EPSON

EPSON RC+ 7.0 Option

Force Control 7.0

Rev.5

EM183S3604F

EPSON RC+ 7.0 Option Force Control 7.0 Rev.5

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FOREWORD

Thank you for purchasing our robot products. This manual contains the information necessary for the correct use of the Force Control 7.0.
Please carefully read this manual and other related manuals when using this software.
Keep this manual in a handy location for easy access at all times.

WARRANTY

The robot and its optional parts are shipped to our customers only after being subjected to the strictest quality controls, tests and inspections to certify its compliance with our high performance standards.
Product malfunctions resulting from normal handling or operation will be repaired free of charge during the normal warranty period. (Please ask your Regional Sales Office for warranty period information.)
However, customers will be charged for repairs in the following cases (even if they occur during the warranty period):

1. Damage or malfunction caused by improper use which is not described in the manual, or careless use.

2. Malfunctions caused by customers' unauthorized disassembly.

3. Damage due to improper adjustments or unauthorized repair attempts.

4. Damage caused by natural disasters such as earthquake, flood, etc.

Warnings, Cautions, Usage:

1. If the robot or associated equipment is used outside of the usage conditions and product specifications described in the manuals, this warranty is void.

2. If you do not follow the WARNINGS and CAUTIONS in this manual, we cannot be responsible for any malfunction or accident, even if the result is injury or death.

3. We cannot foresee all possible dangers and consequences. Therefore, this manual cannot warn the user of all possible hazards.

TRADEMARKS

TRADEMARK NOTIFICATION IN THIS MANUAL

Microsoft® Windows® XP Operating system
Microsoft® Windows® Vista Operating system
Microsoft® Windows® 7 Operating system
Microsoft® Windows® 8 Operating system
Microsoft® Windows® 10 Operating system

Throughout this manual, Windows XP, Windows Vista, Windows 7, Windows 8, and Windows 10 refer to above respective operating systems. In some cases, Windows refers generically to Windows XP, Windows Vista, Windows 7, Windows 8, and Windows 10.

NOTICE

The contents of this manual are subject to change without notice.

Please notify us if you should find any errors in this manual or if you have any comments regarding its contents.

MANUFACTURER

SEIKO EPSON CORPORATION

SAFETY PRECAUTIONS

Installation of robots and robotic equipment should only be performed by qualified personnel in accordance with national and local codes. Please carefully read this manual and other related manuals when using this software.

Keep this manual in a handy location for easy access at all times.

WARNING	This symbol indicates that a danger of possible serious injury or death exists if the associated instructions are not followed properly.
CAUTION	This symbol indicates that a danger of possible harm to people or physical damage to equipment and facilities exists if the associated instructions are not followed properly.

Installation

Hardware

Software

Installation

The following chapters contain information to be known before using Force Control 7.0.
Please be sure to read these chapters.

1. Introduction

1.1 Overview of Force Control 7.0

Force Control 7.0 is an option product and generic name for the following parts:

Force sensor
Intermediate unit (between force sensor and robot controller)
Cable
Software

Force Control 7.0 supports various applications such as fitting, surface processing, pressing, inspection or teaching.

It also allows jogging the robot while checking the output of force sensor and assists with shortening the teaching time.

Force Control 7.0 has the following features.

Force Control function

Position adjustment is done on the coordinate axis moved by external force independently. (Such as only Z-axis or U-axis)
Allows different control characteristics for each axis.
Covers tolerances of provided work pieces.

Force Trigger function

Keeps monitoring precise force, torque, and their changes.

- Possible to program the judgments of success and failure and the conditional branching with operations in an assigned task.
- Detects the position of an end of work piece or protruding and dent position.
- Detects force or torque abnormalities.

Force Monitor function

Displays charts of force and torque in different coordinate systems.
Saves log files in PC.

- Utilizes them for shorter optimization time and process management information.

Gravity compensation function

Minimizes the effect of gravity in the following functions while the orientation changes.
Force Control, Force Trigger, and Force Monitor functions.

Mass property wizard

Measures the gravity center and the mass of an end effector without CAD data or hand removal.

Impedance wizard

Estimates the effect of the Force Control parameters on motion.

1.2 Necessary Basic Knowledge of EPSON RC+ 7.0

Force Control 7.0 is an option used in the EPSON RC+ 7.0 environment. Knowledge of the EPSON RC+ 7.0 development environment and EPSON robots is required to use Force Control 7.0. This manual is intended for users who have knowledge about the following.

- Concept and use of the EPSON RC+ 7.0 project management
- Procedure to create and edit a SPEL$^+$ program in EPSON RC+ 7.0
- Procedure to run a SPEL$^+$ program from the Run window
- Basic language structure, functions, and use of SPEL$^+$

First-time users of EPSON RC+ 7.0 are required to take an introduction training course provided by Epson.

1.3 Training

Before using the Force Control 7.0 please be sure to take our “Force Sensing introduction training”. The training provides safe and easy operation of the product and also helps you to improve productivity of your system.

2. Definition of Terms

Position

Position of an object or a coordinate system in a coordinate system, expressed using position data (X, Y, Z).

Posture

Posture of an object or a coordinate system in a coordinate system, expressed using posture data (U, V, W).

Position/posture

Position and posture of an object or a coordinate system in a coordinate system, expressed using position and posture data (X, Y, Z, U, V, W).

Force Sensor

Sensor made by Epson, which detects the force and torque in six axes in the translation direction (Fx, Fy, Fz) and rotating direction (Tx, Ty, Tz). There are the following eight types.

S250N, S250L, S250P, S250H, S2503, S2506, S25010, SH250LH

Force Sensor I/F unit

Unit that connects the Epson sensor and the controller.
Connect the unit and the controller with a communication cable to use.

Force Sensor I/F board

Option board that connects the Epson sensor and the controller.
Mount the board on the option slot of the controller to use.

Sensor flange

Part to be mounted between the Force Sensor and the robot wrist flange to mount the Force Sensor to the robot.

Flange offset

Offset of the sensor flange. Use the bottom center position of the Force Sensor viewed from the tool 0 coordinate system of the robot as the origin and set the position and posture of the coordinate system so its direction aligns with the Force Sensor coordinate system.

Force functions

Functions using the Force Sensor provided by Force Control 7.0.

Force control function

Function to control the robot to achieve a given target force or torque using the Force Sensor.

Virtual inertia coefficient (Mass)

Parameter for the virtual mass of the force control function. It impacts the acceleration of the force control function.

Virtual viscosity coefficient (Damper)

Parameter for the virtual viscosity of the force control function. It impacts the speed of the force control function.

Virtual elasticity coefficient (Spring)

Parameter for the virtual spring coefficient of the force control function. It impacts the amount of movement of the force control function.

Force trigger function

Function to detect that the force or torque measured using the Force Sensor reached the set value and branch the process.

Force monitor function

Function to measure the force and torque using the Force Sensor.

Force Sensor coordinate system

Coordinate system in which the Force Sensor detects the force. It is a Force Sensor-specific coordinate system. It cannot be changed.

Force coordinate system

Coordinate system in which the force functions are performed. It is defined by the offset of the currently used tool coordinate system.

Gravity compensation

Function to reduce the impact of gravity on the Force Sensor.

Mass properties

Mass characteristic parameter used for gravity compensation. Set the weight and gravity center position of all objects (hand, workpiece, etc.) mounted to the area closer to the tip than the Force Sensor.

Gravity direction

Direction of gravity relative to the robot used for gravity compensation. It is defined by gravity direction vectors (X, Y, Z) in the base coordinate system.

Force object

A set of properties for each function that are necessary to use the force functions.
There are the following types of force objects.

Force control object
Force coordinate object
Force trigger object
Force monitor object

Force control object

Force object used for the force control function.

Force coordinate object

Force object for defining the coordinate system in which the force functions are performed.

Force trigger object

Force object for using the force trigger function.

Force monitor object

Force object for using the force monitor function.

Property

Parameter included in the force object. Properties can be set and acquired.

Status

Value included in the force object which is returned after a force function is executed.

Force File

File in which the force object is stored.

Force Editor

Graphical user interface (GUI) used to edit the force file. It can be opened from Robot Manager and Project Explorer.

Force Monitor

Graphical user interface (GUI) used to display Force Sensor values in graphs.

Impedance Wizard

Wizard used to adjust the parameters of the force control function.

Mass/Gravity Wizard

Wizard used to adjust mass properties.

Rated Load

The maximum load to satisfy the specifications of the sensor.

Overload capacity

The maximum load to retain the sensor accuracy.

3. System Overview

There are two procedures as follows to use the Force Sensor.

1: Force Sensor I/F Unit
A procedure which connect the Force Sensor I/F unit and the robot controller with a communication cable.

2: Force Sensor I/F Board
A procedure which mount the Force Sensor I/F Board on the option slot of the robot controller.

Then, connect the Force Sensor and the Force Sensor I/F unit (or board) with a sensor cable and a Force Sensor M/I cable.

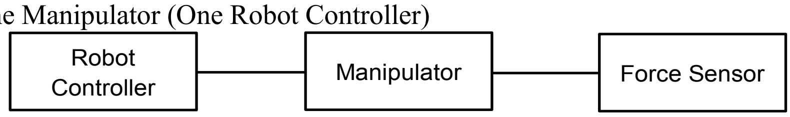
By connecting the Force Sensor and the Drive Unit, multiple manipulators and Force Sensors can be used together.

To use the Force Sensor I/F unit, install the Drive Unit at the following location and connect with cables:

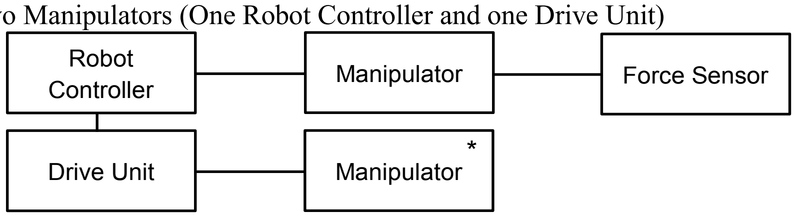
- IN connector of the Force Sensor I/F unit and
  OUT connector of the Robot Controller.
- Connect to the OUT connector of the Force Sensor I/F unit.

When using multiple manipulators and Force Sensors together, setup the system by any of the following combination patterns.

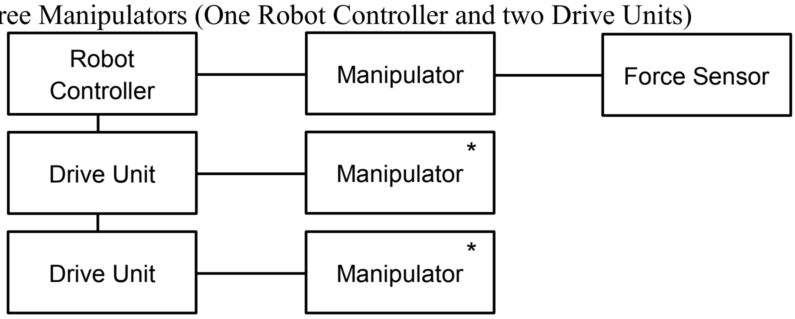
A: One Force Sensor
When using Force Sensor I/F unit or Force Sensor I/F board
One Manipulator (One Robot Controller)



B: One Force Sensor
When using Force Sensor I/F unit
Two Manipulators (One Robot Controller and one Drive Unit)



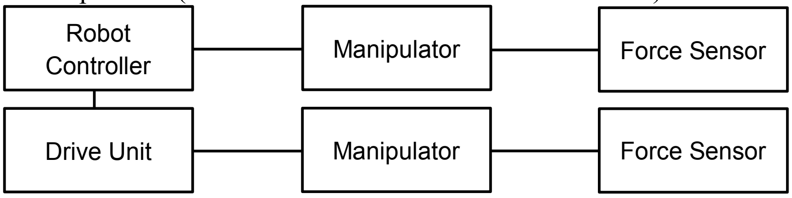
C: One Force Sensor
When using Force Sensor I/F unit
Three Manipulators (One Robot Controller and two Drive Units)



D: Two Force Sensors

When using Force Sensor I/F unit

Two Manipulators (One Robot Controller and one Drive Unit)

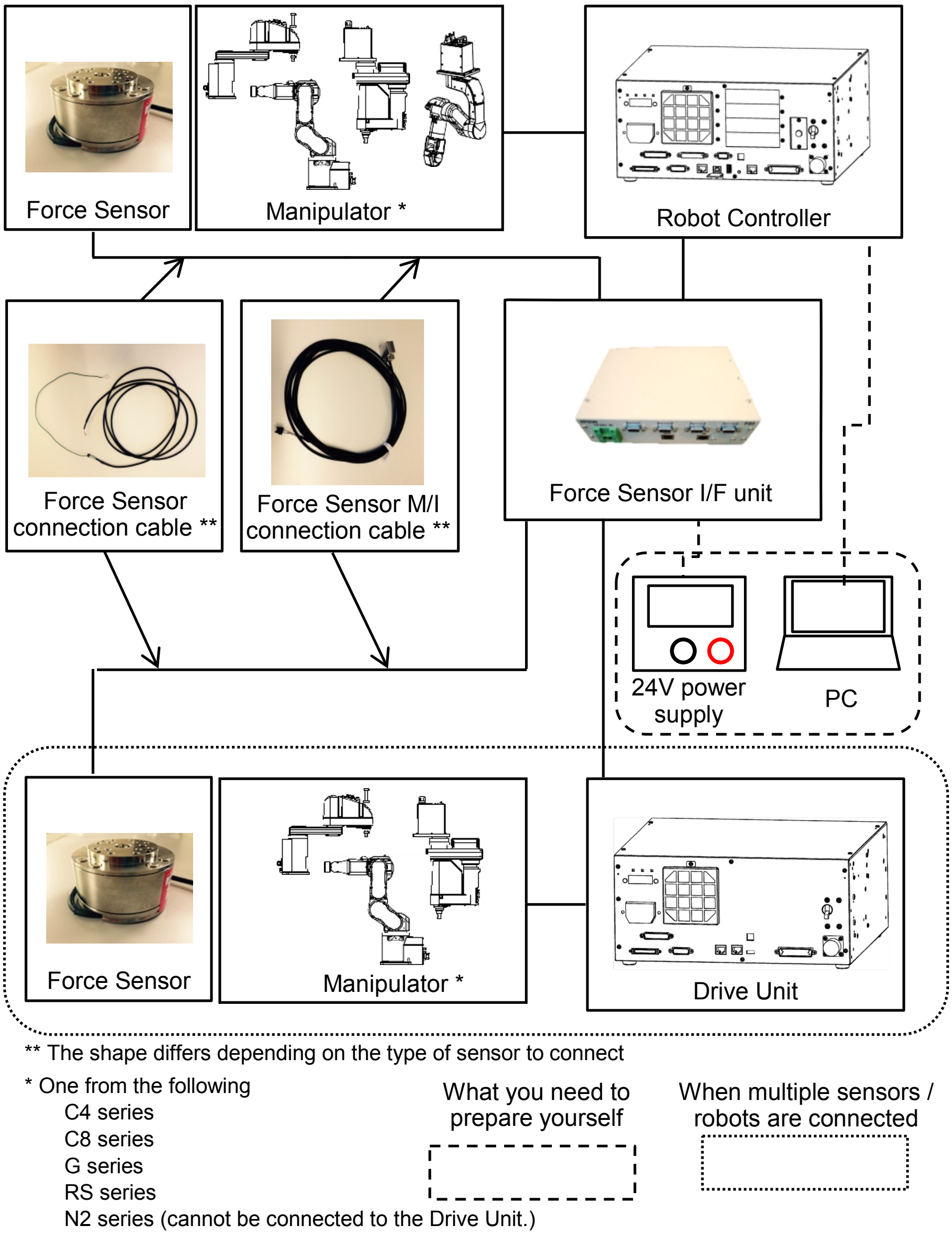


NOTE

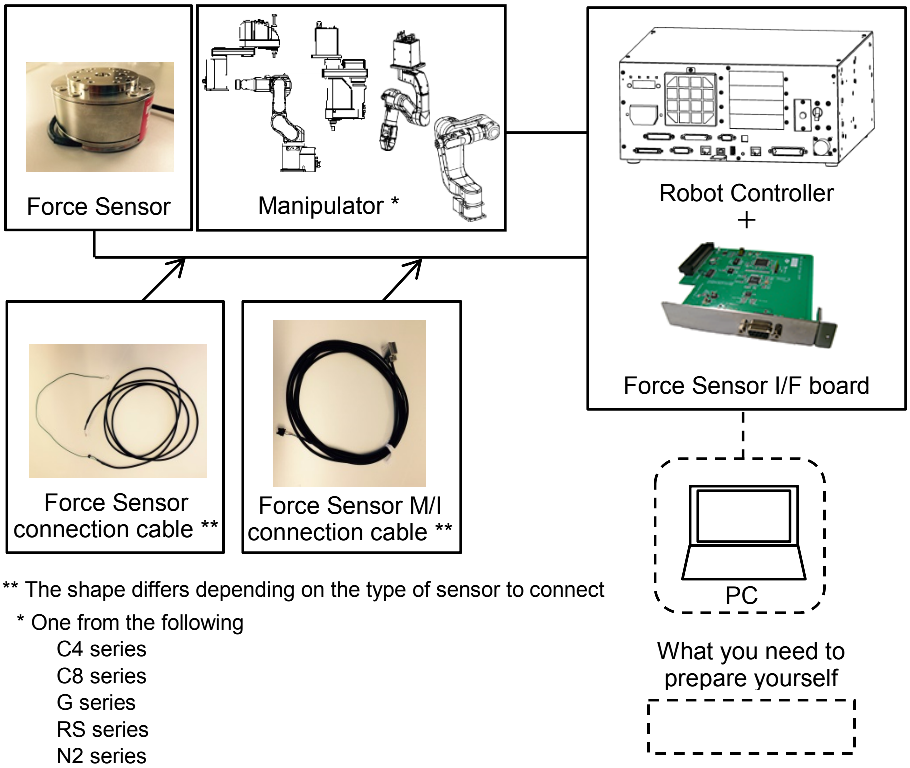
X5 series manipulators cannot use the Force Sensor.

However, X5 series manipulators can be used for Manipulators with “*” mark in the above diagrams as a part of the robot system.

Example of system configuration using the Force Sensor I/F unit.



Example of system configuration using the Force Sensor I/F board.



** The shape differs depending on the type of sensor to connect

* One from the following

C4 series
C8 series
G series
RS series
N2 series
N6 series

4. Functions of Force Control 7.0

4.1 Overview

The following describes the main functions provided by Force Control 7.0.

- Force control function
- Force trigger function
- Force monitor function

CAUTION	■ Functions provided by Force Control 7.0 are not functions to ensure safety. To ensure safety, refer to and observe the safety regulations in each country and region.

4.2 Force Control Function

4.2.1 Overview of the Force Control Function

A force control function is a function to control the robot to achieve a given target force or torque using an Epson Force Sensor.

Normally, a robot moves to the given target position by position control. The force control function is used to ensure that a target force can be achieved. Furthermore, it enables the robot to perform high precision positioning and fitting operations.

The force control function can be used in conjunction with normal CP operation commands or it can be used alone.

The force control function is performed in the specified coordinate system and can be performed independently in each of the six axes (X, Y, Z, U, V, and W). Therefore, the force control function can be enabled for all the axes at the same time or only for the specified axis.

Furthermore, since the characteristics of the force control function can be changed for each axis, it can be used for various applications; for example, the pressing operation is performed in an axis, while force is not controlled in another axis.

4.2.2 Parameters of the Force Control Function

The following describes the three important parameters of the force control function.

Force control with various characteristics can be performed by changing the following three parameters and target force.

Virtual inertia coefficient (Mass)

Virtual mass of the force control function. The unit is as follows.

Translation direction (Fx, Fy ,Fz)   : mN/(mm/sec^2)

Rotating direction (Tx, Ty, Tz)   : mN·mm/(deg/sec^2)

The mass parameter impacts the acceleration of the force control function. When the change in force is the same, decreasing the mass parameter increases the acceleration and increasing the mass parameter decreases the acceleration.

Virtual viscosity coefficient (Damper)

Virtual viscosity of the force control function. The unit is as follows.

Translation direction (Fx, Fy ,Fz) : N/(mm/sec)

Rotating direction (Tx, Ty, Tz) : N·mm/(deg/sec)

The damper parameter impacts the speed of the force control function. Decreasing the damper parameter increases the speed and the response to changes in force, but may cause the motion of the robot to become vibratory. Conversely, increasing the damper parameter decreases the speed and suppresses the vibration, but decreases the response to changes in force.

Virtual elasticity coefficient (Spring)

Virtual spring coefficient of the force control function. The unit is as follows.

Translation direction (Fx, Fy ,Fz): N/mm

Rotating direction (Tx, Ty, Tz): N·mm/(deg)

The spring parameter impacts the amount of movement of the force control function. Setting the spring parameter provides a virtual spring to limit the maximum amount of movement of the robot. Using this parameter can prevent the robot from interfering with objects around it.

Setting "0" does not limit the amount of movement. When the same constant force continues to be applied, decreasing the spring parameter increases the amount of movement, and increasing the spring parameter decreases the amount of movement.

4.3 Force Trigger Function

A force trigger function is a function to detect that the force or torque measured using an Epson Force Sensor reached the set value and branch the process.

The force trigger function can be used with the following commands.

Commands: TILL, Wait, Trap, Find

Using these commands can continue the operation until a certain force is reached or detect changes in force and find an edge or hole on a workpiece. They also can detect excessive force and process the error.

4.4 Force Monitor Function

A force monitor function is a function to measure the force and torque using an Epson Force Sensor.

The force monitor function can acquire and record forces applied during the operation and measure the average and peak values of the forces.

Using this function can adjust the parameters while creating an application, and record and manage forces applied during the operation for each workpiece.

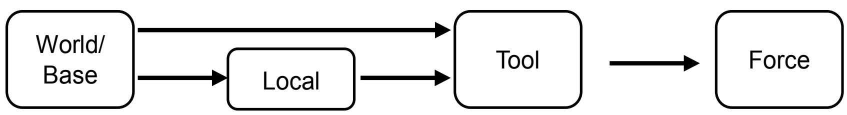
5. Coordinate Systems

5.1 About Coordinate Systems

The following describes the coordinate systems necessary to use Force Control 7.0; in particular, the Force Sensor coordinate system and force coordinate system. All of the coordinate systems are right handed, and the following coordinate systems are used according to the application.

Robot Coordinate System	:	Robot-specific coordinate system. This is also called a default base coordinate system (Base) or world coordinate system (World).
Local Coordinate System	:	User-defined coordinate system positioned in the operation area. (Local)
Tool Coordinate System	:	Coordinate system of a tool mounted to the sixth joint flange of the robot. (Tool) This is generally also called an end-effector coordinate system.
Force Coordinate System	:	Coordinate system with an offset from the tool coordinate system. (Force) All of the force functions are performed in the force coordinate system.
Force Sensor Coordinate System	:	Force Sensor-specific coordinate system, regardless of the robot. (ForceSensor)

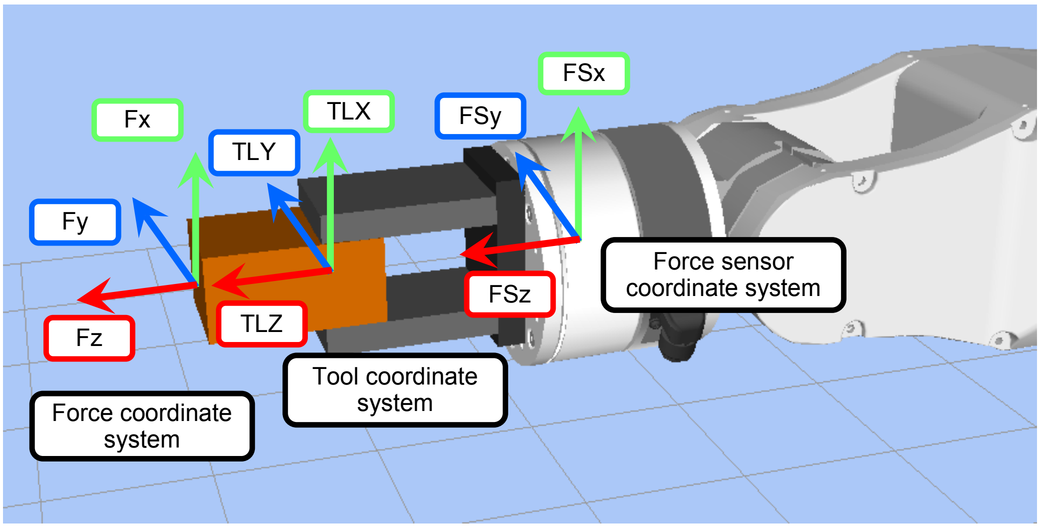
Changes in Position and Posture from Origin to Force Coordinate System



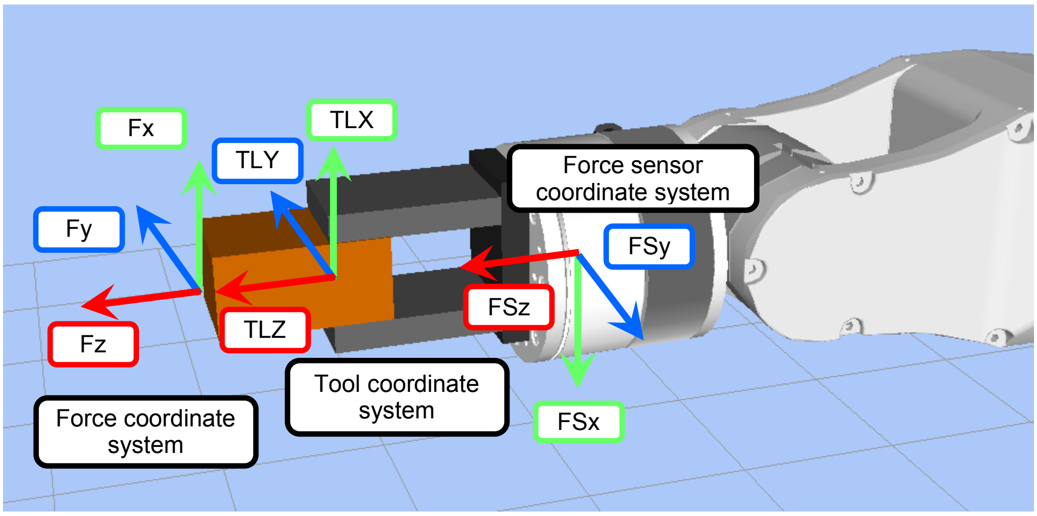
The force coordinate system is impacted by the robot, local, and tool coordinate systems. For details on the coordinate systems that have an impact on the force coordinate system, refer to the following manual.

EPSON RC+ 7.0 User's Control

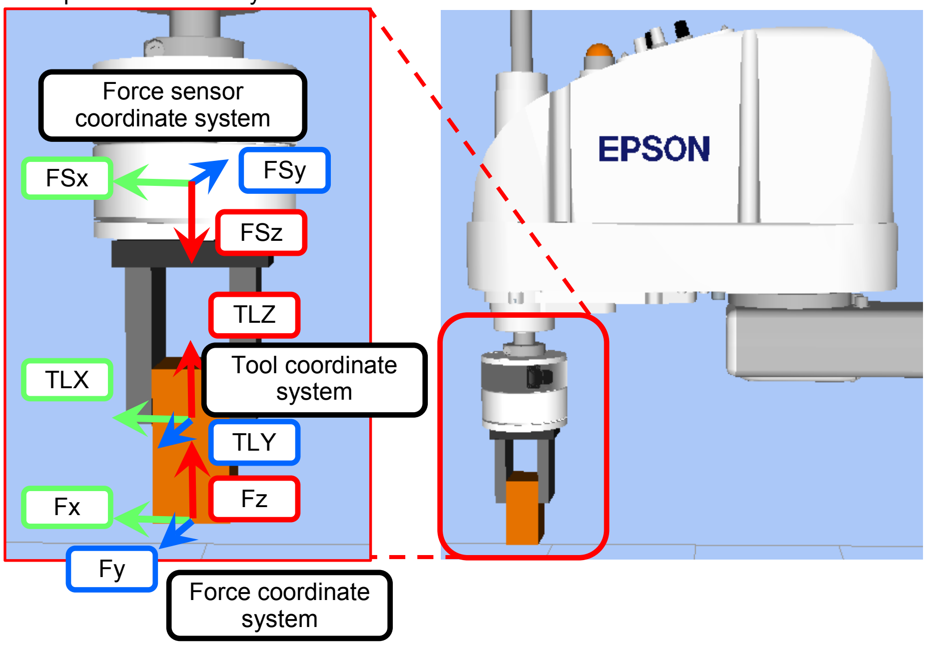
Example: Coordinate Systems of Tabletop-mounted 6-axis Robot



Example: Coordinate Systems of Ceiling-mounted 6-axis Robot



Example: Coordinate Systems of SCARA Robot



5.2 Force Coordinate System

A force coordinate system is a coordinate system in which the force functions are performed.

It is defined by translation directions (Fx, Fy, Fz) and rotating directions (Tx, Ty, Tz). Tx, Ty, and Tz represent a clockwise rotation in the positive directions of Fx, Fy, and Fz.

It is defined by the offset of the currently used tool coordinate system. Therefore, moving the robot or changing the tool settings changes the position and posture of the force coordinate system in the base coordinate system. For the force coordinate system, specify a position where a force is actually applied by contact, such as an edge of a workpiece.

The force coordinate system is defined by the force coordinate object FCS. It is set by the FSet statement or in the Force panel in Robot Manager.

The default force coordinate system is a coordinate system that is aligned with the selected tool coordinate system and is defined by FCS0. It cannot be changed.

5.3 Force Sensor Coordinate System

Coordinate system in which the Force Sensor detects the force.

It is defined by translation Fx, Fy, Fz and axis rotating Tx, Ty, Tz. Tx, Ty, and Tz represent a clockwise rotation in the positive directions of Fx, Fy, and Fz.

It is Force Sensor-specific and cannot be changed. When using the force functions, force values detected in the Force Sensor coordinate system are automatically converted to those in the force coordinate system.

When the Force Sensor and the 6-axis robot are connected using an EPSON sensor flange, the Force Sensor can be mounted to a robot only in a unique manner, so a tabletop-mounted or ceiling-mounted robot rotates at 180 degrees around the TLZ axis in the tool 0 coordinate system when 0 Pulse is selected for the posture.

6. Setting Up Force Control 7.0

The following describes the setup procedure to use Force Control 7.0.

To use the force functions provided by Force Control 7.0, perform the following tasks.

1. Setting up the robot system

   Refer to the following manual and set up the robot system.

   Safety Installation Manual

   EPSON RC+ 7.0 User's Guide

   Manipulator Manual

   Controller Manual

2. Checking the accessories

   Check the parts included in the Force Sensor package.
   For details, refer to the following section.

   Hardware: 1. Accessories

3. Mounting and wiring the Force Sensor

   Mount the Force Sensor to the robot and connect it with the controller.
   For details, refer to the following section.

   Hardware: 6. Mounting Procedure

4. Installing the software

   The software of Force Control 7.0 is included in EPSON RC+ 7.0.
   For the installation procedure, refer to the following manual.

   EPSON RC+ 7.0 User's Guide

5. Setting up the Force Sensor

   First link the Force Sensor with the robot. Then, check that the Force Sensor is connected with the controller correctly and communication is successful.
   For details, refer to the following section.

   Software: 1. Checking the Connection

6. Configuring the Force Sensor correction

   Configure the settings necessary for Force Sensor correction and check that the sensor values that were corrected correctly in the force coordinate system can be acquired.
   For details, refer to the following section.

   Software: 2. Force Sensor Correction

7. Performing the force functions

   Perform the force functions. The force functions are performed mainly in SPEL+ programs.
   For details, refer to the following section.

   Software: 4. SPEL+ Programming of the Force Functions

Hardware

1. Included Items

This section describes the items included in the option by product specification.

1.1 S250N (For C4 series)

Item		Quantity
1. Force Sensor (For C4: S250N)		1
2. Force Sensor I/F (unit or board)	***	1
3. Force Sensor cable (For C4)	*	1
4. Force Sensor M/I connection cable (For C4)		1
5. Connector cover	*	1
6. Motion network cable	**	1
7. Sensor flange (For C4)	*	1
8. Robot fixing bolts (Hexagon socket low head cap bolts: M4×6)		4
9. Force Sensor fixing bolts (Hexagon head bolts: M4×12)	*	4
10. Cable mount	*	1
11. Wire tie	*	1
12. Protection sheet	*	1
13. Labels for cables		1
14. Ground terminal fixing bolt (Hexagon socket head cap bolt: M8×12)		1
15. Labels for Ceiling-mount shaft		1
16. Power connector	**	1

* : Items 3, 5, 7, 9, 10, 11, and 12 are incorporated in “1. Force Sensor (For C4: S250N)” at the time of shipment.

** : Items 6 and 16 may not be included with shipment depending on the type of option.

*** : Item 2 may not be included with shipment depending on the type of option.
If included with shipment, either I/F unit or I/F board.

1. Force Sensor (For C4: S250N)

Unit

Board

2. Force Sensor I/F

3. Force Sensor cable (For C4)

4. Force Sensor M/I connection cable (For C4)

5. Connector cover

6. Motion network cable

7. Sensor flange (For C4)

8. Robot fixing bolts (Hexagon socket low head cap bolts: M4×6)

9. Force Sensor fixing bolts (Hexagon head bolts: M4×12)

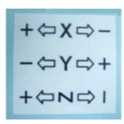
10. Cable mount

11. Wire tie

12. Protection sheet

13. Labels for cables

14. Ground terminal fixing bolt (Hexagon socket head cap bolt: M8×12)



15. Labels for Ceiling-mount shaft

16. Power connector

1.2 S250L (For C8 series: IP20 compliant)

Item	Quantity
1. Force Sensor (C8-IP20 compliant: S250L)	1
2. Force Sensor I/F (unit or board) ***	1
3. Force Sensor cable (C8-IP20 compliant) *	1
4. Force Sensor M/I connection cable (For C8)	1
5. Motion network cable **	1
6. Sensor flange (C8-IP20 compliant) *	1
7. Robot fixing bolts (Hexagon socket button head bolts: M5×15)	4
8. Force Sensor fixing bolts (Hexagon head bolts: M5×12) *	4
9. Cable mount *	1
10. Wire tie *	1
11. Protection sheet *	1
12. Labels for cables	1
13. Labels for Ceiling-mount shaft	1
14. Power connector **	1

* : Items 3, 6, 8, 9, 10, and 11 are incorporated in "1. Force Sensor (C8-IP20 compliant: S250L)" at the time of shipment.

** : Items 5 and 14 may not be included with shipment depending on the type of option.

***: Item 2 may not be included with shipment depending on the type of option.
If included with shipment, either I/F unit or I/F board.

1. Force Sensor
(C8-IP20 compliant:
S250L)

Unit

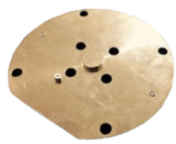
Board

2. Force Sensor I/F

3. Force Sensor cable
(C8-IP20 compliant)

4. Force Sensor M/I
connection cable (For C8)

5. Motion network cable



6. Sensor flange
(C8-IP20 compliant)

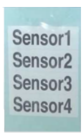
7. Robot fixing bolts
(Hexagon socket button
head bolts: M5×15)

8. Force Sensor fixing bolts
(Hexagon head bolts:
M5×12)

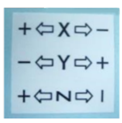
9. Cable
mount

10. Wire tie

11. Protection sheet



12. Labels for cables



13. Labels for
Ceiling-mount shaft

14. Power connector

1.3 S250P (For C8 series: IP67 compliant)

Item		Quantity
1. Force Sensor (C8-IP67 compliant: S250P)		1
2. Force Sensor I/F (unit or board)	***	1
3. Force Sensor cable (C8-IP67 compliant)	*	1
4. Force Sensor M/I connection cable (For C8)		1
5. Motion network cable		1
6. Sensor flange (C8-IP67 compliant)	*	1
7. Robot fixing bolts (Hexagon socket cap bolts: M5×18)		4
8. Seal washer	*	4
9. Force Sensor fixing bolts (Hexagon head bolts: M5×12)	*	1
10. Cable mount	*	1
11. Wire tie	*	1
12. Protection sheet	*	1
13. Labels for cables		1
14. Labels for Ceiling-mount shaft		1
15. Power connector	**	1

* : Items 3, 6, 8, 9, 10, 11, and 12 are incorporated in "1. Force Sensor (C8-IP67 compliant: S250P)" at the time of shipment.

** : Item 15 may not be included with shipment depending on the type of option.

***: Item 2 may not be included with shipment depending on the type of option. If included with shipment, either I/F unit or I/F board.

1. Force Sensor (C8-IP67 compliant: S250P)

Unit

Board

2. Force Sensor I/F

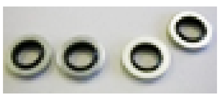
3. Force Sensor cable (C8-IP67 compliant)

4. Force Sensor M/I connection cable (For C8)

5. Motion network cable

6. Sensor flange (C8-IP67 compliant)

7. Robot fixing bolts (Hexagon socket cap bolts: M5×18)



8. Seal washer

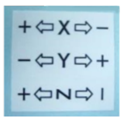
9. Force Sensor fixing bolts (Hexagon head bolts: M5×12)

10. Cable mount

11. Wire tie

12. Protection sheet

13. Labels for cables



14. Labels for Ceiling-mount shaft

15. Power connector

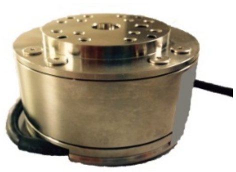
1.4 S250H (For N2 series)

Item	Quantity
1. Force Sensor (For N2: S250H)	1
2. Force Sensor I/F (unit or board) ***	1
3. Force Sensor cable (For N2) *	1
4. Force Sensor M/I connection cable (For N2)	1
5. Motion network cable **	1
6. Sensor flange (For N2) *	1
7. Robot fixing bolts (Hexagon socket cap bolts: M4×6)	4
8. Force Sensor fixing bolts (Hexagon head bolts: M4×12) *	4
9. Cable mount *	1
10. Wire tie *	1
11. Protection sheet *	1
12. Labels for cables	1
13. Labels for Ceiling-mount shaft	1
14. Power connector **	1

* : Items 3, 6, 8, 9, 10 and 11 are incorporated in "1. Force Sensor (for N2: S250H)" at the time of shipment.

** : Items 5 and 14 may not be included with shipment depending on the type of option.

***: Item 2 may not be included with shipment depending on the type of option.
If included with shipment, either I/F unit or I/F board.



1. Force Sensor
(For N2: S250H)

Unit

Board

2. Force Sensor I/F

3. Force Sensor cable
(For N2)

4. Force Sensor M/I
connection cable (For N2)

5. Motion network cable

6. Sensor flange (For N2)

7. Robot fixing bolts
(Hexagon socket cap bolts:
M4×6)

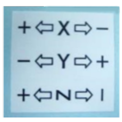
8. Force Sensor fixing bolts
(Hexagon head bolts:
M4×12)

9. Cable mount

10. Wire tie

11. Protection sheet

12. Labels for cables



13. Labels for

14. Power connector

1.5 SH250LH (For N6 series)

Item	Quantity
1. Force Sensor (For N6: SH250LH)	1
2. Force Sensor I/F or board *	1
3. Force Sensor cable (For N6) **	1
4. Force Sensor M/I connection cable (For N6)	1
5. Robot fixing bolts (Hexagon head bolts: M4×12)	4
6. Cable mount	1
7. Wire tie	1
8. Protection sheet	1

* : Item 2 may not be included with shipment depending on the type of option.

** : Items 3 is incorporated in “1. Force Sensor (for N6: SH250LH)” at the time of shipment.

1. Force Sensor (For N6: SH250LH)

2. Force Sensor I/F Board

3. Force Sensor cable (For N6)

4. Force Sensor M/I connection cable (For N6)

5. Robot fixing bolts (Hexagon head bolts: M4×12)

6. Cable mount

7. Wire tie

8. Protection sheet

1.6 S2503, S2506, S25010 (For G, RS series)

Item		Qty.
1. Force Sensor (S2503, S2506, S25010)		1
2. Force Sensor I/F (unit or board)	*5	1
3. Force Sensor cable (S2503, S2506, S25010)		1
4. Force Sensor M/I connection cable (S2503, S2506, S25010)		1
5. Relay cable for external wiring	*1*2	1
6. Branch cable	*1	2
7. Motion network cable	*1	1
8. Adapter	*3	1
9. Sensor flange (S2503, S2506, S25010)	*4	1
10. Force Sensor fixing bolts (Hexagon socket cap bolts: M4×15)	*4	4
11. Sensor flange fixing bolts (Hexagon socket cap bolts: M5×15)		4
12. Cable mount		2
13. Wire tie		2
14. Protection sheet		1
15. Labels for cables		1
16. Labels for Ceiling-mount shaft		1
17. Power connector	*1	1
18. Cable mount fixing bolt		2

*1 :Items 5, 6, 7 and 17 may not be included with shipment depending on the type of option.

*2 :Item 5
G3 series only.
Optional for G6, G10 and G20 series.

*3 :Item 8 differ for each Manipulator.

*4 :Items 9 and 10 are incorporated in "1. Force Sensor (S2503, S2506, S25010)" at the time of shipment.

*5 :Item 2 may not be included with shipment depending on the type of option.
If included with shipment, either I/F unit or I/F board.

1. Force Sensor
(S2503, S2506, S25010)

Unit

Board

2. Force Sensor I/F

3. Force Sensor cable
(S2503, S2506, S25010)

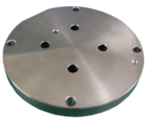
4. Force Sensor M/I connection cable
(S2503, S2506, S25010)

5. Relay cable
for external wiring

6. Branch cable

7. Motion network
cable

8. Adapter



9. Sensor flange
(S2503, S2506, S25010)

10. Force Sensor fixing bolts
(Hexagon socket cap bolts: M4×15)

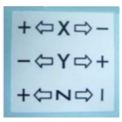
11. Sensor flange fixing bolts
(Hexagon socket cap bolts: M5×15)

12. Cable mount

13. Wire tie

14. Protection sheet

15. Labels for cables



16. Labels for
Ceiling-mount shaft

17. Power connector

Cross recessed round head screws:M4×8

Hexagon socket extra low head cap bolts: M4×6

18. Cable mount fixing bolts

2. Labels

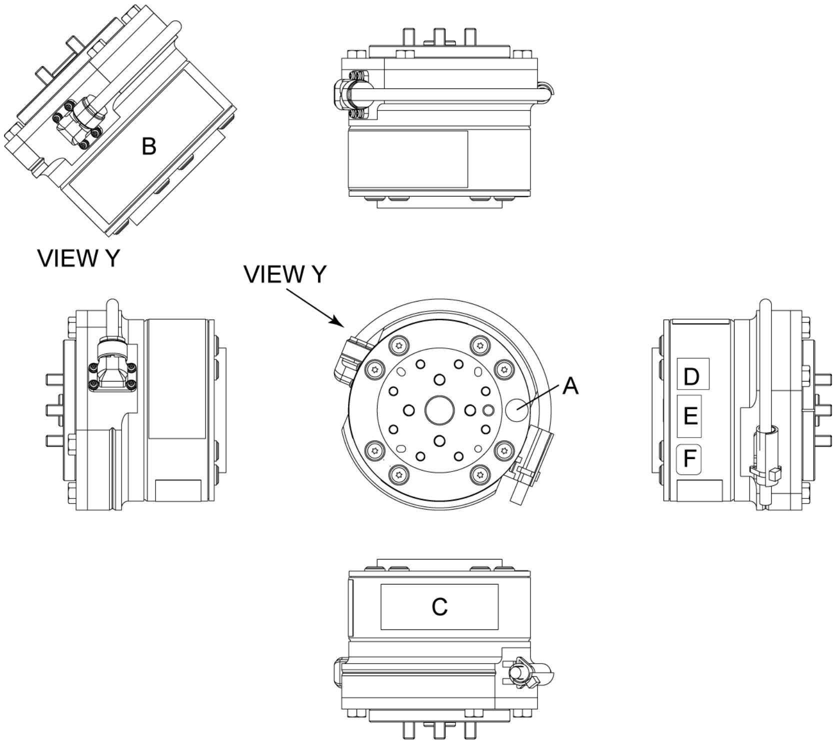
The following labels are attached to the Force Sensor and Force Sensor I/F unit. Be sure to comply with descriptions and warnings on the labels to operate the Force Sensor safely.

Location	Label		Note
A			Do not loosen or remove the screws on the top face of the Force Sensor. If the screws are loosened or removed, the end effector may come off while the Manipulator is moving or accuracy of the Force Sensor may not be achieved.
B	−⇦X⇨+ −⇧Z⇩+ +⇦Y⇨−	S250N S250L S250P S250H S2503 S2506 S25010	The coordinate system of the Force Sensor on table top mount Manipulator.
	−⇦X⇨+ −⇧Z⇩+ −⇦Y⇨+	SH250LH	
C	MODEL : S250P SERIAL NO. : FS03000000 MANUFACTURED : 07/2015 RATED CAPACITY : Fx/Fy/Fz 250N Tx/Ty/Tz 18Nm SEIKO EPSON CORP. MADE IN JAPAN	S250N S250L S250P S250H S2503 S2506 S25010	Serial number label (Force Sensor)
	MODEL : S250N SERIAL NO. : FS01000001 MANUFACTURED : 07/2015 RATED CAPACITY : Fx/Fy/Fz 250N Tx/Ty/Tz 18Nm MADE IN JAPAN SEIKO EPSON CORP.	SH250LH	
D			China RoHS label
E	MSIP-REI-EKL-RE-FS250		KC label (Force Sensor)
F			CE label
G	FORCE SENSOR I/F UNIT MODEL : FS1 SERIAL NO. : FS04000001 MANUFACTURED : 04/2016 DC24V 12W MANUFACTURER : SEIKO EPSON CORPORATION 3-5, OWA 3-CHOME, SUWA-SHI NAGANO-KEN, 392-8502 JAPAN http://global.epson.com/company/ ENTITY PLACING ON EU MARKET : EPSON DEUTSCHLAND GmbH OTTO-HAHN-STR.4, D-40670 MEERBUSCH GERMANY https://neon.epson-europe.com/de/en/robots/ FS04000001		Serial number label (Force Sensor I/F unit)

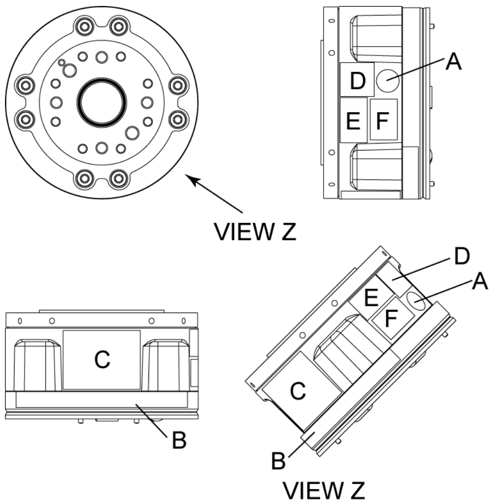
Location	Label	Note
H		KC label (Force Sensor I/F unit)

Location of the labels

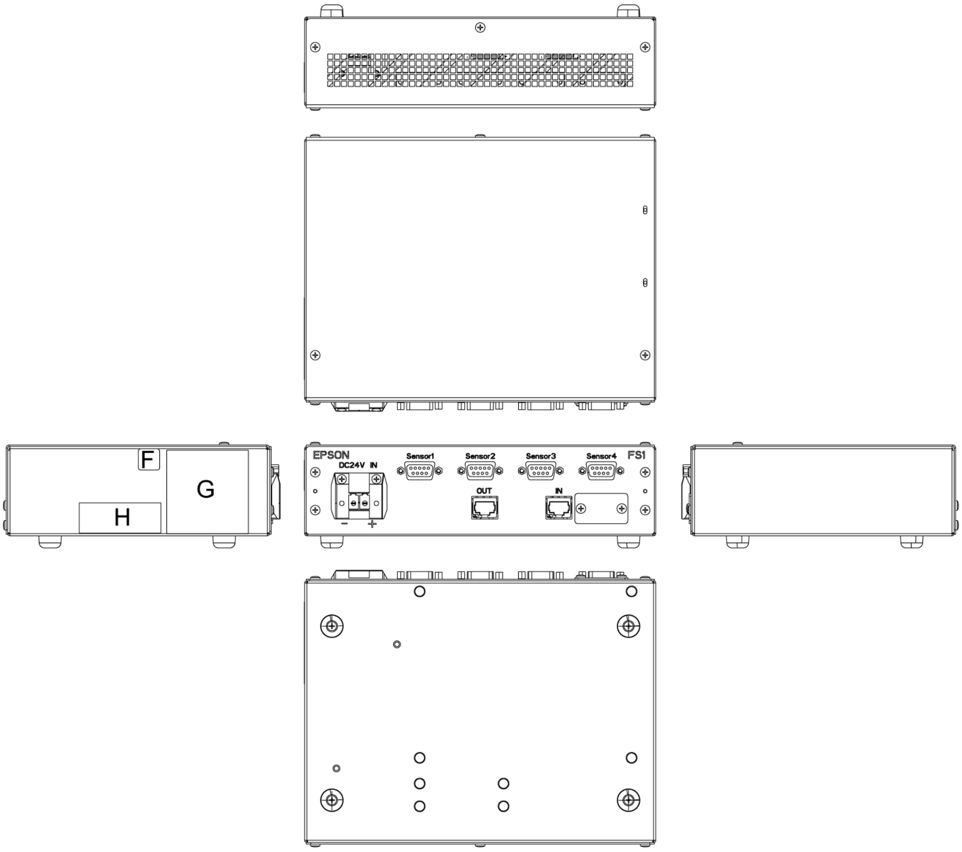
Force Sensor (S250N, L, P, H)



Force Sensor (SH250LH)



Force Sensor I/F Unit



3. Connection Example

The following are the connection examples of the robot system and Force Sensor.

For the combination patterns for using multiple manipulators and Force Sensors, refer to the following section.

Installation 3. System Overview

NOTE

The following items must be prepared by customers.

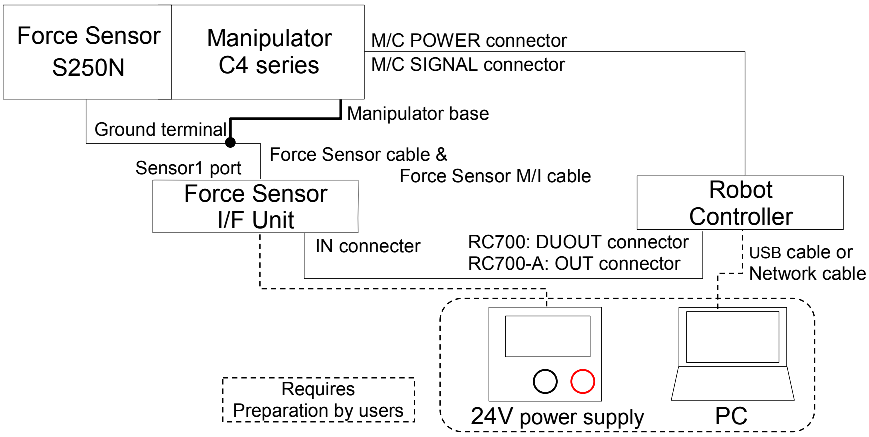
24 V power supply *1
Power connector *1
PC for operating the Manipulator *2

*1 : 24V power supply and power connector are necessary when using Force Sensor I/F unit.
*2 : Force Control 7.0 supports the EPSON RC+ 7.0 Ver.7.2.0 or later.

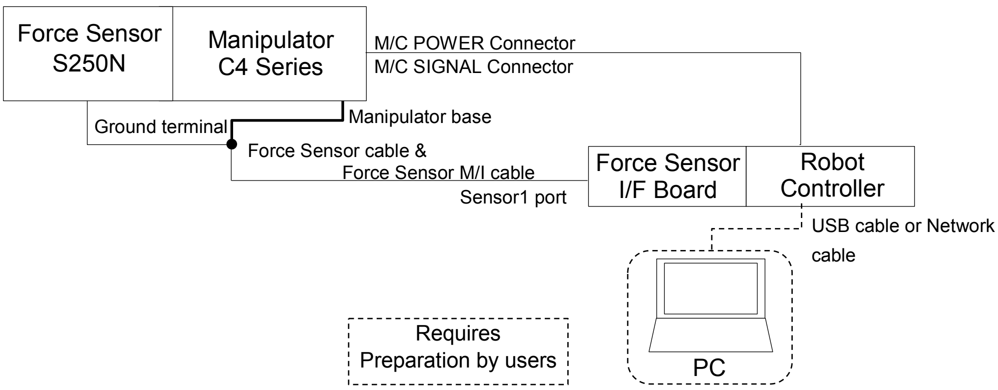
3.1 C4 series-S250N

Example: Connecting one Manipulator and one Force Sensor

Force Sensor I/F unit

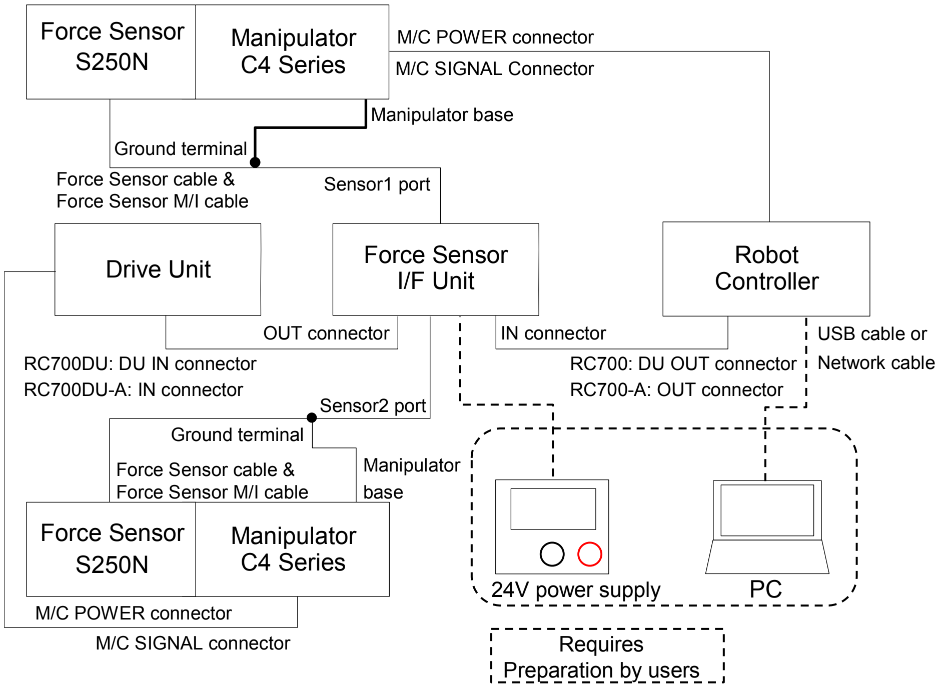


Force Sensor I/F board



Example: Connecting two Manipulators and two Force Sensors

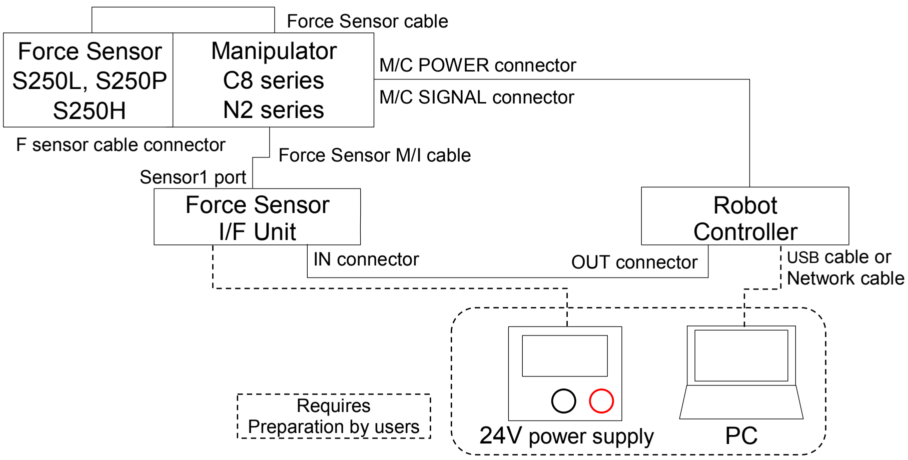
Force Sensor I/F unit



3.2 C8 series-S250L, C8 series-S250P, N2 series-S250H, N6 series-SH250LH

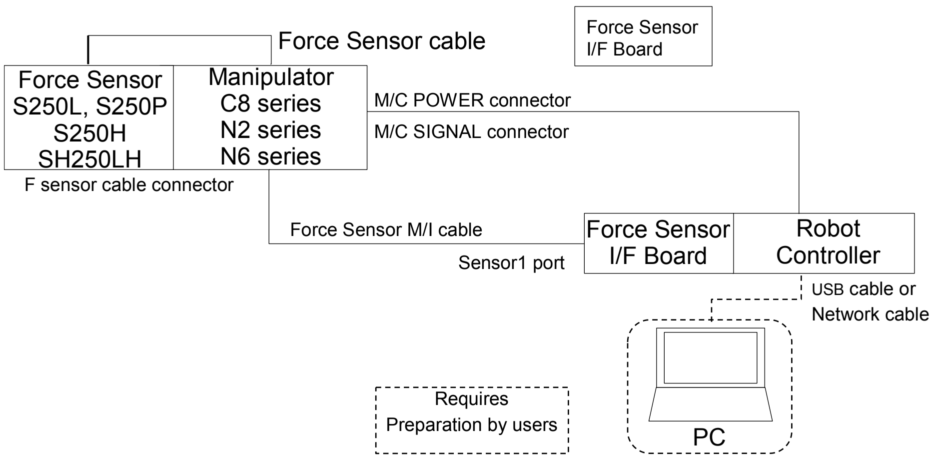
Example: Connecting one Manipulator and one Force Sensor

Force Sensor I/F unit



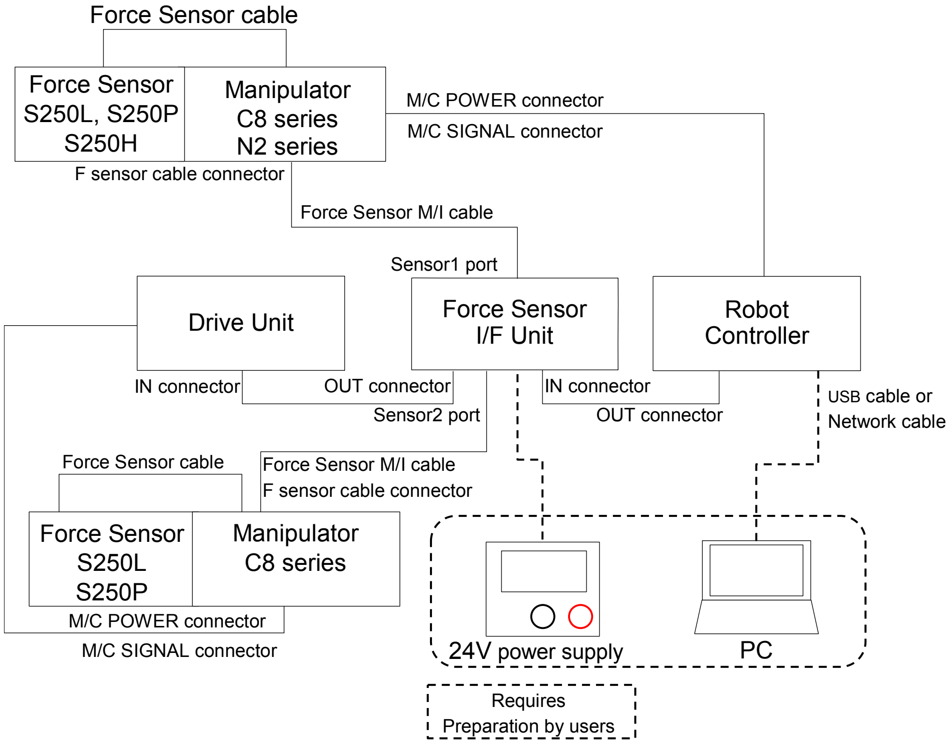
(N6 series cannot connected to the Force Sensor I/F unit)

Force Sensor I/F board



Example: Connecting two Manipulators and two Force Sensors

Force Sensor I/F unit



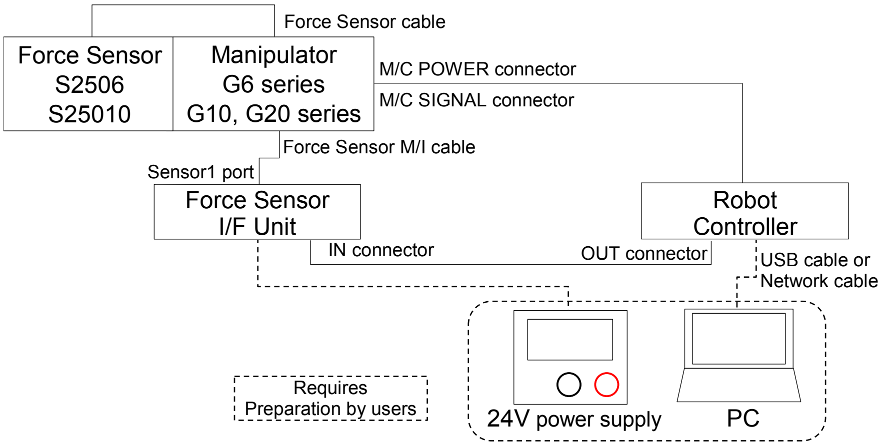
(N6 series cannot be connected to the Force Sensor I/F unit.
N2 series cannot be connected to the Drive Unit)

3.3 G series-S2503, S2506, S25010

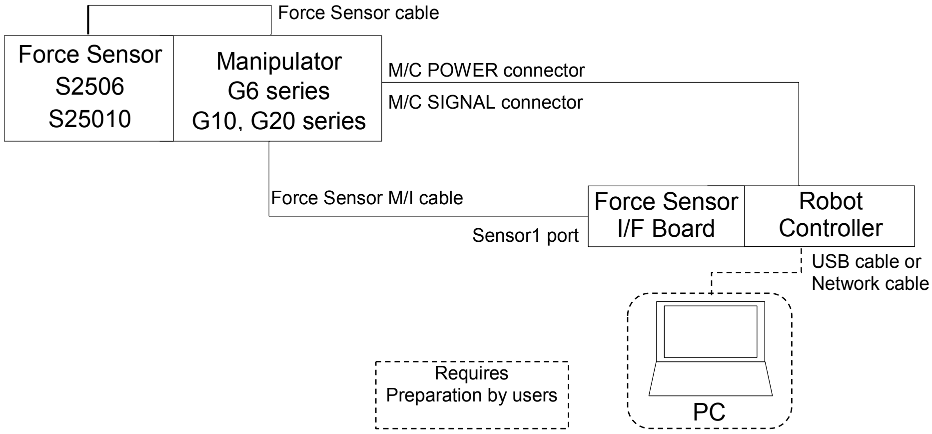
3.3.1 Internal wiring

Example: Connecting one Manipulator and one Force Sensor

Force Sensor I/F unit

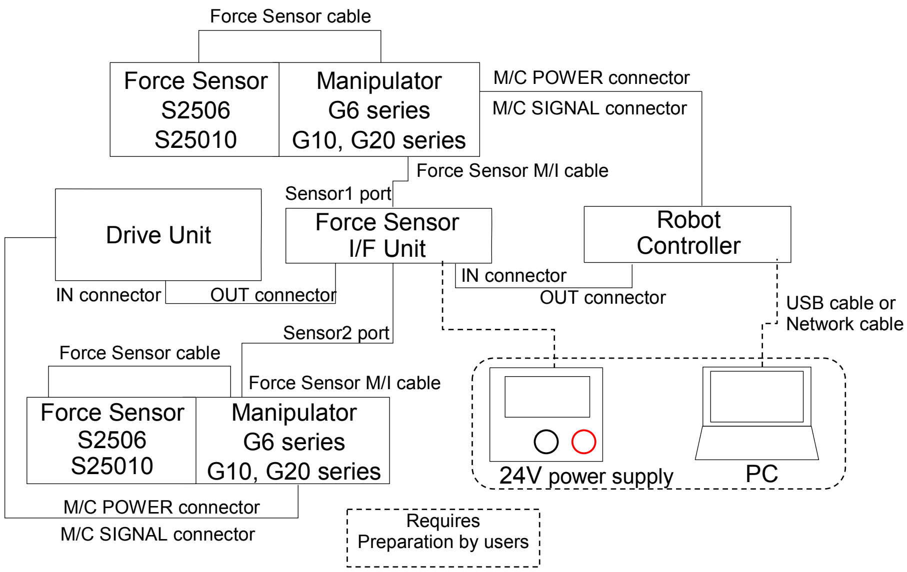


Force Sensor I/F board



Example: Connecting two Manipulators and two Force Sensors

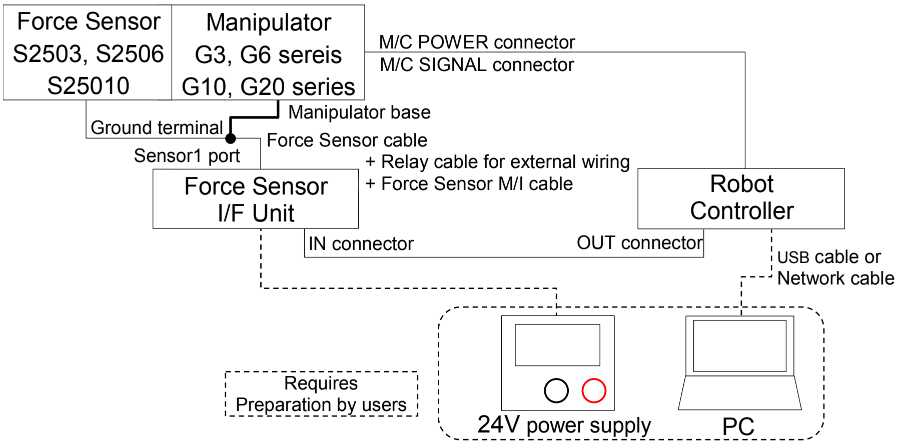
Force Sensor I/F unit



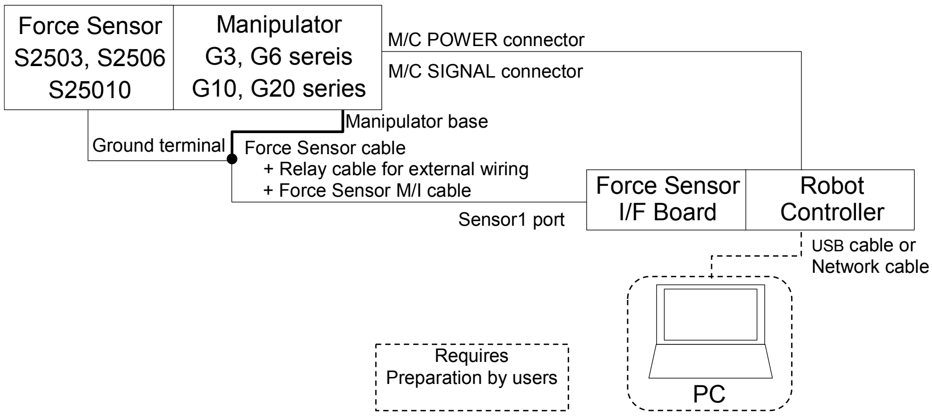
3.3.2 External wiring

Example: Connecting one Manipulator and one Force Sensor

Force Sensor I/F unit

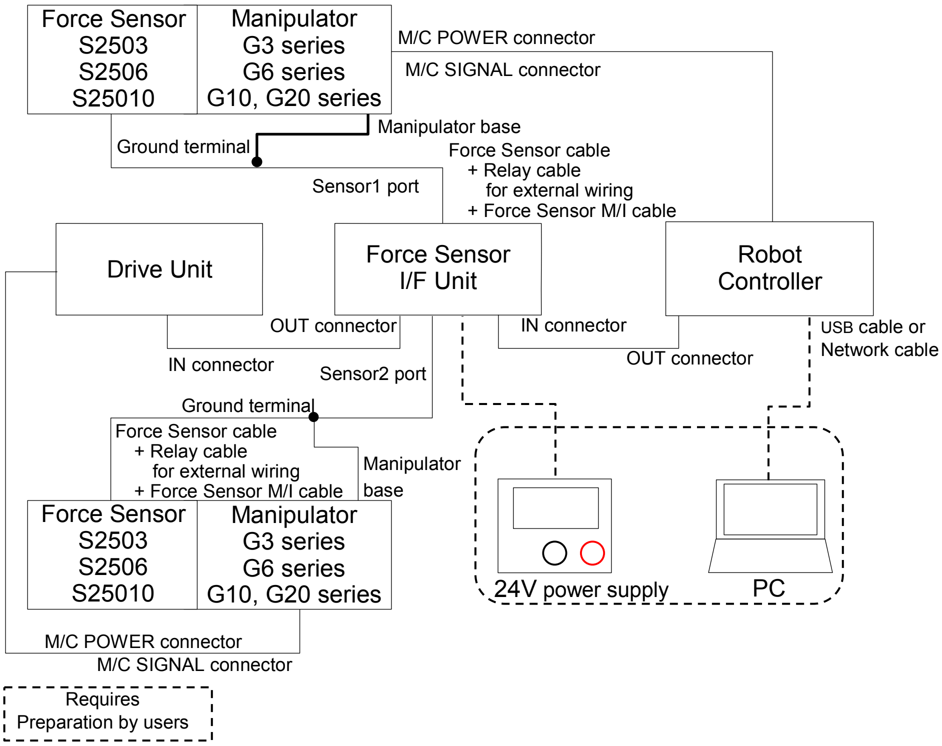


Force Sensor I/F board



Example: Connecting two Manipulators and two Force Sensors

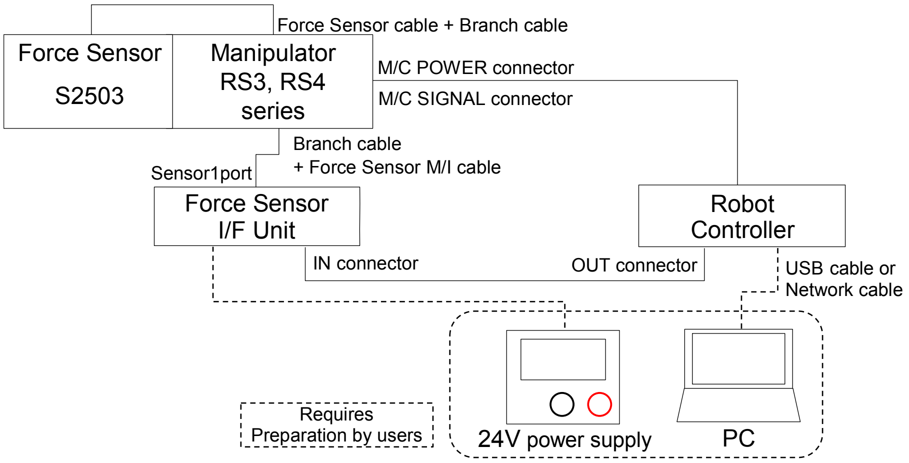
Force Sensor I/F unit



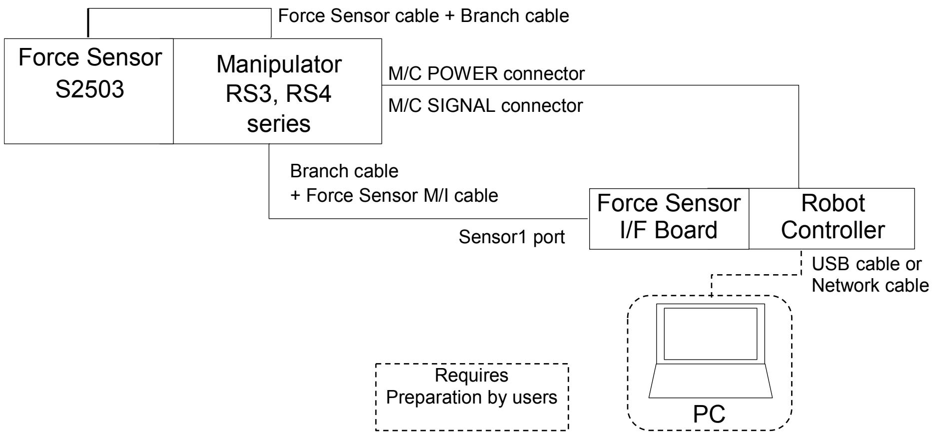
3.4 RS series-S2503

Example: Connecting one Manipulator and one Force Sensor

Force Sensor I/F unit

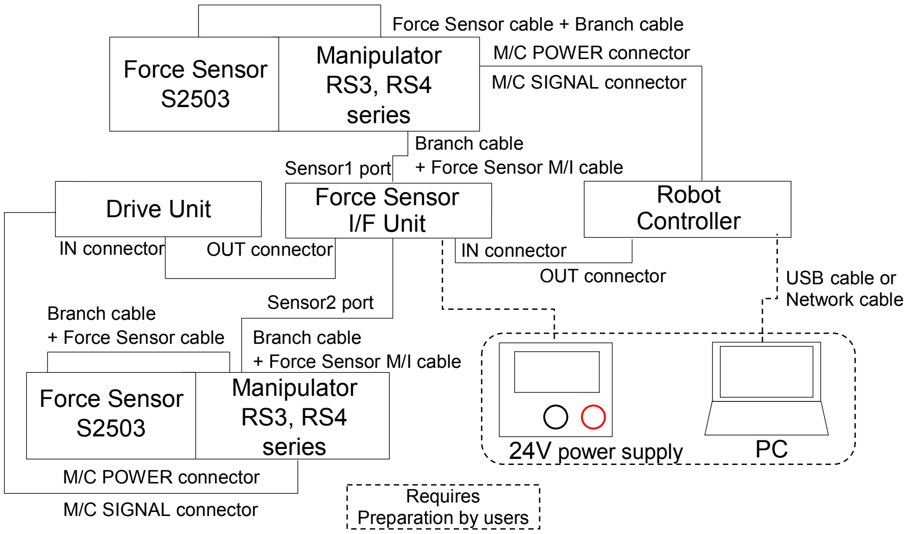


Force Sensor I/F board



Example: Connecting two Manipulators and two Force Sensors

Force Sensor I/F unit



4. Force Sensor

CAUTION	■ The allowable load does not guarantee the sensor's performance. The force may not be detected properly if the load exceeding the allowable value is applied. Be sure to use the sensor within the rated load range. ■ If the option is used in an environment with rapid temperature change, a drift may increase.

4.1 Specifications

4.1.1 Specification Table

Item				Specification	Remarks
Outer dimensions		S250N, S250H		ø80 × H49 mm	Including the sensor flange Reference: *Hardware 4.2 Outer Dimensions*
		S250L		ø88 × H49 mm	
		S250P		ø88 × H66 mm	
		S2503, S2506, S25010		ø80 × H52 mm *1	
		SH250LH		ø85 × H48 mm	
Weight *2		S250N, S250H		460 g	Including the sensor flange
		S250L		520 g	
		S250P		680 g	
		S2503, S2506		620 g	Including the sensor flange and the adaptor
		S25010		640 g	
		SH250LH		460 g	Not including the cables.
Rated load		Fx / Fy / Fz		250 / 250 / 250 [N]	
		Tx / Ty / Tz		18 / 18 / 18 [N·m]	
Overload capacity		Fx / Fy / Fz		1000 [N]	
		Tx / Ty / Tz		36 [N·m]	
Measurement resolution *3		Fx / Fy / Fz		± 0.1 (5 sec, 25 °C) [N] or less	
		Tx / Ty / Tz		± 0.003 (5 sec, 25 °C) [N·m] or less	
	Noise level	Fx / Fy / Fz		0.035 [N] or less	
		Tx / Ty / Tz		0.001 [N·m] or less	
	Time drift	25 °C	Fx / Fy / Fz	± 0.01 [N/s] or less	
			Tx / Ty / Tz	± 0.0003 [N·m/s] or less	
		40 °C	Fx / Fy / Fz	± 0.02 [N/s] or less	
			Tx / Ty / Tz	± 0.0006 [N·m/s] or less	
Measurement accuracy *4		Fx / Fy / Fz Tx / Ty / Tz		± 5 % RO *5 or less	
Temperature drift		Fx / Fy / Fz Tx / Ty / Tz		0.2 [% / °C] or less at 250 [N], 18 [N·m] (full-scale)	
Operating environment		Temperature		– 10 ~ 40 [°C]	
		Humidity		10 ~ 80 %Rh no condensation	
Protection rating				IP67 : S250P IP20 : S250N, S250L S250H, S2503, S2506, S25010	
Safety standard				CE Mark : EMC Directive KC Mark	

*1 Sensor height + height to the bottom edge of the sensor flange.
When installed with the attached adapter, distance between the Z-axis end face and the sensor end face are as follows: (Reference: *Hardware 4.2 Outer Dimensions*)
S2503, S2506: 66mm
S25010: 68mm

*2 The cable options are not included in weight.

*3 The measurement resolution including the noise level and time drift (25 °C), when the measurement time is 5 seconds.

*4 The measurement accuracy when the measurement time is 6 minutes.

*5 RO, Rated Output, is accuracy for the rated output.

4.1.2 ACCEL Setting under Heavy Load

When using the force sensor on the following Manipulators, see the following and set ACCEL properly according to the tip load.

Manipulator models: G10 series, G20 series

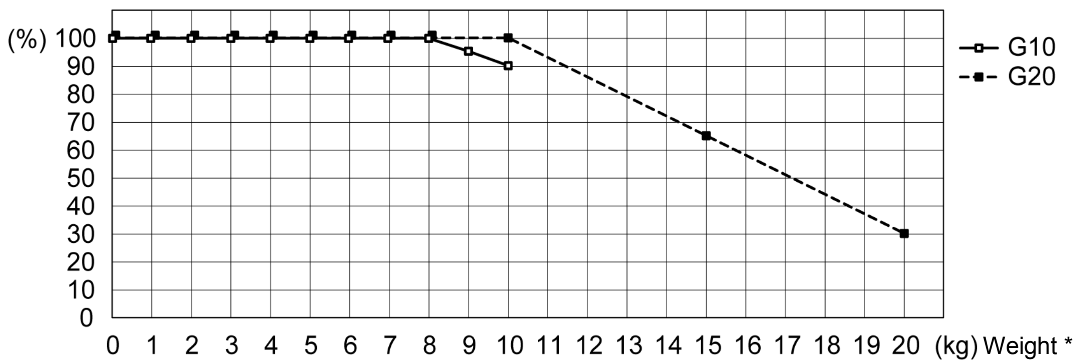
For details of the ACCEL setting and the setting procedures, refer to the Manipulator manuals.

NOTE

Improper setting may cause load exceeding the rated torque for the force sensor depending on operation conditions, and may result in the following problem.

Reduction of the life and damage of the force sensor

Accel setting value

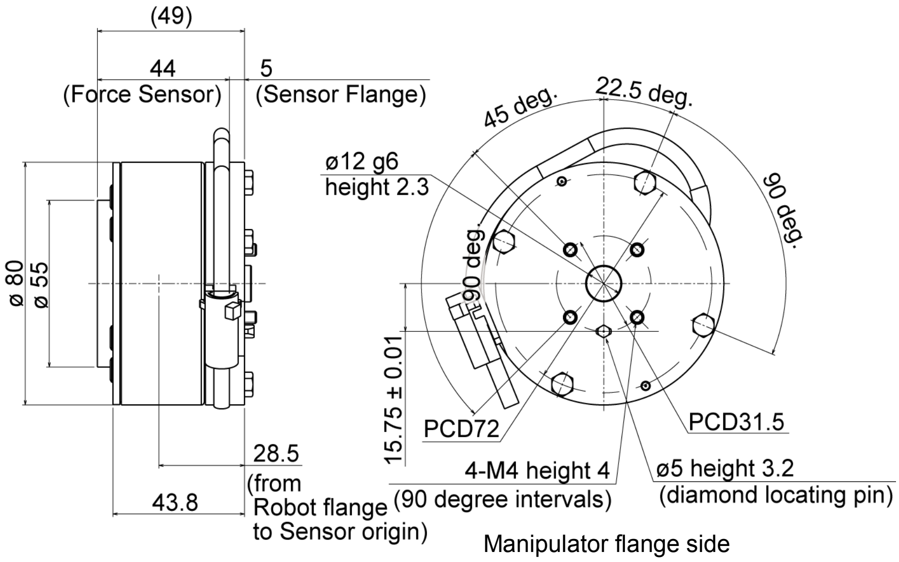


* Weight : Including the weight of the Force Sensor

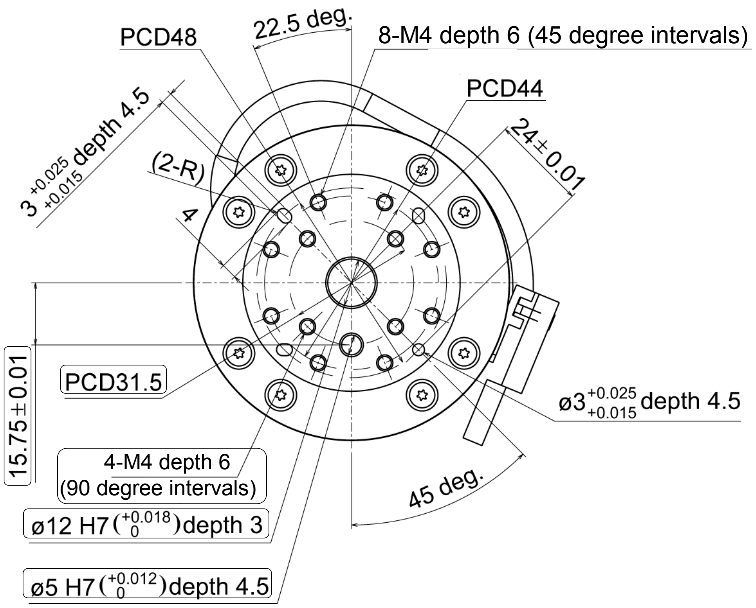
4.2 Outer Dimensions

The following are the dimensions of the assembled sensor flange and Force Sensor.

4.2.1 S250N (For C4 series)

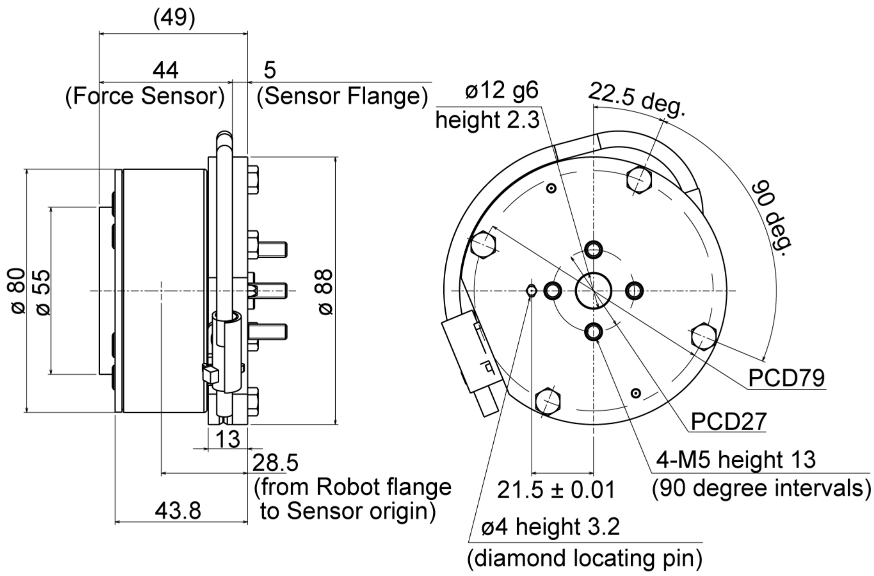


End effector side



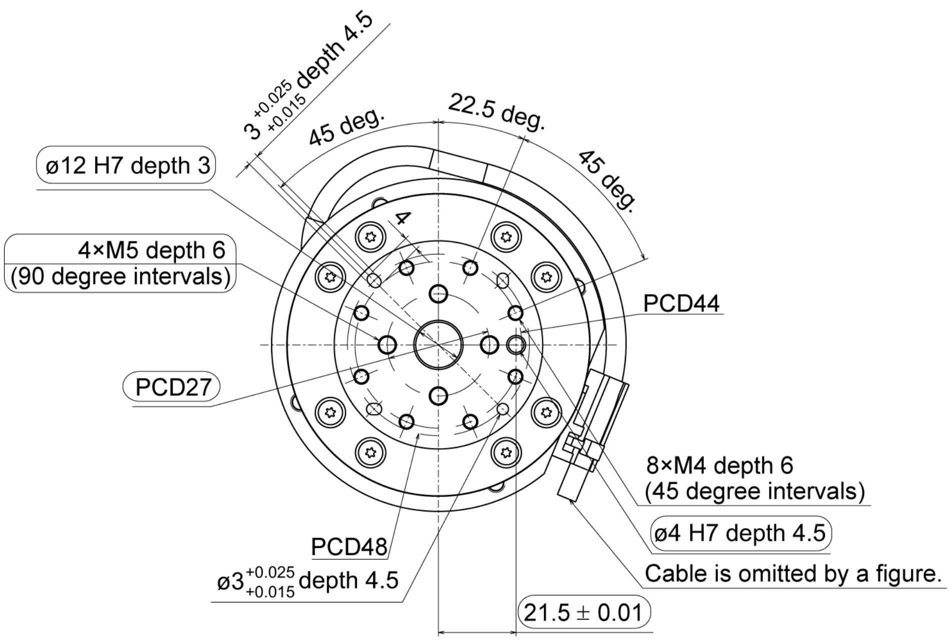
: Dimension is C4 series Manipulator Flange Compatible Form

4.2.2 S250L (For C8 series: IP20 compliant)



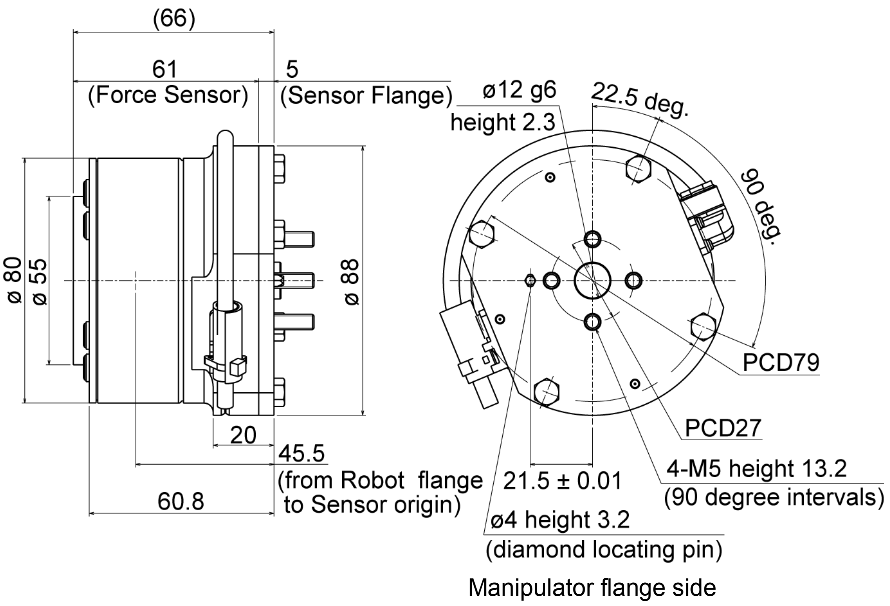
Manipulator flange side

End effector side

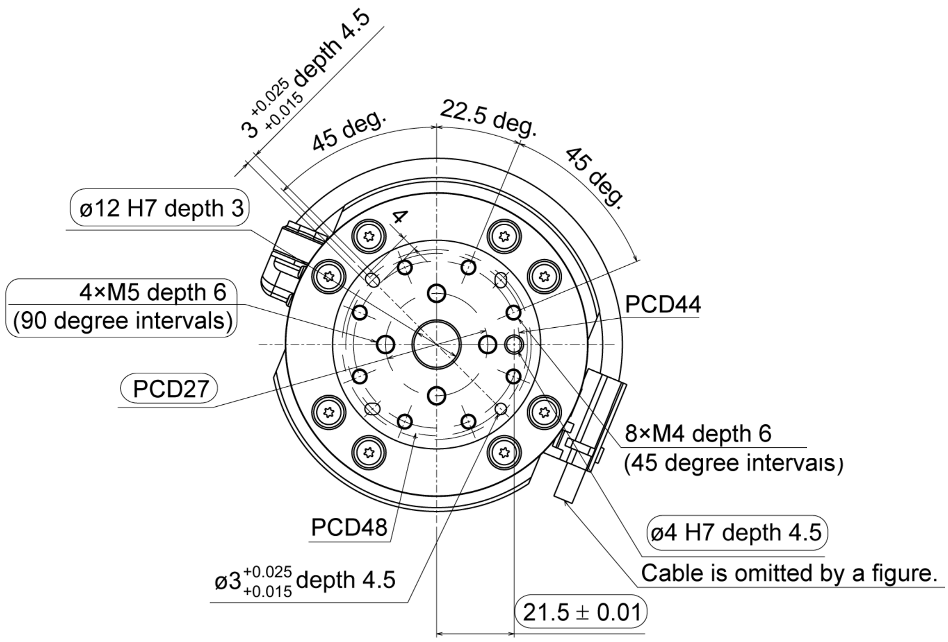


▭ : Dimension is C8 series Manipulator Flange Compatible Form

4.2.3 S250P (For C8 series: IP67 compliant)

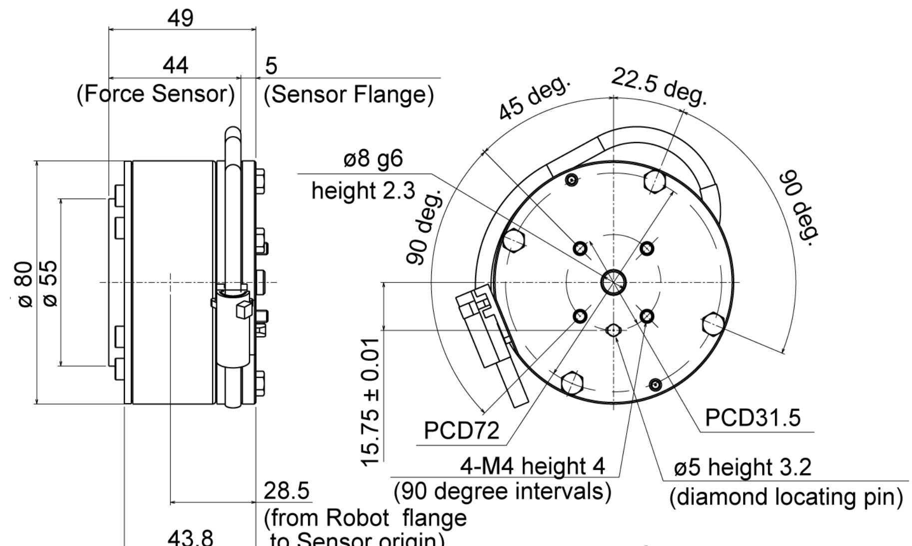


End effector side



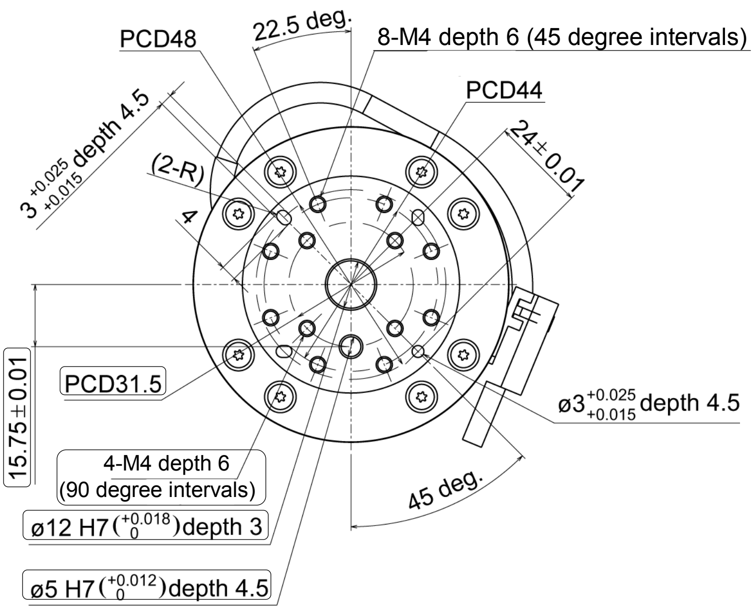
: Dimension is C8 series Manipulator Flange Compatible Form

4.2.4 S250H (For N2 series)



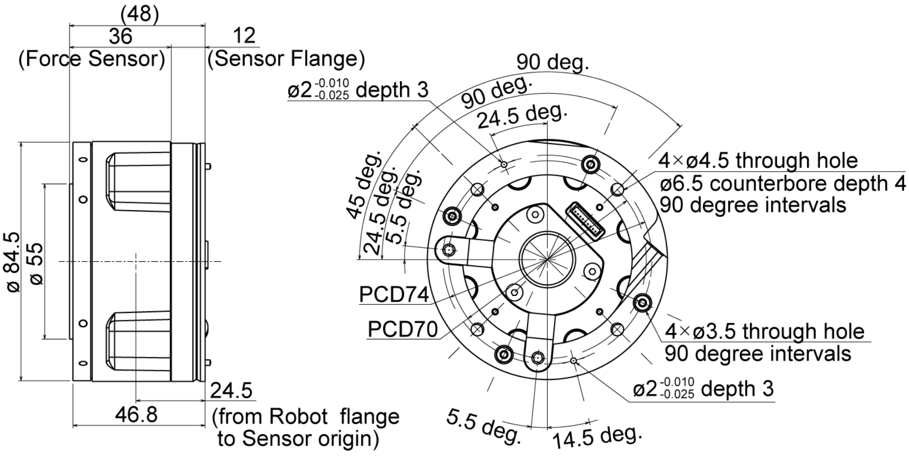
Manipulator flange side

End effector side



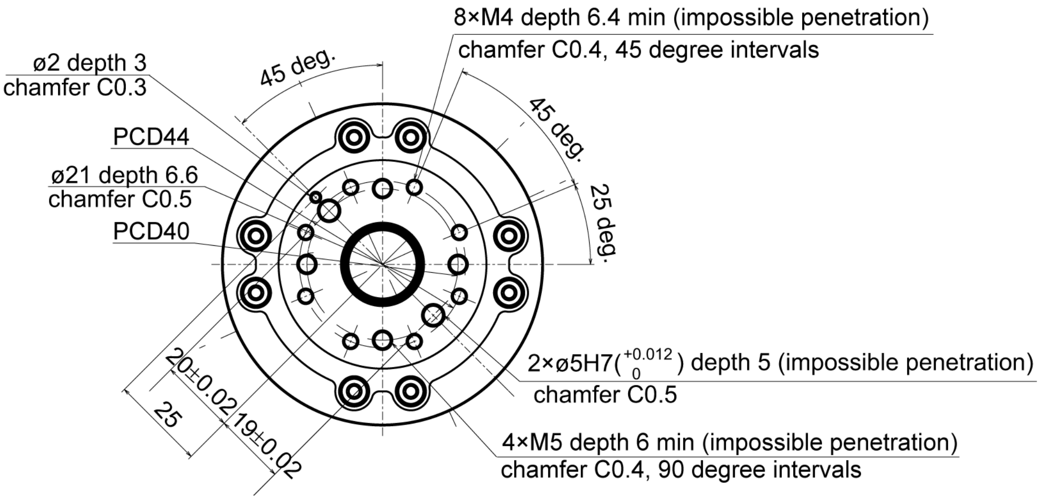
: Dimension is C4 series Manipulator Flange Compatible Form

4.2.5 SH250LH (For N6 series)

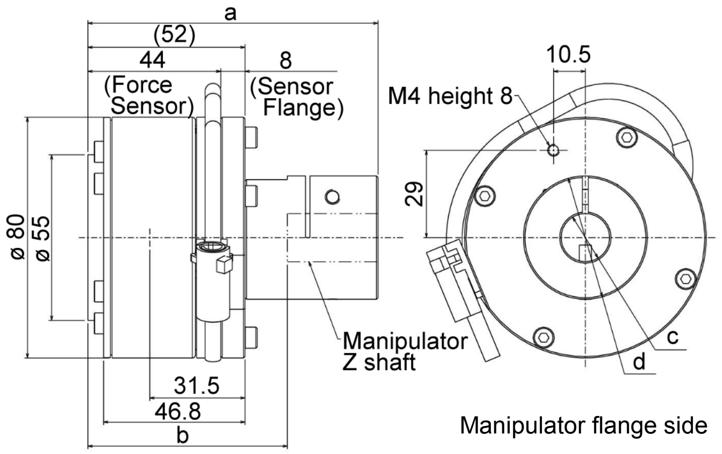


Manipulator flange side

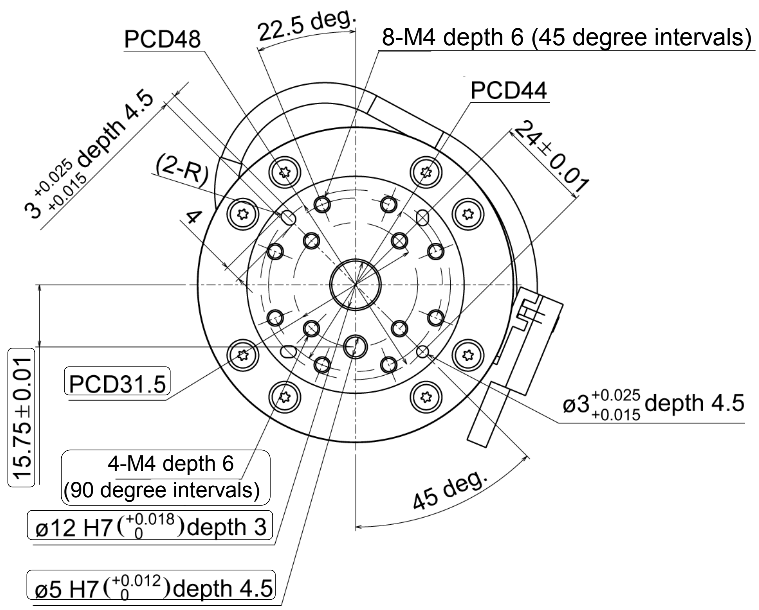
End effector side



4.2.6 S2503, S2506, S25010 (For G, RS series)



End effector side



: Dimension is C4 series Manipulator Flange Compatible Form

(Unit: mm)

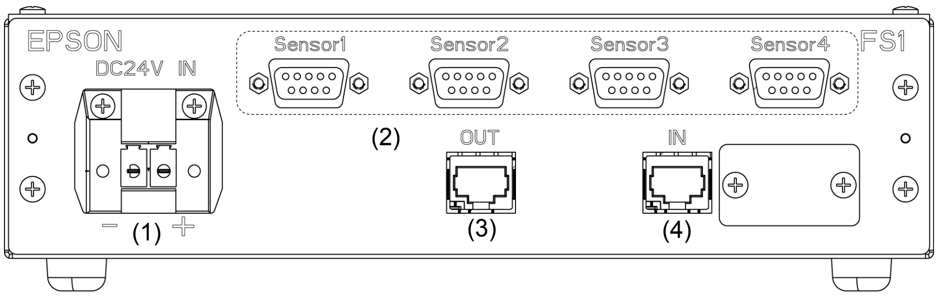
		S2503	S2506	S25010
a	Distance from the upper end of the adapter to the end face of the force sensor	96		98
b	Distance from the end face of the Manipulator Z-shaft to the end face of the force sensor	66		68
c	Diameter of the installation hole for the adapter shaft	16	20	25
d	Outer diameter of the adapter	41		45.5

5. Force Sensor I/F Unit

5.1 Force Sensor I/F Unit (FS1)

5.1.1 Specifications

Item		Specification
Outer dimensions		232 mm × 70 mm × 175 mm
Weight		1360 g
Interface	Power input	Terminal block (1), DC 24V (± 10 %)
	Motion network port	RJ45 (2 ports), IN port/OUT port
	Force Sensor communication port	D-sub 9pin (4 ports), Two communications are supported
Operating environment	Temperature	5 to 40 °C
	Humidity	10 to 80 % (with no condensation)



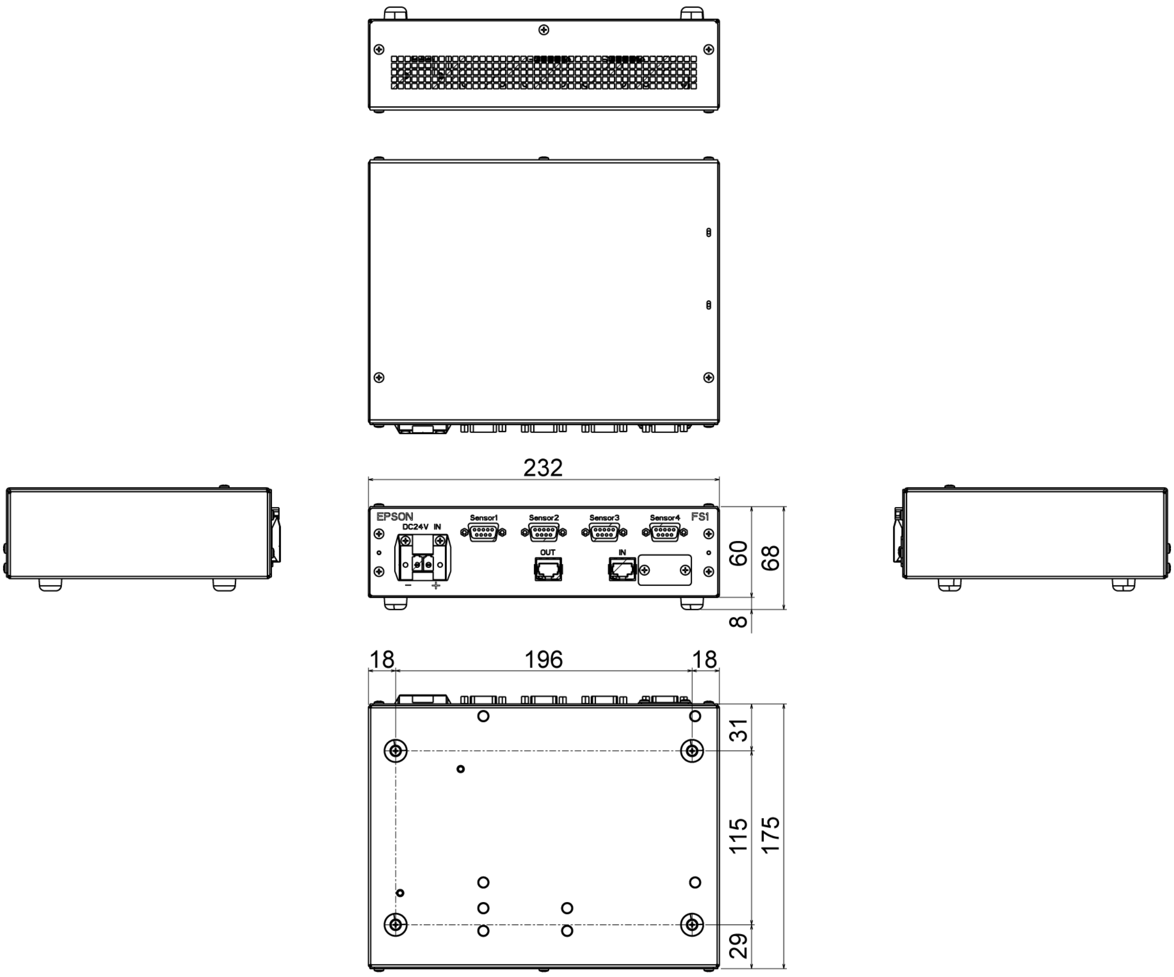
No.	Name	Function
1	24V Input Connector	The connector to supply 24V from the 24V power source.
2	Force Sensor connector	The connector to connect the Force Sensor. 2 sensors can be connected.
3	OUT connector	The connector to connect the Drive Unit.
4	IN connector	The connector for the Robot Controller and Drive Unit

NOTE

For the combination patterns for using multiple manipulators and Force Sensors, refer to the following section.

Installation 3. System Overview

5.1.2 Outer Dimensions



5.1.3 Installation

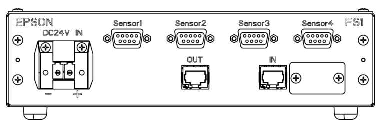
Installation environment

In order to use the Force Sensor I/F unit safely while maintaining performance, it must be installed in the environment that satisfies the following conditions:

- Install indoors only.
- Place in a well-ventilated area.
- Keep away from direct sunlight and radiation heat.
- Keep away from dust, oily mist, oil, salinity, metal powder or other contaminants.
- Keep away from water.
- Keep away from shocks or vibrations.
- Keep away from sources of electronic noise which generate static electricity and surge
- Prevent the occurrence of strong electric or magnetic field.
- Leave 100 mm of space at the rear

Mounting Direction

It is recommended to install the Force Sensor I/F unit horizontally.



5.1.4 Power Supply

Ensure that the power supply to the Force Sensor satisfies the following specifications.

- Voltage: 24 VDC (± 10 %)
  Current limit setting value: 2 A
- Satisfies the EMC standards in an industrial setting
- Have a reinforced insulation against the AC power source
- Have an overcurrent protection circuit build-in

It is recommended to use the power supply specialized for the Force Sensor I/F unit. When sharing the power supply with other equipment, do not to use the power supply connected to the equipment which generates electronic noise, or take adequate measures against electronic noise.

5.1.5 Wiring of Force Sensor I/F Unit and Power Connector

WARNING

- ■ Be sure to turn OFF power when wiring the power supply. Performing any work with the power ON is extremely hazardous and it may result in electric shock and/or improper function of the robot system.
  Make sure that wiring and voltage are correct before turning ON power.
- ■ Do not insert and remove the connector while applying current to the 24 VDC connector. Performing any work with the power ON is extremely hazardous and it may result in electric shock and/or improper function of the robot system.

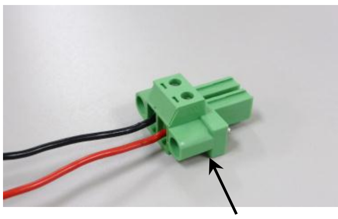
CAUTION

- ■ Use a twisted pair cable for wiring the 24 VDC power supply, and use as thick and short a wire as possible.
- ■ Keep the 24 VDC power cable away from peripheral noise sources as possible.
- ■ Install the ON/OFF switch at AC side of the 24 VDC power supply.
  Inserting and removing the connector while applying current to the 24V connector, or turning ON/OFF at 24 VDC side may cause a fusing inside the Force Sensor I/F unit.
  If fusing occurs, replace the fuse by referring to the following section.

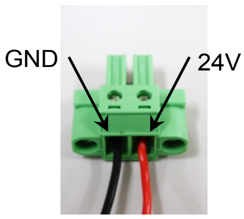
  Hardware 5.6 Replacing the Force Sensor I/F Unit Fuse

Refer to the following and wire the 24 VDC power supply to the connector.

Pin No.	Signal	Description
1	GND	Grounding (24V grounding)
2	24V	24VDC power supply



Force Sensor I/F unit
Power connector (male)

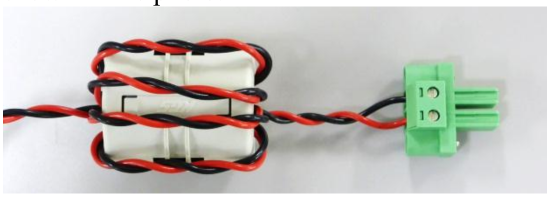


Power Connector (female) Model No. : DFK-PC4/2-GF-7.62 (Phoenix Contact)

Power Connector (male) Model No. : PC4/2-STF-7.62 (Phoenix Contact)

Appropriate Wire Diameter : 0.2 mm^2 to 4.0 mm^2 (manufacturer reference)

Wiring length : Should be within 2.5 m.
If the length exceeds 2.5 m, wrap the power supply wiring (twisted pair) around the ferrite core * with five turns as shown in the photo.



*Ferrite core: Kitagawa Industries Co., LTD RFC-20

5.1.6 Replacing the Force Sensor I/F Unit Fuse

Preparation

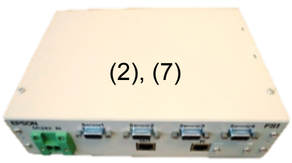
Prepare the following parts.

Name	Standard	Manufacturer	Quantity	Remark
Glass fuse	FGBO 125V 1A	FUJI Terminal Industry	1	Equivalent product available
Wire tie	SG-100	S.G. Industrial	1	Equivalent product available

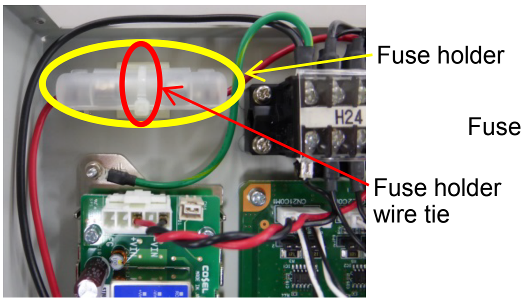
Replacement

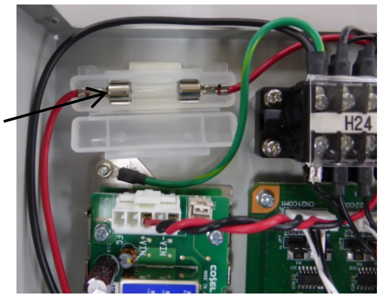
(1) Shut down the power, and then remove the power connector of the Force Sensor I/F unit.

(2) Remove the top cover of the Force Sensor I/F unit.



(3) Cut off the wire tie from the fuse holder.





(4) Open the fuse holder, and then remove the blown glass fuse.

When removing the fuse, be careful of breakage of glass.

(5) Install a new fuse. (The fuse can be installed in either direction.)

Make sure to install the fuse of appropriate standard (equivalent product is available).

(6) Fix the fuse holder with a wire tie.

Fix the holder firmly so as not to move.

(7) Install the top cover of the Force Sensor I/F unit.

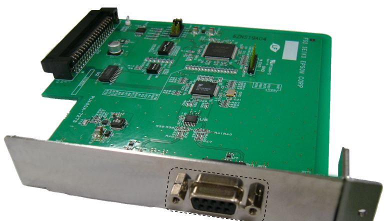
5.2 Force Sensor I/F Board (FS2)

Force Sensor I/F board is an option board to perform 24V power supply and communication for Force Sensor S250 series.

Mount the controller on the option slot and connect the Force Sensor to communicate the controller and the Force Sensor.

5.2.1 Specifications

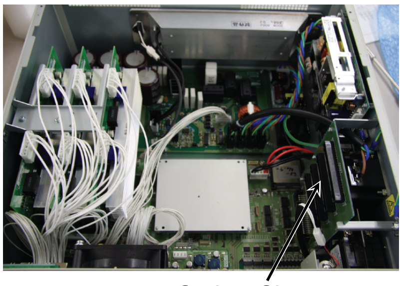
Item		Specification
Outer dimensions		206 mm × 102 mm × 24.5 mm
Weight		135 g
Interface	Force Sensor communication port	D-sub 9pin (1 port), One communications are supported
Operating environment	Temperature	5 to 40 °C
	Humidity	10 to 80 % (with no condensation)



No.	Name	Function
1	Force Sensor connector	The connector to connect the Force Sensor. 1 sensor can be connected.

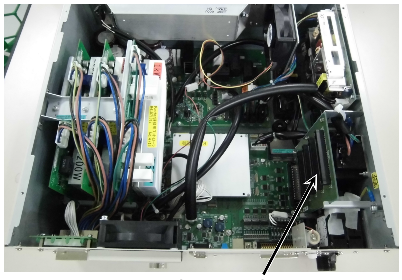
5.2.2 How to Install

RC700



Option Slot

RC700-A



Option Slot

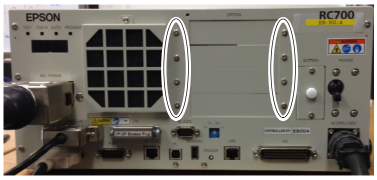
Force Sensor I/F Board Installation

(1) Turn OFF the controller.

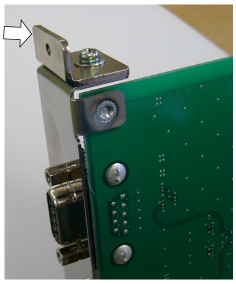
(2) Disconnect the power plug.

(3) Remove the top board. (six mounting screws)

(4) Unscrew the option slot panel.
Remove the option panel on the side you want to mount the Force Sensor I/F board.

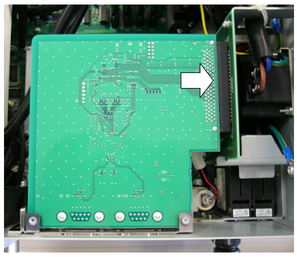


(5) Mount the L-shaped plate on the Force Sensor I/F board.



(6) Mount the Force Sensor I/F board as shown the picture on the right.

Push the board into option slot.
(Direction of an arrow)



(7) Fix the attached L-shaped plate from the front side with screws.

At this time, one screw of the option slot panel will be left.

(8) Mount the top board. (six mounting screws)

(9) After connecting the power plug, turn ON the controller and make sure to operate properly without vibration or abnormal sound.

5.2.3 Cautions about Connection

Force Sensor I/F board supplies DC24V from the connector of the Force Sensor to operate Force Sensor S250 series. Be careful about the followings.

1 : Do not connect a device to the connector for the Force Sensor except the Force Sensor.
It may result in damage of connected device, Force Sensor I/F board, and the controller.

2 : Do not change the each DIP switches and jumper pins.
If you changed those, refer to the following manual and put those back. Force Sensor I/F board may not be recognized properly if changing DIP switches and jumper pins.

Robot Controller RC700/RC700-A
Setup & Operation 14.6 Force Sensor I/F Board

6. How to Install

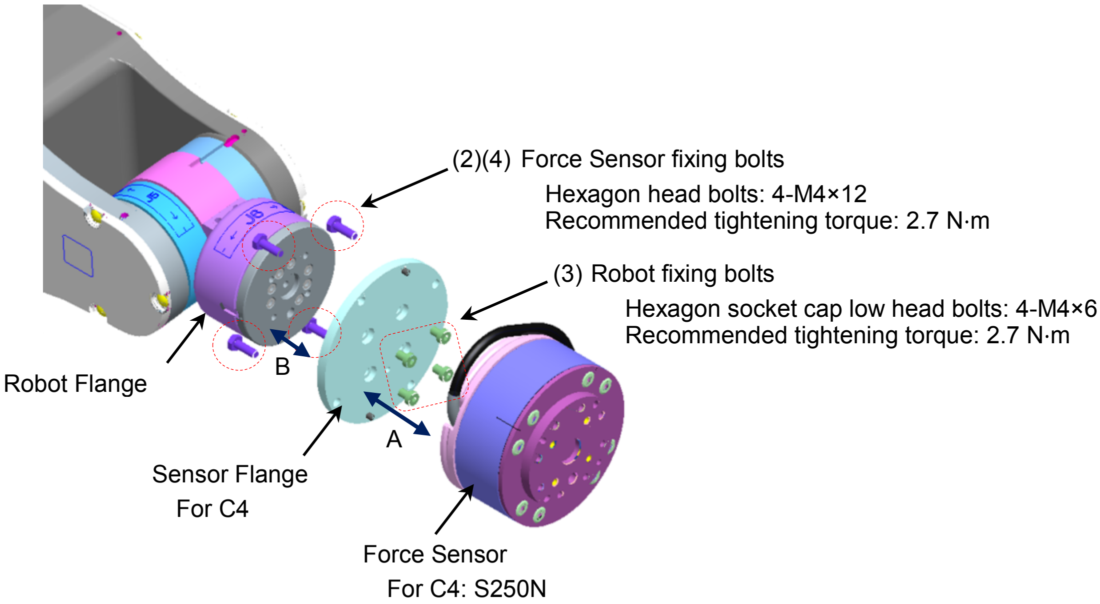
This section describes how to install the Force Sensor.

WARNING	■ Before performing any work, turn OFF the Controller and related equipment, and then disconnect the power plug from the power source. Performing any work with the power ON is extremely hazardous and it may result in electric shock and/or improper function of the robot system. ■ Be sure to connect the cables properly. Do not allow unnecessary strain on the cables. (Do not put heavy objects on the cables. Do not bend or pull the cables forcibly.) Unnecessary strain on the cables may result in damage to the cables, disconnection, and/or contact failure. Damaged cables, disconnection, or contact failure is extremely hazardous and may result in electric shock and/or improper function of the system. ■ Do not touch the sensor circuit board and FFC cables when mounting the Force Sensor. It may result in damage to the cables and connectors, disconnection, and/or contact failure, and may result in electric shock and/or improper function of the system.

CAUTION	■ Install the Force Sensor to the Manipulator properly by referring to the following section. *Hardware 6.1 Installing the Force Sensor.* Installing the Force Sensor in an improper manner may cause accuracy degradation or malfunction of the sensor. ■ Install the Force Sensor to the Manipulator with the recommended tightening torque. If the Force Sensor is fixed with an improper torque, it may result in abnormal sensor performance. If the Force Sensor is fixed with the tightening torque lower than the recommended torque, the Force Sensor may fall during the Manipulator operation and may result in damage to the sensor and the system. ■ When installing the sensor cables to the Manipulator, fix them so as not to interfere with the Manipulator's operation range. Also, load may be applied to the cables even in the movable range of the cables and it may cause cable breakage.

6.1 Installing the Force Sensor

6.1.1 S250N (For C4 series)

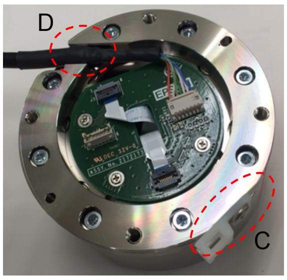


(1) Turn OFF the Controller.

(2) Remove the sensor flange from the Force Sensor. (A)
  Force Sensor fixing bolts (Hexagon head bolts: 4-M4×12)
(The sensor is installed to the sensor flange at the time of shipment.)

(3) Install the sensor flange to the robot flange. (B)
Insert the sensor flange while aligning the two positioning points on the sensor flange (positioning pins and projection at the center) to the robot flange.
Fix the sensor flange to the robot flange with the robot fixing bolts included with shipment.
  Robot fixing bolts (Hexagon socket cap low head bolts: 4-M4×6)
  Recommended tightening torque: 2.7 N·m

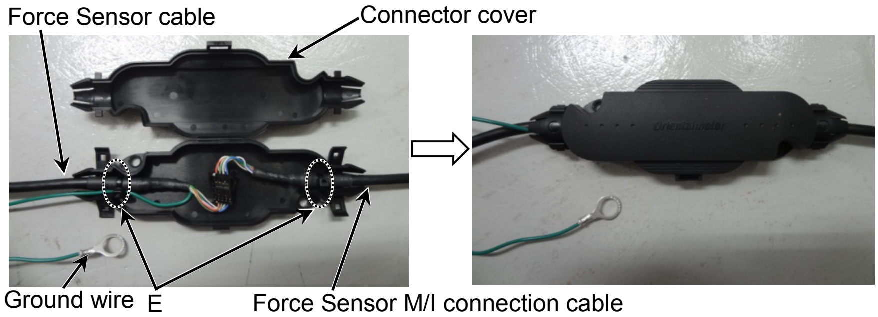
(4) Install the Force Sensor to the sensor flange fixed in the step (3). (A)



Align the cutouts (C) on the sensor flange and the Force Sensor. Install the sensor by inserting the two positioning pins of the sensor flange to the sensor.
At this time, adjust the position of the Force Sensor cable so that the part wrapped with the heat shrinkable tube to be at (D).
Fix the sensor flange and the Force Sensor with the bolts removed in the step (2).
  Force Sensor fixing bolts (Hexagon head bolts: 4-M4×12)
  Recommended tightening torque: 2.7 N·m

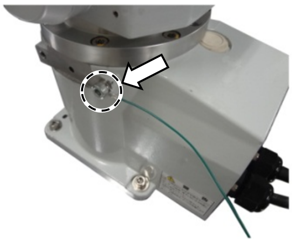
(5) Fix the Force Sensor cable to the Manipulator.
Set the cable so as not to interfere with Manipulator motion and not to apply load on the cable.

(6) Connect the Force Sensor cable and Force Sensor M/I connection cable.
Store the connecting part to the connector cover.
Fix the cables with wire ties included with shipment. (E)
Close the connector cover.



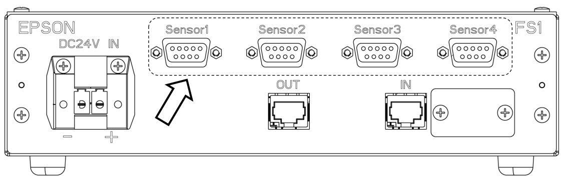
(7) Fix the connector cover to the position where does not interfere with Manipulator motion and not apply load on the cable.

(8) Fix the ground terminal of the Force Sensor lead to the Manipulator base.
Hexagon head bolts: M8×12

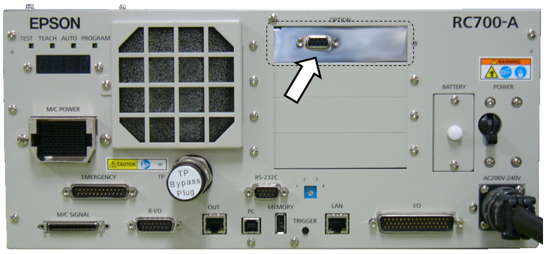


(9) Connect the Force Sensor M/I connection cable to the Force Sensor I/F to be used.
Connect to the Connector Sensor Port for Force Sensor.

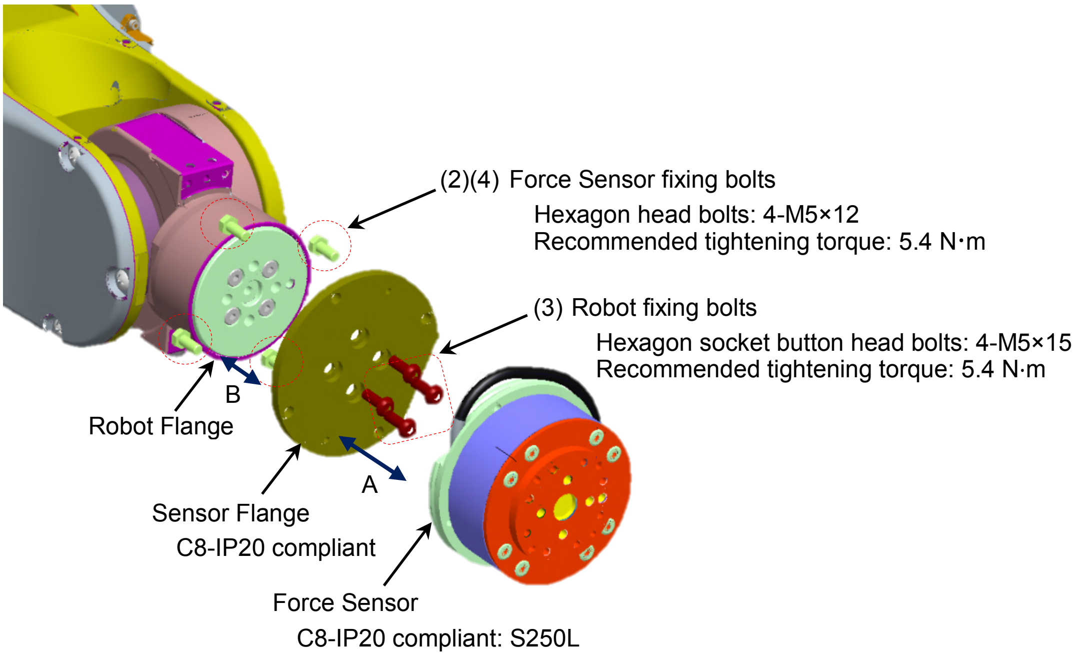
Force Sensor I/F unit:



Force Sensor I/F board:



6.1.2 S250L (For C8: IP20 compliant)

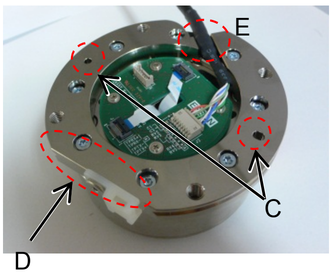


(1) Turn OFF the Controller.

(2) Remove the sensor flange from the Force Sensor. (A)
 Force Sensor fixing bolts (Hexagon head bolts: 4-M5×12)
 (The sensor is fixed to the sensor flange at the time of shipment.)

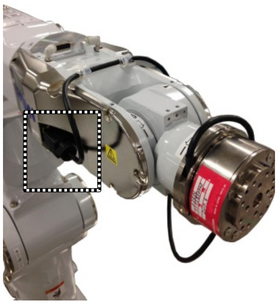
(3) Install the sensor flange to the robot flange. (B)
 Insert the sensor flange while aligning the two positioning points on the sensor flange (positioning pins and projection at the center) to the robot flange.
 Fix the sensor flange to the robot flange with the robot fixing bolts included with shipment.
 Robot fixing bolts (Hexagon socket button head bolts: 4-M5×15)
 Recommended tightening torque: 5.4 N·m

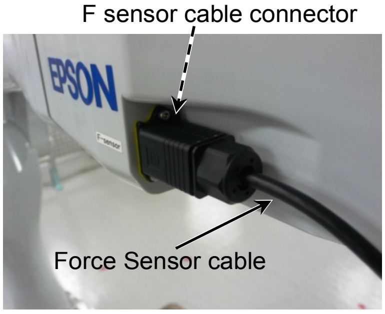
(4) Install the Force Sensor to the sensor flange fixed in the step (3). (A)



Align the cutouts (D) on the sensor flange and the Force Sensor. Insert the sensor flange by inserting the two positioning pins on the sensor flange to the positioning holes (C) on the sensor.
At this time, adjust the position of the Force Sensor cable so that the part wrapped with the heat shrinkable tube to be at (E).
Fix the sensor flange and the Force Sensor with the bolts removed in the step (2).
 Force Sensor fixing bolts (Hexagon head bolts: 4-M5×12)
 Recommended tightening torque: 5.4 N·m

(5) Connect the Force Sensor cable to the F-sensor cable connector on the Manipulator.



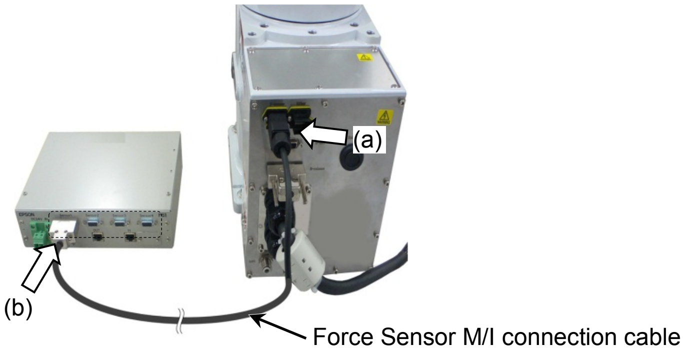


(6) Connect the Force Sensor M/I connection cable to (a) and (b).

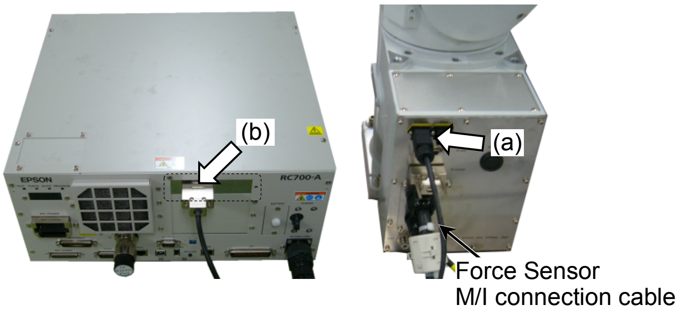
(a) F-sensor cable connector

(b) Connector Sensor Port for Force Sensor of Force Sensor I/F to be used.

Force Sensor I/F Unit:

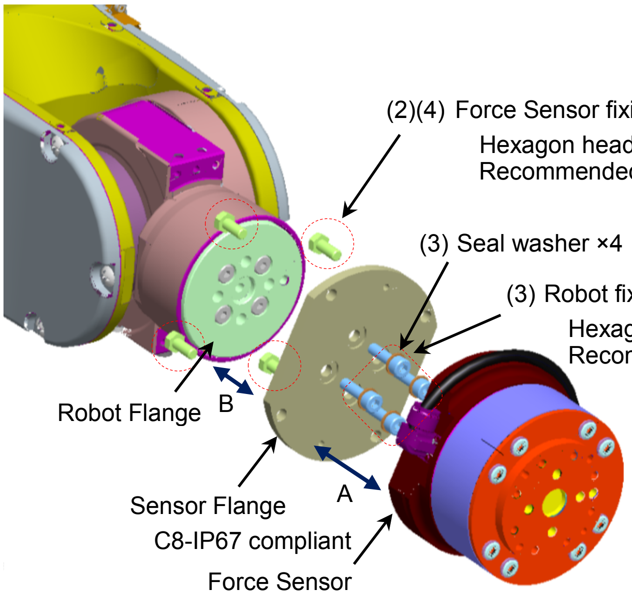


Force Sensor I/F Board:



(7) Operate the Manipulator to any posture, and then record the initial sensor output data.

6.1.3 S250P (For C8: IP67 compliant)

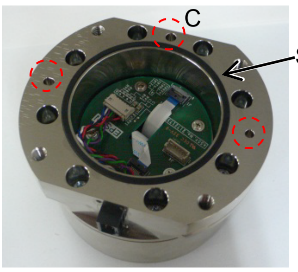


(1) Turn OFF the Controller.

(2) Remove the sensor flange from the Force Sensor. (A)
  Force Sensor fixing bolts (Hexagon head bolts: 4-M5×12)
(The sensor is installed to the sensor flange at the time of shipment.)

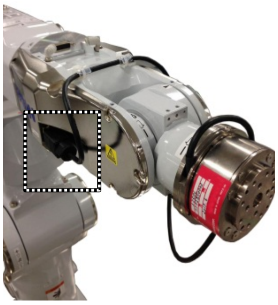
(3) Install the sensor flange to the robot flange. (B)
First, insert the sensor flange while aligning the two positioning points on the sensor flange (positioning pins and projection at the center) to the robot flange.
Then, insert the seal washers to the root of the robot fixing bolts included with shipment.
Fix the sensor flange and the robot flange with the bolts.
  Robot fixing bolts (Hexagon socket cap low head bolts: 4-M5×18)
  Recommended tightening torque: 5.4 N·m

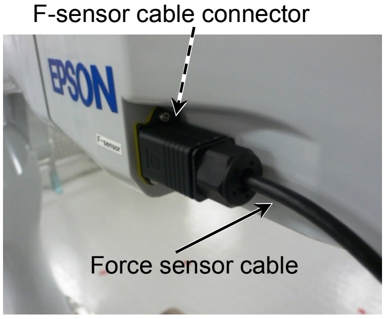
(4) Install the Force Sensor to the sensor flange fixed in the step (3). (A)



Install the Force Sensor so that the three positioning pins on the sensor flange and the positioning holes (C) on the sensor fit each other.
When inserting the sensor, try to prevent the foreign material from attaching to the mounting face. Also, be careful not to touch the sponge.
Fix the sensor flange and the Force Sensor with the bolts removed in the step (2).
  Force Sensor fixing bolts (Hexagon head bolts: 4-M5×12)
  Recommended tightening torque: 5.4 N·m

(5) Connect the Force Sensor cable to the F-sensor cable connector on the Manipulator.



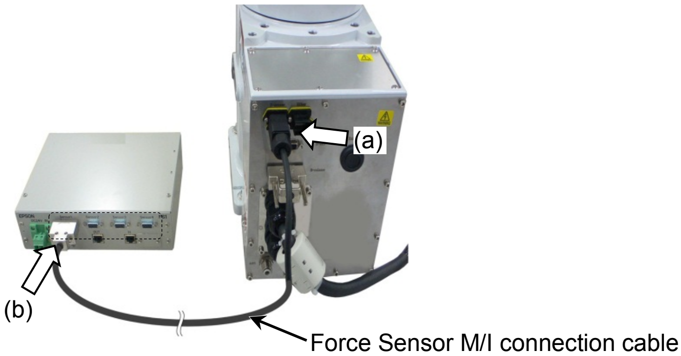


(6) Connect the Force Sensor M/I connection cable to (a) and (b).

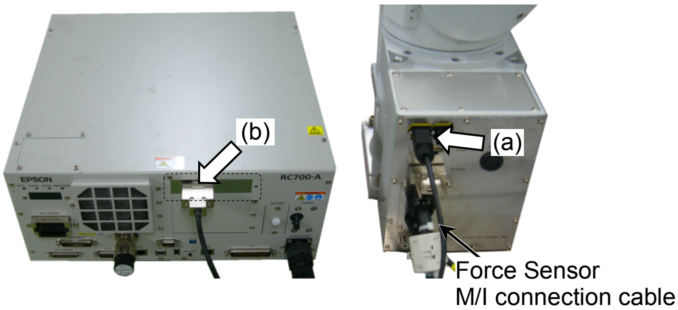
(a) F-sensor cable connector

(b) Connector Sensor Port for Force Sensor of Force Sensor I/F to be used.

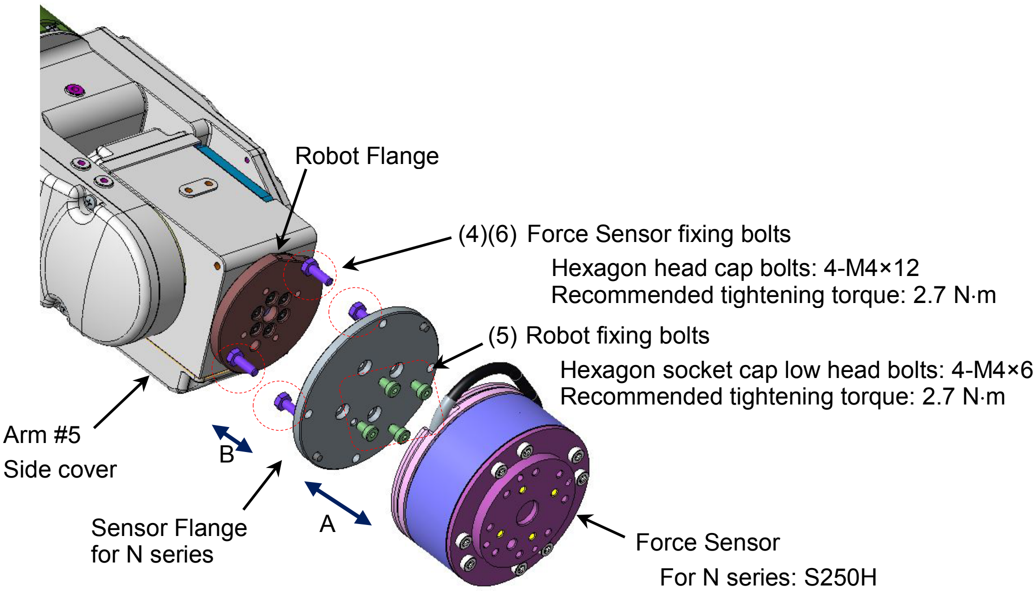
Force Sensor I/F Unit:



Force Sensor I/F Board:



6.1.4 S250H (For N2 series)



(1) Tilt the Joint #6 about +20° from the origin posture.

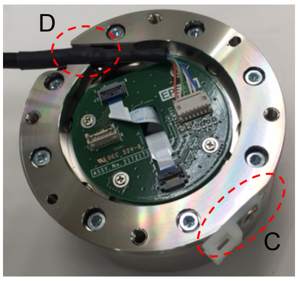
(2) Turn OFF the Controller.

(3) Remove the Arm #5 side cover of the Manipulator.
(Cross recessed head screw: 4-M3×6)

(4) Remove the sensor flange from the Force Sensor. (A)
Force Sensor fixing bolts (hexagon head bolts: 4-M4×12)
(The sensor is installed to the sensor flange at the time of shipment.)

(5) Install the sensor flange to the robot flange. (B)
First, insert the sensor flange while aligning the two positioning points on the sensor flange (positioning pins and projection at the center) to the robot flange.
Fix the sensor flange and the robot flange with the bolts.
Robot fixing bolts (Hexagon socket cap low head bolts: 4-M4×6)
Recommended tightening torque: 2.7 N·m

(6) Install the Force Sensor to the sensor flange fixed in the step (5). (A)

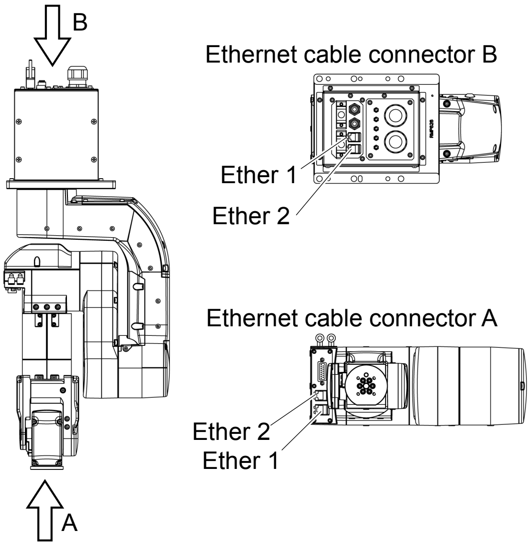


Align the cutouts (C) on the sensor flange and the Force Sensor. Insert the sensor flange while inserting the two positioning pins on the sensor flange to the sensor.
At this time, adjust the position of the Force Sensor cable so that the part wrapped with the heat shrinkable tube to be at (D).
Fix the sensor flange and the Force Sensor with the bolts removed in the step (4)
Force Sensor fixing bolts (Hexagon head bolts: 4-M4×12)
Recommended tightening torque: 2.7 N·m

(7) Install the Arm #5 side cover of the Manipulator.
(Cross recessed head screw: 4-M3×6 Recommended tightening torque: 0.45 N·m)

(8) Fix the Force Sensor cable to the Manipulator.
Set the cable so as not to interfere with Manipulator motion and not to apply load on the cable.

(9) Connect the Force Sensor cable to the following connector.
Ethernet cable connector A (Ether1, or Ether2)

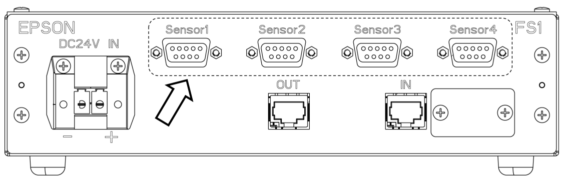


(10) Connect the Force Sensor M/I connection cable to (a) and (b).

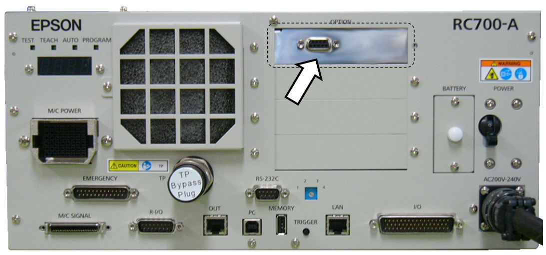
(a) :Ethernet cable connector B
Connector with the same name as the one connected in the step (9)
(Ether1, or Ether2)

(b) :Connect to Force Sensor I/F to be used
Connect to the Connector Sensor Port for Force Sensor.

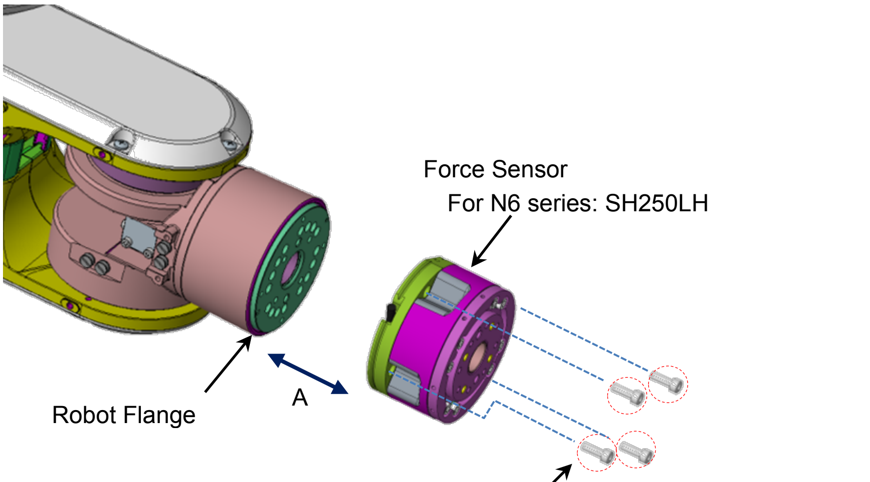
Force Sensor I/F Unit:



Force Sensor I/F Board:



6.1.5 SH250LH (For N6 series)



(1) Move the Joint #6 of the robot the origin posture.

(2) Turn OFF the controller.

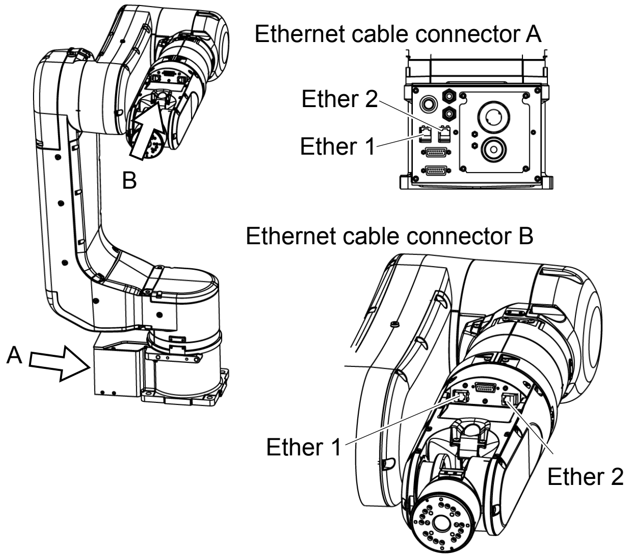
(3) Install the sensor flange to the robot flange. (A)
First, insert the sensor flange while aligning the two positioning points on the force sensor (positioning pins) to the robot flange. (Red circles on the pictures below)
Fix the sensor flange and the robot flange with the bolts.
Robot fixing bolts (Hexagon socket cap low head bolts: 4-M4×12)
Recommended tightening torque: 2.7 N·m

Robot flange

Force Sensor

(4) Fix the Force Sensor cable to the Manipulator.
Set the cable so as not to interfere with Manipulator motion and not to apply load on the cable.

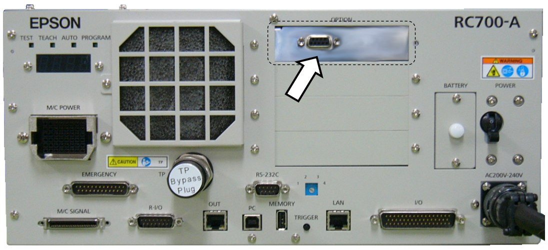
(5) Connect the Force Sensor cable to the following connector.
Ethernet cable connector A (Ether1, or Ether2)



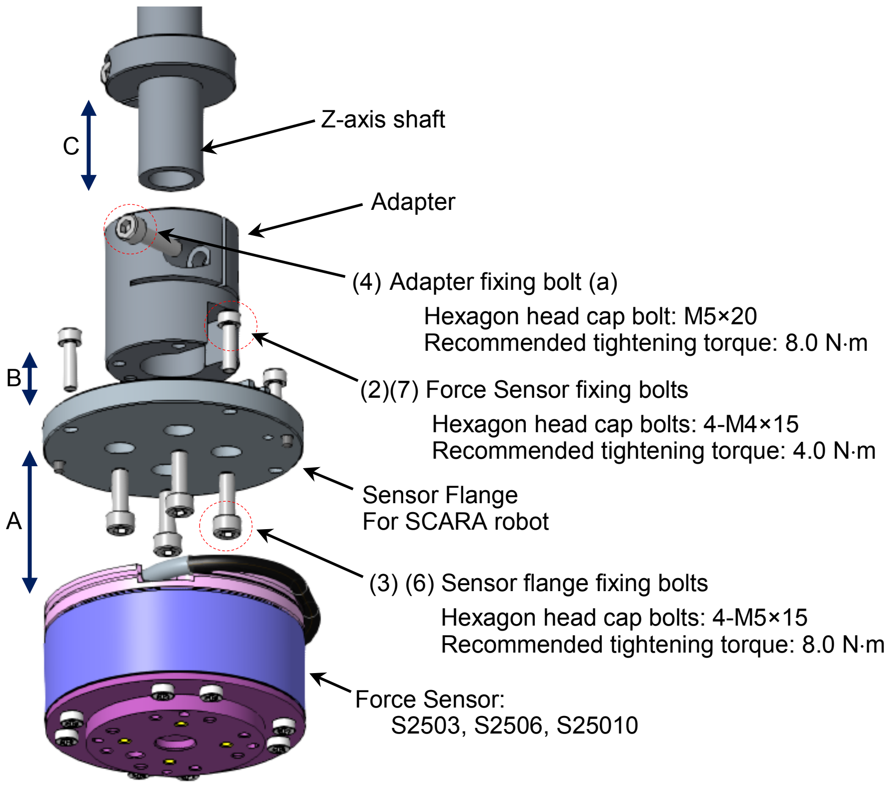
(6) Connect the Force Sensor M/I connection cable to (a) and (b).

(a) : Ethernet cable connector B
Connector with the same name as the one connected in the step (5) (Ether1, or Ether2)

(b) : Connect to Force Sensor I/F to be used
Connect to the Connector Sensor Port for Force Sensor.



6.1.6 S2503, S2506, S25010 (For G, RS series)



(1) Turn OFF the Controller.

(2) Remove the sensor flange from the Force Sensor. (A)
Force Sensor fixing bolts (Hexagon head bolts: 4-M4×15)
(The sensor is installed to the sensor flange at the time of shipment.)

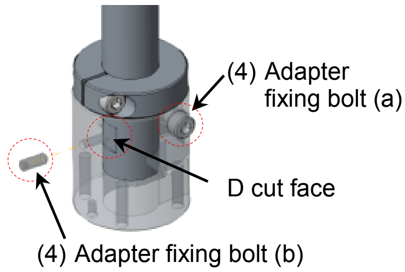
(3) Fix the sensor flange and the adapter (B)
Sensor flange fixing bolts (Hexagon head bolts: 4-M5×15)
Recommended tightening torque: 8.0 N·m

(4) Insert and fix the adapter at 30 mm from the end of the Z-axis shaft. (C)
If the Z stopper position has not been changed since the time of shipment, fix the adapter where it touches the Z stopper.

Fix with the following bolts (a) and (b).
Adjust the direction of the bolt (b) so as to touch the D-cut face on the Z-axis shaft vertically.

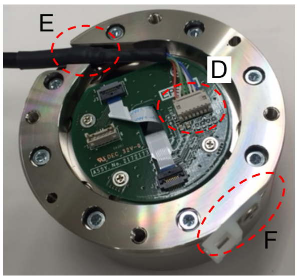
Adapter fixing bolt (a):
Stud clamp bolt
(Hexagon socket head cap bolt: M5×20)
Recommended tightening torque: 8.0 N·m

Adapter fixing bolt (b):
Set screw
(Hexagon socket set screw: M4×10)
Recommended tightening torque: 2.4 N·m



(5) Connect the Force Sensor cable to the connector (D) on the Force Sensor.

When passing the Force Sensor cable to the Z-axis hollow shaft, follow the following steps.
1. Pass the Force Sensor cable from the upper part of the shaft.
2. Pull out the cable from the opening on the adapter.
3. Connect the Force Sensor cable to the connector (D) on the Force Sensor.



(6) Install the Force Sensor to the sensor flange fixed in the step (3). (A)
Align the cutouts (F) on the sensor flange and the Force Sensor. Insert the sensor flange while inserting the two positioning pins on the sensor flange to the sensor.
At this time, adjust the position of the Force Sensor cable so that the part wrapped with the heat shrinkable tube to be at (E).

(7) Fix the sensor flange and the Force Sensor with the bolts removed in the step (2).
Force Sensor fixing bolts (Hexagon head bolts: 4-M4×15)
Recommended tightening torque: 4.0 N·m

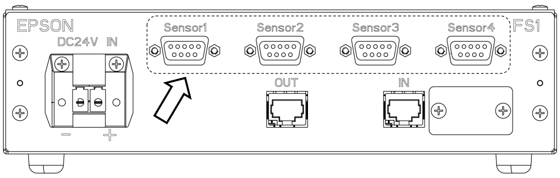
(8) Fix the Force Sensor cable to the Manipulator.
Set the cable so as not to interfere with Manipulator motion and not to apply load on the cable.
For details of cable wiring and grounding, refer to the following section.
Hardware 6.3 Wiring of the Force Sensor cable

(9) Connect the Force Sensor M/I connection cable to (a) and (b).

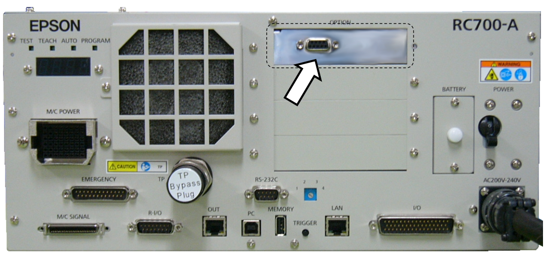
(a) :F Sensor Cable Connector

(b) :Connect to Force Sensor I/F to be used
Connect to the Connector Sensor Port for Force Sensor.

Force Sensor I/F Unit:



Force Sensor I/F Board:



⚠ CAUTION	■ In the case of RS series, when connecting with aligning the Force Sensor with D cut face, positive and negative of X axis and Y axis will be inverted 180 degrees. Sensor labels will be inverted as well. Please take the following actions since force control of X axis and Y axis will be worked in reverse. (When using the flange supplied by us.) When using the firmware that is Ver.7.3.4.0 or before: Execute the following SPEL+ command. `> FSet Robot.FlangOffset, 0, 0, -22, 180, 0, 180` Ref: EPSON RC+ 7.0 Option Force Control 7.0 Property &Status Reference: *FlangeOffset property* When updating the firmware from Ver.7.3.4.0 or before to Ver.7.3.4.0 or later: Click the <Defaults> button in EPSON RC+ Menu - [Tool] - [Robot manager] - [Mass/Gravity] Panel. Ref: EPSON RC+ 7.0 Option Force Control 7.0 Software *3.5.1 [Robot Manager] (Tools Menu)*

6.2 End Effector

The end effector must be fabricated by customers.

NOTE

For details about mounting screw holes position on end effector side, refer to the following section.
Hardware 4.2 Outer Dimensions

⚠ CAUTION	■ Design the sensor installation face of the end effector so that the sensor can be completely contacted to the end effector. Also, use the end effector with sufficient rigidity in order to achieve high performance of the sensor. ■ When operating the Manipulator with the end effector installed, the end effector may collide with the Manipulator body due to following factors. End effector outer diameter / Work piece size / Force Sensor outer diameter/ Arm position, etc. When designing the system, be very careful of interference area of the end effector and Force Sensor.

6.2.1 Guidelines of Allowable Moment

The following describes precautions when designing an end effector.

There is an allowable moment on joints of the robot. You need to design the robot not to exceed the limit of the allowable moment of corresponding joints. Allowable moment is calculated as follows.

When the direction of the load and pressing moment are the same:

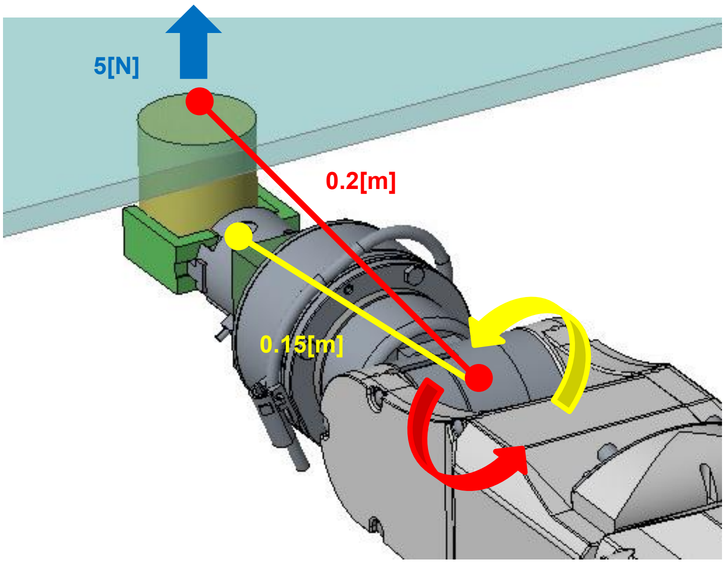
Moment [N·m]
= Load mass (Force Sensor, end effector, workpiece) [kg]×Gravity acceleration [m/s^2] ×Joint distance between center of rotation and gravity center of load [m]+pressing force [N]×Joint distance between center of rotation and contact point [m]

When the direction of the load and pressing moment are different:

Moment [N·m]
= Load mass (Force Sensor, end effector, workpiece) [kg]×Gravity acceleration [m/s^2] ×Joint distance between center of rotation and gravity center of load [m]– pressing force [N]×Joint distance between center of rotation and contact point [m]

Calculation example: Upward (C4: J5)

Calculation procedure of allowable moment which is applied J5 on C4 series manipulator when applying 5N to upward.



Moment [N·m] applied on J5

= Load mass (Force Sensor, end effector, workpiece) [kg]×Gravity acceleration [m/s^2] ×J5 Distance between center of rotation and gravity center of load [m] + pressing force [N]×J5 Distance between center of rotation and contact point [m]

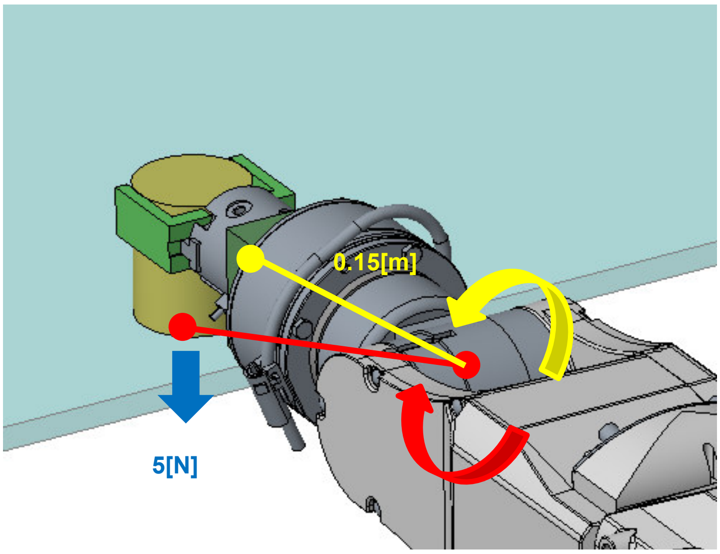
= 1[kg]×9.8[m/s^2]×0.15[m]+5[N]×0.2[m]

= 2.47[N·m]

There is no problem since moment 2.47[N·m] applied on J5 does not exceed the allowable moment 4.41[N·m] of J5.

Calculation example: Downward (C4: J5)

Calculation procedure of allowable moment which is applied J5 on C4 series manipulator when applying 5N to downward.



Moment [N·m] applied on J5

= Load mass (Force Sensor, end effector, workpiece) [kg]×Gravity acceleration [m/s^2]×J5 Distance between center of rotation and gravity center of load [m] – pressing force [N]×J5 Distance between center of rotation and contact point [m]

= 1[kg]×9.8[m/s^2]×0.15[m]-5[N] ×0.2[m]

= 0.47[N·m]

There is no problem since moment 0.47[N·m] applied on J5 does not exceed the allowable moment 4.41[N·m] of J5.

Perform the same consideration or verification for other joints.

6.2.2 Guidelines of Joint Torque

When application applies a great force or load of end effector/workpiece is heavy, follow the directions shown below and check the joint torque.

Check of Joint Peak Torque

PTRQ can acquire or display the peak torque. (Refer to sample program for usage.)

When PTRQ is “1”, problems of security may occur. Make sure to check the PTRQ is less than “1”.

```
Function PTRQ_Check         ' Sample program to acquire or display PTRQ
   Integer i
   Double PT(6)
   Do                       'Repeat motion part and PTRQ acquisition part
       PTCLR                'Clear the peak torque
'--- Motion part (Example)---Motion part is an example and is described by user
       TLSet 1, XY(0, 0, -49, 0, 0, 0) 'Set the tool 1
       Tool 1               'Specify the tool 1
       Motor On             'Motor On
       Power High           'Power high
       Speed 100            'PTP motion speed setting
       Accel 100, 100       'PTP motion acceleration setting
       SpeedS 50            'CP motion speed setting
       AccelS 500, 500      'CP motion speed setting

       Go P1                'PTP motion to P1
       Go P2 +Z(20)         'Move to P2+Z20mm
       Move P2

       FSet FC1.Fz_Enabled, True 'Enable force control function only for Fz
       FSet FC1.Fz_Spring, 0     'Spring value is 0
       FSet FC1.Fz_Damper, 10    'Damper value is 10
       FSet FC1.Fz_Mass, 10      'Mass value is 10
       FSet FC1.Fz_TargetForce, -50 'Set the target force of Fz to -50N
       Wait 0.3             'Wait for 0.3 s
       FSet FS1.Reset       'Reset the Force Sensor
       FCKeep FC1, 10       'Execute force control function for 10 s

       Move P2              'Move to P2
       Go P2 +Z(20)         'Move to P2+Z20mm
'-------------------------------------------------------
       For i = 1 To 6       'Repeat 1 to 6
           PT(i) = PTRQ(i)  'Acquire PTRQ
           Print "PT_J", i, "=", PTRQ(i) 'Display PTRQ
       Next
   Loop
Fend
```

Overload Rate of Joint

OLRate can acquire or display the overload rate. (Refer to sample program for usage.)

OLRate rises when overload is applied on the joints and falls when overload is no longer applied.

Stop as servo error when OLRate keeps rising and becomes “1”. Make sure that OLRate does not keep rising.

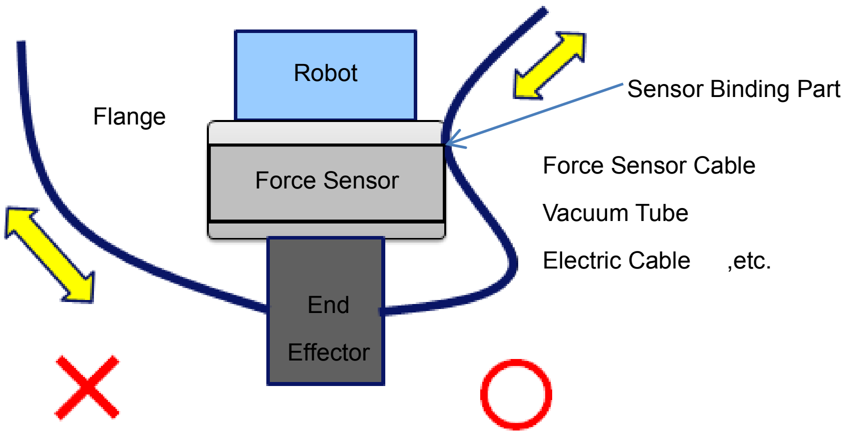
In particular, check the OLRate rising amount of one motion cycle is “0”.

```
Function OLRate_Check      'Program to acquire or display OLRate
   Integer i, j
   Double OLCheck(6), OL(6)
   Do                      'Repeat motion part and PTRQ acquisition part
'--- Motion part (Example)--- Motion part is an example and is described by user
      TLSet 1, XY(0, 0, -49, 0, 0, 0) 'Set the tool 1
      Tool 1               'Specify the tool 1
      Motor On             'Motor On
      Power High           'Power high
      Speed 100            'PTP motion speed setting
      Accel 100, 100       'PTP motion acceleration setting
      SpeedS 50            'CP motion speed setting
      AccelS 500, 500      'CP motion speed setting

      Go P1                'PTP motion to P1
      Go P2 +Z(20)         'Move to P2+Z20mm
      Move P2              'CP motion to P2

      FSet FC1.Fz_Enabled, True ' Enable force control function only for Fz
      FSet FC1.Fz_Spring, 0          'Spring value is 0
      FSet FC1.Fz_Damper, 10         'Damper value is 10
      FSet FC1.Fz_Mass, 10           'Mass value is 10
      FSet FC1.Fz_TargetForce, -50 'Set the target force of Fz to -50N
      Wait 0.3             'Wait for 0.3 s
      FSet FS1.Reset       'Reset the Force Sensor
      FCKeep FC1, 10       'Execute force control function for 10 s

      Move P2              'Move to P2
      Go P2 +Z(20)         'Move to P2+Z20mm

'----------------------------------------------------
      For i = 1 To 6           'Repeat 1 to 6
         If j = 1 Then         'For the second cycle or later
           OLCheck(i) = OLRate(i) - OL(i)
                           'Acquire OLRate rise amount of one motion cycle
           OL(i) = OLRate(i)'Acquire OLRate
           Print "OLCheck_J", i, "=", OLCheck(i)
                           'Display OLRate rise amount of one motion cycle
         Else                  'For the first cycle
           OL(i) = OLRate(i)'Acquire OLRate
         EndIf
      Next
      j = 1
   Loop
Fend
```

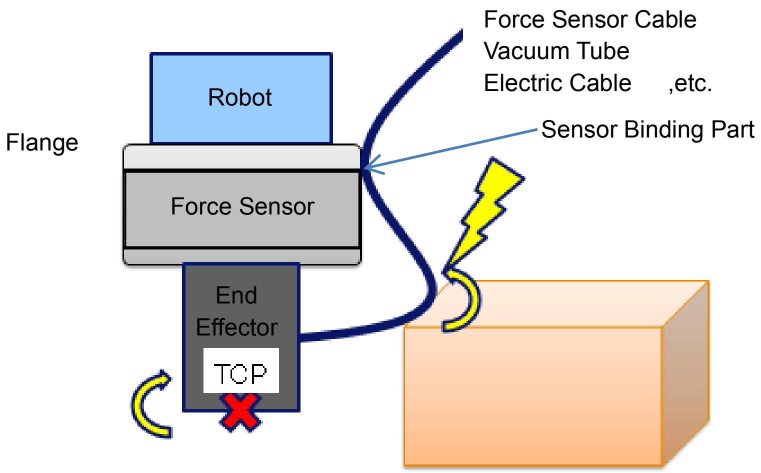
6.2.3 Cautions about Wires and Pipes

Force may be applied to the end effector due to the cable which is connected to the end effector or pulling from the pipes. The force sensor also detects this force. This force may have bad influence for the operation. Therefore, fix the cables and pipes to the sensor binding part.

Fix the wires and pipes to the sensor binding part to reduce the influence of elastic force or gravity.



Force or torque will be generated when wires or pipes touch to surrounding objects. Fix the wires and pipes so as not to touch surroundings.



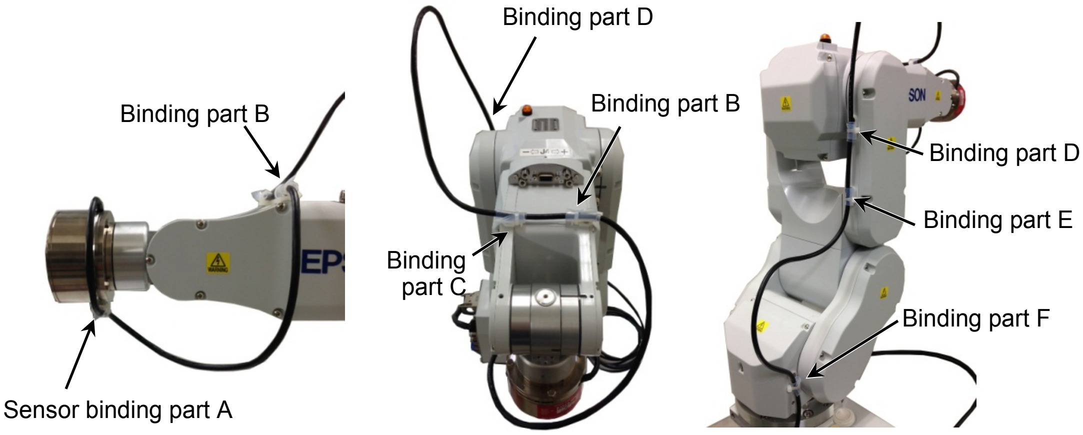
6.3 Wiring of the Force Sensor Cable

The following are recommended wiring examples of the Force Sensor and rough operation ranges of the Manipulator.

For actual applications, fix the wiring according to your manipulator use.

6.3.1 C4 series-S250N

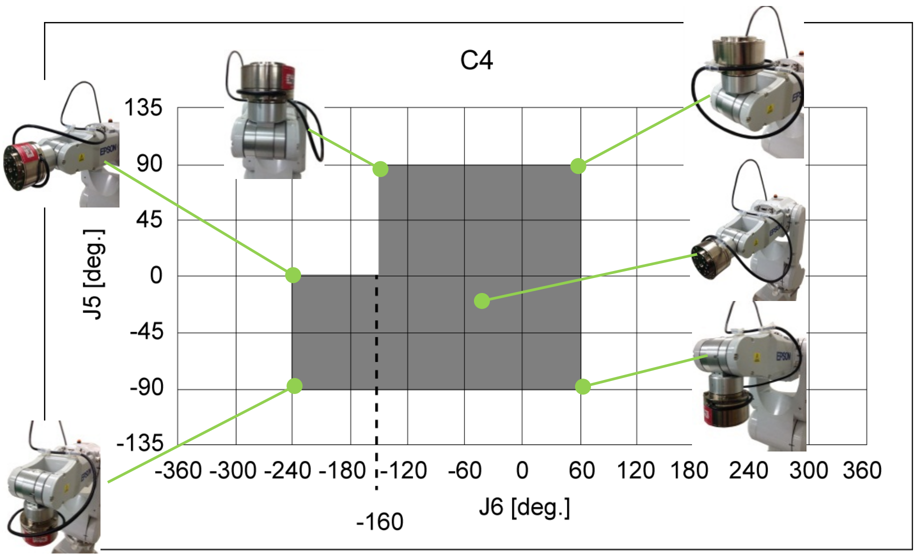
C4 series Manipulator wiring example



Length of A-B (excess length for rotation of J5 and J6): 400 mm

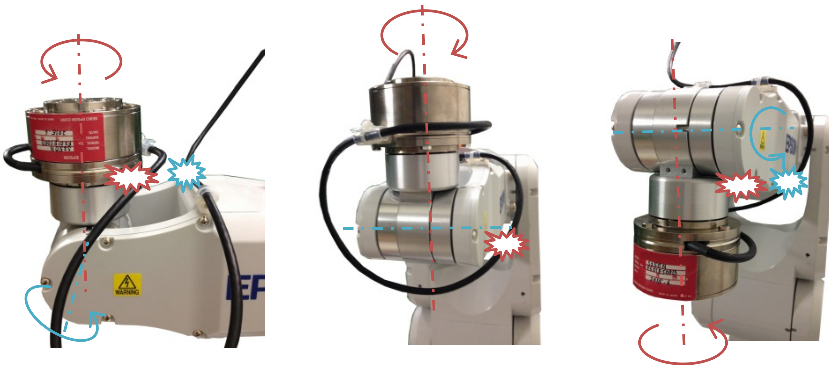
Adjust the lengths of C-D and E-F according to the Manipulator motion.

C4 series Manipulator rough operation range



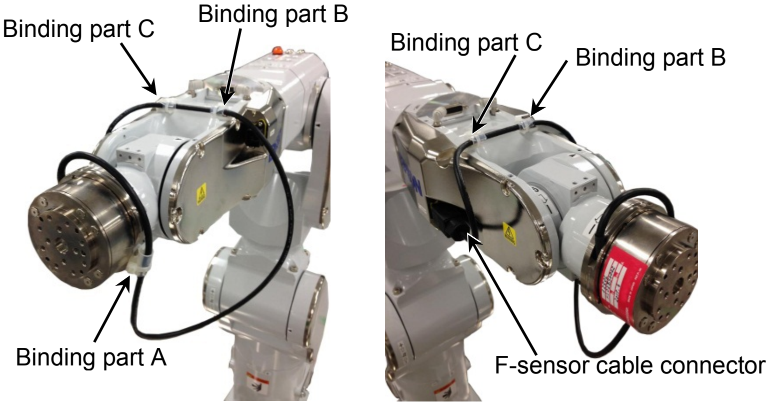
J5	J6
+ 90 deg.	–160 to + 60 deg.
0 to –90 deg.	–240 to + 60 deg.

⚠ CAUTION	■ The cable may deform during storage. Please be careful and make sure that the cable's bend radius is five times larger than the cable diameter (R=30 mm or larger). ■ The cable may rub against the Manipulator as shown in the photos below depending on the Manipulator motion. When routing the cables, make sure to check if the cables touch and rub against the Manipulator.



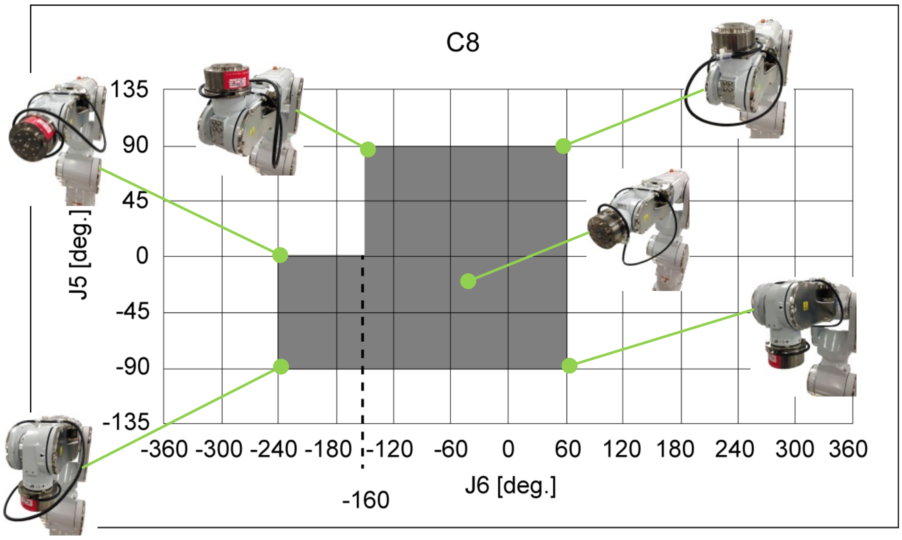
6.3.2 C8 series-S250L, C8 series-S250P

C8 series Manipulator wiring example



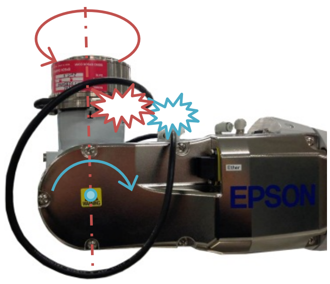
Length of A-B (excess length for rotation of J5 and J6): 475 mm

C8 series Manipulator rough operation range



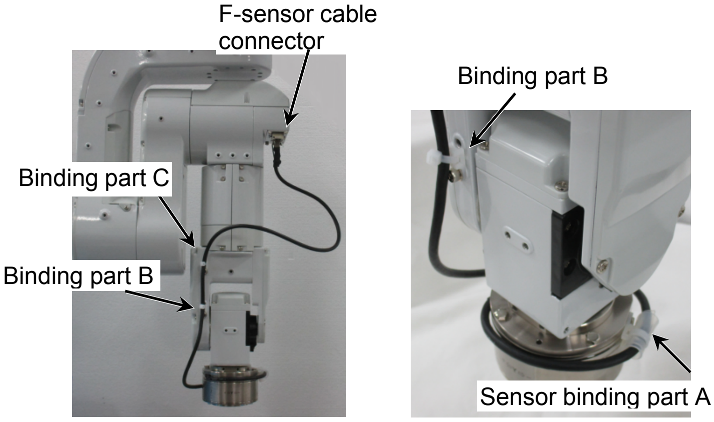
J5	J6
+ 90 deg.	–160 to + 60 deg.
0 ~ to 90 deg.	–240 to + 60 deg.

⚠ CAUTION	■ The cable may deform during storage. Please be careful and make sure that the cable's bend radius is five times larger than the cable diameter (R=30 mm or larger). ■ The cable may rub against the Manipulator as shown in the photos below depending on the Manipulator motion. When routing the cables, make sure to check if the cables touch and rub against the Manipulator.



6.3.3 N2 series-S250H

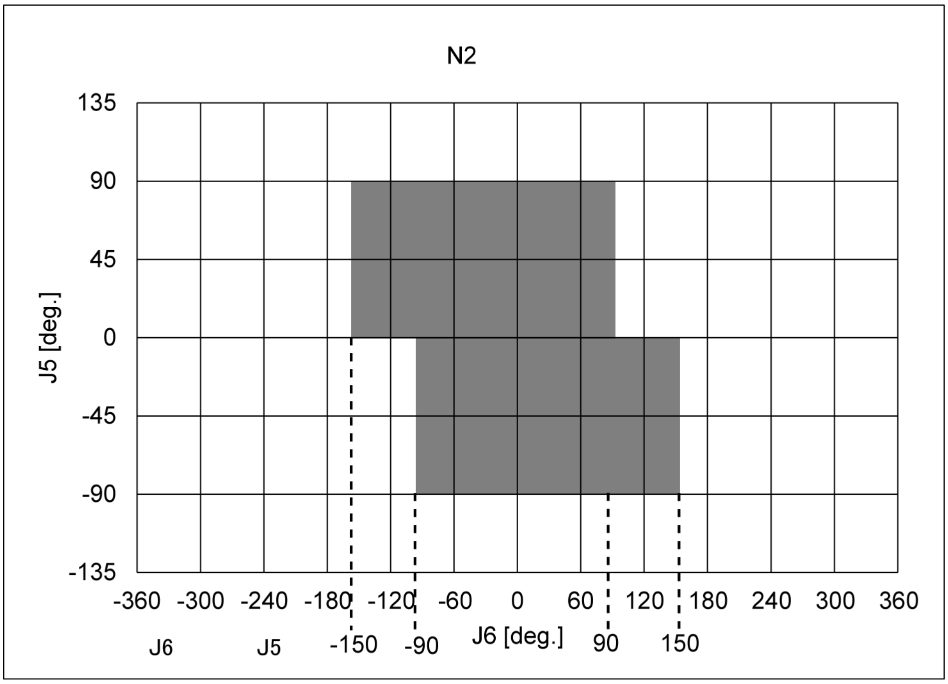
N2 series Manipulator wiring example



Length of A-B (excess length for rotation of J5 and J6): 330 mm

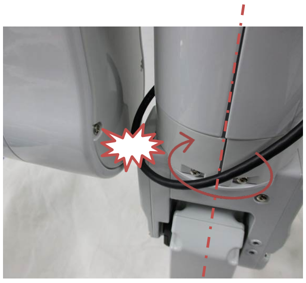
When installing the cables with the above example, the cable diameter should be 13 mm or less.

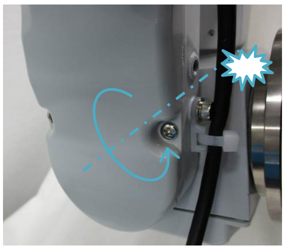
Rough indication of motion range for the N2 series Manipulator when wiring with above example



J5	J6
+ 90 deg.	–150 ~ + 90 deg.
0 deg.	–150 ~ + 150 deg.
-90 deg.	–90 ~ + 150 deg.

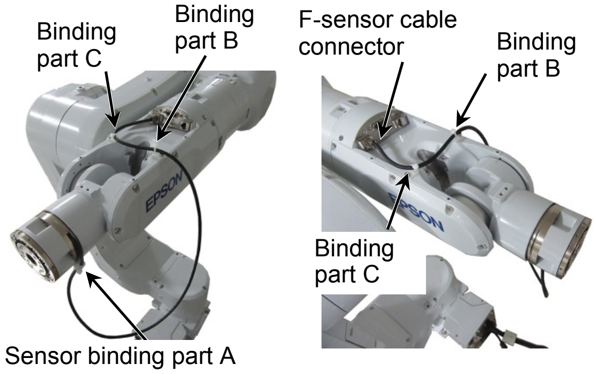
⚠ CAUTION	■ The cable may deform during storage. Please be careful and make sure that the cable's bend radius is five times larger than the cable diameter (R=30 mm or larger). ■ The cable may rub against the Manipulator as shown in the photos below depending on the Manipulator motion. Be very careful when routing the cables and be sure to check if the cables touch and rub against the Manipulator. In particular, if the Joint #4 is rotated when the Arm #2 and #4 overlap each other, the cables may get caught between them. Caution is required in this regard.





6.3.4 N6 series-SH250LH

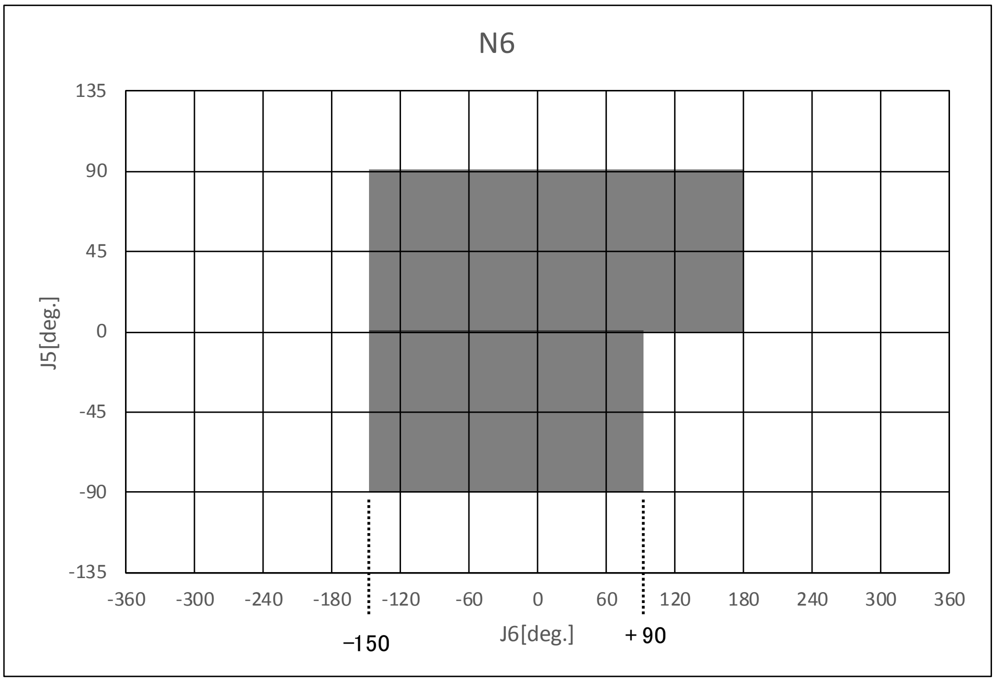
N6 series Manipulator wiring example



Length of A-B (excess length for rotation of J5 and J6):: 500mm

When installing the cables with the above example, the cable diameter should be 13 mm or less.

Rough indication of motion range for the N6 series Manipulator when wiring with above example

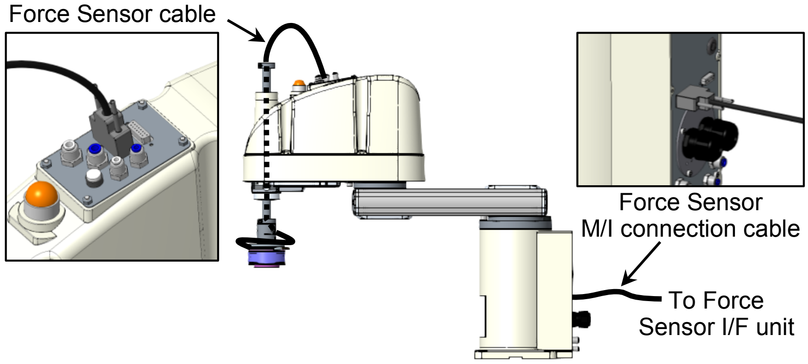


J5	J6
+ 90 deg.	–150 ~ + 180 deg.
0 deg.	–150 ~ + 180 deg.
–190 deg.	–150 ~ + 90 deg.

6.3.5 G series-S2503, S2506, S25010

Wiring example 1: When using the D-sub

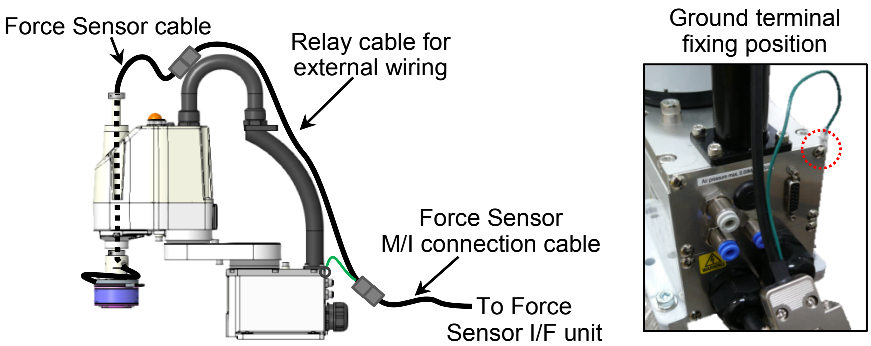
G6, G10, and G20 series use the user connector D-sub (9-pin) to install the Force Sensor.



Wiring example 2: When using the cable duct, external wiring option, etc.

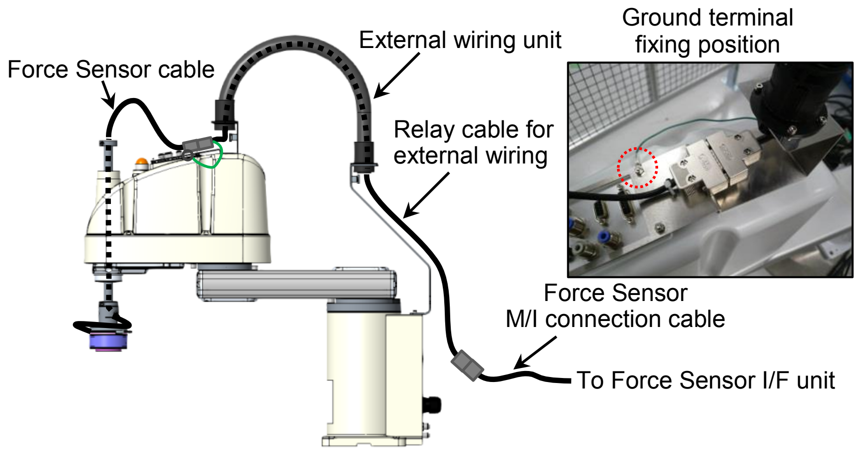
For G3 series, install the cables on the exterior of the Manipulator using the cable duct.

When installing the cables outside the Manipulator, make sure to install the ground wire of the relay cable to the specified position on the Manipulator.

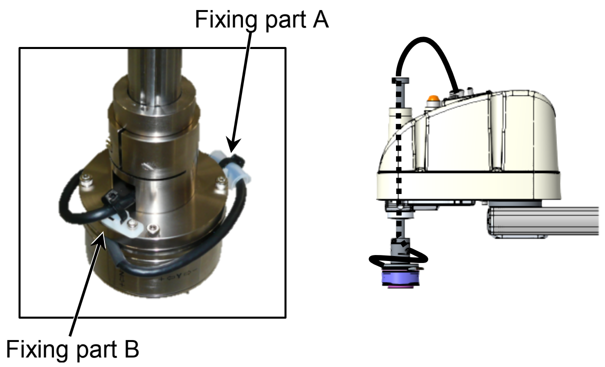


For G6, G10, and G20 series, external wiring is available with the following option products.

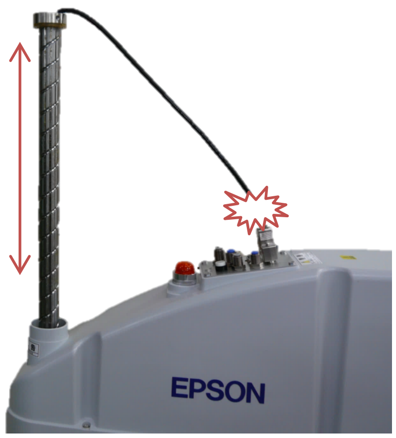
Option product			Code
External wiring unit	G6-***S	For Table top mounting /standard model	R12B031909
	G6-***SR/SW	For Ceiling /Wall mounting /standard model	R12B031910
	G10/G20-***S	For Table top mounting /standard model	R12B031911
	G10/G20-***SR/SW	For Ceiling /Wall mounting /standard model	R12B031912
Relay cable			R12NZ900RW



Wiring example 1 and 2 use the attached cable mounts and wire ties for the following fixing parts A and B. For other parts, fix the cables according to the Manipulator motion.

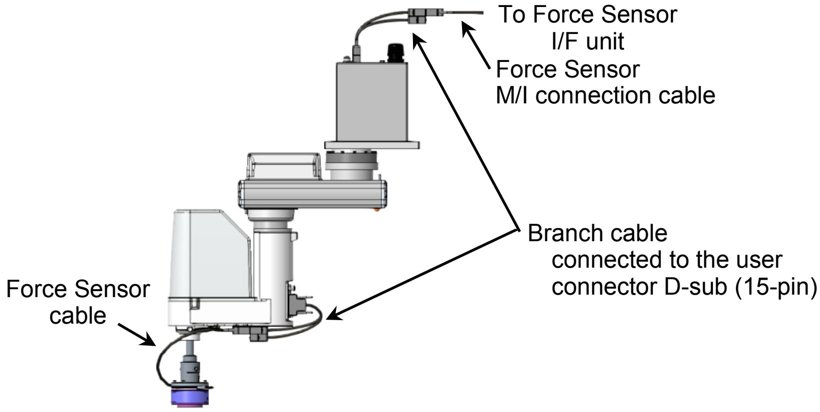


CAUTION	■ The cables may deform during storage. Please be careful and make sure that the cables' bend radius is five times larger than the cable diameter (R=30 mm or larger). ■ The cable may rub against the Manipulator or get under tension as shown in the photo below depending on the Manipulator motion. When routing the cable, be careful in this regard and check if it touches and rubs against the Manipulator or is under tension.



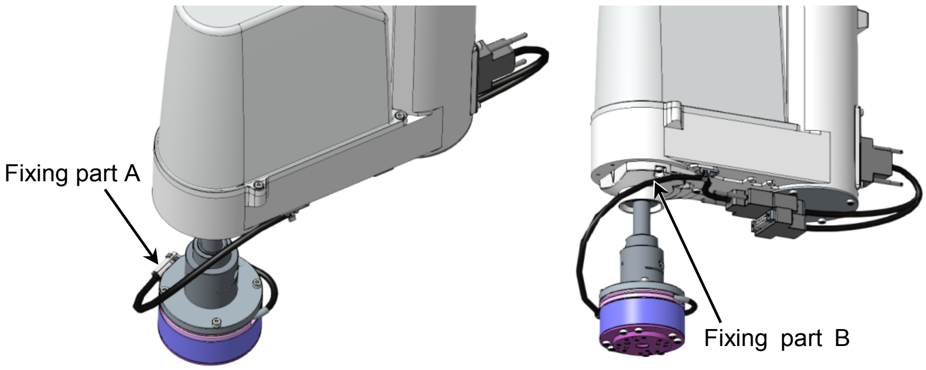
6.3.6 RS series-S2503

RS series uses the user connector D-sub (15-pin) for installing the Force Sensor.
Connect the user connector and the Force Sensor cable by using the attached branch cable.
The branch cable divides the user connector D-sub (15-pin) to 6-pin and 9-pin.



Fix the fixing parts A and B using the attached wire ties and the cable mounts.
For other parts, fix the cables according to the Manipulator motion.

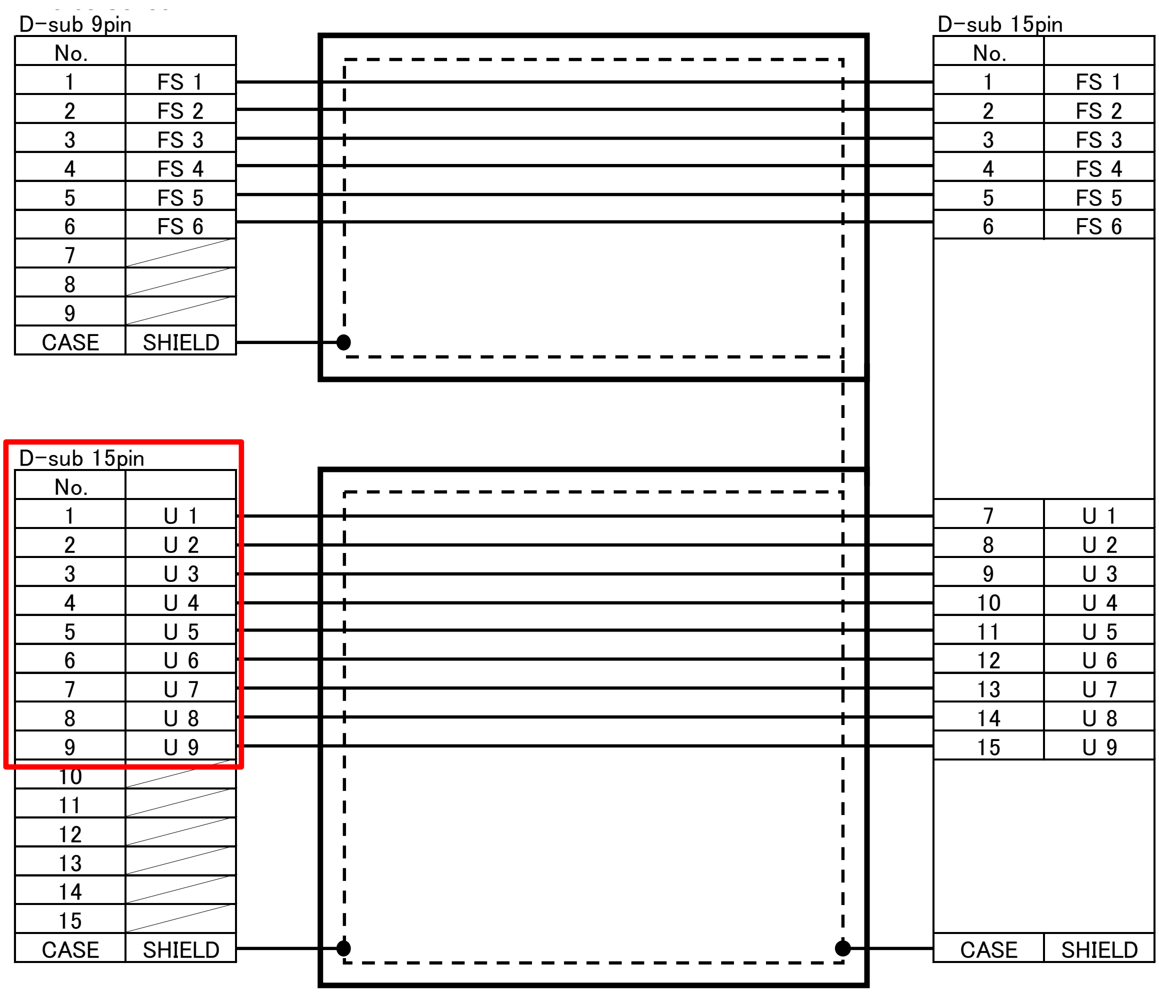
Length of A-B (excess length for rotation of J4): 350 mm



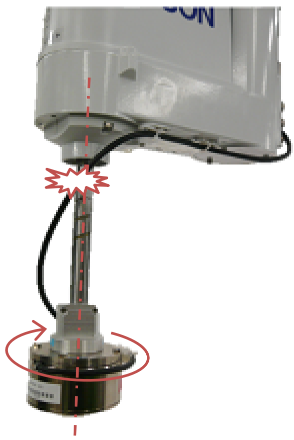
When installing the cables with the above example, set the Manipulator motion with the following range as a rough guide.

J4
+ 180 deg.
– 180 deg.

Among the user connector D-sub (15-pin), branches 6-pin with the branch cable and use it for the Force Sensor. Use the remaining 9-pin by referring to the figure below.



CAUTION	■ The cable may deform during storage. Please be careful and make sure that the cable's bend radius is five times larger than the cable diameter (R=30 mm or larger). ■ The cable may rub against the Manipulator as shown in the photos below depending on the Manipulator motion. When routing the cable, be careful in this regard and check if it touches and rubs against the Manipulator.



7. Maintenance Parts List

To purchase the maintenance parts listed in this chapter, please contact the distributor of your region.

7.1 Force Sensor

Name				Code	Remarks
For C4 series	S250N	Force Sensor *1		1673545	S250N
		Force Sensor cable *2		2174940	C4_STD_FS-RB_CABLE_UNIT
		Force Sensor M/I connection cable *3	3m	2172839	C4_CABLE_UNIT_3m
			5m	2172841	C4_CABLE_UNIT_5m
			10m	2172842	C4_CABLE_UNIT_10m
			20m	2172843	C4_CABLE_UNIT_20m
		Sensor flange		1673548	C4_J6_FLANGE_PLATE_UNIT
		Robot fixing bolt *4		1665754	Hexagon socket cap low head bolt: M4×6 CSHBTT-ST3W-M4-6
		Force Sensor fixing bolt *4		1665741	Hexagon head bolt: M4×12 H.BOLT.SCREW,4×12,F/ZN-3C
		Connector cover		1680038	
For C8 series	S250L (IP20 compliant)	Force Sensor *1		1673546	S250L
		Force Sensor cable *5		2172845	C8STD_FS-RB_CABLE_UNIT
		Sensor flange		1673549	C8_STD_J6_FLANGE_PLATE_UNIT
		Robot fixing bolt *4		1665764	Hexagon socket button head bolt: M5×15 H.B.BOLT.SCREW,5×15,F/ZN-3C
	S250P (IP67 compliant)	Force Sensor *1		1673547	S250P
		Force Sensor cable *5		2172856	C8_IP_FS-RB_CABLE_UNIT
		Sensor flange		1673550	C8IP67_J6_FLANGE_PLATE_UNIT
		Robot fixing bolt *4		1665760	Hexagon socket head cap bolt: M5×18 H.S.C.BOLT.SCREW,5×18,F/ZN-3C
		Seal washer *4		1665759	SEAL WASHER_M5
	S250L S250P	Force Sensor M/I connection cable *3	3m	2172846	C8_RB-BOX_CABLE_UNIT_3m
			5m	2172847	C8_RB-BOX_CABLE_UNIT_5m
			10m	2172848	C8_RB-BOX_CABLE_UNIT_10m
			20m	2172849	C8_RB-BOX_CABLE_UNIT_20m
		Force Sensor fixing bolt *4		1665765	Hexagon head bolt: M5×12 H.BOLT.SCREW,5×12,F/ZN-3C
For N2 series	S250H	Force Sensor *1		1673545	S250H
		Force Sensor cable		2177523	FSSPC01-S250H-HPARM-MV-00
		Force Sensor M/I connection cable *3	3m	2179196	N2_RB-BOX_CABLE_UNIT_3m
			5m	2179197	N2_RB-BOX_CABLE_UNIT_5m
			10m	2179198	N2_RB-BOX_CABLE_UNIT_10m
		Sensor flange		1700933	N2_J6_FLANGE_PLATE_UNIT
		Robot fixing bolt *4		1665754	Hexagon socket cap low head bolt: M4×6 CSHBTT-ST3W-M4-6
		Force Sensor fixing bolt *4		1665741	Hexagon head bolt: M4×12 H.BOLT.SCREW,4×12,F/ZN-3C

Name				Code	Remarks
For N6 sries	SH250LH	Force Sensor *1		1749809	SH250LH
		Force Sensor cable		2189943	N6_CABLE_UNIT
		Force Sensor M/I connection cable *3	3m	2177520	FSSPC3M-HPBASE-FS1-MV-00
			5m	2177521	FSSPC5M-HPBASE-FS1-MV-00
			10m	2177522	FSSPC10M-HPBASE-FS1-MV-00
			20m	2189877	FSSPC20M-N6BASE-FSIF-MV-01
		Robot fixing bolt *4		1546620	Hexagon socket cap low head bolt: M4×12 H_S_C_BOLT_4X12_F_NI
For RS, G series	S2503 S2506 S25010	Force Sensor *1		1673545	
		Sensor flange *6		1701390	SC_FLANGE_PLATE_UNIT
		Force Sensor cable *7	0.4m	2178628	FSSPC0P4-S250-SCARM-MV-00
			1.2m	2178629	FSSPC1P2-S250-SCARM-MV-00
			1.5m	2178630	FSSPC1P5-S250-SCARM-MV-00
			2m	2178631	FSSPC2P0-S250-SCARM-MV-00
		Force Sensor M/I connection cable *3	3m	2179199	SC_RB-BOX_CABLE_UNIT_3m
			5m	2179200	SC_RB-BOX_CABLE_UNIT_5m
			10m	2179201	SC_RB-BOX_CABLE_UNIT_10m
		Relay cable *7	2m	2178635	FS_RELAY_CABLE-MV-00
		Branch cable *7	0.3 m	2178636	FS_BRANCH_CABLE-00
	S2503	Adapter *8		1701391	For G3, RS3, RS4 SC_16ADAPTER_UNIT
	S2506			1701392	For G6 SC_20ADAPTER_UNIT
	S25010			1701393	For G10, G20 SC_25ADAPTER_UNIT
For C4, C8, N2, RS, G series	S250N S250L S250P S250H S2503 S2506 S25010	Cable protection sheet		1675521	CABLE_PROTECTION_SHEET_S250
		Shaft label for ceiling mount		1692029	AXIS_LABEL_S250_FOR_CEILING-MOUNTED_RB

*1 The following parts are not included in the Force Sensor.
Force Sensor cable, Force Sensor M/I connection cable, and Sensor flange

*2 The followings are attached to Force Sensor Cable.
Connector cover, Cable mount, Wire tie, and Protection sheet.

*3 Label for cable is attached to Force Sensor M/I connection cable.

*4 Bolts and washers are provided in a unit of one.
(Four screws and washers are necessary for fixing the parts.)

*5 The followings are attached to Force Sensor Cable of C8.
Cable mount, Wire tie, and Protection sheet.

*6 The following bolts are attached to the sensor flange.
Force Sensor fixing bolts (Hexagon socket head cap bolts 4-M4×15)

*7 The cables vary depending on the Manipulator.

*8 The following bolt is attached to the adapter.
Adapter fixing bolt (Hexagon socket head cap bolt: M5×20, Hexagon socket set screw: M4×10)

7.2 Force Sensor I/F Unit

Name	Code	Remarks
Force Sensor I/F unit	2172811	Power connector (male) and motion network cable are not included.
Power connector (male)	2172812	
Circuit board	2172813	
Power supply board	2172814	
Motion network cable	R12NZ9006R	1.5m
Fuse	2172341	

7.3 Force Sensor I/F Board

Name	Code	Remarks
Force Sensor I/F Board	2184536	Board only

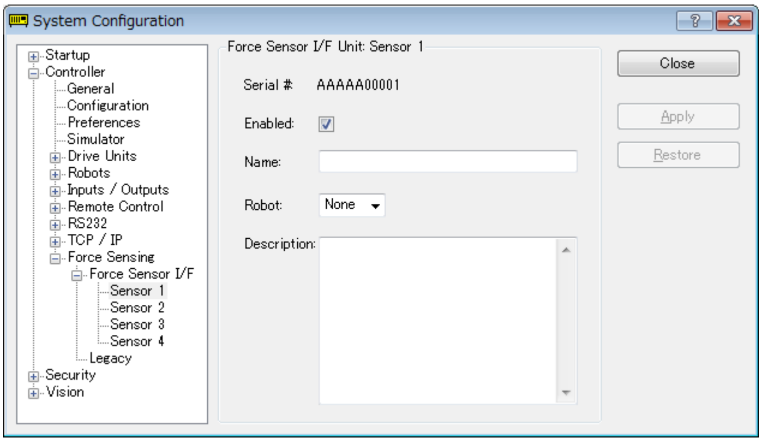
Software

1. Checking the Connections

CAUTION	■ With improper connection setting of the Force Sensor and the robot, the robot moves according to the output of the improperly configured sensor. If the force control function is executed in this state, it may function unintentionally. Be careful when configuring the settings and check operation before executing the force control.

1.1 Configuring the Force Sensor I/F Unit

From the tree, select [Controller]-[Force Sensing]-[Force Sensor I/F]-[Sensor *].
Configure the Force Sensor I/F unit in [System Configuration].



Item	Description
Serial #	This is the serial number of the Force Sensor (up to 10 characters).
Enabled	Set the use of the Force Sensor. Checkbox selected: Gets the force information from the sensor.
Name	Set the name of the Force Sensor (up to 32 single-byte characters).
Robot	Set the link of the Force Sensor with the added robot. Select the number of the robot to which the Force Sensor is connected.
Description	The user can enter any comments (up to 255 single-byte characters).
Close	Closes the [System Configuration] dialog box. Restart the system if the settings are changed.
Apply	Saves the changed values.
Restore	Restores the original values.

Force Sensor Connection Procedure

Connect the Force Sensor with the following procedure.

(1) When using Force Sensor I/F unit:
Connect the robot controller and the Force Sensor I/F unit with a communication cable.
When using Force Sensor I/F board:
Mount the Force Sensor I/F board on the option slot of the robot controller.

(2) Connect the Force Sensor and the Force Sensor I/F unit or board with a Force Sensor cable and a Force Sensor M/I cable.

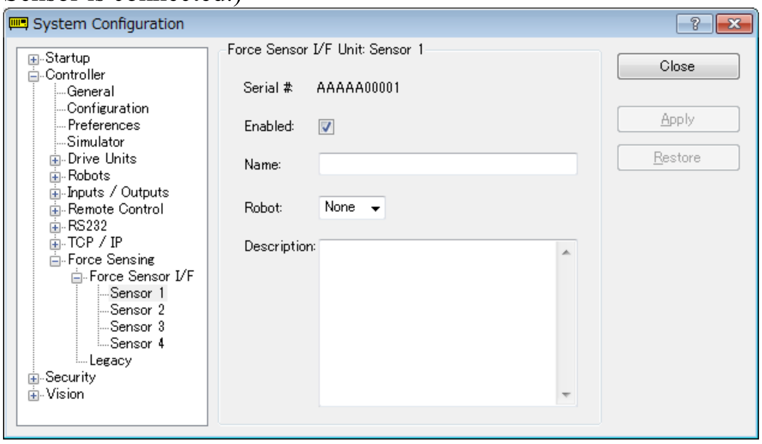
(3) When using Force Sensor I/F unit:
Turn ON the Force Sensor I/F unit.

(4) Turn ON the robot controller.

(5) Start the EPSON RC+7.0 and establish a connection with the robot controller.

(6) From the Setup menu, select [System Configuration].
The [System Configuration] dialog box appears.

(7) From the tree, select [Controller]-[Force Sensing]-[Force Controller I/F]-[Sensor 1].
(Select the number of the sensor port of the Force Sensor I/F unit to which the Force Sensor is connected.)



(8) In [Robot], set the number of the robot to which the Force Sensor is mounted.

(9) To apply the changes to the settings, click the <Apply> button.
To cancel the changes, click the <Restore> button.

(10)Click the <Close> button.
Clicking the button restarts the system and applies the changes to the settings.

Force Sensor Disconnection Procedure

Disconnect the Force Sensor with the following procedure.

(1) Start the EPSON RC+7.0 and establish a connection with the robot controller.

(2) From the Setup menu, select [System Configuration].

(3) From the tree, click [Controller]-[Force Sensing]-[Force Sensor I/F]-[Sensor 1].
(Select the number of the sensor port of the Force Sensor I/F unit to which the Force Sensor is connected.)

(4) Unselect the [Enabled] checkbox.

(5) Click the <Apply> button.

(6) Click the <Close> button.
The robot controller restarts and the changes to the settings are applied.

(7) Turn OFF the robot controller.

(8) When using Force Sensor I/F unit:
Turn OFF the Force Sensor I/F unit

(9) Disconnect the Force Sensor from the Force Sensor I/F unit or board.

Force Sensor Replacement Procedure

Replace the Force Sensor with the following procedure.

(1) Refer to "Force Sensor Disconnection Procedure" described above and disconnect the Force Sensor.

(2) Refer to "Force Sensor Connection Procedure" described above and connect a new Force Sensor.

1.2 Checking the Connection

Checking the Connection

Check the connection between the Force Sensor and the robot system with the following procedure.

(1) Start EPSON RC+7.0 and establish a connection with the robot controller.

(2) Check that there is no error.

(3) From the Setup menu, select [System Configuration].
Check that tree-[Controller]-[Force Sensing]-[Force Sensor I/F]-[Sensor *] are displayed.

(4) Click [Sensor 1] and check that the serial code of the connected Force Sensor is displayed correctly.
(It is the number of the sensor port of the Force Sensor I/F unit to which the Force Sensor is connected.)

(5) If an error does not occur and [Force Sensor I/F] is displayed in the tree, the connection is successful.

If an error occurs, select [System History] from the View menu, identify the error, and take action.

If [Force Sensor I/F] is not displayed in the tree, please check the followings.

When using Force Sensor I/F unit:
Force Sensor I/F unit may not be turned ON or the cable may not be connected.
Check the power and wiring.

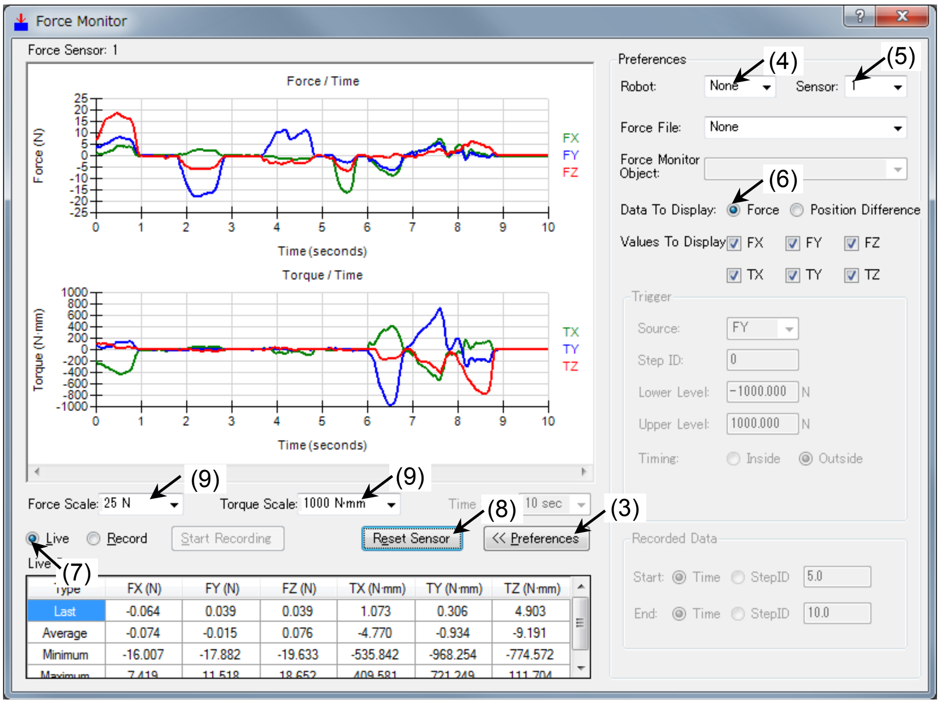
When using Force Sensor I/F board:
Force Sensor I/F board may not be mounted properly on the option slot of the robot controller. Make sure to mount properly.

Checking the Acquisition of Output Values

Perform the following procedure to check that the output values of the Force Sensor can be acquired correctly.

(1) Start the EPSON RC+7.0 and establish a connection with the robot controller.

(2) From the EPSON RC+ 7.0 menu, click [Tools]-[Force Monitor].



(3) Click the <Preferences> button.

(4) Select “None” in [Preferences]-[Robot].

(5) Select the sensor number to be checked in [Preferences]-[Sensor].
(The force and torque in the Force Sensor coordinate system are displayed.)

(6) Select the <Force> button in [Preferences]-[Data to Display].

(7) Select the <Live> button.

(8) Click the <Reset Sensor> button.

(9) Change the values in [Force Scale] and [Torque Scale] to adjust the scale.

(10) Apply a force in each of the axis directions of the Force Sensor coordinate system and check that the force is detected within the specified accuracy of the Force Sensor.

CAUTION	■ When entering the safe guarded area in order to apply a force to the Force Sensor, ensure safety by safety measures such as setting the Manipulator to operation-prohibited status. For details of safety, refer to the following manual. *EPSON RC+ 7.0 User’s Guide*

1.3 Checking the Accuracy of the Force Sensor

1.3.1 Overview

This section describes a method to check if the Force Sensor is working properly.

Accuracy abnormality may occur when the Force Sensor is damaged by being hit during operation or applied the load which exceeds the rated load.

Accuracy abnormality can be checked by comparing the data acquired before use of the Force Sensor (initial data) and the data acquired after the accuracy error was found (comparison data).

If abnormality is found while using the Force Sensor, follow the steps below to check the accuracy of the Force Sensor.

When performing the accuracy check, be sure to obtain the initial data before using the Force Sensor.

Accuracy guaranty of the Force Sensor is ±5%. We recommend to replace the Force Sensor if the guaranty value is exceeded when checking the accuracy. However, depending on the applications, some of them are still available if the guaranty value is exceeded. Replace the Force Sensor depending on the usage.

1.3.2 Acquisition of the Initial Data

This section describes how to obtain the initial data.

The initial data can be obtained by sample programs on the following pages. The programs differ between 6-axis robots and SCARA robots. Choose the program according to your Manipulator.
This data is used when checking the accuracy of the Force Sensor. Be sure to save the acquired data.

CAUTION	■ Change the initial position and motion of the Manipulator according to your usage environment, and make sure that the robot, end effector, cables, and peripherals do not interfere with each other.

```
Function FoeceSensorLog6Axis               ' Sample program for 6-axis robots
  Integer iFileNum
  iFileNum = FreeFile                      ' Gets an empty file number

  ChDir "C:¥Temp"                          ' Specifies a file destination path
  WOpen "Forcelog.csv" As #iFileNum        ' Specifies a file name and opens the file

  Tool 0                                   ' Specifies Tool 0
  FSet FM1.CoordinateSystem, FCS0          ' Specifies the Tool coordinate system for the
                                           ' Force coordinate system
  FSet FM1.ForceSensor, 1                  ' Specifies the Force Sensor number
  FSet FM1.LPF_Enabled, False, False, False, False, False, False, False, False
                                           ' Disables a low pass filter
  MP 0                                     ' Stops the gravity compensation

  Motor On                                 ' Motor ON
  Go AglToPls (0, 0, 0, 0, 0, 0)           ' Moves to the initial position

  FSet FS1.Reset                           ' Resets the Force Sensor
  FSet FM1.LogStart, 60, 0.1, #iFileNum    ' Starts logging the Force Sensor values
  '-----------------Operation part------------------
  Motor On                                 ' Motor ON
  Wait 2
  Go AglToPls (0, 0, 0, 0, 90, 0)
  Wait 2
  Go AglToPls (0, 0, 0, -90, 90, 0)
  Wait 2
  Go AglToPls (0, 0, 0, -90, -90, 0)
  Wait 2
  Go AglToPls (0, 0, 0, 0, -90, 0)
  Wait 2
  Go AglToPls (0, 0, 0, 0, 0, 0)
  Wait 2
  '------------------------------------------
  FSet FM1.LogEnd                          ' Finishes logging the Force Sensor values
  Close #iFileNum                          ' Closes the file
Fend
```

```
Function FoeceSensorLogSCARA              ' Sample program for SCARA robots
  Integer iFileNum
  iFileNum = FreeFile                     ' Gets an empty file number

  ChDir "C:¥Temp"                         ' Specifies a file destination path
  WOpen "Forcelog.csv" As #iFileNum       ' Specifies a file name and opens the file

  Tool 0                                  ' Specifies Tool 0
  FSet FM1.CoordinateSystem, FCS0         ' Specifies the Tool coordinate system for the
                                          ' Force coordinate system
  FSet FM1.ForceSensor, 1                 ' Specifies the Force Sensor number
  FSet FM1.LPF_Enabled, False, False, False, False, False, False, False, False
                                          ' Disables a low pass filter
  MP 0                                    ' Stops the gravity compensation

  Motor On                                ' Motor ON
  Go AglToPls(0, 0, 0, 0)                 ' Moves to the initial position

  FSet FS1.Reset                          ' Resets the Force Sensor
  FSet FM1.LogStart, 60, 0.1, #iFileNum   ' Starts logging the Force Sensor values
  '----------------- Operation part ------------------
  Motor On                                ' Motor ON
  'Power High                             ' High power mode
  'Accel 50, 50                           ' Acceleration setting
  'Speed 50                               ' Speed setting
  Wait 2
  Go AglToPls(0, 90, 0, 0)
  Wait 2
  Go AglToPls(0, 90, 0, -90)
  Wait 2
  Go AglToPls(0, 0, 0, -90)
  Wait 2
  Go AglToPls(0, 0, -50, -90)
  Wait 2
  Go AglToPls(0, 0, 0, -90)
  Wait 2
  Go AglToPls(0, 0, 0, 0)
  Wait 2
  '------------------------------------------
  FSet FM1.LogEnd                         ' Finishes logging the Force Sensor values
  Close #iFileNum                         ' Closes the file
Fend
```

Description

(1) Specify a file location and name, and then open a file.

Set arbitrary file location and name for the file.

(2) Specify Tool 0, and specify the Tool coordinate system for the Force coordinate system.

User-configured Force coordinate system can be used. Also, the user-defined Force coordinate objects can be used while FCS0 is a Force coordinate system which matches the default Tool coordinate system.

(3) Specify the sensor number.

Specify the sensor number of the Force Sensor that the initial data will be acquired.

(4) Disable a low pass filter and stop the gravity compensation.

(5) Turn ON the motor, and move the robot to the initial position.

In the sample program, the robot moves to the home position. The robot also can be moved to the user-specified position.

(6) Reset the Force Sensor.

(7) Start recording the Force Sensor values.
The values will be recorded for 60 seconds with 0.1 second intervals.

(8) Move the robot to change the Force Sensor posture.

In the sample program for 6-axis robots, Joints #4 and #5 are moved from the home position to change posture of the Force Sensor. User-specified motion is also available. Note, however, that motion should contain 10 or more degree angle change of the sensor in each direction from the initial position.
In the sample program for SCARA robots, Joints #2, #3, and #4 are moved from the home position to apply an inertia force to the Force Sensor. In order to record the inertia force, the measurement interval for the sensor values is shorter compared to the sample program for 6-axis robots.
User-specified motion is also available. Note, however, that 1[N] or more force should be applied in each direction of the sensor from the initial position.
In the sample program, the speed and acceleration settings are commented out. Confirm that the motion has no problem and enable the commands.

(9) Stop recording the Force Sensor values.

(10) Close the file and finish the program.

NOTE

Acquired Force Sensor values are affected by the following settings.

Base coordinate setting (Base)
Local coordinate setting (Local)
Tool setting (Tool, TLSet)
Flange offset setting (F_FlangeOffset)
Force coordinate object (FCS#)

Save the above setting values so that these can be reproduced when acquiring the comparison data.

NOTE ☞ The Force Sensor values are affected by physical installation conditions, such as the tilt of the robot, and shapes and weight of the sensor flange and end effectors. Therefore, be sure to acquire the initial data again when the usage environment changes.

1.3.3 Acquisition of the Comparison Data and Comparison with the Initial Data

When the accuracy abnormality of the Force Sensor is found, obtain the comparison data and compare it with the initial data.

The comparison data should be obtained with the same procedure and conditions as the initial data acquisition.
Note that the conditions include physical installation environment, setting values, and motion in data acquisition.

If a large difference between the outputs of the Force Sensor is found by comparing the initial data and the comparison data acquired with the same condition as the initial data, the Force Sensor cannot be used.

Accuracy abnormality may occur if the Force Sensor is damaged by being hit or applied the load which exceeds the rated load. Use the Force Sensor within the range of specifications.

For details of the specifications, refer to the following section.

Hardware 4.1 Specifications

2. Force Sensor Correction

2.1 Resetting the Force Sensor

The Force Sensor has drift characteristics. Therefore, it must be reset every time immediately before using the force functions. Use the force functions within 10 minutes after resetting the Force Sensor.

Executing the reset command initializes the Force Sensor and sets the current force and torque to "0". A reset can be performed in the Reset property of the force sensor object. For details on the Reset property, refer to the following manual.

EPSON RC+ 7.0 Option Force Control 7.0 Property & Status Reference

If the Force Sensor is used for long hours without resetting it, drift errors are accumulated. A Force Sensor error may also occur. Caution is required in this regard. If an error occurs, execute the Reboot property of the Force Sensor object.

⚠ CAUTION	■ Be sure to reset the Force Sensor with no external force applied to it. If it is reset with an external force applied to it, the state in which an external force applied is "0". Therefore, if the force applied is removed, the Force Sensor detects a force even if no force is applied. If the force control function is performed in this state, the robot may move unintentionally. Caution is required in this regard.

2.2 Coordinate Conversion

Coordinate conversion of the Force Sensor refers to converting the output values of the Force Sensor to the force and torque in the force coordinate system.

All of the force functions are performed in the force coordinate system. Coordinate conversion is always performed automatically.

The force coordinate system can be set by the focus coordinate object. The force functions are performed while dynamically switching between the coordinate systems.

⚠ CAUTION	■ If the flange offset or force coordinate object is set incorrectly, the output values of the Force Sensor are converted to the force and torque in a wrong coordinate system. If the force control function is performed in this state, the force control function may perform an unintended operation. Configure the settings carefully, and first verify the operation and then perform the force control function.

Correspondence between the Force Sensor Coordinate System and Tool Coordinate System

To perform coordinate conversion of the output values of the Force Sensor, you need to set the flange offset which means a relative relation between the Force Sensor and the robot.

The physical meaning of the flange offset is the amount of offset by the sensor flange. For the flange offset, use the bottom center position of the Force Sensor viewed from the tool 0 coordinate system of the robot as the origin and set the position and posture of the coordinate system so its direction aligns with the Force Sensor coordinate system.

The offset depending on the robot mounting method using the EPSON sensor flange is as follows.

Manipulator model	Sensor model	Mounting type	Flange offset (X, Y, Z, U, V, W)
C4 series	S250N	Table top mounting	(0, 0, 5, 0, 0, 0)
		Ceiling mounting	(0, 0, 5, 180, 0, 0)
C8 series	S250L, S250P	Table top mounting	(0, 0, 5, 0, 0, 0)
		Ceiling mounting	(0, 0, 5, 180, 0, 0)
		Wall mounting	(0, 0, 5, 0, 0, 0)
N2 series	S250H	Table top mounting	(0, 0, 5, 0, 0, 0)
		Ceiling mounting	(0, 0, 5, 180, 0, 0)
N6 series	SH250LH	Table top mounting	(0, 0, 0, 0, 0, 0)
		Ceiling mounting	(0, 0, 0, 180, 0, 0)
G3, G6 series	S2503, S2506	All	(0, 0, -22, 180, 0, 180)
G10, G20 series	S25010		(0, 0, -24, 180, 0, 180)
RS series	S2503		(0, 0, -22, 180, 0, 180)

When you make a sensor flange yourself, measure the offset and set the flange offset.

The flange offset can be set in [Robot Manager]-[Sensor Panel] or by the F_FlangeOffset statement. For details on the setting procedure, refer to the following section and manual.

Software: 3.5.1 [Robot Manager] (Tools Menu)
[Tools]-[Robot Manager]-[Force] Panel

EPSON RC+ 7.0 Option Force Control 7.0 Property & Status Reference

Correspondence between the Tool Coordinate System and Force Coordinate System

The force coordinate system is a coordinate system with an offset from the tool coordinate system. Therefore, when the tool tip of the robot moves or the offset of the selected tool coordinate system is changed, the force coordinate system also moves following the movement or change.

The offset of the force coordinate system is set in the force coordinate object.

The origin of the focus coordinate system is defined by the offset from the currently selected tool coordinate system using the Position property.

The orientation of the force coordinate system can be selected from the following coordinate systems. The Orientation property is used.

Base coordinate system:	The orientation of the coordinate system is always aligned with the base coordinate system. It does not change even though the posture of the robot or the tool setting is changed.
Local coordinate system:	Select the number of the local coordinate system to be used simultaneously. The orientation of the coordinate system is always aligned with the local coordinate system with the selected number. It does not change even though the posture of the robot or the tool setting is changed.
Tool coordinate system:	The orientation of the coordinate system is always aligned with the tool coordinate system. It changes according to the posture of the robot or the tool setting.
Custom coordinate system:	The values of the rotating movement from the tool coordinate system are set in U, V, and W simultaneously. The orientation of the coordinate system is the orientation with an offset from the tool coordinate system. It changes according to the posture of the robot or the tool setting.

The force coordinate object can be set in [Force Editor] or by the FSet statement. For details on the setting procedure, refer to the following section and manual.

Software: 3.5.1 [Robot Manager] (Tools Menu)
[Tools]-[Robot Manager]-[Force] Panel

EPSON RC+ 7.0 Option Force Control 7.0 Property & Status Reference

2.3 Gravity Compensation

2.3.1 Overview

Gravity compensation is a function to reduce the impact of the gravity on the Force Sensor.

The Force Sensor measures the difference from "0" that indicates the state of force at the moment the force sensor is reset. Therefore, if the posture of the robot is changed to another posture after resetting the Force Sensor, the Force Sensor also measures the weight of the hand and workpiece impacted by the gravity as the force. As a result, the force control function sometimes cannot perform the intended operation due to this effect. Gravity compensation reduces the impact of gravity from the measured force to retrieve only the force from an external object that is applied during the intended operation.

⚠ CAUTION	■ If the setting of the mass property or gravity direction is incorrect or if the mass property number to be used is incorrect, the force control function may perform an unintended operation. Configure the settings carefully, and first verify the operation and then perform the force control function.

2.3.2 Mass Properties

A mass property object is an object to handle the mass properties for gravity compensation.

The mass property object is an object that has the weight (Mass property) and the center of gravity (GravityCenter property) of all objects (e.g. hand and workpiece) mounted to the area closer to the tip than the Force Sensor. For the weight, set the value including the weight of all objects such as the hand and workpiece, and for the center of gravity, set the gravity center position in the tool 0 coordinate system.

Up to 15 mass property object values can be set for each robot simultaneously. They can be set in the [Mass/Gravity] panel in Robot Manager or by the MPSet statement.

The weight and gravity center position can be set directly in the [Mass/Gravity] panel.
They can also be set automatically in Mass / Gravity Wizard for 6-axis robots.

For details, refer to the following section.

Software: 3.5.1 [Robot Manager] (Tools Menu)
[Tools]-[Robot Manager]-[Mass/Gravity] Panel

The value of each property can be set directly in the MPSet statement.
For details, refer to the following manual.

EPSON RC+ 7.0 Option Force Control 7.0 Property & Status Reference

2.3.3 Gravity Direction

Gravity direction is the direction of gravity for the robot necessary for gravity compensation.

The gravity direction is specified by the gravity vector in the base coordinate system of each robot. The robot coordinate system is a coordinate system in which "+z" indicates the upward vertical direction and "+y" indicates the front direction of the robot, and by default, the base coordinate system is also aligned with the robot coordinate system. The gravity works in the downward vertical direction so the gravity direction is represented by the vector (0, 0, -1). This applies to both cases where the robot is mounted to the table and to the ceiling. However, if the base coordinate system was changed using the Base statement, or if the robot is mounted in an inclined state, you need to calculate and set the gravity direction vector in the base coordinate system.

For the gravity direction, set one value for each robot. The gravity direction can be set in the [Mass/Gravity] panel in Robot Manager or in the F_GravityDirection statement.

The values of the gravity direction can be set in the [Mass/Gravity] panel. Furthermore, the gravity direction can be set automatically in Mass / Gravity Wizard for 6-axis robots.

For details, refer to the following section.
Software: 3.5.1 [Robot Manager] (Tools Menu)
[Tools]-[Robot Manager]-[Mass/Gravity] Panel

The values of the gravity direction can be set in the F_GravityDirection statement.
For details, refer to the following manual.
EPSON RC+ 7.0 Option Force Control 7.0 Property & Status Reference

2.3.4 Executing the Gravity Compensation

Gravity compensation is always performed for the Force Sensor that is linked with the robot. Gravity compensation cannot be performed for a Force Sensor that is not linked with the robot. Furthermore, selecting the object to be used from the stored mass property objects allows you to select a parameter according to the operation state at any time. Object selection is performed in the MP statement. After executing the MP statement, reset the Force Sensor in the Reset property of the Force Sensor object.

Example: When performing gravity compensation using Mass Property 1
```
MP 1
```

For details on the MP statement, refer to the following manual.
EPSON RC+ 7.0 Option Force Control 7.0 Property & Status Reference

When performing the force control in each of the states where there is a workpiece and where there is not a workpiece, set the mass property in each of the states since a workpiece has also a weight, and perform the force control while switching between both states.

Selecting number 0 (MP0) or selecting the mass property object with a weight of "0" stops the gravity compensation function. If the gravity compensation is not required for operations where, for example, the posture change is small, select "MP0" to stop the gravity compensation. Selecting a mass property object other than "MP0" after stopping it restarts the gravity compensation.

The selected mass property number and set mass property are retained after the robot controller is turned off until they are changed. Turning on the robot controller also automatically starts the gravity compensation.

2.4 Checking the Gravity Compensation Operation

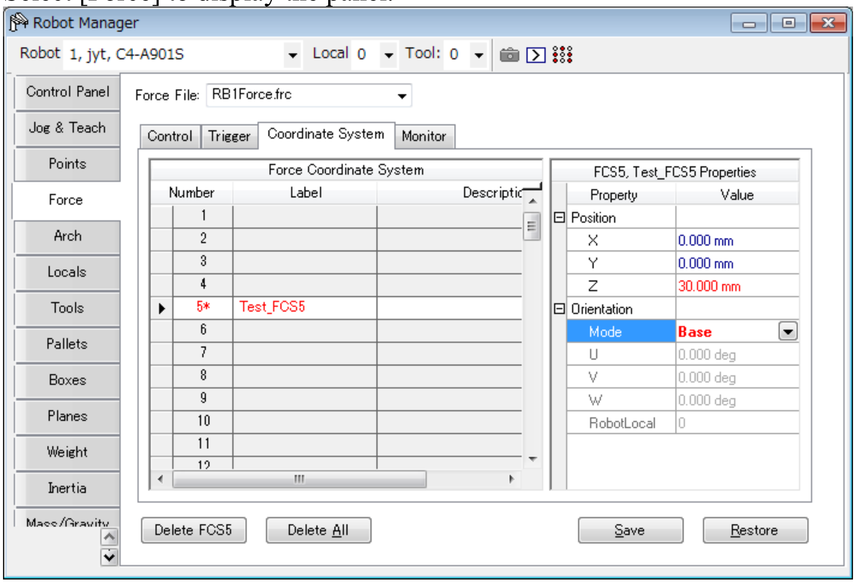
The following describes the procedure to check the Force Sensor correction operation.

1. Setting the force coordinate object
2. Setting the force monitor object
3. Checking that the coordinate conversion is correct in Force Monitor
4. Setting the mass properties and gravity direction
5. Checking that the gravity compensation is correct in Force Monitor

1. Setting the Force Coordinate Object

(1) From the EPSON RC+ 7.0 menu, click [Tools]-[Robot Manager].
The [Robot Manager] dialog box appears.

(2) Select [Force] to display the panel.



If the force file is not created, the [Force] panel does not appear. If the panel does not appear, refer to the following section to create a force file.

Software: 3.2.1 [New File] (File Menu)

(3) Select the [Coordinate System] tab.

(4) In the [Position] property of any force coordinate object, set the origin position of the force coordinate system viewed from the tool coordinate system.

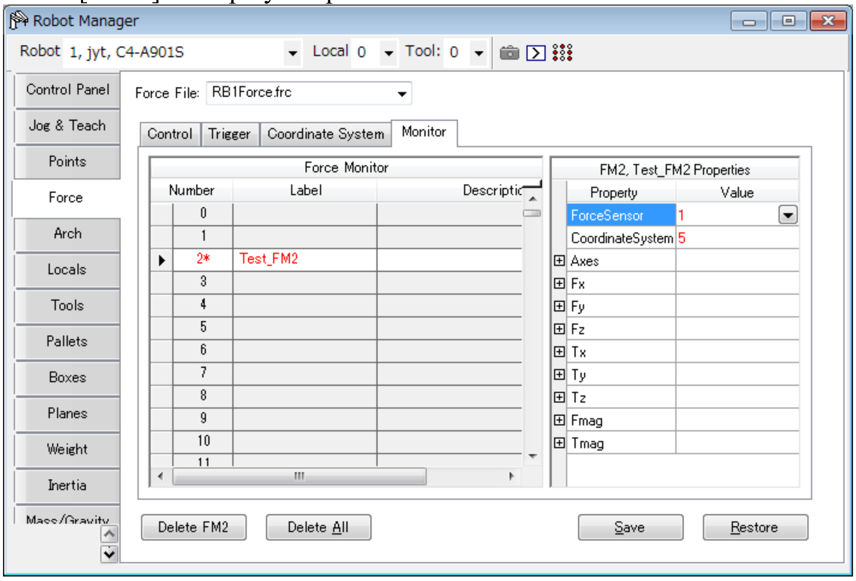
(5) In the [Orientation] property of any force coordinate object, set the orientation of the force coordinate system.

(6) Click the <Save> button to save the changes.

2. Setting the Force Monitor Object

(1) From the EPSON RC+ 7.0 menu, click [Tools]-[Robot Manager].
The [Robot Manager] dialog box appears.

(2) Select [Force] to display the panel.



(3) Select the [Coordinate System] tab.

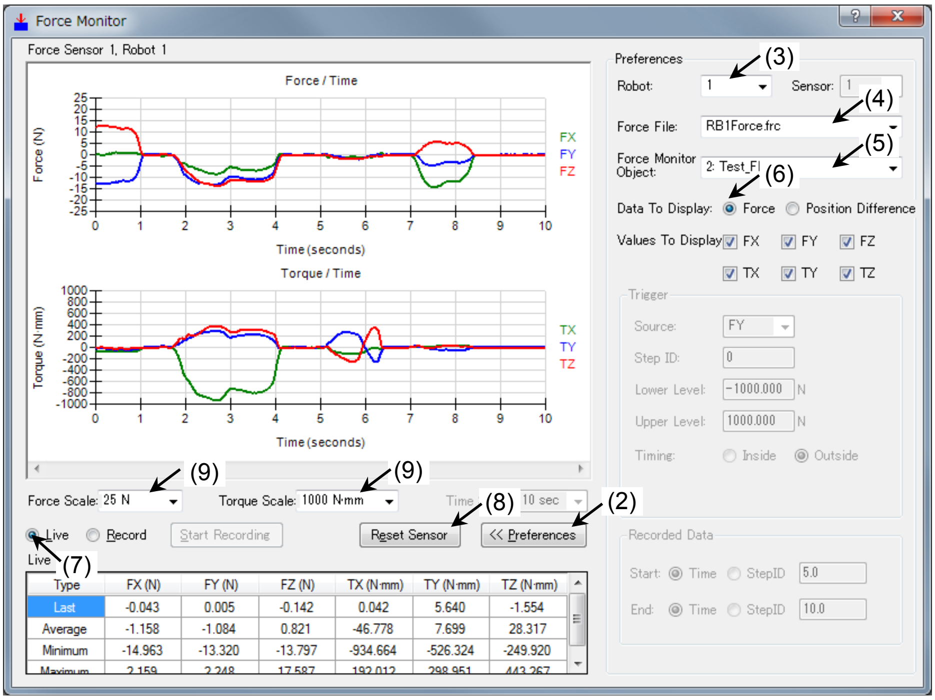
(4) Specify the Force Sensor number to be used in the [ForceSensor] property of any force monitor object.

(5) Specify the created force coordinate system object number in the [CoordinateSystem] property of any force monitor object.

(6) Click the <Save> button to save the changes.

3. Checking that the Coordinate Conversion is Correct in Force Monitor

(1) From the EPSON RC+ 7.0 menu, click [Tools]-[Force Monitor].



(2) Click the <Preferences> button.

(3) Select the robot to be checked in [Preferences]-[Robot].

(4) In [Preferences]-[Force File], select the force file for which the force monitor object was set.

(5) In [Preferences]-[Force Monitor Object], select the set force monitor object.
If the set force monitor object cannot be selected, check whether the force file is correct and the set ForceSensor property is correct.

(6) In [Preferences]-[Data to Display], select the <Force> button.

(7) Select the <Live> button.

(8) Click the <Reset Sensor> button.

(9) Change the values in [Force Scale] and [Torque Scale] to adjust the scale.

(10) Apply a force in each of the axis directions in the set force coordinate system to check that the force is detected within the specified accuracy of the Force Sensor.

If the force is not detected in the set force coordinate system, review the following settings.

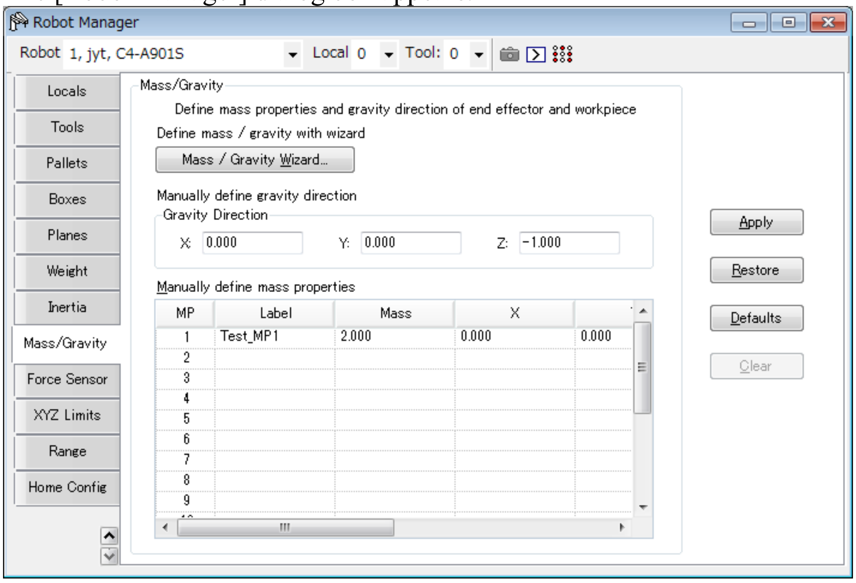
Flange Offset, Base, Tool, Local

Force Coordinate Object, Force Monitor Object

CAUTION	■ When entering the safe guarded area in order to apply a force to the Force Sensor, ensure safety by safety measures such as setting the Manipulator to operation-prohibited status. For details of safety, refer to the following manual. *EPSON RC+ 7.0 User's Guide*

4. Setting the Mass Properties and Gravity Direction

(1) From the EPSON RC+ 7.0 menu, click [Tools]-[Robot Manager].
The [Robot Manager] dialog box appears.



(2) Select [Mass/Gravity] to display the panel.

(3) Directly enter the values in [MP] and [Gravity Direction], or click <Mass / Gravity Wizard> to run the wizard.

(4) Click the <Apply> button to save the settings.

5. Checking that the Gravity Compensation is Correct in Force Monitor

(1) From the EPSON RC+ 7.0 menu, click [Tools]-[Command Window].

(2) Execute the MP statement and specify "MP0" to stop the gravity compensation.

(3) In the [Force Monitor] dialog box, click the <Reset Sensor> button.

(4) From the EPSON RC+ 7.0 menu, click [Tools]-[Robot Manager].

(5) Select the [Jog & Teach] panel.

(6) In Force Monitor, perform the jog operation while measuring the Force Sensor values to change the posture of the robot.
Make sure that the robot does not come in contact with surrounding objects and no force from external objects is applied.
No external force is applied, but since the gravity compensation is stopped, the sensor may be affected by gravity depending on the posture and detect a force.

(7) Execute the MP statement and specify the set mass properties.

(8) In the [Force Monitor] dialog box, click the <Reset Sensor> button.

(9) In Force Monitor, perform the jog operation while measuring the Force Sensor values to change the posture of the robot.
When the gravity compensation works correctly, the absolute sensor value decreases compared with when the gravity compensation is stopped. However, when the robot is operating, a force actually generated by an increase or decrease in speed may be detected as a Force Sensor value.
If there is no change from when the gravity compensation is stopped or the absolute Force Sensor value is larger, identify the set mass properties, and check that the gravity direction is correct and the set mass properties are selected.

3. Force Control 7.0 Graphical User Interface (GUI)

The following describes the Force Control 7.0 graphical user interface (GUI) that was added to the EPSON RC+ 7.0.

- Project Explorer
- [File] menu
- [Edit] menu
- [Project] menu
- [Tools] menu
- Force Editor

Please also read the following manual.

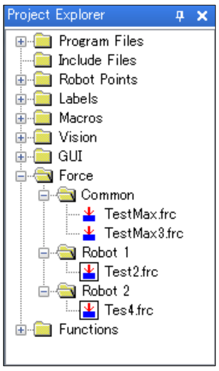
EPSON RC+ 7.0 User's Guide

3.1 Project Explorer

Project force files are listed in the [Force] tree in Project Explorer.

Double-click a force file to display the [Force Editor] window. For details, refer to the following section.

Software: 3.6 Force Editor



Context Menu

Right-click a Force item in the project tree to display the following context menu to manipulate the force file.

Menu Item	Description
New	Creates a new force file. For details, refer to the following section. *Software: 3.2.1 [New File] (File Menu)*
Open	Displays the [Force Editor] window to edit the force file. For details, refer to the following section. *Software: 3.6 Force Editor*
Rename	Renames the force file. For details, refer to the following section. *Software: 3.2.7 [Rename Force File] (File Menu)*
Remove	Removes a force file from the current project. The force file remains.
Delete	Removes a force file from the current project and deletes it.

3.2 [File] Menu

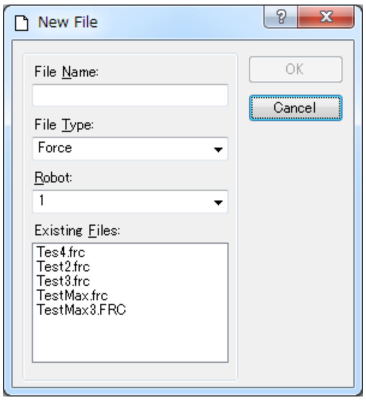
A force file in the current project can be manipulated in the EPSON RC+ 7.0 menu, [File].

3.2.1 [New File] (File Menu)

 : Ctrl + N

Adds a new force file to the current project.

Select "Force" in [File Type] to display the force files in the project folder in [Existing Files].

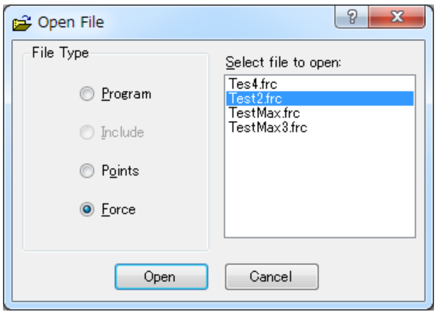


3.2.2 [Open File] (File Menu)

 : Ctrl+O

Opens at least one force file to be edited in the current project.

Select the <Force> button to display a list of the force files in the current project.



3.2.3 [Close File] (File Menu)

Ctrl+D

Closes the window of a force file being edited.

3.2.4 [Save File] (File Menu)

Ctrl+S

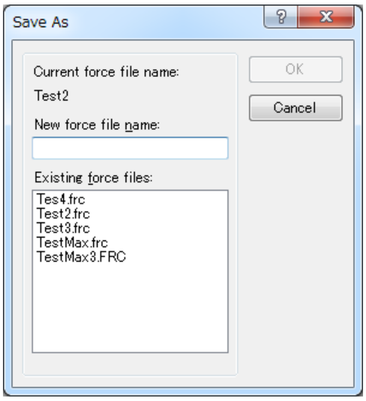
Saves the latest file to the disk.

3.2.5 [Save As] (File Menu)

Saves a force file under a new name and adds it to the project.

The original file is removed from the project but remains on the disk.

Please note that Japanese characters cannot be used in the file name.



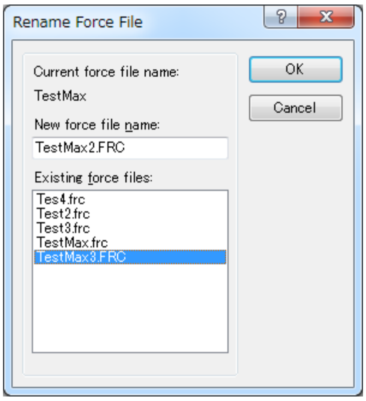
3.2.6 [Restore File] (File Menu)

Restores the force file being edited.

Use this function to restore the file to the last saved state. Executing it displays a dialog box to confirm the operation.

3.2.7 [Rename Force File] (File Menu)

Changes the name of the force file being edited.



For details, refer to the following manual.

EPSON RC+ 7.0 User's Guide: 5.6.7 [Rename File] (File Menu)

3.2.8 [Delete File] (File Menu)

Deletes a force file in the project folder.

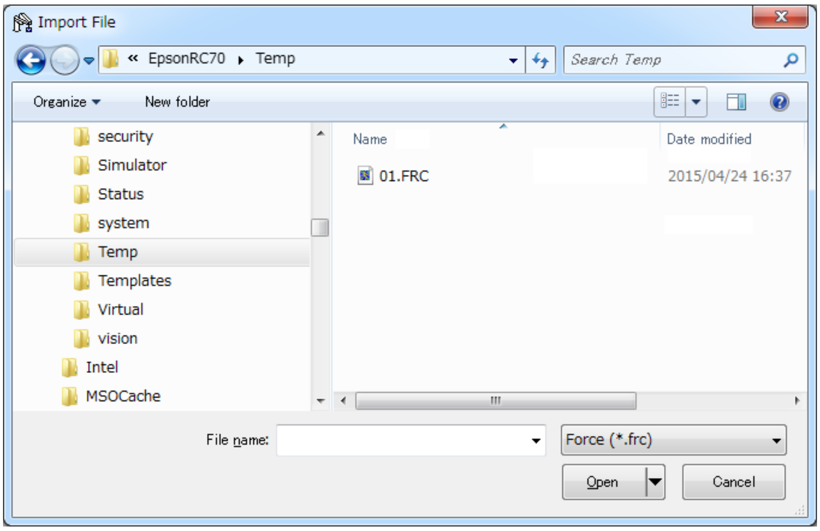
The file to be deleted must be listed in the project.

3.2.9 [Import File] (File Menu)

Imports a force file from another EPSON RC+ 7.0 project.

Pay attention to the following point for the file name.

- The force file to be imported must have an ".frc" extension.



Importing a File

(1) Select "Force (*.frc)" from the file type list.

(2) Select the drive, folder, and file name to be imported.
A file that is already listed in the current project cannot be imported. Select a file that is not listed in the current project.

(3) Click the <Open> button.
If a file with the same name is already listed in the project folder, a message confirming whether to overwrite the existing file appears. The file is copied to the current project folder.

3.2.10 [Exit] (File Menu)

Alt+F4

Exits EPSON RC+ 7.0.

If the force file is not saved, a dialog box confirming whether to save the file appears. Click the <Yes>, <No>, or <Cancel> button.

3.3 [Edit] Menu

A force file can be edited from EPSON RC+ 7.0 menu, [Edit].

3.3.1 [Cut] (Edit Menu)

 : Ctrl+X

Cuts the selected data (string, force object, etc).

3.3.2 [Copy] (Edit Menu)

 : Ctrl+C

Copies the selected data (string, force object, etc).

3.3.3 [Paste] (Edit Menu)

 : Ctrl+V

Pastes the cut or copied data (string, force object, etc) to the cursor position.

3.3.4 [Select All] (Edit Menu)

Ctrl+A

Selects all force object items of the force file being edited. The selected items can be cut and copied.

3.4 [Project] Menu

Projects can be managed and built in the EPSON RC+ 7.0 menu, [Project].

3.4.1 [Open Project] (Program Menu)

Opens an EPSON RC+ 7.0 project.

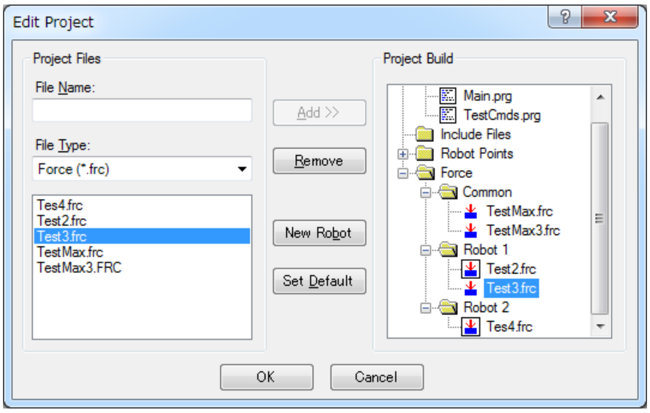
Opening a project closes the open project. A message for confirming whether to save the changes appears.

When a project is opened with the [Read Only] checkbox selected, the force file cannot be edited.

3.4.2 [Edit Project] (Project Menu)

Set the force file to be used in the current project.

The force file is added to [Project Build].



Adding a New Force File

(1) Enter the name of a force file to be created in [File Name]. Be sure to add extension ".frc" to the file name.
Please note that Japanese characters cannot be used in the file name.

(2) From [Project Build]-[Force], select the robot folder to be added.

(3) Click the <Add> button.
A message for confirming whether to create a new file appears. Click the <Yes> button.
A file is created and added to the robot folder selected in [Project Build]-[Force].

Adding an Existing Force File to the Project

(1) Select “Force (*.frc)” from the [File Type] box.

(2) From [Project Build]-[Force], select the robot folder to be added.

(3) From the list, select the force file name to be added to the project.

(4) Click the <Add> button.
The file is added to the robot folder selected in [Project Build]-[Force].

Removing a Force File

(1) Select the file to be removed from the [Project Build] tree.

(2) Click the <Remove> button.
The file name is removed from the [Project Build] tree. Since the file is not deleted from the project folder, it is displayed in the file list.

Setting Default for a Force File

(1) From a robot folder in [Project Build]-[Force], select the force file which you want to set to the default.

(2) Click the <Set Default> button.
The force file is set to the default of the listed robot.

NOTE

A common force file is a force file that can be used in all robots on the controller. To use a common force file, you need to load it from the SPEL+ program using the FLoad command.

A default force file is a force file that is automatically loaded to the robot when loading a project. One force file can be set to the default for each robot.

3.4.3 [Save Project] (Project Menu)

The following items are saved. If nothing needs to be saved, this menu is displayed in gray and cannot be selected.

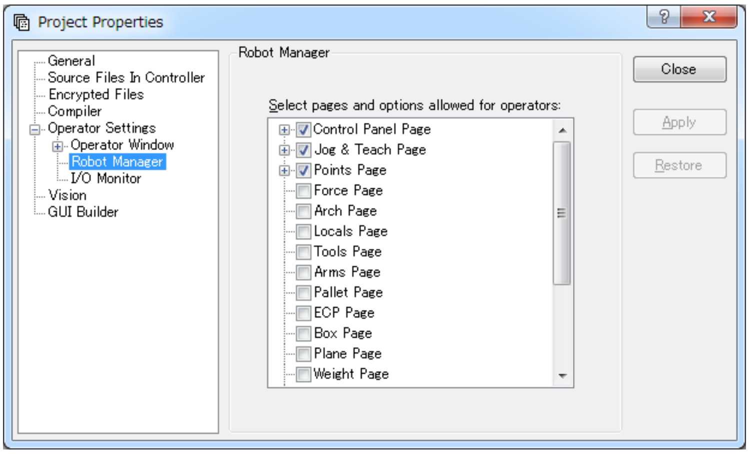
- Program file
- Include file
- Point file
- Force file
- I/O label
- User error

3.4.4 [Project Properties] (Project Menu)

[Project]-[Project Properties]-[Operator Settings]-[Robot Manager]

Set up Robot Manager.

To enable the operator to edit the force data when displaying the operator window, select the [Force Data Tab] checkbox.



3.5 [Tools] Menu

The EPSON RC+ 7.0 has some GUI tools to support system development. You can access all tools from the EPSON RC+ 7.0 menu, [Tools].

3.5.1 [Robot Manager] (Tools Menu)

 : F6

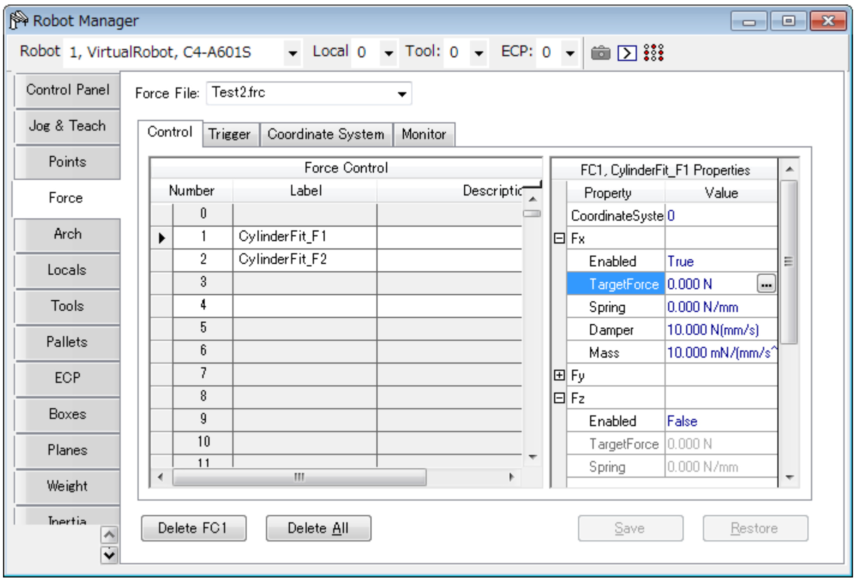
[Tools]-[Robot Manager]-[Force] Panel

Force: You can enter and delete force control, force trigger, force coordinate system, and force monitor objects.

When you select a force file, the controller loads it into the memory. When using Robot Manager as an MDI sub-window, enter “Ctrl+S” to save the force data.

[Control] Panel

You can edit the force control object.

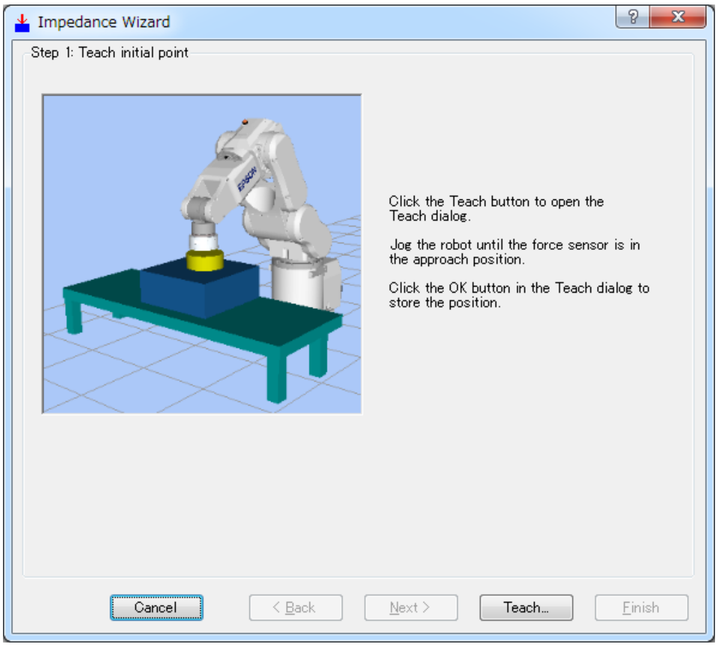


Item	Description
Force file	Selects the force file.
Label	Sets the label (Label property).
Description	Sets the description (Description property).
Properties	Selects the property to set the value.
<Drop-down list>	Displays a list of values that can be selected. Select a value.
<Impedance Wizard>	Displays Impedance Wizard, in which you can set each of the property values for force control objects (TargetForce, Spring, Damper, and Mass).
Delete Fxxx	Deletes the force object. A confirmation screen appears.
Delete All	Deletes all the force objects in the selected tab. A confirmation screen appears.
Save	Saves the values.
Restore	Restores the original values. A confirmation screen appears.

Impedance Wizard

(1) Click the <Impedance Wizard> button in Properties.

The [Impedance Wizard] window appears.

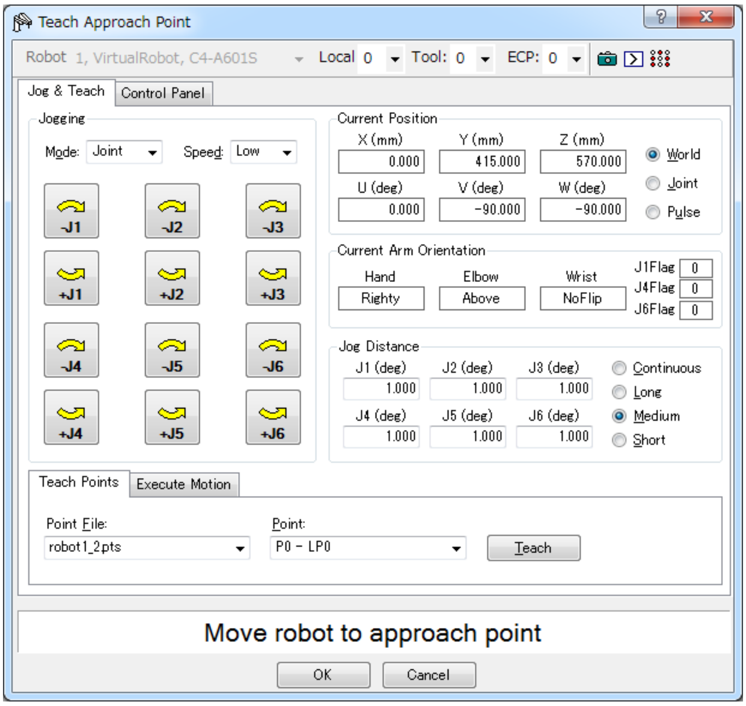


(2) Click the <Teach...> button.

The [Teach Approach Point] dialog box appears.

Select the [Jog & Teach] tab.

Move the robot to the point where the workpiece is about 1 mm above the object to be pressed.



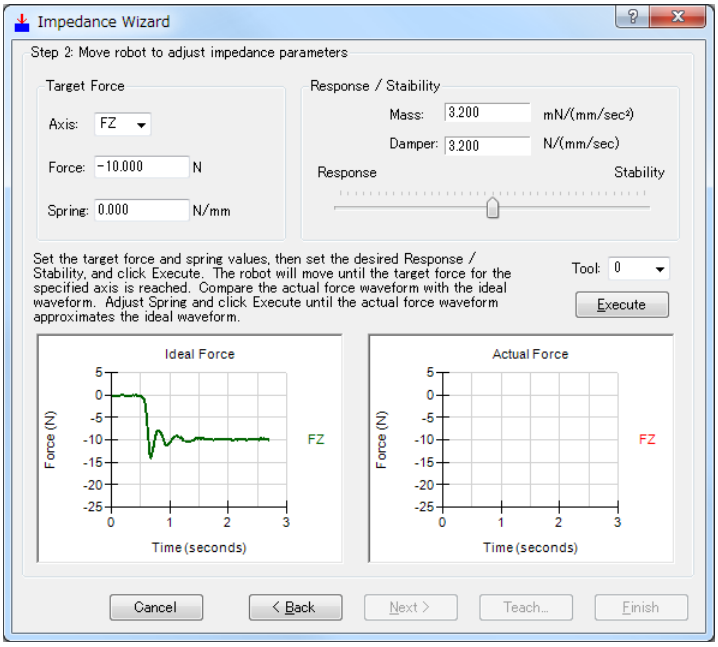
(3) Click the <OK> button.

Save the current position and return to the [Impedance Wizard] window.

Set the values in [Force] and [Spring] of [Target Force].

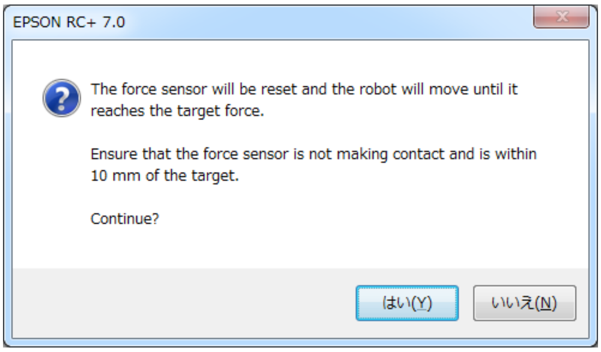
Set the values in [Mass] and [Damper] of [Response / Stability] with a slider.

Set the slider to the "Stability" side first and adjust the values while checking the waveform of the actual force.



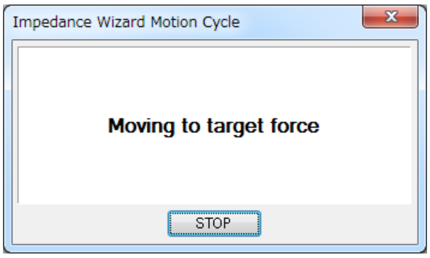
(4) Click the <Execute> button. A confirmation dialog box appears.

Check that the distance between the workpiece at the initial position and the object to be pressed is within 1 mm, and then click the <Yes> button.

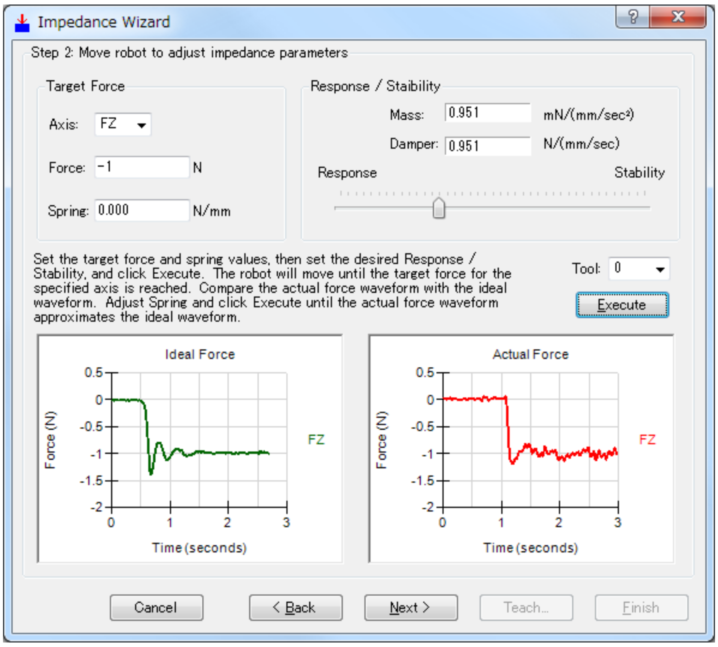


(5) The robot moves until the set axis reaches the target force.

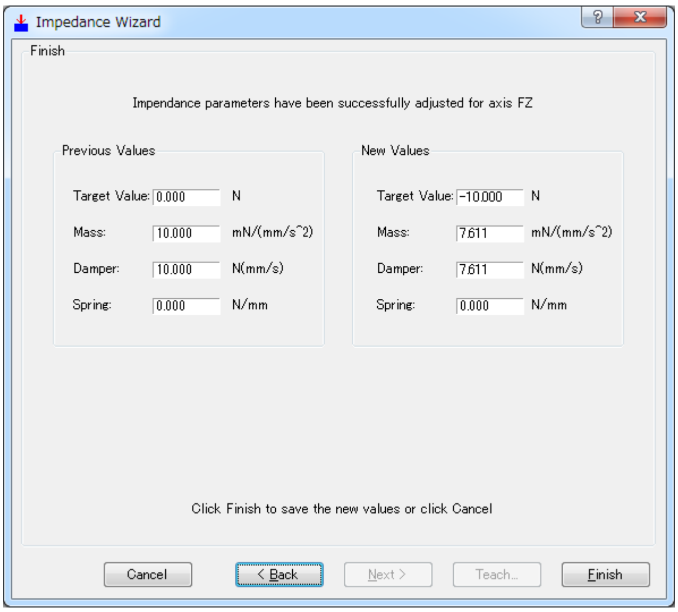
To stop the robot part way through, click the <STOP> button.



(6) Adjust the [Spring] value with a slider until the actual force waveform approximates the ideal waveform, and then click the <Execute> button.
Repeat the procedure until the actual force waveform approximates the ideal waveform.
If the waveform is vibrating or cannot settle at the target force, move the slider to “Stability” side. If the waveform is too smooth, move the slider to “Response” side.
If the slider is moved largely, the force being applied may greatly change. Move the slider little by little to adjust the values.
Note that if the [Spring] value is too large or the slider position is too stable, the robot may not be able to contact the workpiece.

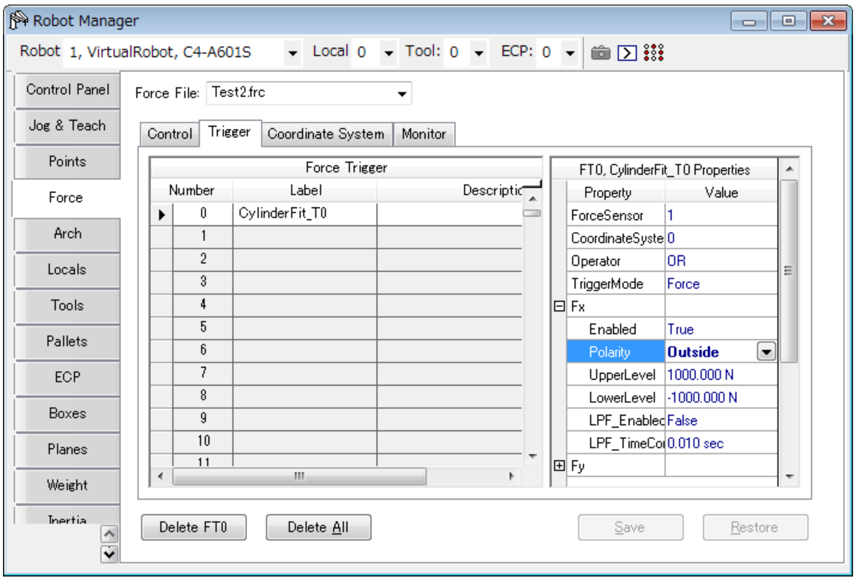


(7) Click the <Next> button.
The impedance parameters before and after the adjustment for the set axis are displayed.
To save the new values, click the <Finish> button, and to cancel them, click the <Cancel> button.



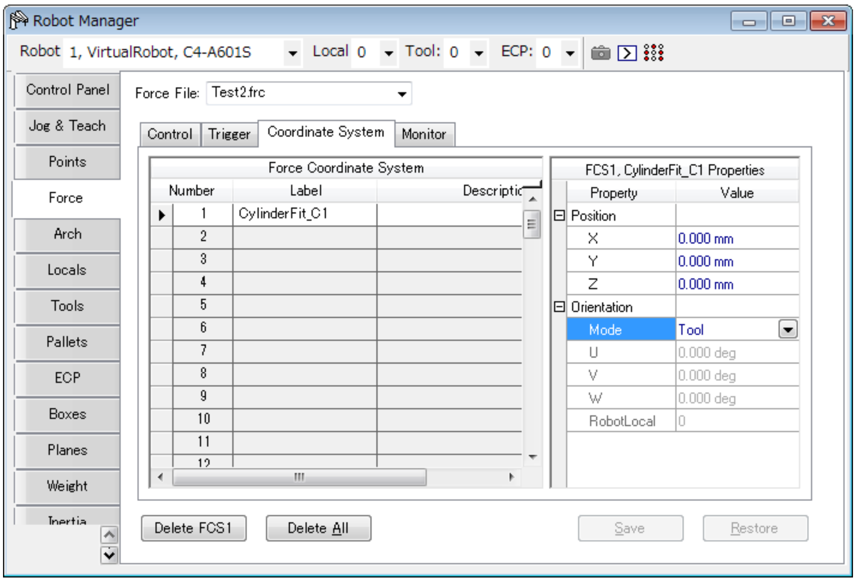
[Trigger] Panel

You can edit the force trigger object.



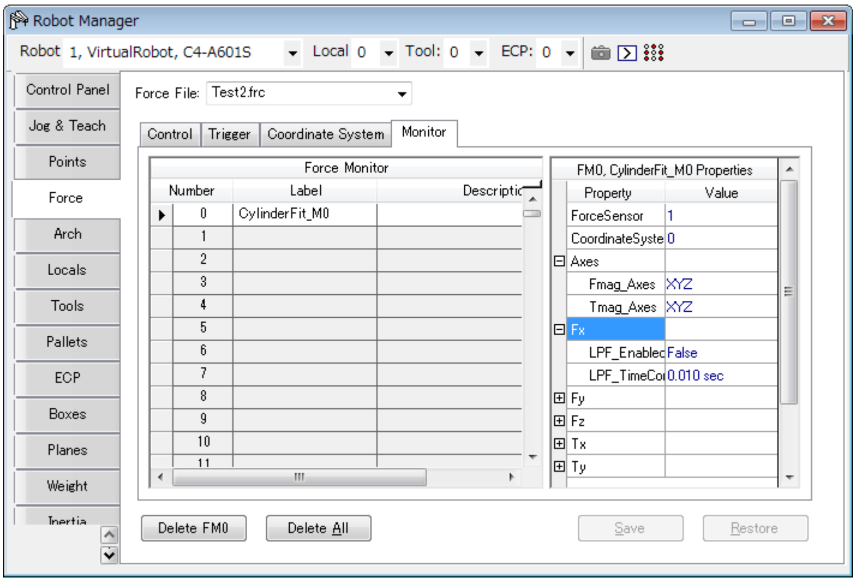
[Coordinate System] Panel

You can edit the force coordinate system object.



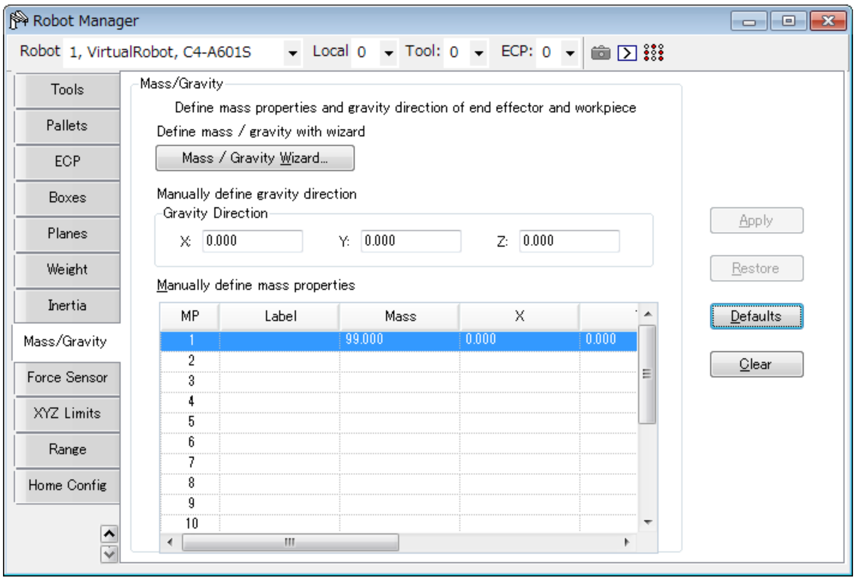
[Force Monitor] Panel

You can edit the force monitor object.



[Tools]-[Robot Manager]-[Mass/Gravity] Panel

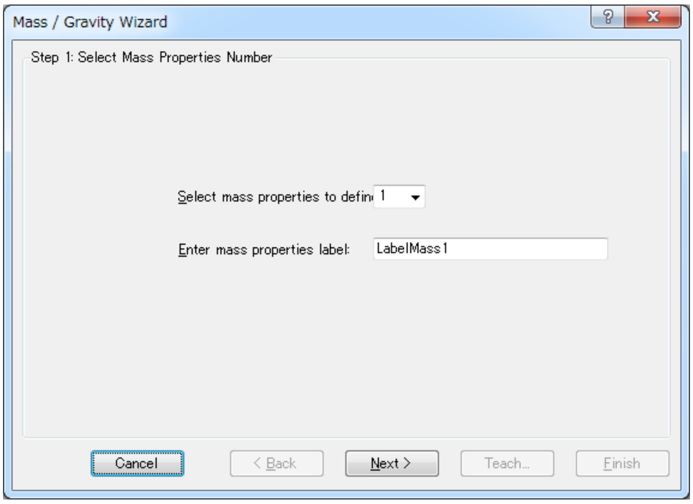
You can set the values of the mass properties.



Item	Description
Mass / Gravity Wizard	Displays Mass / Gravity Wizard, in which you can set the property values of the mass property object.
Gravity Direction	Set the gravity direction of the robot (robot object GravityDirection property).
Mass Properties (MP)	Set the following items of the mass property object with MP (number). Label (Label property) Mass property X / Y / Z (GravityCenter property) Description (Description property)
Defaults	Sets the default value in the gravity direction.
Clear	Deletes the selected mass property object.

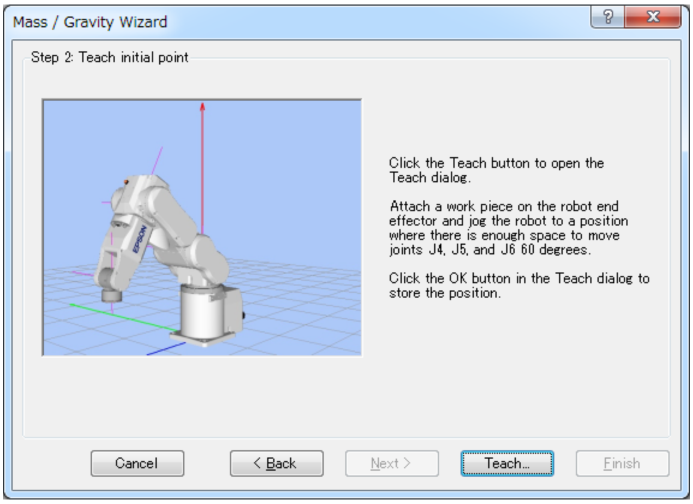
Mass/Gravity Wizard

(1) Click the <Mass / Gravity Wizard> button.
[Step 1: Select Mass Properties Number] appears in the [Mass / Gravity Wizard] window.
You can define the mass properties.

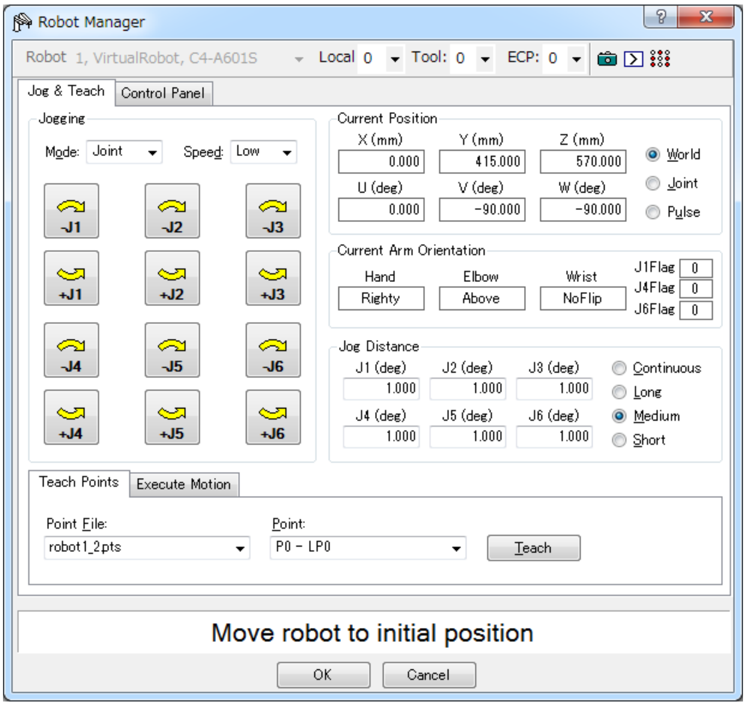


(2) Select the number in [Select mass properties to define].
The mass properties label for the selected number is displayed in [Enter mass properties label]. The label name can be changed.

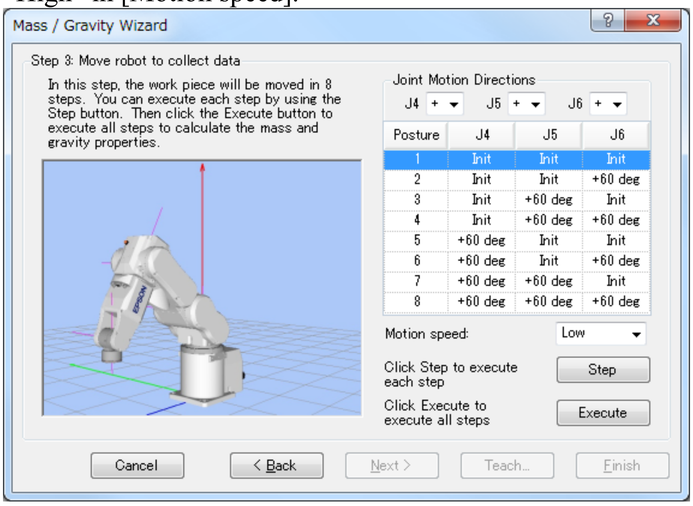
(3) Click the <Next> button.
[Step 2: Teach initial point] appears in the [Mass / Gravity Wizard] window.



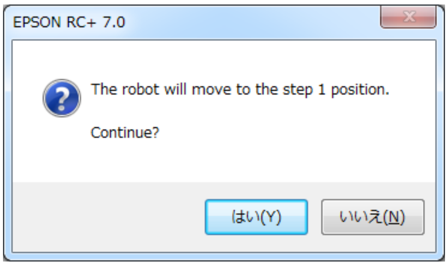
(4) Click the <Teach...> button.
The [Jog & Teach] window appears.
Mount the workpiece to the end effector (hand tip) of the robot and move the robot to the position where J4, J5, and J6 can move at 60 degrees.



(5) Click the <OK> button.
The position information is saved.
[Step 3: Move robot to collect data] appears in the [Mass / Gravity Wizard] window.
In this step, the robot moves in 8 steps.
You can select the motion direction of joints [J4], [J5], and [J6] from "+" and "-" in [Joint Motion Directions].
You can select the speed for the posture check using step buttons from "Low" and "High" in [Motion speed].



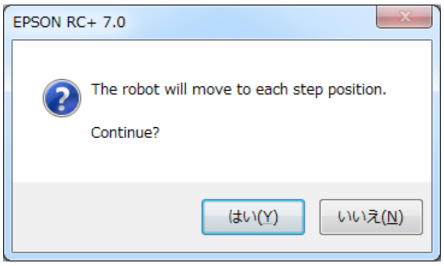
Click the <Step> button in (5) to view the posture of each step.
The following message appears.



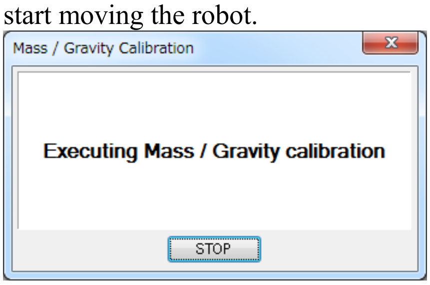
Click the <Yes> button to display the [Execute Command] dialog box and start moving the robot.
Click the <Step> button to check if the robot interferes with the end effector and peripherals for the posture of each step.

To stop the robot part way through, click the <STOP> button.

Click the <Execute> button in (5) to execute all the steps to measure the mass properties. The following message appears.



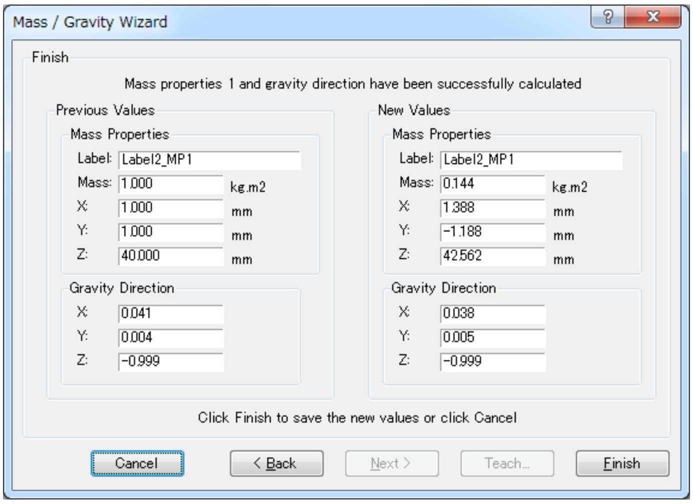
Click the <Yes> button to display the [Mass / Gravity Calibration] dialog box and start moving the robot.



To stop the robot part way through, click the <STOP> button.

(6) When the movement is completed, [Finish] appears in the [Mass / Gravity Wizard] window.

The mass properties and gravity direction values are displayed in [Previous Values] and [New Values].



(7) Click any of the following buttons.

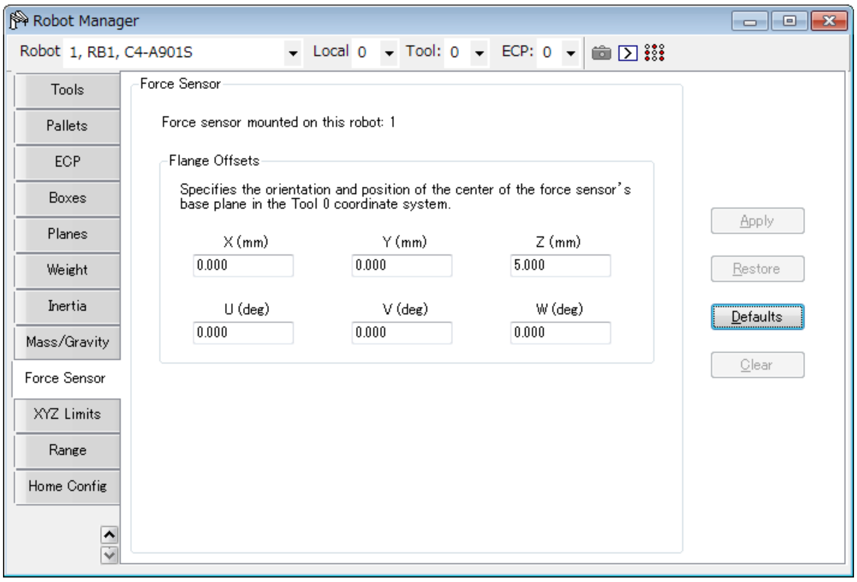
<Finish> button : Saves the new values.

<Cancel> : Cancel the new values.

[Tools]-[Robot Manager]-[Force Sensor] Panel

You can define the Force Sensor values.

(1) Select the [Force Sensor] tab in the [Robot Manager] window.



(2) Set the robot object and flange offset properties in [Flange Offsets].

Click the <Defaults> button to set the default values.

3.5.2 [Force Monitor] (Tools Menu)

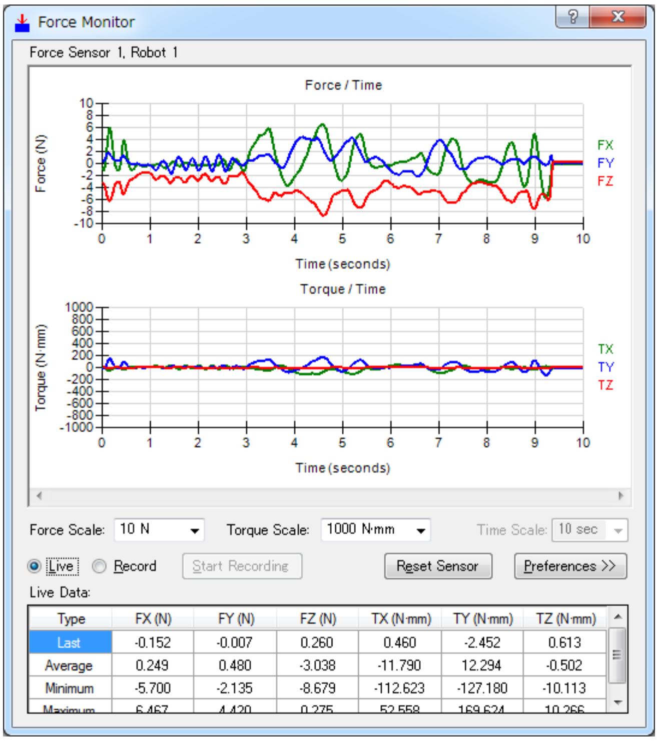
The current force values are displayed.

From the EPSON RC+ 7.0 menu, select [Tools]-[Force Monitor], or click the <Force Monitor>  button on the toolbar.

The [Force Monitor] window appears.

The window display varies depending on whether the <Live> or <Record> button is selected.

Display when the <Live> button is selected

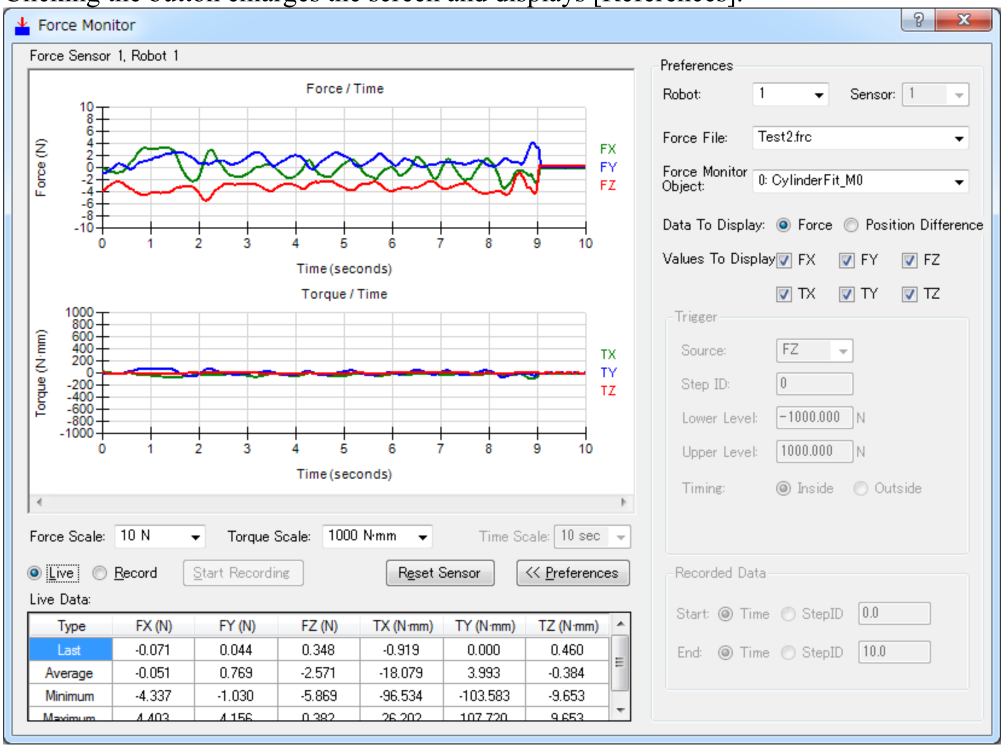


Item	Description
Graph	Displays a graph of the values set in [Preferences]-[Data to Display] that is displayed by clicking the [Preferences] button (described later).
Force (N) FX, FY, FZ	When [Preferences]-[Data to Display]-<Force> is selected Displays the force values for Fx, Fy, and Fz.
Position Difference (mm) DX, DY, DZ	When [Preferences]-[Data to Display]-<Position Difference> is selected Displays a graph of the values for the X, Y, and Z axes regarding the differences between the tool coordinate system command values of the position control and the tool coordinate system command values including those of the force control and position control in the robot coordinate system.
Torque (N·mm) TX, TY, TZ	When [Preferences]-[Data to Display]-<Force> is selected Displays a graph of the torque values for the Tx, Ty, and Tz axes.

Item	Description
Axis Angle Difference (deg) DAX, DAY, DAZ	When [Preferences]-[Data to Display]-<Position Difference> is selected Displays a graph of the axis angle differences of the X, Y, and Z axes regarding the tool coordinate system command values of the position control and the tool coordinate system command values including those of the force control and position control in the robot coordinate system.
Force Scale	Sets the vertical-axis scale in the force graph.
Force Scale	Sets the vertical-axis scale in the torque graph.
Time Scale	Sets the horizontal-axis scale in the force and torque graphs. Selecting the <Record> button enables the time scale.
Live	Displays the current values in the graph.
Record	Displays the recorded values in the graph. Reference: Display when the <Live> button is displayed (described later)
Start Recording	Starts recording. Selecting the <Record> button enables the time scale.
Reset Sensor	Resets the force and torque values to "0."
Preferences	Enlarges the screen to allow you to configure the preferences such as how to display the graph (described later).
Live Data	Displays the current values of the types (last, average, minimum, and maximum) for each axis.

<References> Button

Clicking the button enlarges the screen and displays [References].

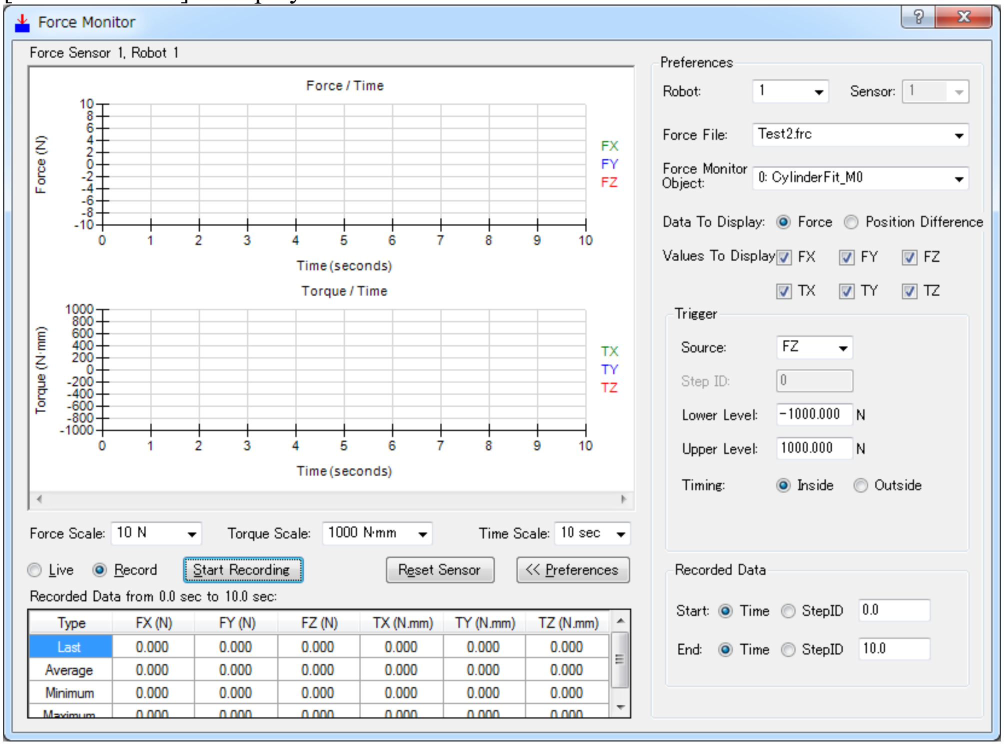


Item	Description
Robot	Set the robot number.
Sensor	Set the number of the Force Sensor. Specifying the Force Sensor number displays the force and torque in the Force Sensor coordinate system.
Force file	Set the file in which the force monitor object is stored.

Item	Description
Force Monitor Object	Select the force monitor object from a list of the defined objects (number and label). Specifying the force monitor object displays the force and torque in the force coordinate system.
Data to Display	Set the data to be displayed in the graph. Force: Force and torque data Display in [Values to Display]: FX FY FZ TX TY TZ Position Difference: Position difference and rotation difference data Display in [Values to Display]: DX DY DZ DAX DAY DAZ
Trigger	Set the triggers to start and end recording when clicking the <Start Recording> button. Selecting the <Record> button and [Preferences]-[Data to Display]-<Force> enables [Trigger]. Source : Select the axis of the trigger. If you do not want to set the trigger (but record all), select “None”. Step ID : Set the *number* when using command FSet Robot.StepID, *number* as a trigger. Lower Level : Set the lower threshold value of the trigger. Upper Level : Set the upper threshold value of the trigger. Timing : Set the timing of the trigger. <Inside> : When the value falls inside the range set above. <Outside> : When the value falls outside the range set above.
Recorded Data	Set the time to start and end recording when clicking the <Start Recording> button. Selecting the <Record> button enables Recorded Data. Time : Set the time (sec). StepID : Set the *number* when using command FSet Robot.StepID, *number* as a trigger to start or end recording.

Display when the <Record> button is selected

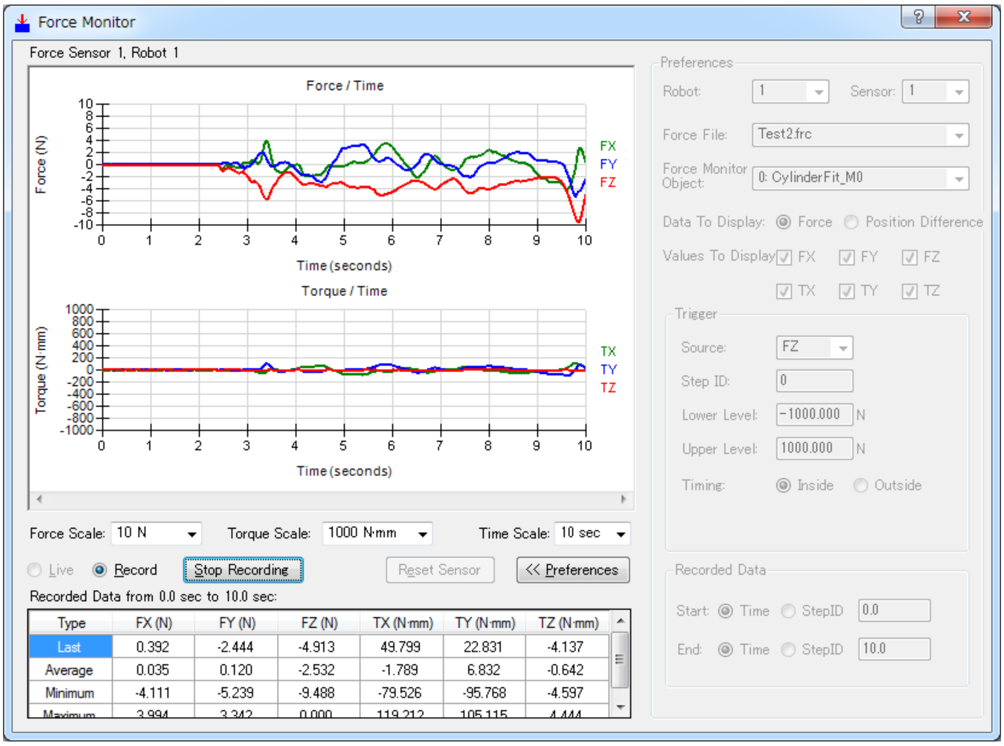
[Recorded Data] is displayed.



With the exception of the item below, refer to "Display when the <Live> button is selected" described above.

Item	Description
[Recorded Data]	Displays the recording time (sec) and recorded data of the types (last, average, minimum, and maximum) for each axis.

<Start Recording> Button
Click the button to change to <Stop Recording>.
Click the button to start recording. The data being recorded is displayed in the graph.
The <Reset Sensor> button and [Preferences] items are displayed in gray and cannot be selected.



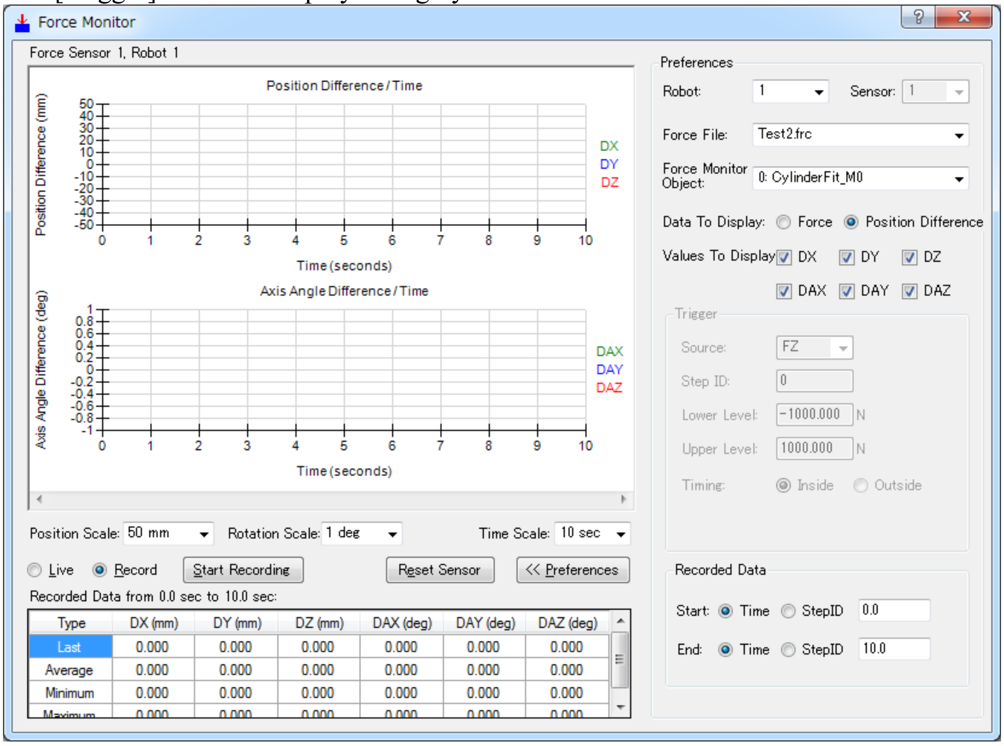
<Stop Recording> Button
Click the button to change to <Start Recording>.
Click the button to update [Recorded Data].
The <Reset Sensor> button and [Preferences] items become selectable.

[Preferences]-[Data to Display]-<Position Difference> Button

Selecting the button displays [Position Difference (mm)] and [Axis Angle Difference (deg)] in the graph.

In addition, data for each axis is displayed in [Recorded Data].

The [Trigger] items are displayed in gray and cannot be selected.

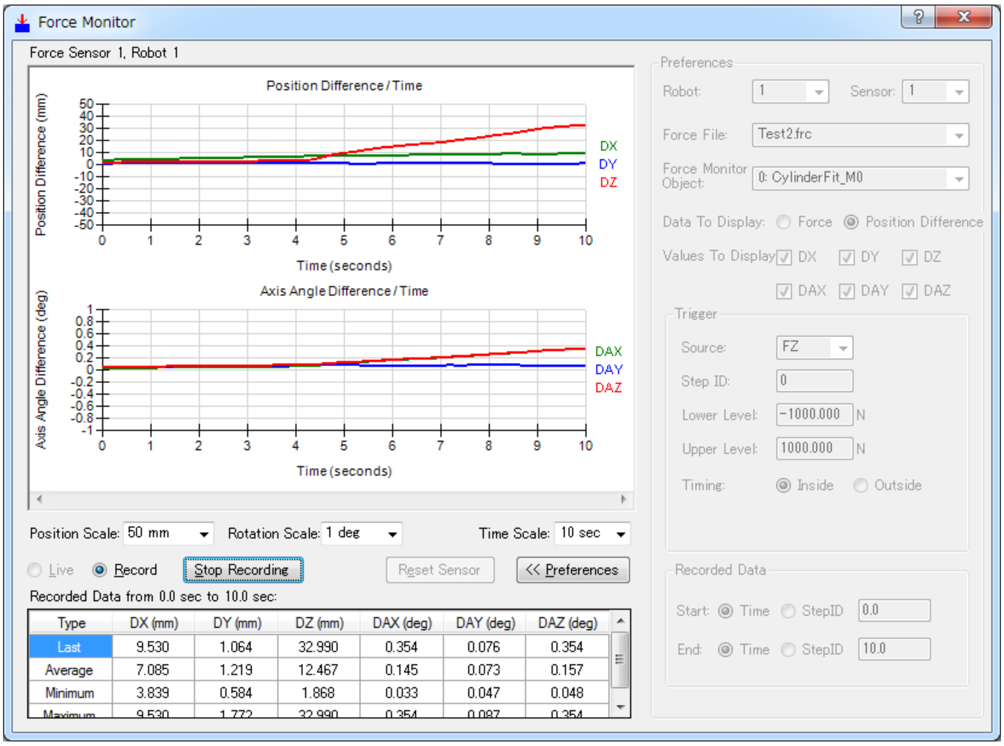


<Start Recording> Button

Click the button to change to <Stop Recording>.

Click the button to start recording. The data being recorded is displayed in the graph.

The <Reset Sensor> button and [Preferences] items are displayed in gray and cannot be selected.



<Stop Recording> Button

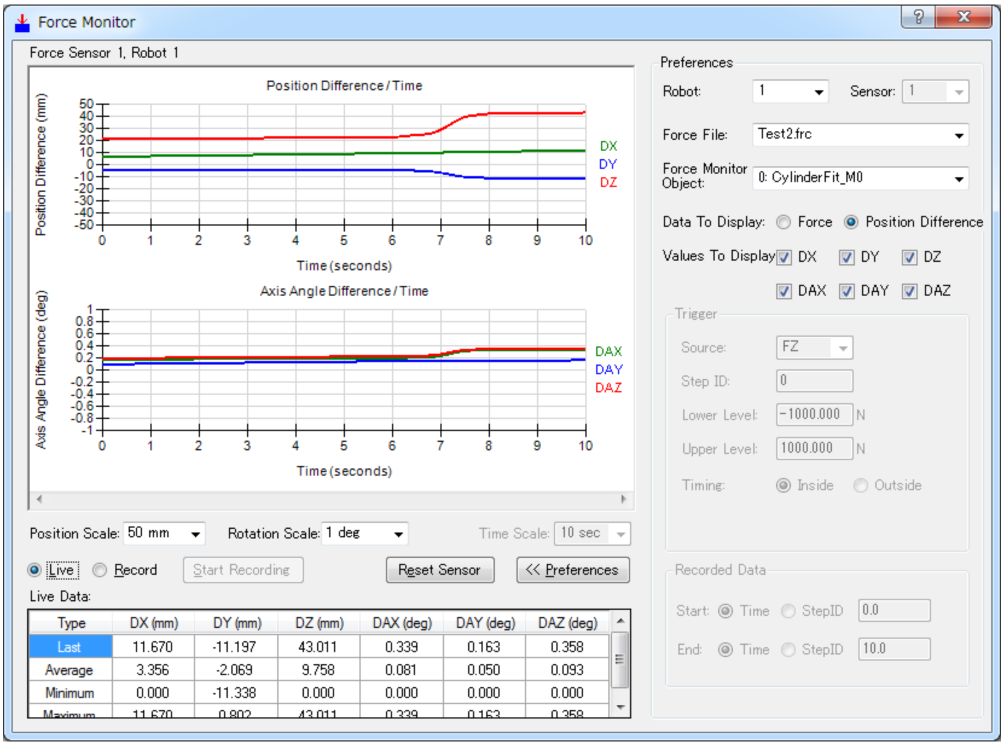
Click the button to change to <Start Recording>.

Click the button to update the display in [Recorded Data].

The <Reset Sensor> button and [Preferences] items become selectable.

<Live> Button

Selecting the button displays the current values in the graph. In addition, [Recorded Data] changes to [Live Data], and the [Preferences]-[Recorded Data] items are displayed in gray and cannot be selected.



3.5.3 [Maintenance] (Tools Menu)

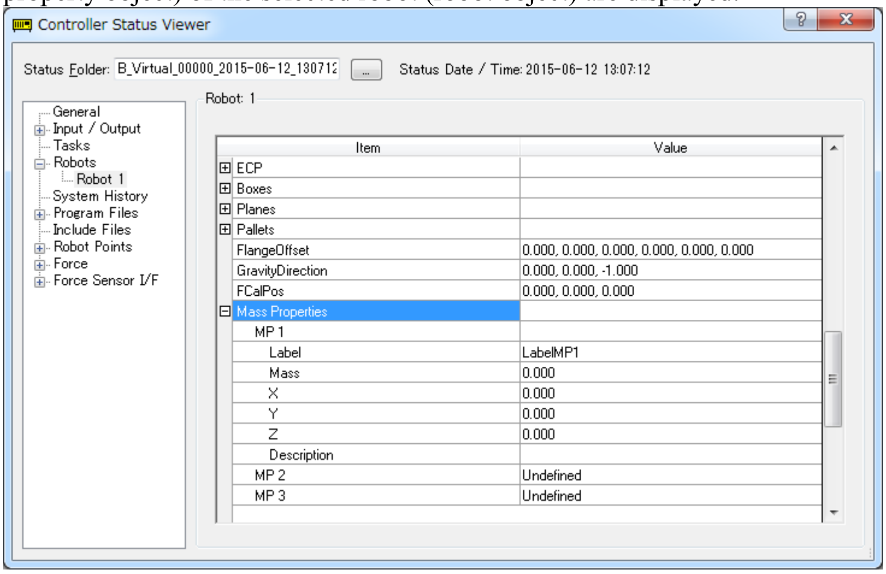
Force sensor-related values can be referred to when displaying the controller status.

(1) Click the <Restore Controller Settings> button.
The [Browse Folder] dialog box appears.

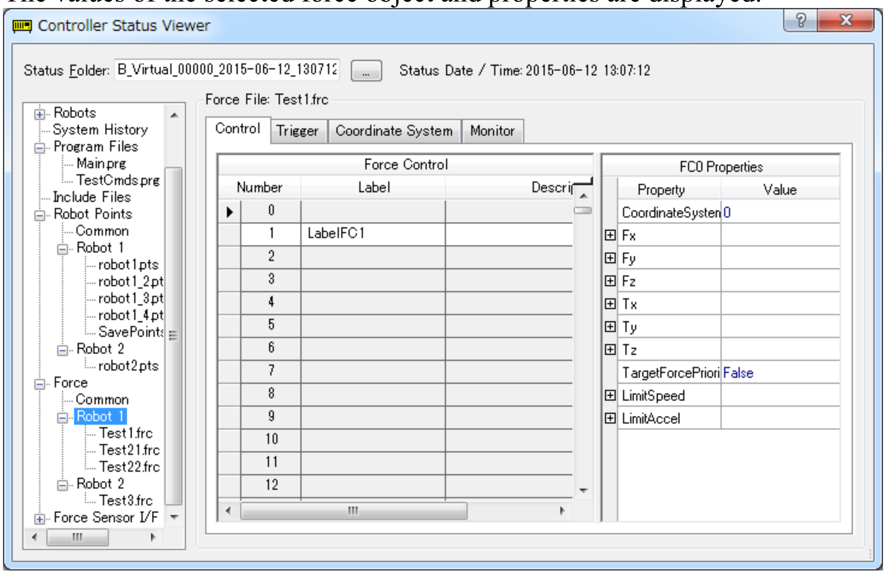
(2) Select the folder in which the information is stored. (The folder with “controller type name, serial number, and date/time” after “B_”)

(3) Click the <OK> button to display the controller status.

(4) From the tree in the [Controller Status Viewer] window, select [Robots]-[Robot*].
The property values of FlangeOffset, GravityDirection, and Mass Properties (mass property object) of the selected robot (robot object) are displayed.



(5) Select [Force]-[Robot*]-[***.frc].
The values of the selected force object and properties are displayed.

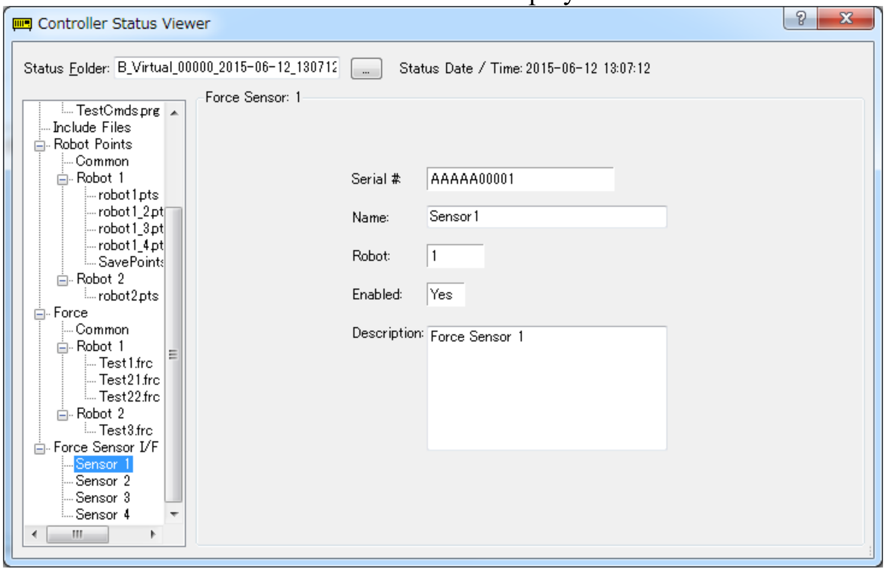


For details, refer to the following section.

Software: 3.5.1 [Robot Manager] (Tools Menu) - [Tools]
[Robot Manager]-[Force] Panel

(6) Select [Force Sensor I/F]-[Sensor *].

The values of the selected Force Sensor are displayed.



For details, refer to the following section.

Software: 1.1 Configuring the Force Sensor I/F Unit

3.6 Force Editor

Open a force file from the object tree of Project in [Project Explorer] to display the [Force Editor] window.

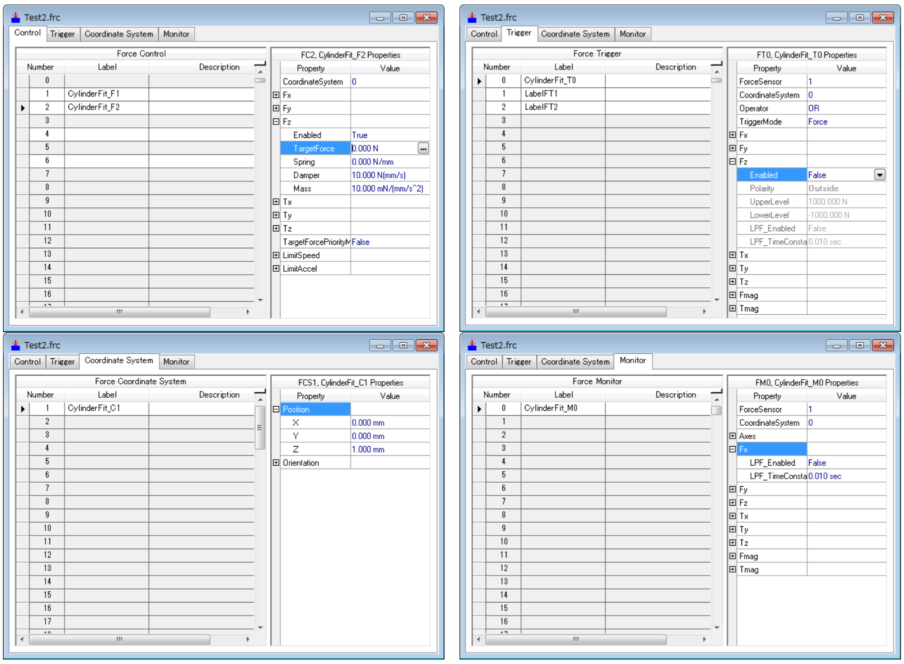
The display can be selected using the tabs, and each object and property can be edited.

When values are changed, a message confirming whether to save the changes appears when closing the window.

For details, refer to the following section.

Software: 3.5.1 [Robot Manager] (Tools Menu)

[Tools]-[Robot Manager]-[Force] Panel



4. SPEL+ Programming of the Force Functions

The following describes the SPEL programming for using the force functions.

The force functions are executed using special commands added to the SPEL+ language.

Various applications can be implemented using the force functions by combining the special commands added to Force Control 7.0 with the existing SPEL+ language.

4.1 SPEL+ Commands of Force Control 7.0.

The following describes the concept necessary for using the SPEL+ commands added to Force Control 7.0.

4.1.1 Force Object

A force object is a set of properties for each function necessary for using the force functions.

Define this object and execute each force function. A force object can be defined using a GUI such as Robot Manager or SPEL+ commands.

There are the following types of force objects.

- "Force control object" used for the force control function
- "Force trigger object" used for the force trigger function
- "Force monitor object" used for the force monitor function
- "Force coordinate object" used commonly for the force functions

4.1.2 Properties

Properties are parameters included in the force objects. The properties can be set and obtained.

The properties can be set using Force Editor before executing a program or can be changed dynamically using SPEL+ commands in a program.

An FSet statement is used to set properties. An FGet statement is used to get properties. Properties set by FSet are copied to the force file at the time when a project is loaded. The set values can be saved in the file using the FSave statement.

4.1.3 Status

A status is a value that is included in the force object and is returned after the force function is executed.

A status can be obtained by a SPEL+ command in a program, and the process can be branched based on it. An FGet statement is used to get a status. Each status is cleared at a unique timing. For details on when each status is initialized, refer to each status in the following manual.

EPSON RC+ 7.0 Option Force Control 7.0 Property & Status Reference

4.2 SPEL+ Programming of the Force Control Function

4.2.1 Overview

A force control function is a function to control the robot to achieve a given target force or torque using the Force Sensor.

Programming of the force control function is performed with the following procedure.

1. Set the coordinate system to be executed
2. Set the parameters
3. Execute the force control function

4.2.2 Coordinate System of the Force Control Function

The force control function works in the force coordinate system.

The force control function calculates the force detected by the sensor, the force applied to the force coordinate system by the torque, and the torque itself, and controls the robot while moving and rotating the force coordinate system according to the results of the calculations.

Specify the origin of the force coordinate system in a point where contact actually occurs and a force is generated. (Example: Tip point of a workpiece)

Furthermore, the orientation of the force coordinate system varies depending on the application. When executing the force control function in a constant direction, regardless of the posture of the robot, like a case where a force is always applied in the vertical downward direction, specify the base coordinate system and local coordinate system.

When executing the force control function in a direction that changes according to the posture of the robot, like a case where a force is applied in a direction of the workpiece held by the robot, specify the tool coordinate system and custom coordinate system.

The force control function can be executed for the six axes (Fx to Tz) specified in the force coordinate system.

4.2.3 Parameters of the Force Control Function

Parameters of the force control function are defined in the properties of the force control object.

They can be set in the GUI before executing a program. For details on the settings in the GUI, refer to the following section.

Software: 3.5.1 [Robot Manager] (Tools Menu)
[Tools]-[Robot Manager]-[Force] Panel

If you want to dynamically change the parameters during executing a program, they can be set using an FSet statement.

CoordinateSystem Property

Specify the force coordinate object for which the force control function is executed.

Changing only the CoordinateSystem property enables the force control function with the same control characteristics to be executed in another coordinate system.

Enabled Property

Specify the axes (Fx to Tz) on which the force control function is executed.

You can enable only the axes necessary for an application; for example, you can enable Fx to Fz and disable Tx to Tz to execute the force control function only in the translation direction.

TargetForce Property

Set the target force or torque of the force control function for each axis.

The robot moves to detect the set force. Note that if a positive value is set, the robot moves in a negative direction to apply a force in the positive direction of the force coordinate system.

If you want to perform the pressing operation in the positive direction of the force coordinate system, set a negative target force.

The robot moves not to apply a force if the TargetForce property is set to 0. The robot can move while following the external force.

Spring Property

Set the spring value of the force control function.

Setting the Spring property enables the force control function to work as if there is a virtual spring, and if an external force is applied, the robot moves to the position to counterbalance the force, and if the applied external force is removed, the robot returns to the original position.

Increasing the value moves the robot as if a harder spring is provided. If “0” is set, there is no virtual spring, so the robot moves as far as it can according to the force.

Damper Property

Set the damper value of the force control function.

Decreasing the Damper property value increases the response of the force control function to changes in the force, but makes the motion of the robot more vibratory. To adjust the Damper property value, decrease the default value gradually.

Mass Property

Set the mass value of the force control function.

Setting a large value for the Mass property increases the overshoot until the target force is achieved and increases the hunting period. Set the Mass and Damper property values so they are about 1:1 to 10:1 in the translation direction and about 1:1 to 1000:1 in rotation to perform stable control.

However, note that the motion may be vibratory, or a ratio larger than those may be appropriate for some applications or operating conditions.

If the Mass property value is too small compared to that of the Damper property value, an error may occur when the force control function is executed.

TargetForcePriorityMode Property

Set the target force priority mode of the force control function. The target force may not be able to be achieved after the passing of enough time for some operating conditions such as mechanical rigidity. In this case, enabling the target force priority mode increases the movement and reduces the time to achieve the target force. However, the movement will differ from that specified in Spring, Damper, and Mass. Normally, disable the target force priority mode, and use the mode only when necessary upon fully understanding the characteristics.

LimitSpeed Property

Set the maximum value of the speed at which the hand tip of the robot works during executing of the force control function.

Specify the three values of translation, rotation, and joint speed. The speed is automatically limited to the specified maximum value during executing of the force control function. This property is useful, for example, if you need to move the robot in a high power mode to perform a pressing operation with a strong force, but want to move it at a low speed.

LimitAccel Property

Set the maximum value of the acceleration at which the hand tip of the robot works during executing of the force control function.

Specify the three values of translation, rotation, and joint acceleration. The acceleration is automatically limited to the specified maximum value during executing of the force control function.

4.2.4 Executing the Force Control Function

The force control function is executed alone as an operation command, or the position control and force control functions are executed simultaneously by adding a modification parameter to the operation command of the position control. When the force control function is executed, the operation always changes depending on the output of the Force

Sensor, so that the robot does not reach the target position of the position control, but even though the same command is executed, the operation ends at different positions every time.

To execute only the force control function, execute the FCKeep statement. The following operation commands can be used in combination with the force control function: Move, BMove, TMove, CVMove, FCSMove, Arc, and Arc3 statements.

To execute the force control function, add the force control object to each statement as a modification parameter.

Example of combination of the force control function with Move:

Move P1 FC1

For details on each statement, refer to the following manual.

EPSON RC+ 7.0 SPEL+ Language Reference

EPSON RC+ 7.0 Option Force Control 7.0 Property & Status Reference

For details on operation commands with the force control function enabled, refer to the following manual.

EPSON RC+ 7.0 Option Force Control 7.0 Property & Status Reference
- Move

The force control function starts at the same time as the operation command and stops when the travel time calculated at the time when the operation command started has elapsed. The execution of the force control function can be continued after the operation command ends by adding a CF modification parameter. However, if another force control function does not execute an effective operation command or a command to stop the force control function within 60 seconds, an error occurs.

Use an FCKeep statement, for example, in standby mode for a certain period of time with the force control function enabled after an operation command is executed.

The operation end conditions of the force control function (for example, the force control function works until a specified force is reached) can be set in combination with the Till modification parameter or force trigger function.

Furthermore, since errors are accumulated due to a drift of the Force Sensor, the force control function must be executed within 10 minutes after resetting the Force Sensor.

The Force Sensor should be reset immediately before using the force control function with no external force applied to it, and should be executed in as short a period of time as possible.

The force control function cannot be executed near the singular point of the robot. Execute the force control function avoiding the vicinity of the singular point. If the robot approaches the vicinity of the singular point during executing of the force control function, an error occurs.

4.3 SPEL+ Programming of the Force Trigger Function

4.3.1 Overview

A force trigger function is a function to detect that the force or torque measured using the Force Sensor reached the set value.

The process can be started, ended, and branched using the results.

Programming of the force trigger function is performed with the following procedure.

1. Set the coordinate system to be executed
2. Set the parameters
3. Execute the force trigger function
4. Get the results

4.3.2 Coordinate System of the Force Trigger Function

The force trigger function works in the force coordinate system.

The force trigger function calculates the force detected by the Force Sensor, the force applied to the force coordinate system by the torque, and the torque itself, and monitors whether the values met the set conditions.

Specify the origin of the force coordinate system in a point where contact actually occurs and a force is generated. (Example: Tip point of a workpiece)

Furthermore, the orientation of the force coordinate system varies depending on the application. When monitoring the force in a constant direction, regardless of the posture of the robot, specify the base coordinate system and local coordinate system.

When monitoring the force in a direction that changes according to the posture of the robot, specify the tool coordinate system and custom coordinate system.

The force trigger function can monitor the following total of 8-dimensional data specified in the force coordinate system.

Six axes Fx to Tz

Fmag: Composite translation force

Tmag: Composite torque

4.3.3 Parameters of the Force Trigger Function

Parameters of the force trigger function are set in the properties of the force trigger object.

They can be set in the GUI before executing a program. For details on the settings in the GUI, refer to the following section.

Software: 3.5.1 [Robot Manager] (Tools Menu)
[Tools]-[Robot Manager]-[Force] Panel

If you want to dynamically change the parameters during executing a program, they can be set using an FSet statement.

ForceSensor Property

Specify the Force Sensor number to execute the force trigger function.

CoordinateSystem Property

Specify the force coordinate object for which the force trigger function is executed.

Operator Property

Specify the criterion for meeting the condition of the force trigger function; specifically whether all conditions for each axis are met or whether the conditions of a particular axis are met.

TriggerMode Property

Specify whether to monitor the force and torque, or to monitor the changes in the force and torque.

If a change value is specified, the change value per second is monitored. Since the Force Sensor is susceptible to noise, use a low-pass filter.

Fmag_Axes Property

Specify the axis from the axes (Fx to Fz) to be combined to calculate the Fmag value.

To monitor the force applied to the X-Y plane, specify the direction to be monitored; for example, specify the X and Y axes.

Tmag_Axes Property

Specify the axis from the axes (Tx to Tz) to be combined to calculate the Fmag value.

Enabled Property

Specify the axis (Fx to Tmag) on which the force trigger function is executed.

The force trigger function can be enabled only for the axes necessary for an application.

Polarity Property

Specify the criterion for meeting the condition, whether the force or torque for each axis falls inside or outside the upper/lower threshold ranges.

To detect that a force outside the threshold range is applied, specify outside.

To detect that a force inside the threshold range is applied, specify inside.

UpperLevel Property

Set the upper level of the force trigger function.

This function monitors whether the value is below or rises above the set value.

LowerLevel Property

Set the lower level of the force trigger function.

This function monitors whether the value is above or falls below the set value.

LPF_Enabled Property

Specify the axis (Fx to Tmag) on which the low-pass filter is executed in the force trigger function.

Use this property to reduce the noise or when ignoring Force Sensor values such as impulse.

LPF_TimeConstant Property

Specify the time constant of the low-pass filter to be executed in the force trigger function.

Increasing the value reduces the noise, but also reduces the response to the Force Sensor values.

4.3.4 Executing the Force Trigger Function

The force trigger function can be specified by Till, Wait, Trap, and Find.

For the basic functions of the commands, refer to the following manual.

EPSON RC+ 7.0 SPEL+ Language Reference

The following describes the force trigger function. Up to 15 force triggers for monitoring can be set for each robot simultaneously. When the maximum number is exceeded, an error occurs.

Till

Specifying the force trigger object in the event expression of the Till statement sets the end condition for the operation of the force trigger function. Thus, when the force reaches the specified value, the operation ends.

Use example:

```
Till FT1
Move P1 FC1 Till
```

The force trigger is set to the Till condition by the Till statement. When the condition set in force trigger object FT1 is met during Move operation, the Move operation stops even if part way through the operation and the next statement is executed.

Trap

Specifying the force trigger object in the event expression of the Trap statement sets the condition for the force trigger function to start the interrupt processing. Thus, the force is always monitored, and when the force reaches the specified value, the interruption starts.

Use example:

```
Trap 1, FT1 Goto TrapLabel
```

The force trigger function is executed by the Trap statement to start monitoring of the condition. When the condition set in force trigger object FT1 is met, the transition to the specified label occurs.

Wait

Specifying the force trigger object in the event expression of the Wait statement sets the condition for the force trigger function to end the standby state. Thus, the force trigger function stands by until the force reaches the specified value.

Use example:

```
Wait FT1
```

The force trigger function is executed by the Wait statement to start monitoring of the condition. The program is stopped until the condition set in force trigger object FT1 is met, and the program is restarted when the condition is met.

Find

Specifying the force trigger object in the event expression of the Find statement sets the condition to save the coordinates while the force trigger function is in operation. Thus, the position at which the specified force is reached is recorded.

Use example:

```
Find FT1
P0=FindPos
```

The force trigger function is executed by the Find statement to start monitoring of the condition. The controller memorizes the position at which the condition set in force trigger object FT1 is met and gets that position with the FindPos function.

The force trigger function can get the position at which the condition is met using the TriggerdPos status. Therefore, Find is useful when specifying an event expression combining multiple conditions. The TriggerdPos status can be used to get the position at which the condition set in the force trigger object is met. The FindPos function can be used to get the position at which an event expression combining multiple conditions is met.

4.3.5 Getting the Results of the Force Trigger Function

Specifying the status of the force trigger object using the FGet statement after executing the force trigger function can get the results. The acquired results can be used to determine the pass or fail of the operation, or perform conditional branching.

The status is initialized when the force trigger function is executed, and the result is set when the force trigger function ends. The set result is retained until either the force trigger function is executed again or a project is loaded.

Triggerd Status

Returns the status of achievement of the force trigger condition.

Returns "True" if the condition is achieved in the previous force trigger condition. This result can be used to determine whether the force exceeded the specified value, and branch the process.

TriggerdAxes Status

Returns the status of achievement of the force trigger condition for each axis.

It can determine more detailed conditions; for example, determine the axis on which the force exceeded the specified value, and branch the process.

TriggerdPos Status

Returns the coordinates at which the force trigger condition was achieved.

It can determine whether the position at which the condition was achieved is within the specified range, and branch the process according to the position.

4.4 SPEL+ Programming of the Force Monitor Function

4.4.1 Overview

A force monitor function is a function to measure the force or torque using the Force Sensor.

The results can be used to adjust the parameters when an application is created, or record and manage the forces applied to each workpiece during the operation.

Programming of the force monitor function is performed with the following procedure.

1. Set the coordinate system to be executed
2. Set the parameters
3. Execute the force monitor function and take measurements

4.4.2 Coordinate System of the Force Monitor Function

The force monitor function works in the force coordinate system.

The force monitor function calculates the force detected by the Force Sensor, the force applied to the force coordinate system by the torque, and the torque itself, gets the values, and calculates the average and peak values.

Specify the origin of the force coordinate system in a point where contact actually occurs and a force is generated. (Example: Workpiece edge point, etc.)

Furthermore, the orientation of the force coordinate system varies depending on the application. When measuring the force in a constant direction, regardless of the posture of the robot, specify the base coordinate system and local coordinate system. When measuring the force in a direction that changes according to the posture of the robot, for example, in the forward direction of a workpiece held by the robot, specify the tool coordinate system and custom coordinate system.

The force monitor function can measure the following total of 8-dimensional data specified in the force coordinate system.

Six axes Fx to Tz

Fmag: Composite translation force

Tmag: Composite torque

4.4.3 Parameters of the Force Monitor Function

Parameters of the force monitor function are set in the properties of the force monitor object. They can be set in the GUI before executing a program. For details on the settings in the GUI, refer to the following section.

Software: 3.5.1 [Robot Manager] (Tools Menu)
[Tools]-[Robot Manager]-[Force] Panel

If you want to dynamically change the parameters during executing a program, they can be set using an FSet statement.

ForceSensor Property

Specify the Force Sensor number to execute the force monitor function.

CoordinateSystem Property

Specify the force coordinate object for which the force monitor function is executed.

Fmag_Axes Property

Specify the axis from Fx to Fz to be combined to calculate the Fmag value.

To measure the force applied horizontally to the X-Y plane, specify the direction to be measured; for example, specify the X and Y axes.

Tmag_Axes Property

Specify the axis from Tx to Tz to be combined to calculate the Fmag value.

LPF_Enabled Property

Specify the axis (Fx to Tmag) on which the low-pass filter is executed in the force monitor function.

Use this property to reduce the noise or when ignoring Force Sensor values such as impulse.

LPF_TimeConstant Property

Specify the time constant of the low-pass filter to be executed in the force monitor function.

Increasing the value reduces the noise, but also reduces the response to the Force Sensor values.

4.4.4 Executing the Force Monitor Function

The following operations can be performed with the force monitor function.

- Getting the Force Sensor values
- Recording the Force Sensor values
- Getting the average value
- Getting the peak value

Getting the Force Sensor Values

Execute the Force property of the force monitor object to get the Force Sensor values.

Use example:

```
FGet FM1.Forces, rVar()
```

Get the 8-dimensional Force Sensor values for Fx to Tmag in real array variable rVar. The Force Sensor values to be acquired are the latest values.

Getting the Average Value

Execute the AvgForceClear property of the force monitor object to start calculating the Force Sensor average value.

After the start, the average value can be acquired using the AvgForce status.

Use example:

```
FSet FM1.AvgForceClear, True, True, True, True, True,
True, True, True
FGet FM1.AvgForces, rVar()
```

Get the 8-dimensional Force Sensor average value for Fz to Tmag in real array variable rVar.

Before executing the AvgForce status, be sure to start calculating the average value using the AvgForceClear property. If the calculation is not started, “0” is acquired.

Executing the AvgForce status stops the calculation of the average value. To get the average value consecutively, every time the average value is acquired, start calculating the average value again and then get the average value.

Executing the AvgForce status more than one minute after starting calculating the average value causes an error to occur. Either execute the AvgForce status within one minute or start calculating the average value again.

Getting the Peak Value

Execute the PeakForceClear property of the force monitor object to start calculating the Force Sensor peak value.

After the start, the peak value can be acquired using the PeakForce status.

Use example:

```
FSet FM1.PeakForceClear, True, True, True, True, True, True,
 True, True
FGet FM1.PeakForces, rVar()
```

Get the 8-dimensional Force Sensor peak value for Fx to Tmag in real array variable rVar.

Before executing the PeakForce status, be sure to start calculating the peak value using the PeakForceClear property. If the calculation is not started, "0" is acquired.

Executing the PeakForce status stops the calculation of the peak value. To get the peak value consecutively, every time the peak value is acquired, start calculating the peak value again and then get the peak value.

Recording the Force Sensor Values

Execute the LogStart property of the force monitor object to record the Force Sensor values in a file.

This enables information on each operation to be stored in a file.

Use example:

```
WOpen "test.txt" As #30
FSet FM1.LogStart, 30, 0.1, #30
```

Open a file in file number 30 using the WOpen statement and execute the LogStart property to start recoding Force Sensor values, etc. in the file with file number 30 at 30-second or 0.1-second intervals. After starting recording, the program goes to the next statement.

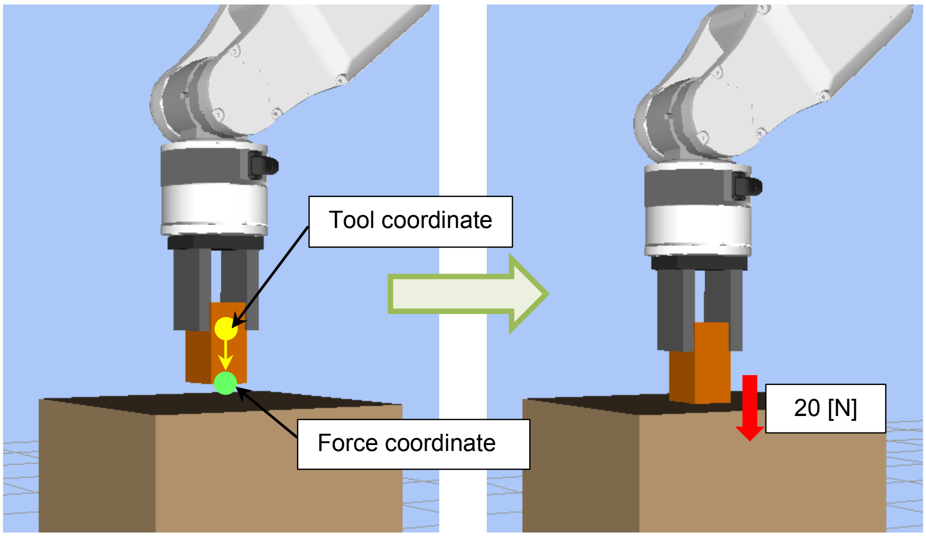
4.5 Example of a Force Function Program

The following describes an example of a simple operation in combination with the force functions.

CAUTION	■ The parameters described in the example are reference values. Please note that relatively stable parameters are used, but the operation may not be successful or the motion may be vibratory in some operating conditions, and the parameters may need to be adjusted. In addition, slow stable parameters are used for convenience of explanation. The parameters need to be adjusted for faster operations.

Pressing Operation

The following describes an example of a program to perform a pressing operation in a constant direction with a target force.



The example operation is to move a workpiece to the position 10 [mm] above the contact position and use the force control function to press the workpiece held by the hand against the worktable with a force of 20 [N].

At the same time, the force trigger function is used to monitor excessive force (100 [N] or more) during the operation, and detecting excessive force causes an error to occur.

Furthermore, the force monitor function is used to measure the Force Sensor values after the operation is completed and also measure the maximum force applied during the operation.

The tool coordinate system is set in the hand tip, and the forward direction of the hand is the Tlz axis direction.

Sample Program

```
Function PressSample_Main
  Real rVar(8)
  Motor On
  Go P0                                 'Go to the operation start position
  PressSample_PropertySetting           'Set the property
  FSet FS1.Reset                        'Reset the Force Sensor
  Trap 1, FT1 Call PressSample_EHandle  'Start monitoring excessive force
  FSet FM1.PeakForceClear, True, True, True, False, False, False, True, False
                                        'Start calculating the peak value
  FCKeep FC1, 10                        'Execute the force control function for 10 seconds
  Print "Motion End"
  FGet FM1.Forces, rVar()               'Get the Force Sensor value
  Print "Force Fz:", rVar(FG_FZ), ", Fmag:", rVar(FG_FMAG)
  FGet FM1.PeakForces, rVar()           'Get the peak value
  Print "PeakForce Fz:", rVar(FG_FZ), ", Fmag:", rVar(FG_FMAG)
Fend

Function PressSample_PropertySetting
  FSet FCS1.Position, 0, 0, 30          'The origin of the force coordinate system is Z30 mm
  FSet FCS1.Orientation, FG_TOOL        'The orientation is aligned with the tool coordinate system
  FSet FC1.CoordinateSystem, FCS1       'Specify the defined force coordinate No. 1
  FSet FC1.Enabled, False, False, True, False, False, False
                                        'Enable the force control function only for the Fz direction.
  FSet FC1.Fz_TargetForce, -20          'Pressing of –20
  FSet FC1.Fz_Spring, 0                 'The spring value is 0
  FSet FC1.Fz_Damper, 10                'The damper value is 10
  FSet FC1.Fz_Mass, 10                  'The mass value is 10

  FSet FT1.ForceSensor, 1               'Specify the Force Sensor No. 1
  FSet FT1.CoordinateSystem, FCS1       'Specify the defined Force coordinate No. 1
  FSet FT1.TriggerMode, FG_FORCE        'Monitor the force
  FSet FT1.Fmag_Axes, FG_XYZ
  FSet FT1.Enabled, False, False, False, False, False, False, True, False
                                        'Enable only Fmag
  FSet FT1.Fmag_Polarity, FG_OUT        'Trigger detects when the value falls outside the threshold range
  FSet FT1.Fmag_Levels, 0, 100          'The range of Fmag is 0 to 100

  FSet FM1.ForceSensor, 1               'Specify the Force Sensor No. 1
  FSet FM1.CoordinateSystem, FCS1       'Specify the defined Force coordinate No. 1

Fend
```

```
Function PressSample_EHandle
    Real rVar(8)
    FGet FM1.PeakForces, rVar()            'Get the peak value
    Print "Error Handle"
    Print "PeakForce Fz:", rVar(FG_FZ), ", Fmag:", rVar(FG_FMAG)
    AbortMotion All                        'Abort the robot motion and put it into an
                                           'error state
Fend
```

Description

(1) Executing the PressSample_Main function moves the robot to the operation start position.

(2) Call PressSample_PropertySetting and execute the settings of the properties.
However, the settings of the properties can also be configured beforehand in Force Editor in the GUI. To do so, you need to call PressSample_PropertySetting.

- (a) Set the force coordinate object.
  For the force coordinate system, specify the Z30 [mm] position in the example to specify the workpiece edge position in the tool coordinate system. The orientation is the same as the orientation of the tool coordinate system.
- (b) Set the force control object.
  Specify FCS1 set as the coordinate system in which the force control function is executed. Specify a negative value for the target force, as the pressing operation is performed in the positive FZ direction. Set the spring, damper, and mass values.
  "0" is set in Spring in this example, so the robot does not have a virtual spring and continues to move until the target force is achieved.
  In addition, stable parameters are used for Damper and Mass. For faster operations, adjust these values by decreasing them gradually. However, decreasing the values increases the overshoot of the force.
- (c) Set the force trigger object.
  Specify the Force Sensor number to be used and the coordinate system in which the force trigger function is executed. Specify a force in the TriggerMode property to monitor excessive force. Specify X, Y, and Z, as the composite force to be monitored is calculated using all Fx to Fz. Specify 0 to 100 [N] for the Fmag range to set 100 [N] for the excessive force, and configure to monitor whether the value falls outside this range.
- (d) Set the force monitor object.
  Specify the Force Sensor number for measurement and the coordinate system.

(3) Reset the Force Sensor before using the force functions.

(4) Specify the force trigger object in Trap and execute the force trigger function.
Thus, excessive force is monitored.

(5) Calculation of the peak value of the force applied during the operation starts.

(6) Execute the force control function for 10 seconds.

(7) Get and display the current and peak values of the Force Sensor and then exit the program.
In this example, only the values are displayed. These values can be used to determine the pass or fail of the operation and branch the process.

(8) If excessive force is detected during the operation, the program is aborted and the interruption of the PressSample_EHandle function is executed.
The peak value applied during the operation is acquired and displayed, the robot motion is aborted, and an error state is entered. In this example, an error state is entered, but processes in the event of an error, such as a retry, also can be executed.

5. Tutorial

The following describes how to use Force Control 7.0 using a simple pressing operation as an example.

This tutorial mainly describes how to use Force Control 7.0 using EPSON RC+ 7.0.

Also, ensure that the following connections and settings are completed correctly.

- EPSON sensor flange is used.
- The Force Sensor is mounted to the robot.
- The Force Sensor is connected to Sensor 1 on the Force Sensor I/F unit or board.
- The Force Sensor I/F unit is connected to the controller or Force Sensor I/F board is connected to the controller properly.
- EPSON RC+ communicates with the controller successfully.
- The robot is connected to the controller.
- The robot is listed as robot 1.

For details on those connections and settings, refer to the following section and manual.

Hardware: 7. Mounting Procedure

EPSON RC+ 7.0 User's Guide: 3. System Operation, 10. Setting up the Robot

The pressing operation in this tutorial is as follows: Move the hand tip of the robot in the positive direction of Tlz in the tool 0 coordinate system, and press it against an object for about 10 seconds with 20 [N].

The object against which it is pressed is fixed to a frame and the surface against which it is pressed is a flat metal block.

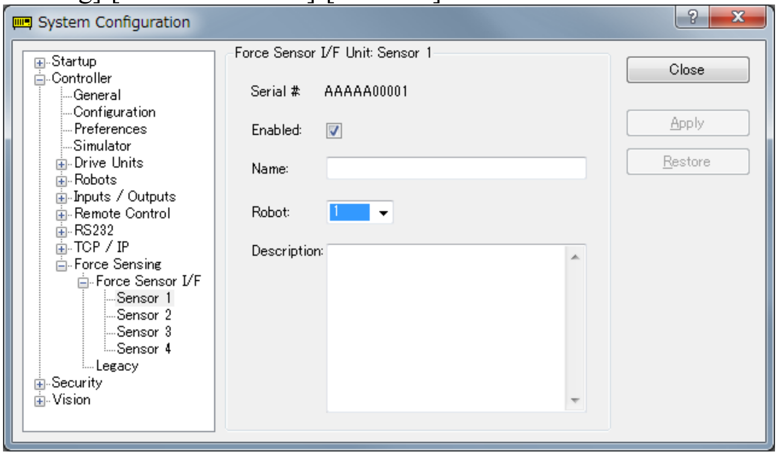
If the operation is performed with the hand mounted to the robot, ensure that the hand can withstand a load of 20 [N] in the negative direction of Tlz.

CAUTION	■ The parameters described in the example on the following pages are reference values. Please note that relatively stable parameters are used, but the operation may not be successful or the motion may be vibratory in some operating conditions, and the parameters may need to be adjusted. In addition, slow stable parameters are used for convenience of explanation. The parameters need to be adjusted for faster operations.

1. Connecting and Configuring the Force Sensor

Link the Force Sensor to the robot for which the force function is executed.

(1) From the EPSON RC+ 7.0 menu, select [System Configuration]-[Controller]-[Force Sensing]-[Force Sensor I/F]-[Sensor 1].



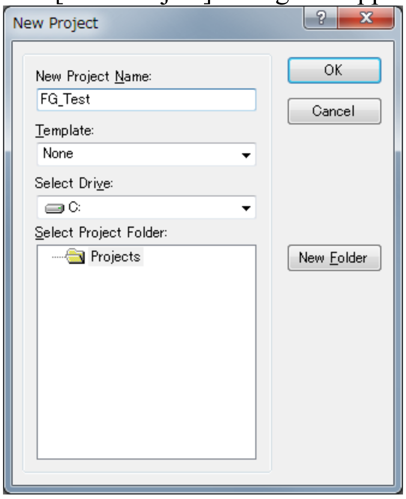
(2) Check the [Enabled] checkbox.

(3) Select “1” in [Robot].

2. Creating a New Project

Create a project for which the force function is executed.

(1) From the EPSON RC+ 7.0 menu, click [Project]-[New Project].
The [New Project] dialog box appears.



(2) Enter “FG_Test” in [New Project Name].

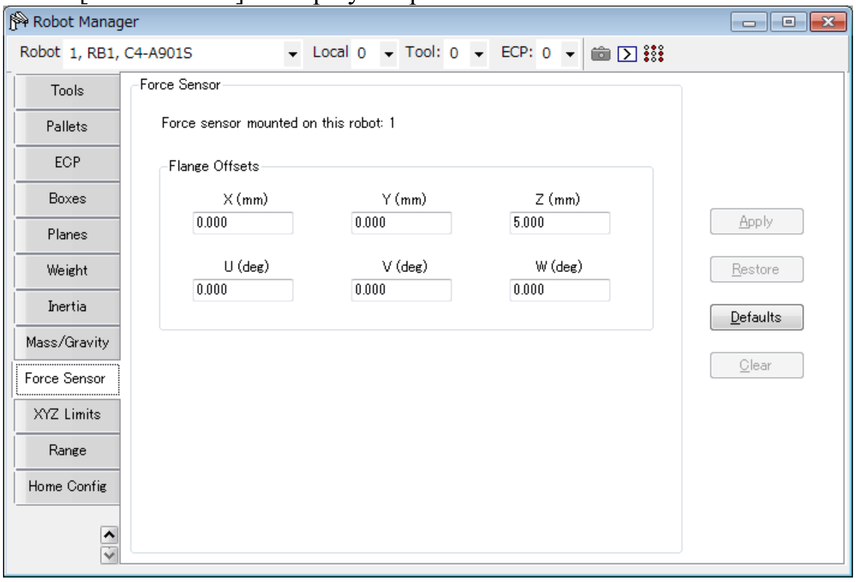
(3) Click the <OK> button.

3. Setting the Flange Offset

Set the flange offset.

(1) From the EPSON RC+ 7.0 menu, click [Tools]-[Robot Manager].
The [Robot Manager] dialog box appears.

(2) Select [Force Sensor] to display the panel.

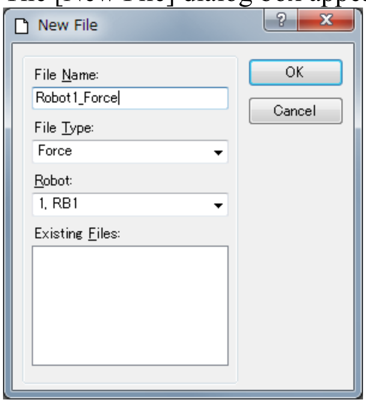


(3) When using an Epson sensor flange
Click the <Defaults> button and then click the <Apply> button.
When using a self-made sensor flange
Enter the values and then click the <Apply> button.

4. Creating a Force File

Create a force file and then add it to the project list.

(1) From the EPSON RC+ 7.0 menu, click [File]-[New File].
The [New File] dialog box appears.



(2) Select “Force” in [File Type].

(3) Check that the robot is “1”.

(4) Enter “Robot1_Force” in [File Name].

(5) Click the <OK> button.

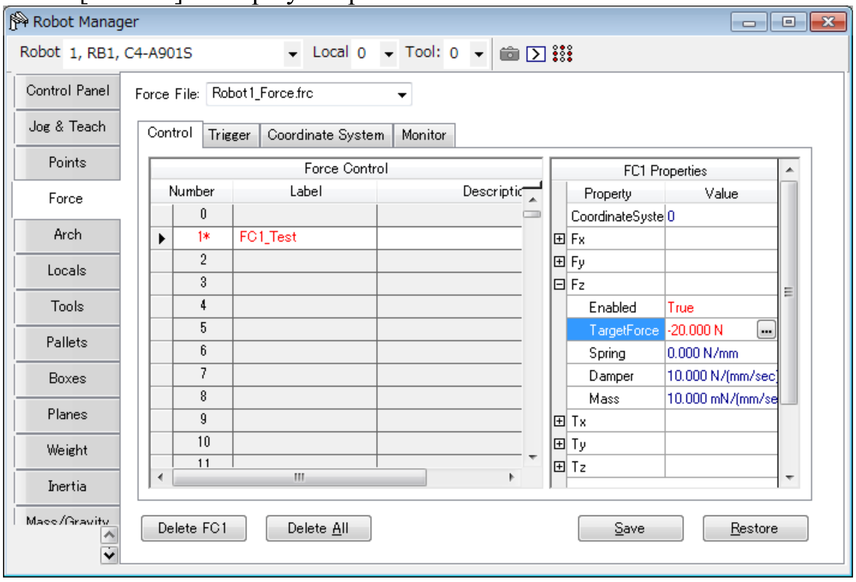
5. Setting the Force Control Object

Set the force control object.

(1) From the EPSON RC+ 7.0 menu, click [Tools]-[Robot Manager].
The [Robot Manager] dialog box appears.

(2) Select [Force] to display the panel.

(3) Select [Control] to display the panel.



(4) Set the following data for force control object “FC1”.

Item	Value
Label	FC1_Test
CoordinateSystem	0
Fx_Enabled	False
Fy_Enabled	False
Tx_Enabled	False
Ty_Enabled	False
Tz_Enabled	False
Fz_Enabled	True
Fz_TargetForce	–20
Fz_Spring	0
Fz_Damper	10
Fz_Mass	10
TargetForcePriorityMode	False
LimitSpeedS	50
LimitSpeedR	25
LimitSpeedJ	50
LimitAccelS	200
LimitAccelR	100
LimitAccelJ	100

(5) Click the <Save> button.

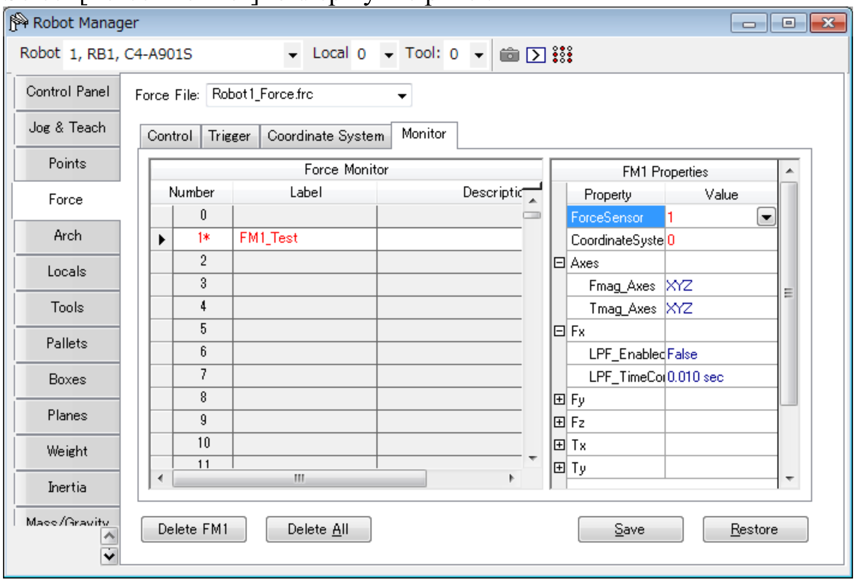
6. Setting the Force Monitor Object

Set the force monitor object.

(1) From the EPSON RC+ 7.0 menu, click [Tools]-[Robot Manager].
The [Robot Manager] dialog box appears.

(2) Select [Force] to display the panel.

(3) Select [Force Monitor] to display the panel.



(4) Set the following data for force monitor object "FM1".

Item	Value
Label	FM1_Test
ForceSensor	1
CoordinateSystem	0
Fmag_Axes	XYZ
Tmag_Axes	XYZ
Fx-Tmag_LPF_Enabled	False
Fx-Tmag_LPF_TimeConstant	0.01

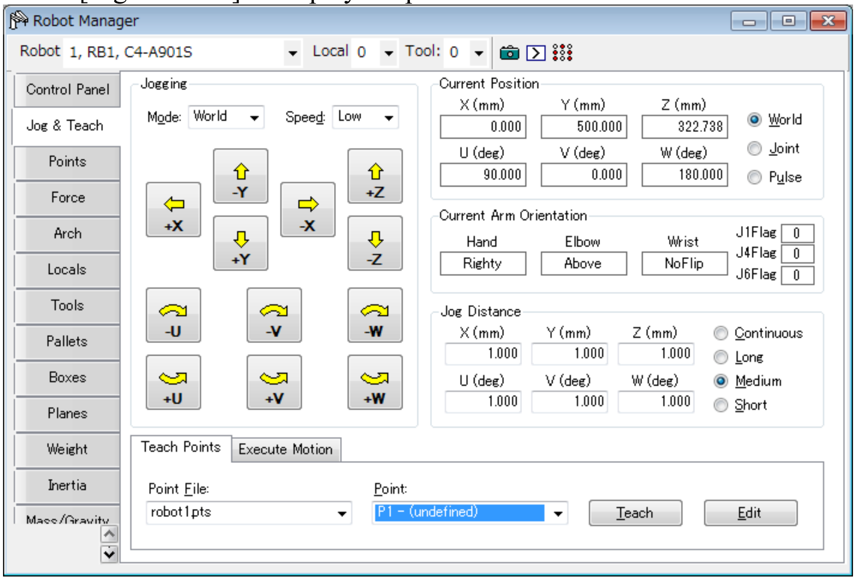
(5) Click the <Save> button.

7. Teaching the Start Position

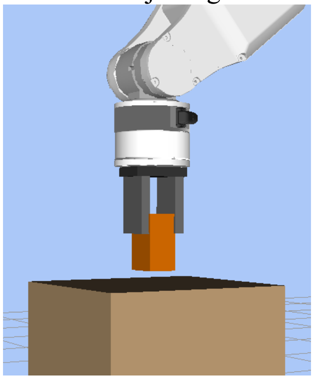
Teach the start position of the pressing operation.

(1) From the EPSON RC+ 7.0 menu, click [Tools]-[Robot Manager].
The [Robot Manager] dialog box appears.

(2) Select [Jog & Teach] to display the panel.

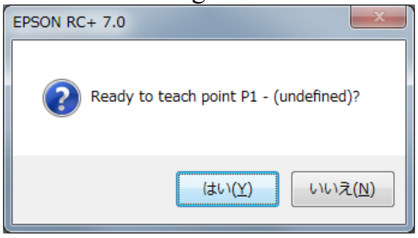


(3) Use the jog button to move the Force Sensor or hand to the position about 5 mm above the object against which the pressing operation is performed.

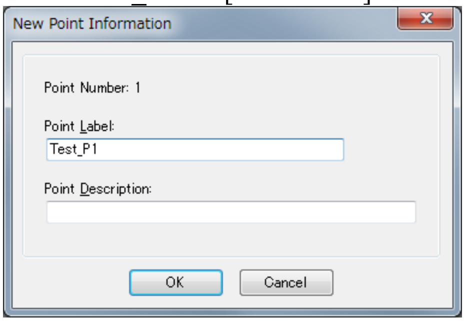


(4) Select “P1” in [Point].

(5) Click the <Teach...> button. The following message appears.
Check the message and then click the <Yes> button.



(6) The [New Point Information] dialog box appears.
Enter “Test_P1” in [Point Label] and then click the <OK> button.

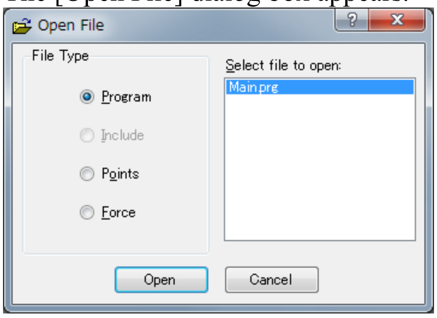


(7) From the EPSON RC+ 7.0 menu, click [File]-[Save All] to save the files.

8. Creating a SPEL+ Program

Create a SPEL+ program to perform the pressing operation.

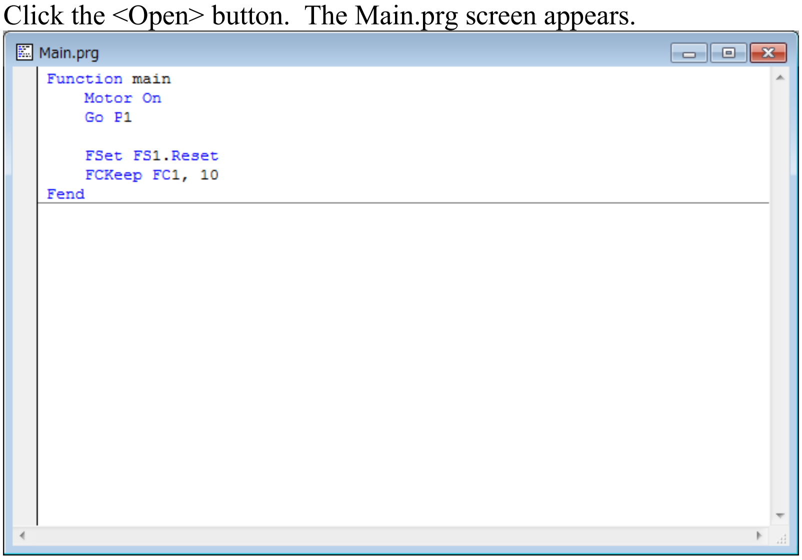
(1) From the EPSON RC+ 7.0 menu, click [File]-[Open File].
The [Open File] dialog box appears.



(2) Select “Program” in [File Type].

(3) Select “Main.prg” in [Select file to open].

(4) Click the <Open> button. The Main.prg screen appears.



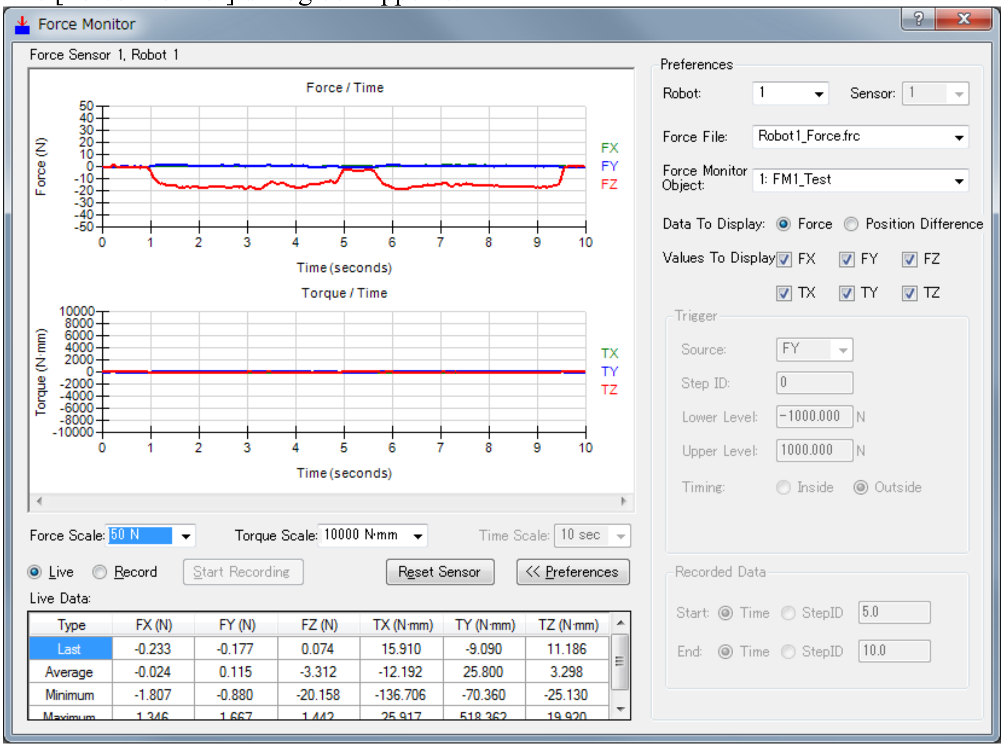
(5) Enter the following sample program in the main function.

```
Function main
    Motor On
    Go P1                  ' Go to the operation start position
    FSet FS1.Reset         ' Reset the Force Sensor
    FCKeep FC1, 10         ' Perform the pressing operation for 10
                           ' seconds
Fend
```

9. Executing the Force Monitor

Execute the force monitor to display a graph of the pressing operation.

(1) From the EPSON RC+ 7.0 menu, click [Tools]-[Force Monitor].
The [Force Monitor] dialog box appears.



(2) Click the <Preferences> button to display the preferences items.

(3) Set the following items in [Preferences].

Item	Value
Robot	1
Force File	Robot1_Force.frc
Force Monitor Object	FM1_Test
Data to Display	Force

(4) Select "50 N" in [Force Scale].

(5) Select <Live>. The Force Sensor values are displayed in the graph.

Apply a force in the pressing direction and check that the Fz value changes. If the Fz value does not change and another axis value changes, refer to the following section and check the settings of the force coordinate system.

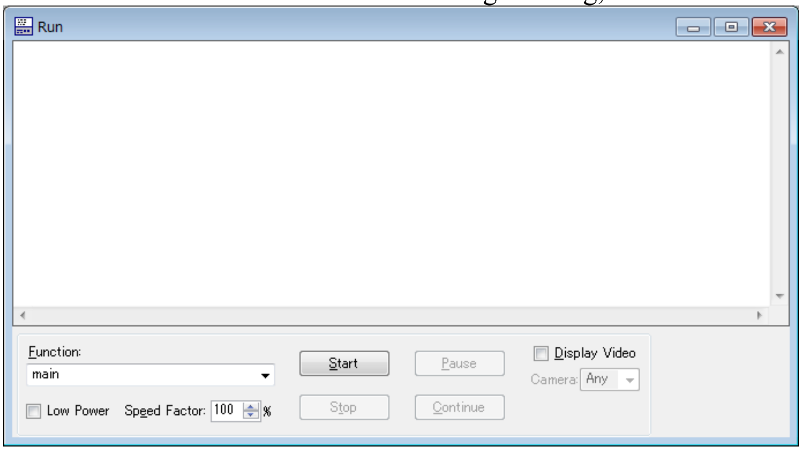
Software: 2. Force Sensor Correction

CAUTION	■ When entering the safe guarded area in order to apply a force to the Force Sensor, ensure safety by safety measures such as setting the Manipulator to operation-prohibited status. For details of safety, refer to the following manual. *EPSON RC+ 7.0 User's Guide*

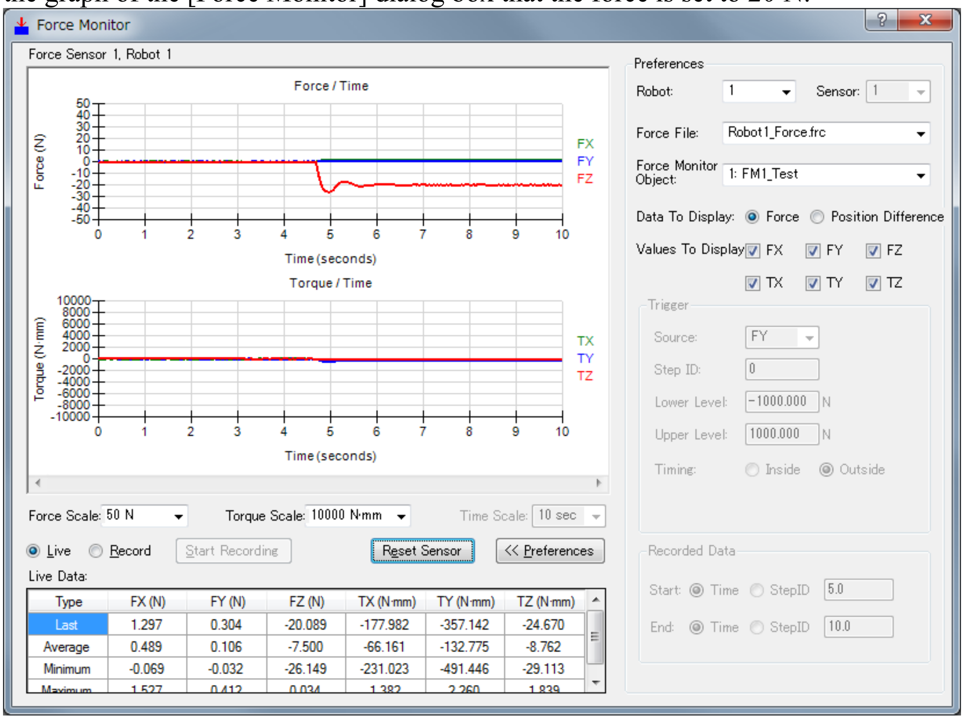
10. Creating the SPEL+ Program

Execute the SPEL+ program to perform the pressing operation.

(1) From the EPSON RC+ 7.0 menu, click [Run]-[Run Window].
The [Run] window appears.
Building of the project is executed and the program and project file are sent to the controller. If an error does not occur during building, the Run window appears.



(2) Click the <Start> button to run the program.
Running the program starts the pressing operation of the robot, and you can check in the graph of the [Force Monitor] dialog box that the force is set to 20 N.



6. Troubleshooting

The Force Sensor I/F unit is not recognized

Refer to the following section and check the wiring.

Hardware: 3. Connection Diagram

Pay particular attention to the following items.

- Connecting the IN Connector
- Connecting the 24-V Power Supply

The Force Sensor is not recognized

Refer to the following section and check the wiring.

Hardware: 3. Connection Diagram

Pay particular attention to the following items.

- Force Sensor Cable
- Force Sensor M/I Cable

Check the hardware connections and then refer to the following section and enable the Force Sensor.

Software: 1. Checking the Connection

The output value of the Force Sensor differs from the actual force direction

Refer to the following section and check the coordinate system.

Introduction, 5. Coordinate Systems

All of the following items impact the Force coordinate system.

- Settings of the Base, Local, and Tool coordinates
- Setting of FlangeOffset
- Setting of the force coordinate object (FCS#)

The output value of the Force Sensor differs from the actual force

The output of the force and torque when the Force Sensor is reset is set as "0" for the Force Sensor. Therefore, if an external force is being applied when the Force Sensor is reset, the Force Sensor detects a force even if no force is actually applied after the external force is removed. To avoid this, reset the Force Sensor when no external force is being applied. Also, weight of the Force Sensor is applied depending of the robot posture since the detection position is located at the center of the Force Sensor structure.

Furthermore, if the posture of the Force Sensor changes from that when the Force Sensor is reset, the output value of the Force Sensor also changes due to the effect of gravity. If the posture of the Force Sensor does not change in the operation using the force functions (force control, force trigger, and force monitor), reset the Force Sensor immediately before using the force functions.

If the posture changes during executing of the force functions, the effect of gravity can be reduced by using gravity compensation. For details, refer to the following section.

Software: 2.3 Gravity Compensation

The output value of the Force Sensor changes over time.

Epson Force Sensor has drift characteristics. If the change is within the range of the time drift described in the following section, it is normal.

Hardware: 4.1 Specifications

To avoid the effect of the time drift, reset the Force Sensor immediately before using the force functions. Use the force functions within 10 minutes after resetting the Force Sensor.

Abnormality occurs on the Force Sensor

If an error regarding the Force Sensor occurs, refer to the following manual and take measures against the error.

EPSON RC+ 7.0 SPEL+ Language Reference
- SPEL+ Error Messages

If the Force Sensor is used for a long time without being reset, an error accumulates due to the drift. This may result in an element error of the Force Sensor. If the error occurs, executes the Reboot property of the force sensor object.

Furthermore, accuracy abnormality of the Force Sensor may occur when the Force Sensor is hit against the peripherals or when an error occurs on the Force Sensor. In this case, check that the Force Sensor is working properly. For the details, refer to the following section.

Software 1.3 Checking the Accuracy of the Force Sensor