FANUC Robot series

R-30*i*B Plus/R-30*i*B Mate Plus Controller

Servo Robot sensor

OPERATOR'S MANUAL

B-84234EN/01

- **Original Instructions**

Thank you very much for purchasing FANUC Robot.
Before using the Robot, be sure to read the "FANUC Robot series SAFETY HANDBOOK (B-80687EN)" and understand the content.

The products in this manual are controlled based on Japan's "Foreign Exchange and Foreign Trade Law". The export from Japan may be subject to an export license by the government of Japan.
Further, re-export to another country may be subject to the license of the government of the country from where the product is re-exported. Furthermore, the product may also be controlled by re-export regulations of the United States government.
Should you wish to export or re-export these products, please contact FANUC for advice.

In this manual, we endeavor to include all pertinent matters. There are, however, a very large number of operations that must not or cannot be performed, and if the manual contained them all, it would be enormous in volume. It is, therefore, requested to assume that any operations that are not explicitly described as being possible are "not possible".

SAFETY PRECAUTIONS

This chapter describes the precautions which must be followed to enable the safe use of the robot. Before using the robot, be sure to read this chapter thoroughly.

For detailed functions of the robot operation, read the relevant operator's manual to understand fully its specification.

For the safety of the operator and the system, follow all safety precautions when operating a robot and its peripheral equipment installed in a work cell.
For safe use of FANUC robots, you must read and follow the instructions in “FANUC Robot series SAFETY HANDBOOK (**B-80687EN)**”.

1 PERSONNEL

Personnel can be classified as follows.

Operator:
- Turns the robot controller power ON/OFF
- Starts the robot program from operator panel

Programmer or Teaching operator:
- Operates the robot
- Teaches the robot inside the safeguarded space

Maintenance technician:
- Operates the robot
- Teaches the robot inside the safeguarded space
- Performs maintenance (repair, adjustment, replacement)

- The operator is not allowed to work in the safeguarded space.
- The programmer or teaching operator and maintenance technician are allowed to work in the safeguarded space. Works carried out in the safeguarded space include transportation, installation, teaching, adjustment, and maintenance.
- To work inside the safeguarded space, the person must be trained on proper robot operation.

Table 1 (a) lists the work outside the safeguarded space. In this table, the symbol "O" means the work allowed to be carried out by the specified personnel.

Table 1 (a) List of work outside the Safeguarded Space

	Operator	Programmer or Teaching operator	Maintenance technician
Turn power ON/OFF to Robot controller	O	O	O
Select operating mode (AUTO/T1/T2)		O	O
Select remote/local mode		O	O
Select robot program with teach pendant		O	O
Select robot program with external device		O	O
Start robot program with operator's panel	O	O	O
Start robot program with teach pendant		O	O
Reset alarm with operator's panel		O	O
Reset alarm with teach pendant		O	O
Set data on teach pendant		O	O
Teaching with teach pendant		O	O
Emergency stop with operator's panel	O	O	O
Emergency stop with teach pendant	O	O	O
Operator's panel maintenance			O
Teach pendant maintenance			O

During robot operation, programming and maintenance, the operator, programmer, teaching operator and maintenance technician take care of their safety using at least the following safety protectors.

- Use clothes, uniform, overall adequate for the work
- Safety shoes
- Helmet

2 DEFINITION OF SAFETY NOTATIONS

To ensure the safety of users and prevent damage to the machine, this manual indicates each precaution on safety with "**WARNING**" or "**CAUTION**" according to its severity. Supplementary information is indicated by "**NOTE**". Read the contents of each **"WARNING"**, "**CAUTION**" and "**NOTE**" before using the robot.

Symbol	Definitions
⚠**WARNING**	Used if hazard resulting in the death or serious injury of the user will be expected to occur if he or she fails to follow the approved procedure.
⚠**CAUTION**	Used if a hazard resulting in the minor or moderate injury of the user, or equipment damage may be expected to occur if he or she fails to follow the approved procedure.
NOTE	Used if a supplementary explanation not related to any of WARNING and CAUTION is to be indicated.

3 SAFATY MEASURES FOR LASERS

Laser has a high power density even with a small emission amount and can be harmful to the human body. FUJI-CAM uses class 2M or class 3B lasers.

- Class 2M is visible light and has low output (wavelengths of 400 to 700 nm). Eye aversive reactions usually protect the eye, however observing with optical means in the bean can be dangerous.
- Class 3B has an output of 0.5W or less. It is dangerous to observe directly in the beam.

Take necessary safety measures according to the laser class to be used in accordance with the safety standards of laser products in each country / region. Table 3 (a) shows the safety precautions stipulated in the Japanese Industrial Safety and Health Law. In this table, the symbol "○" means that the safety precaution is required.

⚠ CAUTION

1 Failure to take the necessary safety measures can cause eye and skin damage to the user.
2 FUJI-CAM emits the laser when the "laser on" warning LED is on. To prevent eye damage, never look inside the sensor when the laser is on. Also, do not look at laser-emitted objects without wearing appropriate protective goggles.
3 FUJI-CAM has a LASER_ENABLE digital input that must be enabled to turn on the laser. This input should be connected to a safety interlock that includes a key lock switch (prepared by customer) and an emergency stop contact (prepared by customer). Also regularly check that the safety interlock is always working properly is required.

Table 3 (a) Safety precautions stipulated in Japan's Industrial Safety and Health Law

Measures			Laser class			
			4	3B	3R	2M1M
Appointment of laser equipment manager			○	○	○	
Controlled area (signs, off-limits)			○	○		
Laser equipment	Laser optical path	Position of the optical path (avoid eye level)	○	○	○	○
		Appropriate design and shielding of optical paths	○	○	○	
		Proper termination	○	○	○	○
	Key control		○	○		
	Emergency stop switch	Emergency stop switch	○	○		
		Warning measures	○	○	○	
		Shutter	○	○		
	Interlock system		○	○		
	Display of emission port		○	○	○	
Work management	Operating position		○			
	Optical system adjustment		○	○	○	○
	Protective equipment	Protective goggles	○	○	○	
		Protective clothing	○	○		
		Use of flame-retardant material	○			
	Inspection / maintenance		○	○	○	○
	Safety and health education		○	○	○	○
	Health care	Anterior eye part examination	○	○	○	
		Fundus examination	○			

Measures			Laser class			
			4	3B	3R	2M1M
Other	Notice	Administrator name	○	○	○	
		Danger notice	○	○	○	○
		Display of installation	○	○		
	High voltage display		○	○	○	○
	Prohibition of bringing in dangerous goods	In the controlled area	○			
		Near the laser optical path	○	○		
	Toxic gas, dust, etc.		○	○		
	Doctor's diagnosis of suspected laser beam damage		○	○	○	○

4 DANGER & WARNING & CAUTION LABEL

(1) Laser warning label

Fig. 4 (a) Laser warning label

Description

This product emits a laser, take appropriate safety measures.

(2) Laser class label

Fig. 4 (b) Laser class label

Description

The laser class of this product is specified.

(3) Laser emission port label

Fig. 4 (c) Laser emission port label

Description

The laser is emitted from the part indicated by the arrow.

PREFACE

This manual explains the operation procedures for the mechanical units of the following robots:

Model name	Mechanical unit specification No.
FUJI-CAM 2.0 3B	A05B-1291-H808
FUJI-CAM 2.0 2M	A05B-1291-H809
FUJI-CAM/SHR 3B	A05B-1291-H804
FUJI-CAM/SHR 2M	A05B-1291-H805

RELATED MANUALS

For the FANUC Robot series, the following manuals are available:

SAFETY HANDBOOK **B-80687EN** All persons who use the FANUC Robot and system designer must read and understand thoroughly this handbook		Intended readers: Operator, system designer Topics: Safety items for robot system design, operation, maintenance
R-30*i*B Plus/ R-30*i*B Mate Plus controller	OPERATOR'S MANUAL (Basic Operation) **B-83284EN** OPERATOR'S MANUAL (Alarm Code List) **B-83284EN-1** OPERATOR'S MANUAL (Optional Function) **B-83284EN-2** ARC WELDING FUNCTION OPERATOR'S MANUAL **B-83284EN-3** Spot WELDING FUNCTION OPERATOR'S MANUAL **B-83284EN-4** DISPENSE FUNCTION OPERATOR'S MANUAL **B-83284EN-5**	Intended readers: Operator, programmer, maintenance technician, system designer Topics: Robot functions, operations, programming, setup, interfaces, alarms Use: Robot operation, teaching, system design
	MAINTENANCE MANUAL **R-30*i*B Plus :** **B-83195EN** **R-30*i*B Mate Plus:** **B-83525EN**	Intended readers: Maintenance technician, system designer Topics: Installation, start-up, connection, maintenance Use: Installation, start-up, connection, maintenance
FANUC Robot ARC Mate 100*i*D M-10*i*D Mechanical unit	Operator's manual **B-83944EN**	Intended readers: System designer, Maintenance technician Topics: Installation, connection to the controller, maintenance Use: Installation, start-up, connection, maintenance

This manual uses following terms.

Name	Terms in this manual
Connection cable between robot and controller	Robot connection cable
Robot mechanical unit	Mechanical unit

TABLE OF CONTENTS

1 TRANSPORTATION AND INSTALLATION

The servo-robot sensor is shipped with robots. For transportation and installation of the robot, refer to the Mechanical unit operator’s manual of each model.

2 BASIC CONSTITUTION

The servo-robot sensor is consisted with the torch and the bracket.

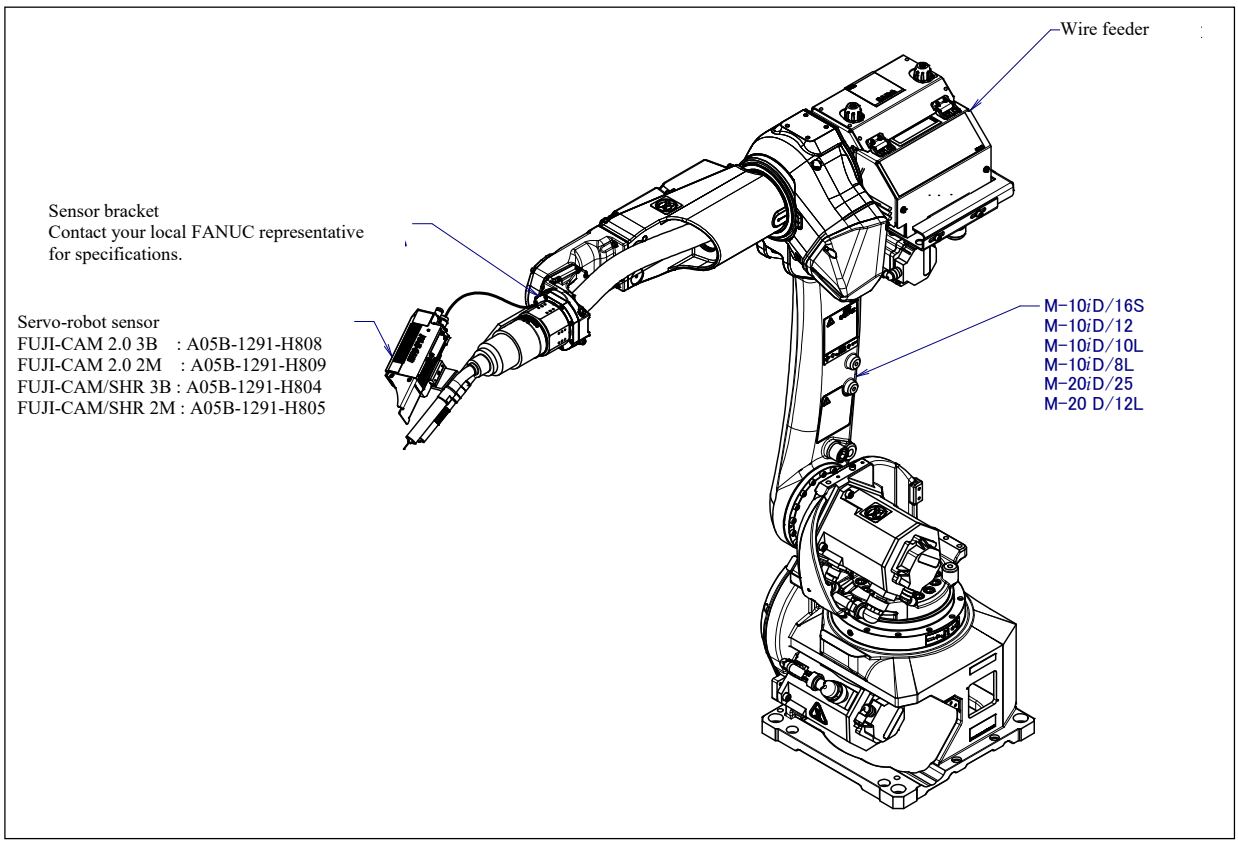


Fig. 2 (a) Basic constitution

3 SPECIFICATIONS

The following shows the servo-robot sensor specifications.

Table 3 (a) Servo robot sensor specification

Model	FUJI-CAM 2.0	FUJI-CAM/SHR
Light Source	3B or 2M	3B or 2M
Dimensions(mm)	69 x 181 x 41	60 x 169 x 39
Weight (g)	500	450
Communication interface	Ethernet	Ethernet
Power input	24 VDC	24 VDC
Operation temperature	5 to 40℃	5 to 40℃

The following items are attached to the servo-robot sensor.

Table 3 (b) Servo-robot sensor attached (FUJI-CAM 2.0)

Items	Parts name
1	Insulation bracket for sensor
2	Sensor to Robot controller connection cable (10m)
3	FUJI CAM 2.0 protection flap
4	FRUIT (Human machine interface) software license
5	TECH PACK –Joint processing software license for GENERAL INDUSTRY
6	Calibration target and calibration software for FANUC Robot

Table 3 (c) Servo-robot sensor attached (FUJI-CAM/SHR)

Items	Parts name
1	Insulation bracket for sensor
2	Sensor to NANO-BOX connection cable (2m)
3	NANO-BOX control unit
4	NANO-BOX to robot controller connection cable (10m)
5	FRUIT (Human machine interface) software license
6	TECH PACK –Joint processing software license for GENERAL INDUSTRY
7	Calibration target and calibration software for FANUC Robot

4 DIMENSION AND VIEW AREA

The following show the servo-robot sensor dimensions and view area.

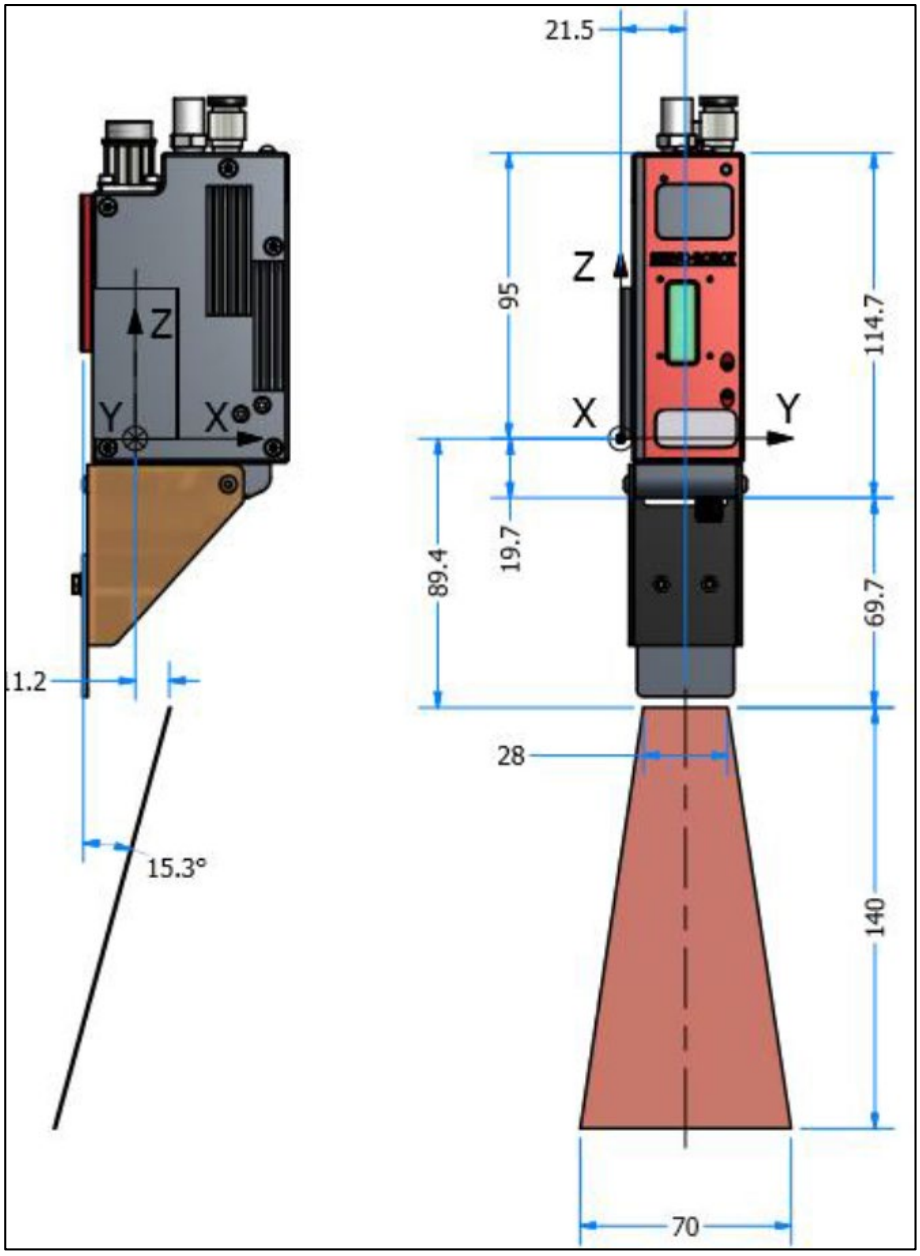


Fig. 4 (a) Dimensions and view area (FUJI-CAM 2.0)

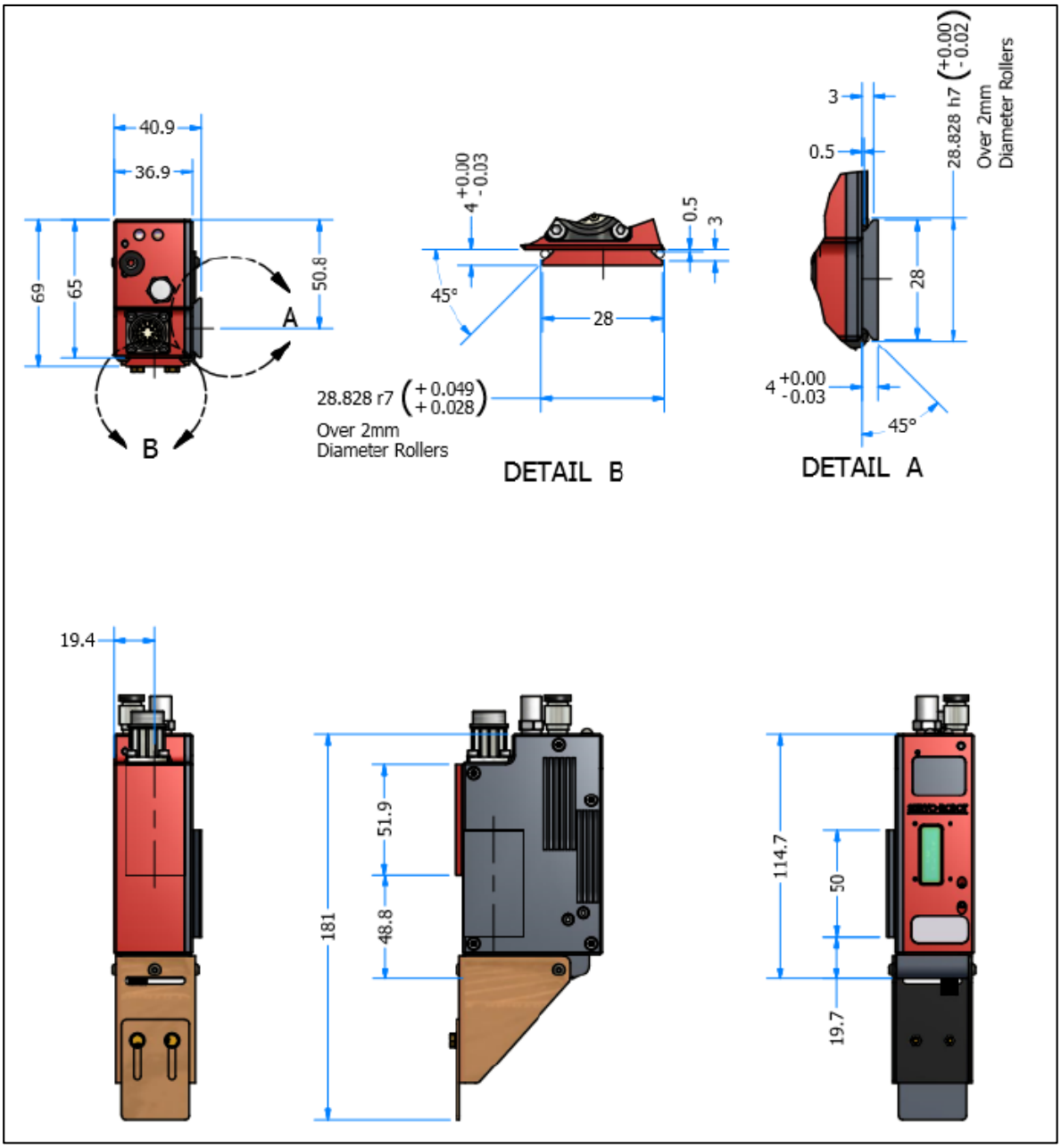


Fig. 4 (b) Detailed dimensions (FUJI-CAM 2.0)

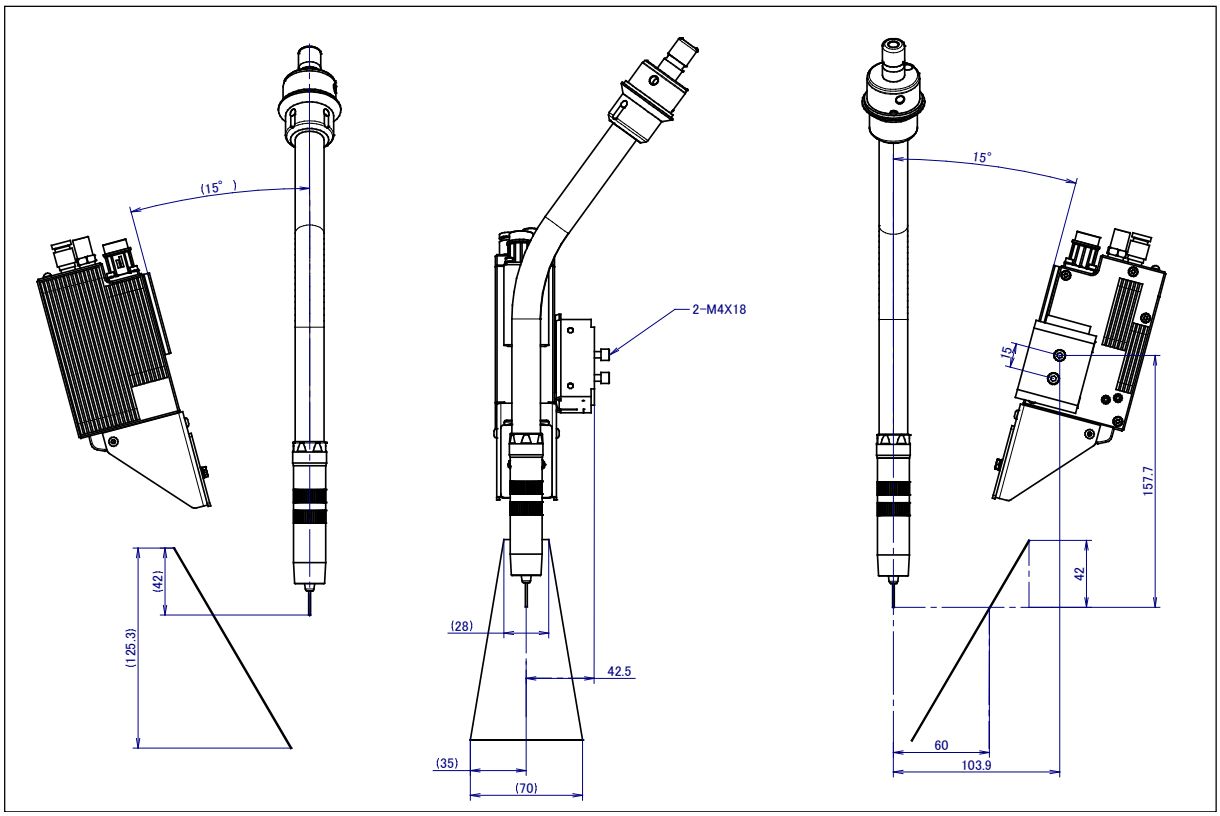


Fig. 4 (c) Recommended installing dimension (FUJI-CAM 2.0)

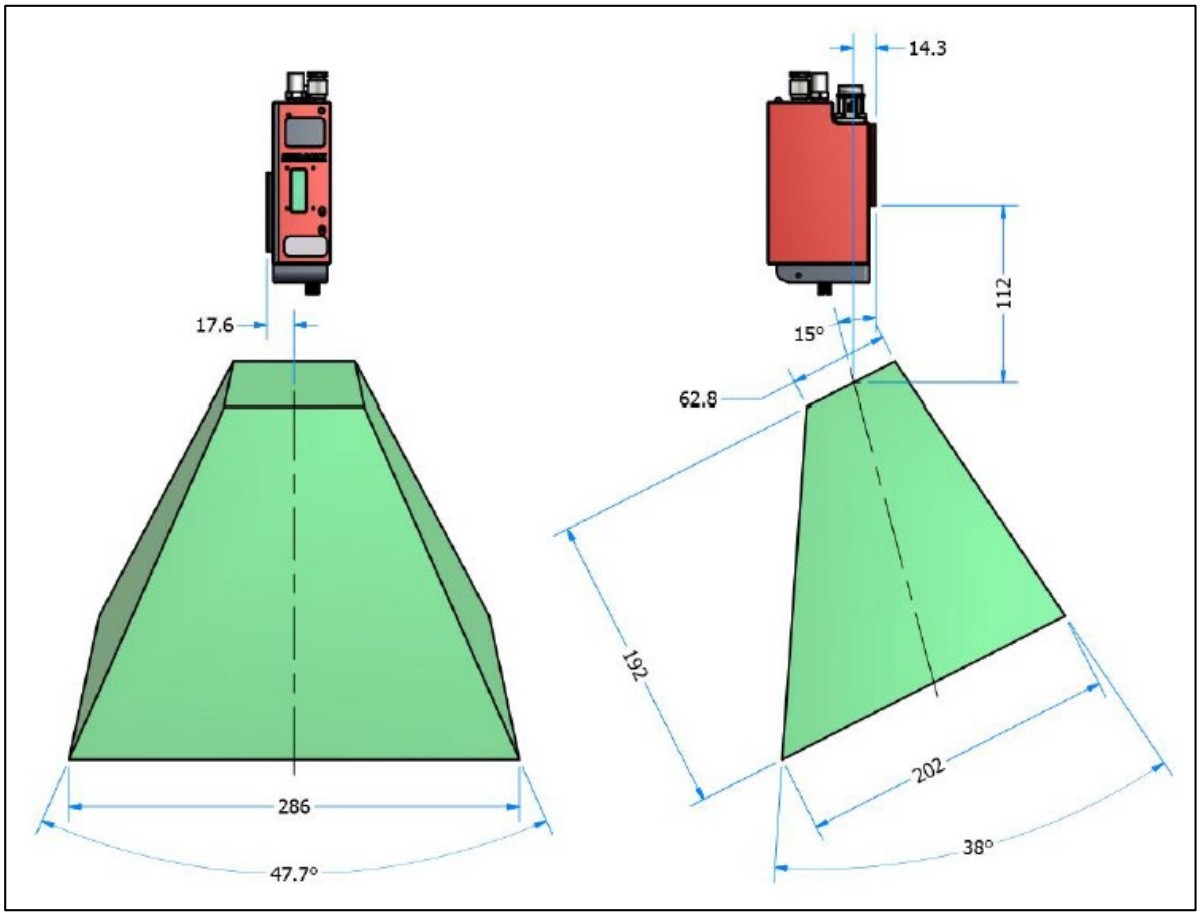


Fig. 4 (d) View area (FUJI-CAM 2.0 video output)

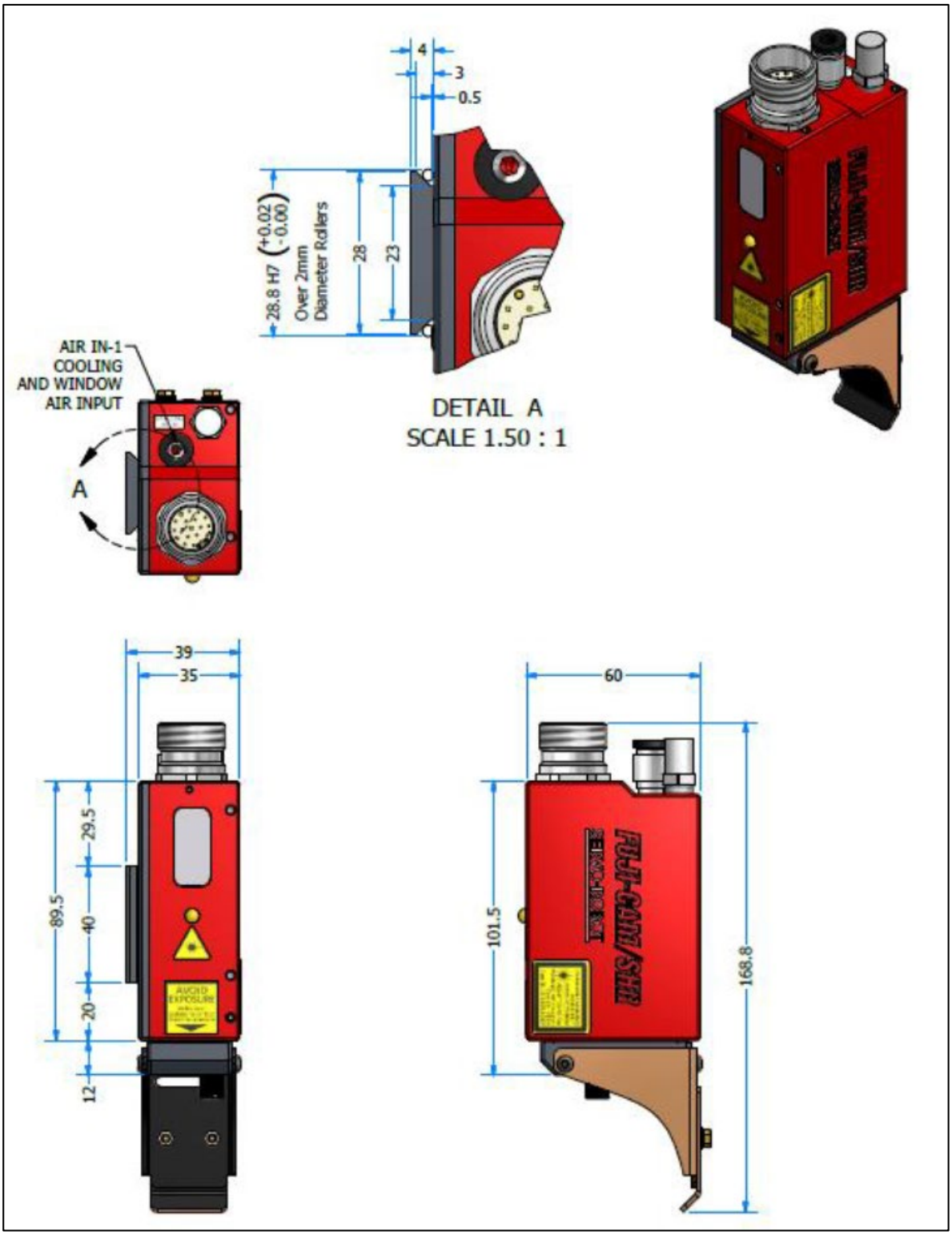


Fig. 4 (e) Detailed dimensions (FUJI-CAM/SHR)

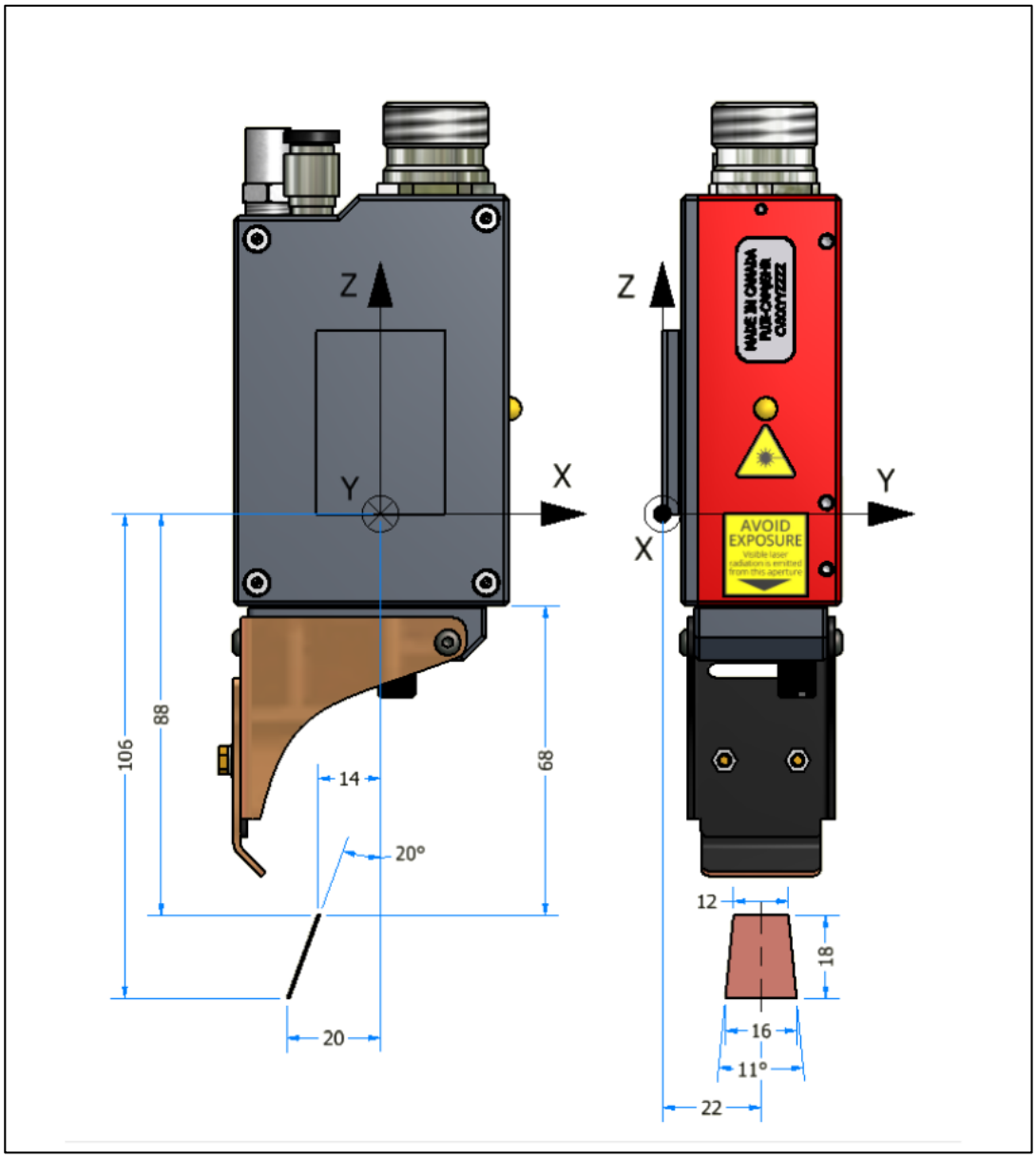


Fig. 4 (f) View area (FUJI-CAM/SHR)

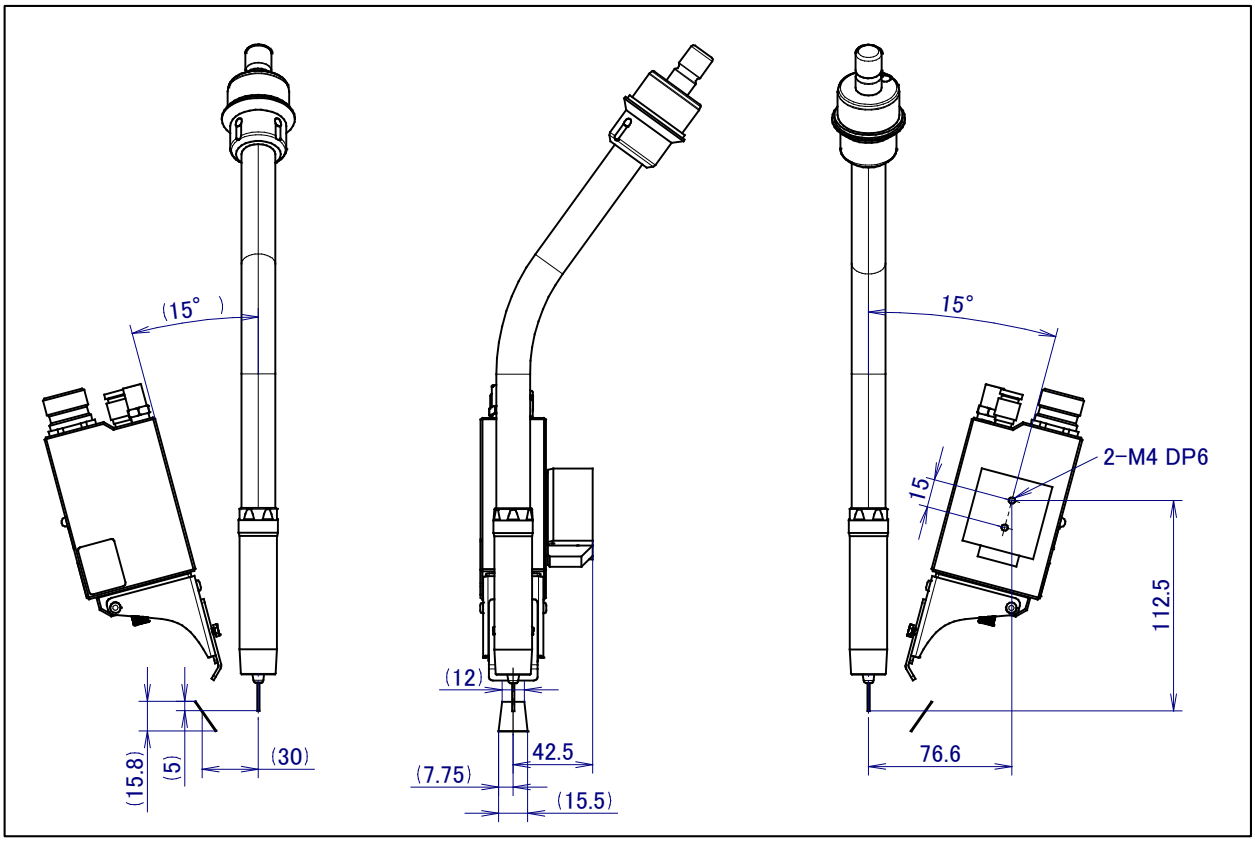


Fig. 4 (g) Recommended installing dimension (FUJI-CAM/SHR)

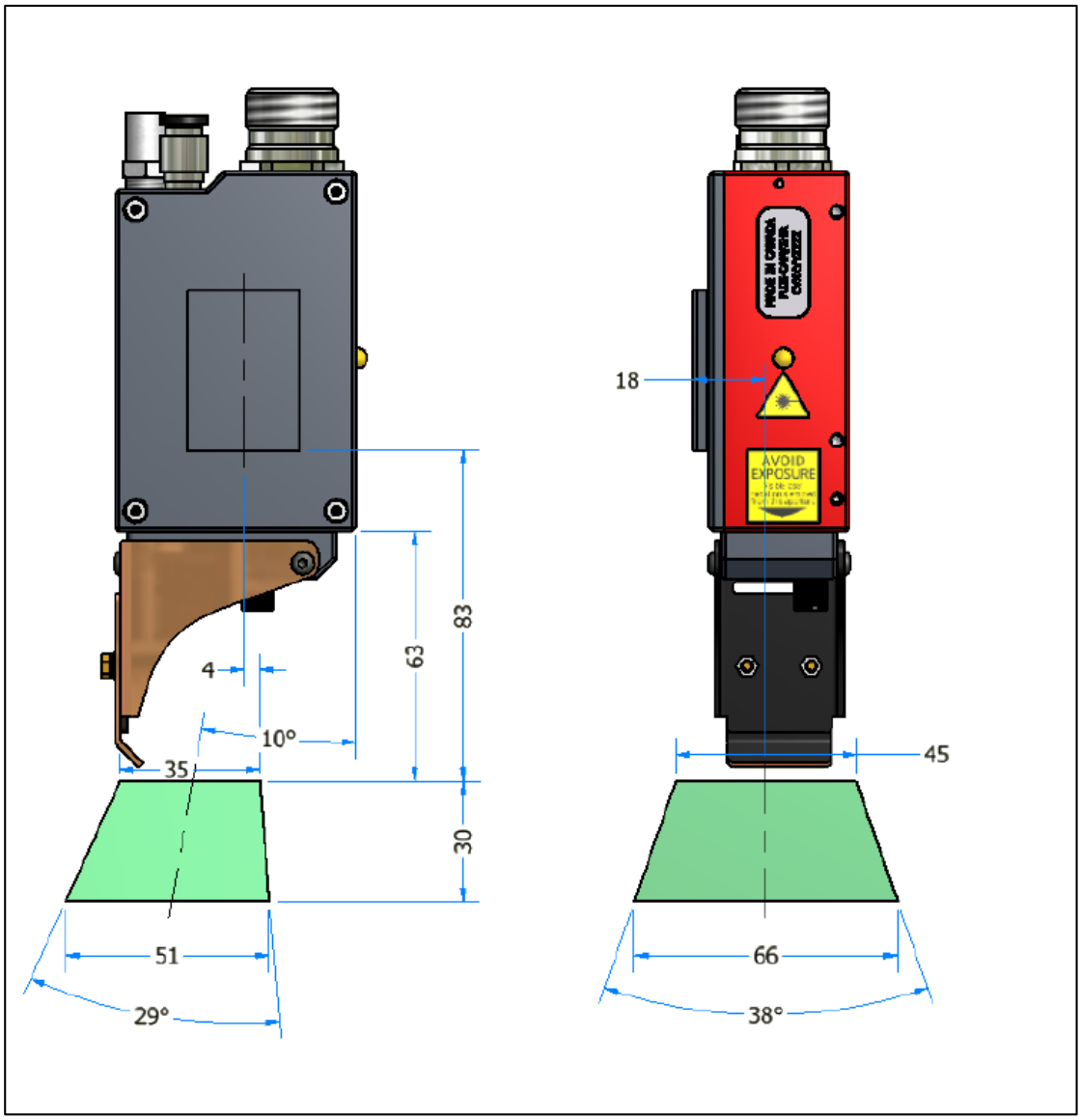


Fig. 4 (h) View area (FUJI-CAM/SHR video output)

5 TCP AND PAYLOAD SETTING

The following show TCP setting parameter and parameter for payload setting of the servo-robot sensor.

Table 5 (a) TCP setting parameter (Fronius torch)

X	-84.8	[mm]
Y	0	[mm]
Z	476.3	[mm]
W	180	[deg]
P	-36	[deg]
R	0	[deg]

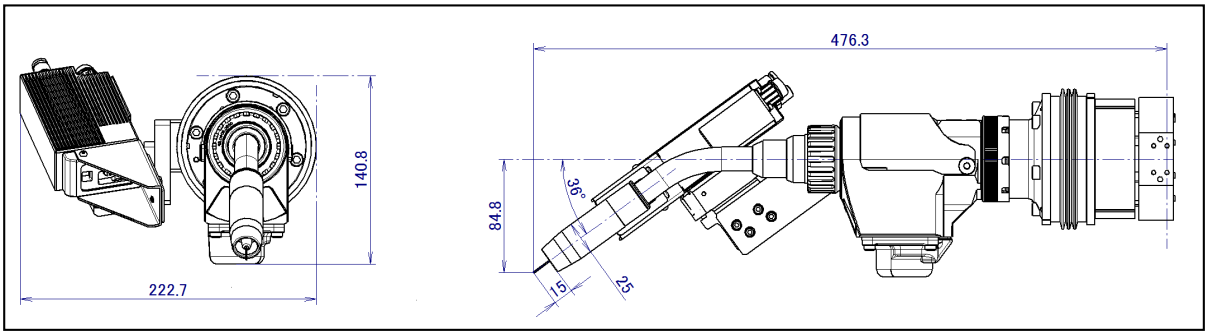


Fig. 5 (b) Fronius torch

Table 5 (b) Parameter for payload setting (Fronius torch)

Payload	6.4	[kg]
X	-0.5	[cm]
Y	2.1	[cm]
Z	16.4	[cm]
Ix	1.2	[kgf·cm·s^2]
Iy	1.1	[kgf·cm·s^2]
Iz	0.2	[kgf·cm·s^2]

6 TROUBLESHOOTING

Table 6 (a) indicates troubleshooting for the servo-robot sensor. If the cause of a failure cannot be identified or action to be taken cannot be determined, contact your local FANUC representative.

Table 6 (a) Troubleshooting

Status	Issue	Cause/Action
The status LED stays off after The +24VDC power is applied to the camera.	The FUJI-CAM sensor is not properly powered.	☆ Check if the power source that powers the camera is ON. ☆ Check that the camera cable connector is properly secured on both ends. ☆ Check if the power supply is properly wired. ☆ Check if the power supply has the correct output (12-28VDC @ 1A) Note: If Servo-Robot's Interconnection kit is used, the power supply input is protected with an over-voltage and over-current protection device (PTC self-settable fuse). If overvoltage or overcurrent situation occurred, it may take a few minutes for the device to rest itself.
The status LED is YELLOW	Warning status	☆ See details about the warning cause using the WeldCom or FRUIT user interface program.
The status LED is RED	Error status	☆ See details about the error cause using the WeldCom or FRUIT user interface program.
The multicolor LED is still WHITE (Red+Green+Blue) More than 2 minutes after power-up.	The internal CPU is not Booting properly.	☆ Contact your local FANUC's representative.
The LASER ON LED does not turn on after activating the laser.	LASER_ENABLE Input not activated.	☆ Make sure that all interlocks connected to the LASER_ENABLE input are closed. ☆ Make sure there are no alarms (Status LED Green) ☆ Make sure the LASER_ENABLE input is properly wired.

7 CHECKS AND MAINTENANCE

This chapter describes every day check, periodic check method and maintenance.

* For the checks and maintenance of the robot mechanical unit, refer to the followings.
"ARC Mate 100*i*D/M-10*i*D mechanical unit operator's manual (B-83944EN)"
"ARC Mate 120*i*D, M-20*i*D mechanical unit operator's manual (B-84074EN)"
* For the robot controller, refer to the followings.
"R-30*i*B/R-30*i*B Plus Controller maintenance manual (B-83195EN)"
"R-30*i*B Mate/R-30*i*B Mate Plus Controller maintenance manual (B-83525EN)"

7.1 EVERY DAY CHECKS

> ⚠ **WARNING**
> Before inspection, adjustment, and replacement, be sure to turn off the switch of the switch box and confirm safety at all times except when an inspection is required while the power is on.
> Otherwise, a serious accident resulting in an electrical shock or burn can occur.

Perform the following items once in every day.

Items	Check items	Check points
1	Protection lens	Check the laser camera protection lens. If necessary, clean it with cotton swabs and Isopropyl alcohol. If damage is too serious, replace it by new one.
2	Laser camera nozzle	Clean the nozzle to prevent too much accumulation of the spatters.

When replacing the protection lens, remove the bolts which fix the lens on the camera.

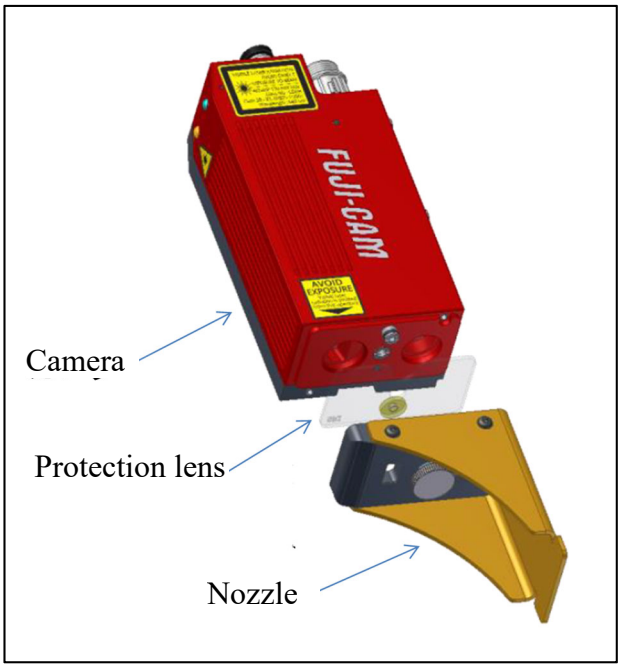


Fig. 7.1 (a) Replacing the protection lens

7.2 TWICE IN ONE WEEK CHECK

Perform the following items twice in one week.

Items	Check items	Check points
1	Air filtering system	Check if the air flow is as per recommendation Recommended air flow rate is as the following. FUJI-CAM: 47 l/min (at 207 kPa) FUJI-CAM/HS, SHR : 47 l/min (at 140 kPa) Recommended air filter spec. : A97L-0318-0664
2		Check if the air filter is blocked or dirty.
3	Cable forming	Check the cable is correctly fixed.
		Check the damage of the cable.
4	Laser camera	Check the fixed lens. Clean it if necessary.
5	Attaching the camera	Clean the camera holder with a brush to make sure there is no electrical contact between the torch and the laser-camera.
6	Calibration for the camera and the tool	Should be checked every week and every time there is a collision between the torch and the part or the laser-camera and the part.

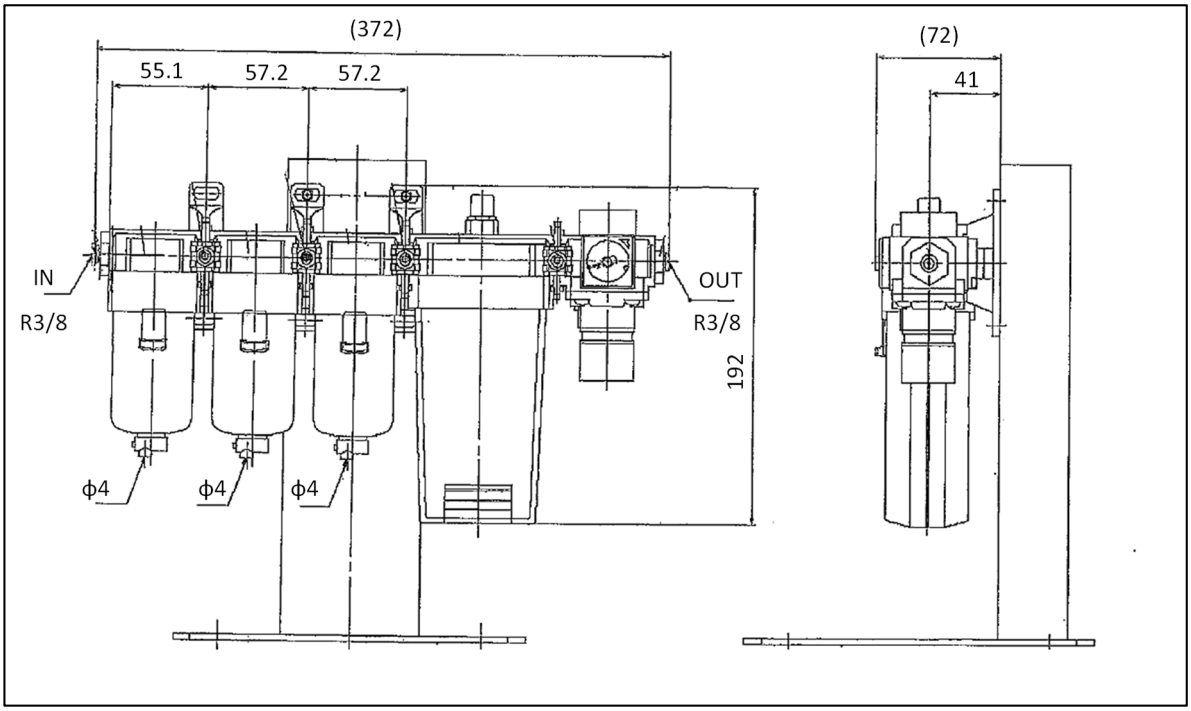


Fig. 7.2 (a) External dimensions of the air filter (A97L-0318-0664)

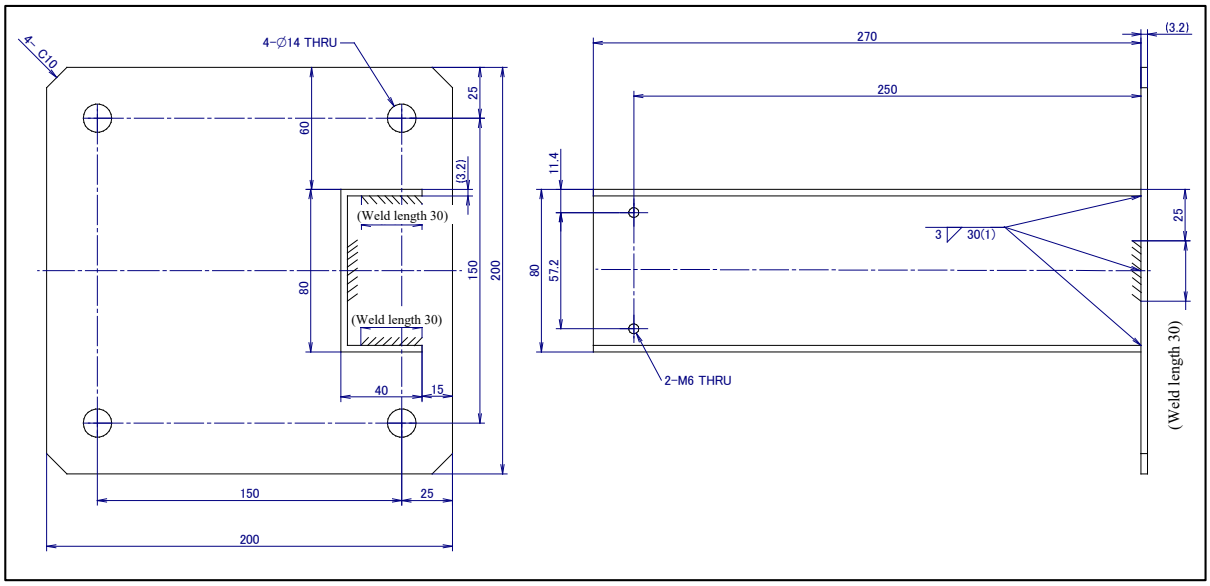


Fig. 7.2 (b) External dimension of the stand for air filter (A97L-0318-0664)

7.3 1-month (320 hours) check

Perform the following checks and maintenance at the intervals based on every 1 month or 320 hours, whichever comes first.

Items	Check items	Check points
1	Ground fault detector	Perform the test of the ground fault detector.
2	Purge air supply system	Check the air purge supply system operation.
3	Air leak	Check leak of the all connectors and tubes.

7.4 3-months (960 hours) check

Perform the following checks and maintenance at the intervals based on every 3 months or 960 hours, whichever comes first.

Items	Check items	Check points
1	Confirm the bracket mounting bolts	Retighten the bracket mounting bolts.

8 WELDING LINE SENSOR CONTROL FUNCTION

8.1 OVERVIEW

FUJI-CAM (Laser tracking sensor) is controlled by the welding line sensor control function. The welding line sensor control function corrects a welding route according to the changes in a welding line shape during welding process. While welding being performed based on the information obtained from the sensor, the welding route is adjusted to ensure a good welding quality.
When using this function, the following option is required.

- R900 : SERVO-ROBOT PKG
- J568 : DCS Safe I/O connect function
- R632 : KAREL function (This is necessary when R650 (North America Setting) is ordered)

> ⚠ **CAUTION**
> This function depends on the welding condition and welding line shape. Therefore, it is recommended to examine the functionality of this function for each condition of use.

> **NOTE**
> Since a sensor configuration depends on welding conditions and joint, we recommend to setup sensor configuration for each weld environments. A seam tracking system requires the following hardware/software.

Perform the following operations to use the welding line detection function.

- Set a sensor frame using Auto calibration, the 10-point teaching or the Direct entry method.
- Create a TP program that includes instructions of the welding line detection function.

Fig. 8.1 (a) shows the outline of the welding line detection system.

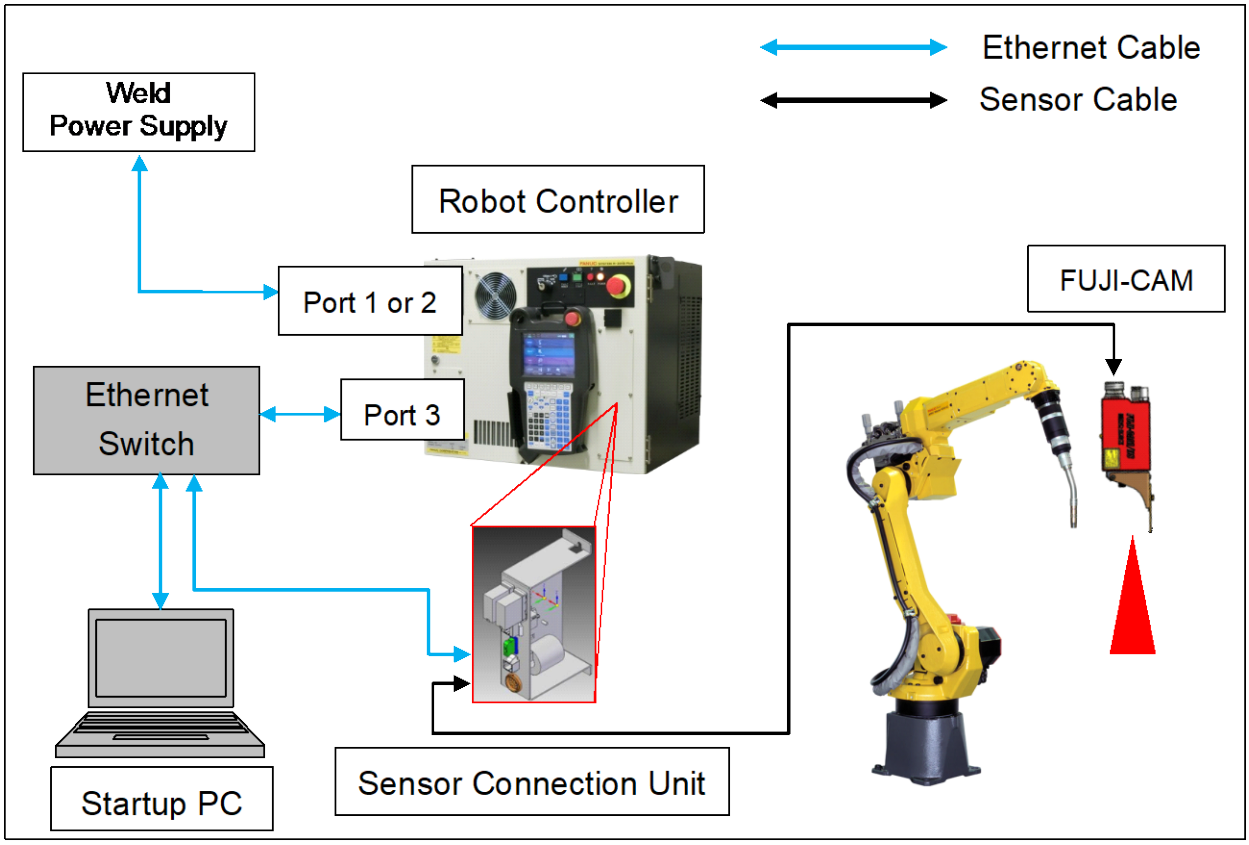


Fig. 8.1 (a) Outline of the welding line detection system

8.2 STARTUP OF THE LASER TRACKING SENSOR

Mount the laser tracking sensor on the robot, and then make the following settings.

- Configure the sensor.
- Connect the sensor controller to the PC, and install the startup software. Configure the welding line library. Configure the sensor referring to the operation manual of the laser tracking sensor.

> ⚠ **CAUTION**
> The welding line detection function supports only the welding line type that the laser tracking sensor can detect. To use the welding line detection function efficiently, it is required to check the definition and measurement method of the welding line type. And it is required to set the parameters of the welding line type of the laser tracking sensor.

8.2.1 Connecting with the FUJI-CAM Sensor

Connect the robot controller and the laser tracking sensor in the following settings.

- Ethernet connection
- Safe I/O connect

8.2.1.1 Ethernet connection

Connect between the LAN port of the Sensor Connection Unit and the LAN port (port-3) of the robot controller using the LAN cable. The factory connection within the cabinet is shown in the figure 8.2.1.1 (a), (b).

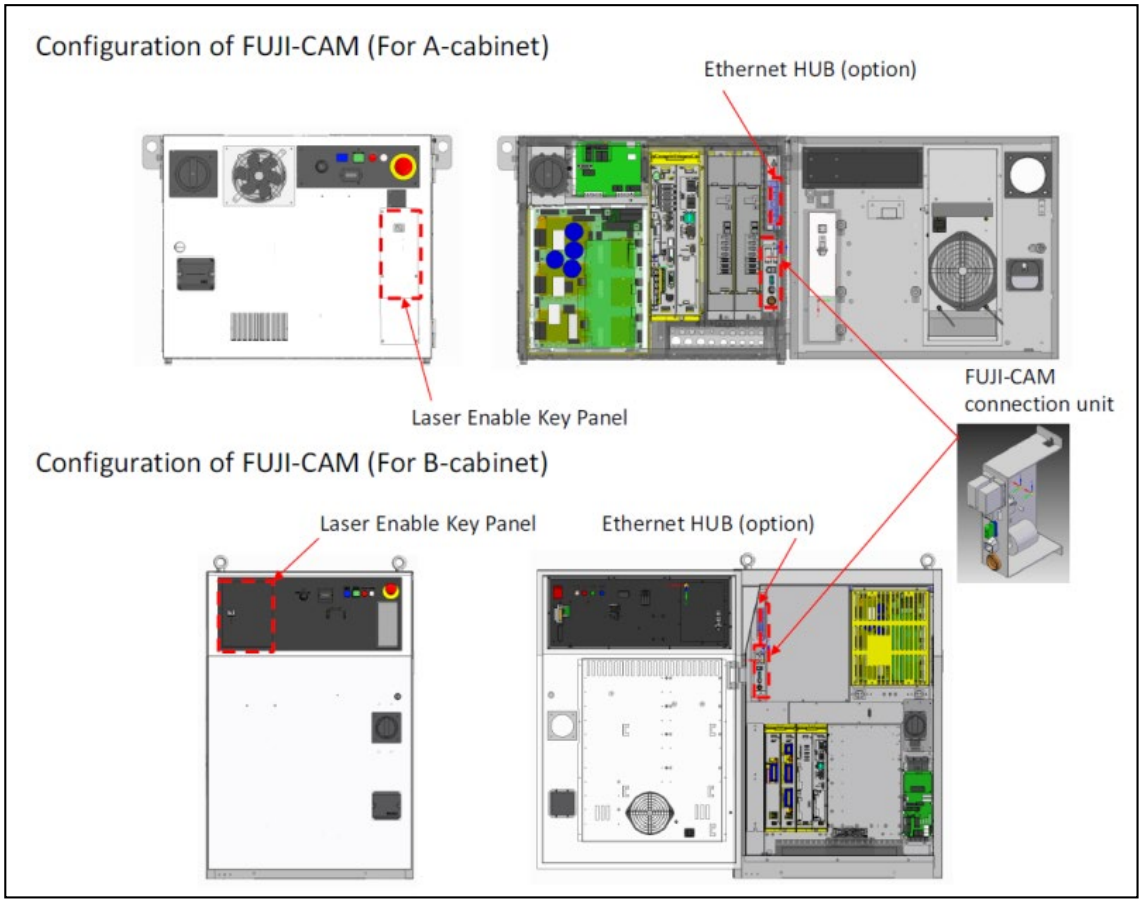


Fig. 8.2.1.1 (a) Connection diagram of the A/B-cabinet FUJI-CAM sensor

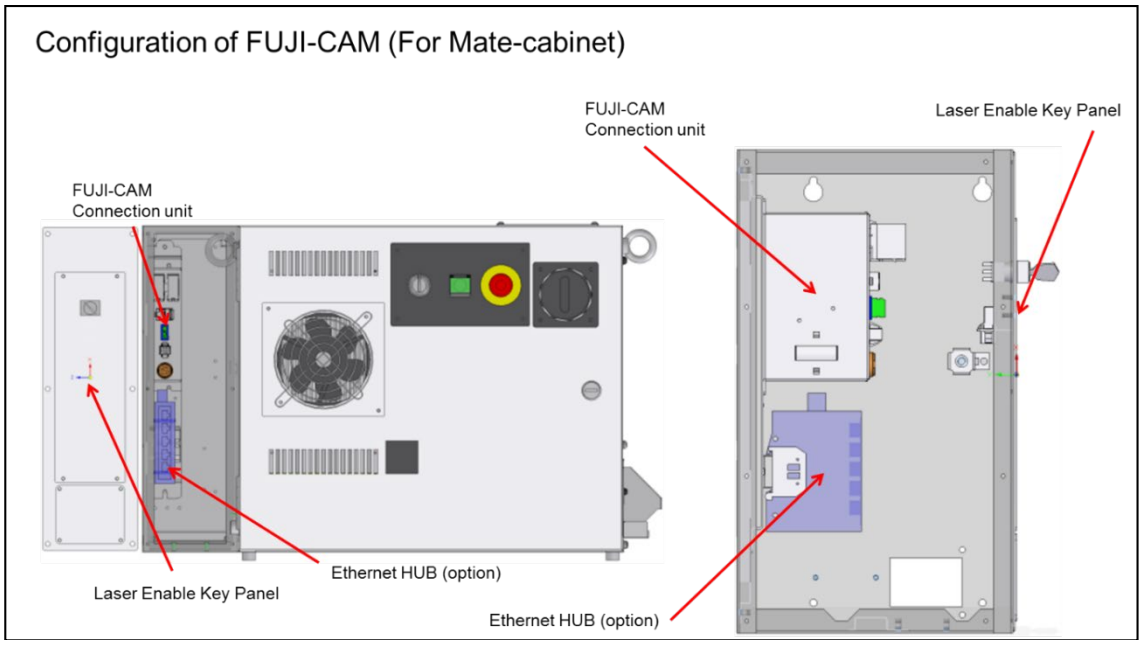


Fig. 8.2.1.1 (b) Connection diagram of the Mate-cabinet

8.2.1.2 Safe I/O connect

It is necessary to connect the laser enable/disable key on the operator panel to the safety I/O and set the DCS safety I/O connection so that the laser will be emergency stopped (laser off) at the same time as the emergency stop. Connect the cabinet as shown in 8.2.1.2 (a), 8.2.1.2 (b), 8.2.1.2 (c) because the connection method is different depending on the type of cabinet of the robot controller.

- The emergency stop is released.
- The laser enable key is enabled.

The standard safe I/O connect within the cabinet is shown in the Fig. 8.2.1.2 (a), (b), (c).

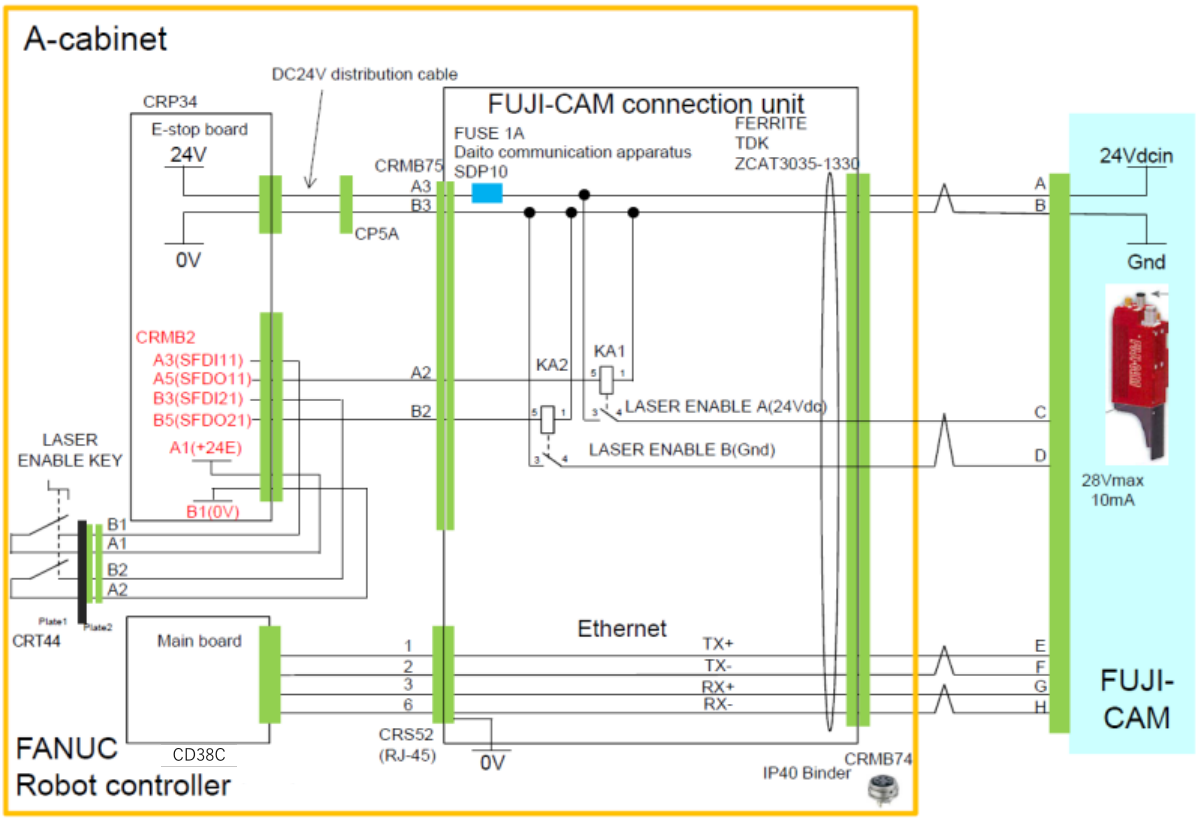


Fig. 8.2.1.2 (a) Safe I/O connection diagram within the A-cabinet

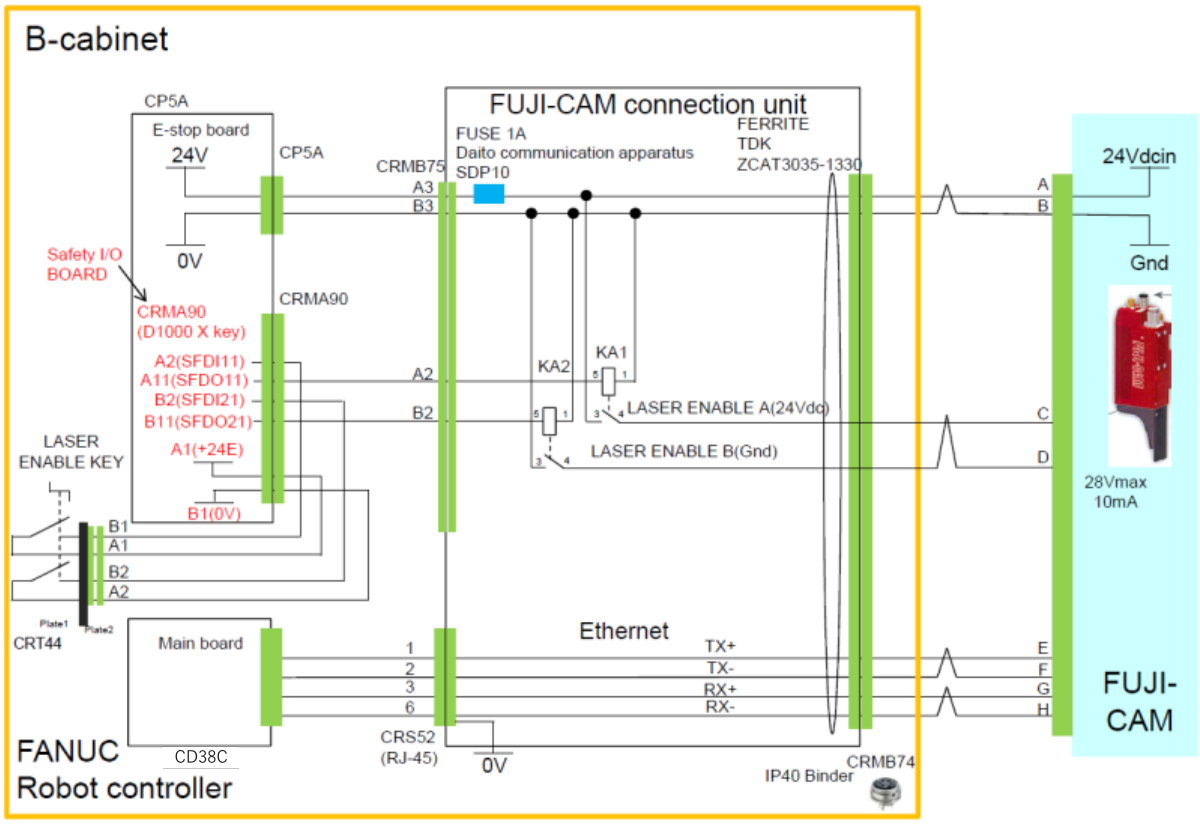


Fig. 8.2.1.2 (b) Safe I/O connection diagram within the B-cabinet

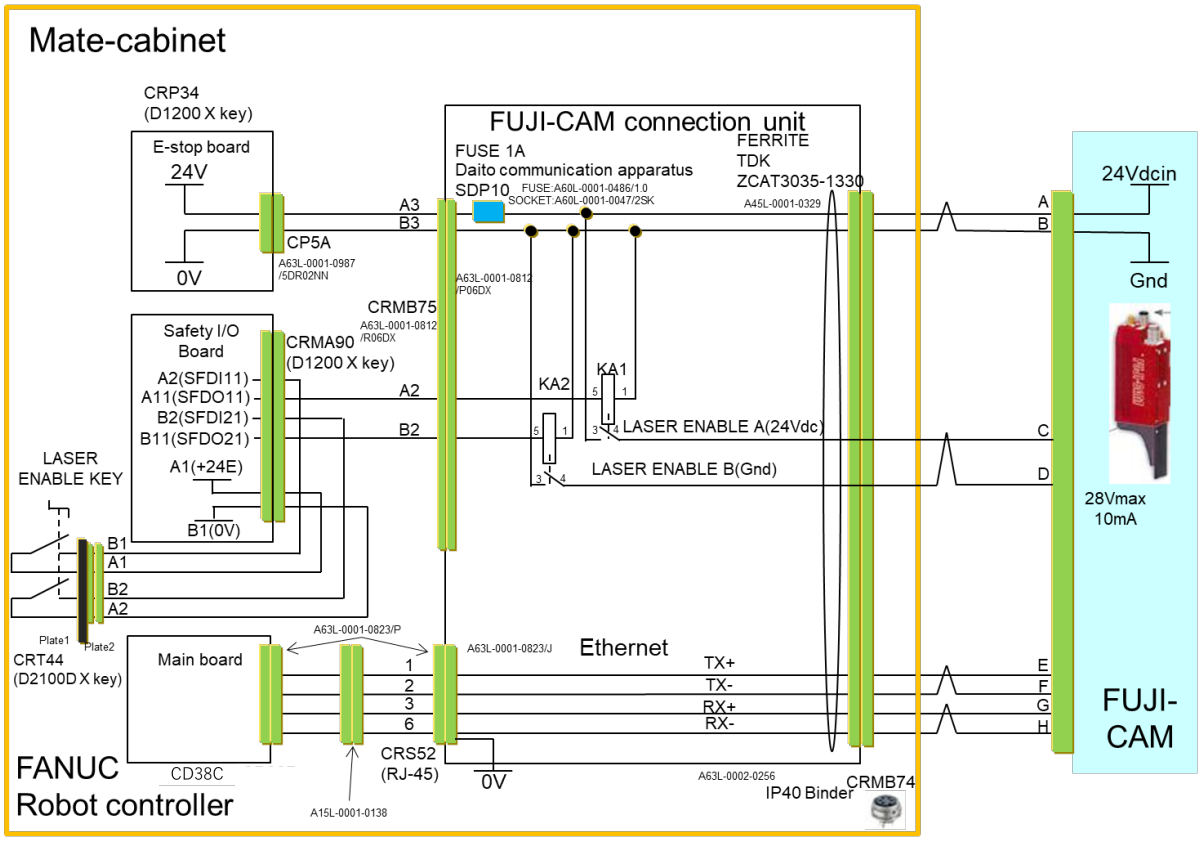


Fig. 8.2.1.2 (c) Safe I/O connection diagram within the Mate-cabinet

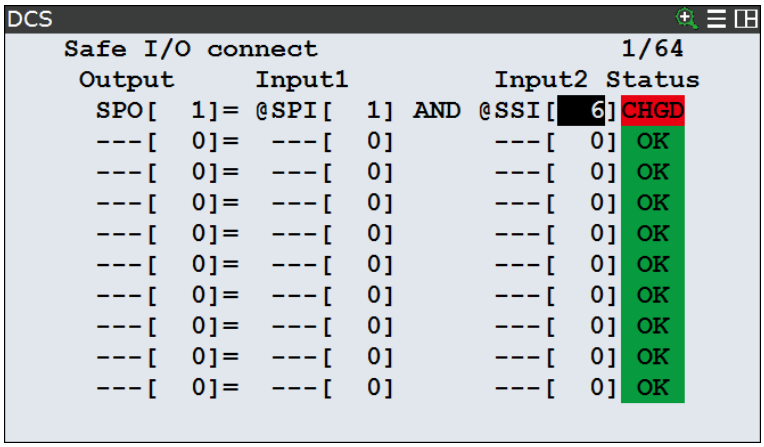
Procedure 8-2 How to set DCS Safe I/O connect

Step

1 Press the [MENU] key, and select [SYSTEM].
2 Press F1 [TYPE], and select DCS. The following screen will displayed.
3 Select Safe I/O connect, and select F3 [DETAIL].
4 Make the setting as shown below.

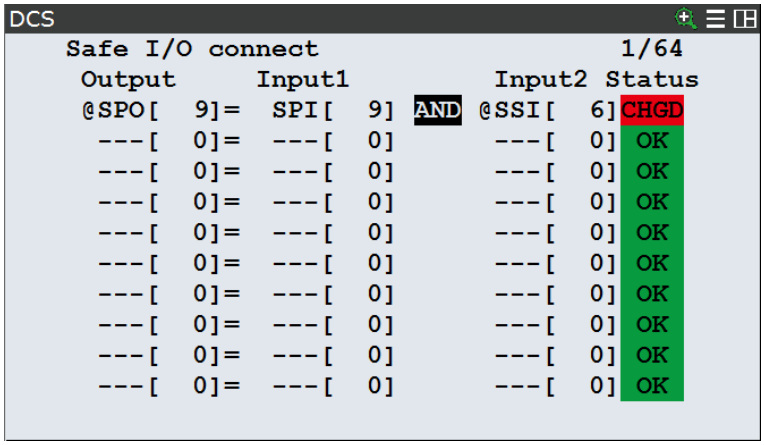
[When using safety signals on the emergency stop board in the A-cabinet or the safe I/O boar in the B-cabinet]

SPO[1] = SPI[1] AND SSI[6]

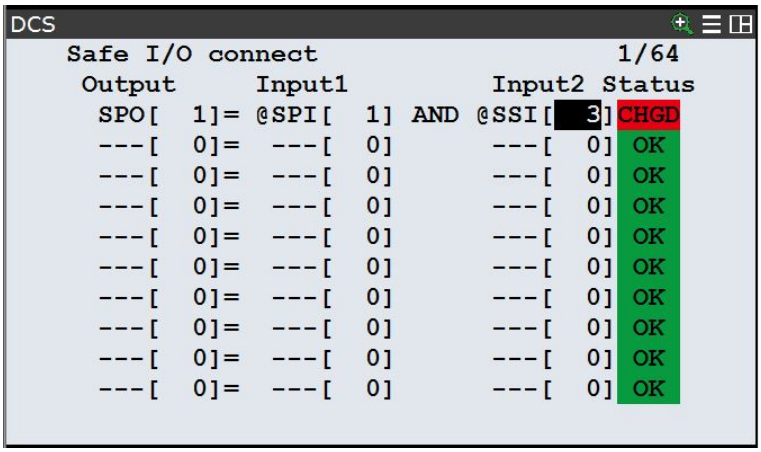


[When using safety signals on the expansion safe I/O board in the A-cabinets]

SPO[9] = SPI[9] AND SSI[6]



[When using safety signals on the safe I/O boar in the Mate-cabinet]
SPO[1] = SPI[1] AND SSI[3]



5 Return to the DCS setting screen, press the F2 [APPLY] key, and enter the PIN code.
6 Press F4 [OK] on the confirmation screen.
7 Turn the power OFF/ON.

8.3 SENSOR CONFIGURATION

8.3.1 Overview

This section describes the following.

- Sensor setting (Subsection 8.3.2)
- Sensor frame setting (Subsection 8.3.3)
- Sensor schedule setting (Subsection 8.3.4)

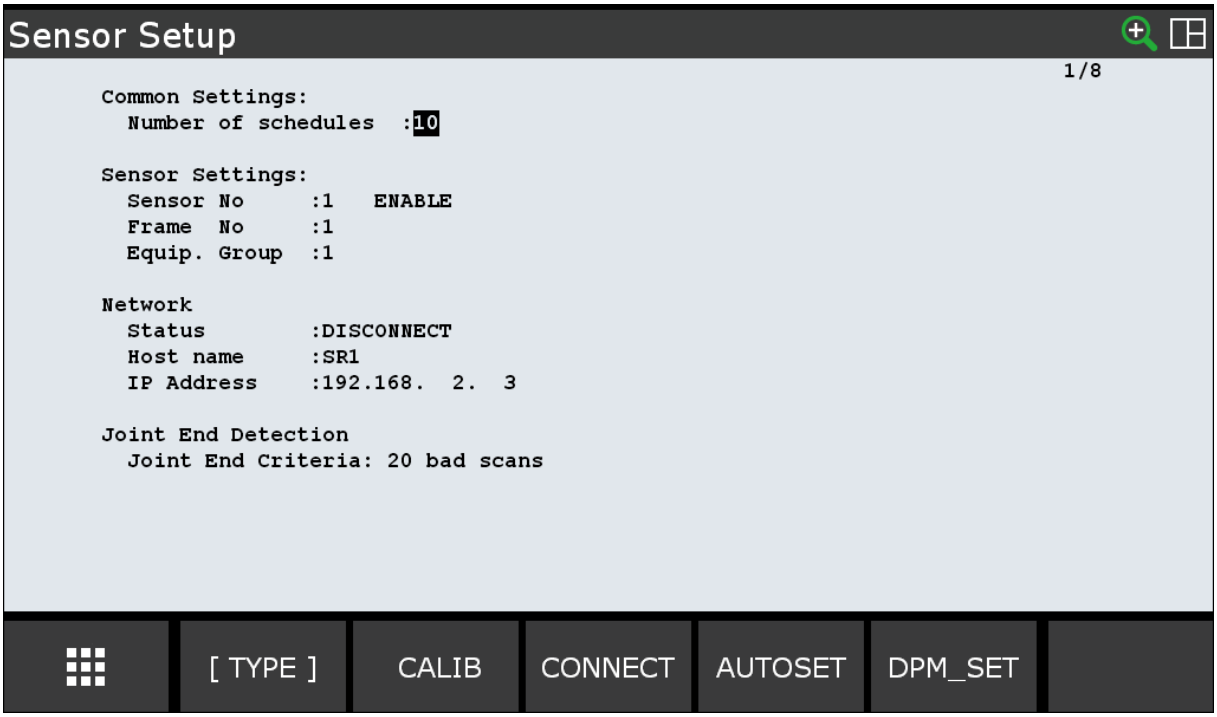
Before setting the sensor frame, the tool frame needs to be set correctly. If the tool frame has not yet been obtained, set the tool frame referring to the Controller Operator's Manual (Basic Function) (B-83284EN) Section 3.9. Referring to the Subsection 8.3.3, set the sensor frame. If the sensor frame has already been obtained, set it using the direct entry method introduced in the Subsection 8.3.3.3

8.3.2 Sensor setting

Procedure 8-3 Show sensor setting screen

Step

1 Press the [MENU] key, and select [SETUP]
2 Press F1[TYPE] and select Sensor Setup then the following screen will be displayed.



3 Enter sensor number you would like to setup “Sensor No”.

8.3.2.1 Sensor setting items

Table 8.3.2.1 (a) Sensor setting screen items

Item	Description
Sensor Schedule	Settings for the system
Number of schedule	The number of sensor schedule per a sensor. 99 schedules is maximum. If the number is changed, the number of tracking schedule is also changed. The number of sensor schedule is same among sensors.
Sensor Settings	Settings for a sensor.
Sensor No	Select the sensor and enable/disable of the sensor.
Frame No	Sensor frame number used for tracking or calibration. There are 4 sensor frames per a sensor.
Equip. group	The robot group number equipped current selected sensor.
Network	Network settings for a sensor.
Status	Connection status between robot controller and sensor.
Host name	Sensor name SR<digit> is used normally.
IP Address	IP address of sensor.
Joint end detection	Settings for joint end detection per a sensor.
Joint End Criteria	The condition that joint end detection treats the end of workpieces. When welded distance is longer than specified distance or sensor detect position has passed the destination, if the counts of continuous misdetection is larger than this value, joint end detection treats it as the end of workpieces.

⚠ CAUTION
- If sensor enable/disable has been changed, please perform COLD start.
- If sensor schedule number has been changed, please perform CONTROLLED start

8.3.2.2 Network setting

Automatic network setting function has been supported.

Procedure 8-4 Automatic setting for controller network

Condition

- IP address of sensor has setup.
- Sensor has connected through port-3.

Step

1 Show sensor setup screen.
2 Enter the every items at Network section in sensor setup screen.
3 Press F4 “AUTOSET”
4 Re-power the robot and sensor controller.

NOTE
Network settings of port-3 become as below. If IP address is duplicated or subnet mask is not correct, please change them manually.

IP address：
x.x.x.1 (x.x.x is same as IP address of sensor)

Subnet mask:
255.255.255.0

8.3.2.3 Automatic settings for tracking condition

Procedure 8-5 Automatic settings for tracking condition

Condition

- Sensor has equipped at the selected robot.

Step

1 Show sensor setup screen.
2 Enter the every items in Sensor Settings.
3 Press F5 “DPM_SET” then the tracking schedule corresponding to the robot group becomes suitable for sensor tracking.

NOTE
- After automatic settings for tracking condition, you cannot the group other tracking inputs (GI, AI etc.)
- At tracking process, the sensor schedule number is always same as tracking schedule number.

8.3.3 Sensor frame setting

There are three types of sensor frame setting: Auto calibration, 10-point teaching, and Direct entry. Table 8.3.3 (a) shows each setting method.

Table 8.3.3 (a) Sensor frame setting types

Setting types	Description
Auto calibration	This is a method to automatically set the sensor frame by creating a TP program. Basically, set the sensor frame by Auto calibration.
10-point teaching	This is the method to set the sensor frame using the superimposed workpiece. If Auto calibration cannot be used, set the sensor frame using the 10-point teaching method.
Direct entry	It is a method to directly input the values of the sensor frame. If the value of the sensor frame is already known, set the sensor frame using the Direct entry method.

8.3.3.1 Auto calibration

This function automatically calculates the sensor frame when the calibration program is executed with the robot set at the reference position by using the calibration plate dedicated to the FUJI-CAM sensor and the KAREL program. Auto calibration requires the sensor to be connected to port-2. And the following preparations are required beforehand.

- Load the KAREL program provided by Servo-Robot Inc.
- Mount the FUJI-CAM sensor.
- Mount the calibration plate manufactured by Servo-Robot Inc. and set the user frame.
- Set the client tag for the socket message.
- Set the calibration start position.

Procedure 8-7 Loading the KAREL program

Condition

- The KAREL program for auto calibration provided by Servo-Robot Inc. is prepared.
  (This program is stored in the USB memory attached to the FUJI-CAM sensor as standard.)

Step

1 Press the [MENU] key, and select [SYSTEM]-> [Variables].
2 Set $KAREL_ENB = 1.
3 Press the MENU key, and select [File].
4 Load the following files that are stored in the storage device beforehand.
  Please load the file whose # in the above file name matches the robot group number that uses the FUJI-CAM sensor.

  - SR#_CAL2_HR.PC
  - SR#_CAL2_STD.PC
  - SR#_CAL2_UFO.PC
  - SR#_GEN_ACK.PC
  - SR#_GEN_CFG.PC
  - SR#_GEN_CNT.PC
  - SR#_GEN_CTE.PC
  - SR#_GEN_DCN.PC
  - SR#_GEN_DISP.PC
  - SR#_GEN_MUTE.PC
  - SR#_GEN_OFF.PC
  - SR#_GEN_ON.PC

- SR#_GEN_STAT.PC
- SR#_GEN_TASK.PC
- SR#_GEN_UNMT.PC

> ⚠ **CAUTION**
> The KAREL program depends on the version of the software series of the robot controller.

Procedure 8-8 Loading the DT file

Condition

- The automatic calibration KAREL programs are already loaded in the robot controller.

Step

1 Press the [MENU] key, and select [FILE].
2 Load the following DT file that is stored in the storage device beforehand.

- ARGDISPyy2x.DT

> ⚠ **CAUTION**
> If the ARGDISPyy2x.DT that is required already exists on the robot controller, the serial number of the file (Change the "2" of the file name of ARGDISPyy2x.DT) will have to be changed to have a unique value that is not currently present on the robot controller.
> If ARGDISPKN21.DT is already loaded, change the file name to ARGDISPKN31.DT and load it.

> **NOTE**
> The name of the file varies depending on the language of the robot controller (here represented as yy) and the motion group to which the Auto calibration is used (here represented as x). Execute the file that matches the language of the robot controller used and the motion group number. The following are example files used.
>
> - The file to load for an English (EG) robot controller with vision on group 1 is: ARGDISPKN21.DT
>
> - The files to load for a Japanese Kanji (KN) robot controller with vision on groups 1 and 2 are: ARGDISPEG21.DT and ARGDISPEG22.DT

Procedure 8-9 User frame setting

Condition

- The FUJI-CAM sensor have mounted on the torch of the robot according to the recommended position in Chapter 4.
- The tool frame setting is completed.
- The calibration plate for the FUJI-CAM sensor is prepared.

Step

1 Mount the calibration plate.

Fig. 8.3.3.1 (a) Calibration plate

2 Press the [MENU] key and select "SETUP".
3 Press the F1 and select "Frames".
4 Press F3 and select "User Frame". Then the tool frame list screen will be displayed.

```
SETUP Frames
      User Frame     / Direct Entry          1/10
            X       Y  Z              Comment
       1 0.0      0.0  0.0           [             ]
       2 0.0      0.0  0.0           [             ]
       3 0.0      0.0  0.0           [             ]
       4 0.0      0.0  0.0           [             ]
       5 0.0      0.0  0.0           [             ]
       6 0.0      0.0  0.0           [             ]
       7 0.0      0.0  0.0           [             ]
       8 0.0      0.0  0.0           [             ]
       9 0.0      0.0  0.0           [             ]
      10 0.0      0.0  0.0           [             ]
     Active TOOL $MNUTOOLNUM[G:1] = 1

    | [ TYPE ] | DETAIL | [OTHER] | CLEAR | SETIND |
```

5 Move the cursor to the line of the tool frame number you want to set and press F2.
Then the tool frame setup screen of the selected frame number will be displayed.
6 Press F2 and select "Three Point" then display the following screen.

```
SETUP Frames
      User Frame          Three Point          1/4
      Frame Number:       1
        X: 0.0      Y: 0.0      Z: 0.0
        W: 0.0      P: 0.0      R: 0.0

       Comment:              UFrame1
       Orient    Origin    Point:
       UNINIT  X  Direction  Point
       : UNINIT Y Direction Point
       :  UNINIT

     Active UFRAME $MNUTOOLNUM[G:1] =
                        1
   [ TYPE ] [METHOD]  FRAME
```

7 Move the cursor to Orient Origin Point.
8 As shown in Figure 8.3.2.1 (b), touch up TCP the hole on the calibration plate (Hole at the intersection of crosses).

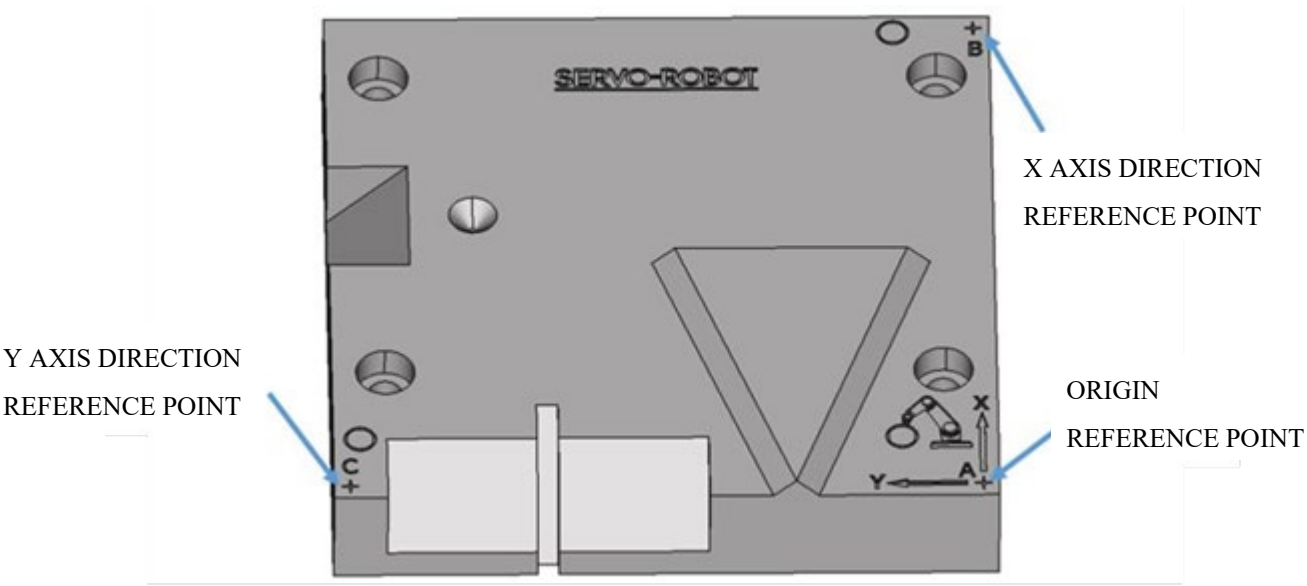


Fig. 8.3.3.1 (b) User frame on the calibration plate

9 Press and hold [SHIFT] key and press F5 to record the hole position of Origin reference as the Orient Origin Point.
10 As with steps 7 to 9, record the holes positions of the X axis direction reference point and Y axis direction reference point as the X direction point and Y direction point on the TP screen.
11 When all the reference points are taught, "USED" will be displayed. The user frame will be set.

Procedure 8-10 Client tag setting

Condition

- Startup of laser tracking sensor (Section 8.2) is completed.
- Usable client tags are prepared.
- The automatic calibration KAREL programs are already loaded in the robot controller.

Step

1 Connect the sensor to port-2 of the robot controller.
2 Set the screen to the two-screen display mode, and display the program edit screen on the left side and the user screen on the right side.
3 Create client tag setting TP program and execute this program as shown below
The number of # in the program name to be called and the robot group number used are the same.

```
1: CALL SR#_GEN_CFG          !-- Automatically set the client tag.
   (Client [#]=4,            !-- Set arguments as below.
    Vision IP='192.168.2.3',
    Host Name='SR1')         !-- 1: Client tag number
                             !-- 2: IP address of the system of the sensor
                             !-- 3: Host name (If argument is missing 'SR' will be set automatically.)
```

4 When the program is executed, the program may pause and a message may be displayed on the user screen. If no message is displayed, proceed to step 8. If a message is displayed, proceed to step 6.
5 Switch to the user screen and check the message contents. If there is no problem, input "1" and press the [Enter] key then go to step 8. Please input "0" when there is a problem. The program ends when "0" is input. Correct the cause of the problem, aborted the program, and then repeat step 5.
6 Switch to the program edit screen and restart the program. If the program is restarted and next message is displayed on the user screen, repeat step 6. If no message is displayed, proceed to step 8.
7 When [Client defined] is displayed after running the program, this means the completion of client tag setting.
8 Turn the power OFF/ON.

NOTE

In the following cases, the client tag cannot be set automatically. Check the message displayed on the user screen on the right. Enter the number according to the message, or remove the cause of the alarm if it occurs.

All Host Names on the SETUP Host Comm screen are already defined.	The program execution stops along with the alarm 990102. Remove unused host names from the HOST NAME list found on the SETUP Host Comm screen
The specified Host Name on the SETUP Host Comm screen exists and is not linked to the desired IP address	The program ask on the user screen if the current address should be replaced or not. If 1 is entered, the IP address will be changed. If 0 is entered, the program execution stops along with the alarm 990101
The Host Name and/or Remote Path are not empty and are not linked to the specified Host Name	The program ask on the user screen if the current CLIENT should be overwritten or not. If 1 is entered, the CLIENT will be changed. If 0 (do not overwrite) is selected, the program execution stops along with the alarm 990103.

For the SETUP Host Comm screen, refer to section 62.2.3.3 of the optional function instruction manual (B-83284EN-2).

Procedure 8-11 Auto calibration execution

Condition

- Startup of laser tracking sensor (Section 8.2) is completed.
- The calibration plate has not moved since the User frame was set in procedure 8-9.
- Usable client tags are prepared.
- The automatic calibration KAREL programs are already loaded in the robot controller.
- The DT file that matches the robot group for which automatic calibration is performed is loaded
- Sensor is connected to port-2 of the robot controller

Step

1 Create the execution program of the auto client tag setting.
2 Check that the sensor is connected to port-2 of the robot controller
3 Set the screen to the two-screen display mode, and display the program edit screen on the left side and the user screen on the right side.
4 Create the Auto calibration program as shown below.
The number of # in the program name to be called and the robot group number used are the same.

```
1: CALL SR#_GEN_CNT          !-- Open the client tag between the robot and servo robot
    (Client [#] = 1,             sensor.
    Status Reg [#] = 50)     !-- Set arguments as below.

                             !-- 1: Client tag number set for auto calibration
                             !-- 2: Register number to output the result of auto calibration

2: UFRAME_NUM[GP1] = 1       !-- Set the user frame number created on the calibration
                                 plate.

3: UTOOL_NUM[GP1] = 1        !-- Set the tool frame number used when setting the user
                                 frame.
4: L P[1] 100mm/sec FINE     !-- Teach the calibration start position.

5: CALL SR#_CAL2_STD         !-- Execute automatic calibration.
    (Iteration [#] = 3,      !-- For standard resolution cameras (FUJI-CAM2.0 etc.),
    Optical TF [#] = 3,          SR#_CAL2_STD must be used.
    User Frame[#] = 1,       !-- For high resolution cameras (FUJI-CAM/SHR etc.),
    2 Metal,                     SR#_CAL2_HR must be used.
    Run Calib,
    Run Check,               !-- Set arguments as below
    Stab Delay = 500,        !-- 1: Number of calibration cycles to execute
    Precision PR[#] = 1,         (Repeating will increase the accuracy. Values between 2
    Sensor ID = 2)               to 10 are supported.)
                             !-- 2: This tool is used to verify the calibration
                                 (Please select an unused tool frame number)
                             !-- 3: User frame number of the calibration target
                             !-- 4: Select “2 Metal”
                             !-- 5: Select “Run Calib”
                             !-- 6: Select “Run Check”
                             !-- 7: Robot stabilization delay (in milliseconds)
                                 (The robot will wait for the specified time before moving
                                 forward in the sequence (to stabilize the arm and
                                 support))
                             !-- 8: Position register number which will contain the
                                      calibration precision calculated after a calibration
                                      check
                             !-- 9: Calibration Sensor ID (optional)
                                 (Overwrites the coordinates generated by calibration to the
                                 coordinate system of the specified sensor ID. If 0 is
                                 specified, the generated coordinates will not be saved.)
6: IF ( R[50] <> 0 ) THEN    !-- Pause if an error occurs during auto calibration.
7: PAUSE                     !-- Enter the register number specified by the argument of
8: ENDIF                         SR#_GEN_CNT

9: CALL SR#_GEN_DCN          !-- Finish the automatic calibration and close the client tag.
```

5 Set the robot at the calibration start position. Adjust the position as described below.
- The sensor tilt is vertical to the plate, as shown in Figure 8.3.3.1 (c). (**The torch is not vertical.**)
- Tolerance is ±5 degrees inaccuracy around each axis (X, Y and Z)
- The laser beam horizontal direction should be about 3 mm inward from the edge of the plate and align the center line of the triangle with the center of the laser beam, as shown in Figure 8.3.3.1 (d).
- The laser light center position and sensor height should be such that the laser irradiation position displayed on the WeldCom or FRUIT screen is near the cross on the screen.

The guideline for the height of the start position for each sensor is as follows. (For soft version Rel15101.135)
- FUJI-CAM 2.0 : 121.4 mm
- FUJI-CAM/SHR 2.0 : 75mm
- FUJI-CAM/HR : 76.2 mm
- FUJI-CAM/HR : 66 mm

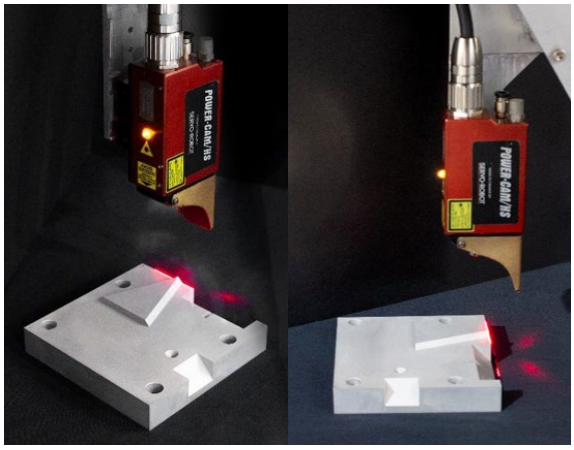


Fig. 8.3.3.1 (c) Calibration START position on target

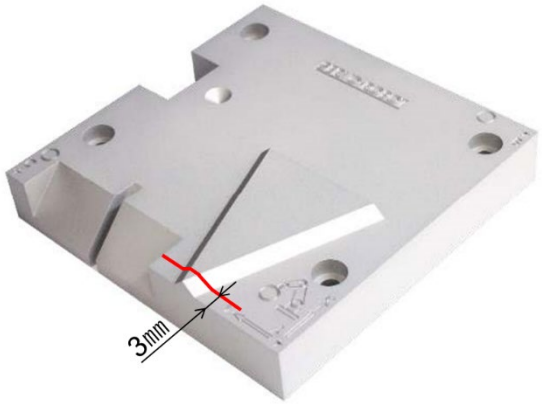


Fig. 8.3.3.1 (d) Calibration position on target and expected profile

⚠ WARNING

1 While the calibration is in process, the robot moves automatically on the user frame set on the calibration plate from the calibration start position described later up to the maximum ranges as shown below. Note that TCP is not at a minus position in Z direction on the user frame. Although the calibration plate does not come in contact with TCP, mount it at a safe location where it does not interfere with neighboring fixtures.

Maximum motion range of X : 40 mm
Maximum motion range of Y : 46 mm
Maximum motion range of Z : 50 mm
Maximum oscillation angle of W : ±15°
Maximum oscillation angle of P : ±10°
Maximum oscillation angle of R : ±20°

2 In the auto calibration, the precision of the user frame affects the precision of the sensor frame. If an error occurs in a value of the sensor frame, set the user frame again and perform the auto calibration, or adjust the sensor offset value in the sensor schedule setting.

6 When the program is executed, the program is temporarily stopped and some messages are displayed on the user screen.
7 Switch to the user screen and check the message contents. If there is no problem, input "1" and press the [Enter] key then go to step 8. Please input "0" when there is a problem. The program ends when "0" is input. Correct the cause of the problem, aborted the program, and then repeat step 5.
8 Switch to the program edit screen and restart the program. If the program is restarted and next message is displayed on the user screen, repeat step 6.
9 Respond to all the messages by the method in step 7 and restart the program to start the calibration operation. The following 5 messages are displayed in total

Do you wish to over write tool : 3?

Did you calibrated or verified calibration of the physical tool used define the target USER FRAME?

Did you set the calibrated physical as the active tool to define target USER FRAME?

Did you defined the target USER FRAME by placing the TCP accurately on each hole and respected the axes directions?

Is the camera perpendicular to the target with the laser line on the tip the triangle near the max. res. point?

⚠ CAUTION

1 Robots repeat the calibration operation the number of times set for the repeat count during program execution. In the first calibration operation, set the override to about 10 to 20% and check that there is no interference during the calibration operation. If there is no problem, increase the override after the second time.
2 Please obtain backup before calibration execution. If some problem occurs after calibration execution, return the backup.

NOTE
Even if correct the calibration start position, a message may be displayed on the user screen and auto calibration may be interrupted. In this case, set the currently set TCP to the flange (all frame values are 0), and execute the auto calibration program again.
In this case, the TCP is set to a position different from the actual position, so the torch may collide with the calibration plate. If set TCP to the flange and execute auto calibration, pay close attention to the robot operation.

10 When [CALIBRATION PRECISION] is displayed on the user frame after the calibration is completed, this means the completion of the calibration.
11 Check the accuracy of calibration displayed on the user screen.
This value is stored in the position register specified by the 8th argument of SR#_CAL2_STD or SR#_CAL2_HR. If the displayed accuracy is as follows, it is recommended to review the calibration settings (mainly User frame settings).

- FUJI-CAM 2.0 etc. : Any value is 0.5 mm or more
- FUJI-CAM / SHR etc. : Y and Z are 0.3 mm or more, X is 0.4 mm or more

12 After the Auto calibration is completed, connect the sensor to port-3.

8.3.3.2 KAREL Program List

KAREL Program specification of Servo-Robot sensor is shown below.

Table 8.3.3.2 (a) KAREL program list

KAREL program name	Argument	Description
SR#_CAL2_HR	1. Number of calibration iteration 2. Optical Tool Frame index 3. Target User Frame index 4. Target model 5. Run the calibration (flag) 6. Run the calibration check (flag) 7. Robot stabilization time 8. Calibration check precision index 9. Calibration Sensor ID (optional)	Runs the calibration and/or calibration check for a high-resolution camera.
SR#_CAL2_STD	1. Number of calibration iteration 2. Optical Tool Frame index 3. Target User Frame index 4. Target model 5. Run the calibration (flag) 6. Run the calibration check (flag) 7. Robot stabilization time 8. Calibration check precision index 9. Calibration Sensor ID (optional)	Runs the calibration and/or calibration check for a standard-resolution camera.
SR#_GEN_ACK		Reset any active alarm on the vision system.
SR#_GEN_CFG	1. Socket Client index to configure 2. IP address of the vision system 3. Host Name	Automatically configure the socket client set in the argument to be used with the vision system of the specified address.

KAREL program name	Argument	Description
SR#_GEN_CNT	1. Socket Client index 2. Error register index	Starts socket communication with the sensor using the defined client tag.
SR#_GEN_CTE		Internal function. Not to be used in user TP programs.
SR#_GEN_DCN		Cuts off socket communication with the sensor.
SR#_GEN_DISP		Internal function. Not to be used in user TP programs.
SR#_GEN_MUTE		Mutes the laser. Sets the laser power to 0% while keeping the laser on.
SR#_GEN_OFF		Turns the laser off.
SR#_GEN_ON		Turns the laser on after a 3 seconds delay.
SR#_GEN_STAT	1. Status register index	Gets the current status of the laser and return it in a register.
SR#_GEN_TASK	1. Desired task number	Changes the active task on the vision system.
SR#_GEN_UNMT		Restore the laser power after being muted.

8.3.3.3 Alarm Message of sensor

The error codes displayed at the time of execution of the KAREL program created by Servo Robot and its countermeasures.

Table 8.3.3.3 (a) Error code list of KAREL programs

Error code	Description	Measure
-1	An argument of a macro is out of range or the communication between the robot and the servo-robot sensor was lost.	Make sure that the selected arguments are within the allowed limits specified in this document and make sure that the Ethernet communication between the robot and the servo-robot sensor is stable.
17030	A non existing register was selected.	Make sure that the registers used to retrieve the information are valid.
17042	A required parameter is missing.	Make sure that all the required parameters are present.
67208	The client tag between the servo robot sensor and the robot must be opened before running the automatic calibration.	Call SR#_GEN_CNT before other programs.
67215	Another KAREL program is currently active.	Any active programs must be aborted.
990000	Special status, displayed in the USER display, returned by the servo-robot sensor.	Correct the source of the rejected profile and retry.
990030	The active Tool Frame must not be 0 when using SRI functions.	A user defined tool frame (1 to 10) must be active when using SRI functions.
990100	Invalid IP address selected.	Make sure a valid IP address is entered when calling SR#_GEN_CFG. The format must be XXX.XXX.XXX.
990101	Host Name and address not defined.	The overwrite request to overwrite the IP address associated to the HR host name was declined. Enter "1" on the user screen the overwrite request in order to configure the client.
990102	All Host Names are already defined.	Remove unused host names from the HOST NAME list found under SETUP -> Host Comm ->
990103	Client configuration was aborted.	The overwrite request to overwrite the socket messaging client was declined. Enter "1" on the user screen the overwrite request in order to configure the client.
990105	Robot TCP IP port-1 or 2 must contain an IP address on the same subnet as the servo-robot sensor.	Connect and configure either robot Ethernet port-1 or 2 to be able to communicate to the servo-robot sensor. They must be on the same subnet.

Error code	Description	Measure
996106	A valid IP address on the same subnet as the vision system must be entered in robot TCP IP port-1 or 2.	Make sure a valid IP address is entered in either robot port-1 or 2 is valid. The format must be XXX.XXX.XXX
996500	Sequence number XX was not made or data is missing (invalid PR). Change the sequence num to XX and run the program.	When running the User Frame optimization tool, the sequences must be made in order.
996505	New positions must be retaught for each sequence. Touch up all positions.	Each position must be touched up for each sequence when running the User Frame optimization tool.
998000	Optical tool number must not be the current tool.	The optical tool frame number defined during the calibration must be other tool frame except the active tool frame.
999001	Communication time out	Make sure that the Ethernet communication is stable and remains connected during the execution.
999002	Error in the communication message	Make sure that the Ethernet communication is stable and remains connected during the execution. If the problem persists, contact your local FANUC representative.
999003		
999004		
999005		
999006		

8.3.3.4 Sensor calibration screen

In the 10-point teaching and direct entry method other than auto calibration, the sensor frame is set on the sensor calibration screen.

Procedure 8-12 Show sensor calibration screen

Step

1 Press the [MENU] key and select "SETUP".
2 Press F1[TYPE] and select "Sensor Setup". Then Sensor Setup screen will be displayed.
3 Press F2 [CALIB] then the following screen will be displayed.

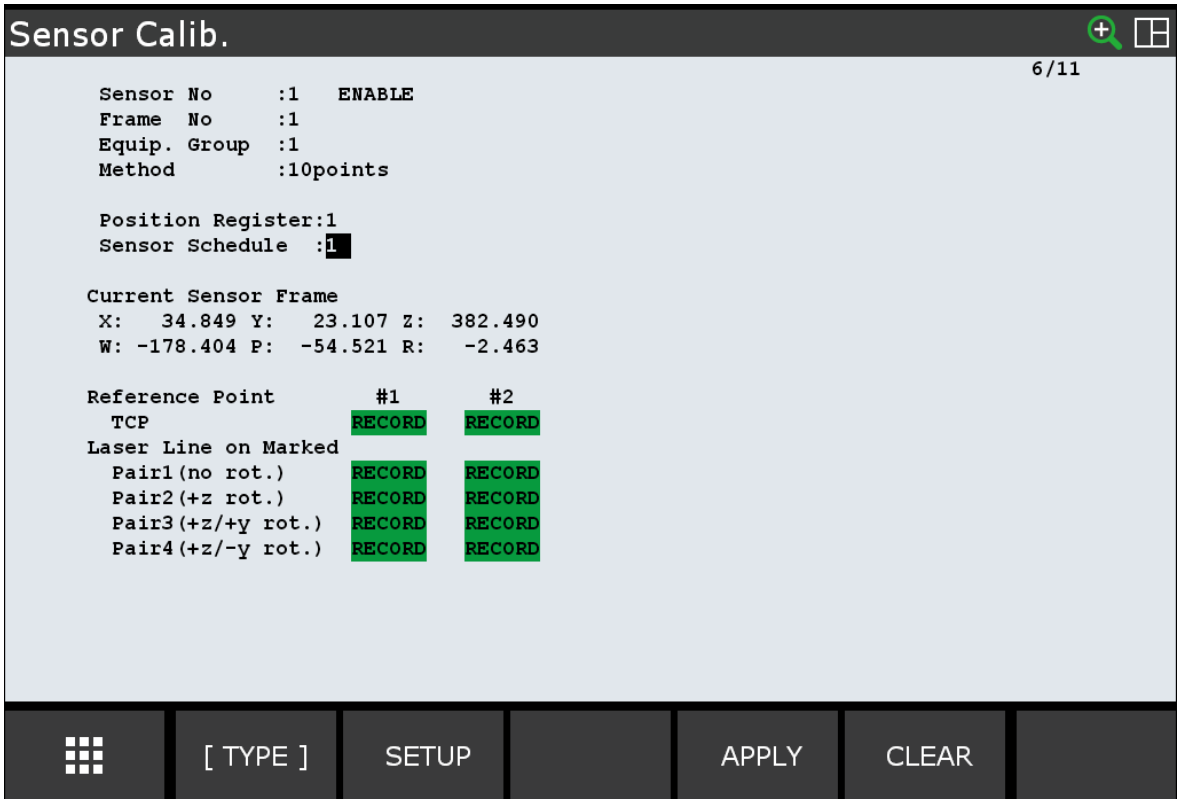


Table 8.3.3.4 (a) Sensor setting screen items

Item	Description
Sensor No	Sensor number to calibrate sensor frame.
Frame No.	Sensor frame number to calibrate. Four frames can be selected.
Robot group	The robot group number equipped current selected sensor.
Method	This is calibration method for the sensor frame. Calibration method, 10-point calibration and direct entry has been supported.

8.3.3.5 10-point teaching method

As shown in Fig. 8.3.2.2 (a), teach reference point 1 and reference point 2 on the superimposed workpiece prepared beforehand. Next, arrange the reference points in the center of the laser line, change the values of X, Y and Z and posture, and teach eight points in total. Then when the prepared program is executed, the sensor frame is automatically calculated.

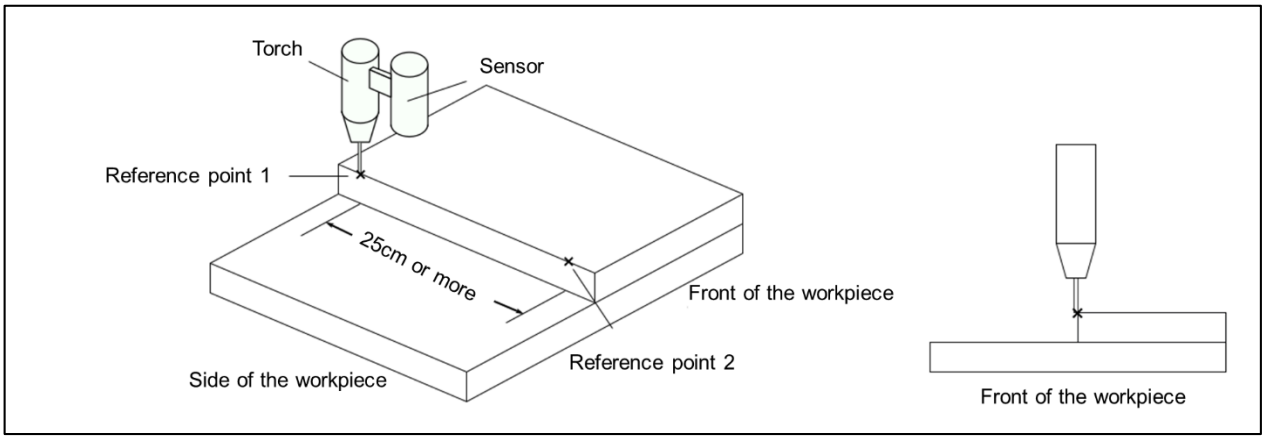


Fig. 8.3.3.5 (a) Sensor frame setting (10-point teaching method)

Procedure 8-13 Select 10-point teaching calibration

Condition

- Sensor calibration screen has appeared.

Step

1 Move cursor on “Method”, press F4 [CHOICE] and select “10points”

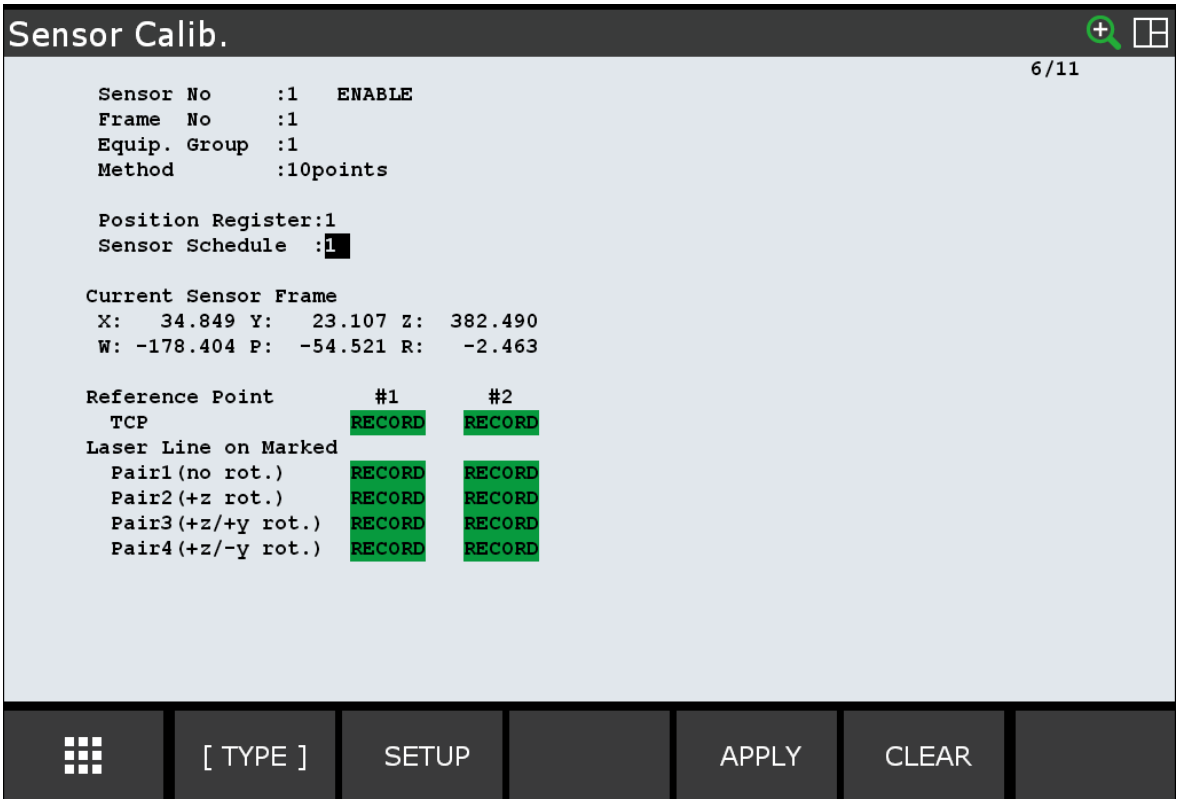


Fig. 8.3.3.5 (b) Sensor frame setting screen for 10-point teaching method

Table 8.3.3.5 (a) Additional items for 10 points calibration

Item	Description
Position register	Temporary used position data
Sensor schedule	Sensor schedule used for calibration process
Reference Points	The pairs for TCP reference positions.
Laser line on marked Pair1/Pair4	Reference position data for calibration

Procedure 8-14 10-point teaching method

Condition

- Sensor calibration screen has appeared.
- 10 points calibration has been selected as calibration method.
- Network settings has setup.
- Sensor schedule has setup.
- Lap-type workpieces has prepared.

Step

1 Move cursor on position register and enter the position register number to use for calibration.

> ⚠ **CAUTION**
> The data of the position register is erased by calibration process, so please select unused position register in TP programs.

2 Move cursor on Sensor Schedule and enter sensor schedule number used for calibration.
3 Define reference point #1, #2 on lap-type workpieces.
4 As shown in Fig. 8.3.3.5 (c), move TCP to reference point 1 by the jog operation of the robot.
5 Move the cursor over TCP reference point 1. While pressing the [SHIFT] key, press the F3 RECORD key. Then [UNINIT] changes to [RECORDED].
6 Without changing the posture of the robot, move TCP of the robot to reference point 2 to record it. Please refer the following figure.

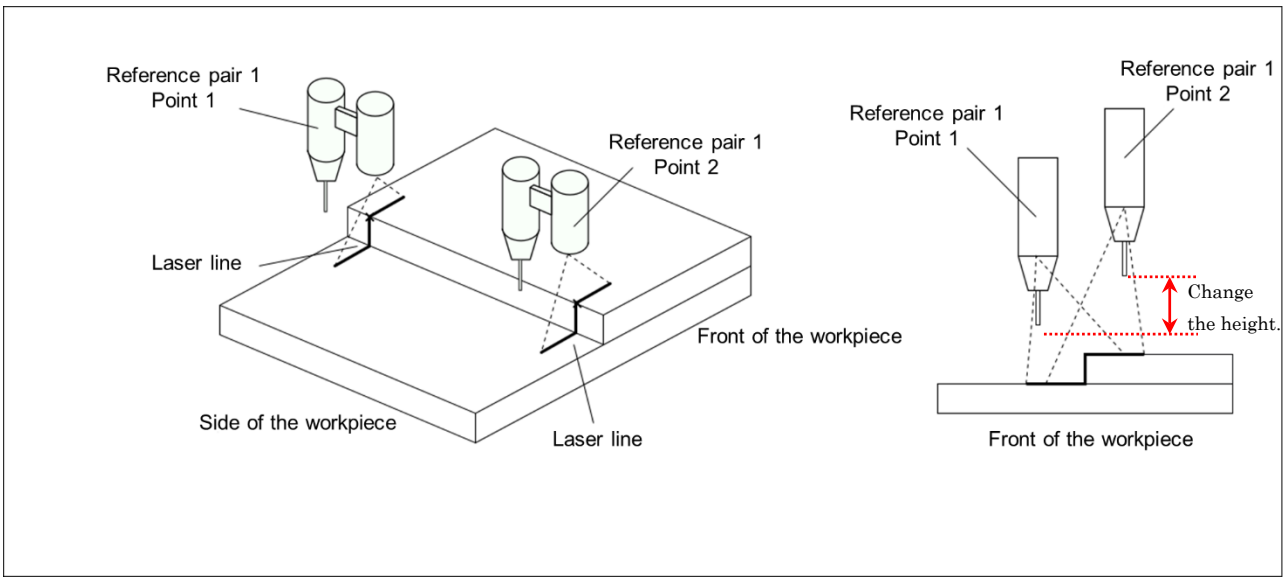
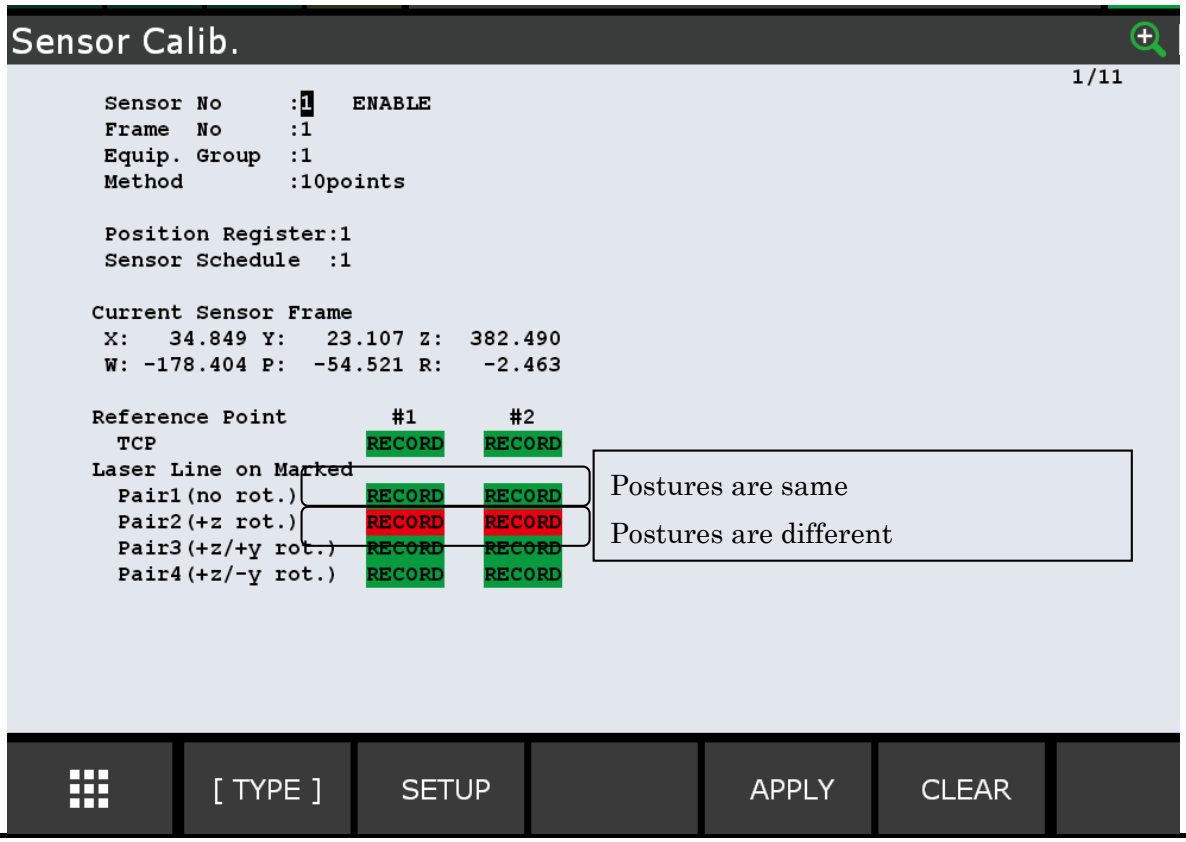


Fig. 8.3.3.5 (c) Method of teaching reference pair 1

7 Turn on the laser tracking sensor, and move the cursor over reference point 1. While pressing the Shift key, press the F2 MOVE_TO key. Then move TCP to reference point 1.
8 Perform jog operation so that reference point 1 comes in the center of the laser line.

9 Move the cursor over reference pair 1 - reference point 1. While pressing the [SHIFT] key, press the F3 RECORD key.
10 Change only the values of X, Y and Z, and perform operation so that reference point 2 comes in the center of the laser line.
11 Move the cursor over reference pair 1 - reference point 2. While pressing the [SHIFT] key, press the F3 RECORD key.

⚠ CAUTION
Do not change the robot postures at moving to reference point 2.
If the robot postures differs in the pair, the background color becomes red as below.



12 As shown in Fig. 8.3.3.5 (d), change the posture, and teach reference pair 2 based on the steps 8 to 11 of reference pair 1.

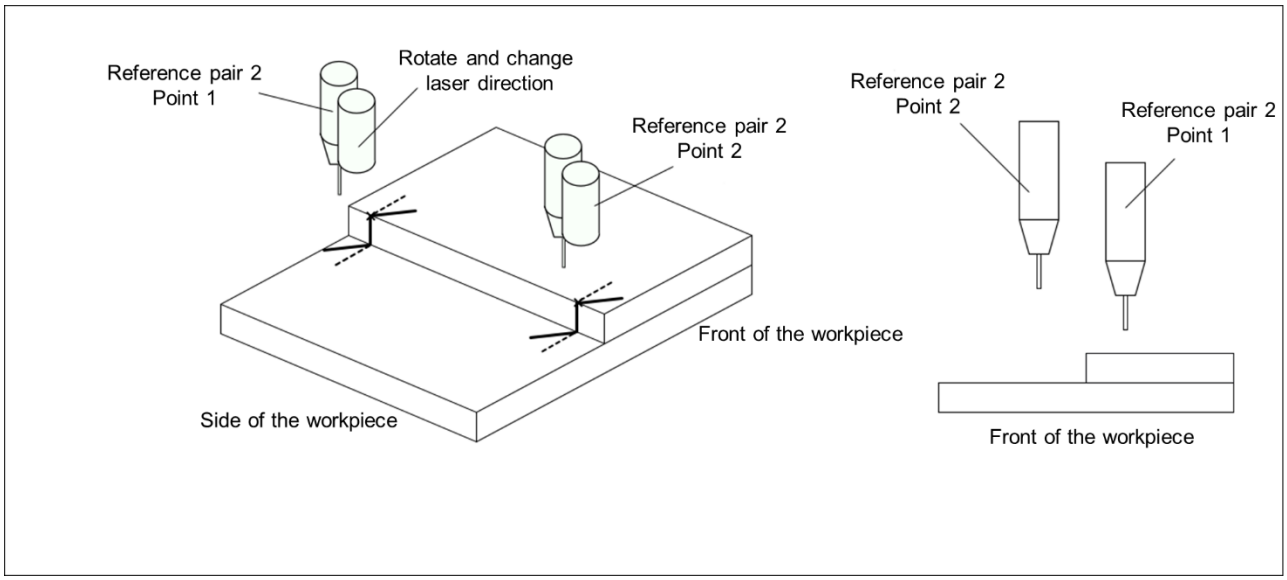


Fig. 8.3.3.5 (d) Method of teaching reference pair 2

13 As shown in Fig. 8.3.3.5 (e), change the posture, and teach reference pair 3 based on the steps 8 to 11 of reference pair 1.

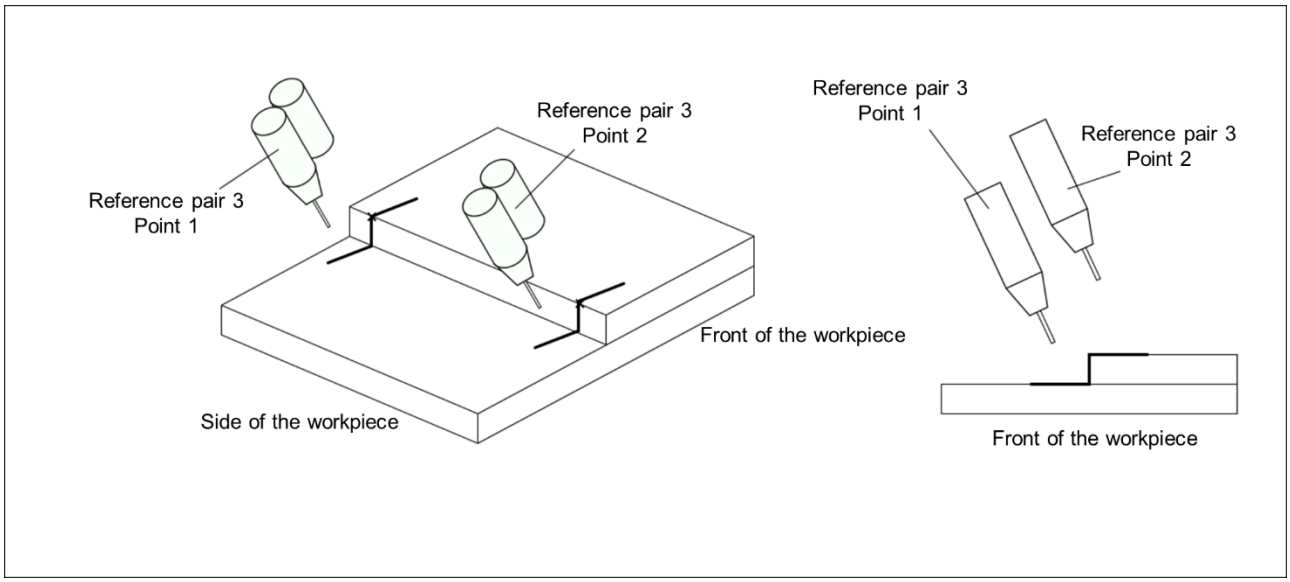


Fig. 8.3.3.5 (e) Method of teaching reference pair 3

14 As shown in Fig. 8.3.3.5 (f), change the posture, and teach reference pair 4 based on the steps 8 to 11 of reference pair 1.

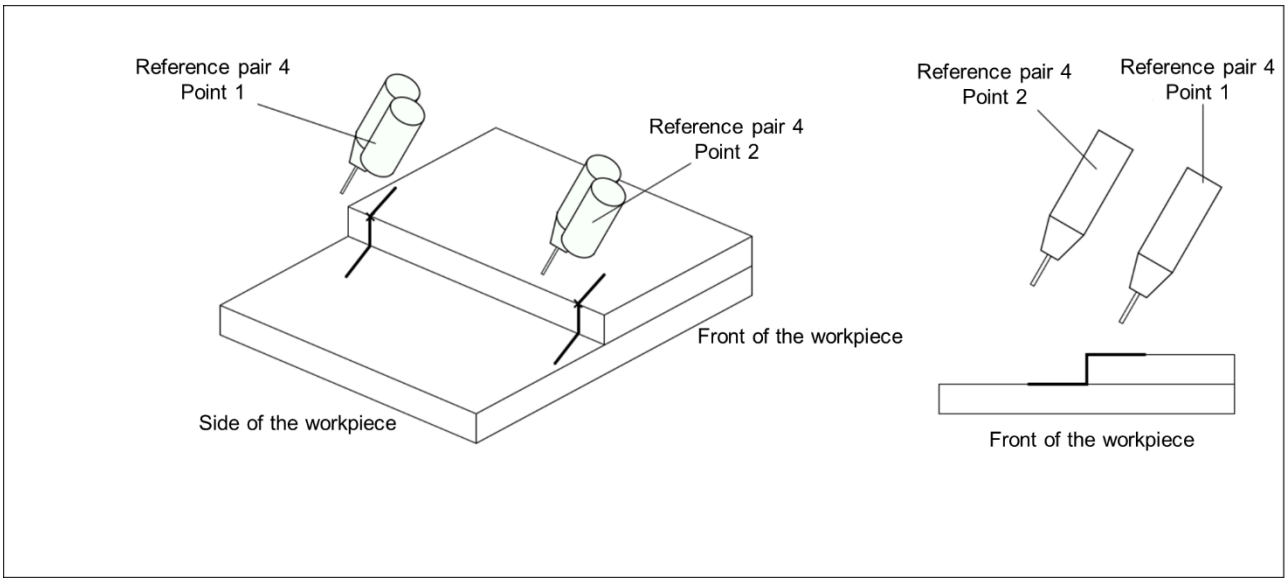


Fig. 8.3.3.5 (f) Method of teaching reference pair 4

15 Calibration execution: Move TCP upward close to reference point 1 by jog operation.

> **⚠ CAUTION**
> 1 Confirm that all the eight points taught are within the field of view of the sensor, and heather the sensor can detect the welding line at a reference point before start calibration
> 2 In the next procedure, the robot automatically moves to the taught reference point. Always be prepared to press the deadman switch or the emergency stop button so that the motion of the robot can be stopped any time.
> 3 At calibration process, the robot specified “Robot group” moves

8.3.3.6 Direct entry method

The sensor frame can be set with the direct entry method if the sensor frame has already been obtained, and the x, y, z, w, p and r values of the sensor frame are prepared beforehand. Referring to Procedure 8-5, set the sensor frame using the direct entry method.

> **⚠ CAUTION**
> When setting the laser tracking sensor for the first time, refer to Section 8.3.3.1 or Section 8.3.3.5 and set the sensor frame.

Table 8.3.3.6 (a) Sensor frame (Direct entry method) screen setting item

Item	Description
Current sensor frame	Shows the current sensor frame. Cannot be edited.
New sensor frame	Input new sensor frame
X, Y, Z, W, P, R	X, Y, Z, W, P and R values of the new sensor frame.

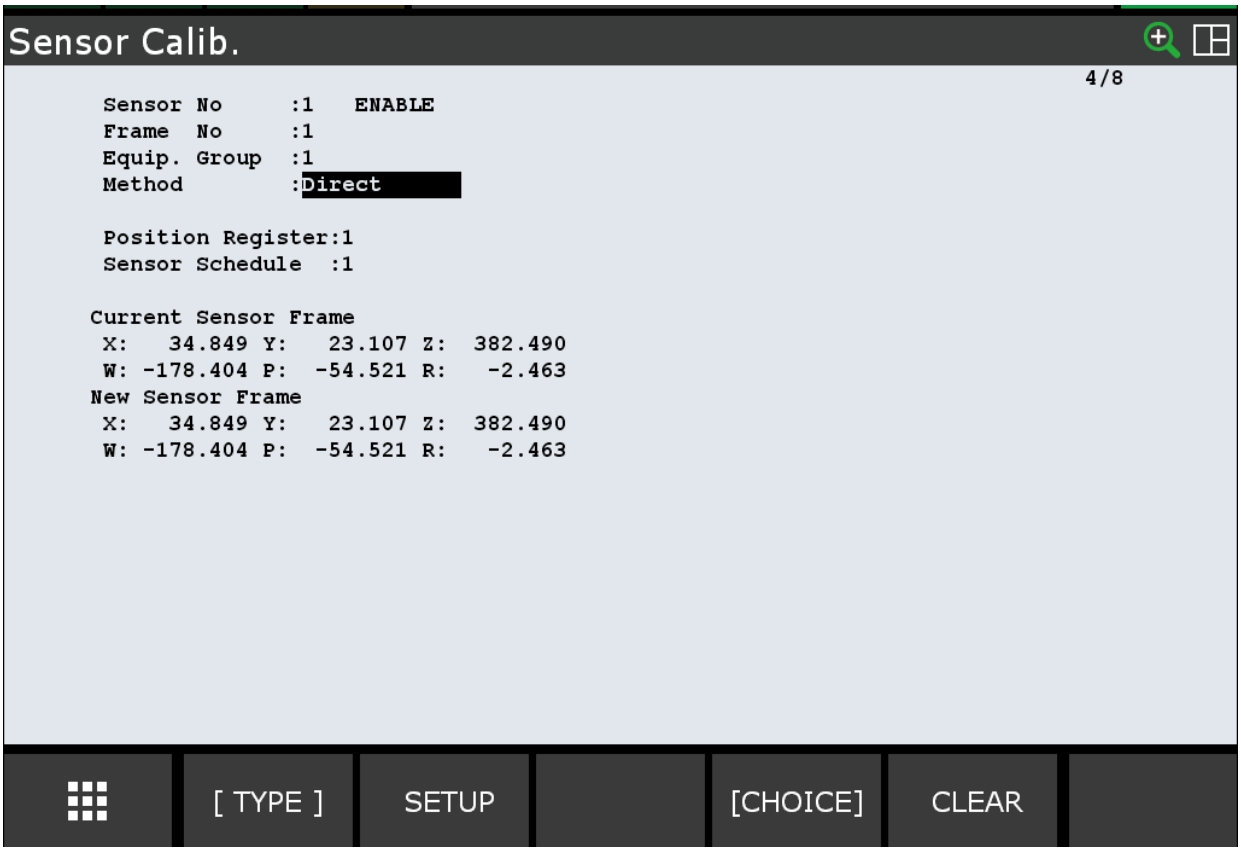
Procedure 8-15 Select direct entry calibration

Condition

- Sensor calibration screen has appeared.

Step

1 Press the [MENU] key and select [SETUP].
2 Press F1[TYPE] and select “Sensor Setup”, then Sensor Setup screen will be displayed.
3 Press F2[CALIB], then the display moves to Sensor Calib. screen
4 Move the cursor on the “Method” and press F4[CHOICE], and then select “Direct”. Then the following screen will be displayed.



5 Enter the frame data; x, y, z, w, p, r to new sensor frame.
6 Apply new sensor frame by pressing the [SHIFT] key +the F4[APPLY] key.

8.3.4 Sensor Schedule Setting

8.3.4.1 Overview

In sensor schedule screen, you adjust and set the following parameters.

- Joint ID
- Tracking sensitivity and search accuracy.
- Sensor frame.
- Bias offset length and direction.
- Retry conditions (retry type, motion conditions; speed, direction etc.).

NOTE
- In mutli-arm robot system and those groups perform tracking or seam find simultaneously, the schedule number is common among the robot group.

8.3.4.2 Sensor schedule List screen

If you would like to only change joint IDs, you change them on list screen.

Procedure 8-16 Show sensor schedule list screen

Step

1 Press the [MENU] key and then select DATA
2 Press F1[TYPE] and select “Sensor sch.”. Then, the following screen will be displayed.

Table 8.3.4.2 (a) Sensor schedule list screen setting item

Item	Description
Sensor No.	Sensor number you change the parameters in the screen.
#	Sensor schedule number
Srch	Joint ID used for search process.
Track	Joint ID used for tracking process.
Comment	Comments for the schedule.

Procedure 8-17 Change the sensor number.

Condition

- Sensor schedule list screen is displayed.

Step

1 Press F3”>”, the sensor number changes to next sensor (1 to 2 etc.)
2 Press F2”<”, the sensor number changes to previous sensor (2 to 1 etc.)

8.3.4.3 Sensor schedule detailed screen

If you would like to change the more detail configurations, you need to use the detailed screen.

Procedure 8-18 Show sensor schedule detailed screen.

Condition

- Sensor schedule list screen is displayed.

Step

1 Move cursor on the schedule you would like to change the more detailed parameters.
2 Press F4 [DETAIL] then the following screen will be displayed.

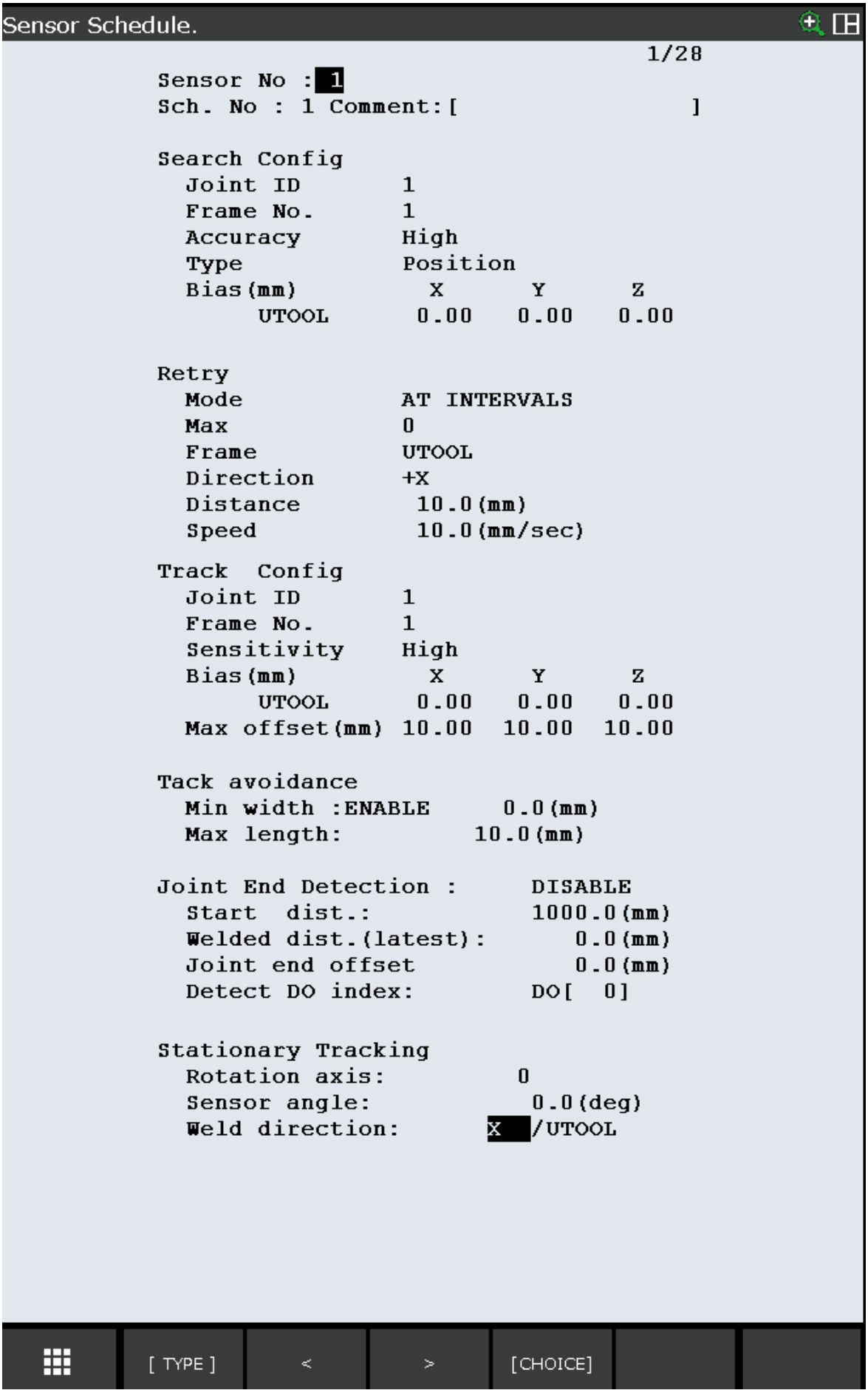

Sensor Schedule.
1/28
Sensor No : 1
Sch. No : 1 Comment:[ ]
Search Config
Joint ID 1
Frame No. 1
Accuracy High
Type Position
Bias(mm) X Y Z
UTOOL 0.00 0.00 0.00
Retry
Mode AT INTERVALS
Max 0
Frame UTOOL
Direction +X
Distance 10.0(mm)
Speed 10.0(mm/sec)
Track Config
Joint ID 1
Frame No. 1
Sensitivity High
Bias(mm) X Y Z
UTOOL 0.00 0.00 0.00
Max offset(mm) 10.00 10.00 10.00
Tack avoidance
Min width :ENABLE 0.0(mm)
Max length: 10.0(mm)
Joint End Detection : DISABLE
Start dist.: 1000.0(mm)
Welded dist.(latest): 0.0(mm)
Joint end offset 0.0(mm)
Detect DO index: DO[0]
Stationary Tracking
Rotation axis: 0
Sensor angle: 0.0(deg)
Weld direction: X /UTOOL
[TYPE]
<
>
[CHOICE]

Table 8.3.4.3 (a) Sensor schedule detailed screen setting item

Item	Description
Sensor No.	Sensor number you change the parameters in the screen.
Sch. No.	Sensor schedule number
Comment	Comments for the schedule.
Search config.	Configurations for search process
Joint ID	Joint ID used for search process
Accuracy	Accuracy at search process. **High** Average based on 9 times measurements. In dynamic search, if the number of continuous valid detection is larger than 9, the search process becomes success. **Middle** Average based on 6 times measurements. In dynamic search, if the number of continuous valid detection is larger than 6, the search process becomes success. **Low** Average based on 3 times measurements. In dynamic search, if the number of continuous valid detection is larger than 3, the search process becomes success.
Type	Position data format for search result. **Position** Actual position data based on WORLD frame. **Offset** Offset data from first measurement position.
Bias	Add offset to search result. UTOOL / UFRAME / SENSOR are supported.
Retry	Retry procedure when search process fails.
Mode	Retry mode **At intervals** Robot moves the specified distance and executes search process after the robot has stopped. **Dynamic** Robot moves the specified distance and also executes search process simultaneously.
Max	Maximum retry count. This item disappears in dynamic search mode.
Frame	Base frame to move the robot at retry. UTOOL / UFRAME / SENSOR are supported.
Direction	Direction to move the robot at retry. +X / -X / +Y / -Y / +Z / -Z are supported.
Distance	Move distance (mm) at each retry. In dynamic search mode, it means maximum moving distance for search.
Speed	Moving speed(mm/sec) at retry process.
Track config	Configurations for tracking process
Joint ID	Joint ID used for tracking process.
Sensitivity	Sensitivity at tracking process. **High** Estimate joint position by data stored during 10mm near TCP. **Middle** Estimate joint position by data stored during 20mm near TCP. **Low** Estimate joint position by data stored during 30mm near TCP.
Bias	Add offset to estimated joint position. UTOOL / UFRAME / SENSOR / PATH / TOOLPATH are supported.

Item	Description
Max offset	The limit of total offset during each tracking process. It specified based on world frame. If offset excesses the limit, DPMO-032 Path Offset Limit Error occurs.
Stationary tracking	This contents used only for stationary tracking with coordinated motion.
Rotation axis	The moving axis number of leader group. Ordinarily, the final axis is used.
Sensor angle	The angle between TCP and sensor detect position. If 0.0deg, the software estimate automatically.
Weld direction	Welding direction. Sensor tracking software does not add any offset for this direction.

Refer to Fig. 8.3.4.3 (a) offset direction with sensor frame.

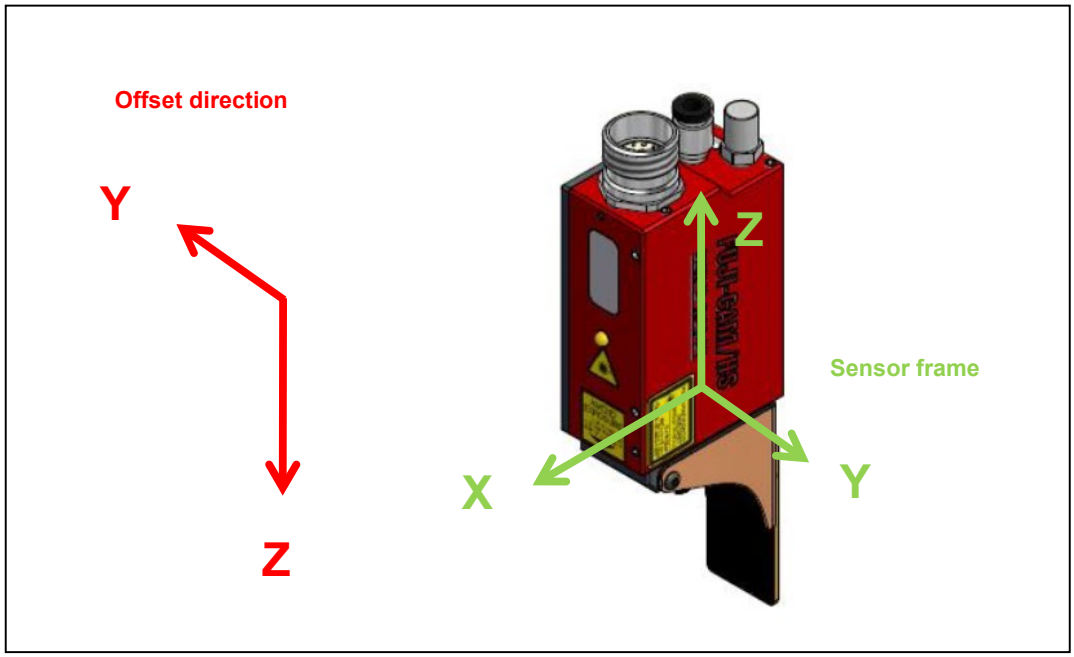


Fig. 8.3.4.3 (a) Sensor offset direction

8.4 SPECIAL TRACKING FEATURES FOR ARCTOOL

8.4.1 Tack avoidance

When sensor cannot detect joint data normally (encounter tack weld etc.), tack avoidance function estimates joint data from latest success joint data and continues the tracking process.

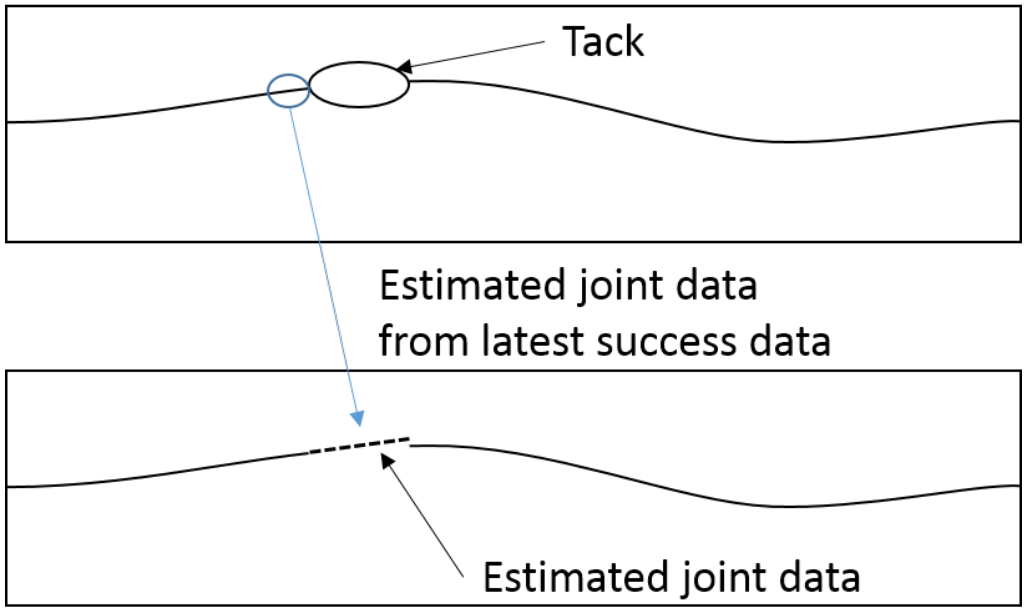


Fig. 8.4.1 (a) Sensor offset direction

Tack avoidance is setup in sensor schedule detailed screen.

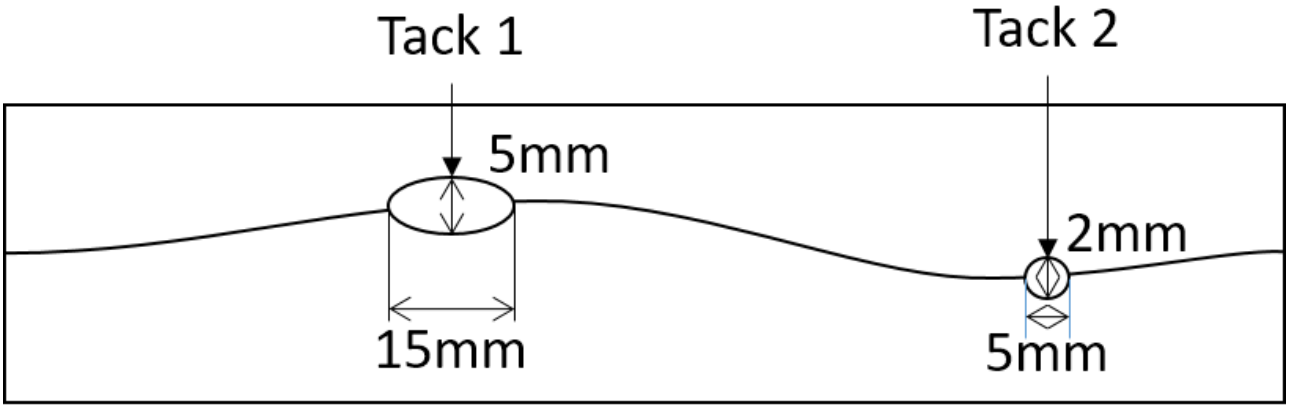
Table 8.4.1 (a) Tack avoidance setting items.

Item	Description
Tack avoidance	Setting for tack avoidance.
Min width	Assumed minimum tack width (mm). If the feature is enabled and the difference between actual detection and estimated detection is longer than the threshold specified by it, the actual detection is treated as invalid.
Max length	Maximum length to generate joint data when sensor cannot detect joint data normally. If actual tack length is longer than it, “XSIF-101 Can't detect joint continuously” occurs.

Procedure 8-19 Adjust tack avoidance setting

Step

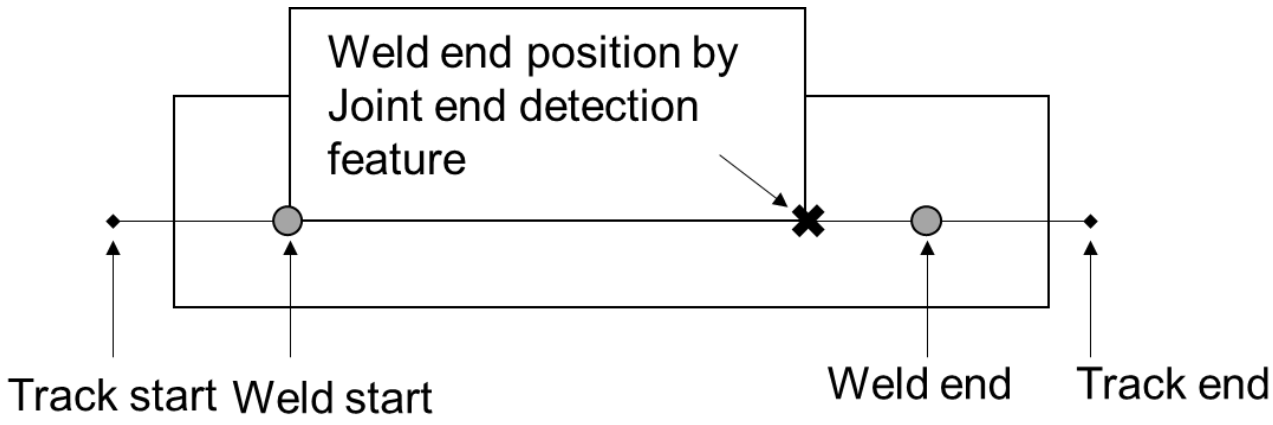
1 Select sensor schedule and show sensor schedule detailed screen.
2 Enter the assumed min tack width in Min width.
3 Enter the assumed max tack length in Max length.
4 For example, min width is 2mm and max length is 15mm in the following case.



NOTE
- When joint recovers normal, an estrangement between generated joint data and actual joint data may occurs.
- According to joint conditions, the sensor detects an edge of tack as valid joint data. If Min width is not suitable, the tracking quality becomes worse. Please adjust Min width and joint condition on sensor if you encounter such behavior.
- If Min width is too short, an ordinary joint data will be treated as invalid.

8.4.2 Joint end detection

When robot welds the workpieces longer than specified length and sensor cannot detect joint continuously, joint end detection judges the sensor position has passed the end of workpieces.
When actual robot TCP has reached the position, joint end detection sends terminated command to weld equipment and sensor controller.
Optionally, the robot also stops current moving process and go to next process.



8.4.2.1 Joint end detection setting for group.

You change the common setting for sensor in sensor setting screen.

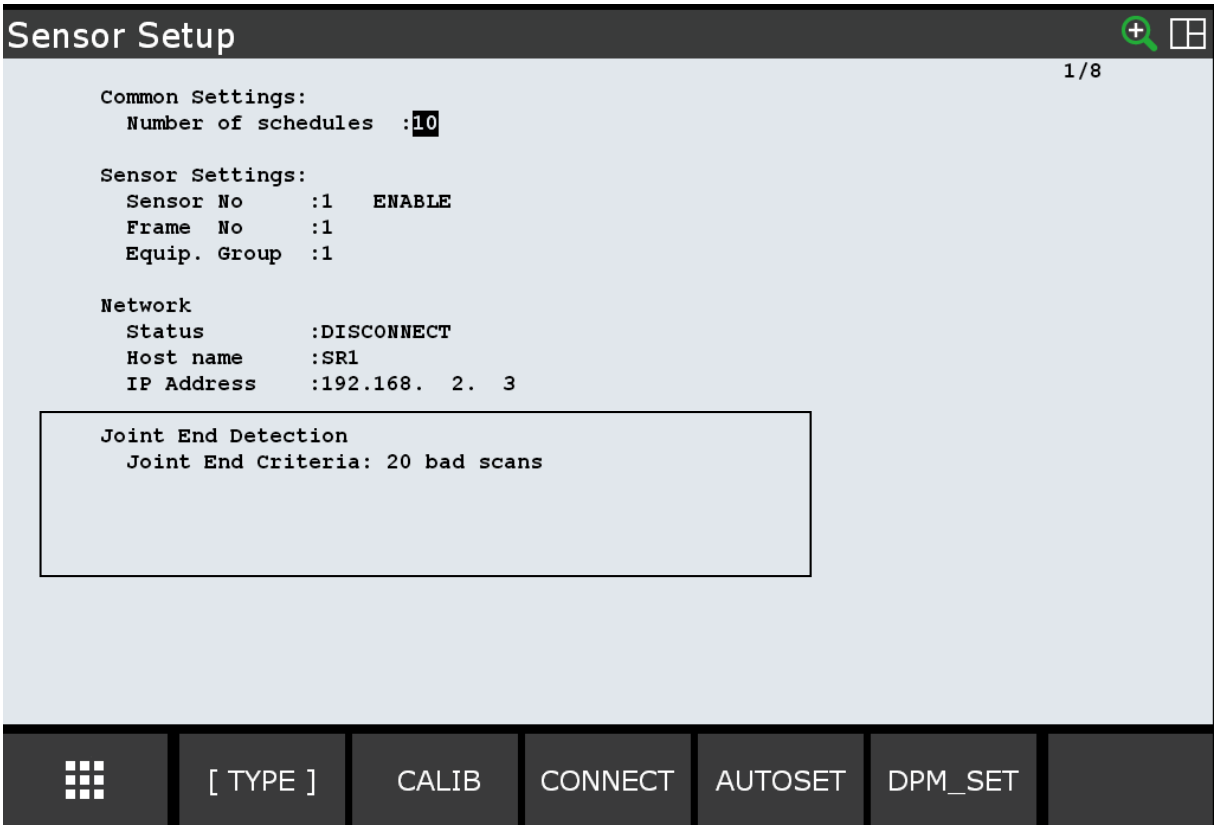


Table 8.4.2.1 (a) Joint end detection setting items for sensor.

Item	Description
Joint end detection	Settings for joint end detection function
Joint End Criteria	If the number of continuous bad scan is larger than the parameter, the sensor judges to the sensor positon has passed joint end position and save the first bad scan position as joint end position.

8.4.2.2 Joint end detection setting for schedule

You change the detailed setting in sensor schedule screen.

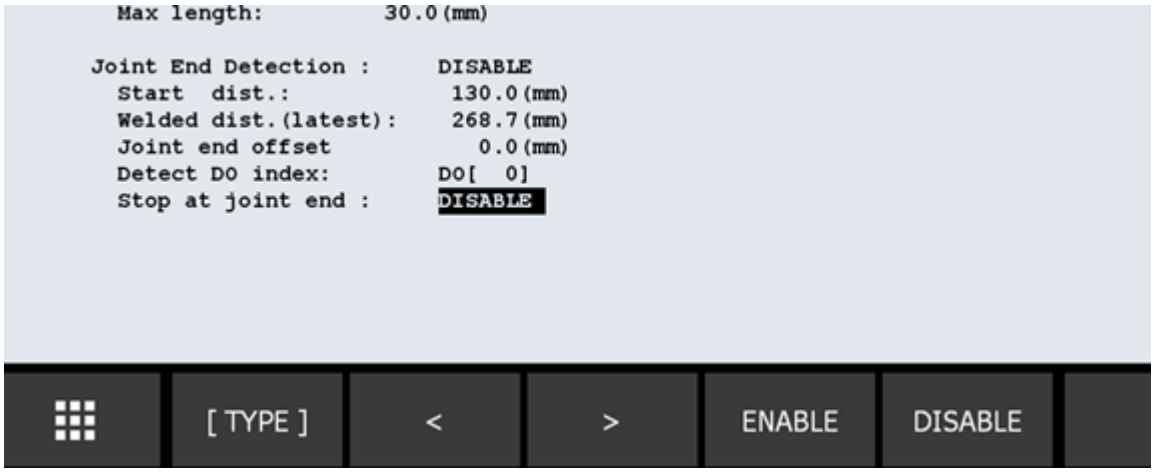


Table 8.4.2.2 (a) Joint end detection setting items for each schedule.

Item	Description
Joint end detection	Settings for joint end detection function
Start dist.	Welded distance the function starts.
Welded dist.(latest)	Latest welded distance with current sensor schedule.
Joint end offset	Adjust parameter when joint end detection sends terminate command to weld equipment and sensor. If this value is negative, joint end detection sends terminate commands before the robot reaches the end of workpieces.
Detect DO I/O	This DO becomes on when joint end detection sends terminate command to weld equipment and sensor. When you would like to notify the end of welding to external devices (PMC etc.), please set this item.
Stop at joint end	Robot also stops at joint end and moves to next process if enabled.

⚠ CAUTION
- In multi-arm simultaneously tracking, “stop at joint end” feature works only when every robots has passed joint end position.
  Weld terminated request sends each robot has passed joint end.
- In multi equipment environments, you need to weld coupling setting correctly.
- If teaching point is unstable, the robot may conflict with workpieces etc. after stop at joint end feature.
- Stop at joint end feature does not use with weaving function at same time.

NOTE
- Welded distance” means the robot movement from weld start position.
  It will be different from tracking distance.
- When joint end detection work, sensor becomes OFF when sensor detects the end of workpieces.
- If Start dist. is not suitable, joint end detection may malfunction at tack weld etc.

8.5 INSTRUCTIONS

8.5.1 Sensor ON/OFF instruction

The sensor turn on/off function supports the following commands.

- SENSOR ON[]
- SENSOR OFF[]

> ⚠ **WARNING**
> The laser operates at high power while the sensor searching instructions are being executed. Do not look directly at the laser beam. Doing so may harm your eyes.

SENSOR ON[*, *, *, *]

The SENSOR ON instruction starts sensor outputs.
Example) Only sensor 1 becomes ON
SENSOR ON[1,*,*,*]
Example) Both sensor 1 and 2 become ON
SENSOR ON[1,1,*,*]

SENSOR OFF[*, *, *, *]

The SENSOR OFF instruction stops sensor outputs.
Example) Only sensor 1 becomes OFF
SENSOR OFF[1,*,*,*]
Example) Both sensor 1 and 2 become OFF
SENSOR OFF[1,1,*,*]

8.5.1.1 Example

Sensor operation program(SENSOR_ON_OFF.TP)

```
SENSOR ON[1,1,*,*]; !-- Both sensor 1 and 2 are ON
WAIT 5.0sec;
SENSOR OFF[1,*,*,*]; !-- Sensor 1 is OFF
WAIT 5.0sec;
SENSOR OFF[*,1,*,*]; !-- Sensor 2 is OFF
```

8.5.2 Search instruction

SEARCH ON [*, *, *, *]

The SEARCH ON instruction specifies the using sensor for search.
Example) Only sensor 1 becomes ON
SEARCH ON[1,*,*,*]
Example) Both sensor 1 and 2 become ON
SEARCH ON[1,1,*,*]

DETECT JOINT [s, p]

Detect joint positon based on specified sensor schedule and stored to specified position register.
If sensor cannot detect a joint, the robot will execute retry process
s: Sensor schedule number.
p: Position register index.

DETECT JOINT [s, p] LBL [j]

DETECT JOINT [s, p] instruction can add LBL [j] behind. In this case, the program jumps to [LBL [j]] when welding line detection fails.

To use LBL [j], input the DETECT JOINT [s, p] instruction, and move the cursor on the right side of this instruction statement. Then press F4 [CHOICE] and select LBL [ ].

If the welding line detection fails by executing the [DETECT JOINT [s, p] LBL [j]] instruction, the robot moves as the following.

- When the search retry function is enabled, the search retry is performed as set in the sensor schedule.
- If the search retry also fails, this program jumps to LBL [j] and continues the program execution.
- The program executes the [LBL [j]] instruction statement from the position where the sensor search has failed.

8.5.2.1 Dynamic Search

The dynamic search function can perform movement of search position by robot and scan processing of weld line by laser track sensor simultaneously. The robot continues to move in the set direction until a weld line is found. The dynamic search is stopped when the welding line is detected. This position information is stored in the specified position register. The dynamic search can detect the welding start point more quickly. This function is valid when the welding line position is unknown or it changes greatly. The dynamic search uses the same searching instruction. Fig. 8.5.2.1 (a) shows the pattern diagram of the dynamic search.

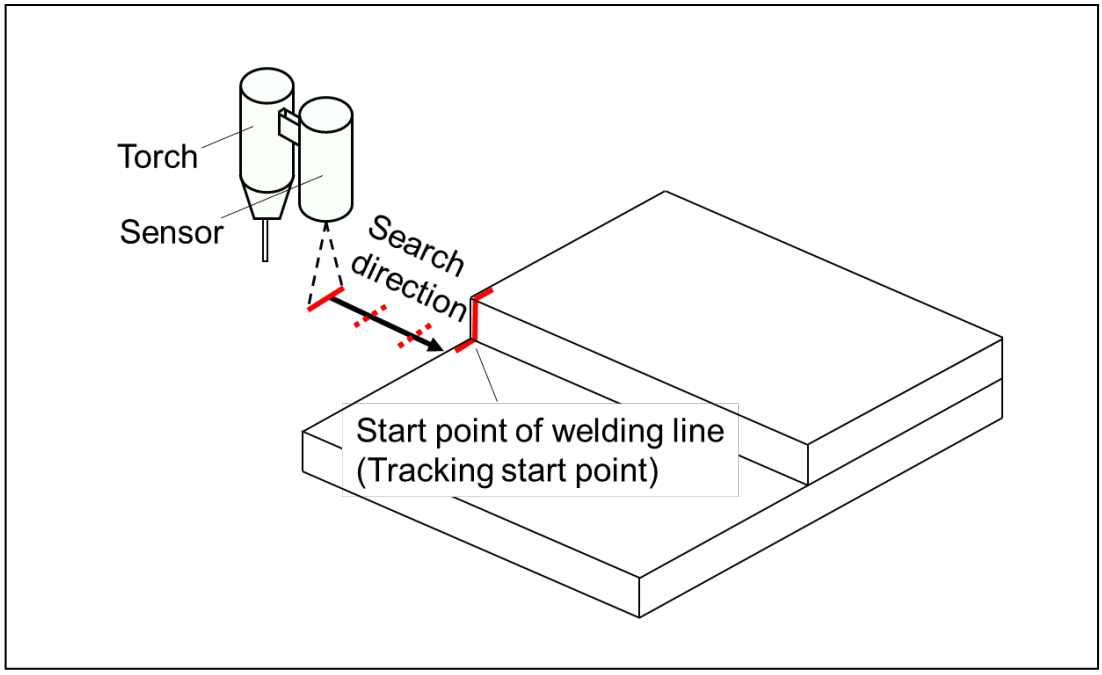


Fig. 8.5.2.1 (a) Dynamic search

8.5.3 SENSOR TRACKING

The Sensor Tracking is the laser track sensor detects the weld line and corrects the position in real time to follow the weld line during welding.

8.5.3.1 Sensor Tracking Instruction

The Sensor Tracking supports the following instructions.

- TRACK DPM [i]
- Track End

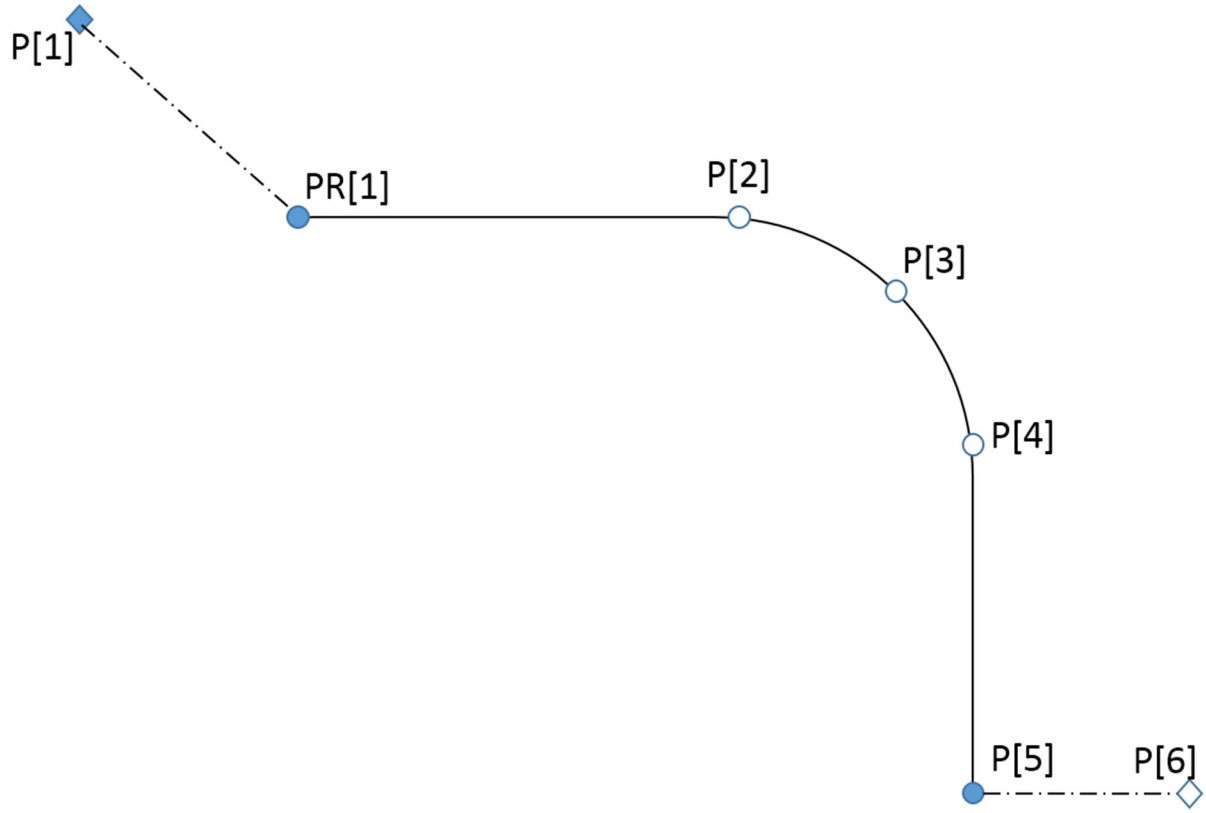
TRACK DPM [i]

This instruction statement specifies the position to start tracking. The parameters used for tracking are determined from the specified sensor schedule.
i = Sensor schedule number

Track End

This instruction statement specifies the track end point.

8.5.4 PRACTICAL SAMPLE PROGRAM



Solid line: Actual joint position.

Dotted line: Approach/evacuation motion of robot.
Filled markers: Operations for arc welding or sensor.

Sample program(TRACK_ALL.TP)

```
 1:J P[1] 25% FINE              !-- Move to search operation position
 2:  WAIT     1.00(sec)         !-- Wait to avoid effect of vibration
 3:  SENSOR ON[1,*,*,*]         !-- Sensor becomes ON
 4:  SEARCH ON[1,*,*,*]!-- Start search process
 5:  DETECT JOINT[2,1]          !-- Detect joint by schedule 2 and store to PR[1]
 6:  LOCK PREG                  !-- Lock PR[1] for look-ahead execution
 7:  Track DPM[1]               !-- Start tracking with schedule 1
                                !-- Move to searched position (approach motion)
 8:L PR[1] 100cm/min FINE
   :  Weld Start [1,1] ;        !-- Start welding with weld procedure 1 and schedule 1
 9:L P[2] 100cm/min CNT100
10:C P[3]
   :  P[4] 100cm/min CNT100
11:L P[5] 100cm/min FINE
   :  Weld End[1,1]             !-- End welding
12:  Track End                  !-- End tracking
13:  UNLOCK PREG                !-- Unlock PR[1]
14:L P[6] 200cm/min FINE        !-- Evacuation motion
```

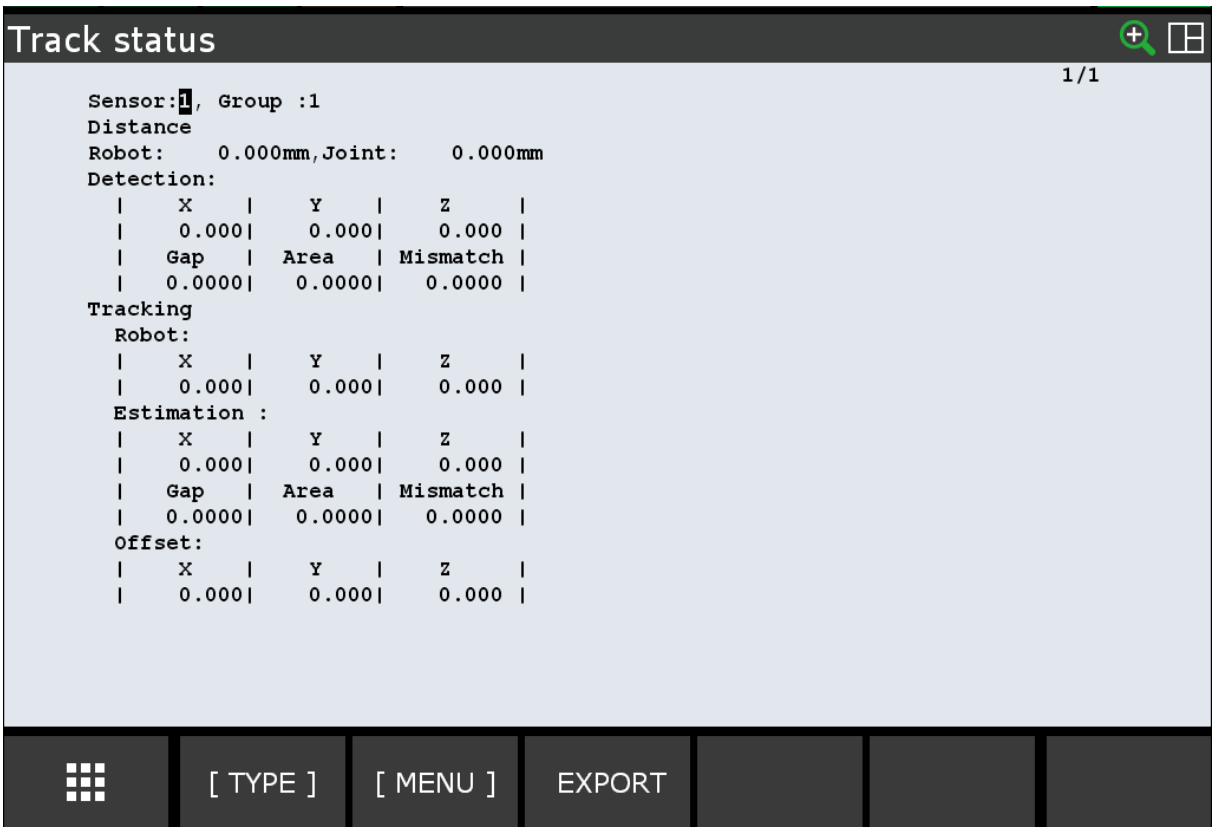
8.6 TRACKING STATUS SCREEN

This screen shows the following data.
- Current sensor detection data.
- Current robot TCP position
- Estimated sensor data.
- Tracking offset.

Procedure 8-20 Show tracking status screen

Step

1 Press the [MENU] key.
2 Select “4. Status”.
3 Press F1[TYPE].
4 Select “Track status” then the following screen will be displayed.



8.6.1 Tracking status screen

Table 8.6.1 (a) Tracking status screen items

Item	Description
Sensor number	Current selecting sensor number
Group	The robot group number equipped the current selected sensor. This configuration cannot change in this screen.
Distance	Moved distance of robot and sensor from tracking start. Sensor distance is calculated by robot distance and lead distance.
Detection	The joint position and shape that the sensor detects currently.
Tracking	Current tracking status
Robot	Current robot actual position
Estimation	Ideal robot position and joint shapes estimated by sensor data

Item	Description
Offset	Current applied tracking offset.

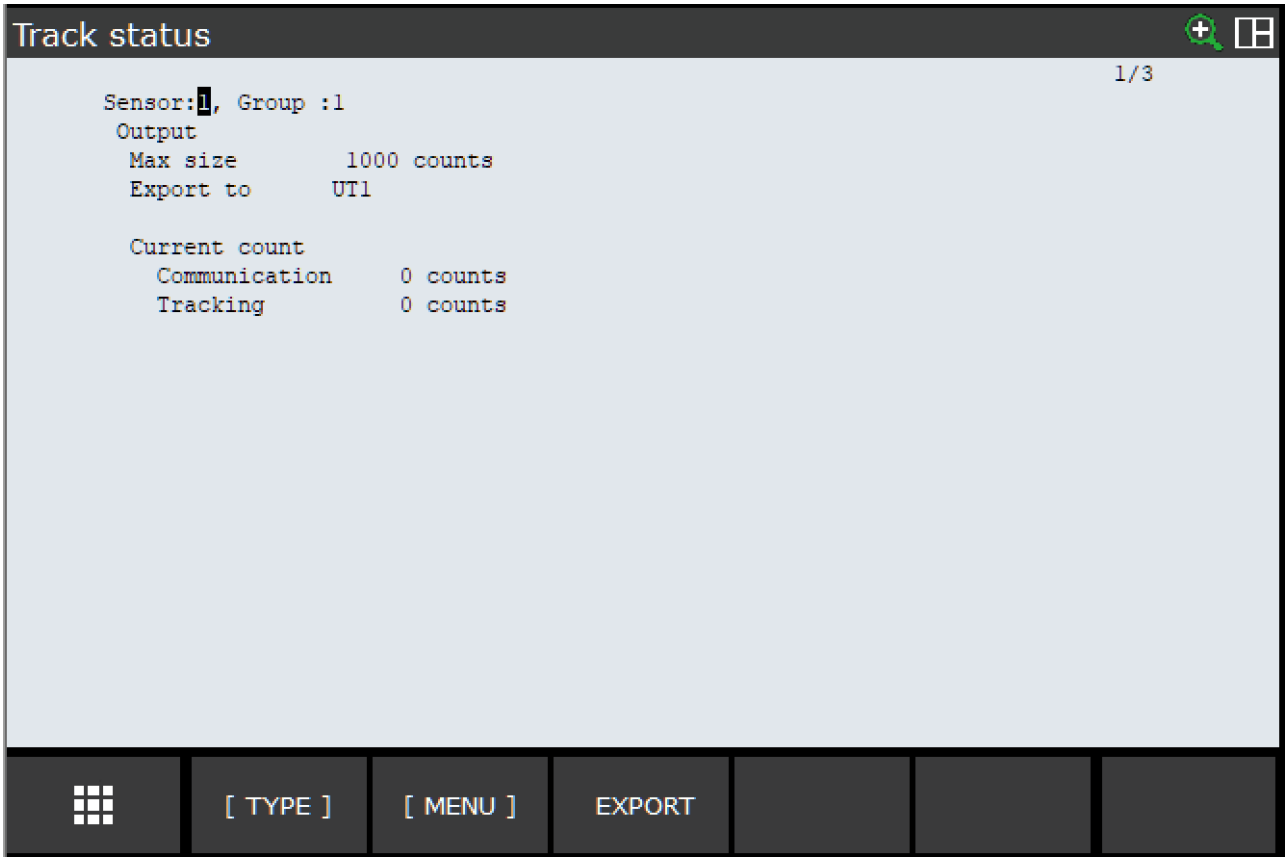
8.6.2 Tracking log function

This function records several parameters and status during tracking process and output as CSV format to external device. This data is useful to adjust sensor parameters and teaching

Procedure 8-21 Show log export setting screen

Step

1 Show tracking status screen.
2 Press F2 [MENU].
3 Select Sensor Log then the following screen will be displayed.



Procedure 8-22 Change maximum log size

Step

1 Show tracking log export setting screen.
2 Move cursor on “Max size”
3 Change the max size. Approximately, 1000count can save 600mm arc welding process.
4 Re-power the controller.

Procedure 8-23 Export log data

Step

1 Show tracking log export setting screen.
2 Move cursor on “Export to”
3 Select device you would like to save the log data.
4 Press F3 [EXPORT], then the log data has saved.

8.7 ALARM CODES

8.7.1 Alarm message of robot.

8.7.1.1 Sensor alarm(XSIF)

XSIF-001 ABORT Internal Error (system)

CAUSE:
Internal error in system software
REMEDY:
- Power off to recover.
- If problem persists, please call FANUC.

XSIF-002 ABORT Internal Error (xsif)

CAUSE:
Internal error in sensor communication software
REMEDY:
- Check communication cable between sensor and robot/sensor controller etc.
- Power off the sensor to recover.
- Power off to recover.
- If problem persists, please call FANUC

XSIF-003 ABORT Internal Error (xsp)

CAUSE:
Internal error in sensor communication software
REMEDY:
- Check communication cable between sensor and robot/sensor controller etc.
- Power off the sensor to recover.
- Power off to recover.
- If problem persists, please call FANUC

XSIF-004 ABORT Internal Error (pmpt)

CAUSE:
Internal error in sensor communication software
REMEDY:
- Check communication cable between sensor and robot/sensor controller etc.
- Power off the sensor to recover.
- Power off to recover.
- If problem persists, please call FANUC

XSIF-005 ABORT Internal Error (dpm)

CAUSE:
Internal error in sensor communication software
REMEDY:
- Check communication cable between sensor and robot/sensor controller etc.
- Power off the sensor to recover.
- Power off to recover.
- If problem persists, please call FANUC

XSIF-006 ABORT Internal Error (intr)

CAUSE:
Internal error in motion software
REMEDY:
- Power off the robot controller to recover.
- If problem persists, please call FANUC

XSIF-007 ABORT Internal Error (fltr)

CAUSE:
Internal error in motion software
REMEDY:
- Power off the robot controller to recover.
- If problem persists, please call FANUC

XSIF-030 PAUSE Sensor Error External

CAUSE:
An error occurs in sensor.
REMEDY:
- Refer the sensor manual to recover.

XSIF-031 PAUSE Sensor Error Unknown code.

CAUSE:
The sensor is received unknown commands from robot controller.
REMEDY:
- Check communication cable between sensor and robot/sensor controller etc.
- Refer the sensor manual to recover.

XSIF-032 PAUSE Sensor Error Checksum

CAUSE:
The sensor is received invalid commands from robot controller.
REMEDY:
- Check communication cable between sensor and robot/sensor controller etc.
- Refer the sensor manual to recover.

XSIF-033 PAUSE Sensor Error Timeout

CAUSE:
No acknowledge code from the sensor in specified wait time.
REMEDY:
- Check communication cable between sensor and robot/sensor controller etc.
- Refer the sensor manual to recover.

XSIF-034 PAUSE Sensor Error Hardware

CAUSE:
An error based on hardware problem occurs in the sensor.
REMEDY:
- Refer the sensor manual to recover.

XSIF-035 PAUSE Sensor Error Bad End

CAUSE:
The sensor is received invalid commands from robot controller.
REMEDY:
- Check communication cable between sensor and robot/sensor controller etc.
- Refer the sensor manual to recover.

XSIF-036 PAUSE Sensor Error Unknown cmd.

CAUSE:
The sensor is received unsupported command from robot controller.
REMEDY:
- Delete the sensor instruction.
- If the sensor supports the command, check communication cable between sensor and robot/sensor controller etc.
- Check the firmware version of sensor.

XSIF-037 PAUSE Sensor Error Setup

CAUSE:
Sensor setting is not correct.
REMEDY:
- Refer the sensor manual to setup again.

XSIF-038 PAUSE Sensor Error Temperature

CAUSE:
Temperature in sensor is too high/low.
REMEDY:
- Do warm-up operation.
- Refer the sensor manual to recover.

XSIF-039 PAUSE Sensor Error Out of Range

CAUSE:
The sensor is received invalid commands from robot controller.
The sensor configuration is out of range.
REMEDY:
- Refer the sensor manual to recover.

XSIF-040 PAUSE Sensor Error Joint not found

CAUSE:
The sensor cannot detect the joint.
REMEDY:
- Check the workpieces position.
- Check the detection range of the sensor.
- Refer the sensor to recover.

XSIF-041 PAUSE Sensor Timeout SR %s CMD %d

CAUSE:
No acknowledge code from the sensor in specified wait time.
REMEDY:
- Check XSIF-042 did not occur at startup the robot controller.
- Check communication cable between sensor and robot/sensor controller etc.
- Refer the sensor manual to recover.

XSIF-042 PAUSE Sensor Fail Connect SR %s

CAUSE:
The robot controller cannot connect to the sensor at startup.
REMEDY:
- Power off the robot controller after the following remedies
- Check communication cable between sensor and robot/sensor controller etc.
- Check the IP address of sensor is correct or not.
- Check the IP address of port-3 of the robot controller is correct or not.
- Refer the subnet mask.

XSIF-043 PAUSE Sensor PORT-3 Not Set SR %s

CAUSE:
Sensor is not connected to port-3 of the robot controller.
REMEDY:
- Use port-3 to communicate to the sensor.

XSIF-044 PAUSE Sensor %d Name Not Set

CAUSE:
IP address is unknown corresponding to sensor name
REMEDY:
- Add relationship between sensor name and IP address to host list.

XSIF-045 PAUSE Sensor Error SR %s E-Code %d

CAUSE:
The sensor sends the E-Code to the robot controller.
REMEDY:
- Refer the sensor manual to recover.
- Press reset key.

XSIF-046 PAUSE Sensor %d Not Enabled

CAUSE:
The sensor is disabled.
REMEDY:
- If you don’t use the sensor, ignore the alarm.
- If you use the sensor,
  1. Enable the sensor.
  2. Power off/on the robot controller.
  3. Setup the sensor.¥

XSIF-060 PAUSE Invalid params. %d^1

CAUSE:
The sensor received an invalid parameters.
REMEDY:
- Check the sensor configuration.
- Check the sensor schedule.

XSIF-061 WARN No group mask G %d^1 SR %d^1

CAUSE:
The group mask of TP program does not include the robot group equipped the corresponding the sensor.
REMEDY:
- Remove the sensor instruction or add the robot group to the TP program.

XSIF-062 PAUSE Req to disable Sensor %d^1

CAUSE:
The sensor that an instruction sends command is disabled.
REMEDY:
- Remove the sensor instruction or enable the sensor.

XSIF-063 WARN G %d^1 has been used for srch

CAUSE:
At multi sensors system, a sensor detects a joint, but other cannot detect a joint and moves to retry process.
REMEDY:
- This is a message.

XSIF-064 PAUSE Search type mismatch %d^1

CAUSE:
At multi sensors system, a sensor is saved search result as position format, but the other is saved it as offset format.
REMEDY:
- Unify the record format.

XSIF-065 PAUSE Invalid offset frame %d^1

CAUSE:
Invalid offset frame is used for bias or retry process.
REMEDY:
- Change the frame type

XSIF-066 PAUSE Invalid offset direction %d^1

CAUSE:
Invalid offset direction is used for retry process.
REMEDY:
- Change the direction type.

XSIF-067 WARN Max search group %d^1

CAUSE:
Retry process will executes with 3 or more robot groups
REMEDY:
- Retry process supports only 2 robot groups.

XSIF-069 PAUSE PREG is duplicated

CAUSE:
The position register to store the search result is used for other process.
REMEDY:
- Change the position register number.

XSIF-070 PAUSE No sensor mask for search

CAUSE:
DETECT JOINT instruction is requested without SEARCH ON instruction.
REMEDY:
- Execute SEARCH ON instruction before DETECT JOINT instruction.

XSIF-071 PAUSE Invalid schedule No.

CAUSE:
The sensor schedule does not exist.
REMEDY:
- Change the sensor schedule number.

XSIF-090 PAUSE Cannot calc. LSM params

CAUSE:
Estimation process cannot execute correctly.
REMEDY:
- Change the Sensitivity to LOW.

XSIF-091 WARN Use old LSM params

CAUSE:
Estimation process cannot execute correctly and use the previous result.
REMEDY:
- This is a message.
- Change the Sensitivity to LOW if recurrent.

XSIF-092 PAUSE Buffer size is out of range

CAUSE:
Detection data for fitting is deleted because lead distance is too long.
REMEDY:
- Adjust the lead distance.

XSIF-093 WARN Not enough data

CAUSE:
Detection data for fitting is no enough because the lead distance is too short or too long.
REMEDY:
- Adjust the lead distance.

XSIF-094 WARN Too long lead dist

CAUSE:
Lead distance is too long.
REMEDY:
- Adjust the lead distance.

XSIF-095 WARN Too short interval to update

CAUSE:
The interval time to communicate to the sensor is too short.
REMEDY:
- Adjust the interval time $XSIF_SR[SR_ID].$TIME_UPD.¥

XSIF-101 PAUSE Cant detect joint continuously

CAUSE:
The sensor fails to detect joint continuously.
REMEDY:
- Change the tack distance.

8.7.1.2 Sensor alarm(DPMO)

DPMO-005 STOP NO Zero Dist Motion

CAUSE:
Cannot tracking when the robot does not have any movements.
REMEDY:
- If stationary tracking, please add COORD instruction to the motion.

DPMO-006 STOP NO Joint Motion

CAUSE:
Cannot tracking with joint motion.
REMEDY:
- Change the motion type to linear or circular.

DPMO-021 STOP WJNT is not supported

CAUSE:
Cannot tracking with WJNT motion.
REMEDY:
- Remove WJNT instruction.

DPMO-031 STOP CD - non CD transition in tracking

CAUSE:
Sensor tracking does not supports transition of coordinated motion(No coord. to coord./coord. to non coord.)in a tracking.
REMEDY:
- Add/Remove COORD instruction.

DPMO-032 STOP Path Offset Limit Error

CAUSE:
Total offset is reached to threshold.
REMEDY:
- Increase the threshold.

9 ADAPTIVE WELDING FUNCTION

9.1 OVERVIEW

Adaptive welding function is used to adjust welding parameters (weld speed, weld schedule, weave amplitude/frequency, tracking bias) based on measured value of joint shape (gap, mismatch, area) in real time during welding.

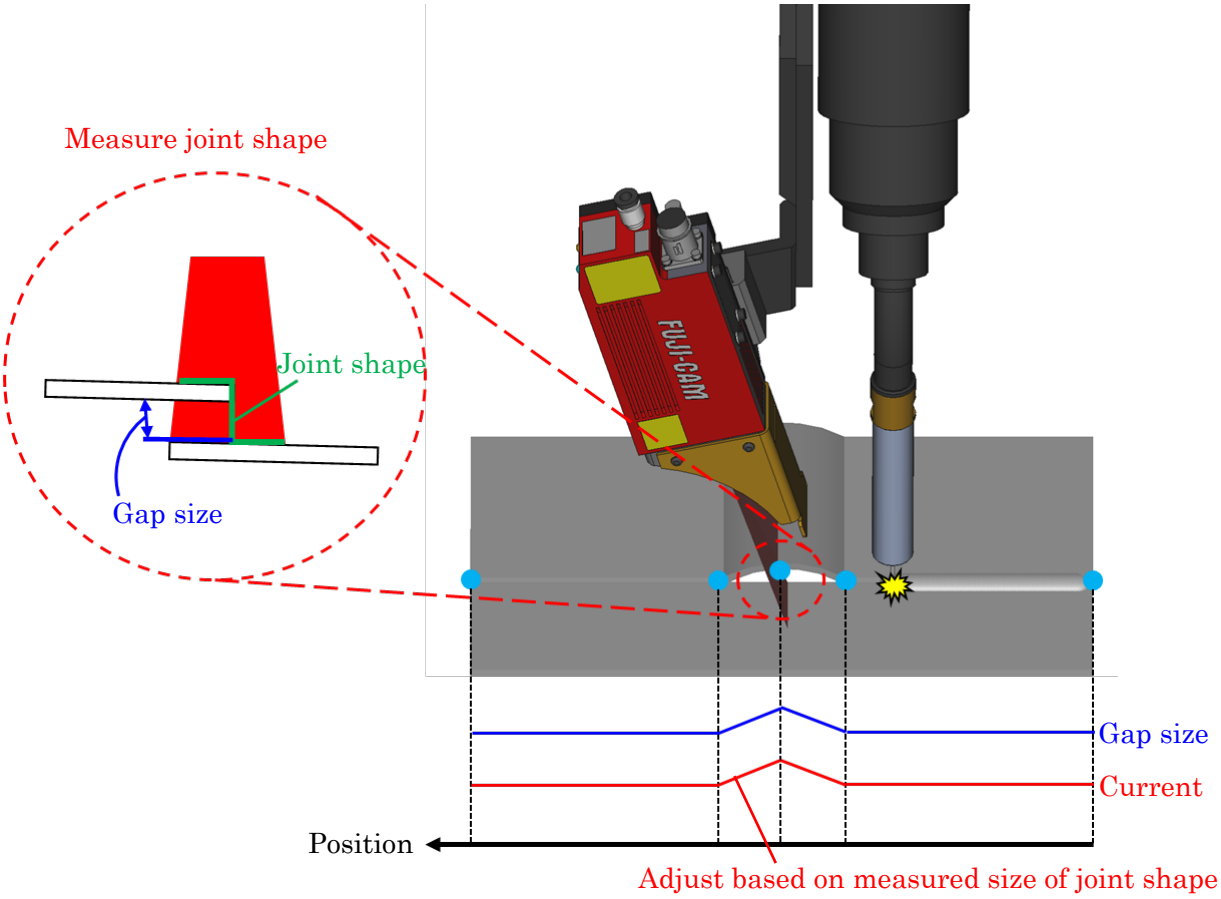


Fig. 9.1 (a) Outline of adaptive welding

NOTE
1 This is special function only for ArcTool.
2 This function has been supported since 7DF3/06.
3 This function adjusts welding parameters based on setup of optimal value correspond to joint shape, so this function does not calculate optimal value automatically based on measured value of joint shape. It is necessary to decide optimal value correspond to joint shape preliminarily, or find optimal value by adjusting setup of this function to achieve stable welding quality.

9.1.1 Restrictions

- Multi-pass welding (adaptive welding after second path) is not supported.

9.1.2 Outline of Adaptive Welding Setup

Adaptive welding function can adjust weld speed, weld schedule, weave schedule (amplitude and frequency) and tracking schedule (bias) based on joint shape (gap, mismatch and area). It is necessary to set what shape corresponds to each parameters and correspondence between command value of welding and measured value of joint shape.

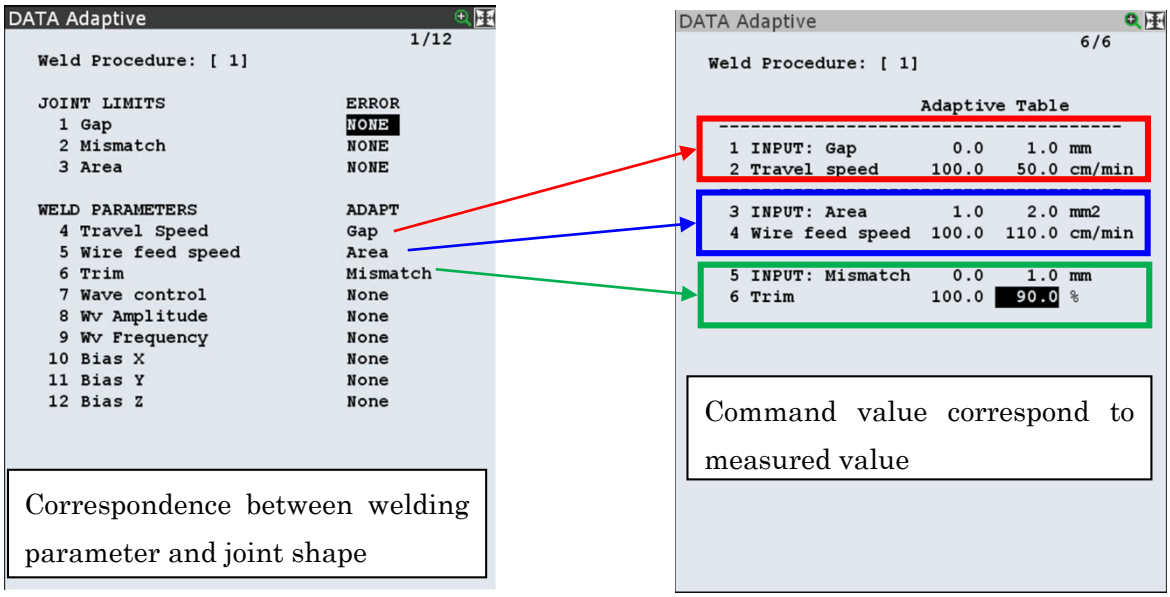
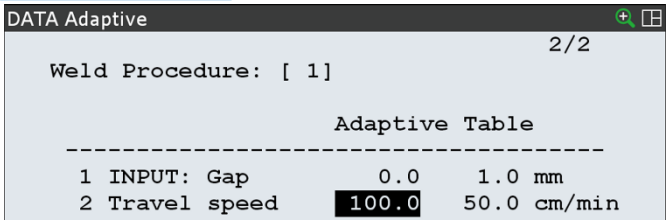


Fig. 9.1.2(a) Outline of adaptive welding setup

Correspondence between welding command value and measured value of joint shape is set in tabular fashion.

2 points table



6 points table

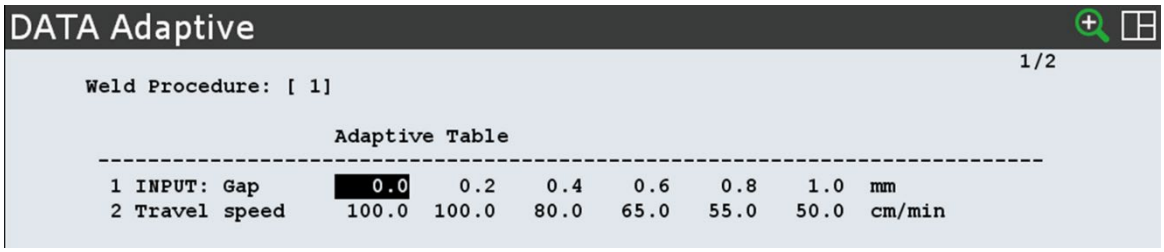


Fig. 9.1.2(b) Adaptive table

9.2 SETTING ADAPTIVE WELDING

9.2.1 Enabling Adaptive Welding Function

Procedure 9-1 Enable adaptive welding function

Step

1 Perform controlled start, then arctool setup screen is displayed.
2 Press the [MENU] key and select “4 Variables”, then system variables screen is displayed.
3 Move the cursor to $AWSADPTCFG and press the [ENTER] key.
4 Move the cursor to $ADPT_WELD and press F4[TRUE].
5 Press the [FCTN] key and select [START (COLD)], and then cold start is performed.

NOTE
This setting is used to make adaptive welding function available. Setting whether use adaptive welding for each weld point is decided by parameter of weld procedure described in Subsection 9.2.3 “Setting Parameters for Adaptive Welding”. So adaptive welding is not executed even if this setting is enabled according to setting of weld procedure.

9.2.2 Enabling Limit Range Setting Function

Limit range setting function allows to post alarm or clamp weld commands to constant value when joint shape size exceeds limit. For more detailed, please refer to Subsection 9.2.5”Limit Method for Joint Shape” and 9.2.6” Limit Method for Weld Command”.

Procedure 9-2 Enable limit range setting function

Step

1 Perform controlled start, then arctool setup screen will be displayed.
2 Press the [MENU] key and select “4 Variables”, then system variables screen will be displayed.
3 Move the cursor to $AWSADPTCFG and press the [ENTER] key.
4 Move the cursor to $ADPT_MINMAX and press F4[TRUE].
5 Press the [FCTN] key and select [START (COLD)], and then cold start will be performed.

NOTE
This function is disabled by default. If it is disabled, limit of joint shape follows setting of table range and limit of weld commands follow original range.

9.2.3 Setting Parameters for Adaptive Welding

When adaptive welding function is enabled, setting items “Adaptive Welding”, “Adaptive Setup” and “Adaptive Table Columns” are added to weld procedure screen.

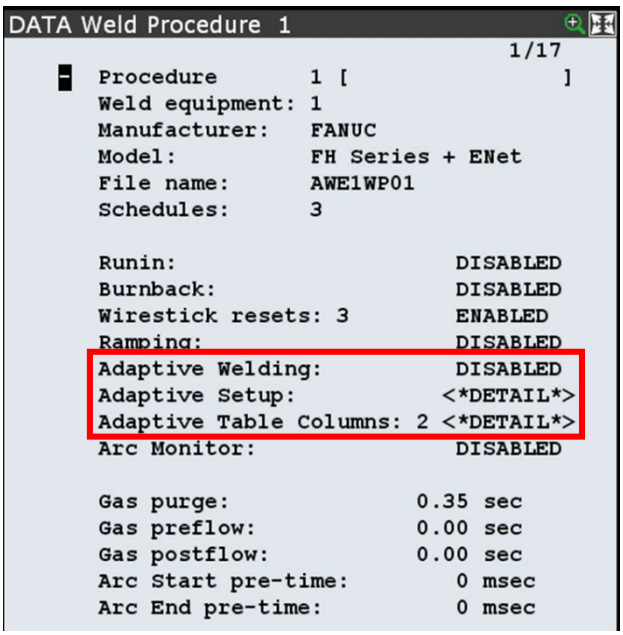


Fig. 9.2.3 (a) Additional items of weld procedure screen

Table 9.2.3 (a) Additional items of weld procedure screen

Item	Description
Adaptive Welding	Shows the sensor schedule. Comments related to this condition can be entered.
Adaptive Setup	The dynamic search function can be enabled or disabled.
Adaptive Table Columns	Specifies the dynamic search speed.

NOTE
These settings cannot be set for each weld schedule. The same settings are used for each weld procedure.

9.2.3.1 Adaptive Setup Screen

This screen is for basic setup of adaptive welding. Please set items on this screen first.

Procedure 9-3 Display adaptive setup screen

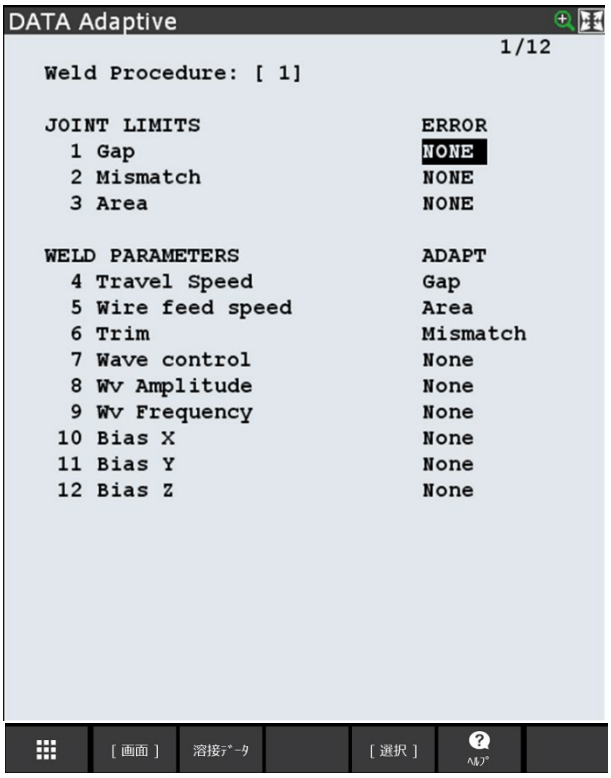
Condition

Adaptive welding function is enabled.

Step

1 Press the [MENU] key and select “3 Data”.
2 Press F1[Type] and select “1 Weld Procedure”. Then weld procedure screen will be displayed.
3 Move the cursor to “Procedure” of weld procedure for adaptive welding and press the [ENTER] key. Then tree view is expanded.
4 Move the cursor to <*DETAIL*> of “Adaptive Setup” and press the [ENTER] key or F2[DETAIL]. Following screen will be displayed.

Limit range setting is disabled



Limit range setting is enabled

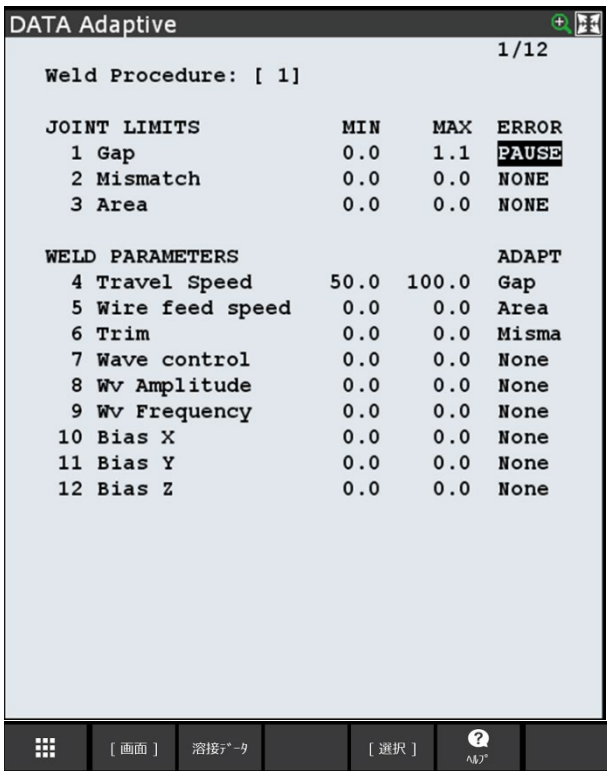


Fig. 9.2.3.1 (a) Setting items of adaptive setup screen

NOTE
Display contents will be changed depending on setup of limit range setting function.

Table 9.2.3.1(a) Setting items of adaptive setup screen

Item	Description
JOINTS LIMITS	Specify alarm severity when joint is out of range. - **NONE:** Alarm is not posted. - **WARN:** Alarm is posted with WARN severity. - **PAUSE:** Alarm is posted with PAUSE severity. - **ABORT:** Alarm is posted with ABORT severity. Alarm codes and messages are as follows. - **Gap:** ARC-260 Gap value is out of range - **Mismatch:** ARC-261 Mismatch value is out of range - **Area** ARC-262 Area value is out of range When limit range setting is enabled, specify minimum and maximum value of joint range to [MIN] and [MAX] columns additionally.

Item	Description
WELD PARAMETERS	Specify joint shape type used to adaptive welding for each parameter. - **None** Disable adaptive welding of this parameter. Weld schedule value is used in this case. - **Gap** Adjust this parameter based on measured gap value. - **Mismatch** Adjust this parameter based on measured mismatch value - **Area** Adjust this parameter based on measured area value **NOTE** Only 1 joint shape type can be specified to 1 parameter. Following weld parameters can be adjusted. - **Weld schedule** Adjust weld speed and weld commands. Available weld command will be changed depending on weld equipment or weld mode. - **Weave schedule** Adjust weave amplitude and weave frequency. Other weave schedule items are not available, so these follow used weave schedule settings. - **Tracking schedule** Adjust bias. Other tracking schedule items are not available, so these follow used tracking schedule settings. **NOTE** If set weld parameter to “None”, please set schedule on each schedule screen. When limit range setting is enabled, specify minimum and maximum value of weld command range to [MIN] and [MAX] columns additionally.

Table 9.2.3.1(b) Function key of adaptive setup screen

Item	Description
F2: WELDPROC	Display specified weld procedure data.

9.2.3.2 Adaptive Table Setup Screen

Correspondence between welding command value and measured value of joint shape can be set in tabular fashion on this screen. For more detailed of how adjust parameters, please refer to Section 9.2.4 “Adjust Method with Adaptive Table”.

Procedure 9-4 Display adaptive table setup screen

Condition

Adaptive welding function is enabled.

Step

1 Press the [MENU] key and select “3 Data”.
2 Press F1[Type] and select “1 Weld Procedure”. Then weld procedure screen is displayed.
3 Move the cursor to “Procedure” of weld procedure for adaptive welding and press the [ENTER] key. Then tree view is expanded.
4 Move the cursor to number of “Adaptive Table Columns”. Then enter number of table column and press the [ENTER] key or F2[DETAIL].
5 Move the cursor to <*DETAIL*> of [Adaptive Setup] and press the [ENTER] key or F2[DETAIL]. Following screen will be displayed.

Fig. 9.2.3.2(a) Adaptive table setup screen (2 columns)

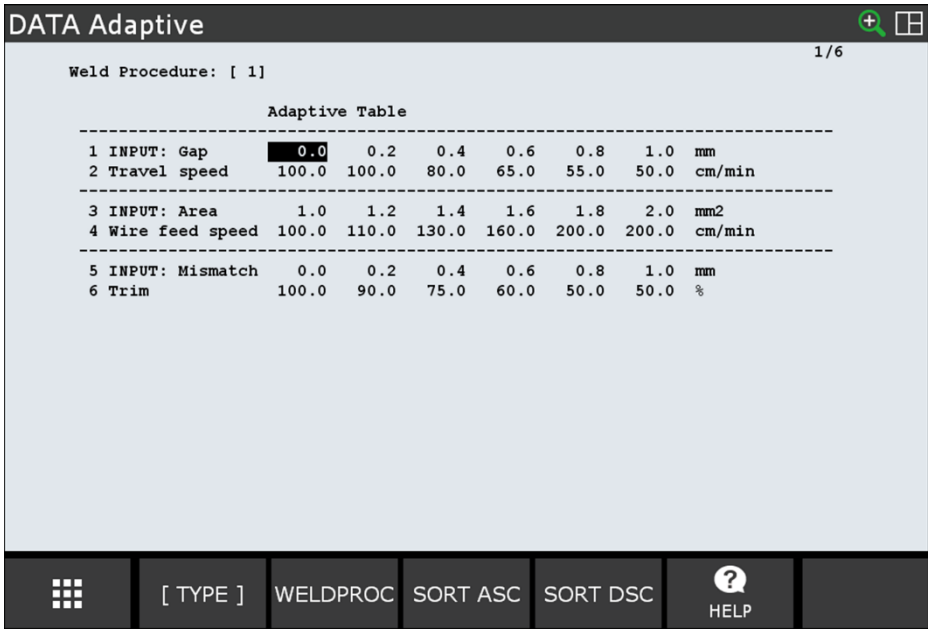


Fig. 9.2.3.2(b) Adaptive table setup screen (6 columns)

NOTE
1. Display contents will be changed depending on setup of adaptive setup screen.
2. Number of columns will be changed depending on setup of “Adaptive Table Columns”.
3. When number of columns is more than “3”, screen is displayed with wide mode automatically if current is single screen. If current is dual screen, displayed with double horizontal mode. After exiting adaptive table setup screen by [PREV] key, screen mode will back to last mode.

Table 9.2.3.2 (a) Setting items of adaptive table setup screen

Item	Description
INPUT: Gap	If there is the parameter whose joint shape type is set to “Gap” on adaptive setup screen, this item and weld parameter will be displayed (in the case of Fig. 9.2.3.2 (a), Travel speed is displayed). Specify correspondence between weld welding command and gap value.
INPUT: Area	If there is the parameter whose joint shape type is set to “Area” on adaptive setup screen, this item and weld parameter will be displayed (in the case of Fig. 9.2.3.2 (a), Wire feed speed is displayed). Specify correspondence between weld welding command and area value.
INPUT: Mismatch	If there is the parameter whose joint shape type is set to “Mismatch” on adaptive setup screen, this item and weld parameter will be displayed (in the case of Fig. 9.2.3.2 (a), Trim is displayed). Specify correspondence between weld welding command and mismatch value.

⚠ CAUTION
Please specify correspondence between welding command and joint shape value to all columns correctly based on assumed joint shape. If there is wrong setting or unset column, adaptive welding may not execute correctly, so unexpected welding or robot motion may occur.

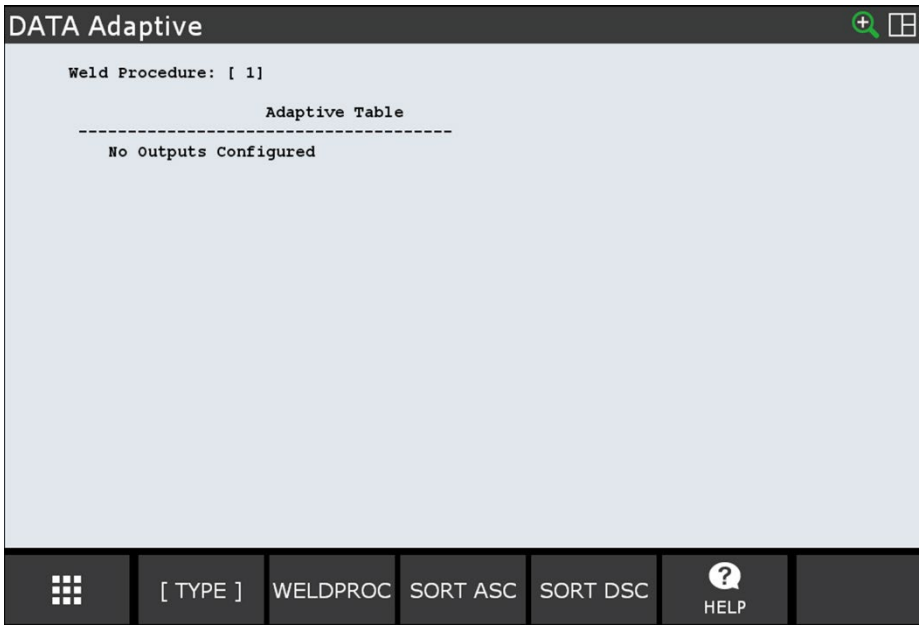
Table 9.2.3.2 (b) Function key of adaptive table setup screen

Item	Description
F2: WELDPROC	Display specified weld procedure data.

Item	Description
F3: SORT ASC	Sort setting values of line with cursor in ascending order.
F4: SORT DSC	Sort setting values of line with cursor in descending order.

NOTE

When joint shape type is set to “None” for all welding parameters on adaptive setup screen, screen is displayed as follows. In this case, adaptive welding is not executed.



9.2.4 Adjust Method with Adaptive Table

Correspondence between welding commands and joint shape can be set as tabular fashion on the screen described in Section 9.2.3.2 “Adaptive Table Setup Screen”. In this section, it is described how this function adjusts welding commands based on the above settings.
Adaptive welding function adjusts welding commands based on adaptive table. Commands which correspond to measured joint shape size is calculated with linear formula between each column. Following is the example of adjustment with 2 and 6 columns table. In the case of Fig. 9.2.4 (a), when measured gap value is 0.3mm, command of 6 columns table is 90cm/min and command of 2 columns table is 85 cm/min.

2 columns table

DATA Adaptive

2/2

Weld Procedure: [1]

Adaptive Table

1 INPUT: Gap	0.0	1.0	mm
2 Travel speed	100.0	50.0	cm/min

6 columns table

DATA Adaptive

1/2

Weld Procedure: [1]

Adaptive Table

1 INPUT: Gap	0.0	0.2	0.4	0.6	0.8	1.0	mm
2 Travel speed	100.0	100.0	80.0	65.0	55.0	50.0	cm/min

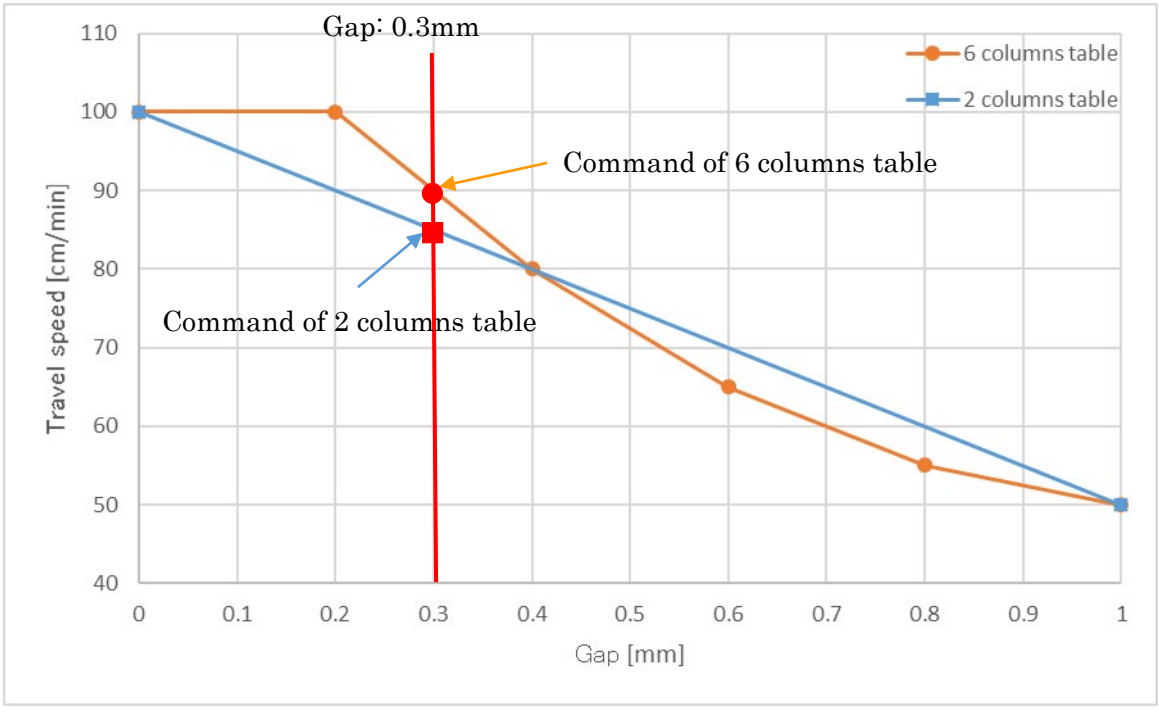
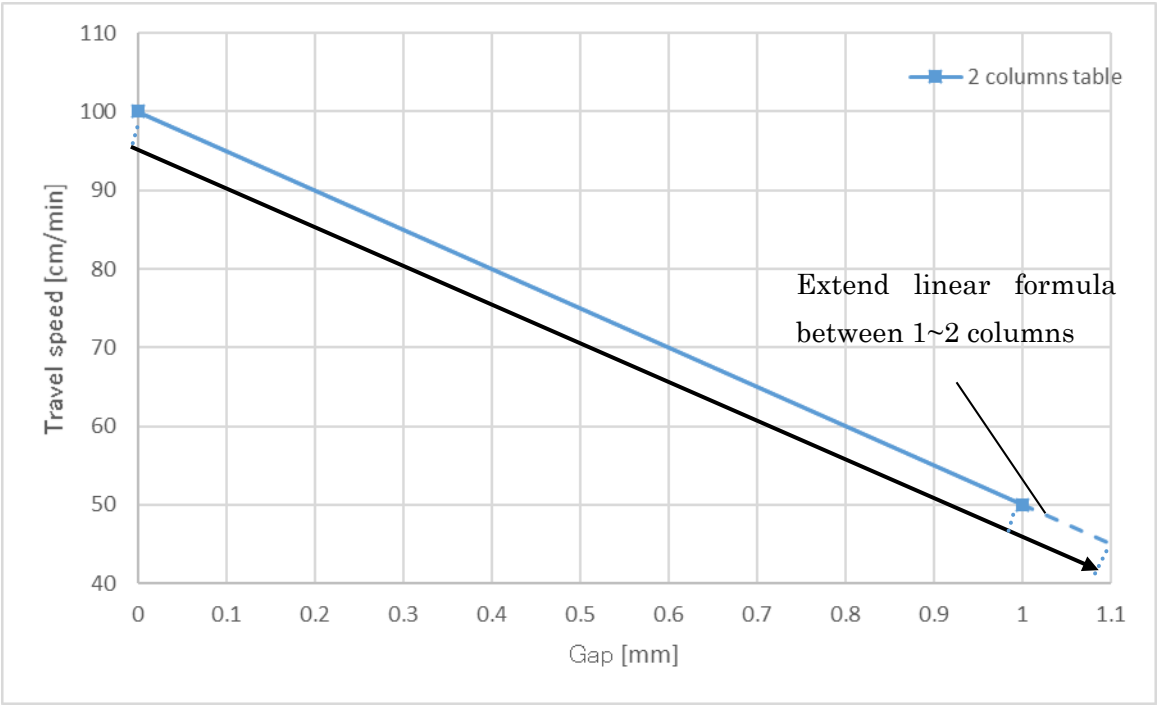


Fig. 9.2.4 (a) Outline of adjustment based on adaptive table

9.2.4.1 Adjustment for Out of Range of Table Setting

If measured joint shape value exceeds range of table setting (in the case of Fiq. 9.2.4 (a), 0~1mm), command is calculated with extended linear formula from last pair. Following is the example of Fig. 9.2.4 (a) setting case.

2 columns table



6 columns table

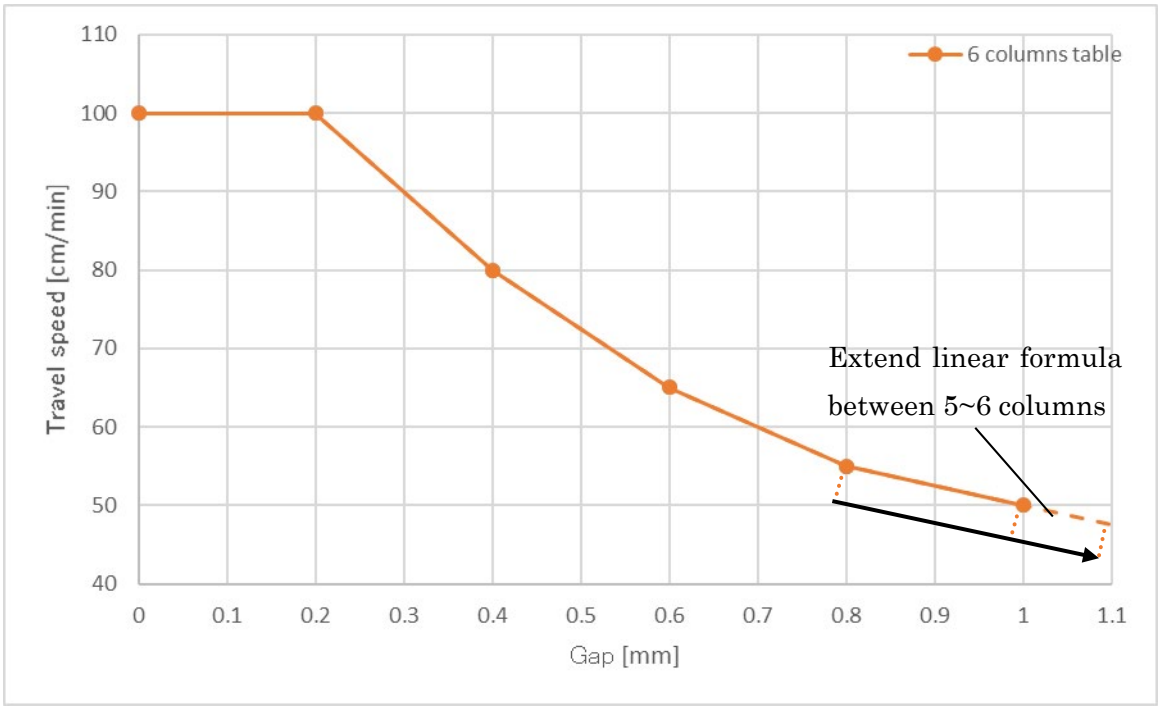


Fig. 9.2.4.1 (a) Adjustment for out of range of table setting

9.2.5 Limit Method for Joint Shape

If limit range of joint shape is set, it is possible to post alarm when measured joint shape value exceeds limit range. There are 2 ways to specify limit range.

9.2.5.1 Use Same Range of Adaptive Table

If the acceptable range of production corresponds to adaptive table range, this method is recommended. In this method, additional setting is not necessary. Minimum and maximum values are used as limit range. Following is the example of 6 columns table. In this case, limit range is 0~1mm, so alarm occurs when measured gap value exceeds 1mm.

6 columns table

DATA Adaptive

1/2

Weld Procedure: [1]

Adaptive Table

1 INPUT: Gap	0.0	0.2	0.4	0.6	0.8	1.0	mm
2 Travel speed	100.0	100.0	80.0	65.0	55.0	50.0	cm/min

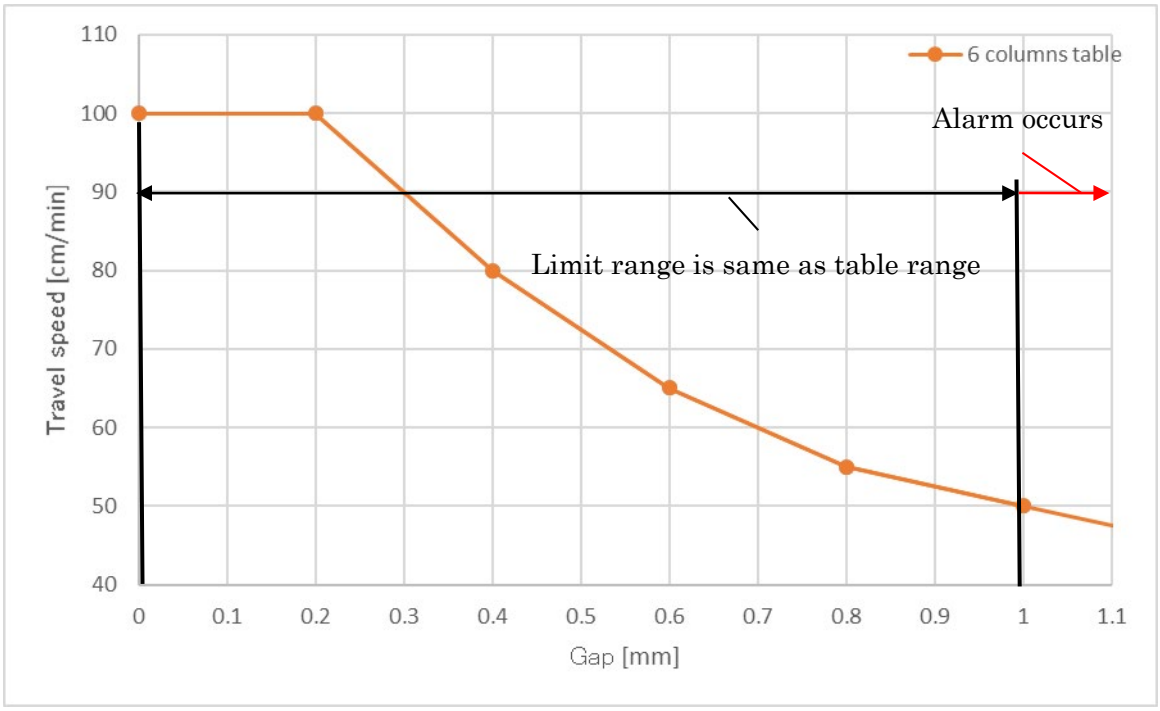


Fig. 9.2.5.1 (a) In the case of that limit range is same as table range

9.2.5.2 Use Limit Range Setting Function

If the acceptable range of production is different from adaptive table range, this method is recommended. In this method, additional setting is necessary on adaptive setup screen. Minimum and maximum values are set as follows. Following is the example when adaptive table is set like Fig. 9.2.5.1 (a). In this case, table range is 0~1mm, but limit range is 0~1.1mm, so alarm occurs when measured gap value exceeds 1.1mm.

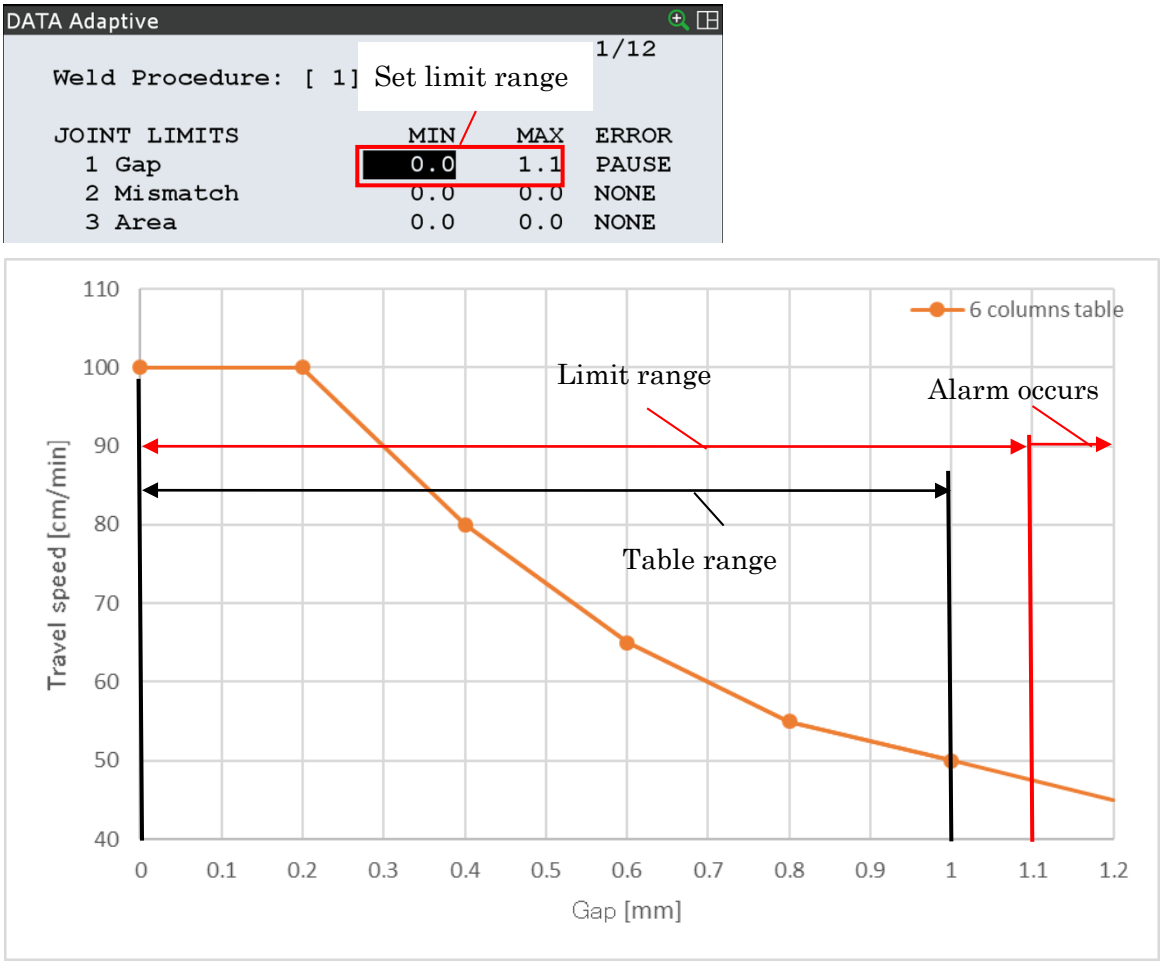


Fig. 9.2.5.2 (a) In the case of that limit range is different from table range

NOTE
This method is disabled by default. It is necessary to enable limit range setting function by procedure 9.2.2.

9.2.6 Limit Method for Weld Command

It is possible to clamp weld command in limit range when adjusted command exceeds limit range with this function. Limit range can be set as follows. Following is the example when adaptive table is set to 6 columns. In this case, if gap exceeds 1mm, command is normally lower than 50cm/min by calculation with extended linear formula like Fig. 9.2.4.1(a). However, if limit range is set, command is clamped to 50cm/min.

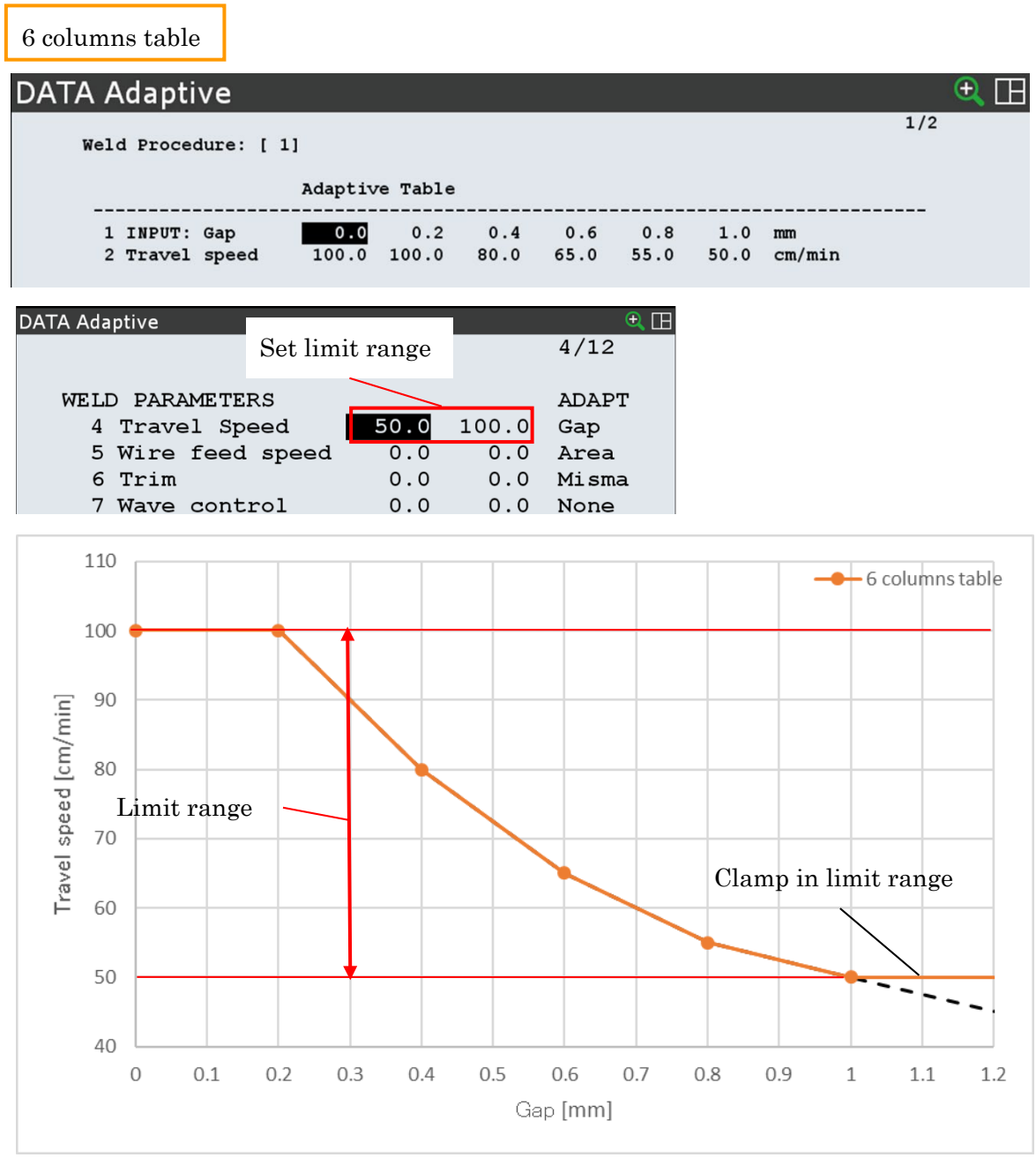


Fig. 9.2.6 (a) Limit weld command

NOTE
This method is disabled by default. It is necessary to enable limit range setting function by procedure 9.2.2.

9.3 TEACHING ADAPTIVE WELDING

Before teaching adaptive welding, please confirm that following settings are completed.
- Weld procedure and weld schedule
- Sensor schedule
- Weave schedule
- Adaptive setup
- Adaptive table setup

NOTE
Please set basic schedule in each schedule screen even if it is adjusted by adaptive welding. It is because it may take some times that adjusted weld command is applied to actual welding. If basic schedule largely differs from adaptive setup, weld quality just after weld start may become worse.

Method of adaptive welding is basically same as normal arc welding. For more detailed of teaching arc welding, please refer to Chapter 4 in OPERATOR'S MANUAL (Arc Welding Function) (B-83284EN-3). For more detailed of teaching weaving, please refer to Chapter 8 in OPERATOR'S MANUAL (Arc Welding Function) (B-83284EN-3).

9.3.1 Sample Program of Adaptive Welding

Followings are sample program and image of robot motion of adaptive welding. In this case, adaptive welding is executed in the area described in Fig. 9.3.1(b).

```
 1:J P[1] 20% FINE              !-- Move to search operation position
 2:  WAIT    1.00(sec)          !-- Wait to avoid effect of vibration
 3:  SENSOR ON[1,*,*,*]         !-- Sensor becomes ON
 4:  SEARCH ON[1,*,*,*]!-- Start search process
 5:  DETECT JOINT[1,1]          !-- Detect joint by schedule 1 and store to PR[1]
 6:  LOCK PREG                  !-- Lock PR[1] for look-ahead execution
 7:  Track DPM[1]               !-- Start tracking with schedule 1
                                !-- Move to searched position (approach motion)
 8:L PR[1] 100cm/min FINE
  :  Weld Start [1,1] ;         !-- Start welding with weld procedure 1 and schedule 1
 9:L P[2] 100cm/min FINE
  :  Weld End[1,1]              !-- End welding
10:  Track End                  !-- End tracking
11:  UNLOCK PREG                !-- Unlock PR[1]
12:L P[3] 200cm/min FINE        !-- Evacuation motion
```

Fig. 9.3.1 (a) Sample program

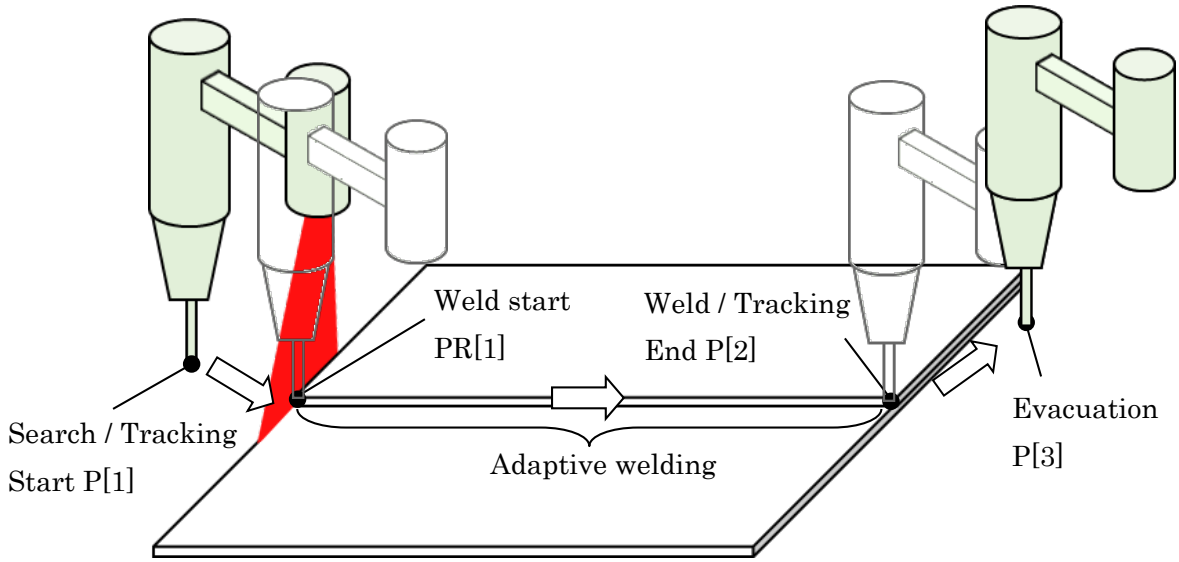
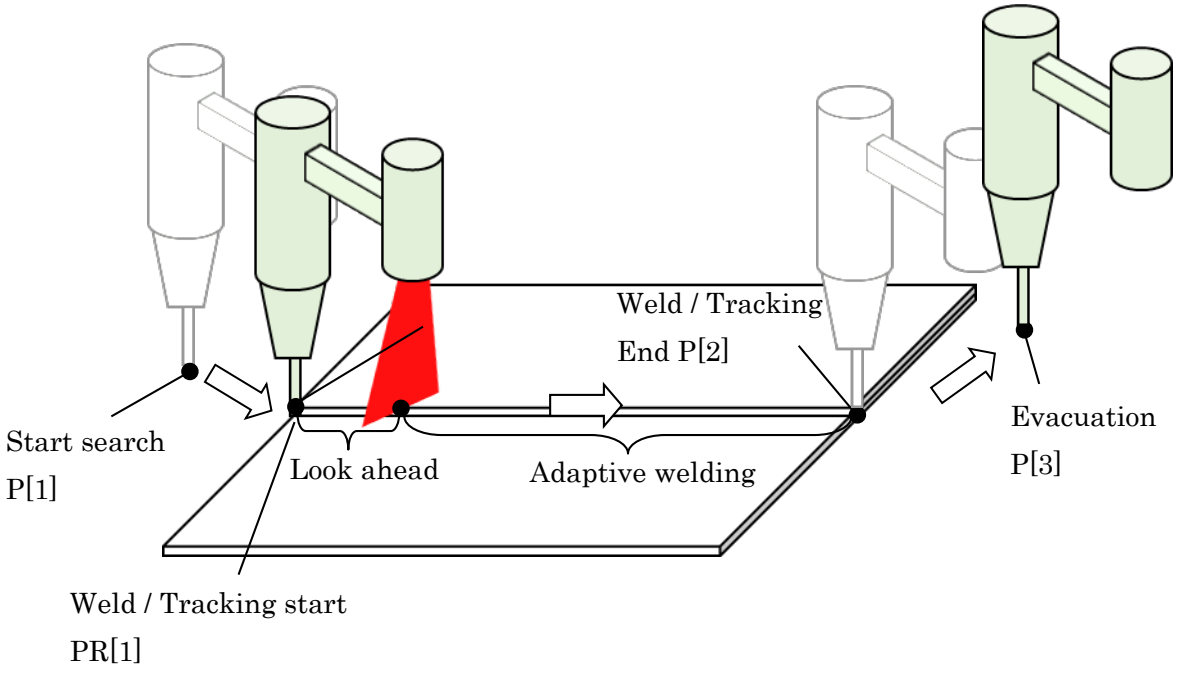


Fig. 9.3.1 (b) Robot motion

NOTE

If it is necessary to execute adaptive welding from weld start position, please teach like the above sample program which starts tracking from approach motion. If program is taught to start tracking from weld start position like following, adaptive welding is not executed in look ahead area described in following figure. Joint shape information cannot be obtained in this area, so normal welding is executed. Adaptive welding is only executed in the area described in following figure.

```
 1:J P[1] 20% FINE              !-- Move to search operation position
 2:   WAIT     1.00(sec)        !-- Wait to avoid effect of vibration
 3:   SENSOR ON[1,*,*,*]        !-- Sensor becomes ON
 4:   SEARCH ON[1,*,*,*]!-- Start search process
 5:   DETECT JOINT[1,1]         !-- Detect joint by schedule 1 and store to PR[1]
 6:   LOCK PREG                 !-- Lock PR[1] for look-ahead execution
                                !-- Move to searched position (approach motion)
 7:L PR[1] 100cm/min FINE
 :   Weld Start [1,1] ;         !-- Start welding with weld procedure 1 and schedule 1
 8:   Track DPM[1]              !-- Start tracking with schedule 1
 9:L P[2] 100cm/min FINE
  :   Weld End[1,1]             !-- End welding
10:   Track End                 !-- End tracking
11:   UNLOCK PREG               !-- Unlock PR[1]
12:L P[3] 200cm/min FINE        !-- Evacuation motion
```



9.4 ADAPTIVE WELDING WITH MULTI EQUIPMENT AND MULTI ARM

Before teaching adaptive welding, please confirm that following settings are completed.
Adaptive welding supports multi equipment and multi arm system like Fig. 9.4.1(b). For more detailed of multi equipment, please refer to Chapter 25 in OPERATOR'S MANUAL (Arc Welding Function) (B-83284EN-3).

NOTE
It is necessary to set motion group coupling to execute adaptive welding in this configuration. For more detailed of motion group coupling, please refer to Section 25.5 in OPERATOR'S MANUAL (Arc Welding Function) (B-83284EN-3).

9.4.1 Sample Program of Adaptive Welding

Fig. 9.4.1(a) and Fig. 9.4.2 are sample program and example of system configuration to execute adaptive welding with multi equipment and multi arm. In this example, positioner of group 3 rotates workpiece and welding robots of group 1 and 2 weld with tracking.

```
 1:J P[1] 20% FINE              !-- Move to search operation position
 2:  WAIT    1.00(sec)          !-- Wait to avoid effect of vibration
 3:  SENSOR ON[1,1,*,*]         !-- Sensor becomes ON
 4:  SEARCH ON[1,1,*,*]         !-- Start search process
 5:  DETECT JOINT[1,1]          !-- Detect joint by schedule 1 and store to PR[1]
 6:  LOCK PREG                  !-- Lock PR[1] for look-ahead execution
 7:  Track DPM[1]               !-- Start tracking with schedule 1
                                !-- Move to searched position (approach motion)
 8:L PR[1] 100cm/min FINE COORD
  :  Weld Start E1[1,1,E2]      !-- Start E1 welding with weld procedure 1 and schedule 1
 9:  Weld Start E2[1,1,E1]      !-- Start E2 welding with weld procedure 1 and schedule 1
10:C P[2]
  :  P[3] 100cm/min CNT100 COORD
11:C P[4]
  :  P[5] 100cm/min CNT100 COORD
12:C P[6]
  :  P[7] 100cm/min FINE COORD
  :  Weld End E1[1,1,E2]        !-- End E1 welding
13:  Weld End E2[1,1,E1]!-- End E2 welding

14:  Track End                  !-- End tracking
15:  UNLOCK PREG                !-- Unlock PR[1]
16:L P[8] 200cm/min FINE        !-- Evacuation motion
```

Fig. 9.4.1 (a) Sample program

> ⚠ **CAUTION**
> When coordinated motion is used, weld speed will be adjusted depending on adaptive settings of weld equipment connected to back robot group. For example, weld speed will be adjusted depending on adaptive settings of EQ2 in the case of that system configuration is group 1: arc robot 1 and EQ1, group 2: arc robot 2 and EQ2, group 3: positioner. Weld speed may be adjusted unexpectedly by weld equipment connected to other group, so don't adjust weld speed basically when coordinated motion is used. If it is necessary, please contact your local FANUC representative.

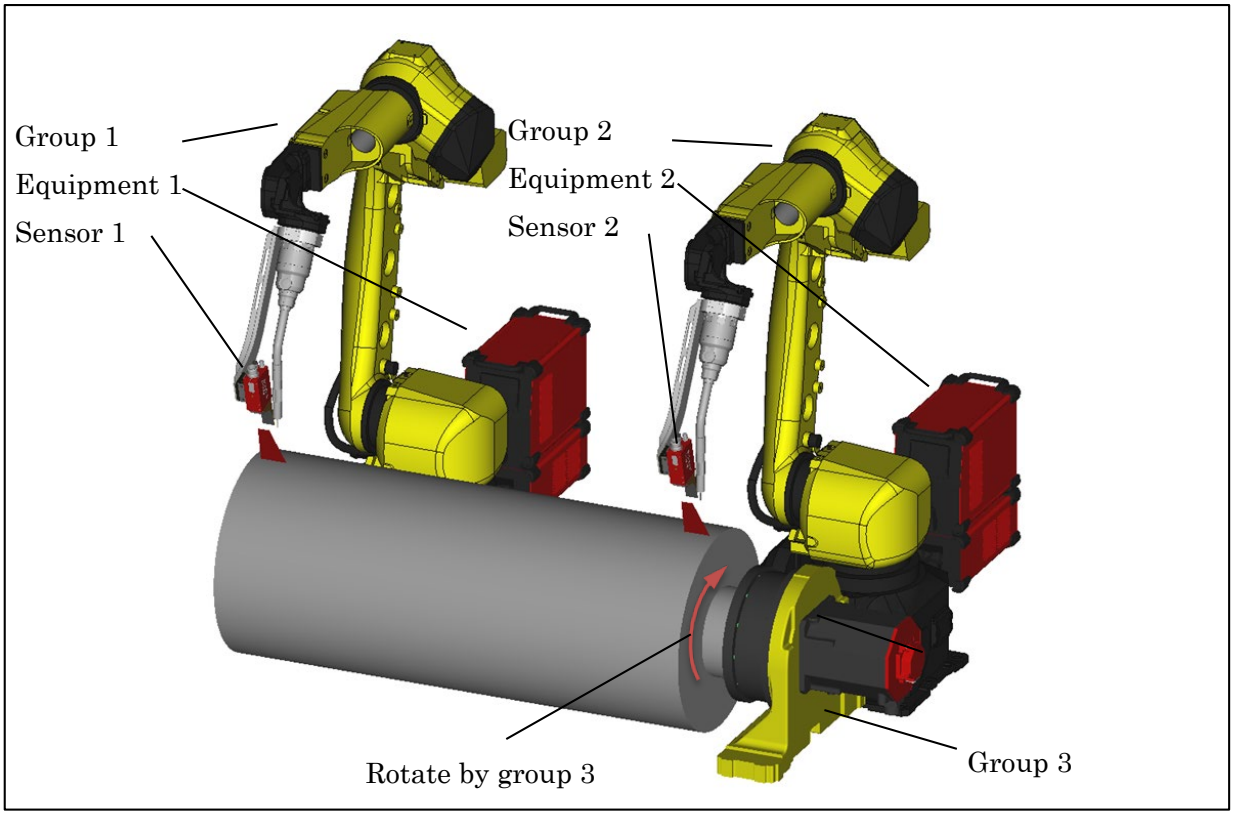


Fig. 9.4.1 (b) Example of system configuration

APPENDIX

A MAINTENANCE PARTS

Table A (a) Maintenance parts

Parts name	Specifications	Remarks
FUJI-CAM 2.0 3B	A14L-0166-0859#3B	Including attached
FUJI-CAM 2.0 2M	A14L-0166-0859#2M	Including attached
FUJI-CAM/SHR 3B	A14L-0166-0854#3B	Including attached
FUJI-CAM/SHR 2M	A14L-0166-0854#2M	Including attached
Connection cable between the sensor and the robot controller 5m	A14L-0166-0852#07702505	For FUJI-CAM2.0 用
Connection cable between the sensor and the robot controller 10m	A14L-0166-0852#07702510	For FUJI-CAM 2.0 (standard appendix)
Connection cable between the sensor and the robot controller 20m	A14L-0166-0852#07702520	For FUJI-CAM 2.0
Connection cable between the sensor and the robot controller 30m	A14L-0166-0852#07702530	For FUJI-CAM 2.0
Connection cable between the sensor and the robot controller 40m	A14L-0166-0852#07702540	For FUJI-CAM 2.0
Connection cable between the NANO-BOX and the robot controller 5m	A14L-0166-0852#07702505	For FUJI-CAM/SHR
Connection cable between the NANO-BOX and the robot controller 10m	A14L-0166-0852#07702510	For FUJI-CAM/SHR (standard appendix)
Connection cable between the NANO-BOX and the robot controller 20m	A14L-0166-0852#07702520	For FUJI-CAM/SHR
Connection cable between the NANO-BOX and the sensor 2m	A14L-0166-0852 #077402	For FUJI-CAM/SHR (standard appendix)
Connection cable between the NANO-BOX and the sensor 5m	A14L-0166-0852#077405	For FUJI-CAM/SHR
Protection lens	A14L-0166-0852#30100042	50 pcs (for FUJI-CAM 2.0)
Protection lens	A14L-0166-0852#2681113	25 pcs (for FUJI-CAM/SHR)

- Make total length of the connection cable between the NANO-BOX and the robot controller and connection cable between the NANO-BOX and the sensor less than 30m.

B PERIODIC MAINTENANCE TABLE

(○ : Item needs to be performed.)

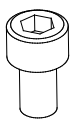
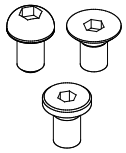
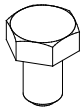
Items	Every day	Twice in one week	1 month (320 hours)	3 month (960 hours)
Check and cleaning the protection lens	○			
Cleaning the laser camera nozzle	○			
Check the air flow of the air filtering system		○		
Check the air filter of the air filtering system		○		
Cable fixation check		○		
Check the cable damage		○		
Check and cleaning the laser camera fixed lens		○		
Cleaning the camera holder		○		
Check the calibration of the camera and the tool		○		
Ground Fault Detector			○	
Purge air supply system			○	
Check air leak from the connectors and the tubes			○	
Check the tightness of the bracket mounting bolts				○

C STRENGTH OF BOLT AND BOLT TORQUE LIST

NOTE
When applying LOCTITE to a part, spread the LOCTITE on the entire length of the engaging part of the female thread. If applied to the male threads, poor adhesion can occur, potentially loosening the bolt. Clean the bolts and the threaded holes and wipe off any oil on the engaging section. Make sure that there is no solvent left in the threaded holes. When finished, remove all the excess LOCTITE when you are finished screwing the bolts into the threaded holes.

Use the following strength bolts. Comply with any bolt specification instructions.
Hexagon socket head bolt made of steel:
Size M22 or less: Tensile strength 1200N/mm^2 or more
Size M24 or more: Tensile strength 1000N/mm^2 or more
All size plating bolt: Tensile strength 1000N/mm^2 or more
Hexagon bolt, stainless bolt, special shape bolt (button bolt, low-head bolt, flush bolt .etc.)
Tensile strength 400N/mm^2 or more
Refer to the following tables if the bolts tightening torque is not specified.

Recommended bolt tightening torques **Unit: Nm**

Nominal diameter	Hexagon socket head bolt (steel)		Hexagon socket head bolt (stainless)		Hexagon socket head button bolt Hexagon socket head flush bolt Low-head bolt (steel)		Hexagon bolt (steel)	
	Tightening torque		Tightening torque		Tightening torque		Tightening torque	
	Upper limit	Lower limit	Upper limit	Lower limit	Upper limit	Lower limit	Upper limit	Lower limit
M3	1.8	1.3	0.76	0.53	———	———	———	———
M4	4.0	2.8	1.8	1.3	1.8	1.3	1.7	1.2
M5	7.9	5.6	3.4	2.5	4.0	2.8	3.2	2.3
M6	14	9.6	5.8	4.1	7.9	5.6	5.5	3.8
M8	32	23	14	9.8	14	9.6	13	9.3
M10	66	46	27	19	32	23	26	19
M12	110	78	48	33	———	———	45	31
(M14)	180	130	76	53	———	———	73	51
M16	270	190	120	82	———	———	98	69
(M18)	380	260	160	110	———	———	140	96
M20	530	370	230	160	———	———	190	130
(M22)	730	510	———	———	———	———	———	———
M24	930	650	———	———	———	———	———	———
(M27)	1400	960	———	———	———	———	———	———
M30	1800	1300	———	———	———	———	———	———
M36	3200	2300	———	———	———	———	———	———
								

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REVISION RECORD

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