring plane

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

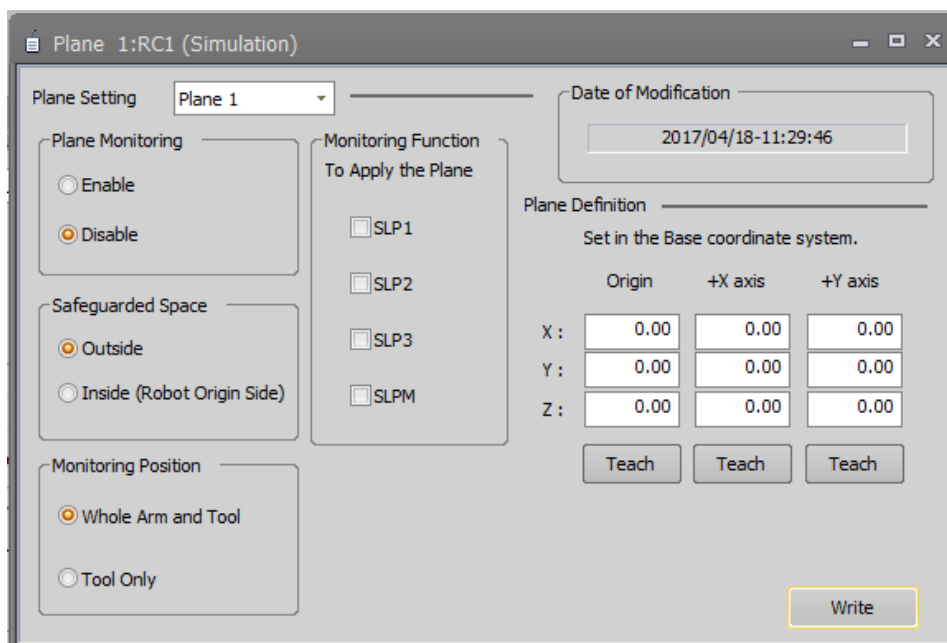


Fig. 4-60: Safety monitoring plane

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.)

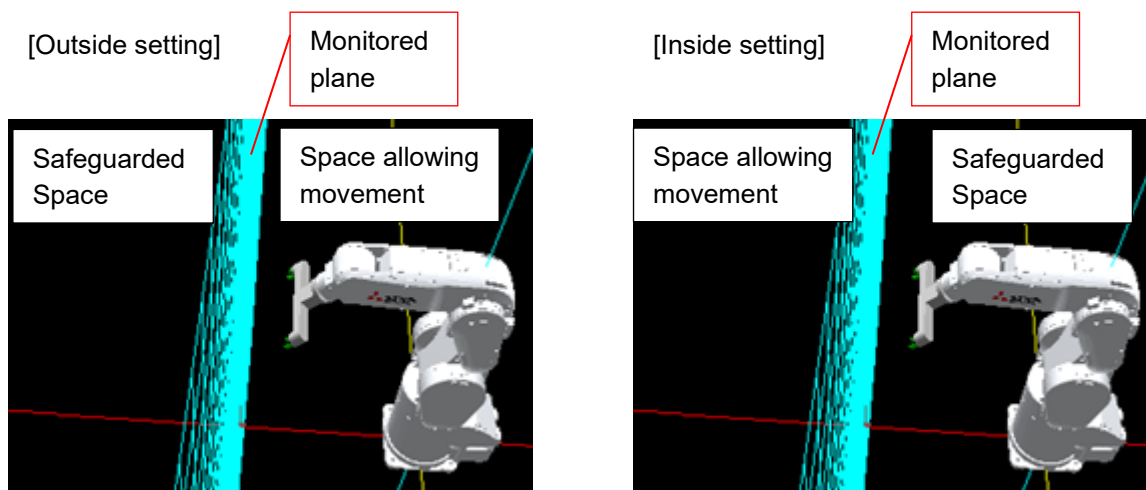


Fig. 4-61: Safeguarded space setting

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, SLP4) 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.

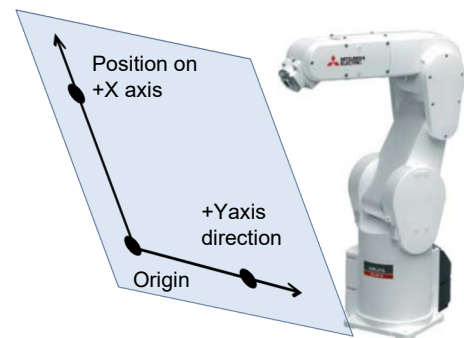


Fig. 4-62: Plane Definition

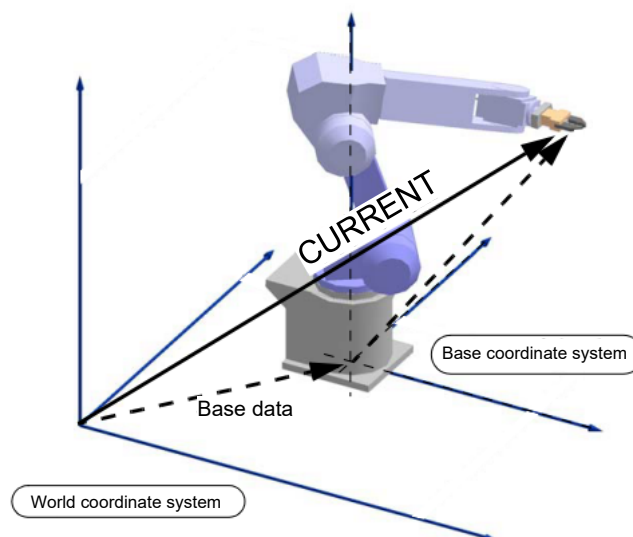


Fig. 4-63: Base coordinate system

(c) Safety monitoring area

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

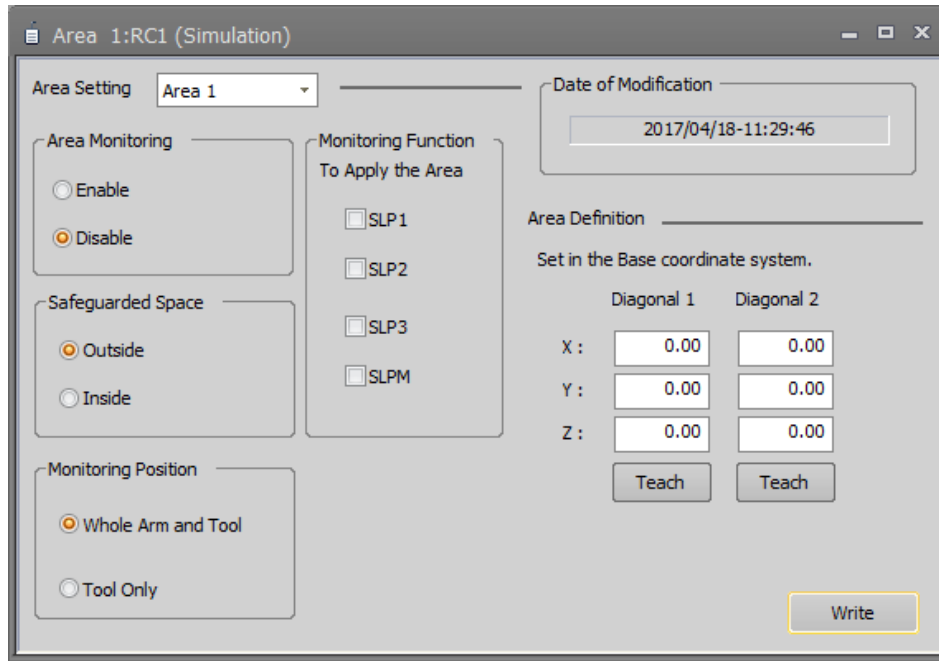


Fig. 4-64: Safety monitoring area

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.

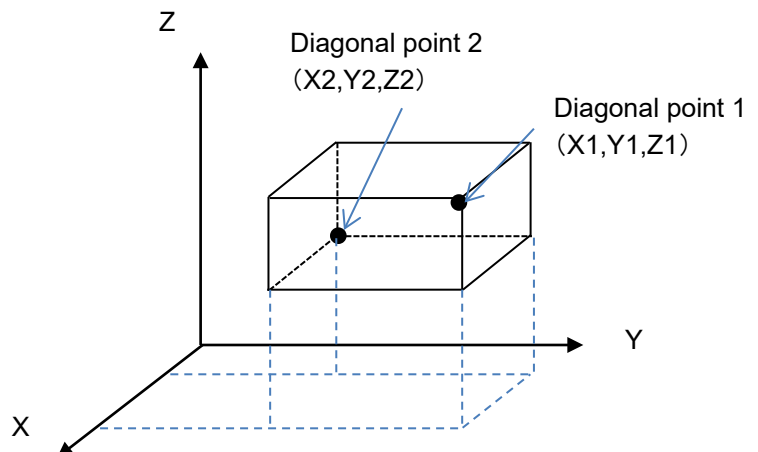


Fig. 4-65: Area Definition

(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] -> [Safety option] -> [SLP] -> [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.

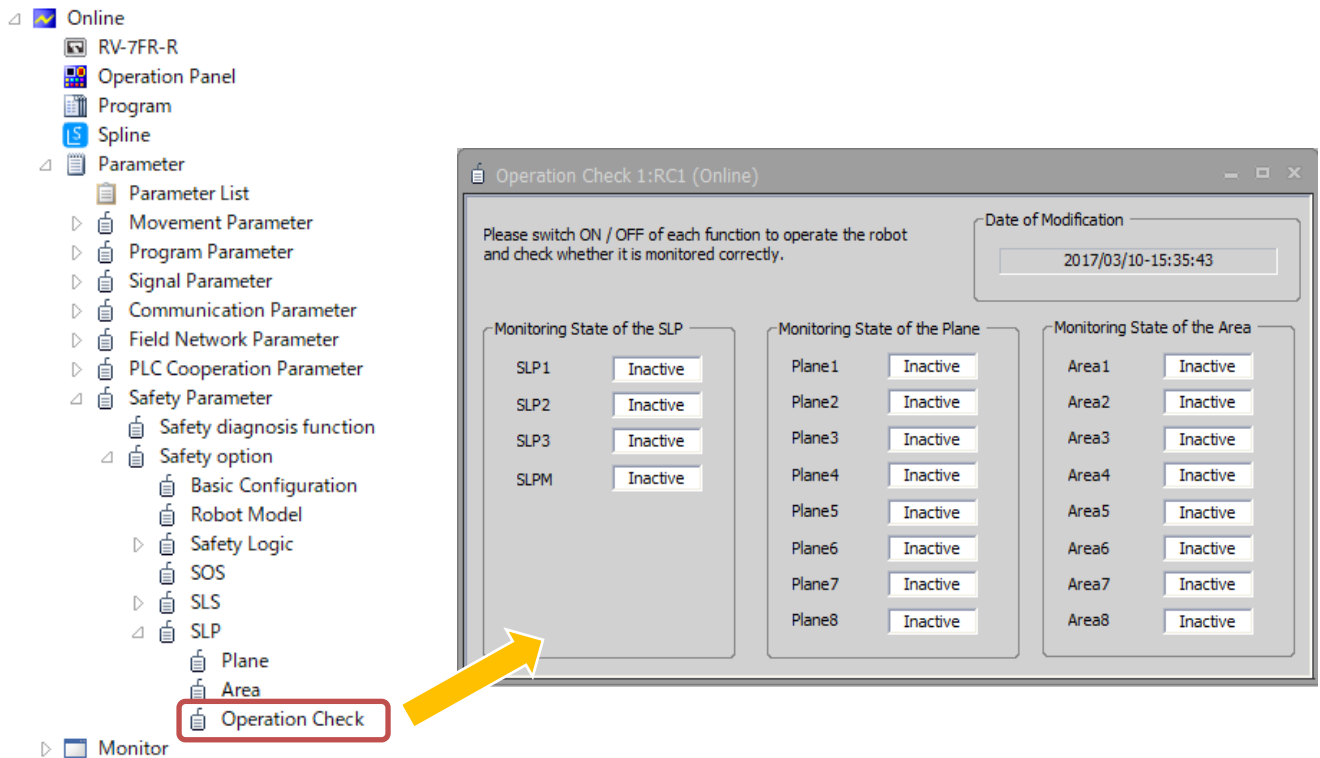


Fig. 4-66: Operation check

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 .

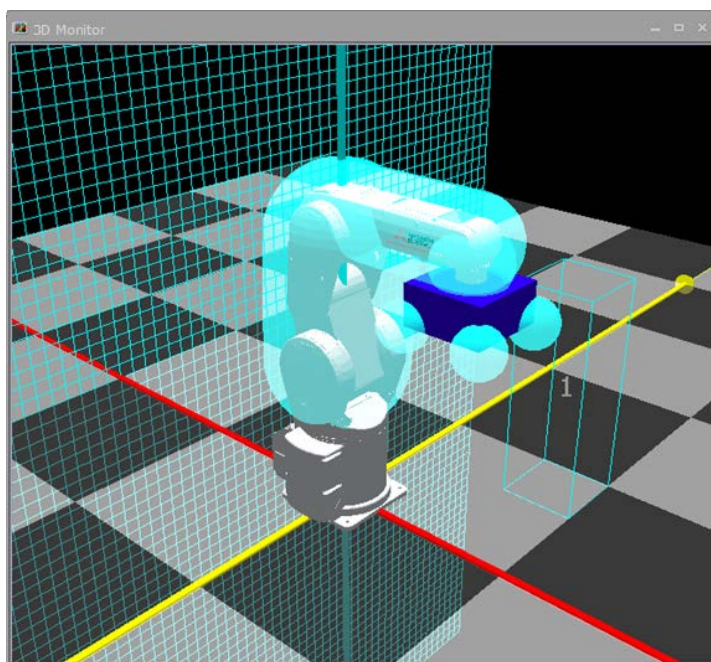


Fig. 4-67: How to check monitoring model definitions

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. 4-69. Make sure to prevent test pulses of this function from causing faulty operation of peripheral devices.

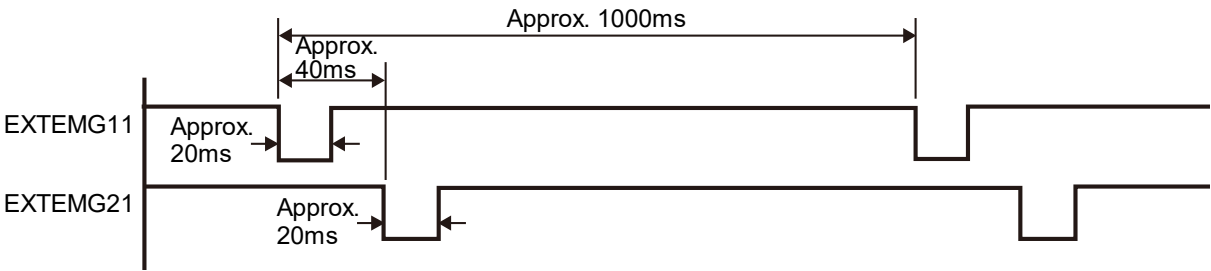


Fig. 4-68: Test pulse diagnosis

Tab. 4-12: Test pulse diagnosis

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

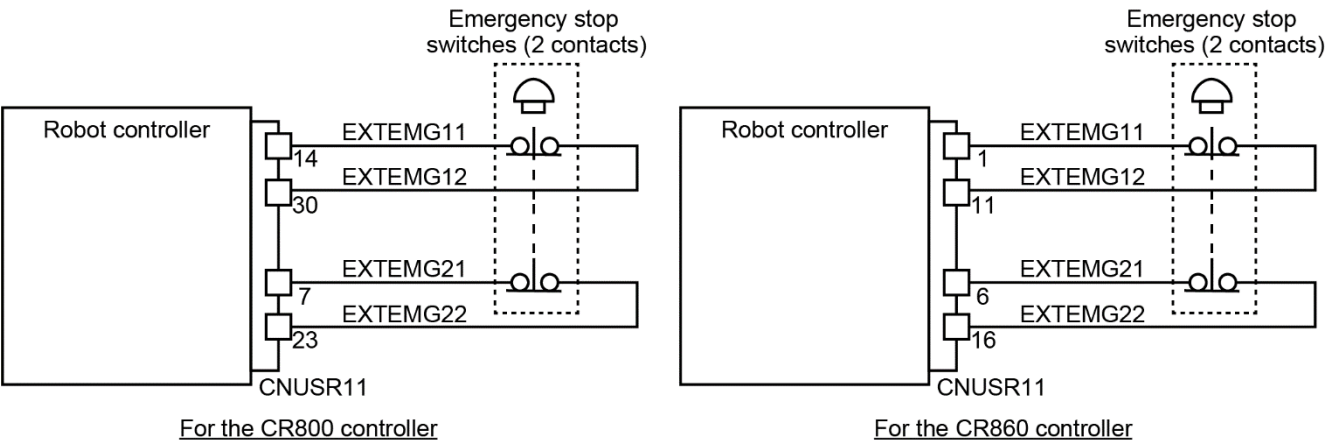


Fig. 4-69: How to wire emergency stop lines

RT ToolBox3 Ver.1.62Q or later supports the safety diagnosis function. The settings can be configured using the following steps.

4.6.2 Safety diagnosis function

You can select the pulse output function of test pulse signal output from emergency stop (EXTEMG11, EXTEMG21). For the safety diagnosis function (test pulse diagnosis), please refer to the “Standard Specifications” of each series.

This function can be used with the CR800 series robot controller and the parameter cannot be set for offline editing.

Double-click [Safety Parameter] -> [Safety Diagnosis Function] under the [Parameter].

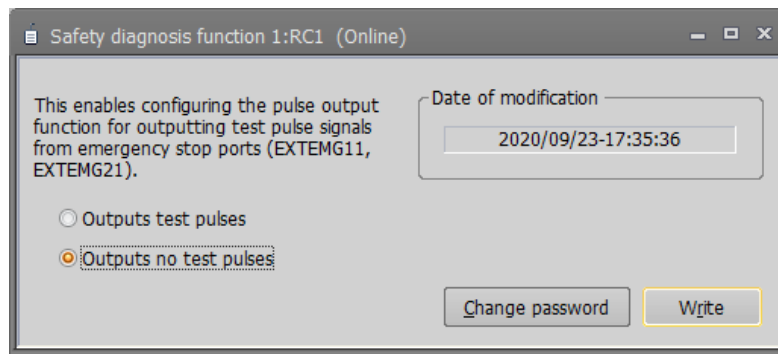


Fig. 4-70: Safety diagnosis function parameter

After changing the parameter value, click the [Write] button to write the parameter to the robot controller.

This parameter requires a password to be written. Enter the correct password and press the [OK], the parameters will be written to the controller. If the password is wrong, the parameter will not be written. The password is required only when writing the first parameter after displaying the parameter editing screen of the safety diagnosis function.

Refer to "4.2.3 Password setting" for further information.

5. STATE VARIABLE

States variable for the safety monitoring function are shown below:

5.1 List of State Variables

Tab. 5-1: List of state variables

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

5.2 State Variables

M_DSI

[Function]

Regarding DSI for functional safety, this refers to the current value.

DSI Input enabled: 1

DSI Input disabled: 0

[Format]

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

[Terminology]

<Numerical variable> This specifies where to store the DSI state.

<DSI number> This specifies a number for DSI whose state to be obtained.

Setting range: 1 to 8

[Reference Program]

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

[Explanation]

(1) Regarding DSI for functional safety, this refers to the current state.

(2) The value changes after the DSI filter setting time elapses following change in the input signals DSIn_A and DSIn_B.

(3) Assigning a value other than 1 to 8 to <DSI number> causes the L.3880 error on execution.

M SflLogic**[Function]**

Regarding functional safety input Logic, this returns the current value. (n = 1 to 3)

Logic Input state Enabled:1

Logic Input state Disabled:0

[Format]

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

[Terminology]

<Numerical variable> This specifies where to store the LOGICn input state.

<Logic number> This specifies a number for LOGIC whose state to be obtained.

- Setting range: 1 to 3

[Reference Program]

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

[Explanation]

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

M SflArea**[Function]**

This refers to the Area Input state.

(Enabled:1, Disabled: 0)

[Format]

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

[Terminology]

<Numerical variable> This specifies where to store the AREAn input state.

<Area number> This specifies a number for Area whose state to be obtained.

- Setting range: 1 to 3

[Reference Program]

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

[Explanation]

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

M SfSts**[Function]**

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

[Format]

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

[Terminology]

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

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

Tab. 5-2: List of function number

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

[Reference Program]

Msto = M_SfSts(1) 'The running state of STO is stored in Msto. (0: Disabled, 1: Enabled)

Msls = M_SfSts(5) 'The running state of SLS1 is stored in Msls. (0: Disabled, 1: Enabled)

If Msls = 1 then

M_YDev(0) = 1 'If SLS1 is enabled, sequencer output signal No.1 is turned on.

EndIf

[Explanation]

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

M_DSO

[Function]

Regarding DSO for functional safety, this refers to the current value.

DSO Output enabled: 1

DSO Output disabled: 0

[Format]

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

[Terminology]

<Numerical variable> This specifies where to store the DSO state.

<DSO number> This specifies a number for DSO whose state to be obtained.

Setting range: 1 to 4

[Reference Program]

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

[Explanation]

(1) Regarding DSO for functional safety, this refers to the current state.

(2) Assigning a value other than 1 to 4 to <DSO number> causes the L.3880 error on execution.

M_SlpPreStp**[Function]**

The variable returns the present SLP pre-stop status.

[Format]

Example) <Numerical variables>=M_SlpPreStp
--

[Terminology]

<Numerical variable>The current SLP pre-stop status is returned.

Not in pre-stop status: 0

During pre-stop:

1 to 8 (number of the applicable position monitoring plane)

101 to 108 (100 + number of the applicable position monitoring area)

[Reference Program]

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

[Explanation]

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

6. TROUBLESHOOTING

6.1 Error List for the Safety Monitoring Functions

Errors related to the safety monitoring functions are listed below.

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

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

Error number	Error causes and solutions	
H0230 *	Error message	Safety parameter error (xxxxx)
	Cause	Detect errors in safety parameter value.
	Solution	There is something wrong with a safety function parameter setting. Check the parameter setting shown in (xxxxx) of the error message, and set it to an appropriate value.
H0231 *	Error message	Parameter CRC error (xxxxx)
	Cause	Detect CRC errors in safety parameter.
	Solution	Please check the safety parameters settings and write parameters.
C0240	Error message	Setting mismatch of safety func
	Cause	The safety function is disabled.
	Solution	Although the safety logic is configured, the relevant safety functions are disabled. Delete the safety logic or enable the safety functions.
H0241 *	Error message	Fault in Safety Communication
	Cause	Detect a fault in safety communication.
	Solution	Turn the power OFF and ON once. If the error recurs after that, contact the manufacturer. This error also occurs when the machine lock function and controller CPU drive mode are used. Disable the function/mode, then cycle the power of the robot controller.
H0242 *	Error message	Fault in Safety Data
	Cause	Detect a fault in safety data.
	Solution	Turn the power OFF and ON once. If the error recurs after that, contact the manufacturer.
H0243	Error message	Safety function unavailable (XXX)
	Cause	The Safety Function is not supported by this robot.
	Solution	Disable the safety function.
C0244	Error message	Setting mismatch of safety IO
	Cause	Safety IO logic is set, but the safety IO is disabled.
	Solution	Delete the safety IO logic settings or enable safety IO.
H0250 *	Error message	Illegal setting of safety IO I/F
	Cause	Safety IO and Safety comm. are disabled.
	Solution	To enable the safety function, enable either safety IO or safety communications.
H0251 *	Error message	Illegal setting of safety IO I/F
	Cause	Both safety IO and safety communication are set to valid. Safety IO and safety communication cannot be used together.
	Solution	Disable either safety IO or safety communications.
H0311 *	Error message	Remotel/O unit config error
	Cause	The multiple Remotel/O units which do not support are connected.
	Solution	If a safety extension unit is connected, turn off the robot and, after restarting the safety extension unit, turn on the robot again.
H220m (The letter "m" is a number for a monitoring plane or monitoring area [1 to 8])	Error message	SLP (ROBOT position error:CMD Plane)
	Cause	SLP detected the robot position CMD over the monitoring plane.
	Solution	Please confirm the robot movement or related parameter setting.
	Error message	SLP (ROBOT position error:FB Plane)
	Cause	SLP detected the robot position FB over the monitoring plane.
	Solution	Please confirm the robot movement or related parameter setting.
	Error message	SLP (ROBOT position error:CMD Area)
	Cause	SLP detected the robot position CMD over the monitoring area.
	Solution	Please confirm the robot movement or related parameter setting.
	Error message	SLP (ROBOT position error:FB Area)
	Cause	SLP detected the robot position FB over the monitoring area.
	Solution	Please confirm the robot movement or related parameter setting.

Error number	Error causes and solutions	
H222m * (The letter "m" is a DSI number. [1 to 8])	Error message	Mismatch of Dual Safety Input
	Cause	State of the redundant wiring do not match (Dual Safety Input)
	Solution	The duplex DSI signal ON/OFF states are not consistent. Check the following for the DSI. • DSI wiring • Duplex signal ON/OFF states • Timing of switching of ON/OFF states (The error occurs when the ON/OFF states of the duplex signals remain inconsistent for about 0.1 seconds.)
H2230 *	Error message	Mismatch of Dual Safety Output
	Cause	The duplex DSO states are not consistent.
	Solution	Turn the power OFF and ON once. If the error recurs after that, contact the manufacturer.
H2231 *	Error message	Mismatch of Dual Safety Output Feedback
	Cause	State of Dual Safety Output and the feedback do not match.
	Solution	Turn the power OFF and ON once. If the error recurs after that, contact the manufacturer.
H2240 *	Error message	Origin data change
	Cause	The origin data is changed during execution of the position monitoring function.
	Solution	The origin is set while position monitoring is being executed. This error occurs if the origin position data is changed while position monitoring is being executed. Cycle the power of the robot controller, then reset the error.
C2250	Error message	Safety function execution disabled (No origin setting)
	Cause	The safety function cannot be executed because the origin is not set.
	Solution	If the origin is not set, the safety monitoring functions will not work. Configure the origin settings.
H2260 *	Error message	Safety Unit communication error
	Cause	Extended Safety Unit communication failed
	Solution	In order to use the safety monitoring functions, the Safety extension unit must be connected to the robot controller. Connect the Safety extension unit to the robot controller. If the error occurs even when the Safety extension unit is connected, check that the Safety extension unit is powered on. Or check whether pseudo-input mode has been enabled. If none of these solutions rectify the problem, the Safety extension unit may be faulty. Contact Mitsubishi Electric.
H2261 *	Error message	Extended safety unit's No. error
	Cause	The extended safety unit's station No. is illegal.
	Solution	Set the extended safety unit's station No. to 2.
H2270	Error message	Cannot servo ON (SS1/STO active)
	Cause	The servo cannot be turned ON while SS1/STO is active.
	Solution	Disable SS1 before turning the servo ON.
H2280 *	Error message	SS1 deceleration time exceeded
	Cause	The robot didn't stop within deceleration time from SS1 enabled.
	Solution	Check operation instructions, terminal load, and stop speed (SFSPZERO) parameter of the robot.
H2281 *	Error message	SS2 deceleration time exceeded
	Cause	The robot didn't stop within deceleration time from SS2 enabled.
	Solution	Check operation instructions, terminal load, and stop speed (SFSPZERO) parameter of the robot.
H2282	Error message	SOS (Position error)
	Cause	Detect the change of position FB on SOS.
	Solution	During the SOS monitoring, change in the position FB due to external force was detected. Remove the external force factor or assess risks and adjust parameter SOSTLRNC to extend the allowable range of the SOS monitoring.
	Error message	SOS (Speed error)
	Cause	Detect FB speed over on SOS.
	Solution	Please check external force or related parameter settings.
	Error message	SOS (Position command error)
	Cause	Detect the change of position CMD on SOS.
	Solution	Please confirm the robot movement or related parameter setting.
	Error message	SOS (Speed command error)
	Cause	Detect CMD speed over on SOS.
	Solution	Please confirm the robot movement or related parameter setting.
H230n (The letter "n" is an axis number. [1 to 8])	Error message	SLS (Joint Speed Error)
	Cause	Speed monitor detected the speed over.
	Solution	The speed monitoring function detected a speed exceeding the predetermined speed. Check the robot movement or the monitoring speed setting. Also, check that the deceleration monitoring time is not too short.

Error number	Error causes and solutions					
H231n (n shows the direction where a problem is detected.) 1: Synthesized speed 2: X+, 3: X- 4: Y+, 5: Y- 6: Z+, 7: Z-	Error message	SLS (XYZ Speed Error)				
	Cause	Speed monitor detected the speed over.				
	Solution	The speed monitoring function detected a speed exceeding the predetermined speed. Check the following. 1) Robot movement and monitoring speed setting 2) Deceleration monitoring time (if it is too short) (A deceleration monitoring time is the waiting time from when the SLS command is enabled until when monitoring starts.) 3) Execution line (if it is the Tool command or M_Tool variable) of the program in the error state For further information on 1) and 2), refer to "4.5.5 Safely-limited speed function (SLS)". Since 3) occurs when the Tool command or M_Tool variable is executed before the robot's movement is completed (the feedback speed becomes zero), take one of the following countermeasures. For further information, refer to the "Instruction Manual/Detailed explanations of functions and operations". <ul style="list-style-type: none">• Create position data including tool conversion data using relative operations without using the Tool command or M_Tool variable. Program examples <table><tr><th>Before</th><th>After</th></tr><tr><td>Mov P1 Tool Ptool1 Mov P2</td><td>Mov P1 Mov P2 * Inv(Ptool1) * P_tool</td></tr></table> <ul style="list-style-type: none">• Add the Dly command before the Tool command or M_Tool variable. Alternatively, specify a positioning completion condition for the immediately preceding operation command using a Fine command so that the Tool command or M_Tool variable will be executed after the robot's movement is completed (the feedback speed becomes zero).• Decrease the movement speed so that the Tool command or M_Tool variable will be executed after the robot's movement is completed (the feedback speed becomes zero).	Before	After	Mov P1 Tool Ptool1 Mov P2	Mov P1 Mov P2 * Inv(Ptool1) * P_tool
		Before	After			
		Mov P1 Tool Ptool1 Mov P2	Mov P1 Mov P2 * Inv(Ptool1) * P_tool			
H2320	Error message	SF robot control error				
	Cause	The robot motion command and the feedback are inconsistent.				
	Solution	The robot's position command and feedback position do not match. Check the movement of the robot, the load on the hand, and whether the robot is interfering with any peripheral devices.				
H2370 *	Error message	SF (Process error)				
	Cause	The Safety Function is not normally executed.				
	Solution	Reset the error by power-cycling the robot. If the same error recurs, contact the manufacturer.				
	Error message	SF (Process Counter error)				
	Cause	The Safety Function of servo CPU is not normally executed.				
	Solution	Reset the error by power-cycling the robot. If the same error recurs, contact the manufacturer.				

6.2 Errors Whose Specification Is Changed by Safety Monitoring Functions

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

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

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

Error number	Error message
H0039	Faulty wiring (Door Switch)
H0046	Faulty wiring (Mode sel. switch)
H0049	Faulty Line (T/B Enable Switch)
H0051	Faulty wiring (External EMG)
H0059	Faulty wiring (Enabling Device)
H0061	Faulty line (O/P EMG)
H0071	Faulty line (T/B EMG)
H0074	Faulty line (T/B Enable/Disable)
H1680	Cannot servo ON (timeout)
H1681	Unexpected servo OFF
H1682	Servo ON Timeout(Safety relay)
H1683	Servo ON Timeout.(Contactor)

7. SAFE STOPPING DISTANCE

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

7.1 How to Calculate a Stopping Distance

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

(Assume that the robot has brakes on all the axes.)

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

$d_{\max}$: Maximum stopping distance

$V_{\max}$: Maximum speed (Equivalent to the SLS monitoring speed when the SLS function is enabled)

T_{res} : Reaction time (time from error detection to stop) (Approximately 7.1 msec)

$T_{\max}$: Maximum stopping time (Differs from robot to robot, see chapter 7.2)

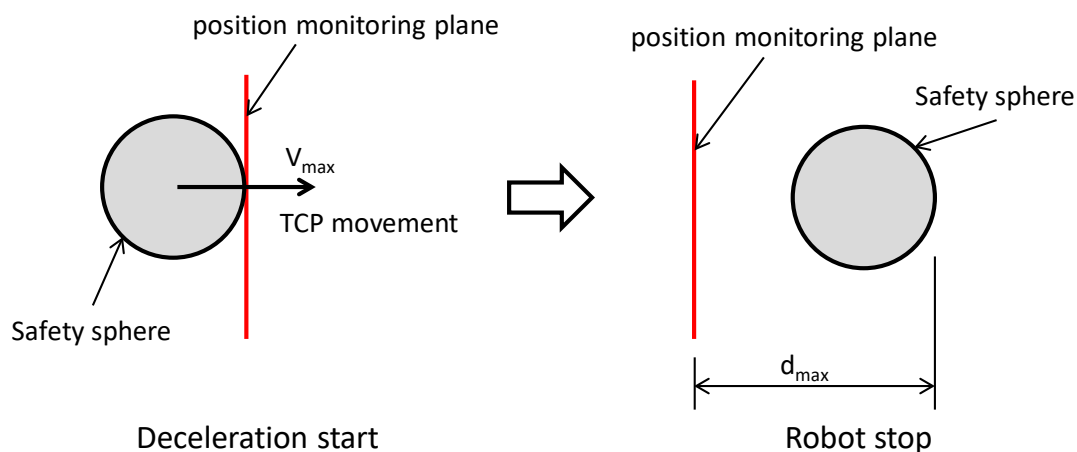
α : Safety factor (1 or more)



Caution

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

Depending on the posture of the robot, the arm may droop if the axis does not have a brake. The amount of droop is not considered in the calculation of the stopping distance described in this section.



<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 stop the robot. Therefore, the SLS monitoring speed can be considered equivalent to the maximum speed. Thus, reducing the SLS monitoring speed enables shortening the maximum stopping distance when power supply shut-off or an internal error shuts off the driving energy.

When Advanced Mode of the SLS function is configured, each of the X, Y, Z components are monitored for their speed, which enables restricting the maximum stopping distances for each of the X, Y, Z components. For example, if there is a safeguarded space in +X direction and the other directions are covered with safety fences, reducing the SLS speed only in +X direction enables ensuring safety and minimizing impact on tact time.

<Reaction time>

The delay between when an error detection enables the SS1 command and when deceleration starts is approximately 7.1 ms.

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

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

If an error occurs in the reading of the DSI input, there may be a delay of up to 72 ms before the signal is read.

<Maximum stopping time>

The maximum stopping time differs from robot to robot.

(see chapter 7.2)

(Example) In case of the table on the right, the maximum stopping time is the stopping time of J1 or 0.29 seconds, which results in the maximum stopping time of the robot being 0.29 seconds.

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

7.2 Maximum Stopping Time and Maximum Operating Angle

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

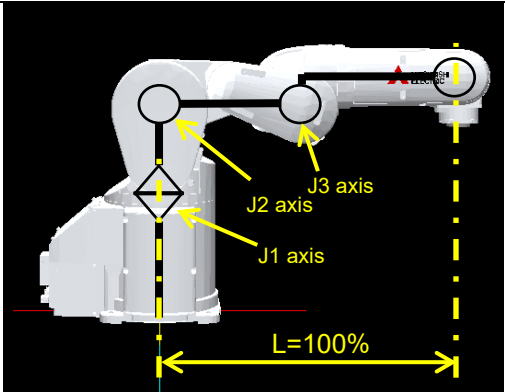
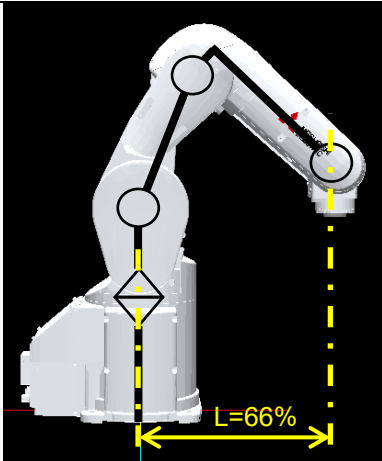
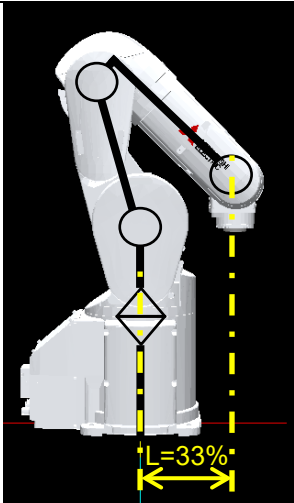
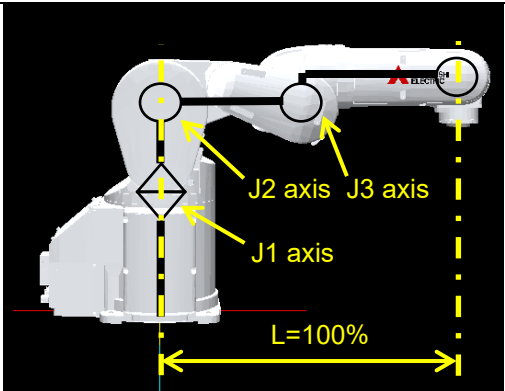
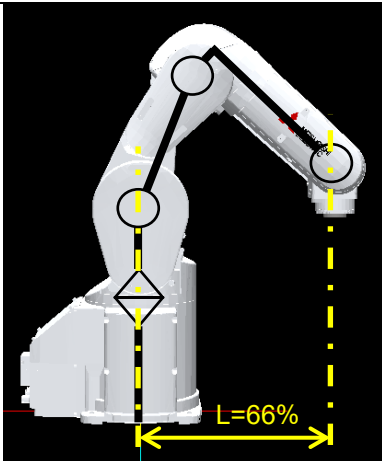
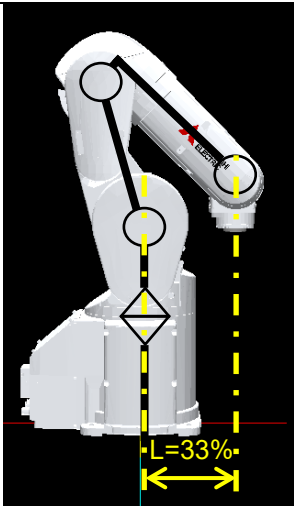
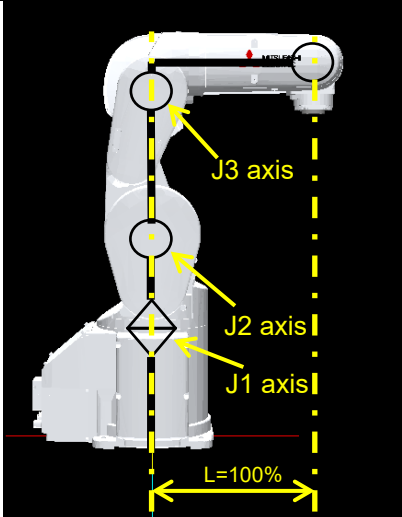
(1) What symbols mean

The following shows meanings of symbols used in this chapter.

String	Unit	Description	Description
L	mm	Degree of arm extension	This is the degree of extension of the arm in relation to each rotation axis. For details, see page 7-103.
M	%	Load ratio	This is the ratio of a load on the robot to the maximum load. Take for an example a robot with a maximum load of 4 kg. If M = 66%, the load on the robot is 2.64 kg.
OVRD	%	Robot override	This is an override for the robot speed.
t	s (second)	Stopping time	This is the maximum duration that elapses from when the SS1 function starts to when the motor power supply is shut off.
deg	°(degree)	Stopping angle	This is the maximum angle that the robot moves from when the SS1 function starts to when the robot stops.
d	mm	Stopping distance	This is the maximum distance that the robot moves from when the SS1 function starts to when the robot stops. This is applicable to the J3 axes of RH-FRH and RH-CRH series robots.

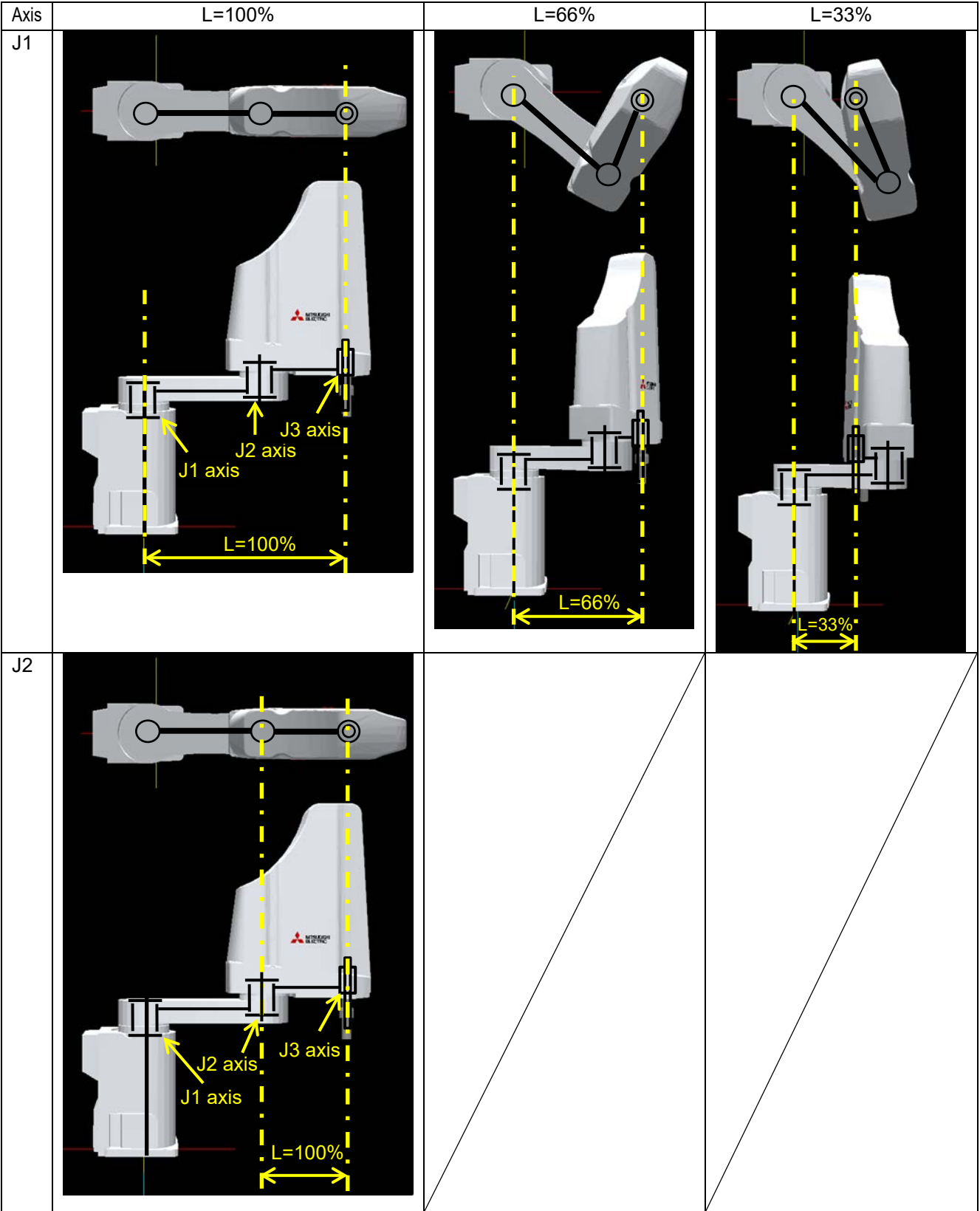
(2) The degree of extension of the robot arm

(a) RV-FR/RV-CR series

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

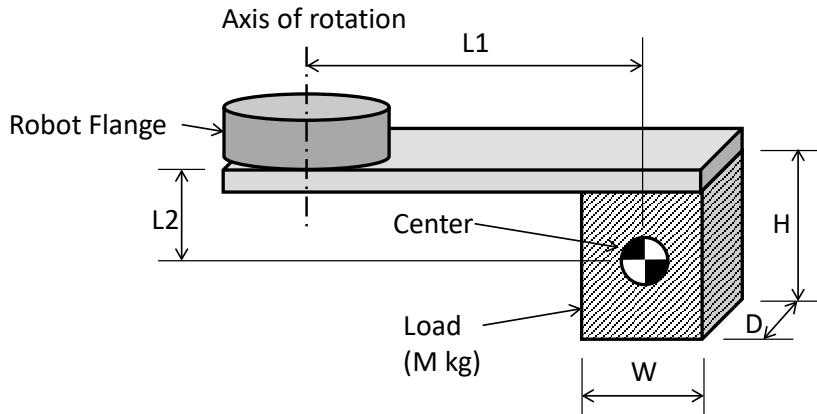
Note) The robot in the figure is RV-4FR.

(b) RH-FRH/RH-CRH series



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

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



Robot model	Load type	Mass kg	Size mm			Distance mm	
		M	W	D	H	L1	L2
RV-2FRB	Load 1	2	70	70	50	100	45
RV-2FRLB	Load 1	2	70	70	50	100	45
RV-4FR	Load 1	4	78	78	90	100	95
RV-4FRL	Load 1	4	78	78	90	100	95
RV-4FRJL	Load 1	4	78	78	90	100	95
RV-7FR	Load 1	7	95	95	95	100	170
RV-7FRL	Load 1	7	95	95	95	100	170
RV-7FRLL	Load 1	7	95	95	95	100	170
RV-13FR	Load 1	12	120	120	105	96	124
RV-13FRL	Load 1	12	120	120	105	96	124
RV-20FR	Load 1	15	160	160	78	73	189
RV-35FR	Load 1	35	797	797	915	336	387
RV-50FR	Load 1	50	684	684	784	375	405
RV-80FR	Load 1	80	450	450	530	373	335
RV-8CRL	Load 1	7	95	95	95	100	165
RV-12CRL	Load 1	12	330	260	115	95	131
RH-3FRH	Load 1	1	72	72	42	71	13
	Load 2	3	82	82	61	142	22
RH-6FRH	Load 1	3	82	82	61	60	23
	Load 2	6	104	104	74	140	29
RH-12FRH	Load 1	3	125	80	33	108	19
	Load 2	12	165	165	54	158	29
RH-20FRH	Load 1	5	125	125	34	133	19
	Load 2	20	165	165	91	233	52
RH-3FRHR	Load 1	1	180	60	9	50	-5
	Load 2	3	82	82	61	77	37
RH-1FRHR	Load 1	1	72	72	42	71	13
RH-3CRH	Load 1	1	85	85	52	58	12
	Load 2	3	115	115	58	131	23
RH-6CRH	Load 1	2	93	93	52	54	13
	Load 2	6	138	138	45	133	36
RH-10CRH	Load 1	5	70	70	128	61	55
	Load 2	10	206	206	24	153	24
RH-20CRH	Load 1	10	92	92	150	67	71
	Load 2	20	258	258	34	199	33

7 SAFE STOPPING DISTANCE

RV-2FRB

Stopping time and stopping distance (emergency stop)

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

Stopping time and stopping distance (power off)

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

RV-2FRLB

Stopping time and stopping distance (emergency stop)

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

Stopping time and stopping distance (power off)

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

7 SAFE STOPPING DISTANCE

RV-4FR

Stopping time and stopping distance (emergency stop)

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

Stopping time and stopping distance (power off)

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

RV-4FRL

Stopping time and stopping distance (emergency stop)

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

Stopping time and stopping distance (power off)

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

7 SAFE STOPPING DISTANCE

RV-7FR

Stopping time and stopping distance (emergency stop)

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

Stopping time and stopping distance (power off)

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

RV-7FRL

Stopping time and stopping distance (emergency stop)

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

Stopping time and stopping distance (power off)

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

7 SAFE STOPPING DISTANCE

RV-7FRLL

Stopping time and stopping distance (emergency stop)

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

Stopping time and stopping distance (power off)

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

RV-13FR

Stopping time and stopping distance (emergency stop)

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

Stopping time and stopping distance (power off)

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

7 SAFE STOPPING DISTANCE

RV-13FRL

Stopping time and stopping distance (emergency stop)

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

Stopping time and stopping distance (power off)

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

RV-20FR

Stopping time and stopping distance (emergency stop)

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

Stopping time and stopping distance (power off)

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

7 SAFE STOPPING DISTANCE

RV-35FR

Stopping time and stopping distance (emergency stop)

Axis	Arm extension	Load rate	Stopping time [s]			Stopping distance [deg]		
			Ovrd 33%	Ovrd 66%	Ovrd 100%	Ovrd 33%	Ovrd 66%	Ovrd 100%
J1	L=100%	M=100%	0.94	1.26	1.59	28.73	76.29	144.96
		M=66%	0.91	1.23	1.55	27.74	74.29	141.94
		M=33%	0.88	1.19	1.52	26.71	72.23	138.82
		M=0%	0.84	1.15	1.48	25.60	70.02	135.47
	L=66%	M=100%	0.90	1.22	1.54	27.49	73.80	141.19
		M=66%	0.86	1.17	1.50	26.12	71.06	137.05
		M=33%	0.81	1.12	1.45	24.66	68.13	132.60
		M=0%	0.79	1.10	1.43	24.06	66.93	130.79
	L=33%	M=100%	0.90	1.22	1.54	27.39	73.61	140.90
		M=66%	0.85	1.17	1.49	26.01	70.84	136.71
		M=33%	0.80	1.12	1.44	24.52	67.86	132.20
		M=0%	0.74	1.06	1.39	22.82	64.46	127.04
J2	L=100%	M=100%	0.90	1.17	1.46	27.32	71.11	133.45
		M=66%	0.86	1.14	1.43	26.32	69.11	130.41
		M=33%	0.83	1.10	1.39	25.28	67.03	127.27
		M=0%	0.79	1.07	1.35	24.16	64.79	123.88
	L=66%	M=100%	0.85	1.13	1.41	25.90	68.27	129.14
		M=66%	0.80	1.08	1.36	24.53	65.52	124.98
		M=33%	0.75	1.03	1.31	23.05	62.57	120.51
		M=0%	0.73	1.01	1.29	22.44	61.35	118.66
	L=33%	M=100%	0.87	1.15	1.44	26.70	69.86	131.55
		M=66%	0.83	1.11	1.39	25.31	67.08	127.34
		M=33%	0.78	1.05	1.34	23.81	64.09	122.80
		M=0%	0.72	1.00	1.28	22.10	60.66	117.61
J3	-	M=100%	0.80	0.99	1.20	25.06	62.20	113.11
		M=66%	0.76	0.96	1.16	23.97	60.02	109.81
		M=33%	0.72	0.92	1.13	22.83	57.75	106.36
		M=0%	0.68	0.88	1.09	21.59	55.26	102.60
J4	-	M=100%	0.76	0.96	1.16	33.72	84.4	154.43
		M=66%	0.73	0.93	1.14	32.56	82.1	150.92
		M=33%	0.71	0.90	1.11	31.35	79.7	147.27
		M=0%	0.68	0.87	1.08	30.06	77.1	143.36
J5	-	M=100%	0.76	0.96	1.16	33.72	84.4	154.43
		M=66%	0.73	0.93	1.14	32.56	82.1	150.92
		M=33%	0.71	0.90	1.11	31.35	79.7	147.27
		M=0%	0.68	0.87	1.08	30.06	77.1	143.36
J6	-	Load 1	0.76	0.96	1.16	46.73	117.0	213.98

Stopping time and stopping distance (power off)

Axis	Arm extension	Load rate	Stopping time [s]	Stopping distance [deg]
			Ovrd 100%	Ovrd 100%
J1	L=100%	M=100%	0.54	50.86
J2	L=100%	M=100%	0.73	57.26
J3	L=100%	M=100%	0.51	49.43
J4	-	M=100%	0.21	31.46
J5	-	M=100%	0.24	39.96
J6	-	Load 1	0.36	65.76

RV-50FR

Stopping time and stopping distance (emergency stop)

Axis	Arm extension	Load rate	Stopping time [s]			Stopping distance [deg]		
			Ovrd 33%	Ovrd 66%	Ovrd 100%	Ovrd 33%	Ovrd 66%	Ovrd 100%
J1	L=100%	M=100%	1.00	1.31	1.64	30.27	79.36	149.61
		M=66%	0.95	1.27	1.59	28.93	76.68	145.55
		M=33%	0.90	1.22	1.55	27.52	73.85	141.27
		M=0%	0.85	1.17	1.49	25.96	70.73	136.55
	L=66%	M=100%	0.96	1.28	1.60	29.25	77.32	146.52
		M=66%	0.90	1.22	1.54	27.45	73.72	141.08
		M=33%	0.83	1.15	1.48	25.48	69.79	135.11
		M=0%	0.79	1.11	1.44	24.24	67.29	131.33
	L=33%	M=100%	0.96	1.27	1.60	29.17	77.15	146.27
		M=66%	0.90	1.21	1.54	27.35	73.52	140.77
		M=33%	0.83	1.15	1.47	25.36	69.54	134.74
		M=0%	0.75	1.07	1.39	23.00	64.81	127.58
J2	L=100%	M=100%	0.90	1.18	1.46	27.44	71.34	133.80
		M=66%	0.85	1.13	1.42	26.09	68.65	129.72
		M=33%	0.81	1.08	1.37	24.67	65.80	125.40
		M=0%	0.75	1.03	1.32	23.10	62.66	120.64
	L=66%	M=100%	0.90	1.18	1.46	27.49	71.44	133.95
		M=66%	0.84	1.12	1.40	25.68	67.83	128.48
		M=33%	0.77	1.05	1.34	23.71	63.88	122.49
		M=0%	0.73	1.01	1.29	22.44	61.35	118.66
	L=33%	M=100%	0.90	1.18	1.46	27.40	71.27	133.69
		M=66%	0.84	1.11	1.40	25.58	67.63	128.18
		M=33%	0.77	1.05	1.33	23.58	63.63	122.12
		M=0%	0.69	0.97	1.25	21.20	58.87	114.91
J3	-	M=100%	0.74	0.93	1.14	23.22	58.53	107.55
		M=66%	0.69	0.89	1.09	21.77	55.62	103.14
		M=33%	0.64	0.84	1.04	20.21	52.52	98.44
		M=0%	0.58	0.78	0.98	18.47	49.03	93.16
J4	-	M=100%	0.73	0.93	1.13	32.26	81.5	150.01
		M=66%	0.69	0.89	1.09	30.70	78.4	145.28
		M=33%	0.65	0.85	1.06	29.05	75.1	140.29
		M=0%	0.61	0.81	1.01	27.23	71.4	134.78
J5	-	M=100%	0.81	1.00	1.21	35.60	88.2	160.15
		M=66%	0.77	0.97	1.17	34.04	85.1	155.42
		M=33%	0.73	0.93	1.13	32.40	81.8	150.43
		M=0%	0.69	0.89	1.09	30.58	78.1	144.92
J6	-	Load 1	0.79	0.99	1.19	48.19	119.9	218.38

Stopping time and stopping distance (power off)

Axis	Arm extension	Load rate	Stopping time [s]	Stopping distance [deg]
			Ovrd 100%	Ovrd 100%
J1	L=100%	M=100%	0.68	59.67
J2	L=100%	M=100%	0.61	51.76
J3	L=100%	M=100%	0.43	41.88
J4	-	M=100%	0.28	38.55
J5	-	M=100%	0.36	49.66
J6	-	Load 1	0.43	77.38

7 SAFE STOPPING DISTANCE

RV-80FR

Stopping time and stopping distance (emergency stop)

Axis	Arm extension	Load rate	Stopping time [s]			Stopping distance [deg]		
			Ovrd 33%	Ovrd 66%	Ovrd 100%	Ovrd 33%	Ovrd 66%	Ovrd 100%
J1	L=100%	M=100%	1.07	1.38	1.71	32.43	83.68	156.17
		M=66%	1.00	1.32	1.65	30.49	79.80	150.29
		M=33%	0.93	1.25	1.57	28.38	75.58	143.89
		M=0%	0.85	1.17	1.49	25.96	70.73	136.55
	L=66%	M=100%	1.05	1.37	1.69	31.90	82.62	154.56
		M=66%	0.96	1.28	1.61	29.37	77.56	146.90
		M=33%	0.87	1.19	1.51	26.53	71.87	138.27
		M=0%	0.79	1.10	1.43	24.06	66.93	130.79
	L=33%	M=100%	1.07	1.38	1.71	32.36	83.54	155.95
		M=66%	0.98	1.30	1.62	29.82	78.46	148.25
		M=33%	0.88	1.20	1.53	26.95	72.72	139.55
		M=0%	0.76	1.08	1.41	23.35	65.53	128.66
J2	L=100%	M=100%	0.97	1.25	1.54	29.61	75.68	140.37
		M=66%	0.91	1.18	1.47	27.66	71.79	134.47
		M=33%	0.84	1.11	1.40	25.54	67.55	128.05
		M=0%	0.75	1.03	1.32	23.10	62.66	120.64
	L=66%	M=100%	0.86	1.14	1.43	26.40	69.27	130.66
		M=66%	0.78	1.06	1.34	23.87	64.20	122.98
		M=33%	0.68	0.96	1.25	21.01	58.49	114.33
		M=0%	0.60	0.88	1.16	18.52	53.51	106.78
	L=33%	M=100%	0.99	1.27	1.55	30.07	76.61	141.78
		M=66%	0.90	1.18	1.47	27.52	71.51	134.05
		M=33%	0.81	1.08	1.37	24.64	65.75	125.33
		M=0%	0.68	0.96	1.25	21.03	58.52	114.37
J3	-	M=100%	0.83	1.03	1.23	22.57	55.60	100.56
		M=66%	0.76	0.96	1.16	20.77	51.99	95.09
		M=33%	0.69	0.89	1.09	18.78	48.02	89.08
		M=0%	0.60	0.80	1.00	16.45	43.36	82.01
J4	-	M=100%	0.82	1.01	1.22	25.61	63.3	114.80
		M=66%	0.76	0.96	1.16	23.93	60.0	109.70
		M=33%	0.70	0.90	1.10	22.18	56.5	104.41
		M=0%	0.64	0.83	1.04	20.17	52.4	98.30
J5	-	M=100%	0.81	1.01	1.21	22.78	56.3	102.19
		M=66%	0.76	0.96	1.16	21.34	53.5	97.84
		M=33%	0.70	0.90	1.10	19.79	50.4	93.12
		M=0%	0.64	0.83	1.04	17.99	46.8	87.68
J6	-	Load 1	0.81	1.01	1.22	38.70	95.7	173.56

Stopping time and stopping distance (power off)

Axis	Arm extension	Load rate	Stopping time [s]	Stopping distance [deg]
			Ovrd 100%	Ovrd 100%
J1	L=100%	M=100%	0.75	67.05
J2	L=100%	M=100%	0.75	55.60
J3	L=100%	M=100%	0.50	42.52
J4	-	M=100%	0.23	24.89
J5	-	M=100%	0.27	23.99
J6	-	Load 1	0.38	58.90

RV-8CRL

Stopping time and stopping distance (emergency stop)

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

Stopping time and stopping distance (power off)

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

7 SAFE STOPPING DISTANCE

RV-12CRL

Stopping time and stopping distance (emergency stop)

Axis	Arm extension	Load rate	Stopping time [s]			Stopping distance [deg]		
			Ovrd 33%	Ovrd 66%	Ovrd 100%	Ovrd 33%	Ovrd 66%	Ovrd 100%
J1	L=100%	M=100%	0.89	0.95	1.01	40.9	87.2	140.3
		M=66%	0.86	0.91	0.98	39.3	83.9	135.4
		M=33%	0.82	0.88	0.94	37.6	80.6	130.3
		M=0%	0.78	0.84	0.90	39.7	85.2	138.3
	L=66%	M=100%	0.73	0.79	0.85	33.6	72.4	118.0
		M=66%	0.73	0.79	0.85	33.8	72.9	118.8
		M=33%	0.70	0.76	0.82	32.5	70.2	114.7
		M=0%	0.69	0.75	0.81	31.9	69.1	113.1
	L=33%	M=100%	0.66	0.72	0.78	30.6	66.6	109.2
		M=66%	0.73	0.79	0.85	33.9	73.1	119.0
		M=33%	0.67	0.73	0.79	30.9	67.0	109.8
		M=0%	0.64	0.70	0.76	29.5	64.4	105.8
J2	L=100%	M=100%	1.12	1.18	1.24	47.9	100.7	160.3
		M=66%	1.09	1.15	1.21	46.3	97.7	155.7
		M=33%	1.05	1.11	1.17	44.8	94.5	150.9
		M=0%	1.01	1.07	1.13	43.1	91.1	145.8
	L=66%	M=100%	0.72	0.78	0.84	31.2	67.3	109.7
		M=66%	0.66	0.72	0.78	28.5	62.0	101.7
		M=33%	0.63	0.69	0.75	27.3	59.5	97.9
		M=0%	0.62	0.68	0.74	26.8	58.5	96.4
	L=33%	M=100%	0.68	0.74	0.80	29.6	64.1	104.8
		M=66%	0.62	0.68	0.74	26.9	58.8	96.9
		M=33%	0.55	0.61	0.67	24.1	53.2	88.4
		M=0%	0.52	0.58	0.64	22.9	50.7	84.6
J3	-	M=100%	0.67	0.73	0.79	33.2	72.0	118.0
		M=66%	0.63	0.69	0.75	31.4	68.6	112.8
		M=33%	0.59	0.65	0.72	29.6	65.0	107.3
		M=0%	0.55	0.61	0.67	27.7	61.1	101.4
J4	-	M=100%	0.89	0.95	1.01	73.2	155.9	251.2
		M=66%	0.85	0.91	0.97	70.3	150.1	242.4
		M=33%	0.81	0.87	0.93	67.2	144.1	233.2
		M=0%	0.77	0.83	0.89	64.0	137.5	223.3
J5	-	M=100%	0.72	0.78	0.84	58.8	127.1	207.3
		M=66%	0.68	0.74	0.80	56.0	121.4	198.6
		M=33%	0.64	0.70	0.76	53.0	115.4	189.5
		M=0%	0.60	0.66	0.72	49.7	108.9	179.8
J6	-	Load 1	0.88	0.94	1.00	116.1	247.6	399.0

Stopping time and stopping distance (power off)

Axis	Arm extension	Load rate	Stopping time [s]	Stopping distance [deg]
			Ovrd 100%	Ovrd 100%
J1	L=100%	M=100%	0.69	88.6
J2	L=100%	M=100%	0.63	83.2
J3	L=100%	M=100%	0.53	79.0
J4	-	M=100%	0.13	22.1
J5	-	M=100%	0.21	38.4
J6	-	Load 1	0.21	47.0

RH-3FRH

Stopping time and stopping distance (emergency stop)

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

Stopping time and stopping distance (power off)

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

7 SAFE STOPPING DISTANCE

RH-6FRH

Stopping time and stopping distance (emergency stop)

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

Stopping time and stopping distance (power off)

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

RH-12FRH

Stopping time and stopping distance (emergency stop)

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

Stopping time and stopping distance (power off)

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

7 SAFE STOPPING DISTANCE

RH-20FRH

Stopping time and stopping distance (emergency stop)

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

Stopping time and stopping distance (power off)

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

RH-3FRHR

Stopping time and stopping distance (emergency stop)

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

Stopping time and stopping distance (power off)

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

7 SAFE STOPPING DISTANCE

RH-1FRHR

Stopping time and stopping distance (emergency stop)

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

Stopping time and stopping distance (power off)

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

RH-3CRH

Stopping time and stopping distance (emergency stop)

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

Stopping time and stopping distance (power off)

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

7 SAFE STOPPING DISTANCE

RH-6CRH

Stopping time and stopping distance (emergency stop)

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

Stopping time and stopping distance (power off)

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

RH-10CRH

Stopping time and stopping distance (emergency stop)

Axis	Arm extension	Load rate	Stopping time [s]			Stopping distance J1/J2/J4 axis [deg] J3 axis [mm]		
			Ovrd 33%	Ovrd 66%	Ovrd 100%	Ovrd 33%	Ovrd 66%	Ovrd 100%
J1	L=100%	M=100%	0.85	1.04	1.23	36.22	88.25	158.39
		M=66%	0.87	1.14	1.43	53.77	140.93	265.65
		M=33%	0.87	1.18	1.51	61.74	167.38	322.15
		M=0%	0.82	1.14	1.46	58.56	161.04	312.54
	L=66%	M=100%	0.85	1.04	1.23	36.22	88.25	158.39
		M=66%	0.87	1.14	1.43	53.74	140.88	265.57
		M=33%	0.82	1.14	1.46	58.59	161.09	312.62
		M=0%	0.75	1.06	1.39	53.34	150.58	296.70
	L=33%	M=100%	0.85	1.04	1.23	36.22	88.25	158.39
		M=66%	0.87	1.14	1.43	53.74	140.88	265.57
		M=33%	0.82	1.14	1.46	58.59	161.09	312.62
		M=0%	0.78	1.09	1.42	55.46	154.82	303.12
J2	-	M=100%	0.68	0.77	0.87	49.98	113.50	193.13
		M=66%	0.65	0.79	0.93	70.13	168.87	300.54
		M=33%	0.63	0.79	0.96	78.18	194.00	352.69
		M=0%	0.60	0.76	0.92	73.89	185.41	339.67
J3	-	M=100%	0.56	0.64	0.72	106.42	241.59	410.93
		M=66%	0.50	0.58	0.66	95.51	219.76	377.86
		M=33%	0.47	0.55	0.63	89.82	208.40	360.63
		M=0%	0.43	0.51	0.60	83.26	195.27	340.75
J4	-	Load 2	1.03	1.09	1.16	84.29	178.88	287.09
		Load 1	1.48	1.61	1.74	240.83	522.44	855.24

Stopping time and stopping distance (power off)

Axis	Arm extension	Load rate	Stopping time [s]	Stopping distance J1/J2/J4 axis [deg] J3 axis [mm]
			Ovrd 100%	Ovrd 100%
J1	L=100%	M=100%	0.85	50.84
J2	-	M=100%	0.80	36.76
J3	-	M=100%	0.28	36.51
J4	-	Load 2	0.62	44.49

7 SAFE STOPPING DISTANCE

RH-20CRH

Stopping time and stopping distance (emergency stop)

Axis	Arm extension	Load rate	Stopping time [s]			Stopping distance J1/J2/J4 axis [deg] J3 axis [mm]		
			Ovrd 33%	Ovrd 66%	Ovrd 100%	Ovrd 33%	Ovrd 66%	Ovrd 100%
J1	L=100%	M=100%	1.05	1.11	1.18	18.55	39.41	63.32
		M=66%	0.98	1.11	1.24	33.45	75.40	127.51
		M=33%	0.93	1.17	1.42	59.32	148.04	270.20
		M=0%	0.84	1.08	1.33	53.64	136.69	253.00
	L=66%	M=100%	1.05	1.11	1.18	18.55	39.41	63.32
		M=66%	0.98	1.11	1.24	33.45	75.40	127.51
		M=33%	0.93	1.17	1.42	59.23	147.86	269.94
		M=0%	0.79	1.03	1.28	50.62	130.65	243.86
	L=33%	M=100%	1.05	1.11	1.18	18.55	39.41	63.32
		M=66%	0.98	1.11	1.24	33.45	75.40	127.51
		M=33%	0.93	1.17	1.42	59.23	147.86	269.94
		M=0%	0.76	1.00	1.24	48.52	126.43	237.47
J2	-	M=100%	0.78	0.79	0.80	22.32	45.26	69.53
		M=66%	0.67	0.69	0.71	37.00	76.26	119.09
		M=33%	0.54	0.58	0.62	55.75	119.35	193.07
		M=0%	0.45	0.49	0.53	47.27	102.39	167.37
J3	-	M=100%	0.80	0.88	0.96	317.88	696.74	1150.87
		M=66%	0.67	0.75	0.83	268.76	598.51	1002.04
		M=33%	0.51	0.59	0.67	206.96	474.91	814.76
		M=0%	0.43	0.51	0.59	173.67	408.33	713.89
J4	-	Load 2	1.33	1.35	1.37	52.24	106.05	163.12
		Load 1	2.19	2.21	2.24	109.83	222.25	340.79

Stopping time and stopping distance (power off)

Axis	Arm extension	Load rate	Stopping time [s]	Stopping distance J1/J2/J4 axis [deg] J3 axis [mm]
			Ovrd 100%	Ovrd 100%
J1	L=100%	M=100%	0.96	29.48
J2	-	M=100%	0.71	27.75
J3	-	M=100%	0.28	48.92
J4	-	Load 2	0.51	39.65

7.3 Calculating stopping distance and stopping time

This section explains how to calculate stopping distance and stopping time with RT ToolBox3.

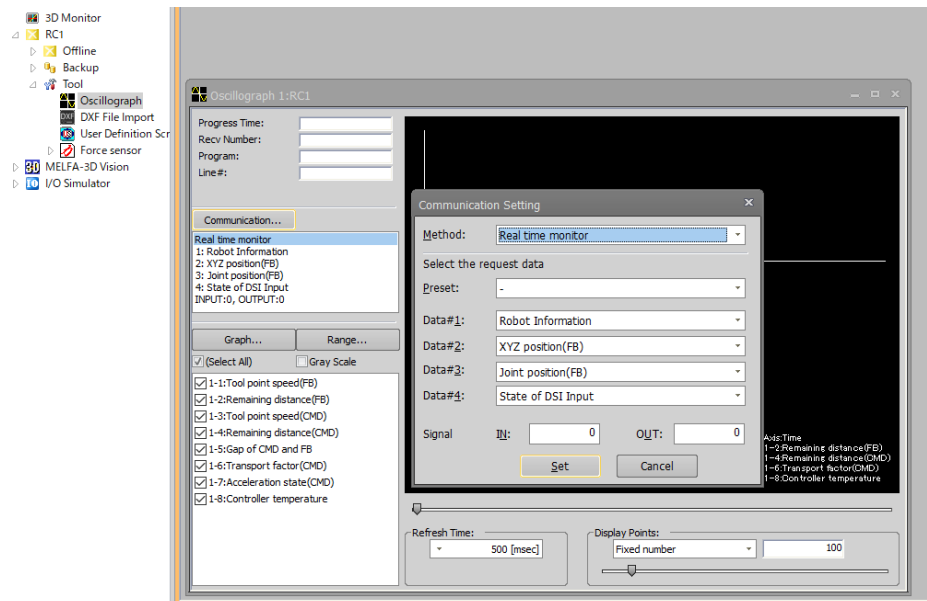
Calculating the stopping distance and time based on actual peripheral devices (such as hands) and the program that will be used will provide more accurate results. For information on how to use RT ToolBox3 or how to configure the advanced settings, refer to the RT ToolBox3 or RT ToolBox3 mini Instruction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

① Configure the log settings of the oscillograph function.

Connect the robot controller to RT ToolBox3 via Ethernet, set the controller to Online mode, then select Tool → Oscillograph. Configure the communication settings as follows:

- Method: Real time monitor

- Data No.1 to 4: Robot Information / XYZ position (FB) / Joint position (FB) / State of DSI Input

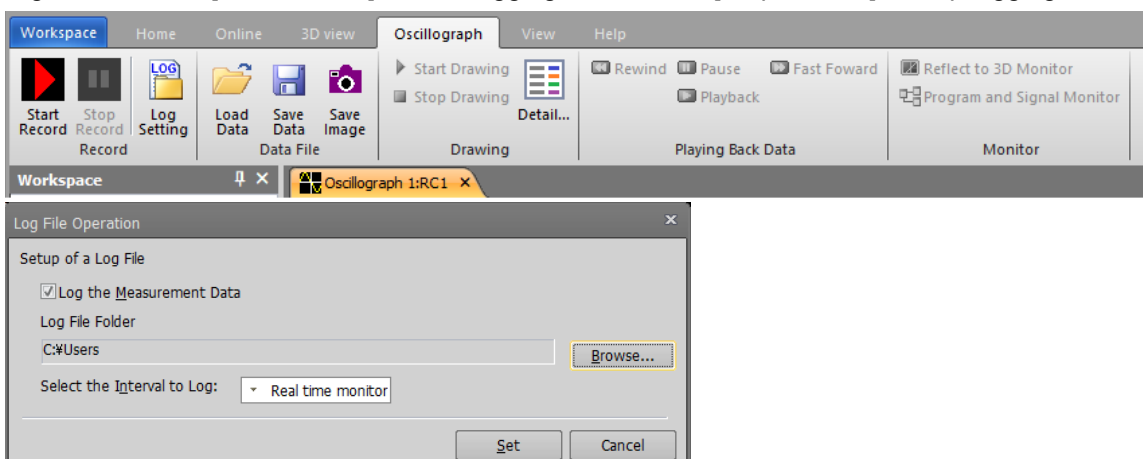


Note that Real time monitor cannot be selected when the robot controller is connected to RT ToolBox3 via USB.

If some of the data that has been received is lost, we recommend connecting the robot controller and computer directly (not via a network hub), using a high-performance computer, or not using this software while any other application is open.

② Create the robot log.

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



③ Log data.

Operate the robot and start data logging.

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



Caution

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

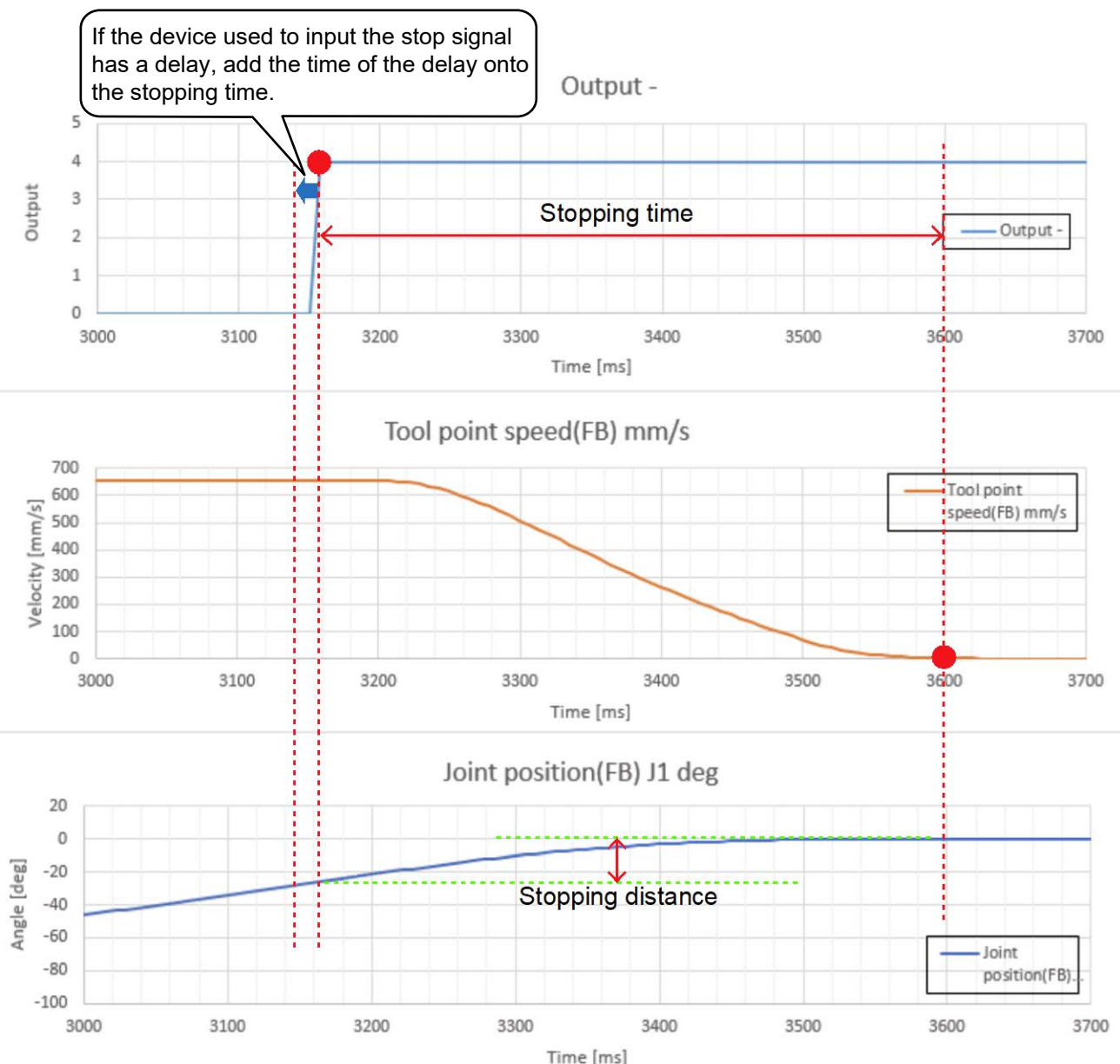
The initial value is 10 ms, therefore there will be a delay of 10 ms until the DSI input is enabled for the input signal.

④ Interpret the stopping distance and stopping time.

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

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

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



8. APPENDIX

8.1 Appendix 1: Selection Conditions for 24VDC Stabilized Power Supply

Consider the following characteristics when selecting the stabilized power supply (prepared by machine manufacturer).

Use a power supply that complies with CE Marking or that follows the safety standards given below.

(1) Stabilized power supply selection items

Item		Selection criteria	Remarks
Output	Voltage	DC24V	If the distance between the stabilized power supply and the 24VDC input unit is far, select a stabilized power supply capable of setting 24VDC or higher as the output voltage, taking into account the effect of voltage drop due to cables.
	Voltage fluctuation	±5%	±5% or less of 24VDC output
	Ripple noise	120mV (maximum)	
	Spike noise	500mV (maximum)	
	Overcurrent output cutoff function	—	Select a power supply with an overcurrent output cutoff function.
Output current		—	Refer to the maximum current consumption of the unit in use and calculate.
Output holding time		20ms(min)	Instantaneous power failure time (AC side)

(2) Standards

Item	Selection criteria
Safety Standards	UL1950, CSA C22.2 No. 234 approved, IEC950 compliant
Noise Terminal Voltage	FCC Class A, VCCI-Class A
High Harmonics Current Restrictions:	IEC61000-3-2

(3) Reference values for current consumption at 24 V supply voltage

Item		Consumption current	Remarks
①	Control power supply	0.3A	
②	Input circuit	5mA/point	
③		80mA	When all 8 input points are used (16 points in total due to signal duplication)
④	Output circuit	2.0A/point	
⑤		approx. 8.0A	When all 4 points are used in the entire unit

When using a single stabilized power supply with the maximum input and output specifications, the total current consumption (①+③+⑤) is approximately 8.38A.

Therefore, it is necessary to select a stabilized power supply of 24 V/200 W or more.

8.2 Appendix 2: How to Install the Safety Extension Unit

As a metal plate to install the safety extension unit, install a metal plate of the following size or smaller.

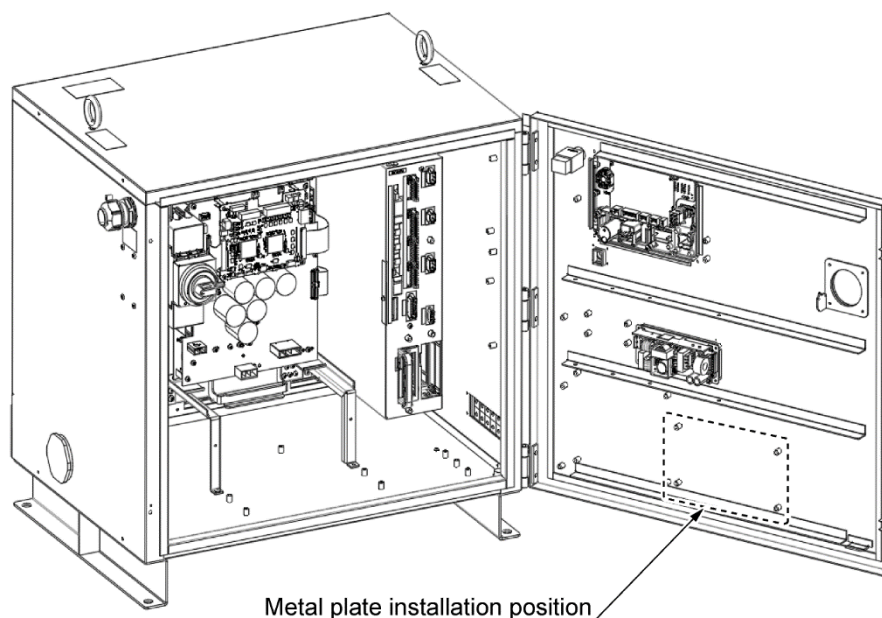
Where to install: Studs in the lower part of the door (four locations)

Metal plate installation pitch and screw size: 188mm×90mm (M4 screws)

Metal plate installation size: 200mm×116mm or less

Installation height: 50mm or less

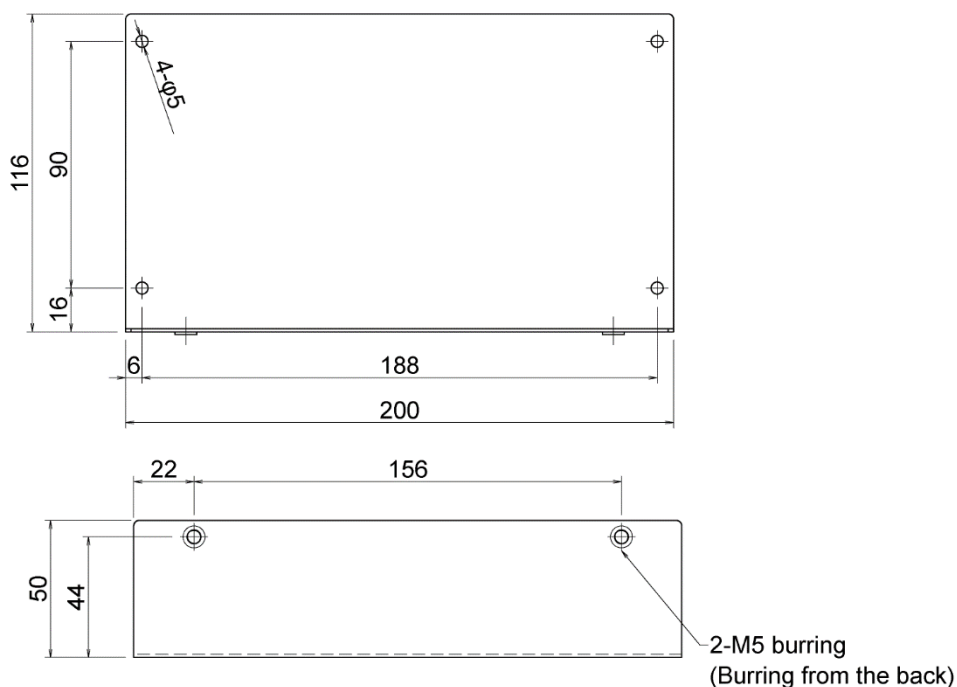
Installation thickness: 1.2mm to 1.6mm



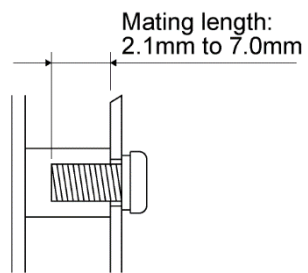
Use the following steps for the installation.

- 1) A metal plate with a size of 200mm×116mm or less can be installed.

Prepare the metal plate as shown in the figure below (metal plate installation pitch: 188mm×90mm, M4 screws).



- 2) Fix the metal plate to the installation position using the M4 screws (supplied by customer).
Select a screw length so that 2.1mm or more and less than 7.0mm of the screws can be tightened in the studs on the controller.



- 3) After the metal plate has been installed, fix the safety extension unit to the plate using the M5 screws (supplied by customer).
Select a 10mm to 12mm long screw.

8.3 Appendix 3: How to Install the Stabilized Power Supply for the Safety Extension Unit

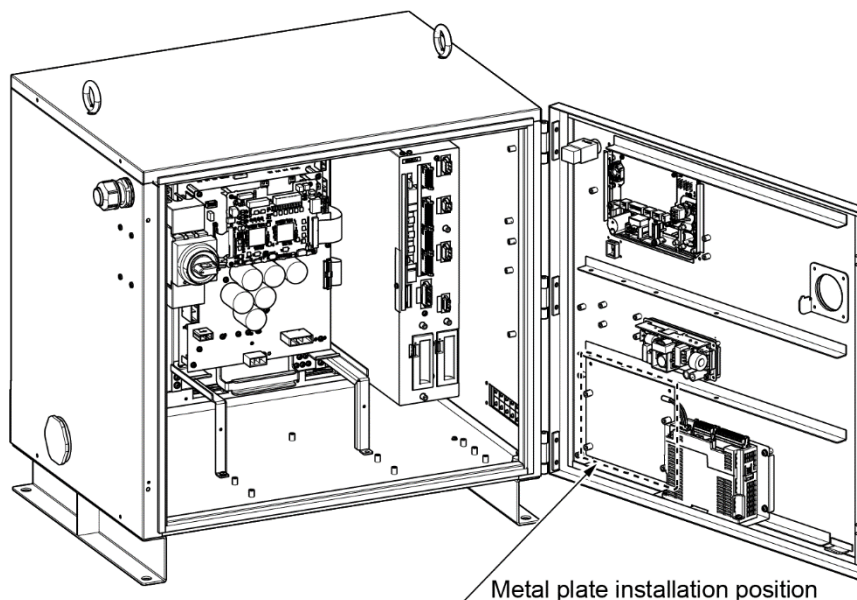
To fix the stabilized power supply for the safety extension unit, install a metal plate of the following size or smaller.

Where to install: Safety extension unit's left

Metal plate installation pitch and screw size: 170mm×140mm (M4 screws)

Metal plate installation size: 190mm×160mm or less

Installation height: 51mm or less

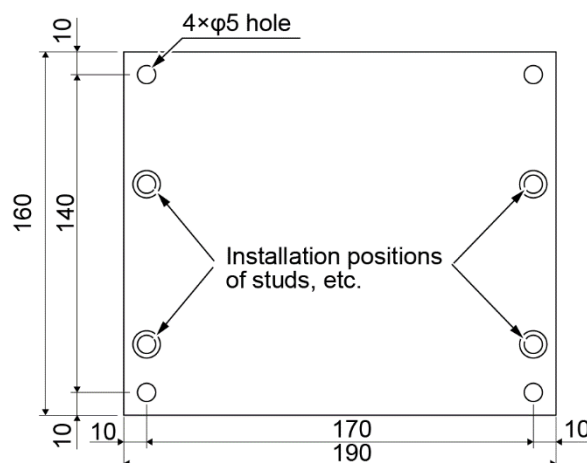


When installing the stabilized power supply (supplied by customer), use the following steps:

- 1) A metal plate with a size of 190mm×160mm or less can be installed.

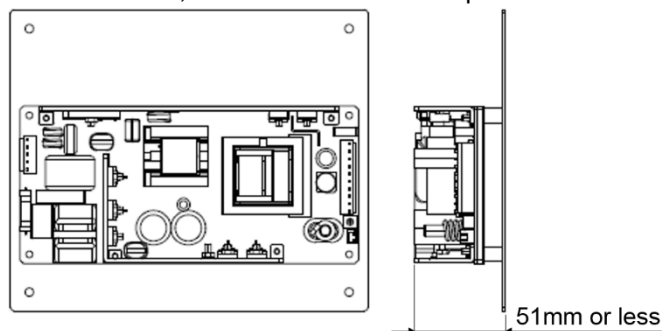
Prepare the metal plate as shown in the figure below (metal plate installation pitch: 170mm×140mm, M4 screws).

* Based on the specifications of the stabilized power supply selected in 8.1 Appendix 1: Selection Conditions for 24VDC Stabilized Power Supply, add studs or similar items to the metal plate. Additionally, ensure the strength of the metal plate by bending the plate or in other ways if necessary.

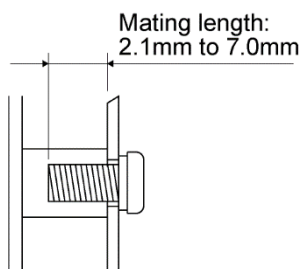


- 2) Ensure that the height of the selected stabilized power supply with the fixed metal plate (supplied by customer) is 51mm or less.

Caution: If the height is more than 51mm, interference with other parts in the controller may occur.



- 3) Fix the metal plate to the installation position using the M4 screws (supplied by customer).
Select a screw length so that 2.1mm or more and less than 7.0mm of the screws can be tightened in the studs on the controller.



8.4 Appendix 4: EMC installation guideline

8.4.1 Outlines

The EMC directive is coerced from January 1, 1996, and it is necessary to attach the CE mark which shows that the product is in conformity to directive.

Since the industrial robot is the component of the automation system, it considers that the EMC directive is not the target product of the direct. However, because it is one of the main components, introduces the method and components of the measures for conforming the automation system to the EMC directive.

And also we are carrying out the qualification test about the conformity of the EMC directive under the environment based on the contents of this document. However, the noise level is changed by the kind of equipment to be used, the layout, the construction of the controlling board, the course of wiring, etc. Therefore, please confirm by the customer eventually.

8.4.2 EMC directive

The Mitsubishi Electric industrial robot follows the European EMC directive. EMC can be broadly classified into two categories: EMI and EMS.

(1) Emission (EMI: Electromagnetic Interference).....The capacity not to generate the disturbance noise which has a bad influence outside.

(2) Immunity (EMS: Electromagnetic Susceptibility)....The capacity which does not malfunction for the disturbance noise from the outside.

Each contents are shown below.

Item	Name	Contents
Emission (EMI)	Radiative noise disturbance	The electromagnetic noise etc. which are emitted to environs.
	Electrical-conduction noise disturbance	The electromagnetism noise etc. which flow out of the power-supply line.
Immunity (EMS)	Electrostatic discharge immunity test	The noise from the electrified human body.
	Radiated, radio-frequency, electromagnetic field immunity test susceptibility test	The electromagnetism noise from the transceiver, the broadcasting station, etc.
	Electrical fast transient burst immunity test	The relay noise or the electromagnetism noise etc. which are caused in power-supply ON/OFF.
	Immunity to conducted disturbances induced radio-frequency fields	The electromagnetism noise etc. which flow in through the power source wire and the grounding wire.
	Power frequency magnetic field immunity test	The electromagnetism noise with a power supply frequency of 50/60 Hz etc.
	Voltage dips, short interruptions and voltage variations immunity test	The noise in the variation of the source voltage of the power dispatching, etc.
	Surge immunity test	The electromagnetism noise by the thunderbolt, etc.

8.4.3 EMC measures

There are mainly following items in the EMC measures.

- (1) Store into the sealed metal board.
- (2) Grounding all the conductor that have floated electrically (makes the impedance low).
- (3) Wiring so that the power source wire and signal wire are separated.
- (4) Use the shield cable for the cable which wired outside of the metal board.
- (5) Install the noise filter.

To suppress the noise emitted out of the board, be careful of the following item.

- (1) Ensure grounding of the equipment.
- (2) Use the shield cable.
- (3) Separate the metal board electrically. Narrows the distance/hole.

The strength of electromagnetic noise emitted to environment is changed a lot by the shielding efficiency of cable and the distance of metal board, so it should be careful.

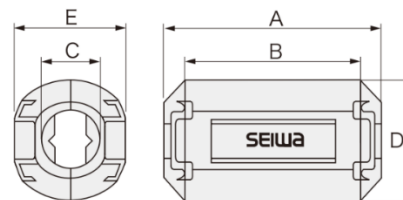
8.4.4 Component parts for EMC measures

(1) Ferrite core

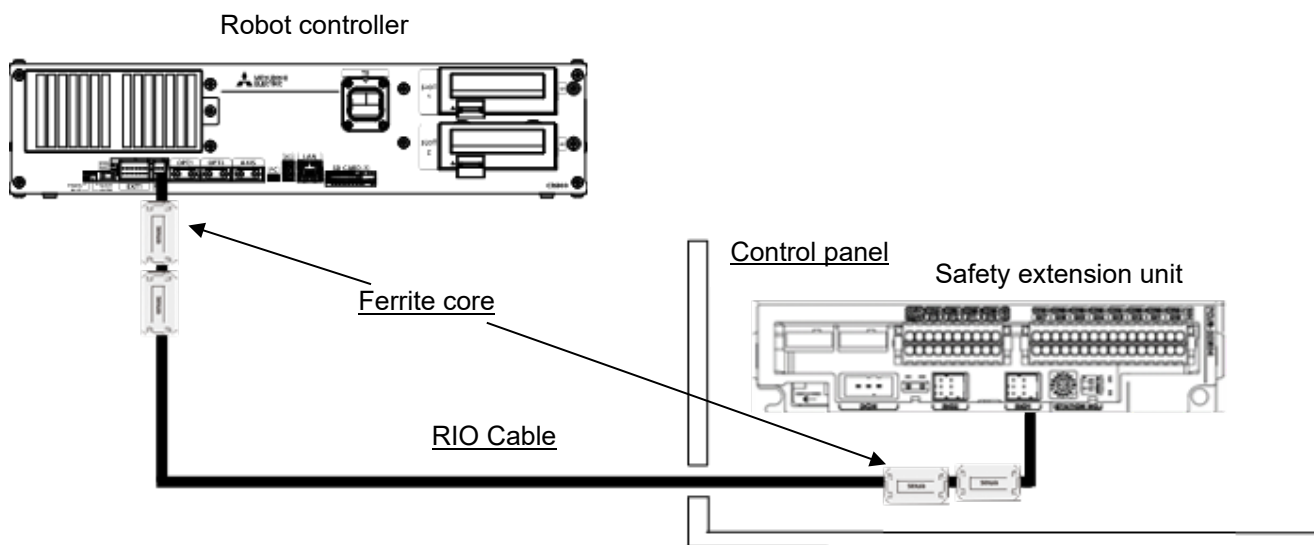
The ferrite core is mounted by the plastics case as one. It can attach by the one-touch, without cutting the cable. This has the effect in the common-mode noise. The measures against the noise are made not influential in the quality of the signal.

Manufacturer: SEIWA ELECTRIC MFG. CO., Ltd

Type	Outside dimension (mm)					Applicable cable diameter[max] (mm)
	A	B	C	D	E	
E04SR170730A	30.0	23.0	7.0	16.5	15.0	φ 4.0-7.0



Example of installation)

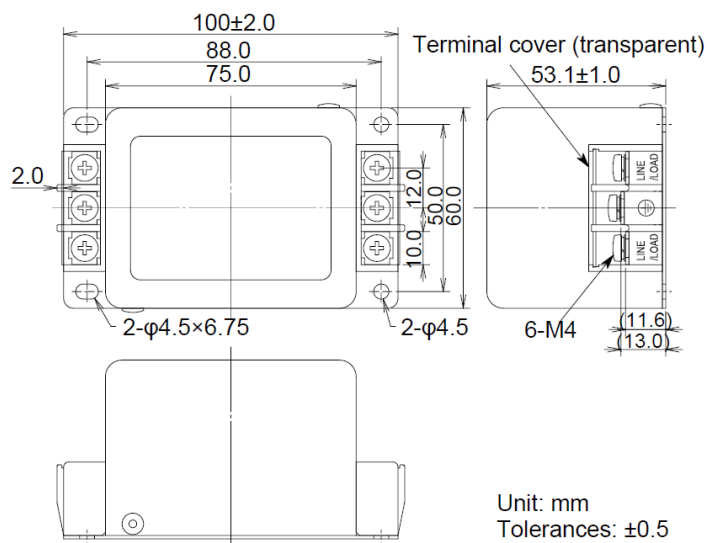


(2) Line noise filter

Install a line noise filter to AC input line.

Type: SUP-EL20-ER-6

Manufacturer: OKAYA ELECTRIC INDUSTRIES CO., LTD.



(3) Surge Absorber

Make sure that the surge does not directly enter the AC line of the general-purpose stabilized power supply (userprepared) supplying power to the control unit and DIO.

Select a product equivalent to or higher than the following products for the surge absorber.

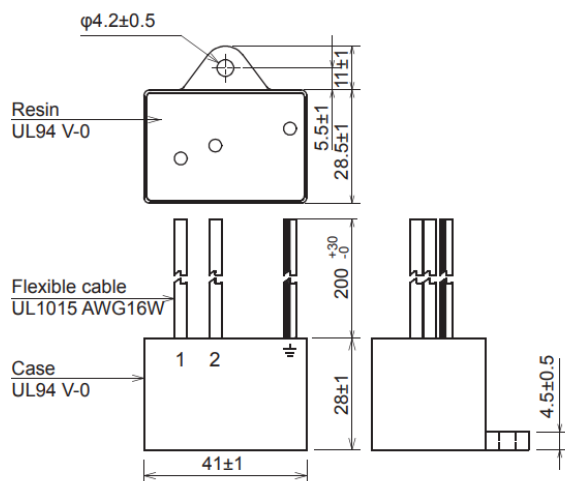
Refer to the manufacturer catalog for detailed characteristics, outline and connection methods of the surge absorber.

Type: RSPD-250-Q4

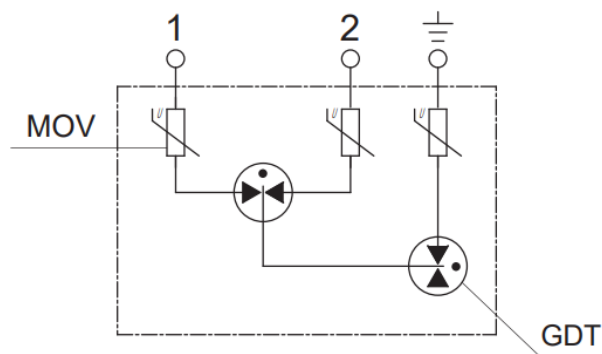
Manufacturer: OKAYA ELECTRIC INDUSTRIES CO., LTD.

Rated Voltage (50/60HZ)	DC Breakdown voltage	Voltage protection level	Normal discharge current	Maximum discharge current	Surge current life
AC250V(1 Phase)	700V $\pm$ 25%	1,3kV	8/20 μ s 2,5kA	8/20 μ s 5kA	8/20 μ s-1kA Approximately 300 times

• Outline drawing



• Circuit drawing



mitsubishi electric corporation

HEAD OFFICE: TOKYO BLDG., 2-7-3, MARUNOUCHI, CHIYODA-KU, TOKYO 100-8310, JAPAN
NAGOYA WORKS: 1-14, YADA-MINAMI 5-CHOME, HIGASHI-KU, NAGOYA 461-8670, JAPAN