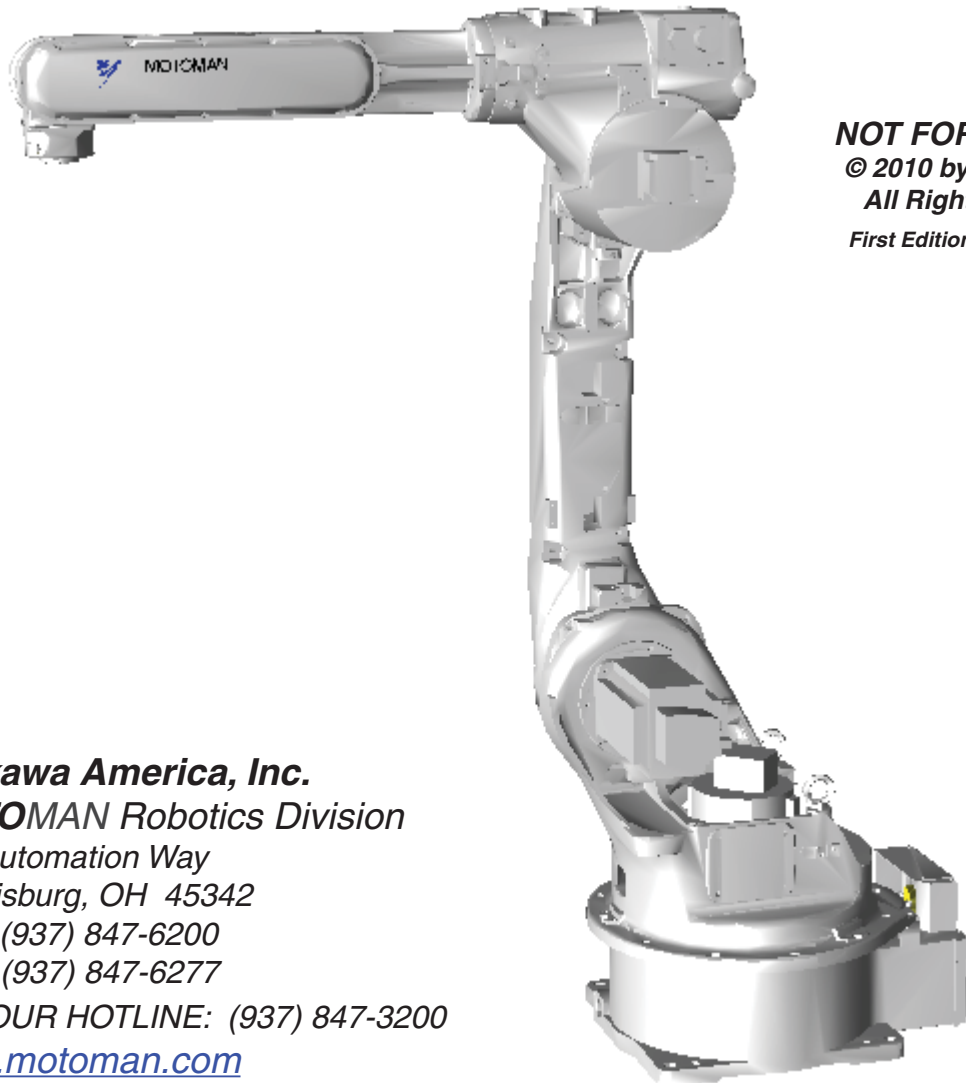




MOTOMAN ROBOTICS

DX100 Robot Controller

Functional Safety Unit Training Manual



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PREFACE

PURPOSE OF THIS MANUAL

MOTOMAN TECHNICAL EDUCATION CENTER training manuals are not intended for use as stand alone training tools. This manual is to be used in conjunction with the DX Functional Safety Unit course.

WHO SHOULD USE THIS MANUAL

This manual is only issued to attendees of the DX Functional Safety Unit course. Do not use the manual as a reference tool unless you have attended the course and received certification through *MOTOMAN TECHNICAL EDUCATION CENTER*.

HOW TO USE THIS MANUAL

This training manual has been written according to the daily structure of the DX Functional Safety Unit course. It is designed to assist students in understanding the DX Functional Safety Unit for the DX100 controller and a *MOTOMAN* robot. Use this manual as a step-by-step guide through the course.

DISCLAIMER

Information in this manual is based on the assumption that the DX100 controller is in the MANAGEMENT Security Level and is using the Expanded Language. Be aware that the keystrokes described in this manual may vary based on other settings, software versions, and options.

NOTE: *This manual is not for resale and will not be sold separately. All training manuals developed by MOTOMAN TECHNICAL EDUCATION CENTER are copyrighted. Do not copy any portion of these manuals.*

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1.0 SAFETY RANGE FUNCTION FOR ROBOT

1.1 Changing Security Mode

The DX100 Controller is protected by a security system that allows operation, editing, and modification of settings according to three SECURITY modes. An icon in the Status Area indicates the current security level.

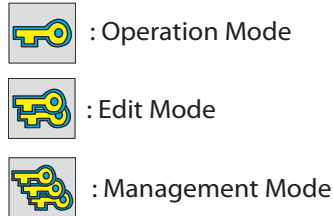


Figure 1-1 Security Level Icons

OPERATION MODE is the lowest access level and does not require a User ID number. EDITING and MANAGEMENT are each protected by a separate 4 to 8-digit User ID number. Ensure personnel have the correct training for each level to which they are granted access. The preset factory User ID/password for the EDITING MODE is 00000000 (8 zeros), and MANAGEMENT MODE is 99999999 (8 nines).

NOTE: *No password is necessary to change from a higher to a lower level of security.*

Changing Security Modes

To change the Security level setting to EDITING or MANAGEMENT, complete the following steps:

1. From MAIN MENU, choose SYSTEM INFO.
2. Choose SECURITY.
3. With the cursor on the MODE, press SELECT, cursor to the desired level (EDITING or MANAGEMENT), and press SELECT.
4. Enter the appropriate password using the number keypad; press ENTER.

NOTE: *Only in MANAGEMENT Security Level can data such as the operating range be edited or viewed. The "Safety Unit FLASH Erase" can be performed in the maintenance mode.*

1.2 **Preparation for Safety Range Function**

For the safety range function for the robot arm, set the safety range of the robot arm as polygonal columns in advance. Then, the robot arm is monitored so that it does not exceed the safety range.

If any monitoring error is detected, the servo power will be turned OFF.

The outline of the operating procedure is as follows:

- Setting tool interference file
- Setting safety range for robot
- Confirming safety range for robot
- Starting safety range function for robot

1.3 **Setting Tool Interference File**

The safety unit also monitors that the robot tool does not exceed the safety range. In this case, set the tool shape in the tool interference file. To set the tool interference file, the security mode must be MANAGEMENT MODE or higher.

Tool interference file

- Cylinders and spheres for up to 5 positions can be set.
- Both ends of a cylinder are set by POINT1 and POINT2. The distance from the center of T axis flange should be set like tool dimension setting.
- The radius of the spheres and cylinder between POINT1 and POINT2 is set. The spheres are set to POINT1 and POINT2.
- The specified radius must have a margin of at least 10 mm compared with the actual tool.

NOTE: *A single tool interference file can be used for a robot.*

The safety range function is set to the data in the tool interference file #0 for R1 and that in the tool interference file #1 or R2.

To setup a tool interference file, perform the following steps:

1. From the MAIN MENU, choose ROBOT, then choose TOOL INTERFERE.

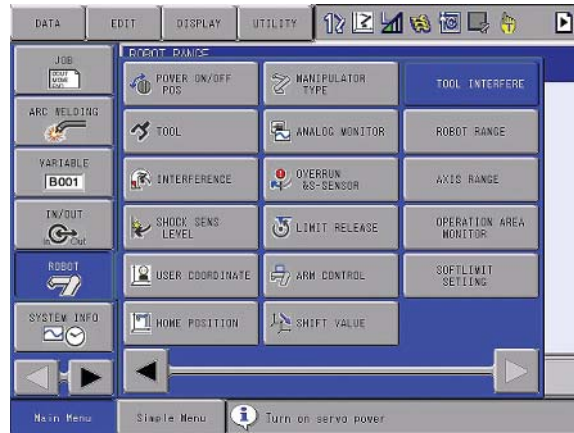
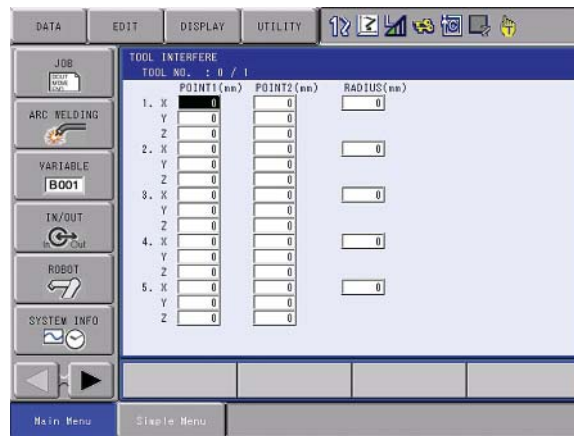


Figure 1-2 TOOL INTERFERE select.



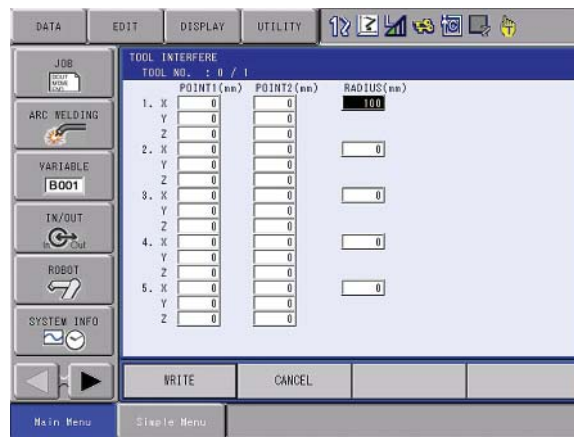
2. When the data is set in the TOOL INTERFERE screen, the READBACK screen is displayed.



In the READBACK screen, you can check that the set data is correct.

Compare the MODIFY VALUE with the READBACK VALUE.

- If the data is OK, press YES on the screen to set the tool interference file setting
 - If the data is NG, press NO on the screen to restore to the value before changing.
3. After the READBACK screen is displayed, WRITE and CANCEL buttons are displayed in the lower position of the screen.



WRITE: Robot controller records the setting of the tool interference file.

CANCEL: The tool interference file settings are restored to the previous status.

NOTE: Be sure to press **WRITE** after performing tool interference file settings or the data could be lost when you exit the screen.

Figure 1-3 below shows an example of modeling a tool for the settings in the tool interference file

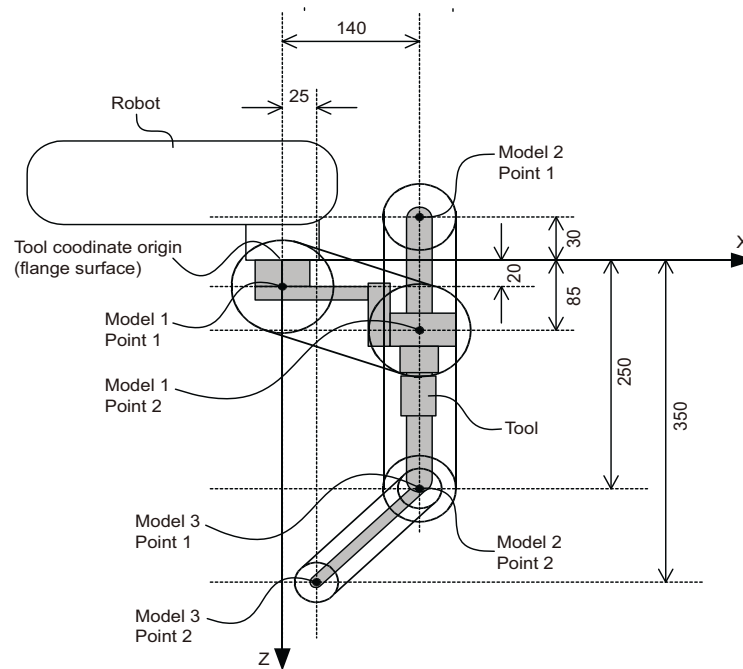


Figure 1-3 Tool interference modeling example

Model 1: Set the flange surface as Point 1, and (X=140, Z=85) as Point 2.

Model 2: Set (X=140, Z=-30) as Point 1, and (X=140, Z=250) as Point 2. This setting defines a model that is parallel to the Z direction of the tool coordinates.

Model 3: Set (X=140, Z=250) as Point 1, and (X=25, Z=350) as Point 2.
 Models 2 and 3 are defined at consecutive positions when point 2 of
 model 2 and point 1 of model 3 are set at the same position.

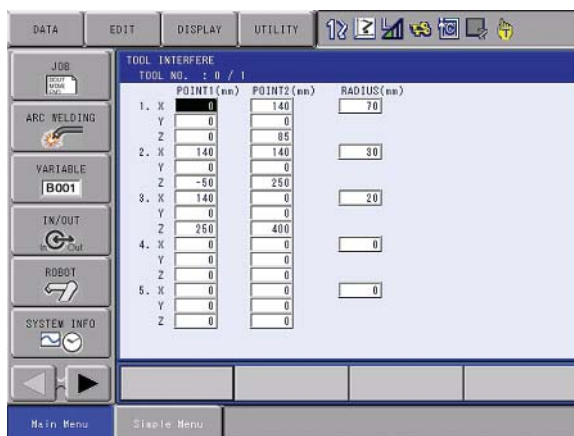


Figure 1-4 complete tool interference file

1.4 Setting Safety Range for Robot

The robot operating space is defined by setting XY line segments. Up to 16 line segments can be used to define the operating space. The Z-direction is defined by a top and bottom direction.

The system can have up to eight user-defined safety zones with the expansion option selectable by dual channel inputs on the Functional Safety Unit. Each zone can be defined with up to 16 line segments.

To set the ROBOT RANGE line segments, perform the following steps:

1. From the MAIN MENU, choose ROBOT, then choose ROBOT RANGE



Figure 1-5 ROBOT RANGE Select

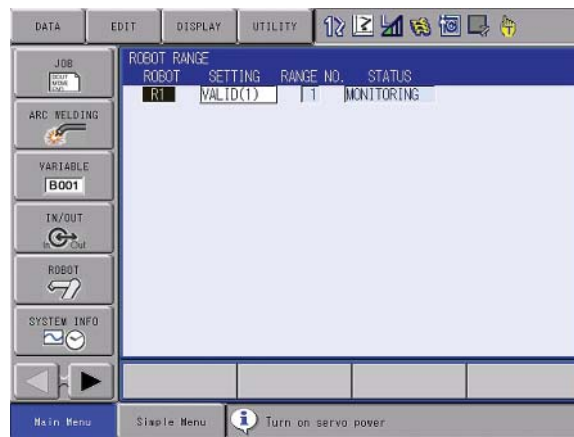
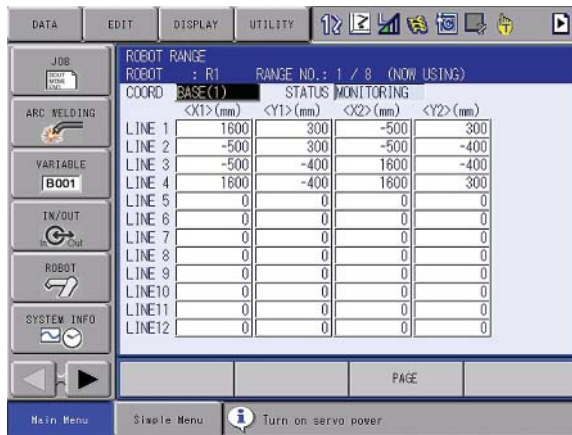


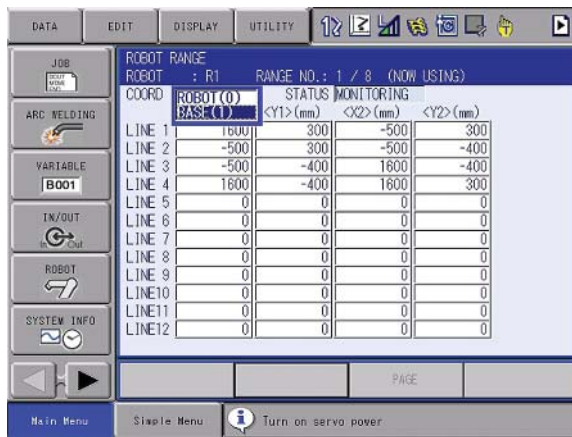
Figure 1-6 The ROBOT RANGE Screen

Below is a discription of the screen.

- **ROBOT:** Selects a robot to be set in case the of a multiple robot system. To set R1, move the cursor to R1 and press SELECT.
 - **SETTING:** Sets the safety range limit function status.
 - **INVALID:** The safety range function can be disabled temporarily. The system output signal “Range Monitoring” is turned OFF.
 - **VALID:** The safety range function is enabled. The system output signal “Range Monitoring” is turned ON.
 - **SETTING:** Is displayed when setting the data.
 - **CONFIRMING:** Is displayed when confirming the range after data setting.
 - **MONITORING:** is displayed after confirming the data. While MONITORING is displayed, the safety range function is performed.
2. Select R1. Then the ROBOT RANGE setup screen is displayed.



3. Select a coordinate type; ROBOT or BASE.



4. Make line segments connecting X1 and Y1, X2 and Y2, to set the safety range. Up to 16 line segments can be used for setting.
5. Set the safety range of Z-direction top surface.
6. Set the safety range of Z-direction bottom surface.

To set the range with the X direction + side: 3000 mm, X direction - side: -2000 mm, Y direction + side: 2500 mm, and Y direction - side: -1500 mm, enter the numbers as shown in table 1-1 below.

Table 1-1 Line segments

	X1	Y1	X2	Y2
Line 1	3000	2500	-2000	2500
Line 2	-2000	2500	-2000	-1500
Line 3	-2000	-1500	3000	-1500
Line 4	3000	-1500	3000	2500

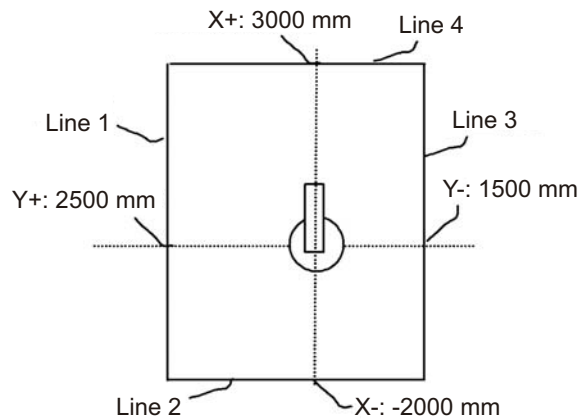


Figure 1-7 Line segment example

- When the data is set in the ROBOT RANGE screen, the READBACK screen is displayed.

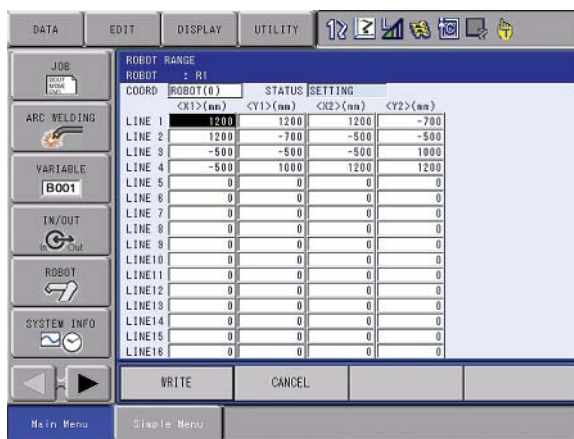


Figure 1-8 READBACK screen

In the READBACK screen, you can check that the set data is correct.

Compare the MODIFY VALUE with the READBACK VALUE.


- If the data is OK, press YES on the screen to set the tool interference file setting
 - If the data is NG, press NO on the screen to restore to the value before changing.
- After the READBACK screen is displayed, WRITE and CANCEL buttons are displayed in the lower position of the screen.



WRITE: Robot controller records the setting of the tool interference file.

CANCEL: The tool interference file settings are restored to the previous status.

NOTE: Be sure to press **WRITE** after performing the safety range setting. Unless the safety ranges are set and the status is set to **MONITORING** for all the robots used in the system, robot operations by the axis keys (X,Y,Z,rX,rY,rZ) cannot be performed except for each axis operation(S,L,U,R,B,T).

- When setting multiple ranges, press the page key  and switch the screen to make the settings. For multiple ranges, set an overlap area. Switch between ranges only when the robot is in the overlap area.

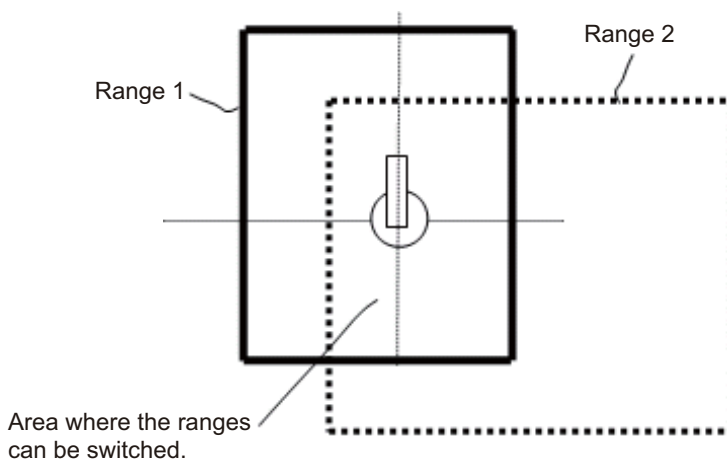


Figure 1-9 Overlapping Ranges

1.5 Confirming Safety Range for Robot

After the completion of ROBOT RANGE setting, it is necessary to confirm that the monitoring is performed according to the ROBOT RANGE settings

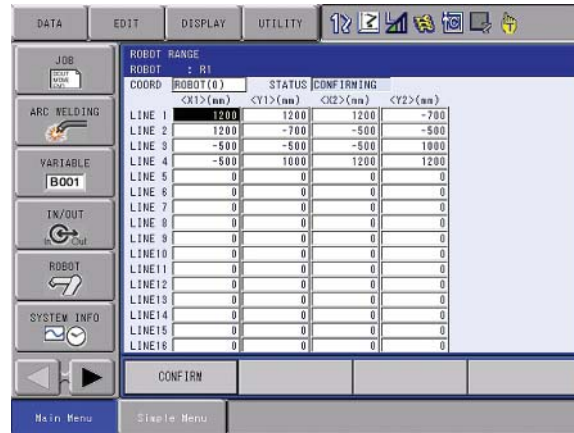


Figure 1-10 ROBOT RANGE settings

At that time, the STATUS in ROBOT RANGE screen indicates CONFIRMING. Move the robot to check if the manipulator stops before it exceeds the safety range. When multiple ranges are set, change the range switch signals to check for all the ranges. Check that the specified safety range is correct with the jog operation. Make the robot operate toward the specified four limits to see that the robot stops operating within the range. If the range is not rectangular solid, check that the robot stops before all the limits of the range.

CAUTION! Do not forget to move the robot to see that it stops within the specified safety range.

1.6 Starting Safety Range Function for Robot

After confirming that the robot can move in the set safety range, press CONFIRM. The STATUS indication is changed to MONITORING and the safety unit starts the safety range function for the robot.

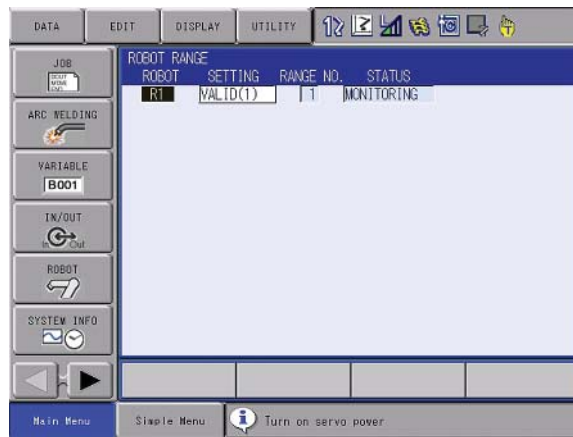


Figure 1-11 ROBOT RANGE valid

Check the following items with the actual job in PLAY mode:

1. Check the teaching point of the job.

If an alarm occurs and the robot does not operate when the job is played back, the following causes are possible:

- The specified range is inappropriate.
- Teaching is inappropriate.

If the teaching position is out of the specified range. Alarm 4682: MOTION RANGE LIMIT INTERFERENCE will occur.

In the case of the Alarm 4682.

- The teaching position is out of the specified range.
- Check that the specified range is correct.
- Change the teaching position so that it falls in the range.

2. Endurance running must be normally performed. Try to move the actual job. If the robot moves near the specified range, an alarm may occur.

If Alarm 1629: OPERATION AREA MON. ERR(ROBOT) occurs.

- The range error was detected when the robot operated.
- This alarm was detected by the safety unit. The safety unit monitors the position based on the feedback pulse from the motor. The speed and coasting value is considered during calculation so that the robot does not move out of the range. Thus, this alarm occurs when the teaching position is near the safety range or the teaching speed is fast.
- Modify teaching so that the teaching position is not near the safety range.
- Reduce the teaching speed.

NOTE: If the STATUS is CONFIRMING, PLAY mode operation is disabled. Be sure to perform confirming operation and press CONFIRM button on the screen.

1.7 Confirming Safety Range and Robot Position

The positional relation between the specified safety range and the actual robot posture can be checked by showing them on the programming pendant.

To confirm the Safety Range and Robot Position, perform the following steps:

1. From the MAIN MENU, choose ROBOT, then choose OPERATION AREA MONITOR.



Figure 1-12 OPERATION AREA MONITOR select

The Disp Operation Area screen is displayed.

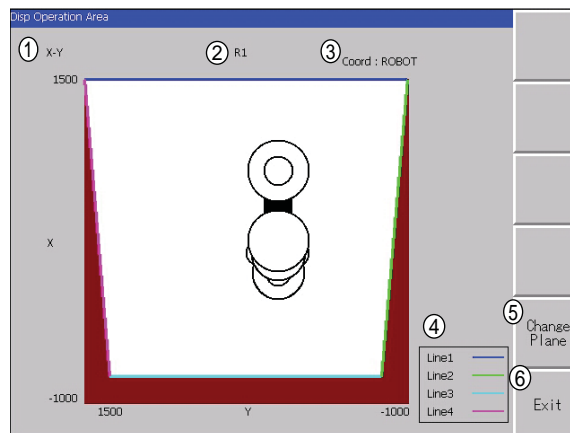


Figure 1-13 Disp Operation Area screen X-Y plane

The discription of the screen is as follows:

1. This is the plane currently displayed. The brown section indicates the area out of the safety range.

- X-Y plane: The safety range is a white area enclosed with straight lines.
2. The number of the robot currently displayed.
 3. The coordinate system of the safety range.
 4. The correspondence table of the illustrated straight lines. The numbers of straight lines correspond to the straight line numbers on ROBOT RANGE screen.
 5. Change Plane key. Each time pressed, the displayed plane is switched between the X-Y, Y-Z & X-Z display screens.

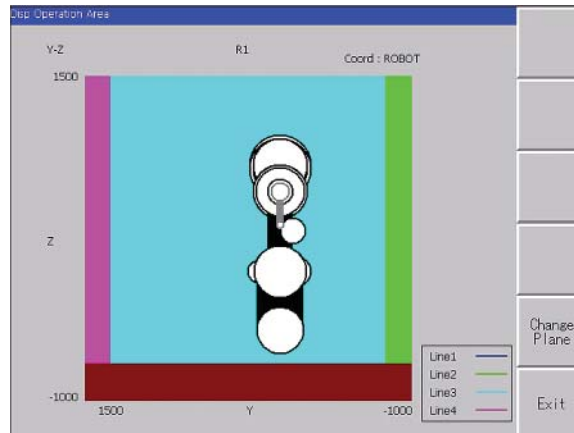


Figure 1-14 Disp Operation Area screen Y-Z plane

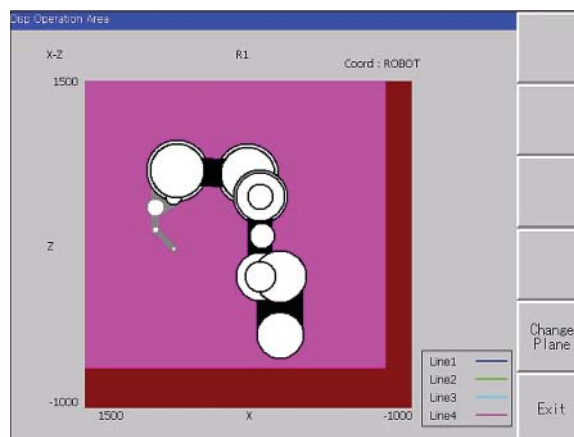


Figure 1-15 Disp Operation Area screen X-Z plane

6. Exit key Closes the Disp Operation Area screen.

NOTE: When the Disp Operation Area screen is closed, other opened screens are also closed. This means that data not yet confirmed is discarded if the Disp Operation Area screen is opened while editing the data. Thus, make sure to confirm the editing data before opening the Disp Operation Area screen.

2.0 SAFETY RANGE SWITCHING FUNCTION

2.1 Function Outline

The safety range number (1 to 8) is specified according to the combinations of range switch signals which are three types of dual signal from an external device. Each meaning of range switch signal is explained in the table below.

Table 2-1 Range Switch Signal

Signal	Status	Terminal	Range switch bit information
GSIN1 (IN#6)	OPEN	CNEXT1-5/6	d0 bit OFF
	CLOSE	CNEXT1-7/8	d0 bit ON
SAFF (IN#7)	OPEN	CNEXT1-9/10	d1 bit OFF
	CLOSE	CNEXT1-11/12	d1 bit ON
EXESP (IN#8)	OPEN	CNEXT1-13/14	d2 bit OFF
	CLOSE	CNEXT1-15/16	d2 bit ON

The range No. can be specified by the combination of range switch signals. The combinations are explained in the table below.

Table 2-2 Signal Combination

Selected range No.	1	2	3	4	5	6	7	8
d0 bit	OFF	ON	OFF	ON	OFF	ON	OFF	ON
d1 bit	OFF	OFF	ON	ON	OFF	OFF	ON	ON
d2 bit	OFF	OFF	OFF	OFF	ON	ON	ON	ON

The following alarm occurs when the functional safety unit has detected the inconsistency of the safety range switch signals.

ALARM 4705 SIGNAL COMPARISON ERROR(SAFETY)

- Sub code 41: GSIN1 signal inconsistent
- Sub code 5: SAFF signal inconsistent
- Sub code 3: EXESP signal inconsistent

2.2 Wiring Method for Range Switching Function

The wiring method for the Range Switching Function is explained in the figure below.

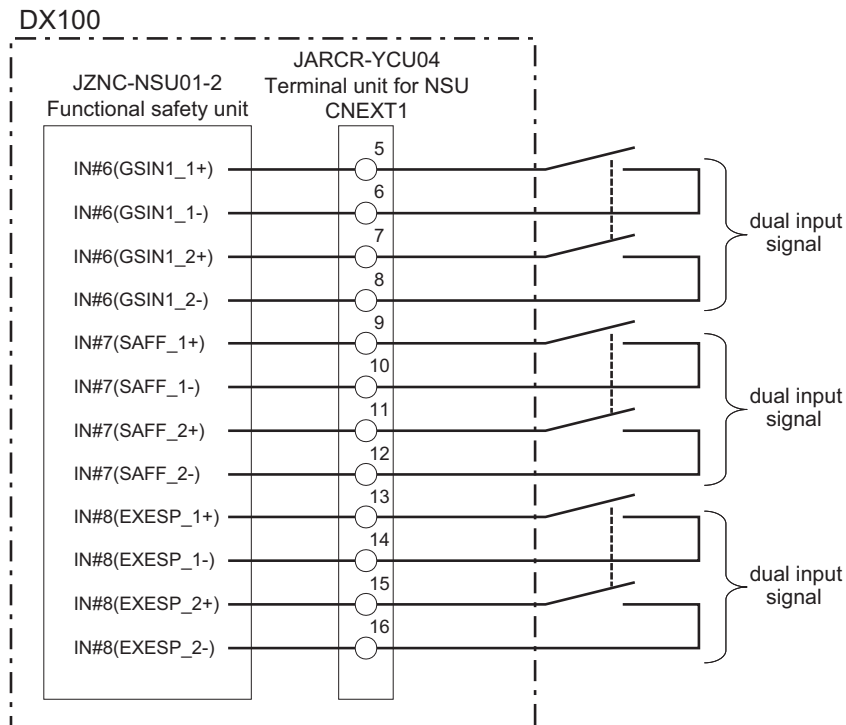


Figure 2-1 Connection Exampel

CAUTION! Connect an independent switch (dry contact) for the signal. If the semiconductor output (*periodic OFF check diagnosis) is directly connected, the input circuit may malfunction. The signal must be received by a control device such as a safety relay unit before connecting the contact signal.

NOTE: An appropriate control device must be used to achieve the safety function.

CAUTION! The load current of 24 VDC/6.5 mA (typ) flows through each input circuit. For the connection, use a switching device capable of switching 24 VDC at 6.5 mA (typ).

CAUTION! The dual input signals are checked whether they are synchronized. Set the dual input signals as the signals which turn ON and OFF simultaneously. If the dual input signals's turning ON and OFF are different in timings with 500 ms or more, the alarm of "INPUT SIGNAL ERROR" occurs.

2.3 Switching Safety Range

Multiple safety ranges can be set/confirmed in advance, and the ranges can be switched by Eight ranges switching signals. For multiple safety ranges, set an overlap area as in the figure below. Switch between ranges only when the robot is in the overlap area.

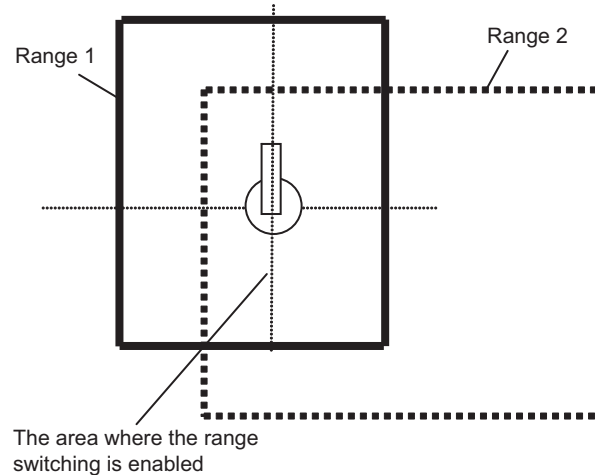


Figure 2-2 Overlapping Ranges

Use the Eight ranges switching signals of the functional safety unit to switch between safety ranges. If the range set by the signal is selected and the robot is outside that range, the following alarm occurs. Alarm4691 OPERATION AREA SET ERR (SAFETY). Select the range that matches the robot current position to reset the alarm.

If the range is selected while it is being set or confirmed during the robot program operation, the following alarm occurs. Alarm 4679: SPECIFIED MOTION RANGE ERROR. Select another range already confirmed to reset the alarm.

Selected safety range numbers are output to the following system outputs. (Refer to chapter 7 System Output Signal) for a complete list of signals.

- 50940 to 50947 RANGE NO.: (d0)
- 50950 to 50957 RANGE NO.: (d1)
- 50960 to 50967 RANGE NO.: (d2)

CAUTION! *When performing the teaching operation of the robot program, the operator should always check the range number before each operation. Prepare a means to identify the selected range number, and check the selected range number before performing operations.*

NOTE: *If the STATUS is “CONFIRMING”, PLAY mode operation is disabled. Be sure to perform confirming operation and press CONFIRM button on the screen. Confirm the safety range in PLAY mode while MONITORING is indicated.*

2.4 Robot Operating Range Data

The functional safety unit can save and load the robot operating range data. However, the robot operating range data differs between conventional specification and safety signal expansion specification. The functional safety unit can save and load the robot operating range data. However, the robot operating range data differs between conventional specification and safety signal expansion specification. There is no compatibility between RNGROBO.CND and RNGROBO2.CND. Therefore, the data RNGROBO.CND saved in the functional safety unit specification cannot be loaded to the system for the safety signal expansion specification. That is, RNGROBO.CND cannot be used when Safety Range Switching Function is used. On the other hand, RNGROBO2.CND also cannot be used for the conventional functional safety unit. The table below shows which file goes with which unit.

Table 2-3 File Types

Safety signal expansion specification	Robot operating range data file name	The number of Operating range definitions
NOT USED	RNGROBO.CND	4
USE	RNGROBO2.CND	8

To save the file perform the following:

1. From the MAIN MENU select EX. MEMORY and then SAVE.

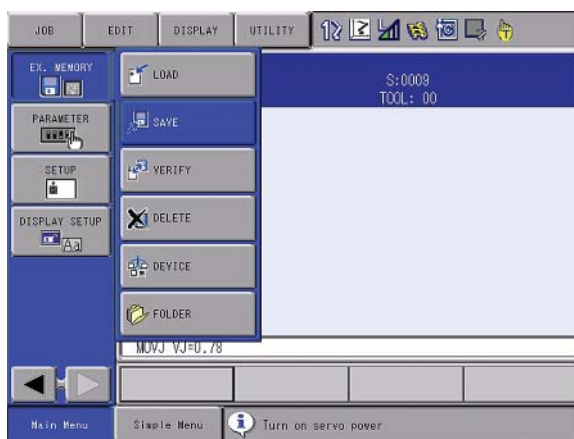


Figure 2-3 SAVE SELECT

2. Move the cursor to FILE/GENERAL DATA and press SELECT.

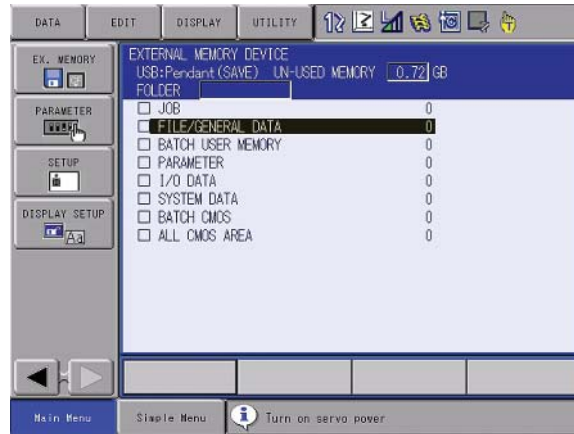


Figure 2-4 FILE/GENERAL DATA

3. Move the cursor to ROBOT RANGE DATA. In case of conventional functional safety unit specification, the ROBOT RANGE DATA is shown as RNGROBO.CND. In case of the safety signal expansion specification, the ROBOT RANGE DATA is shown as RNGROBO2.CND.

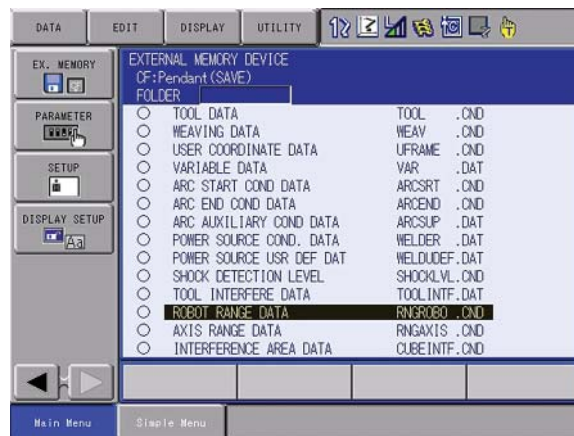


Figure 2-5 RNGROBO.CND

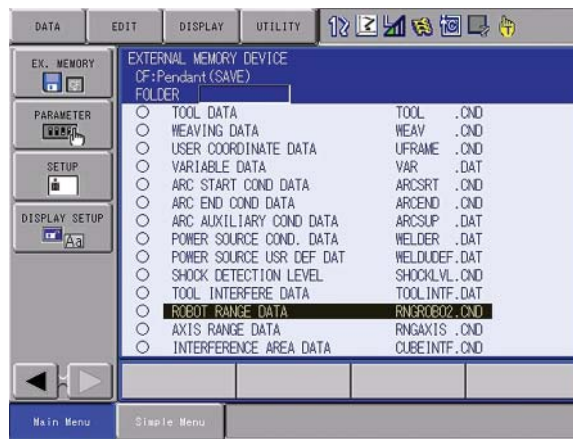


Figure 2-6 RINGROBO2.CND

4. Press SELECT to mark the file, then press ENTER. Cursor to YES and press SELECT to SAVE.

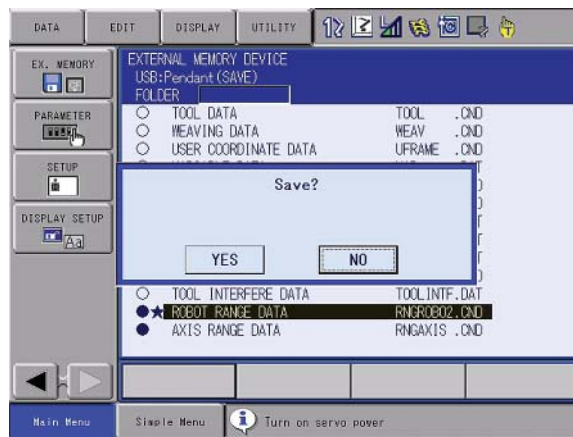


Figure 2-7 Confirm SAVE

5. To LOAD, From the MAIN MENU select EX. MEMORY and then LOAD and repeat the process.

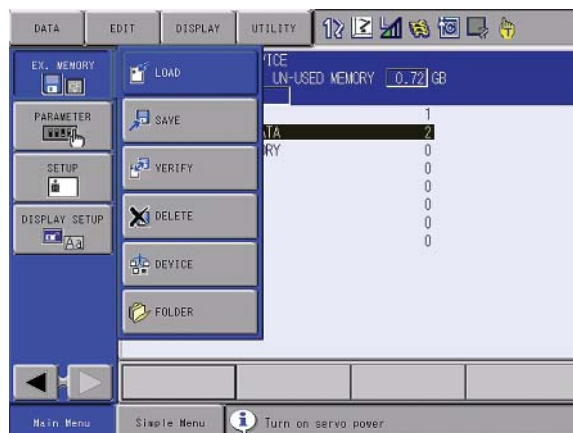


Figure 2-8 LOAD SELECT

3.0 SAFETY RANGE FUNCTION FOR EACH AXIS

3.1 Preparation for Safety Range Function

For the safety range function for each axis, set the movement amount of each axis of the robot in advance. Then, each axis is monitored so that it does not exceed the safety range. If any monitoring error is detected, the servo power will be turned OFF.

3.2 Setting Safety Range for Each Axis

To set the Safety Range for Each Axis , perform the following:

1. From the MAIN MENU, choose ROBOT, then choose AXIS RANGE.



Figure 3-1 AXIS RANGE Select

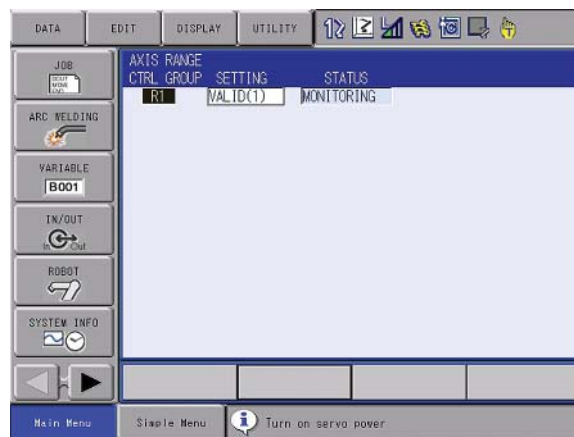


Figure 3-2 AXIS RANGE Screen

Below is a discription of the screen.

- CTRL GROUP: Selects a control group to be set in case the of a multiple control group system. To set S1, move the cursor to S1 and press SELECT.
 - SETTING: Sets the safety range limit function status.
 - INVALID: The safety range function can be disabled temporarily. The system output signal “Range Monitoring” is turned OFF.
 - VALID: The safety range function is enabled. The system output signal “Range Monitoring” is turned ON.
 - SETTING: Is displayed when setting the data.
 - CONFIRMING: Is displayed when confirming the range after data setting.
 - MONITORING: is displayed after confirming the data. While MONITORING is displayed, the safety range function is performed.
2. SELECT a control group. The AXIS RANGE screen of the selected control group will be displayed.

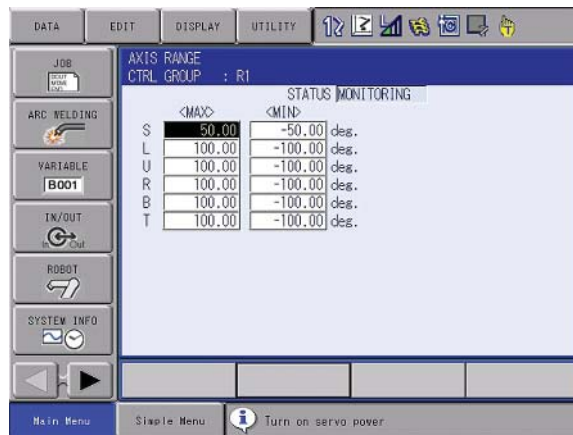


Figure 3-3 AXIS RANGE R1

MAX/MIN: The maximum and minimum values of the safety range are shown for each axis of the selected control group.

3. SELECT a MAX/MIN setting to input a value. Input the desired setting and press ENTER. When MAX/MIN data are set, the READBACK screen is displayed.

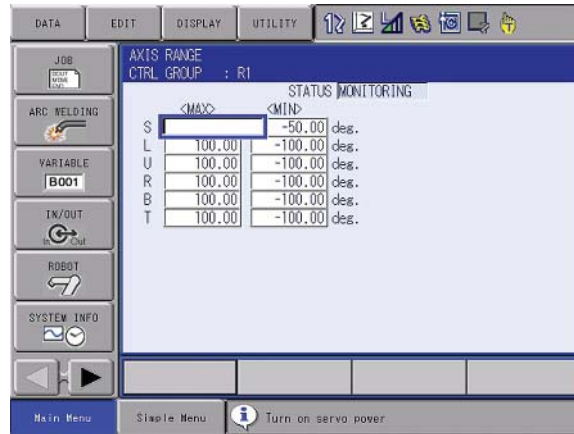


Figure 3-4 AXIS RANGE edit screen

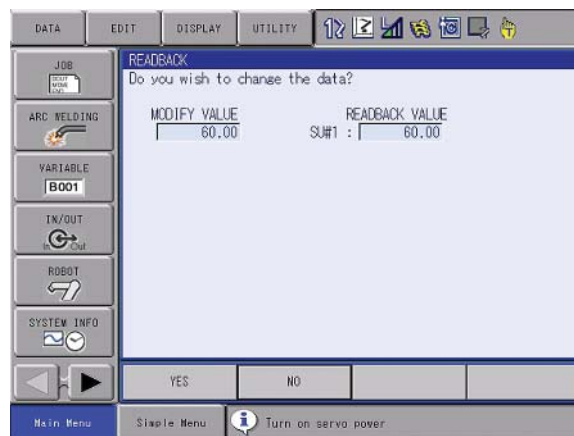


Figure 3-5 READBACK screen

Check that MODIFY VALUE and READBACK VALUE are the same, then press YES. The selected data will be changed. Press NO to cancel editing.

- When the data is set, WRITE and CANCEL buttons are displayed in the lower position of the screen.

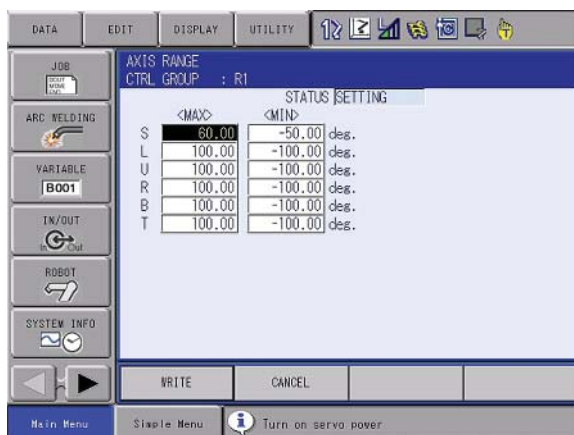


Figure 3-6 WRITE and CANCEL buttons

WRITE: Robot controller records the setting of the tool interference file.

CANCEL: The tool interference file settings are restored to the previous status.

3.3 Confirming Safety Range for Each Axis

After the completion of safety range for EACH AXIS setting, it is necessary to confirm if the monitoring is performed according to the safety range set. At that time, the “STATUS” in AXIS RANGE screen indicates CONFIRMING. Move the manipulator or the external axis to check if it stops before it exceeds the safety range.

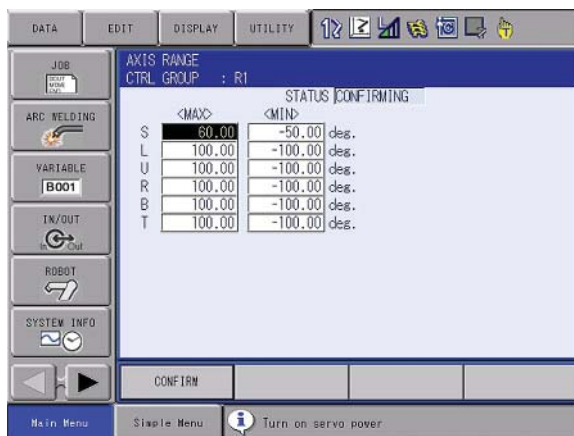


Figure 3-7 AXIS RANGE CONFIRMING

3.4 Starting Safety Range Function for Each Axis

After confirming that the robot can move in the set safety range, press CONFIRM. The STATUS indication is changed to MONITORING and the safety unit starts the safety range function for EACH AXIS.

Check the following items with the actual job in PLAY mode:

1. Check the teaching point of the job.

If an alarm occurs and the robot does not operate when the job is played back, the following causes are possible:

- The specified range is inappropriate.
- Teaching is inappropriate.

If the teaching position is out of the specified range. Alarm 4683: MOTION RANGE LIMIT will occur.

In the case of the Alarm 4683.

- The teaching position is out of the specified range.
- Check that the specified range is correct.
- Change the teaching position so that it falls in the range.

2. Endurance running must be normally performed. Try to move the actual job. If the robot moves near the specified range, an alarm may occur.

If Alarm 1625: OPERATION AREA MON. ERR(AXIS) occurs.

- The range error was detected when the robot operated.
- This alarm was detected by the safety unit. The safety unit monitors the position based on the feedback pulse from the motor. The speed and coasting value is considered during calculation so that the robot does not move out of the range. Thus, this alarm occurs when the teaching position is near the safety range or the teaching speed is fast.
- Make the safety range setting INVALID, move the robot within the safety range, then make the setting VALID again. Modify teaching so that the teaching position is not near the safety range.
- Reduce the teaching speed.

NOTE: *If the STATUS is CONFIRMING, PLAY mode operation is disabled. Be sure to perform confirming operation and press CONFIRM button on the screen.*

NOTES

4.0 SPEED LIMIT FUNCTION DURING PLAY

4.1 Speed Limit Function

This function controls the manipulator's speed during PLAY mode so that it wouldn't exceed the safety speed 250 mm/sec. In case of over speed, the functional safety unit immediately shuts down the power supply to the servo part to turn the servo power OFF.

Valid/Invalid setting for this function is determined by switching ON/OFF the PLAY Speed Limit Signal that is a dual signal from the external device.

To use this function, it is necessary to implement the wiring specific for the safety signal expansion specification. The combinations of Valid/Invalid status and Signal ON/OFF status are as follows:

Table 4-1 Valid/Invalid Setting

Signal	Status	Terminal	Valid/Invalid
GSIN0 (IN#5)	OPEN	CNEXT1-1/2, CNEXT1-3/4	Speed limit function during PLAY is valid.
	CLOSE		Speed limit function during PLAY is invalid.

The following alarm occurs when the functional safety unit has detected the inconsistency of the PLAY Speed Limit Signal.

- ALARM 4705 SIGNAL COMPARISON ERROR (SAFETY) Sub code 40: GSIN0 signal inconsistent

Execute the JOB in Play mode and confirm that the speed monitoring function during play mode setting is switched between Valid and Invalid by switching the GSIN0 signal. The following alarm occurs if the speed has exceeded the safety speed.

Table 4-2 Speed Monitor Alarms

4694	SPEED MONITOR ERROR 1 (SAFETY)	The speed at TCP exceeded the safety speed. Lower the operation speed.
4695	SPEED MONITOR ERROR 2 (SAFETY)	The speed at the manipulator flange exceeded the safety speed. Lower the operation speed.

NOTE: *If the system consists of multiple control groups, the safety speed monitoring function in the play mode cannot be performed for each axis separately. The monitoring is performed only for the whole controller.*

4.2 Wiring Method for Speed Limit Function During PLAY

The wiring method for Speed Limit Function during PLAY is as follows:

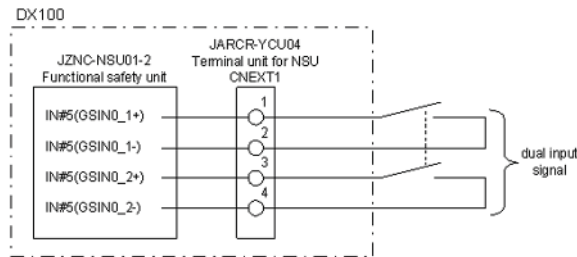


Figure 4-1 Connection Example

CAUTION! *Connect an independent switch (dry contact) for the signal. If the semiconductor output (*periodic OFF check diagnosis) is directly connected, the input circuit may malfunction. The signal must be received by a control device such as a safety relay unit before connecting the contact signal.*

NOTE: *An appropriate control device must be used to achieve the safety function.*

CAUTION! *The load current of 24 VDC/6.5 mA (typ) flows through each input circuit. For the connection, use a switching device capable of switching 24 VDC at 6.5 mA (typ).*

CAUTION! *The dual input signals are checked whether they are synchronized. Set the dual input signals as the signals which turn ON and OFF simultaneously. If the dual input signals's turning ON and OFF are different in timings with 500 ms or more, the alarm of "INPUT SIGNAL ERROR" occurs.*

5.0 SAFETY RANGE STATUS OUTPUT FUNCTION

5.1 Status Output Function

This function determines the range number which is currently selected by the manipulator and transmits the output signal to inform the external device of whether the manipulator is in the range or not. However, the available output signals are range numbers from 1 to 3. This function transmits the data to the external device by switching ON/OFF safety range status output signal, a dual output signal.

The meaning of safety range status output signal is as follows:

Table 5-1 Meaning of Safety Range Status Output Signal

<i>Output singal</i>	<i>Status</i>	<i>Description</i>
SFRON2 (OUT#1)	ON	Range No.1. The manipulator exists in the range.
	OFF	Case other than above
SFRON3 (OUT#2)	ON	Range No.2. The manipulator exists in the range.
	OFF	Case other than above
SFRON4 (OUT#3)	ON	Range No.3. The manipulator exists in the range.
	OFF	Case other than above

If the safety range status output signal becomes inconsistent statuses, the functional safety unit detects the inconsistency of feedback signal of the output signal to generate the following alarm.

ALARM 4705 SIGNAL COMPARISON ERROR (SAFETY)

- Sub code 24: SFRDY2 signal inconsistent
- Sub code 30: SFRDY3 signal inconsistent
- Sub code 34: SFRDY4 signal inconsistent

Details of result of Safety Range Output function is as follows:

Table 5-2 Output Information of Safety Range Status Output Function

Zone select input	ROBOT RANGE SETTING	Robot is Inside/ Outside of Zone	OUTPUT SFRON2 (in Zone 1)	OUTPUT SFRON3 (in Zone 2)	OUTPUT SFRON4 (in Zone 3)
Zone 1	VALID	Inside	ON	OFF	OFF
	VALID	Outside	OFF	OFF	OFF
	INVALID	Inside	OFF	OFF	OFF
	INVALID	Outside	OFF	OFF	OFF
Zone 2	VALID	Inside	OFF	ON	OFF
	VALID	Outside	OFF	OFF	OFF
	INVALID	Inside	OFF	OFF	OFF
	INVALID	Outside	OFF	OFF	OFF
Zone 3	VALID	Inside	OFF	OFF	ON
	VALID	Outside	OFF	OFF	OFF
	INVALID	Inside	OFF	OFF	OFF
	INVALID	Outside	OFF	OFF	OFF
Zone 4 over	VALID	Inside	OFF	OFF	OFF
	VALID	Outside	OFF	OFF	OFF
	INVALID	Inside	OFF	OFF	OFF
	INVALID	Outside	OFF	OFF	OFF

5.2 Wiring method for Safety Range Status Output Function

The wiring method for Safety Range Status Output Function is as follows:

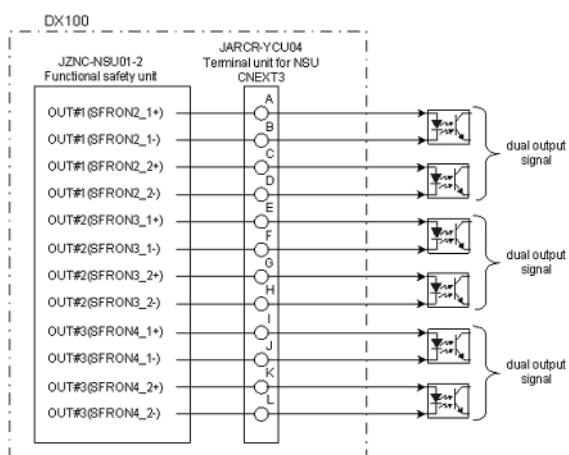


Figure 5-1 Connection Example

CAUTION! *The load current of 24 VDC/50mA (max.) can flow through each output circuit. For the connection, use the equipment which operates by less than 24 VDC/50mA.*

CAUTION! *Configure a safety system using dual signal. Configuring the safety system using only one signal will jeopardize the safety function. Use appropriate equipment to be connected, for realization of safety function. If appropriate equipment is not used, the safety function may deteriorate.*

CAUTION! *When connecting an inductive load to the output, protect the output circuit with a surge absorber. DO NOT connect a capacitive load.*

NOTES

6.0 DATA PROTECTION

6.1 Saving Dual Data

The data related to this function is saved in a duplicated manner for safety. When the control power is turned ON, a check is performed to see that dual data sets are the same. If they are different when the control power is turned ON, the following alarm occurs.

Alarm 0300: VERIFY ERROR(SYSTEM CONFIG-DATA)[10]

If the alarm occurs, the following causes are possible:

- The data related to this function is loaded from an external storage.
- The home position calibration or the home position change operation is performed.
- The tool calibration operation is performed.
- The data saving has not been performed correctly.
- The zeroing function is performed.

NOTE: *When the zeroing function is performed, make sure to perform “Safety Unit FLASH Reset” after recalibrating the home position.*

6.2 Operation When VERIFY ERROR Occurs

If the following alarm occurs when the control power is turned ON,

Alarm 0300: VERIFY ERROR(SYSTEM CONFIG-DATA)[10]

perform the following operations to re-set the data of the functional safety unit:

1. When Alarm 0300: VERIFY ERROR(SYSTEM CONFIG-DATA)[10] occurs the system will start up in maintenance mode.



Figure 6-1 Maintenance Mode display

2. Select SYSTEM under the main menu. Then, change the security mode from EDIT MODE to MANAGEMENT MODE with the procedure described in chapter 1.0 Changing Security Mode on Page 1-1.
3. Select FILE under the main menu. Then, select INITIALIZE under the sub menu.

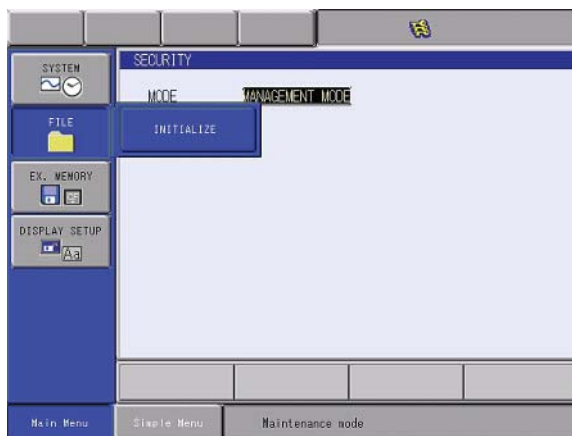


Figure 6-2 INITIALIZE screen

4. The INITIALIZE screen will be displayed. Move the cursor to Safety Unit FLASH Reset and press ENTER.

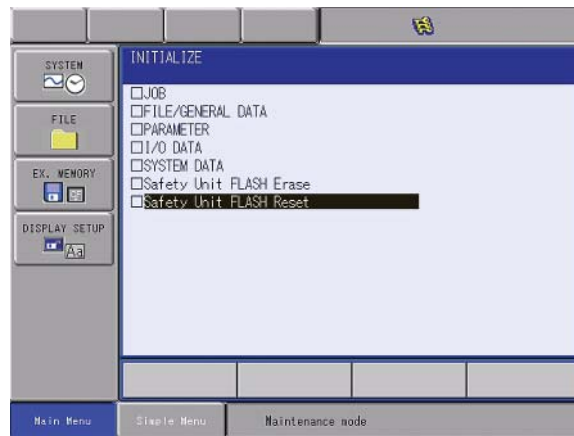


Figure 6-3 INITIALIZE screen display

5. The dialog box Reset? is displayed. Select YES to start the reset process. A few seconds later, the buzzer sounds and the data setting is completed.

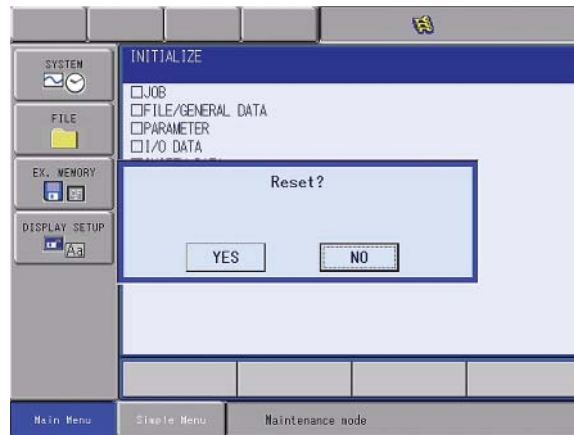


Figure 6-4 Reset confirm

6. When the data reset is completed, turn the control power OFF and then turn the power ON again.

NOTE: To set the safety unit data, the security mode must be *MANAGEMENT MODE* or higher. Thus, the administrator or a user with higher privilege must perform these settings.

NOTES

7.0 SYSTEM OUTPUT SIGNAL

7.1 System Outputs

The signals output while using the functional safety unit are shown below.

50917	50916	50915	50914	50913	50912	50911	50910
SOUT#728	SOUT#727	SOUT#726	SOUT#725	SOUT#724	SOUT#723	SOUT#722	SOUT#721
							SF. UNIT CONNECT

- 50910: SF. UNIT CONNECT. When one or more functional safety units (NSU01) are connected with the system, this signal turns ON.

50937	50936	50935	50934	50933	50932	50931	50930
SOUT#744	SOUT#743	SOUT#742	SOUT#741	SOUT#740	SOUT#739	SOUT#738	SOUT#737
MONITOR RANGE (R8)	MONITOR RANGE (R7)	MONITOR RANGE (R6)	MONITOR RANGE (R5)	MONITOR RANGE (R4)	MONITOR RANGE (R3)	MONITOR RANGE (R2)	MONITOR RANGE (R1)

- 50930 to 50937: MONITOR RANGE (R1 to 8). This signal shows the operation status of the safety range function for each robot. Set VALID/INVALID to turn ON/OFF this signal on the ROBOT RANGE window.

50947	50946	50945	50944	50943	50942	50941	50940
SOUT#752	SOUT#751	SOUT#750	SOUT#749	SOUT#748	SOUT#747	SOUT#746	SOUT#745
RANGE NO.: d0 (R8)	RANGE NO.: d0 (R7)	RANGE NO.: d0 (R6)	RANGE NO.: d0 (R5)	RANGE NO.: d0 (R4)	RANGE NO.: d0 (R3)	RANGE NO.: d0 (R2)	RANGE NO.: d0 (R1)

- 50940 to 50947: RANGE NO.: d0 (R1 to 8)

50957	50956	50955	50954	50953	50952	50951	50950
SOUT#760	SOUT#759	SOUT#758	SOUT#757	SOUT#756	SOUT#755	SOUT#754	SOUT#753
RANGE NO.: d1 (R8)	RANGE NO.: d1 (R7)	RANGE NO.: d1 (R6)	RANGE NO.: d1 (R5)	RANGE NO.: d1 (R4)	RANGE NO.: d1 (R3)	RANGE NO.: d1 (R2)	RANGE NO.: d1 (R1)

- 50950 to 50957: RANGE NO.: d1 (R1 to 8)

50967	50966	50965	50964	50963	50962	50961	50960
SOUT#768	SOUT#767	SOUT#766	SOUT#765	SOUT#764	SOUT#763	SOUT#762	SOUT#761
RANGE NO.: d2 (R8)	RANGE NO.: d2 (R7)	RANGE NO.: d2 (R6)	RANGE NO.: d2 (R5)	RANGE NO.: d2 (R4)	RANGE NO.: d2 (R3)	RANGE NO.: d2 (R2)	RANGE NO.: d2 (R1)

- 50960 to 50967: RANGE NO.: d2 (R1 to 8)

The RANGE NO. under monitoring for each manipulator. Specifies the range number from 1 to 8 by 3 bits: d0, d1 and d2. The table below shows the bit status.

Table 7-1 Bit Status

Selected safety range No.	d2	d1	d0
1	OFF	OFF	OFF
2	OFF	OFF	ON
3	OFF	ON	OFF
4	OFF	ON	ON
5	ON	OFF	OFF
6	ON	OFF	ON
7	ON	ON	OFF
8	ON	ON	ON

8.0 ALARM LIST

Alarm No.	Message	Explanation
0020	CPU COMMUNICATION ERROR	The connected board's presence was not confirmed. This alarm also occurs when an error is detected in the serial communication between YIF01 and EAXA01 or YIF01 and NSU01. Subcode 1: YCP01 (main CPU board) 50 to 57: EAXA01 60 to 67: NSU01
0021	COMMUNICATION ERROR (SERVO)	An error is detected in the serial communication between YIF01 and EAXA01 or YIF01 and NSU01. Subcode 50 to 57: EAXA01 60 to 67: NSU01
0110 to 0117	COMMUNICATION ERROR (SU#1 to 8)	An error is detected in the serial communication between YIF01 and NSU01. The last digit of the alarm number indicates the node number. Alarm 0110: NSU 1st node Alarm 0111: NSU 2nd node
0300	VERIFY ERROR (SYSTEM CONFIG-DATA)	The DX100 has detected an error in the validity check on the data files between YCP01 and the safety unit (NSU) when the power is turned ON. Execute "Safety Unit FLASH Erase" in the maintenance mode. This alarm also occurs when the functional safety unit is replaced with the unit whose data has not been set.
0400	PARAMETER TRANSMISSION ERROR	An error is detected in the parameter transmission between YIF01 and EAXA board or YIF and NSU. Subcode: same as the alarm 0021
0410	MODE CHANGE ERROR	The DX100 changes its operation modes during a startup process from the power-on operation until the startup process completion. An unsuccessful mode change was detected. Subcode: same as the alarm 0021
0510	SOFTWARE VERSION UNMATCH	The combination of software is incorrect. Subcode 60: The software version of the functional safety unit (NSU01) is incorrect.
1610	SAFETY UNIT CPU SYNCHRO ERROR	The DX100 has detected an error in the communication between YCP01 and the safety unit (NSU) when the power is turned ON. Check the cables and connectors between these boards, then turn the power OFF and ON again.
1612	COMMUNICATION ERROR (SAFETY)	There is a communication error between YIF01 and NSU. There may be poor contact of connectors. Check the cables and connectors between these boards, then turn the power OFF and ON again.
1613	ENCODER COMM. ERR 1 (SAFETY)	The DX100 has detected an error in the communication between the encoder (each axis) and the safety unit (NSU). Check the encoder cables, then turn the power OFF and ON again.
1614	ENCODER COMM. ERR 2 (SAFETY)	The DX100 has detected an error in the communication between the encoder (all axes) and the safety unit (NSU). Check the encoder cables and connectors, then turn the power OFF and ON again.
1615	SYSTEM ERROR (SAFETY)	NSU01 could not execute the process successfully. Turn the power OFF and ON again. If this alarm occurs frequently, replace NSU01 unit.
1616	SYSTEM ERROR 1 (SAFETY)	NSU01 could not execute the process successfully. Turn the power OFF and ON again. If this alarm occurs frequently, replace NSU01 unit.

Alarm List

Alarm No.	Message	Explanation
1618	ARITHMETIC ERROR (SAFETY)	NSU01 detected an arithmetic error. Turn the power OFF and ON again. If this alarm occurs frequently, replace NSU01 unit.
1619	PARAMETER ERROR (SAFETY)	NSU01 detected an error in the setting value of parameter or file. Check for an error in the setting of the safety range, then turn the power OFF and ON again. If this alarm occurs frequently, replace NSU01 unit.
1622	DEFECTIVE ENCODER (SAFETY)	NSU01 detected an error in the encoder data. Check the encoder cables, then turn the power OFF and ON again.
1623	ENCODER CORR. NUM OVER (SAFETY)	Reading encoder data failed multiple times in a row. Turn the power OFF and ON again. If this alarm occurs again, replace NSU01 unit.
1625	OPERATION AREA MON. ERR (AXIS)	The safety unit (NSU) has detected the manipulator motion exceeding the safety range of each axis. Check the teaching points and range setting.
1629	OPERATION AREA MON. ERR (ROBOT)	The safety unit (NSU) has detected the manipulator motion exceeding the safety range. Check the teaching points, range setting, and motion speed near the end of the range.
1630	MUTUAL DIAGNOSIS ERR (WDT)	Data inconsistency occurred in the duplicated monitoring by the safety unit (NSU). One CPU detected an error in the timing check of the other. This alarm may be accompanied by the alarm 1610 and 1615. Turn the power OFF and ON again.
1631	MUTUAL DIAGNOSIS ERR (HW SETTING)	Data inconsistency occurred in the duplicated monitoring by the safety unit (NSU). The hardware setting failure of one of the dual systems was detected. This alarm may occur due to the failure of the rotary switch. Turn the power OFF and ON again. Subcode 1: rotary switch setting error 2: other errors
1632	MUTUAL DIAGNOSIS ERR (MONITOR)	Data inconsistency occurred in the duplicated monitoring by the safety unit (NSU). Turn the power OFF and ON again. This alarm occurs when an error was detected in one of the CPUs.
1634	FEEDBACK SIGNAL ERROR (SAFETY)	Data inconsistency occurred in the feedback monitoring of the safety signal outputs. Check the safety signal cables, then turn the power ON again. <Check point> Connectors and cables of NSU01: CNLO, CNSF 1 to 4
1635	LOW VOLTAGE (SAFETY)	The internally-generated voltage of NSU fell below the low voltage threshold. The failure of the unit may have occurred. Replace NSU01 unit.
1636	OVER VOLTAGE (SAFETY)	The internally-generated voltage of NSU exceeded the over voltage threshold. The failure of the unit may have occurred. Replace NSU01 unit.
1637	RAM DIAGNOSIS ERROR (SAFETY)	An error was detected by the hardware diagnosis of NSU. Turn the power OFF and ON again. If this alarm occurs frequently, replace NSU01 unit.
1639	RAM AREA CONVERSION ERR (SAFETY)	An error was detected by the hardware diagnosis of NSU. Turn the power OFF and ON again. If this alarm occurs frequently, replace NSU01 unit.
1640	REAL TIME MONITOR ERROR (SAFETY)	An error was detected by the hardware diagnosis of NSU. Turn the power OFF and ON again. If this alarm occurs frequently, replace NSU01 unit.

Alarm No.	Message	Explanation
1641	SAFETY OUTPUT FB ERROR (SAFETY)	An error was detected in the connection between NSU and another unit. Check the safety signal cables, then turn the power OFF and ON again. <Check point 1> communication cable between NSU (CNSF1 connector) and YSU (CN207 connector) <Check point 2> communication cable between NSU (CNSF1 connector) and YPU (CN609 connector)
1642	WATCHDOG SIGNAL ERROR (SAFETY)	An error was detected by the hardware diagnosis of NSU. Turn the power OFF and ON again. If this alarm occurs frequently, replace NSU01 unit.
1643	SIGNAL SETTING ERROR (SAFETY)	When a multiple robot system (with 2 or more manipulators) is used, the DX100 has detected an error in the link signal between the safety units (NSU01) or in the jumper cable setting of NSF02 board. Turn the power OFF and then ON again. <Check point> CNMA connector of NSU01 of the first robot, CNMB connector of NSU01 of the second robot, and the cables between the connectors <Check point> CNLO connector of NSU01 of the first robot, CNLI connector of NSU01 of the second robot, and the cables between the connectors <Check point> The jumper cable setting of NSF02 board of the rotary switch
1644	24V LOW VOLTAGE (SAFETY)	The externally supplied 24V voltage for NSU is not supplied. Check the fuse, power supply connector, and cables of NSU01. <Check point> F2, F3 fuses, CN01 connector, and power cable of NSU01
1645	CRC ERROR (SAFETY)	An error was detected in the stored data of NSU01. Turn the power OFF and ON again. If this alarm occurs frequently, replace NSU01 unit.
1646	COMM. SETTING ERROR (SAFETY)	An error was detected by the hardware diagnosis of NSU. Turn the power OFF and ON again. If this alarm occurs frequently, replace NSU01 unit.
4208	SYSTEM ERROR (ARITH)	A teaching point is set outside the range. Check the teaching points and range setting.
4679	SPECIFIED MOTION RANGE ERROR	Upper YCP01 detected that the range whose setting and confirmation are not completed is selected. Check the status of range selection signal and the setting of the safety range.
4680	SAFETY UNIT COMMAND ERROR	An error is detected in the serial communication between NIF01 and NSU01. This alarm may be accompanied by the alarm 0020 or 0100. Turn the power OFF and ON again. If this alarm occurs frequently, replace NSU01 unit.
4682	MOTION RANGE LIMIT INTERFERENCE	Upper YCP01 detected the manipulator motion exceeding the safety range. Check the teaching points and range setting.
4683	AXIS MOTION RANGE LIMIT	Upper YCP01 detected the motion of each axis exceeding the safety range. Check the teaching points and range setting.
4685	WRITE ERROR (SAFETY)	Data was not recorded successfully in the functional safety unit. Turn the power OFF and ON again. If this alarm occurs frequently, replace NSU01 unit.
4687	OPERATION AREA MON. ERR 2 (AXIS)	The safety unit (NSU) detected the motion of each axis exceeding the safety range. Check the teaching points and range setting.
4689	OPERATION AREA MON. ERR 2 (ROBOT)	The safety unit (NSU) detected the manipulator motion exceeding the safety range. Check the teaching points and range setting.

Alarm No.	Message	Explanation
4691	OPERATION AREA SET ERR (SAFETY)	The safety unit (NSU) detected that the range whose setting is not completed is selected. Check the status of range selection signal and the setting of the safety range.
4692	ENCODER BACKUP ERROR (SAFETY)	This alarm occurs when the voltage of encoder battery drops. Replace the encoder battery. <Check point> CN03A connector and connection cables of NSU01
4693	READBACK PROC. ERROR (SAFETY)	An error was detected in the readback process at the data change between NSU01 and the programming pendant. Turn the power OFF and ON again. If this alarm occurs frequently, replace NSU01 unit.
4694	SPEED MONITOR ERROR 1 (SAFETY)	The speed at TCP exceeded the safety speed. Lower the operation speed.
4695	SPEED MONITOR ERROR 2 (SAFETY)	The speed at the manipulator flange exceeded the safety speed. Lower the operation speed.
4703	OPERATION MODE ERROR	An error was detected by the internal diagnosis of NSU. Turn the power OFF and ON again. If this alarm occurs frequently, replace NSU01 unit.
4704	STOPPING POS. MON. ERR (SAFETY)	NSU01 detected that the robot moved when the stop position monitoring function was enabled. Check the status of GSIN signal, set GSIN signal to the short-circuit status, then reset the alarm.
4705	SIGNAL COMPARISON ERROR (SAFETY)	Data inconsistency occurred in the duplicated monitoring of the safety signals. Check the safety signal cables, then turn the power ON again. <Check point> Connectors and cables of NSU01: CNMA, CNMB, CNIFA, CNIFB, and CNSF 1 to 4 Subcode 1: Signal inconsistency in PPDSW 5: Signal inconsistency in YCU02 board A to D 3: Signal inconsistency in YCU02 board E to H 40: Signal inconsistency in GSIN signal 41: Signal inconsistency in GSIN signal
4706	ROBOT MOTION RANGE OVER (SAFETY)	The manipulator exists out of the range due to range setting and range switching. Disable the safety range setting and return the manipulator within the safety range.

8.1 7 segment LED indication of safety unit NSU01

7 segment LED indication of safety unit NSU01 are as follows.
(Left side LED: CPU1, Right side LED: CPU2)

Table 8-1 7 segment LED indication

7 seg. LED indication	Status
All Lit	After power on
[0] to	Under boot up
[d]	Normal status
[E]	Error status

When an error occurs in safety unit, 5 digits LED are indicated with 7 seg. LED.

Each digit is indicated for 1.0sec and all turning off status is for 0.3 sec.

Table 8-2 Example of “F001.” error.

Sequence	7 seg. LED indication	Indication time	Total time
1	[F]	1.0 [sec]	1.0 [sec]
2	Turning off	0.3 [sec]	1.3 [sec]
3	[0]	1.0 [sec]	2.3 [sec]
4	Turning off	0.3 [sec]	2.6 [sec]
5	[0]	1.0 [sec]	3.6 [sec]
6	Turning off	0.3 [sec]	3.9 [sec]
7	[1]	1.0 [sec]	4.9 [sec]
8	Turning off	0.3 [sec]	5.2 [sec]
9	[.]	1.0 [sec]	6.2 [sec]
10	Turning off	0.3 [sec]	6.5 [sec]

Table 8-3 Meaning of 7 segment LED indication

5 digits indication code	Error meaning	Cause
F001. F002. F003. F004. F010.	Communication error	Data communication error occurs. Check cable F002. wiring and a terminator then power on again.
0100. 0200. 0210. 0300. 0400. 0500. 0600. 0700. 0800. 0900. 0C00. 0D00. 1000. 1100. 1200. 1300. 1400.	CPU error	CPU internal error occurs. Power on again.

NOTES

9.0 RESTRICTIONS

9.1 Confirming Safety Range and Robot Position

This function also records parameters, files and other data in the safety unit. Therefore, this function cannot be used with a function that changes parameters or files during playback.

- T axis endless function and external axis endless function
- PMT function
- Gun change function and group change function
- System for painting
- Tool file number change

9.2 System Software Version

The system must have the following version:

When downgrading the software version from DS1.50.00A(-)-67 or later version or the version using safety signal expansion specification to the version before DS1.50.00A(-) 67, disable the safety signal specification in advance.

9.3 Software Version of Machine Safety Unit

This function checks the signals from the functional safety unit in the machine safety unit (YSU01-1E). The machine safety unit must have the following version:

YSU01-1: 1.08-00 or later

If the YSU version is earlier than the above version, ALARM 510 “SOFTWARE VERSION UNMATCH [70]” occurs.

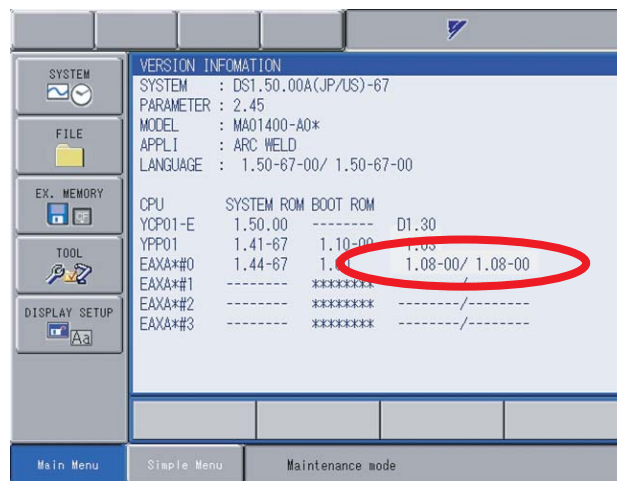


Figure 9-1 Software version of MSU

9.4 Software Version of Functional Safety Unit

The functional safety unit (NSU01) must have the following version:

NSU01: 4.01-00 or later

If the NSU version is earlier than the above version, ALARM 510
“SOFTWARE VERSION UNMATCH [60]” occurs.

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