MITSUBISHI ELECTRIC

Mitsubishi Electric Industrial Robot

Collaborative Robot: Detailed explanations of functions and operations

RV-5AS-D

SAFETY PRECAUTIONS

Read the separate "Collaborative Robot Safety Manual" thoroughly before using this product. Take precautions as necessary.

BASIC PRECAUTIONS AND IMPORTANT POINTS WHEN USING COLLABORATIVE ROBOTS

Collaborative robots have a variety of safety functions, so unlike conventional industrial robots, they can work in the same space as humans without being separated by a machine guard.
Even though collaborative robots are equipped with safety functions, it does not guarantee that they will not cause injury. To prevent injury, robot users, machine manufacturers who construct robot systems, and system builders such as system integrators must select and use functions correctly. Peripherals must be designed, manufactured, set, programmed, maintained, and inspected appropriately. Before working with collaborative robots, conduct risk assessments, check that no risk is present, and ensure all required documentation is in order.
It is vitally important that all the points mentioned above are fully understood in order to work with collaborative robots safely and without incident. When using collaborative robots, always keep in mind that they may move unexpectedly.

CONTENTS

1 BEFORE USE

1.1 Instruction manuals

This section describes the instruction manuals included with this product. Use these manuals according to the application.

Name	Description	Manual No.
Collaborative Robot Safety Manual	To ensure the safety of robot users, this manual provides information on common precautions and safety measures that should be taken when handling the robot or creating and designing robot systems. Read this manual first.	BFP-A3733
Hello ASSISTA Quick Set-up Guide	Describes procedures including unpacking, installation, programming using RT VisualBox, and operation of the robot.	BFP-A3715
Standard Specifications	Provides information on standard product specifications, options, and maintenance parts. It also provides information on safety and technical precautions when introducing the robot into a new environment.	BFP-A3727
Robot Arm Setup and Maintenance	Explains pre-operation requirements for the robot (unpacking, transportation, installation, and operation checks) and how to carry out maintenance and inspection.	BFP-A3729
Controller Setup and Maintenance	Explains the steps that must be taken before using the robot controller (unpacking, transportation, and installation). It also contains information on maintenance and inspection.	BFP-A3731
Collaborative Robot: Detailed explanations of functions and operations (this document)	Provides information on functions specific to collaborative robots.	BFP-A3735
Detailed explanations of functions and operations*1	Describes details on functions and operation methods, including information of how to use MELFA-BASIC VI commands in programs, how to connect external input/output devices, and how to set parameters. The FR series is used as an example for explanation purposes. For information on unsupported functions, refer to the following page: ☞ Page 4 Limited functions	BFP-A3478
Troubleshooting*1	Provides information on the causes and solutions to errors that may occur while operating the robot.	BFP-A3480
Tracking Function*1	Provides information on the specifications, functions, and usage of the conveyor tracking function.	BFP-A3520
GOT Direct Connection Extended Function*1	Describes the data configuration of the memory between the GOT and the robot, monitoring, and operating procedures.	BFP-A3546
Ethernet Function*1	Explains how to communicate with a computer over Ethernet using TCP/IP protocols.	BFP-A3379

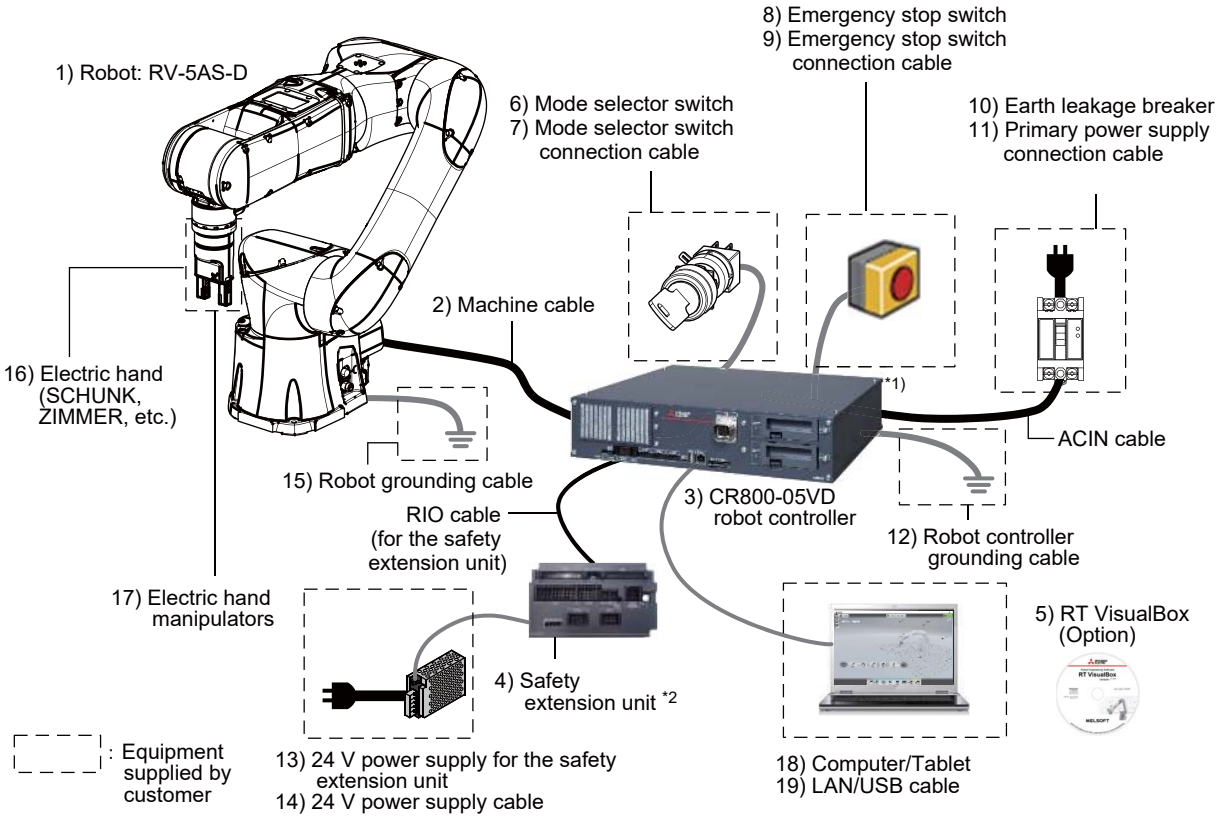
*1 Instances where the CR800-D controller is mentioned also refer to the CR800-05VD.

1.2 Limited functions

The following functions are available for the FR series. They are not available for this robot.

- MELFA Smart Plus
- Interference avoidance
- Additional axis
- MELFA-BASIC V
- Parallel input/output unit
- Multifunctional electric hand
- Position recovery support
- Maintenance forecast
- JRC command

1.3 System configuration



*1 Short circuit pins 6-22 and 13-29 of the CNUSR11 connector if not using a door switch.

*2 Always connect this unit.

*3 The option described in this section is required for startup. For any other optional items, refer to the option list in the following manual.
RV-5AS-D Standard Specifications (BFP-A3727)

System configuration

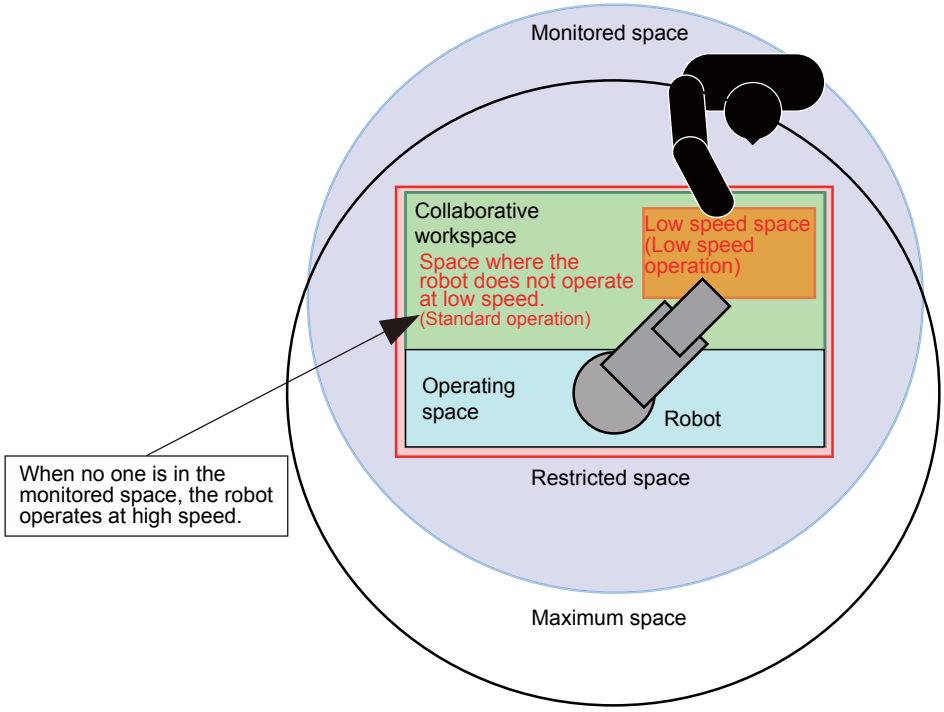
No.	Item	Specifications/Recommended products	Remarks
1)	Robot	RV-5AS-D	Standard configuration
2)	Machine cable	Fixed /Length: 5 m /Mass: 5 kg	Standard configuration
3)	Robot controller	CR800-05VD Ver.B1 or later	Standard configuration
4)	Safety extension unit	4F-SF002-01	Standard configuration
5)	RT VisualBox	Ver.1.0.0 or later (Japanese): 3G-30C-WINJ (English): 3G-30C-WINE	Option
6)	Mode selector switch	Recommended product: HA1K-2C2A-2 (manufactured by IDEC)	Supplied by customer
7)	Mode selector switch connection cable	Refer to the mode selector switch catalog to select a connector cable.	Supplied by customer
8)	Emergency stop switch	Use an IEC 60204-1 compliant emergency stop switch, which has two NC contacts for redundancy and a mechanical latching function.	Supplied by customer
9)	Emergency stop switch connection cable	Refer to the emergency stop switch catalog to select a connector cable.	Supplied by customer
10)	Earth leakage breaker	Recommended product: Single phase NV30FAU-2P-10A-AC100-240V-30mA (manufactured by Mitsubishi Electric). Make sure to attach the TCS-05FA2 terminal cover (manufactured by Mitsubishi Electric).	Supplied by customer Recommended specifications: • Rated current: 10 A • Rated sensed current: 30 mA • Rated breaking capacity: 2.5 kA
11)	Primary power supply connection cable	AWG14 (2 mm^2) or above	Supplied by customer
12)	Robot controller grounding cable	AWG14 (2 mm^2) or above	Supplied by customer
13)	24 V power supply for the safety extension unit	Choose a product that meets the following specifications: Voltage: 24 VDC ±5% Max. current draw: 300 mA	Supplied by customer

No.	Item	Specifications/Recommended products	Remarks
14)	24 V power cable	Recommended cable specifications Conductor size: 0.5 to 1.42 mm^2, (20 to 16 AWG) Outer sheath diameter: 1.8 to 2.8 mm Shielded	Supplied by customer
15)	Robot arm grounding cable	AWG11 (4.2 mm^2) or above	Supplied by customer
16)	Electric hand	Use a hand that satisfies the needs of the customer. For recommended hands, refer to the following manual: 📖RV-5AS-D Standard Specifications (BFP-A3727)	Supplied by customer
17)	Electric hand manipulators	Use manipulators that satisfy the needs of the customer.	Supplied by customer
18)	Tablet/Computer	Refer to the following manual: 📖RV-5AS-D Standard Specifications (BFP-A3727)	Supplied by customer
19)	LAN/USB cable	LAN: 10BASE-T / 100BASE-TX USB: USB Type-A to Mini USB Type-B	Supplied by customer

2 SAFETY MONITORING FUNCTION

2.1 Terms

Term	Description
Power and force limiting	Power and force limiting is one method of collaborative operation mentioned in ISO/TS 15066. A method of ensuring that the force and pressure generated in a collision between a human and a robot does not exceed a predetermined value by limiting both power and force. This robot uses the SLS and STR functions to achieve power and force limiting. The system builder must do the following before considering functional safety. • Clarify what a collision is (e.g. how and where a collision occurs). • Reduce inherent collision risks (use a collision-free system layout).
Maximum space	All the space that the robot (including its end effector and workpiece) is capable of entering.
Monitored space	The space monitored by devices such as area sensors and light curtains that detect the presence of humans.
Restricted space	The area within the maximum space in which the robot's movement is restricted by limiting devices.
Operating space	The area within the restricted space which the robot uses to execute all of its program-specified operations.
High-speed operation	The robot operation mode when people are not in the monitored space (i.e. when people are not near the robot). The maximum operation speed is 1000 [mm/s].
Collaborative space	A space within the robot system (including workpieces) where the robot and humans can work together.
Collaborative operation	The robot operation mode when people are in the monitored space (i.e. when people are near the robot). An operation mode that collectively refers to standard operation mode and low-speed operation mode.
Standard Operation	The robot operation mode when people are in the monitored space (people are beside the robot) and robot monitor models are not in the low-speed space. The maximum operation speed is 250 [mm/s]. Use this operation mode only in situations where there is no risk of body parts, such as hands and fingers, becoming trapped. Use devices, such as area sensors, to monitor spaces when switching from High-speed operation mode to Standard operation mode.
Low-speed space	The space in the collaboration area where it is necessary to reduce the possibility of harm to people.
Low-speed operation	The robot operation mode when people are in the monitored space (people are beside the robot) and robot monitor models are in the low-speed space. The maximum operation speed is 50 [mm/s]. Use this operation mode only in situations where there is a risk of body parts, such as hands and fingers, becoming trapped or where collision points cannot be limited.



Definition of space

For terms other than the above, refer to the following.

📖Robot Safety Option Instruction Manual (BFP-A3531)

2.2 Overview

This section explains how to use the robot's safety monitoring functions.

The following table shows the safety monitoring functions of the CR800 series robot safety option added to this robot.

Added safety functions

No.	Item	Description	Reference
1	STR function	Stops the robot with SS1 when a force exceeding a set value is applied to the robot.	—
2	SLP: Axis monitoring function	Monitors whether the positions of the robot's joints are within the threshold being monitored.	—

The following table shows additional functions associated with the above safety monitoring functions.

Additional functions

No.	Item	Description	Reference
1	Automatic speed adjusting function	Automatically adjusts the operation speed of the robot to the speed specified in the SLS monitoring speed or less.	—
2	Operation status output signal	Outputs the collaborative operation status with the dedicated output signal "SFMODE" to external devices.	☞ Page 30 Dedicated Output

2.3 Specifications

Specifications

Item			Description	Remarks
Safety function[*1]	STO function		Electrically shuts off power to the motors in the robot.	IEC 60204-1 Applicable to stop category 0
	SS1 function		Decelerates the motors in the robot. After the motors stop, the robot goes into the STO state.	IEC 60204-1 Applicable to stop category 1
	SS2 function		Decelerates the motors in the robot. After the motors stop, the robot goes into the SOS state.	IEC 60204-1 Applicable to stop category 2
	SOS function		Checks that the robot has stopped without shutting off power to the motors in the robot.	When SOS, SLS, SLP, and STR detect error, activate SS1. EN 61800-5-2 compliant
	SLS function		Checks that parts of the robot arm do not exceed the speed limit.	
	SLP function		Checks that a predetermined position does not pass through the position monitoring plane.	
	STR function		Ensures that the torque limits of each motor in the robot are not exceeded.	
Safety performance	Standard		EN ISO 10218-1: 2011 ISO/TS 15066: 2016 EN ISO 13849-1: 2015 IEC 61800-5-1: 2007 EN 61800-5-2: 2017 EN 61000-6-7: 2015 EN 61326-3-1: 2017 IEC 61508-1: 2010 IEC 61508-2: 2010 IEC 61508-3: 2010 EN 62061: 2005/A2: 2015 IEC 62061: 2005/AMD1: 2012/AMD2: 2015	—
	Performance[*2]	STO	SIL2, PLd/Category 3 (at factory settings) SIL3, PLe/Category 4 (with changes to parameters)[*3]	—
		SS1, SOS, SS2, SLS, SLP, STR	SIL2, PLd/Category 3	—
	Dangerous failure rate[*4]	STO	PFH = 1.40×10^{-8} [1/h]	—
		SS1, SS2, SOS	PFH = 3.42×10^{-7} [1/h]	—
		SLS	PFH = 3.42×10^{-7} [1/h]	—
		SLP	PFH = 3.42×10^{-7} [1/h]	—
		STR	PFH = 3.62×10^{-7} [1/h]	—

Item			Description	Remarks
Safety extension unit	Power supply specifications	Voltage	24 V DC ±5% Ripple voltage: 0.2 V (P-P)	Supplied by customer
		Maximum current consumption	300 mA	—
	Structure (IP rating)		IP20	—
	Mass		0.8 kg	—
	Environment	Operating temperature	0 to 40℃	Do not use the unit near heat sources including heating appliances.
		Relative humidity	45 to 75%	Non-condensing
		Vibration	During transportation 3.5 G During operation: 0.5 G or less	—
		Atmosphere	No corrosive gas, flammable gas, oil mist, and dust	—
		Installation environment	Indoor use. Install on environments free from strong electric or magnetic fields. Install on a smooth, level surface.	No direct sunlight. Do not install the unit on a rough surface.
	Input signal		8 routes (duplicate signals)	—
	Output signal		4 routes (duplicate signals)	—

*1 The safety functions conform to EN 61800-5-2.

*2 Safety performance of this product complies with IEC/EN 61508 and EN ISO 13849-1.

*3 To conform to SIL3, PLe/Category 4, a pulse test for the input is required. Refer to the following manual for further details.
RV-5AS-D Standard Specifications (BFP-A3727)

*4 The robot controller PFH or PFHd (Probability of Dangerous Failure per Hour). The PFH of the emergency stop switch and enable switch on the teaching pendant is shown in the table below.

Switch	Model No. / manufacturer	B10d [cycle]	n_{op} [cycle/year]	MTTFd [year]	DC [%]	PFH [1/hour]
Emergency stop switch	AB6E-3BV02PTRM / IDEC	1×10^{6}	6000	1667	99	2.47×10^{-8}
Enable switch	HE5B-M2PY / IDEC	1×10^{6}	6000	1667	99	2.47×10^{-8}

PFH as described in Table K of ISO 13849-1: 2015.

E.g.) If the teaching pendant emergency stop switch is used to enable the controller's SS1 function, the PFH of the system will be $2.47 \times 10^{-8} + 3.42 \times 10^{-7} = 3.67 \times 10^{-7}$ (PL = d).

To calculate the PFH of systems that use the I/O signals of the safety extension unit, use the PFH value shown in the table below. Safety performance of the Safety extension unit complies with PLd/Category 3.

MTTFd [[year]	DC [%]	PFH [1/hour]
318	90	2.41×10^{-8}

2.4 Differences from FR Series

Safety functions

It is essential that the Safety extension unit is installed as this robot's safety monitoring functions are always enabled. The safety monitoring function cannot be disabled. Therefore, the following restrictions are imposed.

- The parallel input/output unit cannot be used (because the safety extension unit cannot be connected simultaneously).
- An error will occur if the Safety extension unit is not connected or disconnected.

For information on how to install the Safety extension unit, refer to the following manual:

📖Robot Safety Option Instruction Manual (BFP-A3531)

Recovery-Mode

When this robot is in recovery mode, SLP and STR stop states can be temporarily released. The default value of dedicated output signal number for the recovery-mode is "5".

For the operation procedure of the recovery-mode, refer to the following.

📖Robot Safety Option Instruction Manual (BFP-A3531)

Precautions

When using recovery mode, check that the R32TB software version is 1.9.5 or later.

Operation Status

The robot's operation status will change under the following conditions:

Operation mode		Conditions
High speed operation (1000 mm/s)		No presence of anyone in the monitored space that is monitored by area sensors, etc. (No one is approaching the robot.) The robot can be set to operate at low speed in low-speed spaces. Do not use this setting for collaborative operation with humans.
Collaborative operation	Standard operation*1 (250 mm/s)	• A person is in the monitored space. (Someone is approaching the robot.) Use devices, such as area sensors, to monitor spaces when switching from High-speed operation mode to Standard operation mode. • The robot is not in the low-speed space*3. (The robot is operating outside the low-speed space*3.)
	Low-speed operation*2 (50 mm/s)	• A person is in the monitored space. (Someone is approaching the robot.) • The robot is in the low-speed space*3. (The robot is operating inside the low-speed space*3.)

*1 Use this operation mode only in situations where there is no risk of body parts, such as hands and fingers, becoming trapped.

*2 Use this operation mode only in situations where there is a risk of body parts, such as hands and fingers, becoming trapped or where collision points cannot be limited.

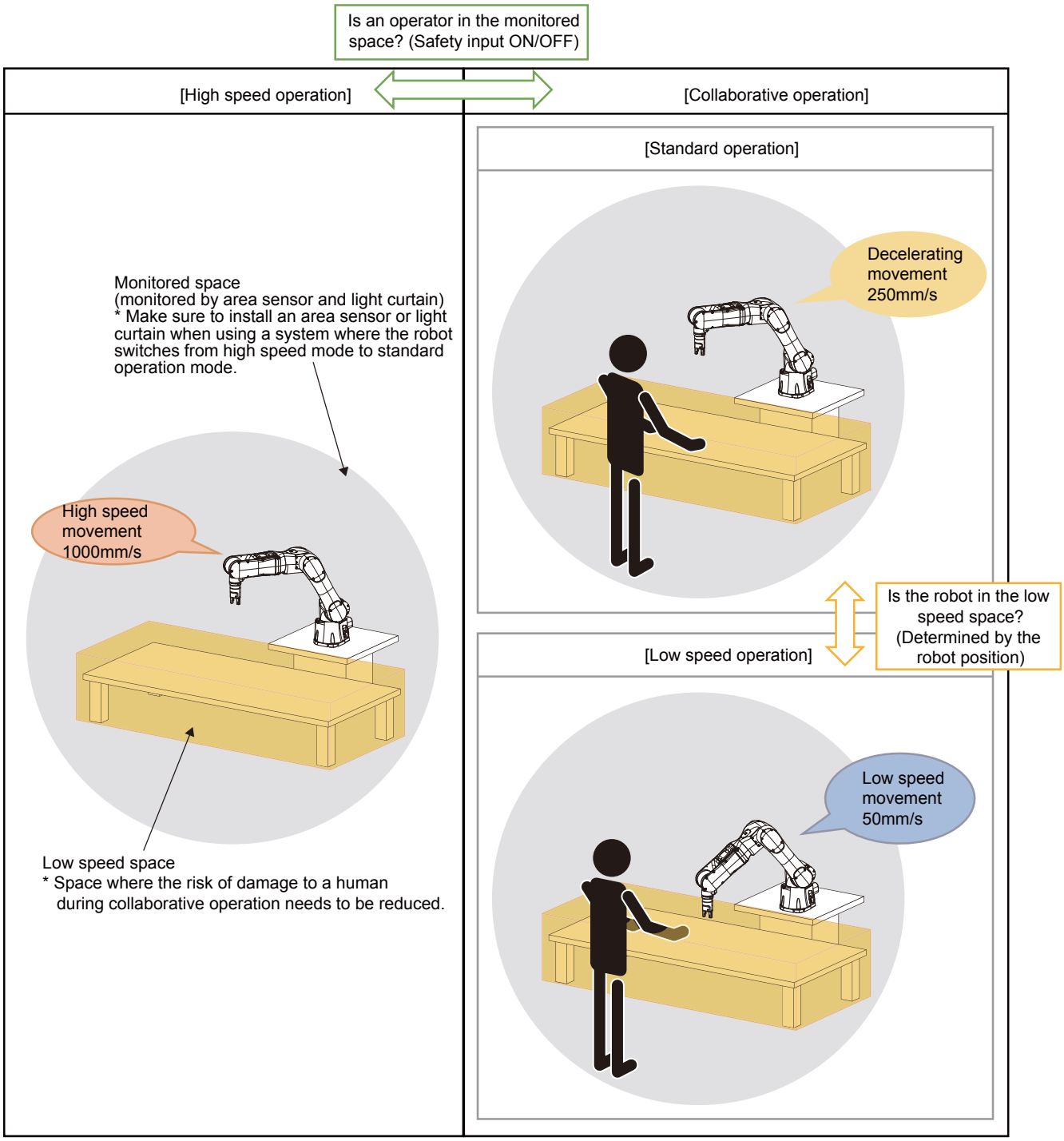
*3 The low-speed space*2 is specified by a cuboid.

⚠DANGER

Design the robot system so that people are prevented from approaching the robot during High-speed operation. The robot will not be able to stop safely if a collision occurs while it is operating at high speed.

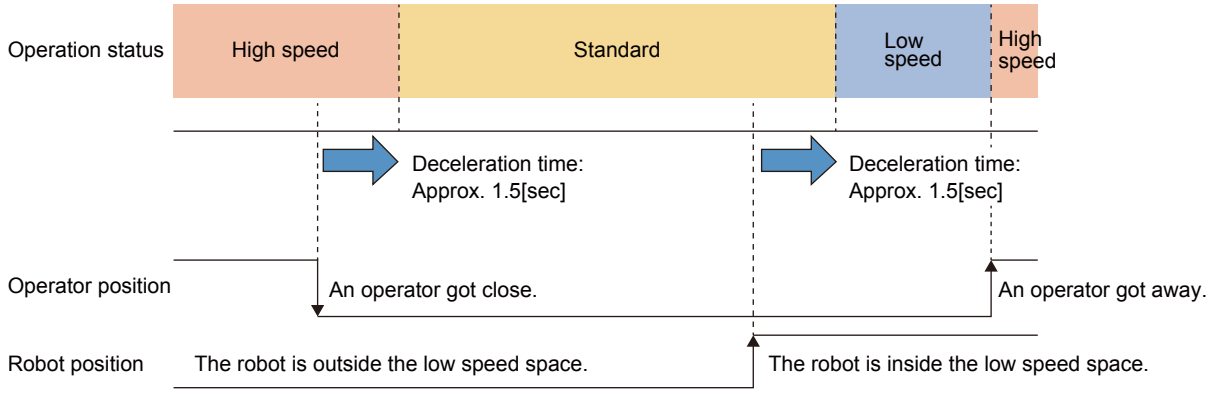
⚠CAUTION

When using High-speed operation, always connect the safety sensors (such as area sensors and light curtains) or interlock to DSI1 according to the result of the risk assessment.



Operation status switching conditions

The following shows the operation status switching according to the above conditions.



⚠DANGER

The robot must enter Collaborative operation mode when a person approaches.

Safe Stop 2 (SS2)/Safe Operating Stop (SOS)

The SOS automatic resumption setting of this robot is enabled at the factory setting. When SS2 is disabled, the robot will automatically restart operation.

By default, the stopping speeds of each axis are as follows:

J1 to J4: 1.00 [deg/s]; J5 and J6: 3.00 [deg/s]; J7 and J8: 0.00 [deg/s]

To change the settings, use RT ToolBox3.

For further information, refer to the following manual:

📖Robot Safety Option Instruction Manual (BFP-A3531)

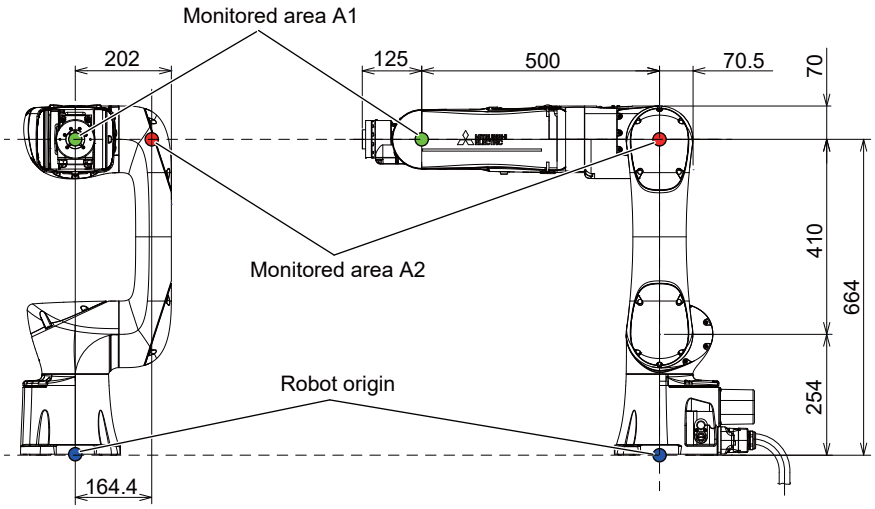
Safely Limited Speed function (SLS)

This robot automatically limits the operation speed according to the set monitoring speed. The table below details features of the SLS function.

SLS specifications

No.	Item		RV-5AS-D	FR series	Remarks
1	Monitoring mode		Advanced mode	Simple mode Advanced mode	Only advanced mode
2	Monitored speed		Composite speed XYZ speed Joint speed	Composite speed XYZ speed Joint speed	—
3	Operation speed limits		The operation speed is limited according to the value set for the monitored speed.	Speed limit Ovrd	The operation speeds of X, Y, and Z cannot be individually limited.
4	Monitored areas	Mechanical interface	—	○	—
5		J5 center of rotation(A1) *1	○	○	—
6		Elbow joint (A2) *1	○	○	—
7		Tools (T1 to T4) *1	○	○	—
8		TCP	○	—	—

*1 A1 and A2 indicate arm monitor models. T1 to T4 indicate tool monitor models.
The coordinates of the positions monitored for arm models A1 and A2 when the robot is in the posture shown below are as follows:
(Unit: mm)
A1: X = 500, Y = 0, Z = 664
A2: X = 0, Y = 164.4, Z = 664



For further information on monitored areas, refer to the following manual:
Robot Safety Option Instruction Manual (BFP-A3531)

Point

- The monitored speed cannot be set to a higher speed than the initial one.
- Do not use compliance control, force sense control, real-time external control, Ex-T control interpolation, spline interpolation, the tracking function, or the direct teaching function outside the monitored speed limit.

Precautions

As the monitored positions are within the structure of robot arm, even if the monitored positions are within the speed limit, the surface of the robot may be exceeding the speed limit.

Ex.

When axes J1 or J2 rotate while the arm is folded at the elbow, the end of the elbow will be the furthest point from the monitored positions.

To limit the speed of the surface of the robot, reduce the speed limit.

The SLS function monitors the speed of tool monitor models T1 to T4 even if the radius is set to 0. If X, Y, Z, and the radius are all set to 0 (no settings), the center of the mechanical interface is monitored.

Safe Torque Range function (STR)

Overview

Based almost entirely on the movements of the robot, a permissible torque range is established from the estimated torque of each motor. This function checks whether the actual torque (feedback torque) is within the torque range. When the torque feedback exceeds the permissible limit, error H221n ("n" is the joint axis number) occurs, and the robot is stopped by the SS1 function.

The torque limit values cannot be modified.

⚠CAUTION

• Pre-use inspection

Before using the robot, check that the STR function is operating properly.

With the robot stopped and the servos in the ON state, check that the STO function turns the servos off when force is applied to the robot arm.

• Set the hand and workpiece conditions correctly. The force cannot be detected correctly when incorrect values are set. The force generated upon an impact may also be larger than if the correct values were set, and errors may occur during operation.

• Torque feedback is calculated based on information acquired from sensors. These sensors have a function that detects faults. However, the STR function will not detect a fault in the following cases: There is a low level fault with the sensor or the joint has stopped. If there is a fault with a sensor but the fault has not been detected, there is the risk that the force generated during a collision will not be reduced. Run the axes using an override speed of 10% or more for about 10 seconds before using the robot to check if any of the sensors are faulty. For further information, refer to "RESIDUAL RISK (SPECIFIC TO EACH FUNCTION)" in the following manual:

Collaborative Robot Safety Manual (BFP-A3733)

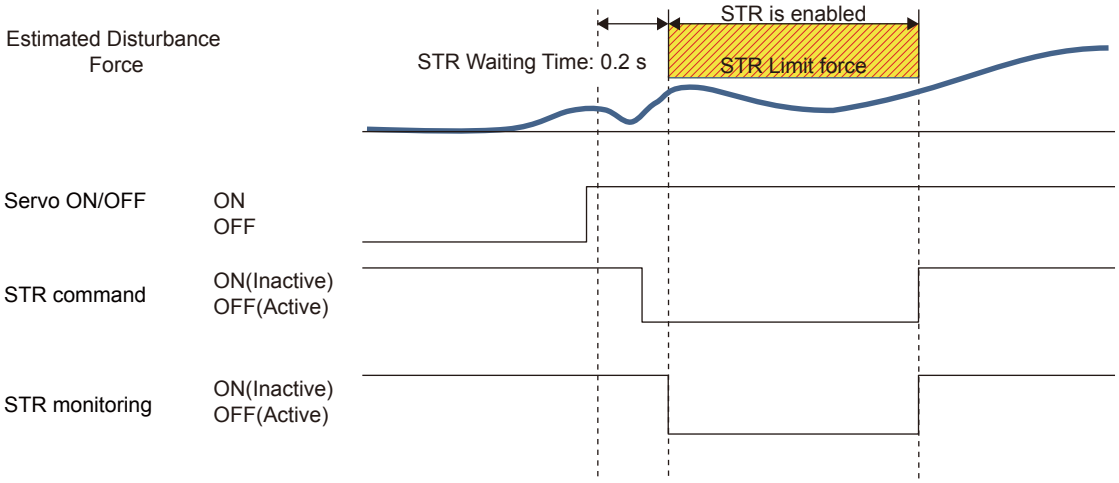
Point

- The STR function is activated even when the direct teaching function is used. Moving the robot arm abruptly may trigger error H221n.
- The STR function may not detect changes in torque accurately at low temperatures, causing the error "H221n" to occur. To clear this error, warm up the robot using the warm-up operation while the robot is in High-speed operation mode. Warming up an affected joint by releasing its brake and moving it around will also clear this error.
- If torque is limited with the Torq command, the STR function may not detect changes in torque accurately.

Operating sequence

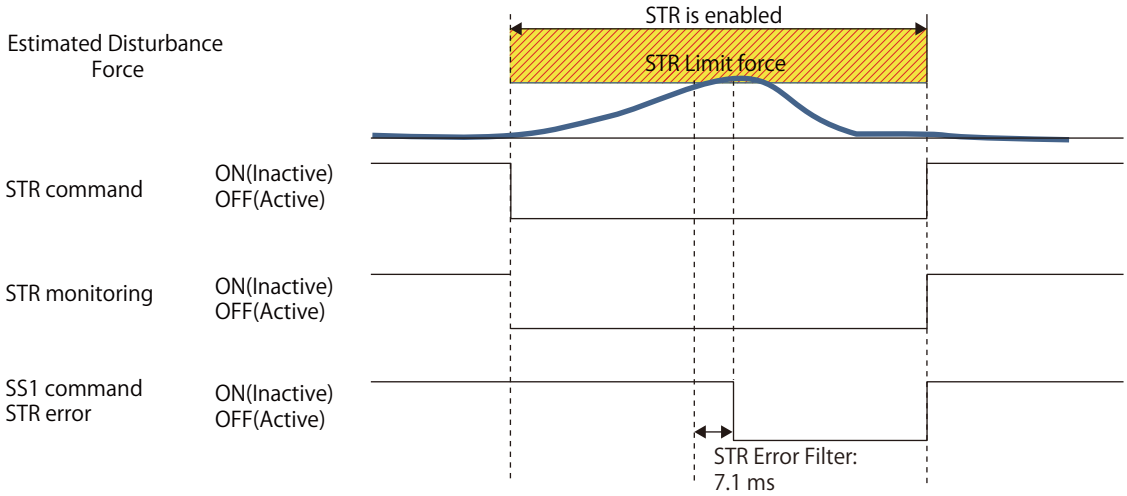
■When the STR command is enabled during the servo ON waiting time after servo ON

STR monitoring starts once the servo ON waiting time has elapsed. The servo ON waiting time is counted from servo ON, which is not affected by the STR command.



■When the permissible limit is exceeded

When the difference of the estimated torque and torque feedback exceeds the permissible limit during the STR monitoring, error H221n ("n" is the joint axis number) occurs, and the robot is stopped by the SS1 function.



Safely Limited Position function (SLP)

This robot's SLP function monitors all of the robot axes. Axis monitoring is enabled from the factory. If the robot's axes exceed the monitored positional threshold, an error will occur and SS1 will stop the robot. To clear the error, the axes must be returned to a position within the monitored positional threshold. This can be done by releasing the brakes or by using JOG operation in recovery mode.

For information on how to release the brakes, refer to the following manuals:

📖Instruction Manual: Robot Arm Setup and Maintenance (BFP-A3729)

📖Instruction Manual: Detailed explanations of functions and operations (BFP-A3478)

📖RT VisualBox Instruction Manual (BFP-A3696)

For information on recovery mode, refer to the following manuals:

📖Robot Safety Option Instruction Manual (BFP-A3531)

📖Collaborative Robot Safety Manual (BFP-A3733)

SLP specifications

No.	Monitoring item	RV-5AS-D	FR series
1	Plane	○	○
2	Area	○	○
3	Joint axis	○	—

Collision detection function

If the collision detection function detects a collision, this robot will stop in a different manner from what the FR series does. FR series robots come to a complete stop after servo OFF. However, the RV-5AS-D comes to a complete stop after the arm has decelerated to a stop and the servos have turned off.

LoadSet command

For FR series robots, the LoadSet command affects the settings of hands and workpieces when a program is reset and when the END line is executed. The LoadSet command does not affect the settings of the RV-5AS-D. In the aforementioned situations, the hand and workpiece settings of FR series robots will be reset to default values, but the RV-5AS-D will retain its current settings.

Parameter settings

The following parameters are related to safety monitoring, and they can only be written using RT ToolBox3 (Ver. 1.70Y or later), RT VisualBox, or the R56TB (Ver. 4.2 or later).

- Hand and workpiece conditions: HNDDAT0 to HNDDAT8, WRKDAT0 to WRKDAT8, HNDHOLD1 to HNDHOLD8
- Gravity direction: MEGDIR
- Tool data: MEXTL, MEXTLNO, MEXTL1 to MEXTL16

Attempting to write these parameters using devices not mentioned above (such as the R32TB) will trigger the error C7081 (The parameter CRC value is illegal).

2.5 Safety settings

This chapter explains how to configure safety settings.

Connecting RT VisualBox

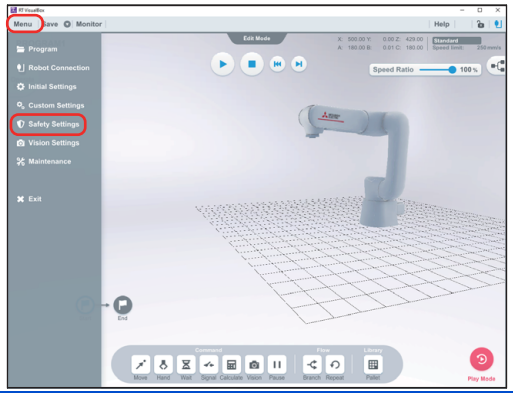
To configure the safety monitoring function settings, connect RT VisualBox to the controller and configure them while the robot is online.

For information on online operation, refer to the following manual:

📖RT VisualBox Instruction Manual (BFP-A3696)

Safety Settings Screen

Tapping/clicking [Menu] → [Safety Settings] on the menu bar displays the Safety Settings screen.



⚠CAUTION

These settings greatly affect the safety of the robot. Before configuring these settings, read "Basic Precautions and Important Points when Using Collaborative Robots" in this document and the separate "Collaborative Robot Safety Manual" thoroughly, and take appropriate measures accordingly.

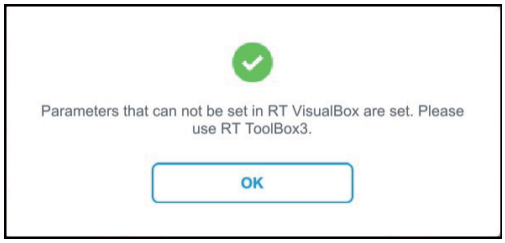
The following settings can be configured on the Safety Settings screen.

Item	Description
Speed Limiting	This setting is used to set the maximum speed and low-speed area for each operation type.
Safety I/O	This setting is used to assign safety inputs and safety outputs.
Position Limiting	This setting is used to set the areas where the robot cannot enter.
Monitor Model	This setting is used to set the areas to be monitored.
Change Password	This setting is used to change the password for the safety settings.

If the robot is connected to this software, a password must be entered to change these settings.

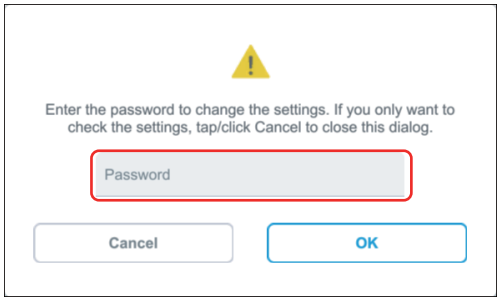
Precautions

The settings of some windows/screens cannot be configured using RT VisualBox if safety parameters have been set with RT ToolBox3. If the error message below appears, configure the settings in RT ToolBox3.



Entering/changing passwords

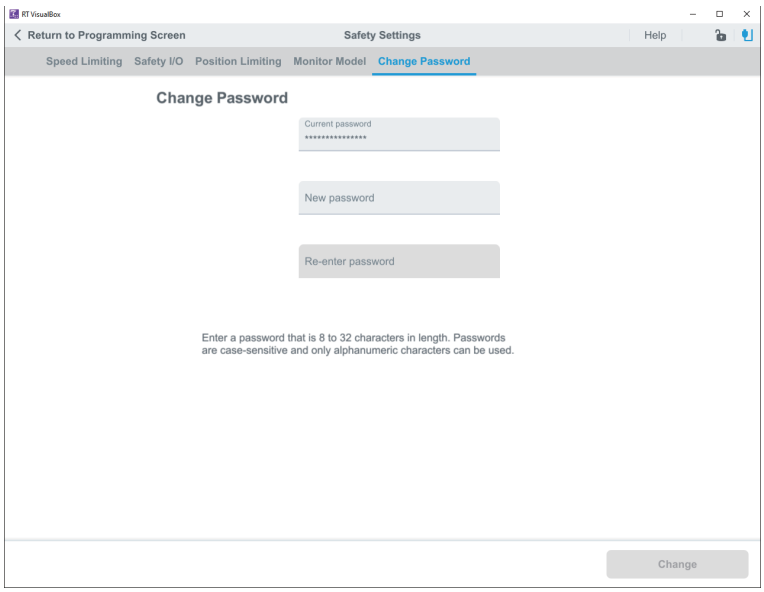
The Password Input window will appear when a robot is connected to this software or if an incorrect password has been entered. Enter the correct password.
The default password is "MELFASafetyPSWD".



The safety settings cannot be changed without changing the default password. When the default password is entered, the Change Password screen will appear. Change the password.

Precautions

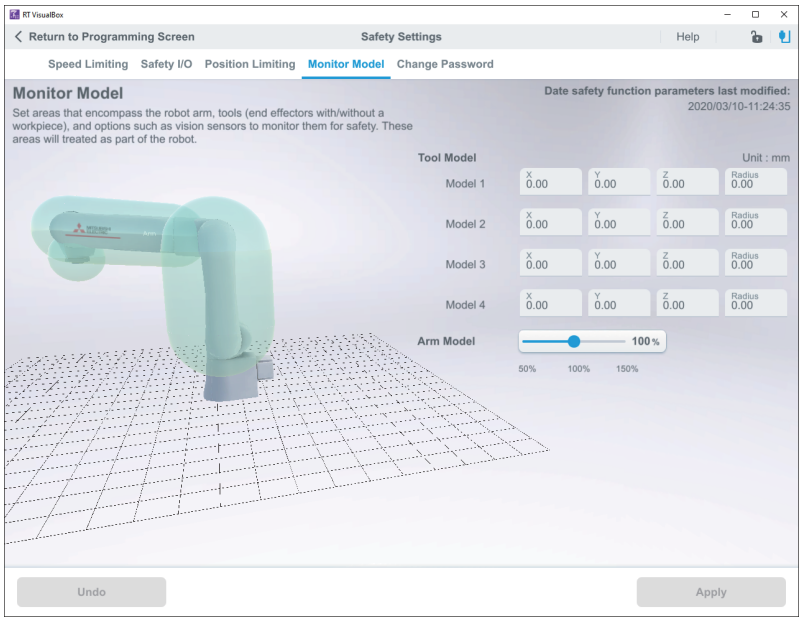
Even if a password has not been entered, it is still possible to view the Safety Settings screen. However, the setting values cannot be changed.
The password must be 8 to 32 characters long. Passwords are case-sensitive and only single-byte alphanumeric characters (0 to 9 and A to Z) can be used.
Safety settings cannot be set without entering the correct password so ensure the password is something that is not easily forgotten. To reset the password, the robot controller must be returned to factory settings. Resetting the robot type will clear the controller memory and return it to factory settings. For further information on resetting the robot type, refer to the following manual:
📖Detailed explanations of functions and operations (BFP-A3478)
To prevent inadvertent changes to the safety settings, keep your password secret and do not share it with third parties.



Monitor Model

Areas set in this screen are monitored as a part of the robot and also used in the speed limiting settings and the position limiting settings.

If tools such a hand or a vision sensor are installed, configure the settings for "Tool Model" so that the set area can be recognized as a part of the robot. If accessories such as cables or solenoid valves are installed, set "Arm Model" so that the set area can be recognized as a part of the robot.



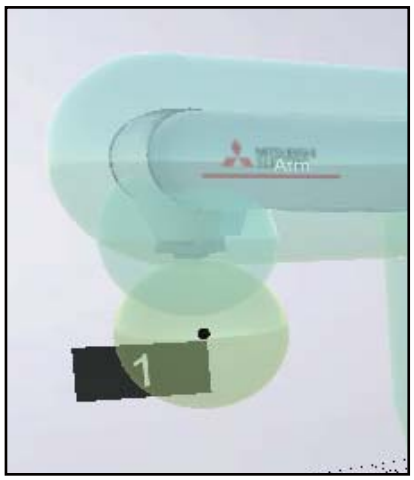
Tool Model

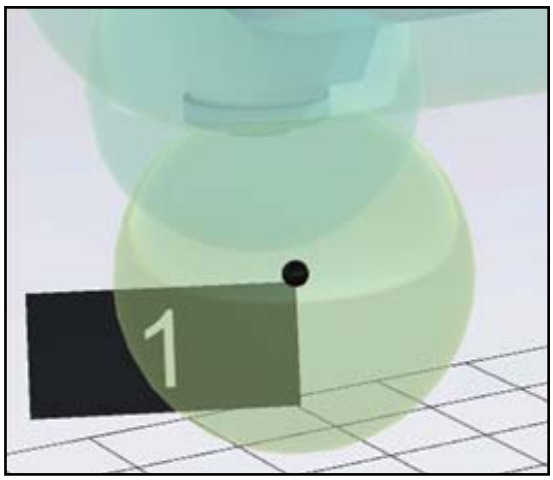
Define the shape of the tool (hand, vision sensor, etc.) with up to four spheres. Create a shape that is roughly the size of the tool that is attached to the robot. If the radius is greater than 0, the tool model will be subject to position monitoring.

The center of the tool model sphere will also be subject to speed monitoring. All tool models are subject to speed monitoring by default. Use RT ToolBox3 to disable the speed monitoring of specific tool models.

The coordinates are set in the mechanical interface coordinate system. By default (all coordinates set to "0"), the center of the mechanical interface is subject to speed monitoring. For information on the mechanical interface coordinate system, refer to the following manual:

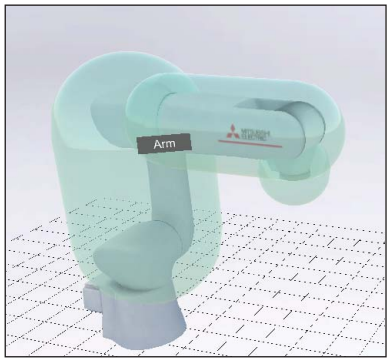
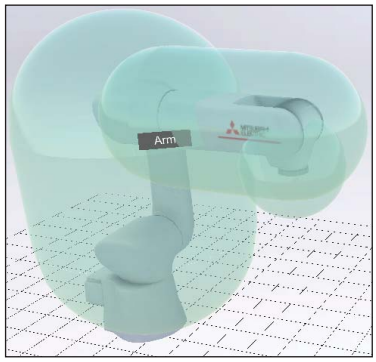
📖Detailed explanations of functions and operations (BFP-A3478)





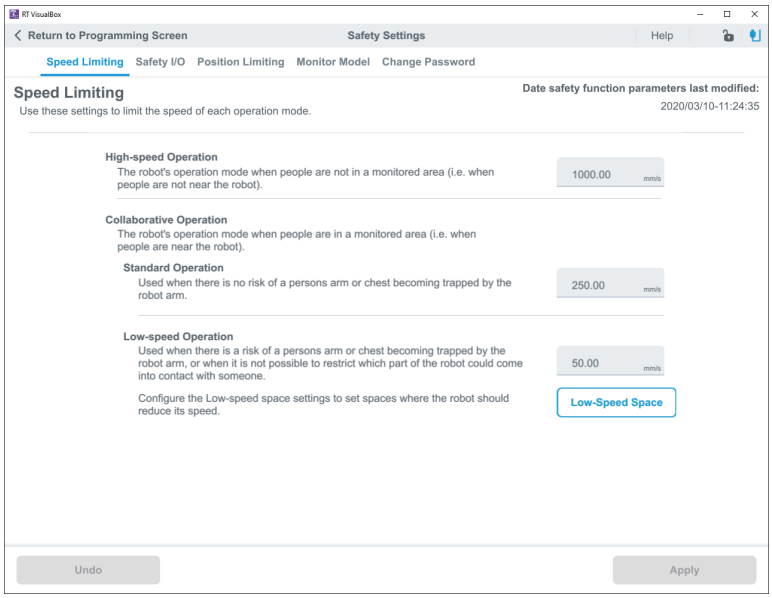
Arm Model

After modeling the shape of the robot arm with spheres and cylinders, the speed and area of the robot can be determined.
When attaching accessories, such as cables and solenoid valves, to the robot arm, resize the model accordingly.
It is possible to adjust the radius of the spheres and cylinders. The length of the cylinders cannot be changed.

Scale: 70%	Scale: 100%	Scale: 150%
		

Speed Limiting

The maximum speed and low-speed area can be set for each operation mode.
This setting is used for the speed-limiting safety function (SLS). This function monitors the speed of the robot arm and tools so that the speed does not exceed the specified value. For further information on this function, refer to the following manual:
📖Robot Safety Option Instruction Manual (BFP-A3531)
The maximum speed for each operation mode can be set.



The settings of the following operation modes can be configured.

- High-speed Operation:
- Collaborative Operation (Standard Operation)
- Collaborative Operation (Low-speed Operation)

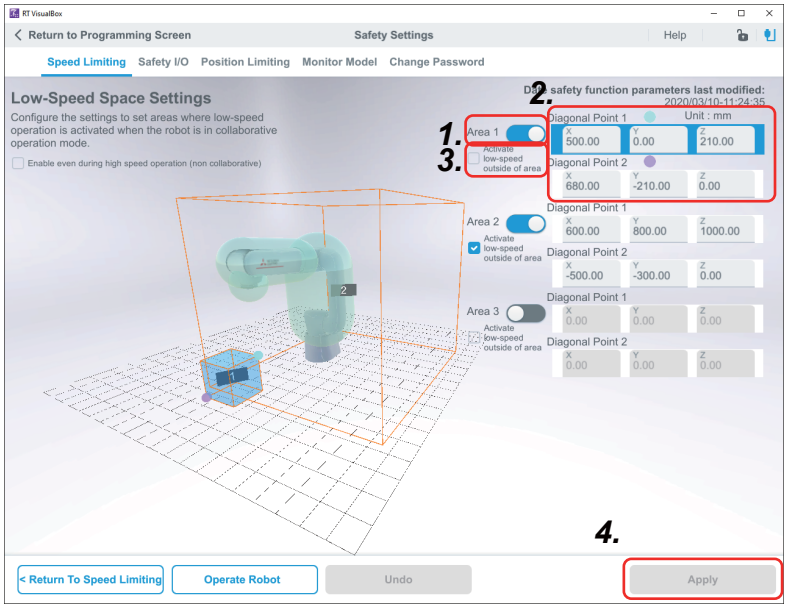
After changing the setting values, tap/click the [Apply] button.
A lower speed than the default setting value*1 can be set. A higher speed than the default setting value cannot be set.
To set low-speed areas, tap/click the [Low-Speed Space] button.

*1 Default setting values for the speed limit setting
High-speed operation: 1000 [mm/s]
Standard operation: 250 [mm/s]
Low-speed operation: 50 [mm/s]

Low-Speed Space Settings

Up to three low-speed areas can be set.

Operating procedure



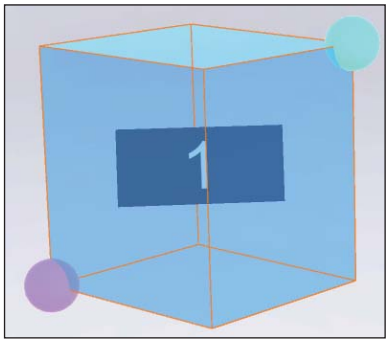
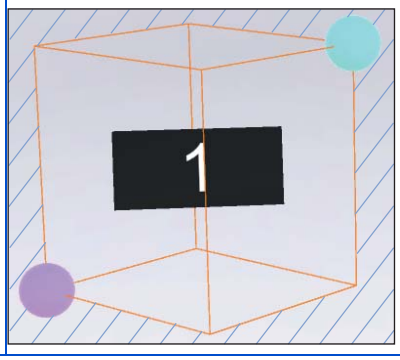
1. Turn on the area switch.

2. Enter two diagonal points. An area will appear on-screen once valid values have been set.

Diagonal points can also be set while moving the robot. To set points while moving the robot, tap/click the [Operate Robot] button, and move the robot to the desired destination. Then, tap/click the [Teach] button. The current position is stored in the X, Y, and Z coordinates of the currently selected diagonal point.

3. Set which side of the created area is to be set as the low-speed area with the [Activate low-speed outside of area] check box.

4. Tap/click the [Apply] button.

[Activate low-speed outside of area]: OFF	[Activate low-speed outside of area]: ON
If the robot enters this area, it will operate at low speed.	If the robot exits this area (shaded area), it will operate at low speed.
	

⚠CAUTION

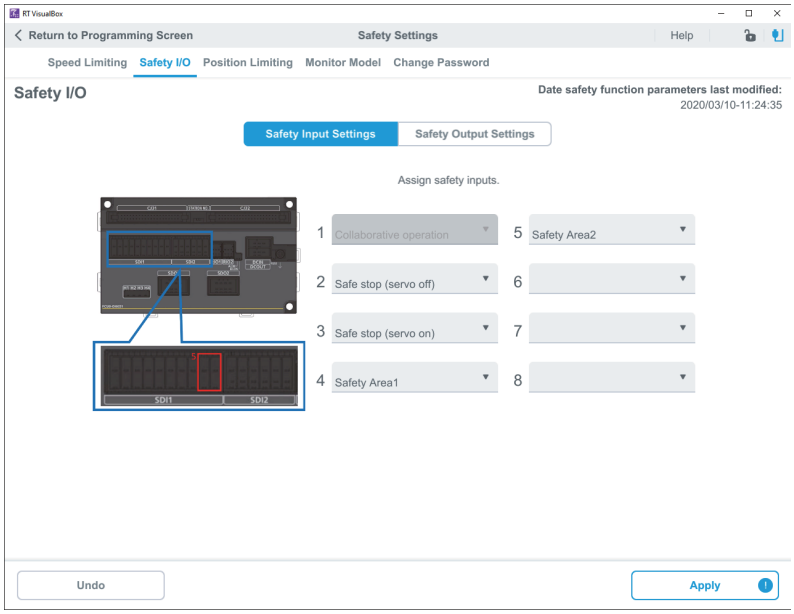
If [Enable even during high speed operation (non collaborative)] indicated by "a" and the area switch of a low-speed area are set to On, the robot operating at high speed will slow down upon entry into the low-speed area. In this situation, the robot is not in Collaborative operation mode. To work with the robot in the same space, follow risk assessments, use Safety input 1 and operate the robot in Collaborative operation mode.

Safety I/O

Safety inputs/outputs can be assigned.

Safety Input Settings

Assign safety inputs to the eight duplicated signals of the SDI1 and SDI2 ports on the safety extension unit.



Assign the inputs show in the table below. Safety input 1 cannot be changed from "Collaborative operation". "Collaborative operation" can only be assigned to Safety input 1.

Input	Description
Collaborative operation	When the input is enabled (Open), the robot is set to Collaborative operation mode[*1]. When the input is disabled (Closed), the robot is set to High-speed operation mode.
Safe stop (servo OFF)	When the input is enabled (Open), Safe stop 1 (SS1)[*2] is activated.
Safe stop (servo ON)	When the input is enabled (Open), Safe stop 2 (SS2)[*3] is activated.
Safety areas 1 and 2	When input is enabled (Open), the area which the robot is not permitted to enter is enabled. Safety areas are set in "Position Limiting".

*1 Collaborative operation mode switches depending on whether the monitored area of the robot is in the low-speed area.

Collaborative operation mode	Conditions that enable this mode
Standard operation	When Safety input 1 is enabled (Open)
Low-speed operation	When Safety input 1 is enabled (Open) and the monitored area of the robot enters the low-speed area

*2 Safe stop 1: stops the robot safely and shuts off power to the motors after the robot has stopped.

*3 Safe stop 2: stops the robot safely, maintains control over the motors even after they have stopped, and ensures that the robot does not move.

For further information, refer to the following manual:

📖Robot Safety Option Instruction Manual (BFP-A3531)

Point

- Advanced settings can be configured with RT ToolBox3. For further information, refer to the following manual:

📖Robot Safety Option Instruction Manual (BFP-A3531)

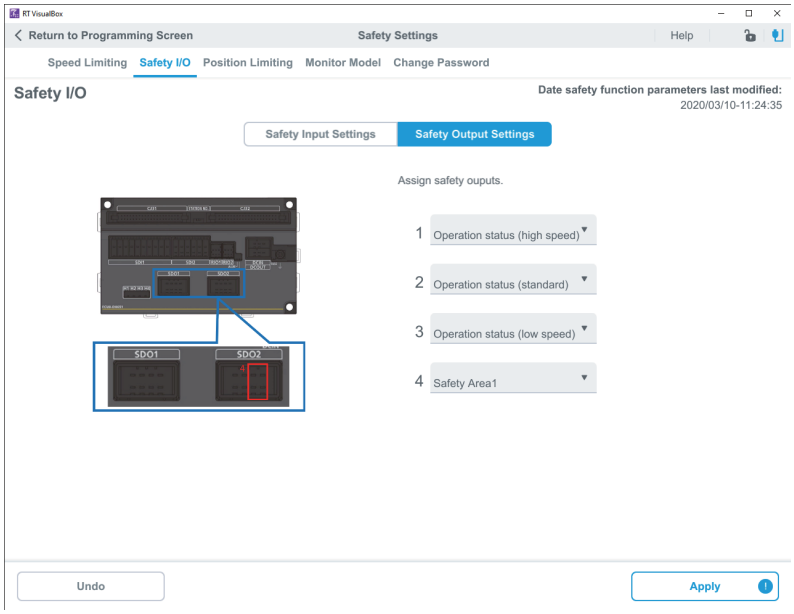
Safety inputs are set from the factory as shown in the table below. The settings indicated by red boxes cannot be changed.

		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	☐	☐	☐	☐	☑	☐	☐	☐	☐	☐
	DSI1 AND AREA2	☐	☐	☐	☐	☑	☐	☐	☐	☐	☐
	DSI1 AND AREA3	☐	☐	☐	☐	☑	☐	☐	☐	☐	☐
MODE	AUTO			☑	☐	☐	☐	☐	☐	☐	☑
	MANUAL			☑	☐	☐	☑	☐	☐	☐	☑

- Do not change the safety input settings multiple times during the SLS deceleration monitoring time (about 1.5 s). Doing so may cause error H242 "Fault in safety data (S_STS)".

Safety Output Settings

Assign safety outputs to the four duplicated signals of the SDO1 and SDO2 ports on the safety extension unit.



Assign the outputs show in the table below.

Output	Description
Operation status (high speed, standard, low speed)	This signal turns on when the operation status has been switched and monitoring enabled.
Safe stop (servo OFF)	This signal turns on after the robot stops and the servo turns off (STO [Safe Torque Off]).*1
Safe stop (servo ON)	This signal turns on after the robot stops (SOS [Safe Operating Stop]).*2
Safety areas 1 and 2	These signal turn on when safety areas are enabled.

*1 Safe Torque Off: shuts off power to the motors in the robot.

*2 Safe Operating Stop: checks that the robot has stopped without shutting off power to the motors in the robot. For further information, refer to the following manual:

Robot Safety Option Instruction Manual (BFP-A3531)

Point

- Advanced settings can be configured with RT ToolBox3. For further information, refer to the following manual:

RT ToolBox3 / RT ToolBox3 mini User's Manual (BFP-A3495)

- Servo OFF:

When the robot servos are off, the safety outputs that set the robot's operation mode turn off.

CAUTION

There is a delay of up to 21.3 ms from when the duplicated output signals turn off until the safety outputs turn off. This may temporarily cause multiple operation mode commands to be output at the same time (e.g. High speed and Standard operation mode commands output at the same time). Conduct a risk assessment to ensure safety.

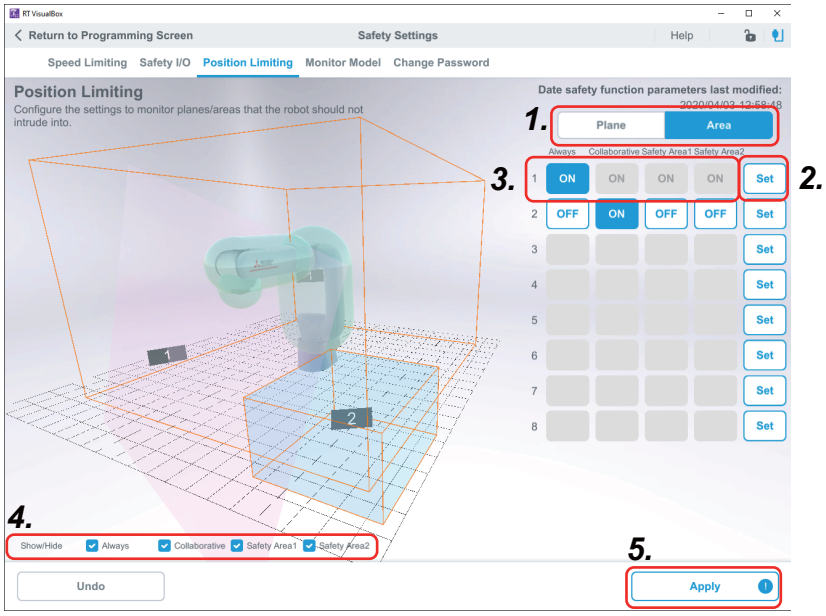
Position Limiting Settings

Areas and conditions can be set to prevent robot interfering with the workpiece platform or other equipment. The robot will stop when it nears designated safe areas.

This setting is used for the Safely Limited Position function (SLP). This function monitors whether the hand or robot arm has entered a safe area. For further information, refer to the following manual:

📖Robot Safety Option Instruction Manual (BFP-A3531)

Operating procedure



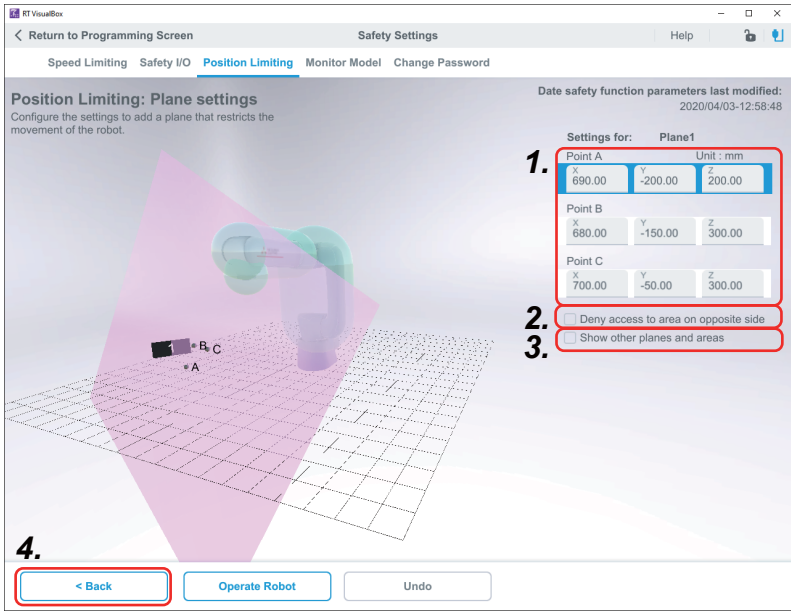
1. Select the plane or area to set by selecting the [Plane] or [Area] tab.
2. Tap/click the [Set] button, and set a plane or area in the Plane settings or Area settings screen.
3. Use the ON/OFF buttons to enable/disable the conditions for each plane or area. ON/OFF buttons are only available if a plane or area has been created. Create a plane or area first.
4. Configure the settings then check them. Using the [Show/Hide] check boxes, show or hide a plane or area and check whether the conditions for enabling the plane or area are correct.
5. Tap/click the [Apply].

Conditions	Description
Always	The plane or area is always enabled while the robot is moving.
Collaborative operation	The plane or area is enabled when the robot is in Collaborative operation mode (Standard or Low-speed operation mode). The plane or area is disabled when the robot is in High-speed operation mode.
Safety areas 1 and 2	The plane or area is enabled when the safety inputs assigned in "Safety Input Settings" are enabled.

Plane Settings

Set a plane to be used in the position limiting settings.

Operating procedure



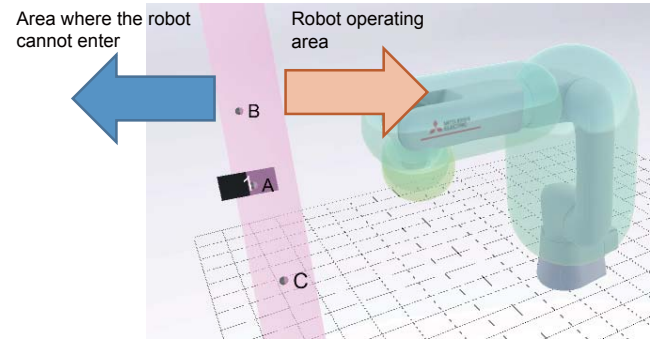
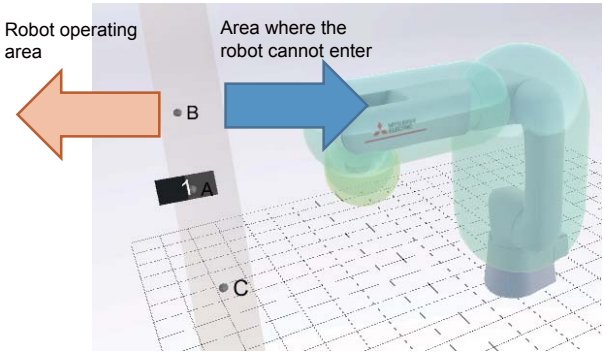
1. Enter points A to C. After the three points have been entered, a plane passing through the points will appear on the screen.

The points can also be set while moving the robot. To set points while moving the robot, tap/click the [Operate Robot] button, and move the robot to the desired destination. Then, tap/click the [Teach] button. The current position is stored in X, Y, and Z of the currently selected point.

2. The robot cannot access the area on the pink side of the plane. By default, the area on the outside of the plane is inaccessible. To change the setting, select the [Deny access to area on opposite side] check box.

3. To keep previously set planes and areas visible while creating a new plane, select the [Show other planes and areas] check box.

4. After setting the plane, tap/click the [< Back] button to return to the Position Limiting screen.

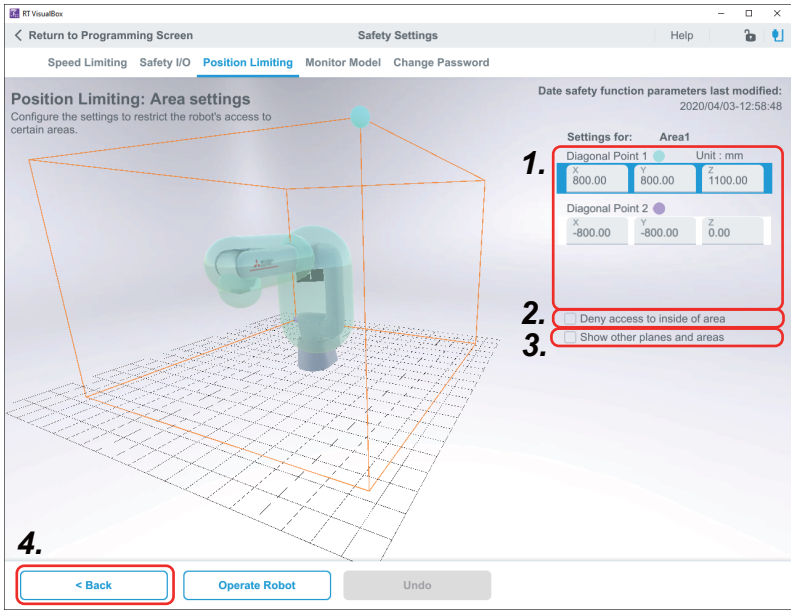
[Deny access to area on opposite side]: OFF	[Deny access to area on opposite side]: ON
	

* Robot origin indicates that X, Y, and Z (all axes) are 0.

Area Settings

Set an area to be used for the position limiting settings.

Operating procedure



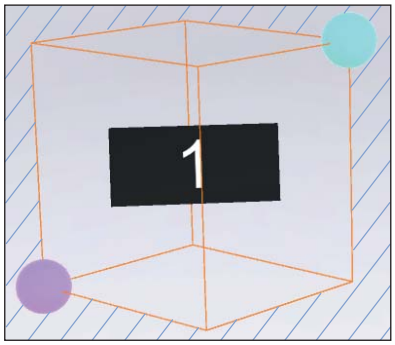
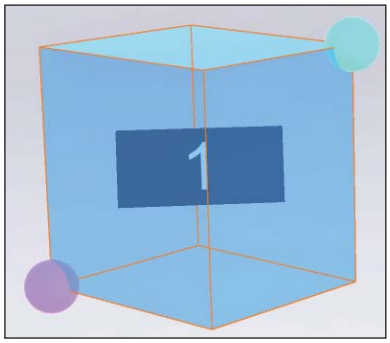
1. Enter two diagonal points. An area will appear on-screen once valid values have been set.

Diagonal points can also be set while moving the robot. To set points while moving the robot, tap/click the [Operate Robot] button, and move the robot to the desired destination. Then, tap/click the [Teach] button. The current position is stored in the X, Y, and Z coordinates of the currently selected diagonal point.

2. By default, the area on the outside of a defined area is inaccessible. To change the settings, select the [Deny access to inside of area] check box.

3. To keep previously set planes and areas visible while creating a new plane, select the [Show other planes and areas] check box.

4. After setting the area, tap/click the [< Back] button to return to the Position Limiting screen.

[Deny access to inside of area]: OFF	**[Deny access to inside of area]: ON**
The robot will stop moving before it leaves the defined area.	The robot will stop moving before it enters the blue area.
	

2.6 Status variable

The table below shows a status variable that is related to this robot's safety monitoring function.

Status variable list

Status variable list

Status variable name	Description
M_CollaboSts	Refers to the operation status.

Status variable

M_CollaboSts

■Function

This function acquires which operation mode the robot is in (High-speed operation mode or Collaborative operation mode [standard/low-speed operation]).

-1: Disabled

0: High-speed operation

1: Standard operation

2: Low-speed operation

■Syntax

Ex.

<Numerical variable> = M_CollaboSts

■Term

<Numerical variable>: Specify a numerical variable to which a value is to be assigned.

■Reference program

1 Select M_CollaboSts 'Judgment by the operation status

2 Case 1 'For standard operation

3 M_Out(65) = 1 'The signal number 65 is turned on

4 Break

5 Case 2 'For low-speed operation

6 M_Out(66) = 1 'The signal number 66 is turned on

7 Break

8 Default 'When operation is not the collaborative operation

9 Break

10 End Select

■Explanation

1. Returns the robot's current operation mode (High-speed operation mode or Collaborative operation mode [standard/low-speed operation]).

2. According to the enabled SLS speed-limiting and STR torque restriction state, this status variable is as follows.

SLS1 monitoring and STR1 monitoring	SLS2 monitoring and STR2 monitoring	SLS3 monitoring and STR2 monitoring	M_CollaboSts	Operation status
Disabled	Disabled	Disabled	-1 (Disabled)	*1
Enabled	Disabled	Disabled	0 (High-speed operation)	High-speed operation
Enabled	Disabled	Enabled	-1 (Disabled)	—
Enabled	Enabled	Disabled	1 (Standard operation)	Standard operation
Enabled	Enabled	Enabled	2 (Low-speed operation)	Low-speed operation

*1 When functional safety is disabled (the Safety extension unit is not connected or the origin has been lost) or the robot is in the servo-off state.

3. When the origin is not set, functional safety is disabled and -1 is always returned.
4. Always returns "-1" as the SLS and STR monitoring functions are disabled at servo-OFF.
5. Always returns "-1" for robots that are not collaborative robots.
6. Read-only.

■Supplement

Variables that can be described in <Numerical variable>

—	Numeric value type				Position type	Joint type	Character string type
	Integer Example) M1%	Long-precision integer Example) M1&	Real number Position component Joint component	Double-precision real number			
Constant	×	×	×	×	×	×	×
Variable	○	○	○	○	×	×	×
Logical/arithmetic expression	×	×	×	×	×	×	×
Function	×	×	×	×	×	×	×

○: Can be described, ×: Cannot be described (syntax error when registered)

2.7 Parameter

The specifications of this robot's "SFMODE" have been changed so that the operation status (high-speed operation/standard operation/low-speed operation) can be output to external devices.

Parameter	Parameter name	No. of arrays	Description	Factory setting
Operation status output signal	SFMODE	Integer 2	Set the start number and end number of the signal that outputs the operation status. First element: System reservation Second element: Start number of operation status output signal Setting range: -1 to 19999 When the output signal area for 3 bits from the signal start number does not exist, an error occurs.	-1, 6

2.8 Dedicated Output

The following shows the relation between the operation status output and status variable/dedicated output signal.

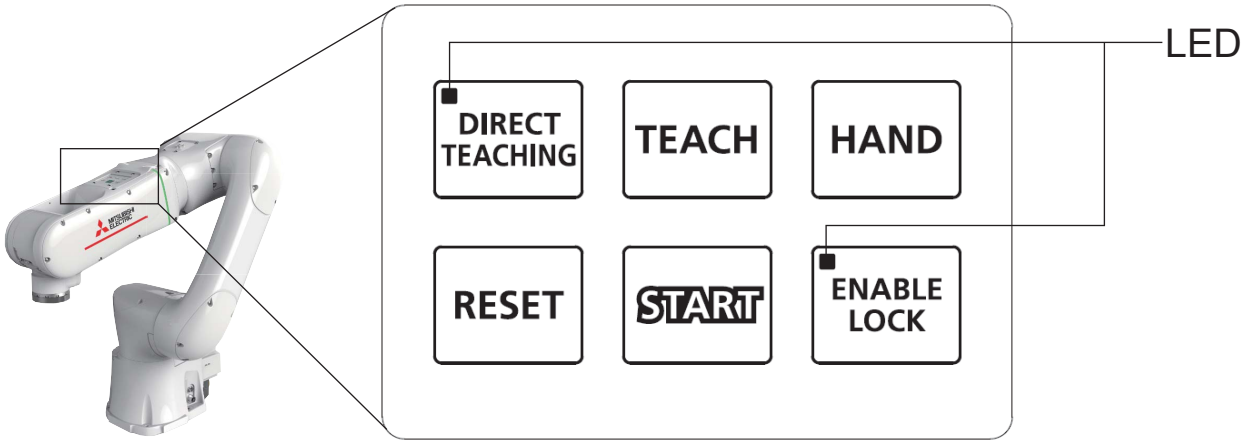
Operation status	Status variable M_CollaboSts	Dedicated output signal SFMODE			
		bit0	bit1	bit2	Output signal
*1	-1	0	0	0	0
High-speed operation	0	1	0	0	1
Standard operation	1	0	1	0	2
Low-speed operation	2	0	0	1	4

*1 When functional safety is disabled (the Safety extension unit is not connected or the origin has been lost) or the robot is in the servo-off state.

3 OPERATION BUTTONS

This chapter explains the operation buttons on the robot forearm.

Operation button placement



3.1 Operation buttons

Button	Function	Description
DIRECT TEACHING	Direct teaching	Hold for 2+ seconds to turn direct teaching On/Off. Press once to change the direct teaching mode. Switches the operation mode in the following order: Joint free → Translational → Rotational Pressing this button in Rotational mode switches the motion type back to Joint free mode. (Rotational mode is supported with controller software version B1c or later.) When direct teaching is turned on, the mode is set to Joint free mode. The LED behavior is as follows. Off: Direct teaching stopped On: Direct teaching is on (Joint free mode) Quick flashing: Direct teaching is on (Translational mode) Slow flashing: Direct teaching is on (Rotational mode)
TEACH	Position teaching	Press once to teach the current position. A position is taught every time this button is pressed. RT VisualBox is required for it to be possible to teach positions using this button. This button cannot be used unless RT VisualBox is connected.
HAND	Hand operation	Hold for 2+ seconds to align the hand. For information on hand alignment, refer to the following manual: 📖Detailed explanations of functions and operations (BFP-A3478) Press once to open/close the hand.
RESET	Reset	When errors occur: Press once to reset errors. While programs are suspended: Press once to reset the program.
START	Start	When collaborative operation has stopped: Hold for 2+ seconds to execute the program from the start. While collaborative operation is suspended: Hold for 2+ seconds to restart the program from the current command. Use RT VisualBox to check whether collaborative operation has stopped or has been suspended.
ENABLE LOCK	Acquires operation rights	Press once to enable/disable the lock. Taking control of operation rights via this button prevents other devices from operating the robot. The LED behavior is as follows. On: operation rights acquired Off: operation rights relinquished For information on operation rights, refer to the following page: ☞ Page 32 "Operation rights"

⚠CAUTION

Before opening/closing the hand, ensure that doing so will not cause workpieces to fall or fingers to become trapped.

Point

Pressing or holding any button during program execution will stop the robot and suspend the program.

4 DIRECT TEACHING

Direct teaching is the operation performed by holding and moving the robot by hand.

⚠CAUTION

- If the settings for the hand are not configured correctly, the arm may rise or fall when direct teaching is turned on. Furthermore, the safety functions may not work properly. Ensure the settings are correct.
- Workpiece settings are not enabled during direct teaching. The robot arm may fall depending on the weight of the workpiece. Do not release your hands from the robot arm until it stops completely.
- If using one of the hand settings from HADDAT1 to HADDAT8 set in RT ToolBox3, be aware that the hand setting in the controller will be reset to HNDDAT0 if the controller's power is cycled. In this case, the arm may rise or fall as the correct hand settings will no longer be set.

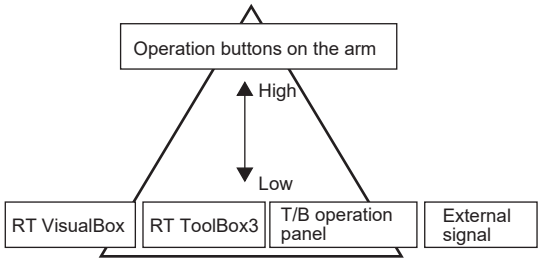
4.1 Operation rights

Multiple devices, such as the operation buttons on the robot arm, RT VisualBox, or external signals, can be used to operate the robot controller. However, only one of these devices can operate the controller at the same time as another device (commands for operation, servo ON, etc.). This single device has "operation rights".
Operations that involve risk require operation rights. It is essential that other workers are not able to obtain operation rights when you are near the robot while it is operating.
Operations that start the robot, such as starting a program or servo ON, require operation rights. For safety reasons, operations that stop the robot, such as stopping a program or servo OFF, do not require operation rights.

Devices that can acquire operation rights in specific modes

Mode	Device
MANUAL	Teaching pendant
AUTOMATIC	Operation buttons on the arm, RT VisualBox, RT ToolBox3, external signals, T/B operation panel

Priority of operation rights in AUTOMATIC mode



Conditions required to acquire operation rights from other devices

Operation rights can only be acquired from devices of lower priority.
They cannot be acquired from devices with the same level of priority.

Precautions

Operation rights are not required to change the settings such as the installation type, hand settings, workpiece settings, and workpiece grasp position. Ensure it is safe to do so before changing these settings.
The settings cannot be changed during direct teaching or automatic operation.

Operations that require operation rights

Direct teaching requires operation rights.

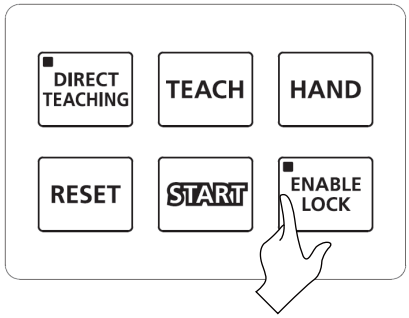
For other operations that require operation rights, refer to the following manual:

📖Detailed explanations of functions and operations (BFP-A3478)

Acquiring/relinquishing operation rights

When using operation buttons

The [ENABLE LOCK] button on the arm is used to acquire/relinquish operation rights.



LED status

On: operation rights acquired

Off: operation rights relinquished

When using RT VisualBox

The padlock icon on the right of the menu bar indicates whether operation rights have been secured or requested. Clicking this icon allows the user to secure or request operation rights.

■Location

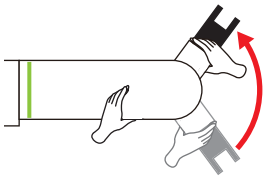
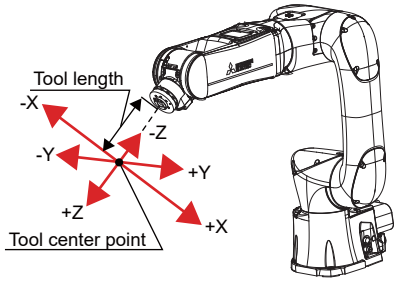
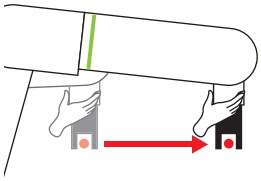
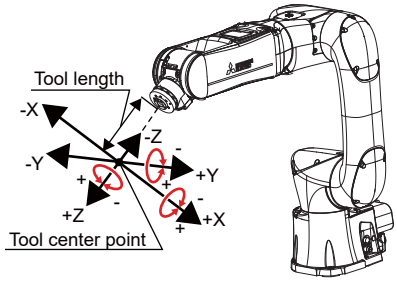
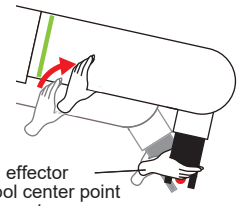
■Status

	This icon indicates that operation rights have not been requested. Tap/click the icon to request operation rights.
	This icon indicates that operation rights have been requested but have not yet been secured. Other devices, such as the operation buttons or teaching pendant, may have already taken operation rights. Tap/click this icon to cancel the request for operation rights.
	This icon indicates that operation rights have been secured. Tap/click the icon to release operation rights.

4.2 Direct teaching modes

There are three direct teaching modes.

Direct teaching modes

Mode	Description	Operation image
Joint free	Axes can be moved individually or collectively to the desired position. With the J4 axis and J6 axis aligned (singular posture), the J4 axis may rotate when the J6 axis is operated.	
Translational motion	The robot arm can be moved relative to the tool center point in the tool coordinate system. Refer to the following figure for information on the tool coordinate system. 	
Rotational (Supported with controller software version B1c or later.)	The robot arm can be rotated about the tool center point in the tool coordinate system. Refer to the following figure for information on the tool coordinate system.  Change the tool center point according to the hand being used.	 Hold the end effector so that the tool center point (red dot) does not move. If the tool center point itself moves (red dot), the STR robot torque error (H221n) will occur.

Point

- When teaching positions directly in Translational mode, hold an area of the robot which is close to the tool center point, such as the hand.
- When teaching positions directly in Rotational mode, use the tool center point as the fulcrum.
- When teaching positions in Translational or Rotational mode, more force will be required to move the robot arm near the singularities stated below due to vibration and coasting control.

Translational

J3 axis: -30° to +30°

Rotational

J3 axis: -25° to +25°

- The SLS function is enabled even during direct teaching. Moving the robot arm at a speed exceeding the speed limit will trigger an error. Move the robot arm at a speed below the speed limit. Be aware that is it easy to exceed the monitored speed in Low-speed operation mode.
- Switching to Translational or Rotational mode near singularities will cause an error and direct teaching will turn off. If an error occurs in this situation, switch to Joint free mode and retry direct teaching.
- The STR function is activated even when the direct teaching function is used. Moving the robot arm abruptly will trigger the STR robot torque error (H221n).

4.3 How to use direct teaching with operation buttons

This section explains how to use direct teaching with operation buttons.

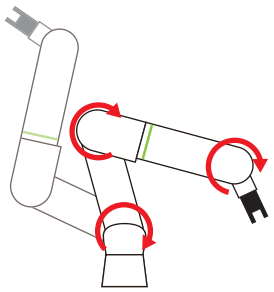
Point

- Direct teaching can only be turned on when the robot is in AUTOMATIC mode or Collaborative operation mode (standard operation or low-speed operation).
- Direct teaching cannot be turned on with the teaching pendant.

⚠CAUTION

- Place an emergency stop switch in an easily accessible place near the robot. Connect the emergency stop switch to the external emergency stop terminals of the robot controller.
- If the settings for the hand are not configured correctly, the arm may rise or fall when direct teaching is turned on. Furthermore, the safety functions may not work properly. Ensure the settings are correct.
- Inertia may cause the robot arm to move. Do not release your hands from the robot arm until it stops completely.
- Workpiece settings are not enabled during direct teaching. The robot arm may fall depending on the weight of the workpiece. Do not release your hands from the robot arm until it stops completely.
- If using one of the hand settings from HADDAT1 to HADDAT8 set in RT ToolBox3, be aware that the hand setting in the controller will be reset to HNDDAT0 if the controller's power is cycled. In this case, the arm may rise or fall as the correct hand settings will no longer be set.

1. Set the mode selector switch input of the controller to "AUTOMATIC".
2. Hold the [DIRECT TEACHING] button (for 2+ seconds) to turn on direct teaching. Check that the LED of the [DIRECT TEACHING] button is on or the status indicator LED is on or flashing green.
3. Hold the robot arm directly with your hands, and move it to the desired position/posture.



4. Press the [DIRECT TEACHING] button once to change mode. The mode switches in the following order:
   Joint free → Translational → Rotational → Joint free
5. Press the [TEACH] button once to teach the current position. Then, the current position is applied to RT VisualBox.
6. Hold the [DIRECT TEACHING] button again (for 2+ seconds) to turn off direct teaching. Check that the LED of the [DIRECT TEACHING] button turns off or the status indicator LED changes from green to blue.

Point

The LED behavior of the [DIRECT TEACHING] button is as follows.

- Off: Direct teaching stopped
- On: Direct teaching is on (Joint free mode)
- Quick flashing: Direct teaching is on (Translational mode)
- Slow flashing: Direct teaching is on (Rotational mode)

(Rotational mode is supported with controller software version B1c or later.)

RT VisualBox is required in order to teach positions.

Direct teaching is turned off under the following conditions:

- If the robot arm is not moved for a certain period of time (the initial value is 60 seconds) after direct teaching is turned on.

To change the time until direct teaching automatically turns off, change parameter DTTMR.

- When stop signals are input
- When a high or low level error occurs. For further information on errors, refer to the following manual:

Troubleshooting (BFP-A3480)

- If communication with RT VisualBox is lost for 30 seconds.

4.4 How to use direct teaching in RT VisualBox

This section explains how to use direct teaching in RT VisualBox.

Point

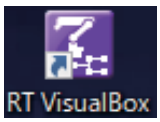
- Direct teaching can only be turned on when the robot is in AUTOMATIC mode or Collaborative operation mode (standard operation or low-speed operation).
- Direct teaching cannot be turned on with the teaching pendant.

⚠CAUTION

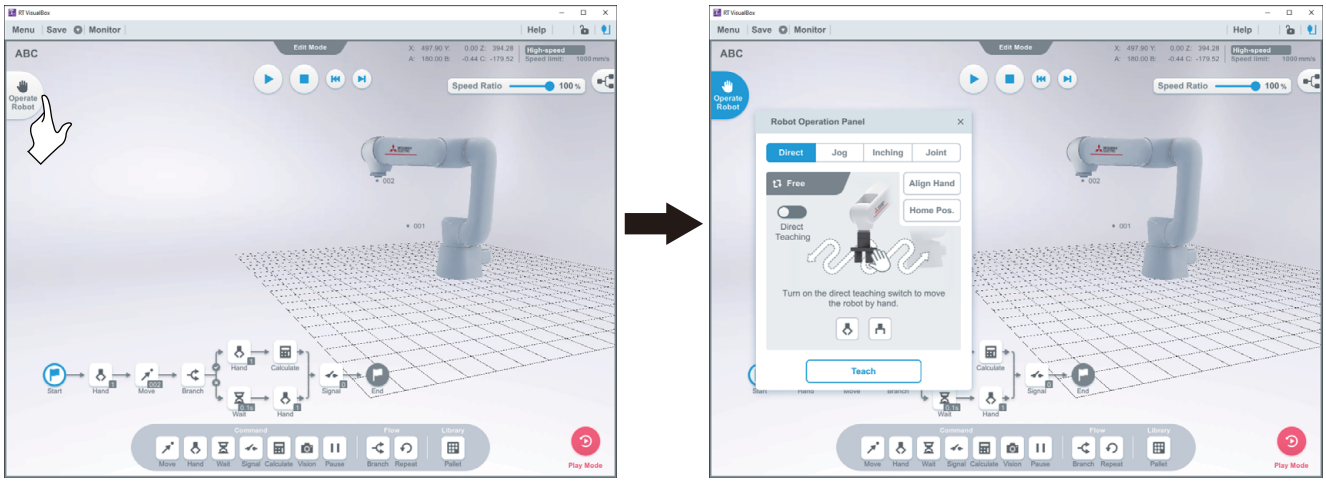
- Place an emergency stop switch in an easily accessible place near the robot. Connect the emergency stop switch to the external emergency stop terminals of the robot controller.
- If the settings for the hand are not configured correctly, the arm may rise or fall when direct teaching is turned on. Furthermore, the safety functions may not work properly. Ensure the settings are correct.
- Inertia may cause the robot arm to move. Do not release your hands from the robot arm until it stops completely.
- Workpiece settings are not enabled during direct teaching. The robot arm may fall depending on the weight of the workpiece. Do not release your hands from the robot arm until it stops completely.
- If using one of the hand settings from HADDAT1 to HADDAT8 set in RT ToolBox3, be aware that the hand setting in the controller will be reset to HNDDAT0 if the controller's power is cycled. In this case, the arm may rise or fall as the correct hand settings will no longer be set.

1. Set the mode selector switch input of the controller to "AUTOMATIC".

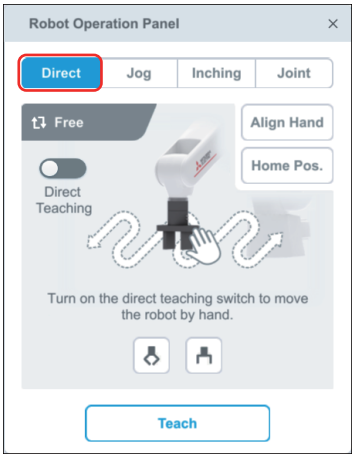
2. Double-click the shortcut to start RT VisualBox.



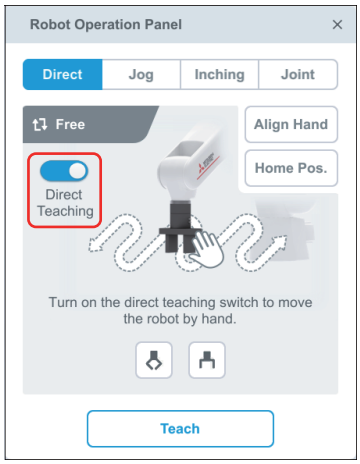
3. Tap/click the [Operate Robot] button to display the Robot Operation panel.



4. Select the [Direct] tab in the Robot Operation panel.



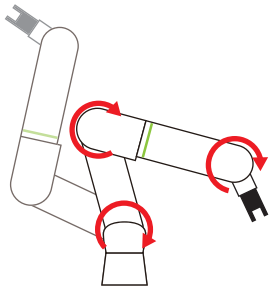
5. Tap/click the [Direct Teaching] switch in the Robot Operation panel to turn on direct teaching. Direct teaching will remain enabled until the [Direct Teaching] switch is turned off.



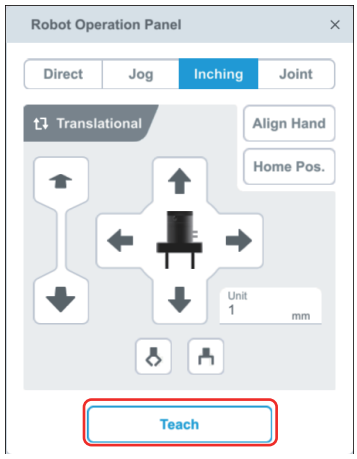
Point

Direct teaching is automatically turned off when switching to the Jog, Inching, or Joint windows, or when an error occurs.

6. Hold the robot arm directly with your hands, and move it to the desired position/posture.



7. Tap/click the [Teach] button in the Robot Operation panel to teach the current position. RT VisualBox is required for it to be possible to teach positions using this button.



8. Tap/click the [Direct Teaching] switch again in the Robot Operation panel to turn off direct teaching.

Point

Direct teaching is turned off under the following conditions:

- If the robot arm is not moved for a certain period of time (the initial value is 60 seconds) after direct teaching is turned on To change the time until direct teaching automatically turns off, change parameter DTTMR.
- When stop signals are input
- When a high or low level error occurs. For further information on errors, refer to the following manual:

📖Troubleshooting (BFP-A3480)

- If communication with RT VisualBox is lost for 30 seconds.

4.5 Direct teaching parameters

Parameter	Parameter name	No. of arrays No. of characters	Description	Factory setting
Direct teaching automatic OFF setting	DTTMR	Integer 2	Sets the direct teaching automatic OFF function. • Element 1: Enables/disables the automatic OFF function. 0: Disabled, 1: Enabled • Element 2: Time for automatic OFF [sec] Setting range: 1 to 300	1, 60
Robot arm moving judgment speed value	DTVTHD	Real number 6	Sets the threshold value of the robot arm movement speed to check that the arm is not moved at direct teaching. • Element 1: Threshold of J1 [rpm] Range: 0.00 to 1.00 • Element 2: Threshold of J2 [rpm] Range: 0.00 to 1.00 • Element 3: Threshold of J3 [rpm] Range: 0.00 to 1.00 • Element 4: Threshold of J4 [rpm] Range: 0.00 to 1.00 • Element 5: Threshold of J5 [rpm] Range: 0.00 to 1.00 • Element 6: Threshold of J6 [rpm] Range: 0.00 to 1.00	0.50, 0.50, 0.50, 0.50, 0.50, 1.00

4.6 Dedicated I/O signals

Parameter name	Category	Name	Function	Signal level	Signal number at the factory setting input/output
DTON	Input	—	—	—	-1 (No meaning), -1
	Signal	Direct teaching ON state output	Sets the signal that outputs the ON state of direct teaching.	Level	
DTMD	Input	—	—	—	-1 (No meaning), -1 (No meaning), -1, -1
	Signal	Direct teaching operation mode output	Sets the start and end numbers of the signal area that outputs direct teaching operation mode. Assigns an operation mode to each bit. 1/0 = Used/Not used ↓Start number 7 0 00000000 | | |...bit 0: Direct teaching is on (Joint free mode) | |.....bit 1: Direct teaching is on (Translational mode) |.....bit 2: Direct teaching is on (Rotational mode) All bits are set to "0" when direct teaching is stopped.	Level	

5 PREVENTIVE MAINTENANCE FUNCTION

As a guide, it is recommended that the robot is overhauled before the servo ON time reaches the specified hours (robot arm: 36,000 hours, robot controller: 36,000 hours). Note that the degree of part wear and degradation may differ depending on the environment. Use the following formulas to gauge how fast the robot operation will wear out the robot's parts. If the results from the formulas indicate that the robot's parts will wear out quickly, address the issue by reducing the speed or using another method. Otherwise, the robot arm may need to be overhauled before 36000 hours have passed.

5.1 Formulas

If a value larger than 1.0 is obtained by the following formulas, it indicates that the robot operation will wear the parts in a shorter period of time than the number of hours specified.

Formula 1: Wear ratio of overhaulable parts [%] / (cumulative servo ON time [hours] / 36,000 [hours] × 100)

Formula 2: Wear ratio of consumable parts [%] / (cumulative servo ON time [hours] / 36,000 [hours] × 100)

5.2 How to check values

In the Variable Monitor window of RT VisualBox, you can check the wear ratio of overhaulable parts, cumulative servo ON time, and wear ratio of consumable parts. Refer to the table below for formulas and their respective variables.

Formula	Variable
Wear ratio of overhaulable parts [%]	M_PMCsmOH
Cumulative servo ON time [hours]	M_SrvOnTime
Wear ratio of consumable parts [%]	M_PMCsmMnt

Operating procedure

1. In RT VisualBox, tap/click [Monitor] → [Variable Monitor] from the menu. The Variable Monitor window will appear.
2. Tap/click the [Add] button and enter "M_PMCsmOH" in the variable name input window. Then, tap/click the [Add] button.
3. Check that the variable has been added and its value appears in the window.
4. Add "M_SrvOnTime" and "M_PMCsmMnt" in the same manner as Step 2.
5. Use the obtained values in the wear formulas.

5.3 Status variables

The table below shows status variables that are related to this robot's preventive maintenance function.

Status variable list

Status variable list

Status variable name	Description
M_PMCsmOH	Returns the wear ratio of overhaulable parts.
M_SrvOnTime	Returns the cumulative servo ON time.
M_PMCsmMnt	Returns the wear ratio of consumable parts.

Status variables

M_PMCsmOH

■Function

Returns the overall wear ratio of overhaulable parts (reduction gears, bearings, ball screws, and ball splines). (Unit: %)

■Syntax

Ex.

<Numerical variable> = M_PMCsmOH

■Term

<Numerical variable>: Specify a numerical variable to which a value is to be assigned.

■Reference program

1 M1 = M_PMCsmOH 'M1 indicates the overall wear ratio of overhaulable parts.

■Explanation

1. Returns the overall wear ratio of overhaulable parts (reduction gears, bearings, ball screws, and ball splines) used in the robot (mechanism 1).

2. Read-only.

3. Returns "-1" when the preventive maintenance function is disabled.

M_SrvOnTime

■Function

Returns the robot's cumulative servo ON time since the last overhaul. (Unit: hours)

■Syntax

Ex.

<Numerical variable> = M_SrvOnTime

■Term

<Numerical variable>: Specify a numerical variable to which a value is to be assigned.

■Reference program

1 M1 = M_SrvOnTime 'M1 indicates the cumulative servo ON time of the robot (mechanism 1).

■Explanation

1. Returns the cumulative servo ON time of the robot (mechanism 1). "Cumulative time" indicates the time since the last overhaul.

2. Read-only.

3. Returns "-1" when the preventive maintenance function is disabled.

M_PMCsmMnt

■Function

Returns the overall wear ratio of consumable parts (grease and timing belts). (Unit: %)

■Syntax

Ex.

<Numerical variable> = M_PMCsmMnt

■Term

<Numerical variable>: Specify a numerical variable to which a value is to be assigned.

■Reference program

1 M1 = M_PMCsmMnt 'M1 indicates the overall wear ratio of consumable parts.

■Explanation

1. Returns the overall wear ratio of consumable parts (grease and timing belts) of the robot (mechanism 1) .

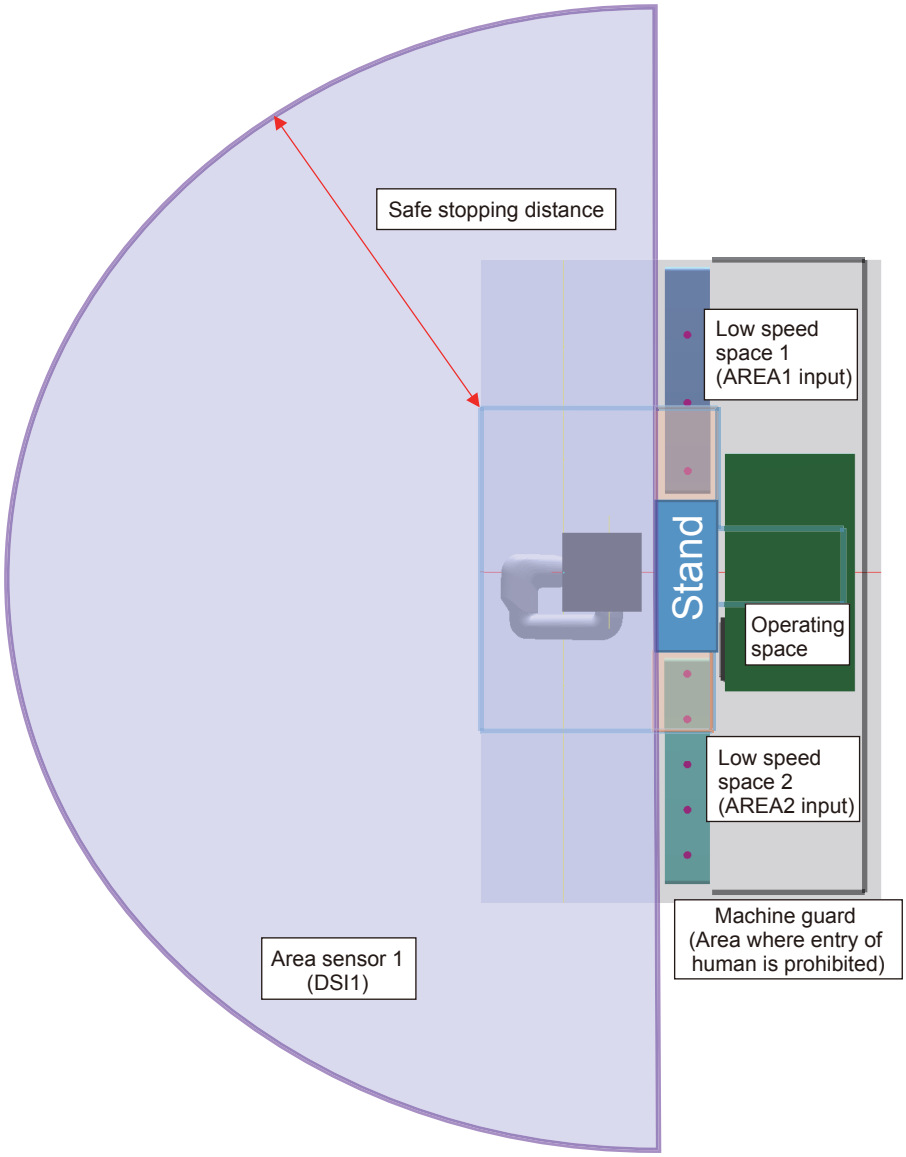
2. Read-only.

3. Returns "-1" when the preventive maintenance function is disabled.

APPENDIX

Appendix 1 Safe stopping distance

This section explains how to calculate a safe stopping distance. The distance is required for the robot to switch from High-speed operation mode to Collaborative operation mode after the area sensor has detected the presence of humans.



The safe stopping distance (d_{dec}) can be calculated using the following variables: human speed (V_h), time from detection of human in monitored area until deceleration initiation (T_{res}), Max. time from deceleration initiation until deceleration stops (T_{max}), and a safety factor of 1 or more (α). The formula used to calculate the safe stopping distance is as follows:

$d_{dec} = V_h \times (T_{res} + T_{max}) \times \alpha$

In the following conditions, the safe stopping distance is 2259.68 [mm]. This is the distance required between the operating space border and monitored space border.

- Movement speed of humans V_h: 1600 [mm/s]
- Deceleration start time T_{res}: 132.3 [ms] + 10 [ms]*1
- Maximum deceleration time T_{max}: 1.27 [sec]
- Safety factor α: 1.0

*1 Reaction time of the area sensor (example). Check the specifications of the area sensor used.

REVISIONS

*The manual number is on the bottom left of the back cover.

Revision date	*Manual No.	Description
April 2020	BFP-A3735	First edition
October 2020	BFP-A3735-A	Added Rotational mode to direct teaching.

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