

DENSO ROBOT

Vertical articulated

V*-G SERIES

Horizontal articulated

H*-G SERIES

SUPPLEMENT

Extended-Joints Support (T03)

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Preface

Thank you for purchasing the DENSO high-speed, high-accuracy assembly robot.

This manual is a supplement to those manuals listed on the next page. It describes "Extended-joint support system" that enables you to control up to 2 extended joints with the robot controller.

This manual covers:

the following robot systems configured with an extended-joint support robot controller.

-
- VM-G -Tseries
 - VS-G-T series
 - HM-G-T series
 - HS-G-T series
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Important

To ensure operator safety, be sure to read the precautions and instructions in "SAFETY PRECAUTIONS."

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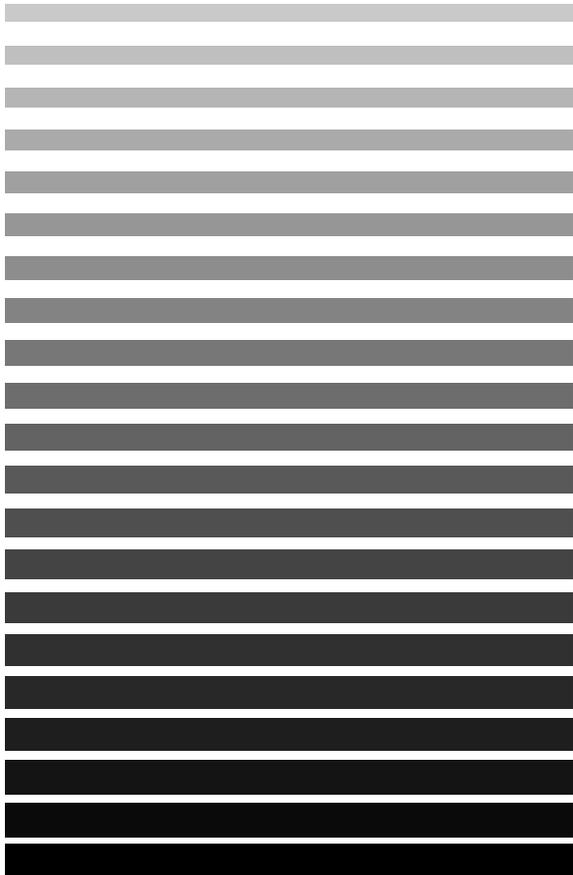
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Chapter 1



Overview



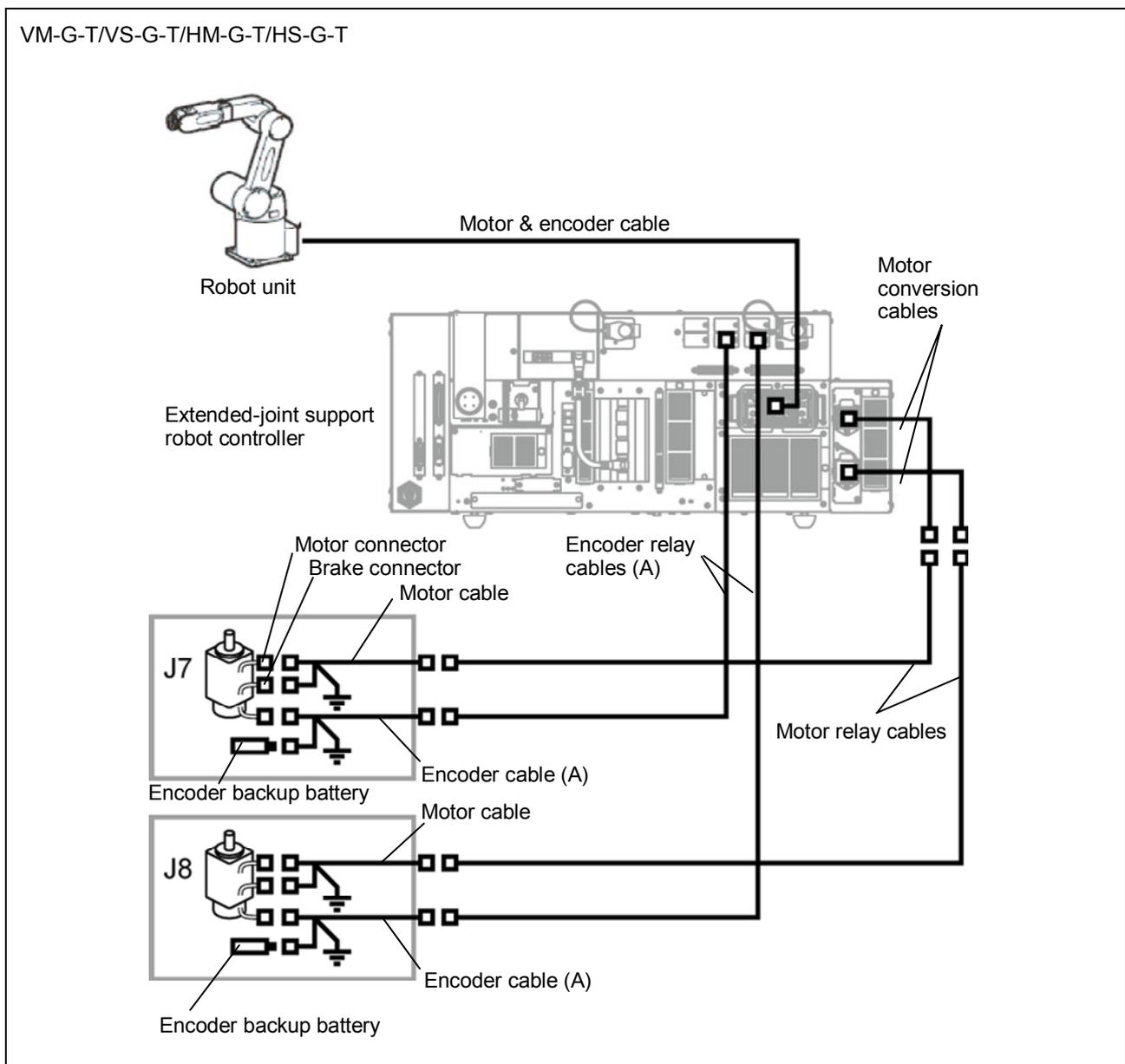
This chapter outlines the extended-joint support system.

The extended-joint support system, which can be optionally configured for the VM-G, VS-G, HM-G, HS-G, XYC-4G, and XR-G series, enables the extended-joint support robot controller to control up to two extended-joints in addition to the conventional robot joints.

1.1 Configuration of Extended-Joint Support System

The extended-joint support system is different from the conventional robot system in the following points:

- (1) Robot controller which is equipped with an IPM board (factory option) suited to extended-joint motors to be connected
- (2) The robot controller and extended-joint motors are connected using extended-joint motor cables, motor conversion cables, encoder cables, and encoder backup batteries (all of these are options).
- (3) Extended-joint motors (option) which are equipped with bus-line encoders (Up to 2 motors, motor type selectable)



1.2 Extended-Joint Related Functions

(1) Extended-joint function

The extended-joint function allows you to control extra joints independently of robot joints through the standard interface of the robot controller (NetwoRC).

(2) Configuring extended-joint parameters

To use extended-joints, you need to configure the "path configuration parameters" and "servo configuration parameters" by using the teach pendant. The former is for motion definitions (including speed, acceleration, and range of motion); the latter is for setting the gain and others of the extended-joint servo system.

(3) Gain tuning for extended-joints

After setting the motion conditions of extended-joints and checking the motion of the optional mechanism connected to the extended-joint motors, you need to do gain tuning for the servo system. There are the following two types of tuning methods:

- Auto gain tuning

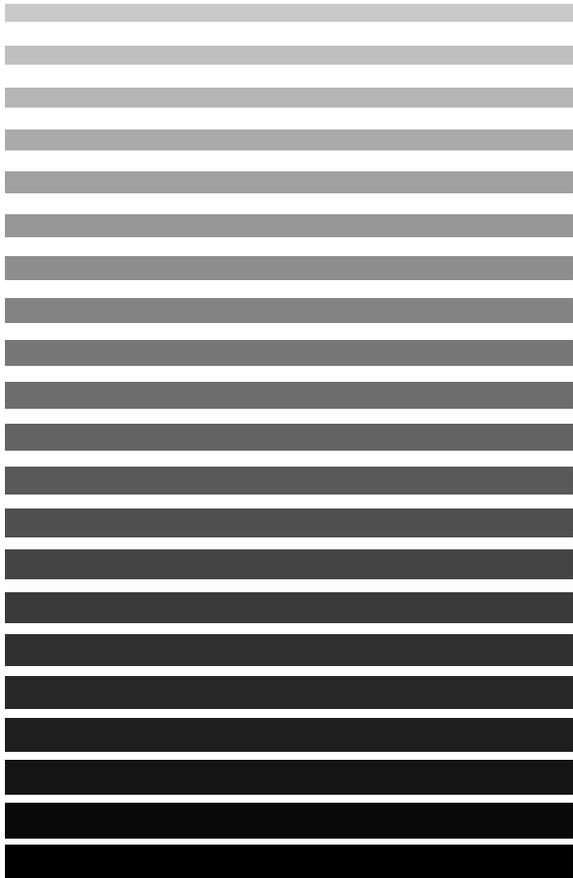
The robot controller performs acceleration/deceleration operation of the extended-joints according to the default pattern preset in the controller. Based on the motion of the extended-joints in that operation, the controller will estimate the inertia of payload and set the appropriate gain automatically. With this method, you can easily do gain tuning of the extended-joint motors.

- Manual gain tuning

The monitor function of the single-joint servo data monitors the motor speed control value, current motor speed, motor angle deviation, and torque control value. According to the monitored results, you can adjust the gain and torque control filter parameters for optimizing the motion of the extended-joints.

Chapter 2

Robot Components of Extended-Joint Support System



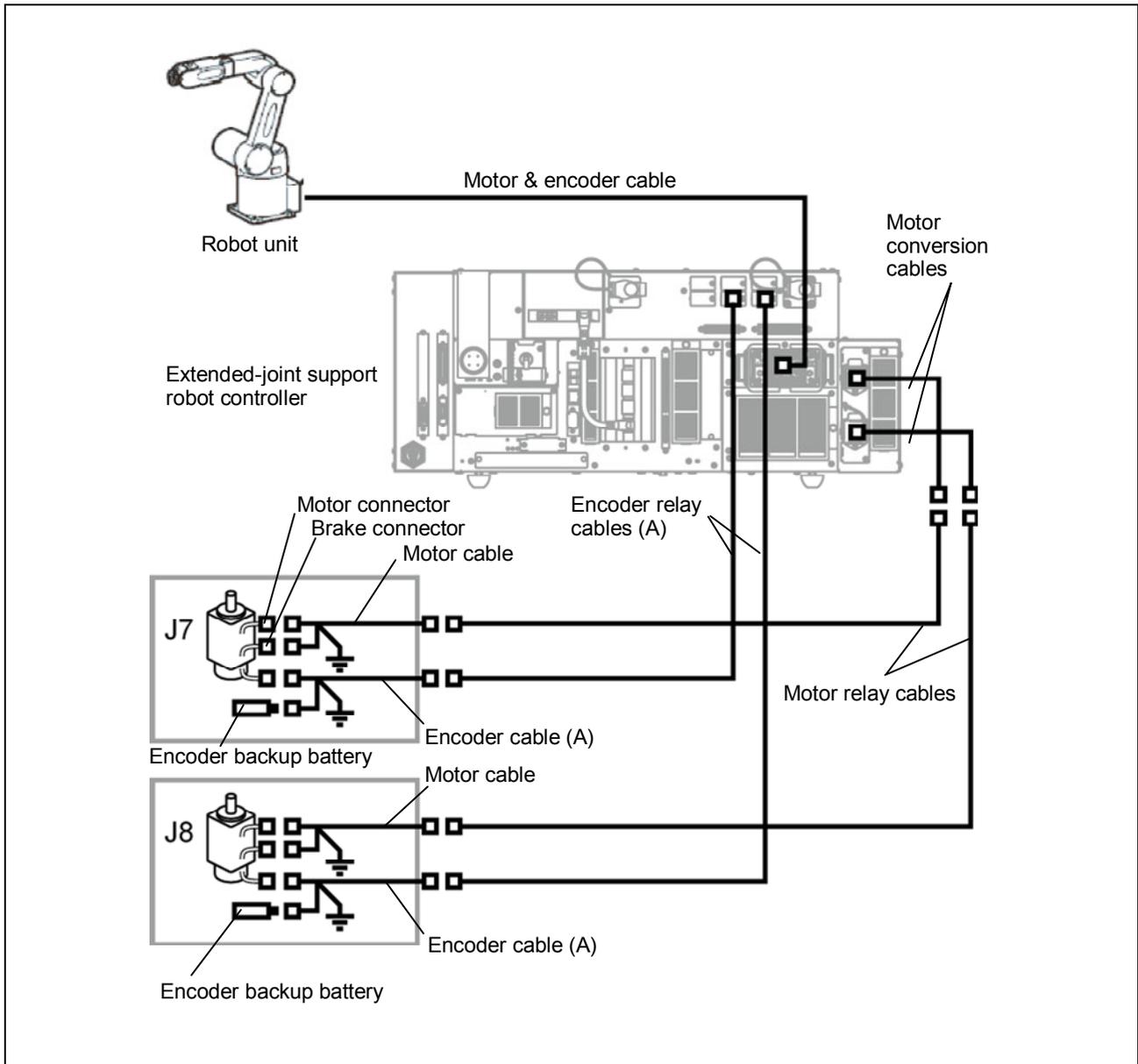
This chapter describes the components of the extended-joint support system and their specifications.

2.1 Configuration of Extended-Joint Support System

2.1.1 System Configuration

An extended-joint support system can be configured by connecting extended-joint motors to a compatible robot controller.

Up to two extended-joint motors can be connected.



2.1.2 Precautions for Safe Use of the Robot System

Note: This section provides safety precautions to be taken when you configure the robot system with extended-joint motors. For details, refer to the ISO 10218-1:2006, Safety Requirements.

[1] For extended-joint motor driven mechanism

- (1) If the mechanism involves a risk of bodily injury to workers, set up a safety fence to prevent danger.
- (2) When the extended-joint in the mechanism has the largest motion range in all joints (including robot joints), prepare mechanical stops with sufficient rigidity.
- (3) When the extended-joint in the mechanism has the 2nd or 3rd largest motion range in all joints (including robot joints), prepare joint limiters with sufficient rigidity.
- (4) If the mechanism involves a risk of bodily injury to workers when the brakes are released, use warning labels to alert workers to danger.
- (5) If it is not easy to carry the mechanism, prepare any measures for hoisting it.

[2] When connecting extended-joint motors

- (1) When connecting the extended-joint motors using the motor cables and their conversion cables, protect those cables from electrical noise.

[3] When mounting extended-joint motors

- (1) If the motor surface gets hot and the workers are at risk of touching the heated surface, attach a warning label, alerting them to the high temperature.

[4] For providing data to the end user

- (1) When the motion range of the extended-joint is 3rd largest or below in all joints (including robot joints), provide the end user with the maximum stop time and distance of that joint, using instruction manuals, etc.

2.2 Extended-Joint Support Controller

2.2.1 Customized Controller

The extended-joint support robot controller is customized for motors specified by individual customer in both hardware and software at the factory. The allowable combination of the controller's axes and motor types is printed in (3) OTHER MODIFICATIONS on the "THE SETPRM LIST" labeled on the top of the controller.

According to the allowable combination, connect motors to the controller correctly. Incorrect connection will result in a motor malfunction, motor overheat, controller overheat, and other problems.

Note: When shipped, the controller has a built-in IPM board suited to AC servomotors to be connected to 7th and 8th axes.

Motor capacity	50 W	100 W	200 W	400 W	750 W
IPM board model	SS	SS	S	S	M

Controller Configuration Table (SETPRM LIST)

Controller Configuration Table (SETPRM LIST)

Robot Controller

AXIS	IPM	MOTOR	AXIS	IPM	MOTOR
7	5	200W (A) (B)	8	SS	50W (A)

The motor specifications are coded as shown below.

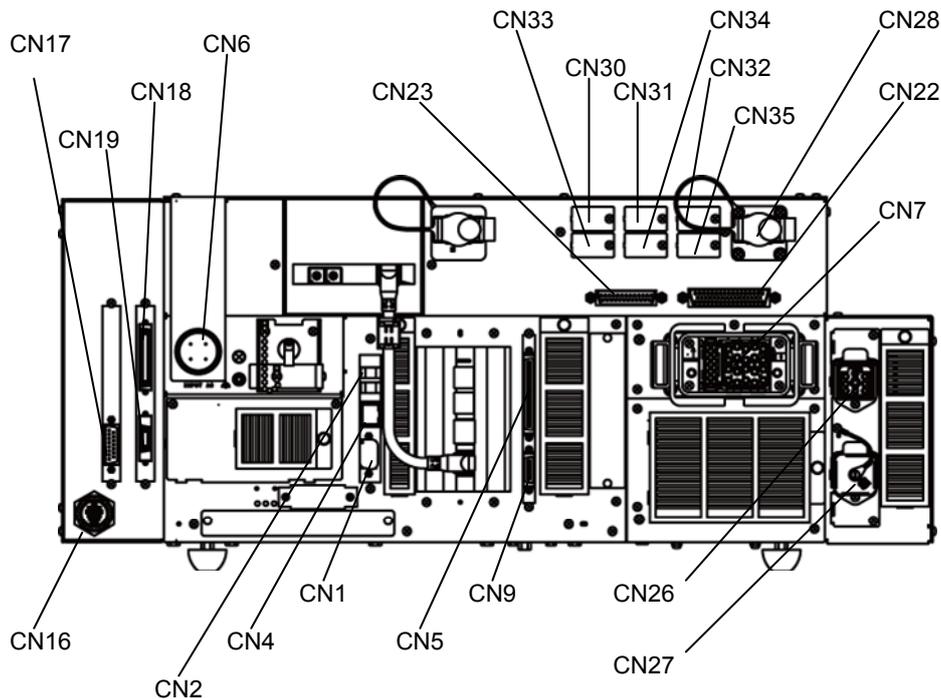
****** W * ***

- Brake: w/brake:(B), w/o brake:None
- Motor type: Standard:(A)
- Motor capacity: 750W,400W,200W,100W,50W

(Ex.) Standard type,50W with brake
50W(A)(B)

SETPRM LIST

2.2.2 Connectors on Extended-Joint Support Controller



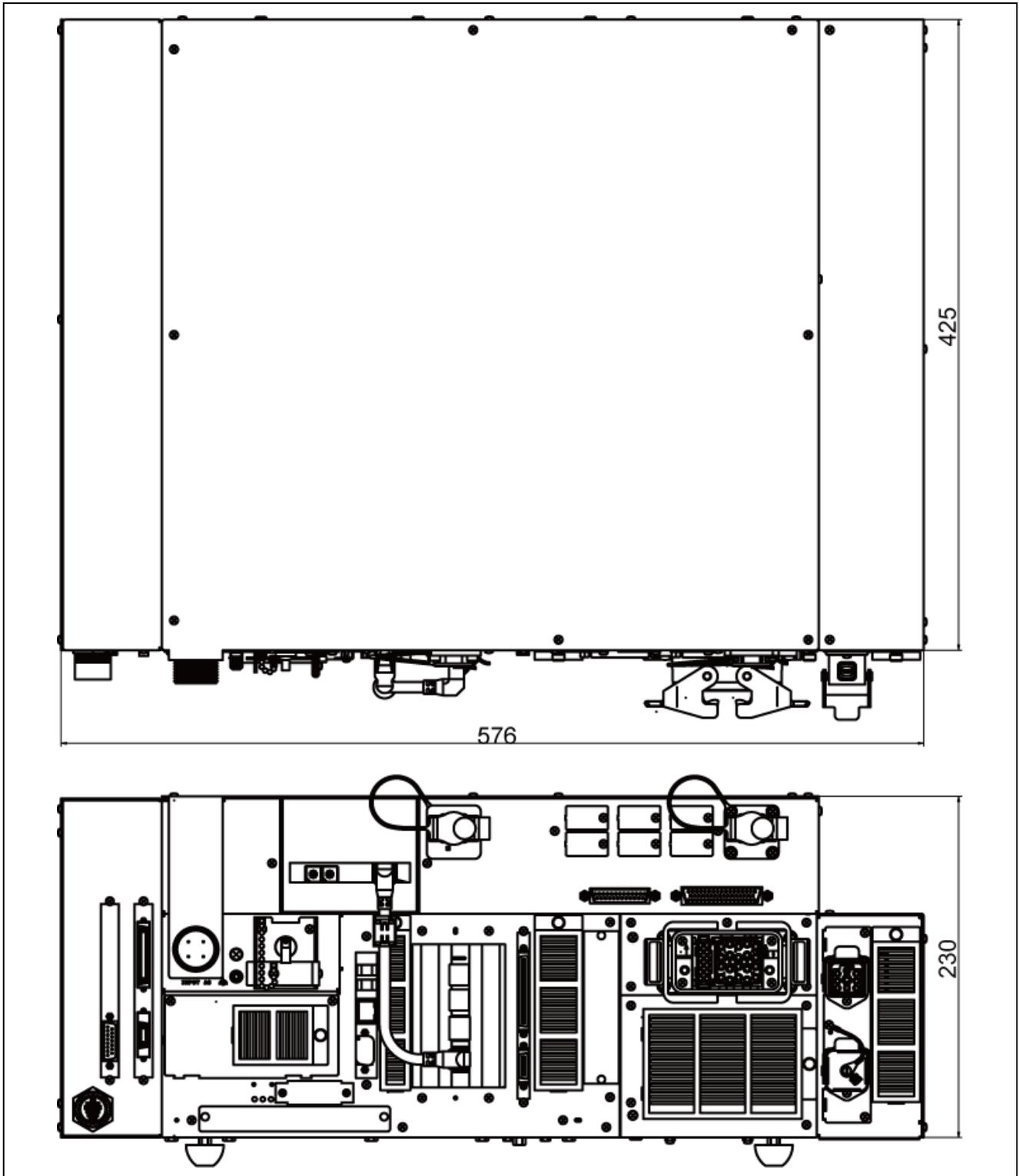
Connector No.	Interface name	Description
CN1	RS-232C	Serial interface connector
CN2	USB	USB connector (2 lines)
CN4	LAN	Ethernet connector
CN5	Mini I/O	User and system I/O connector
CN6	INPUT AC	Power supply connector
CN7	MOTOR	Motor & encoder connector
CN9	HAND I/O	HAND I/O connector
CN16	PENDANT	Teach pendant connector
CN17	S ON	Servo ON output & user power input connector
CN18	X-OP2	Operation panel connector
CN19	X-LNE1	Line controller wiring connector
CN22	X-10A3	User wiring connector for robot unit
CN23	X-RSV	User wiring connector (Reserved.)
CN26	MOTOR J7	Extended-joint J7 motor connector
CN27	MOTOR J8	Extended-joint J8 motor connector
CN28	RSC-I/F	USB interface (B type) between RSC1 unit and PC (RSCwin)
CN30	ENCODER J1	XY-X robot J1 encoder connector
CN31	ENCODER J2	XY-X robot J2 encoder connector
CN32	ENCODER J3	XY-X robot J3 encoder connector
CN33	ENCODER J4	XY-X robot J4 encoder connector
CN34	ENCODER J7	Extended-joint J7 encoder connector
CN35	ENCODER J8	Extended-joint J8 encoder connector

⚠ Caution: Be sure to turn off the power switch of the robot controller before connecting or disconnecting the connectors to/from the controller. Otherwise, the internal circuitry of the controller may be damaged.

When connecting the encoder relay cables to the controller, secure them to the facility to prevent the connectors from getting subjected to stress.

2.2.3 External Dimensions of Extended-Joint Support Controller

The figure below shows the outer dimensions of the extended-joint support controller.



External Dimensions of Extended-Joint Support Controller

2.2.4 Controller Specifications

The table below lists the specifications of the extended-joint support controller.

Item		Specifications	
Applicable controller		RC7M + Extended-joint options	
Robot series		VM-G-T, VS-G-T, HM-G-T, and HS-G-T	
Number of controllable axes		VM-G-T and VS-G-T: Up to eight axes simultaneously (6 robot axes and 2 extended-joints) HM-G-T and HS-G-T: Up to six axes simultaneously (4 robot axes and 2 extended-joints)	
Control system		PTP, CP 3-dimensional linear, 3-dimensional circular (Only PTP control for extended-joints)	
Drive system		All axes: Full-digital AC servo	
Language used		DENSO robot language for Toyota specifications (conforming to SLIM) in Japanese and English	
Memory capacity		3.25 MB (equivalent to 10,000 steps, 30,000 points)	
Teaching system		1) Remote teaching 2) Numerical input (MDI)	
External signals (I/O)	Standard I/O	Mini I/O	Input signals: 8 user open points Output signals: 8 user open points
		HAND I/O	Input signals: 8 user open points Output signals: 8 user open points
	SAFETY I/O (Only for global type)		Input signals: 6 fixed system points Output signals: 5 fixed system points
	PLC	PLC I/O	Available with FL remote I/O
		DLNK-M2	Available with extension unit
		FL-net	Built in TOYOPUC PC10P
CMP-LNK		Available with extension unit	
External communication		RS-232C: 1 line Ethernet: 1 line USB: 2 lines (supporting USB flash memory drives)	
Extension slots		1 (Two out of three extension slots have been already used.)	
Self-diagnosis function		Overrun, servo error, memory error, input error, etc.	
Timer function		0.02 to 10 sec. (in units of 1/60 sec.)	
Error display		Error codes will be outputted on the external I/O. Error messages will be displayed in English on the teach pendant.	

Chapter 2 Robot Components of Extended-Joint Support System

Item		Specifications
Cables	VM-G-T, VS-G-T, HM-G-T, HS-G-T Motor & encoder cable	2m, 4 m, 6 m, 12 m (Splash-proof type)
	I/O cable (option)	8 m, 15 m (For Mini I/O, HAND I/O, Optional board for parallel I/O and SAFETY I/O)
	Power supply cable	5 m
	Extended-joint motor cable and encoder cable (option)	Refer to "Extended-joint related cables."
Environmental conditions (in operation)		Temperature: 0 to 40°C Humidity: 90% RH or less (no condensation allowed)
Power supply (in full configuration)		Three-phase, 200 VAC-15% to 230 VAC+10%, 50/60 Hz, 3.3 kVA Single-phase, 230 VAC±10%, 50/60 Hz, 3.3 kVA
I/O power source		A 24 VDC ±10% should be supplied from external equipment.
Safety category (Controller with safety box only)		Compliant with safety category 4
Degree of protection		IP20
Weight (in full configuration)		Approx. 33 kg (72.8 lbs.)

When handling the controller, be sure to observe the following.

Controller Handling Notes

WARNING

- **NEVER touch fins. Their hot surfaces may cause severe burns.**
- **NEVER insert fingers or foreign objects into openings. Doing so may cause bodily injury.**
- **Before opening the controller cover and accessing the inside of the controller for maintenance, be sure to turn off the power switch, disconnect the power cable, and wait at least 3 minutes. This is for protecting you from electric shock.**
- **NEVER connect or disconnect connectors to/from the controller when the AC power or the 24 VDC power for I/O is being supplied. Doing so may cause electric shock or controller failure.**

CAUTION IN INSTALLATION

- This controller is not designed to be dust-proof, splash-proof, or explosion-proof.
- Read user's manuals before installation.
- Do not place anything on the controller or apply any impact to the controller.
- Avoid placing the controller in an environment where it may be subjected to excessive vibration.
- When releasing the connector locks of the extended-joint motor cables, take care not to let those locks scratch or damage the controller panel.

CAUTION

- The robot controller connectors are of a screw-lock type or ring-lock type. Lock the connectors securely. If even one of the connectors is not locked, weak contact may result thereby causing an error.
- Be sure to turn the robot controller OFF before connecting/ disconnecting the power connector or motor connector. Otherwise, the internal circuits of the robot controller may be damaged.

2.2.5 Total Output Capacity for Extended-Joint Motors

Up to two extended-joint motors can be connected to an extended-joint support robot controller. Note that there is the restriction on the total output capacity of the robot controller for extended-joint motors as listed below.

To connect extended-joint motors to the robot controller, it is necessary to use dedicated.

CAUTION

- (1) Use the extended-joint support robot controller with specified motors whose total capacity is less than the allowable limit.
If the total capacity of connected motors exceeds the limit, the robot controller will cause an error. In the worst case, the internal circuits in the robot controller may be damaged.
- (2) Even with the specified capacity of motors, the robot controller could cause a power error, overcurrent, overvoltage, overload and other errors, depending upon the use conditions of the extended-joint motors.
Those problems may be solved by adjusting acceleration, deceleration, maximum speed, and gain of each extended-joint servo loop.

(1) If supplied with 3-phase, 200V power: Max. 3 kW

Applicable robot and controller			Total output capacity for extended-joints, when both the robot unit and extended-joints operate simultaneously: (*1)	Total output capacity for extended-joints, when robot unit is on halt: (*2)	
Robot series	Motor capacity	Robot controller models		If extended-joints will be subjected to reaction force (e.g., when used as traverse accelerator): (*3)	If extended-joints will not be subjected to reaction force:
VM-G-T	3150W	RC7M-VMG6BA-FP-3AD-E	Max. 795W	Max. 1065W	Max. 2175W
VS-G-T	1580W	RC7M-VSG6BA-FP-3AD-E	Max. 1894W	Max. 2030W	Max. 2585W
HM-G-T	3100W	RC7M-HMG4BA-FP-3AD-E	Max. 830W	Max. 1110W	Max. 2600W
HS-G-T	2200W	RC7M-HSG4BA-FP-3AD-E	Max. 1460W	Max. 1646W	Max. 2740W
XY-X	(*4)	RC7M-SMT6BA-FP-3AD-E	(*4)	(*4)	(*4)

(*1) When both the robot unit and extended-joint motors operate simultaneously, the total output capacity for extended-joints can apply as listed above.

Connection example: If the output capacity for extended-joints is 800 W, the robot controller can connect up to two joints of 400 W each.

(*2) If extended-joint motors are to be driven only when the robot is on halt, these output capacities can apply.

(*3) The total output capacity for extended-joint motors is further restricted if extended-joints are used as traverse accelerators of the robot so that they receive reaction force from the robot unit.

(*4) The motor capacity of the XY-X series differs depending upon the joint configuration. The total output capacity for extended-joints also differs. For selection of motors, contact your Denso sales representative.

Note: The above table assumes the following operating conditions: Arm folded, 70% robot load, and 30% extended-joint load

(2) If supplied with single-phase, 230V power: Max. 2 kW

Applicable robot and controller			Total output capacity for extended-joints, when both the robot unit and extended-joints operate simultaneously: (*1)	Total output capacity for extended-joints, when robot unit is on halt: (*2)	
Robot series	Motor capacity	Robot controller models		If extended-joints will be subjected to reaction force (e.g., when used as traverse accelerator): (*3)	If extended-joints will not be subjected to reaction force:
VM-G-T	3150W	RC7M-VMG6BA-FP-3AD-E	—	Max. 65W	Max. 1175W
VS-G-T	1580W	RC7M-VSG6BA-FP-3AD-E	Max. 894W	Max. 1030W	Max. 1585W
HM-G-T	3100W	RC7M-HMG4BA-FP-3AD-E	—	Max. 110W	Max. 1600W
HS-G-T	2200W	RC7M-HSG4BA-FP-3AD-E	Max. 460W	Max. 646W	Max. 1740W
XY-X	(*4)	RC7M-SMT6BA-FP-3AD-E	(*4)	(*4)	(*4)

(*1) When both the robot unit and extended-joint motors operate simultaneously, the total output capacity for extended-joints can apply as listed above.
Connection example: If the output capacity for extended-joints is 800 W, the robot controller can connect up to two joints of 400 W each.

(*2) If extended-joint motors are to be driven only when the robot is on halt, these output capacities can apply.

(*3) The total output capacity for extended-joint motors is further restricted if extended-joints are used as traverse accelerators of the robot so that they receive reaction force from the robot unit.

(*4) The motor capacity of the XY-X series differs depending upon the joint configuration. The total output capacity for extended-joints also differs. For selection of motors, contact your Denso sales representative.

Note: The above table assumes the following operating conditions: Arm folded, 70% robot load, and 30% extended-joint load

2.2.6 Notes on Installing the Extended-Joint Support Robot Controller

Instructions given in this section are exclusive to the robot controller incorporating the motion monitoring option. For others, refer to the RC7M Controller Manual.

Installation type

The robot controller can only be floor mounted. Do not wall mount it.

Connecting the FL-net cables

When transporting the robot controller, disconnect the FL-net cables from the controller beforehand to prevent them from getting broken.

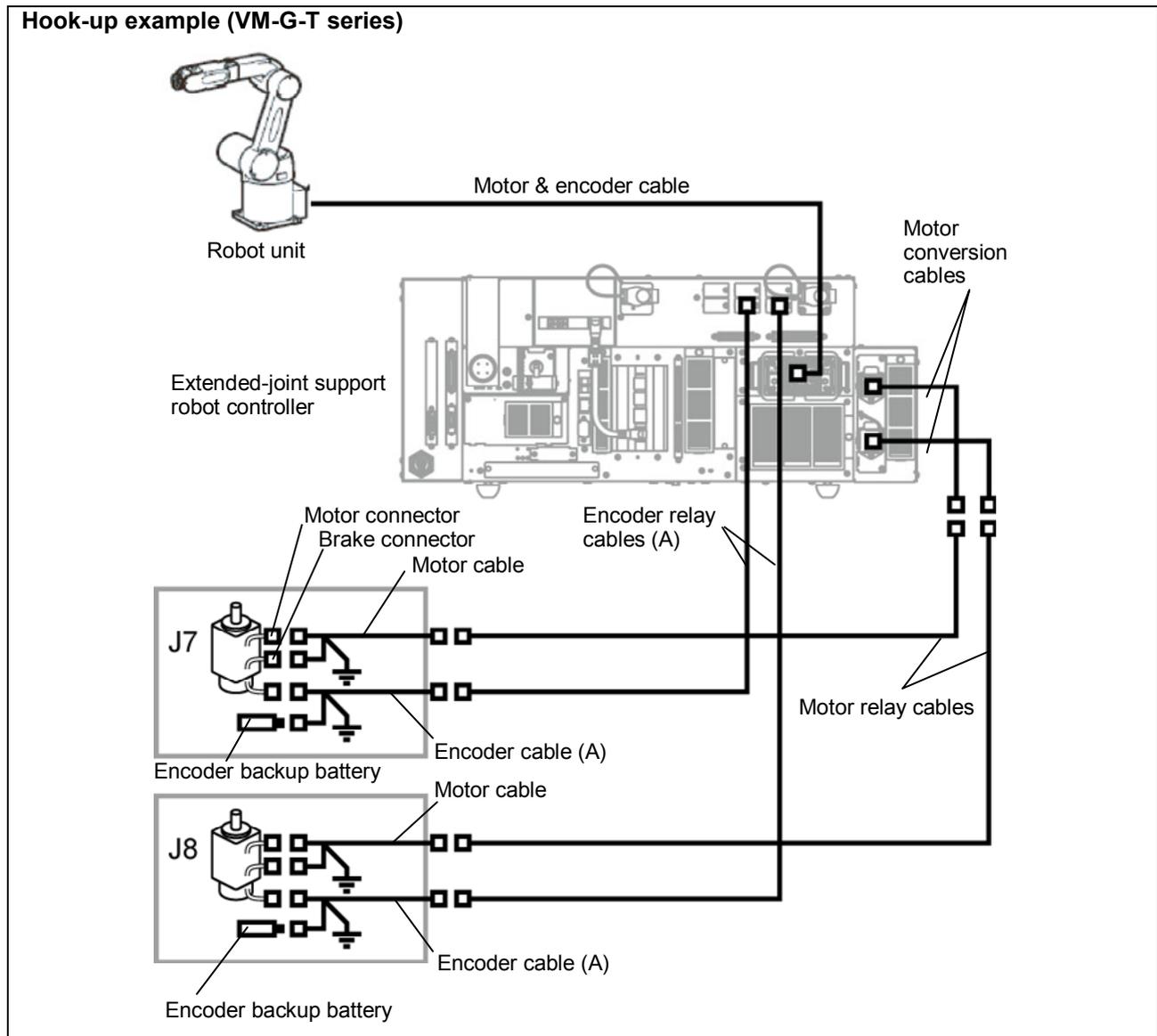
About protection box

Protection boxes having an old parts number cannot be used. Use the ones having a new parts number.

- Old parts number
410181-0090
- New parts number
410181-0091

2.2.7 Connecting Cables to the Robot Controller

A hook-up example of the extended-joint support system is illustrated below.



⚠ CAUTION

(1) Use DENSO WAVE-authorized extended-joint.

Never modify those cables or use cables other than DENSO WAVE-authorized ones to configure an extended-joint support system.

(2) Miswiring of extended-joint cables could cause malfunction the motors.

To prevent miswiring of extended-joint motors, attach the labels that come with a set of extended-joint cables to those cables.

(3) Water or dust may get into the cable connection sections depending upon the usage environment. Take any protective measures for cable connectors.

(4) The extended-joint support controller is shipped with connector caps mounted on the 8th joint motor and encoder connectors. To connect a motor to the 8th joint, remove those connector caps.

(5) Be sure to connect all of the shield wires of the motor cables and encoder cables and the FG wires of the motors to ground.

2.2.7.1 Extended-joint related cables

Select extended-joint related cables from the table below.

NOTE: The total length of the motor & encoder cable, encoder relay cables (A) and encoder cables (A) for all joints should be 48 m or less.

When a single extended-joint is connected, the total length of the encoder relay cable (A) and encoder cable (A) should be 24 m or less.

When two extended-joints are connected, the total length of the encoder relay cable (A) and encoder cable (A) per joint should be 12 m or less.

Parts Name	Length	Parts Number
Motor conversion cable		410149-0980
Motor relay cable (750 W or below)	4 m	410141-4990
	6 m	410141-5000
	8 m	410141-5010
	12 m	410141-5020
Motor cable (750 W or below)	1 m	410141-4960
	2 m	410141-4970
	3 m	410141-4980
	4 m	410414-4100
	6 m	410141-4110
	8 m	410141-4820
	12 m	410141-4120
	20 m	410141-4830
Encoder relay cable (A)	4 m	410141-4840
	6 m	410141-4850
	8 m	410141-4860
	12 m	410141-4870
Encoder cable (A)	1 m	410141-5030
	2 m	410141-5040
	3 m	410141-5050
	4 m	410141-5060
	6 m	410141-5070
	8 m	410141-5080
	12 m	410141-5090
	20 m	410141-5100
Encoder backup battery (one piece)		410611-0030

2.2.7.2 Replacement of encoder backup batteries

To replace encoder backup batteries, turn on the power of the controller and set the motor to OFF state.

 **Caution:** The information of the encoder will be lost if you replace an encoder backup battery with the controller power OFF.

2.2.8 Teach Pendant for Extended-Joint Support Controllers

Use a teach pendant matching the controller specifications.

The teach pendant software version 1.1.0 or later supports the extended-joint function.

2.3 Choosing AC Servomotors

Select motors to be used for extended-joints from the table below.

Rated Output	Motor Model	Parts Number
50 W (without brake)	R2AA04005FXPAV	410627-0700
50 W (with brake)	R2AA04005FCPAV	410627-0750
100 W (without brake)	R2AA04010FXPAK	410627-0710
100 W (with brake)	R2AA04010FCPAK	410627-0760
200 W (without brake)	R2AA06020FXPAL	410627-0720
200 W (with brake)	R2AA06020FCPAL	410627-0770
400 W (without brake)	R2AA06040FXPAL	410627-0730
400 W (with brake)	R2AA06040FCPAL	410627-0780
750 W (without brake)	R2AA08075FXPAL	410627-0740
750 W (with brake)	R2AA08075FCPAL	410627-0790

2.3.1 AC Servomotor Characteristics

The characteristics of each motor model are as shown below.

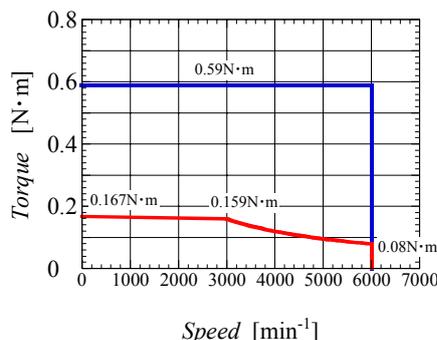
For external dimensions of motors, refer to Section 5.1 "External Dimensions of Extended-Joint Motors."

Motor Model	R2AA04005F	R2AA04010F	R2AA06020F	R2AA06040F	R2AA08075F
Rated output (W)	50	100	200	400	750
Rated rotation speed (r/min)	3000	3000	3000	3000	3000
Maximum rotation speed (r/min)	6000	6000	6000	6000	6000
Rated torque (Nm)	0.159	0.318	0.637	1.27	2.39
Maximum momentary torque (Nm)	0.59	1.18	2.2	4.8	8.5
Rotor inertia (10^{-4} kgm ²)	0.0409	0.066	0.2223	0.4153	1.8233
Allowable load inertia	10 times or below of rotor inertia				
Torque constant (Nm/Arms) *	0.246	0.424	0.476	0.524	0.559
Mass (without brake) (kg)	0.27	0.39	0.84	1.3	2.6
Mass (with brake) (kg)	0.5	0.62	1.07	1.65	3.45
Brake holding torque (Nm)	0.32 or above	0.32 or above	1.37 or above	1.37 or above	2.55 or above

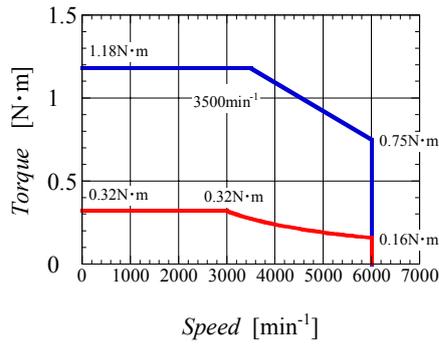
*The torque constant is expressed in amperes (root mean square, rms).

2.3.2 Torque-Rotation Speed Characteristics

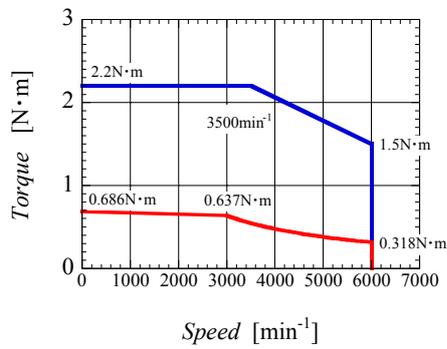
R2AA04005F



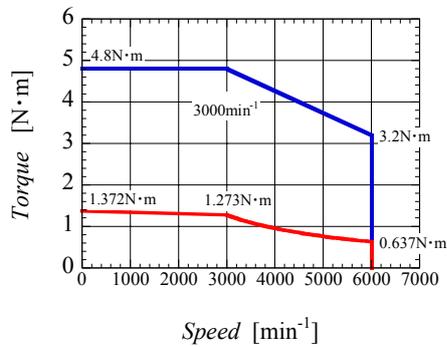
R2AA04010F



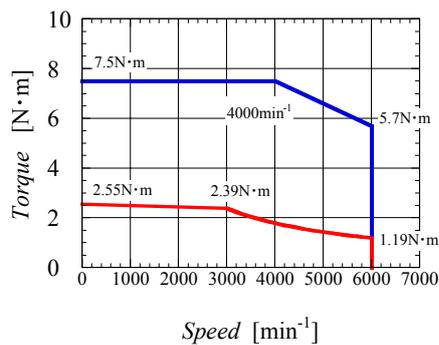
R2AA06020F



R2AA06040F



R2AA08075F



2.3.3 Safety Rules for Using Extended-Joint Motors

Note: This section gives important points only for handling extended-joint motors. For the general precautions for handling robots, refer to manuals prepared for individual robot series.

[1] Motor handling notes

- (1) When moving, wiring, maintaining motors, confirm that the controller power has been shut down.
- (2) Take care not to damage or crush motor cables or let them undergo much stress or heavy load.
- (3) When a motor is running, never reach out towards the rotating part.
- (4) Do not touch a motor and its peripheral devices when the motor power is on and for a while after it is cut off, since they are HOT.
- (5) When carrying a motor, hold the motor body not the cables, shafts or encoders.
- (6) Do not put heavy materials on motors or hang them onto motors.
- (7) Avoid letting motors undergo strong shock or impact.
- (8) If an earthquake or any other disaster happens, confirm the installation conditions of motors and machines for safety before starting motors.
- (9) Do not disassemble or modify motors.

[2] Precautions for installing motors

- (1) Before connecting motors, be sure to configure the encoder axis numbers. Connecting motors having the same axis number to the controller may break all motors being connected.
When extended-joint motors leave the factory, encoder axis number "1" is assigned to them. Refer to the manual included in the motor package for configuration of encoder axis numbers.
- (2) Install specified extended-joint motors. Do not install motors other than specified ones.
- (3) The robot controller and extended-joint motors will operate in combination. According to the specified capacity, select the proper motors.
- (4) When hooking up motors to an extended-joint support robot controller, be sure to check the motor models and joint numbers which are labeled on motors.
- (5) When routing motor cables, observe the following to prevent them from undergoing stress:
 - Protect the cable clamps and connector pins from excessive stress due to bending or cable weight.
 - When installing extended-joint motors on moving mounts, be sure to fasten their cables to those mounts at the connector ends and route the relay cables through cable bearers to minimize excessive bending stress.
 - Make the radius of each cable loop as large as possible.

- (6) Observe the following notes relating to the allowable loads of motor output shafts:
 - Design mechanisms so that the radial or thrust load that will apply to motor shafts at installation or in operation will be kept within the allowable range specified for each motor model.
 - To keep radial load that would be caused by a slight runout of the center within the allowable range, use flexible couplings exclusively designed for servomotors and as rigid as possible.
 - When using rigid couplings, mount them with extra care. If applied in installation, excessive bending load will break motor shafts or shorten the service life of bearings.
- (7) When mounting or removing a coupling to/from the end of a motor shaft, do not apply any direct impact onto the motor shaft with a hammer. An encoder fitted on the other end of the shaft will be damaged.

Perform centering sufficiently. Misalignment will produce vibration, resulting in damaged bearings.
- (8) Never use motors in an environment where they may be subjected to water splash, corrosive gases, or inflammable gases. Do not use them in the vicinity of the inflammable. (Extended-joint motors have not been designed to withstand explosions, dust-proof, nor are they splash-proof.)
- (9) Be sure to install and set up motors so that they will never cause a fire or bodily injury even if an earthquake or any other disaster occurs.

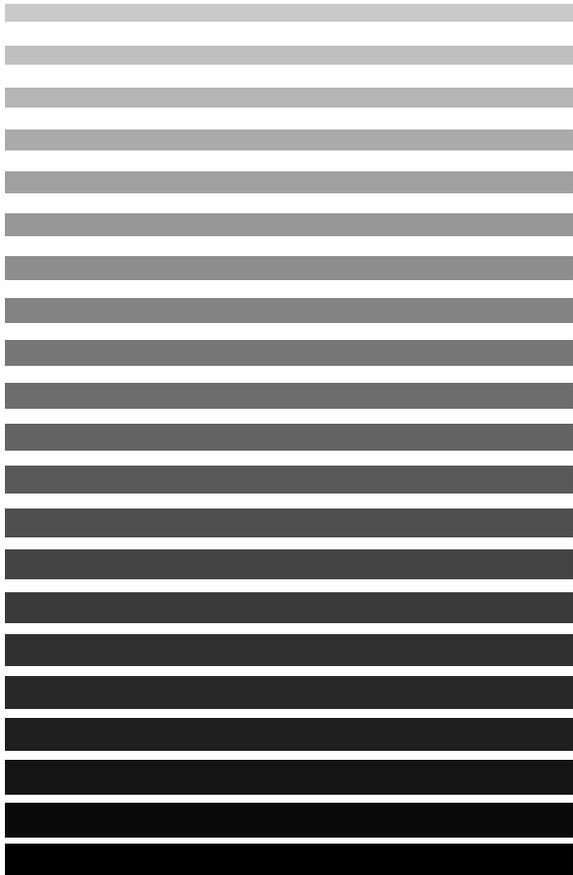
[3] Motor storage notes

- (1) Do not store motors in an environment where they may be subjected to rain, water splash, harmful gases or liquids.
- (2) Shield motors from direct sunlight and store them within the specified temperature/humidity range (-20°C to 80°C, RH 90% or less, without dew condensation).

Chapter 3



Extended-Joint Related Functions



This chapter covers extended-joint related functions.

3.1 Extended-Joint Related Functions

The extended-joint related functions allow you to control extra joints independently of robot joints through the standard interface of the robot controller (NetwoRC).

The extended-joint related functions include the following.

- | |
|--|
| <ul style="list-style-type: none">[1] Operating extended-joints manually[2] Getting extended-joint positions[3] Operating extended-joints by specifying a desired variable[4] Operating extended-joints by program
(Several commands are extended and added.)[5] Setting the boundless rotation of extended-joints[6] Setting the link info[7] Setting the radius of gyration[8] Configuring the origin points of extended-joints |
|--|

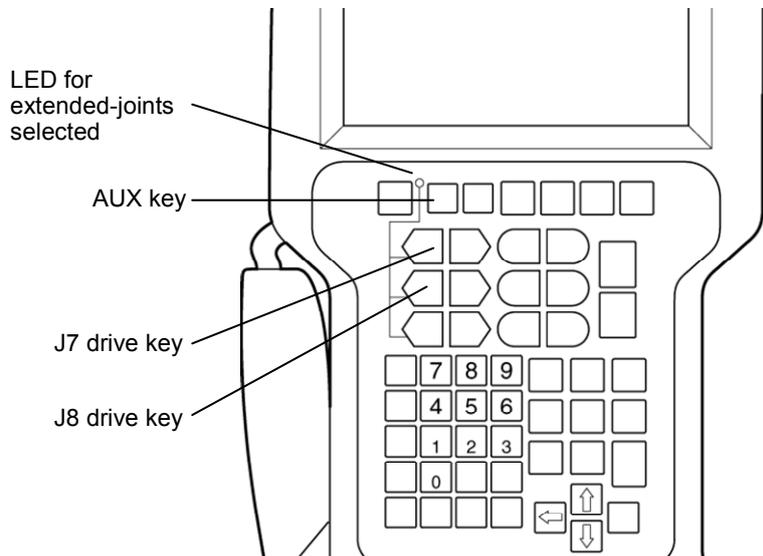
<p>NOTE: Before using these functions, you need to set various parameters of extended-joints properly.</p>

3.1.1 Operating Procedures of the Extended-Joint Related Functions

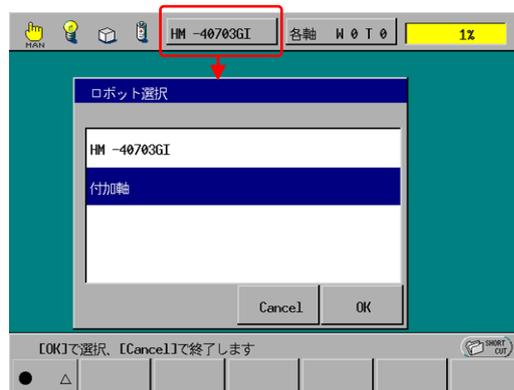
This section describes the operating procedures of the extended-joint related functions listed above.

[1] Operating extended-joints manually

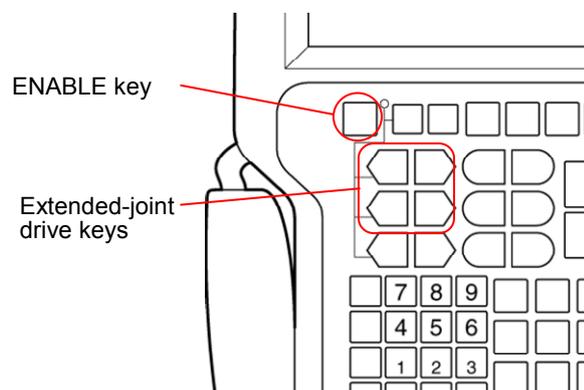
To operate extended-joints, press the AUX key on the teach pendant to select extended-joints. The LED adjacent to the AUX key comes on, indicating that the J7 and J8 drive keys are available to drive the extended-joints.



TIP: Selecting extended-joints by pressing the AUX key is functionally equivalent to selecting of them on the Select Robot window of the extended screen (shown below).



NOTE: Manual operation of extended-joints except a traverse accelerator requires two-hand operation. Press the drive key of the target joint with the ENABLE key held down.



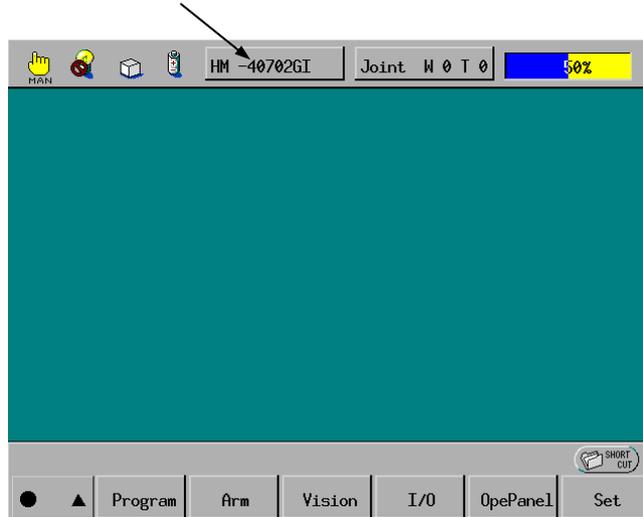
NOTE: Joints requiring two-hand operation cannot be changed by the customer. Contact your Denso service representative for change.

[2] Getting extended-joint positions

While a step inserted for reading positions in a base program gets the current positions of all valid joints containing extended-joints, the following procedure on the extended screen gets the positions of extended-joints into floating-point variables, one by one.

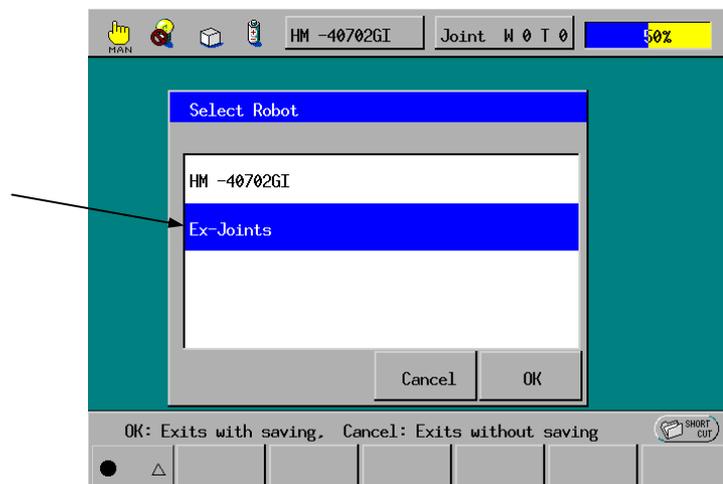
■ **From the teach pendant**

Step 1 On the top screen, press the robot select button (or R-SEL key).



The Select Robot window will display as shown below.

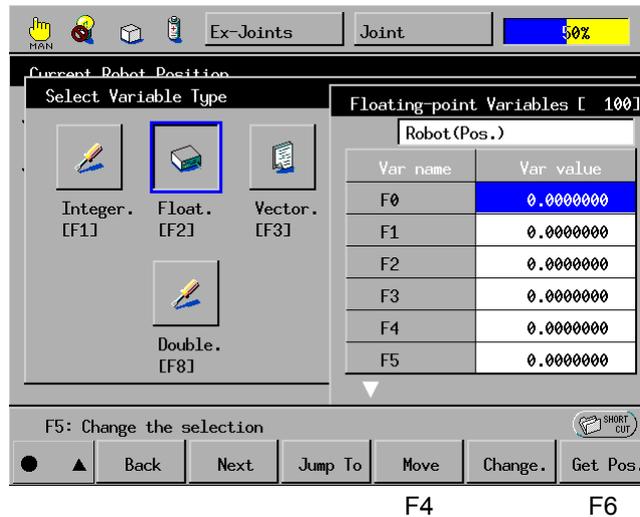
Step 2 Choose "Ex-Joints" and then press the OK button.



NOTE: In the Select Robot window, the "Ex-Joints" appears only when any extended-joint is set to "Valid" in the servo configuration parameters window. If no "Ex-Joints" appears, access [F2 Arm]—[F12 Maint.]—[F7 Joints]—[F8 Servo] and then enable the desired extended-joint. For more details, refer to "Configuring the Extended-Joint Parameters."

Step 3 From the top screen of the teach pendant, access [F2 Arm]—[F4 Var.]—[F2 Float.] to call up the Floating-point Variables window.

Select a variable name to which you want to get a position value.

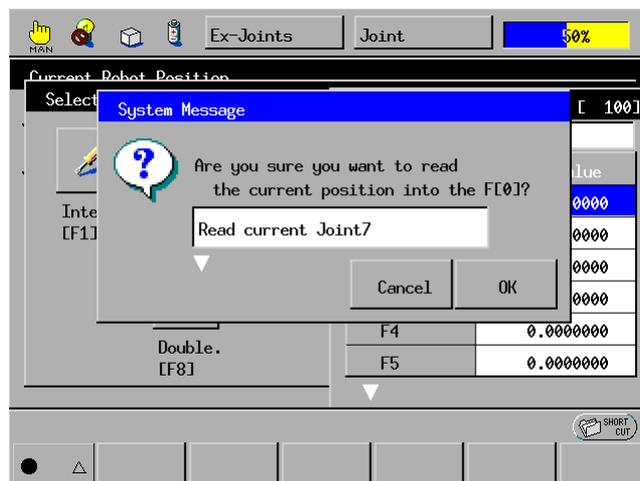


This example will get the extended-joint position value into variable F0.

NOTE: The [Move] and [Get Pos.] function buttons for the floating-point variables appear only when the "Ex-Joints" is selected in the Select Robot window.

Step 4 Press [F6 Get Pos.].

The window below will appear. Select a joint whose position should be read in, and then press OK.



This example will read in the position of the 7th joint.

NOTE: Only extended-joints that are set to "Valid" in the servo configuration parameters window may be read into floating-point variables. No robot joints can be read.

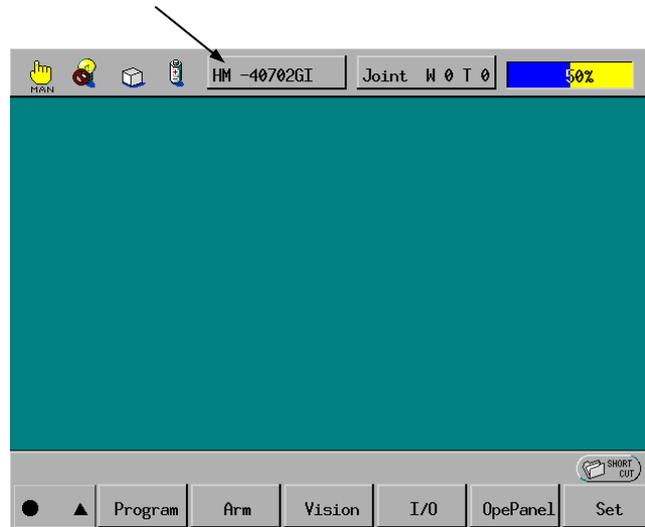
The above procedure reads the current position of the 7th joint into floating-point variable F0.

[3] Operating extended-joints by selecting a desired variable

While execution of the step containing read positions in a base program drives all valid joints containing extended-joints, the following procedure on the extended screen drives joints one by one by specifying a desired floating-point variable.

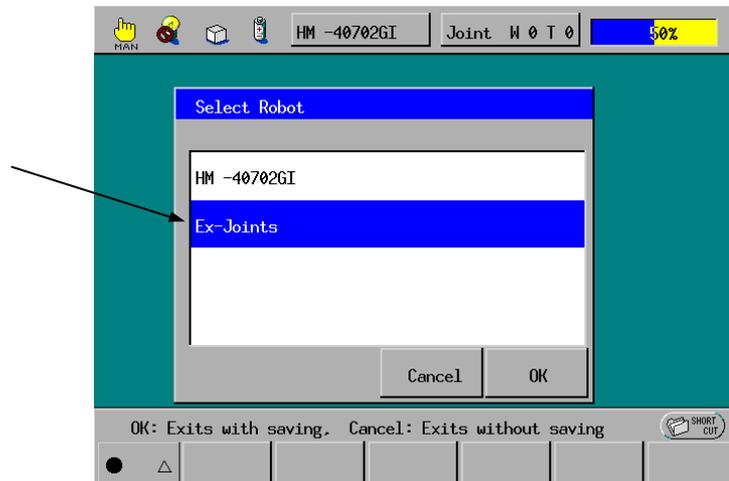
■ **From the teach pendant**

Step 1 On the top screen, press the robot select button (or R-SEL key).



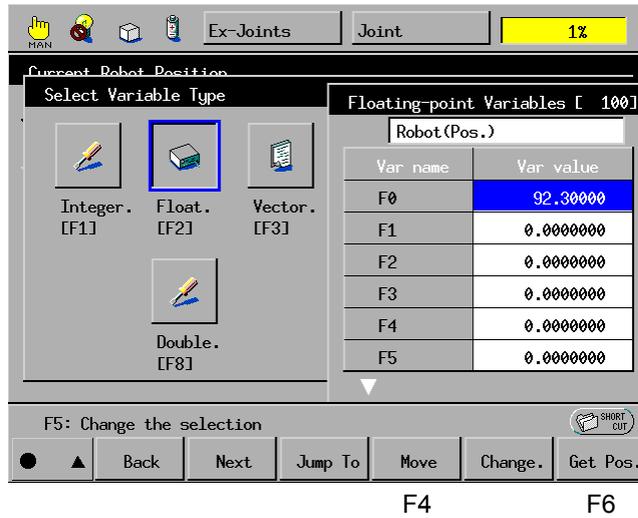
The Select Robot window will display.

Step 2 Choose the "Ex-Joints" and then press the OK button.



NOTE: In the Select Robot window, the "Ex-Joints" appears only when any extended-joint is set to "Valid" in the servo configuration parameters window. If no "Ex-Joints" appears, access [F2 Arm]—[F12 Maint.]—[F7 Joints]—[F8 Servo] and then enable the desired extended-joint.

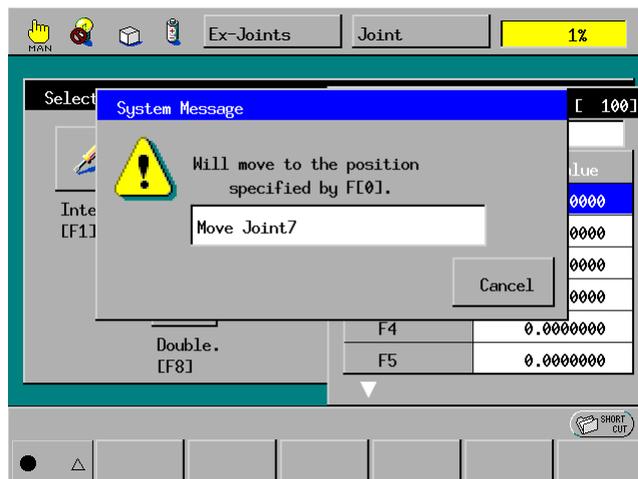
- Step 3** From the top screen of the teach pendant, access [F2 Arm]—[F4 Var.]—[F2 Float.] to call up the Floating-point Variables window. Select a variable having the desired movement value.



This example is to move an extended-joint to the position 92.30 assigned to floating-point variable F0.

NOTE: The [Move] and [Get Pos.] function buttons for the floating-point variables appear only when the "Ex-Joints" is selected in the Select Robot window.

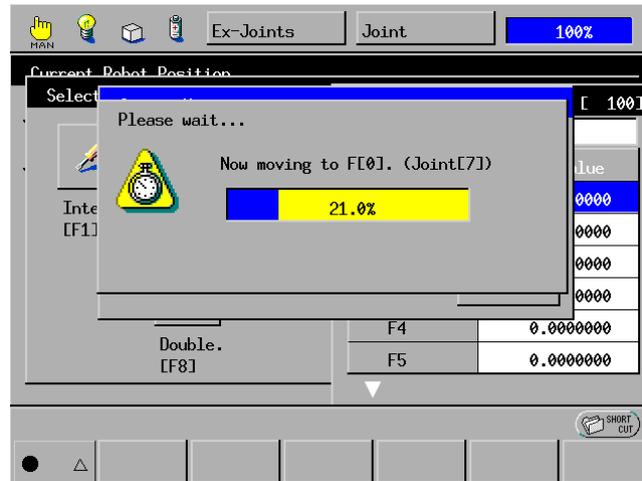
- Step 4** Press [F4 Move]. The window below appears. Select an extended-joint you want to move by using the floating-point variable specified in Step 3.



This example is to move the 7th joint to the position 92.30 assigned to floating-point variable F0.

NOTE: Only extended-joints that are set to "Valid" in the servo configuration parameters window may be read into floating-point variables. No robot joints can be read.

- Step 5** While holding down either one of the deadman switches, keep on pressing the OK button until the progress bar shows 100%.



The above procedure moves the 7th joint to the position 92.30 assigned to floating-point variable F0.

Note: If an extended-joint(s) you want to move by using variables is contained in an arm group and any task holding its semaphore is active, then the extended-joint cannot be moved by using variables. For more details on the arm group semaphore.

[4] Operating extended-joints by program

To operate extended-joints by program, you need to set up an arm group.

■ Concept of an arm group

"Arm Group" is a semaphore to control joints in a group as a single unit. Only when a task holds an "arm group" semaphore (herein called "arm group" and expressed as "Group n"), it can control robot joints and extended-joints. An arm group prevents more than one task from executing motion commands to a same joint at the same time.

Example of Arm Group Configuration (For 4-axis robots)

ArmGroup Settings								
	J1	J2	J3	J4	J5	J6	J7	J8
Group 0	○	○	○	○	×	×	×	×
Group 1	×	×	×	×	×	×	○	○
Group 2	○	○	○	○	×	×	○	○
Group 3	×	×	×	×	×	×	×	×
Group 4	×	×	×	×	×	×	×	×

Robot joints enclosed in this box

In the above example:

Group 0: Only robot joints involved.

Group 1: Only extended-joints (7th and 8th) involved.

Group 2: Robot joints and extended-joints (7th and 8th) involved.

By activating a task holding the "arm group" semaphore with extended-joints involved, you can operate the extended-joints.

In the above configuration example, a task holding Group 1 can control the 7th and 8th extended-joints only.

■ Getting an arm group

To make tasks get an arm group, give a TAKEARM command an arm group number as an argument as shown below.

```
PROGRAM PRO1
TAKEARM 1
:
:
END
```

Program PRO1 gets Deadman switch (on the backside)

■ *Restrictions on the application of arm groups*

If more than one task involves joints shared in their arm groups, those tasks cannot be *simultaneously* executed.

Tasks involving arm groups without shared joints can be *simultaneously* executed.

Example: Getting an Arm Group in Programs

	J1	J2	J3	J4	J5	J6	J7	J8
Group 0	○	○	○	○	×	×	×	×
Group 1	×	×	×	×	×	×	○	○
Group 2	○	○	○	○	×	×	○	○
Group 3	×	×	×	×	×	×	×	×
Group 4	×	×	×	×	×	×	×	×

PROGRAM PRO0	PROGRAM PRO1	PROGRAM PRO2
TAKEARM 0	TAKEARM 1	TAKEARM 2
⋮	⋮	⋮
⋮	⋮	⋮
END	END	END

Arm Groups 0 and 1 involve no shared joint, so PRO0 and PRO1 can be executed simultaneously. (Robot joints and extended-joints can be simultaneously controlled by different programs.)

Arm Groups 0 and 2 involve shared joints (J1 to J4), so PRO0 and PRO2 cannot be executed simultaneously. When the later TAKEARM command is executed, an error will occur.

■ *Releasing the currently held arm group*

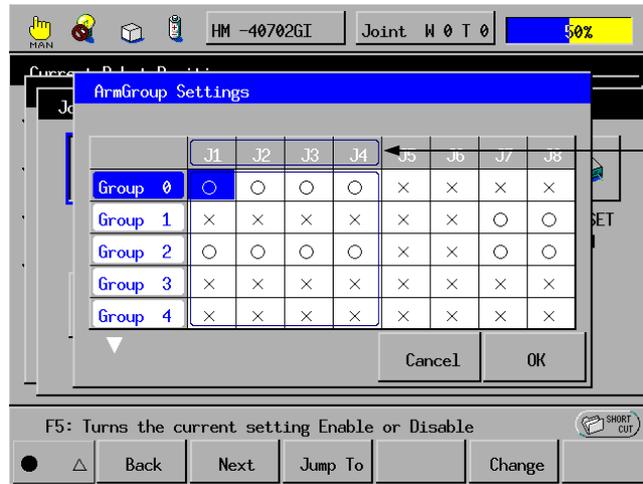
Executing a GIVEARM command releases the currently held arm group.

The currently held arm group will be automatically released also if a program stops due to occurrence of an error or because of normal program end.

NOTE: No arm group will be released by a Halt or Step stop signal.

■ **Setting up an arm group**

Step 1 Call up the Arm Group Settings window by accessing:
[F2 Arm]—[F12 Maint.]—[F7 Joints]—[F1 ArmGroup]



Robot joints enclosed in this box

F5

Step 2 Move the cursor to a joint to be grouped and then press [F5 Change].

Step 3 After marking joints to be grouped or not with "O" or "X", respectively, press OK.

Notes for setting up an arm group

- (1) New settings will go into effect when the controller is turned off and then on after the settings are changed.
- (2) Arm Group 0 cannot be accessed.
- (3) Robot joints may be set all to either "Enabled" or "Disabled." For example, in a 4-joint robot, all four joints are either "Enabled" or "Disabled."
- (4) Extended-joints that you want to enable in an arm group should be set to "Valid" in the servo configuration parameters window beforehand. If not, an error will occur when you are attempting to set up an arm group.

Access to the servo configuration parameters window is:

[F2 Arm]—[F12 Maint.]—[F7 Joints]—[F8 Servo]



[5] Boundless rotation of extended-joints

The boundless rotation function suppresses errors that could occur if an extended-joint keeps on rotating in the same direction. You need to set the boundless rotation parameter to [1: Boundless] in the path configuration parameters window.

Notes for allowing boundless rotation on extended-joints

- (1) When an extended-joint is used as a rotary joint, an absolute motion command (`DRIVEA` or `MOVE` with `EXA` option) can drive it within the range of $\pm 360^\circ$. When it is used as a sliding joint, the allowable motion range is ± 32768 in the number of motor rotations from the reference position (CALSET position).
- (2) If a movement of a rotary joint exceeding the range of $\pm 360^\circ$ is commanded, the joint rotates the specified angle and then it automatically returns to the position within the range of $\pm 360^\circ$. This correction operation changes the reference position (CALSET position). Therefore, the Step Back function cannot return the program control back to the steps preceding the change of the reference position.
- (3) When an extended-joint keeps on rotating in the same direction, the current value might jump (overflow) suddenly and greatly. Performing an absolute motion in this state moves the extended-joint to the position different from the specified one.
- (4) In a boundless rotation motion command, the effective number of digits is 7. If a value exceeding 7 digits is specified, the actual rotation amount will differ from the specified one.

For example

If `DRIVE (5, 11111115555)` is specified, `11111115555` will be internally interpreted as `1.111111*E+10` so that `5555` will be trimmed due to the definition of a single precision floating point number.

- (5) If a large value is specified as the amount of movement at one time in boundless rotation, then the "Out of range" error will occur. The quantum of movement depends on the gear ratio.
- (6) When an extended-joint is used as a rotary joint requiring positioning, e.g., index table, observe the following instructions.
 - For the reduction gear, enter an integer multiple. Entering a non-integer multiple will result in a positioning error after a lot of rotations.
 - If a relative motion command specifies a motion amount using a decimal, the extended-joint could reach the position slightly different from the specified one. Using such a relative motion command repeatedly will result in a positioning error after a lot of rotation.

To avoid such a positioning error, correct the difference from the specified position, for example, using an absolute motion command or `MoveIndexHome` library after completion of one rotation to return the extended-joint to the home position.

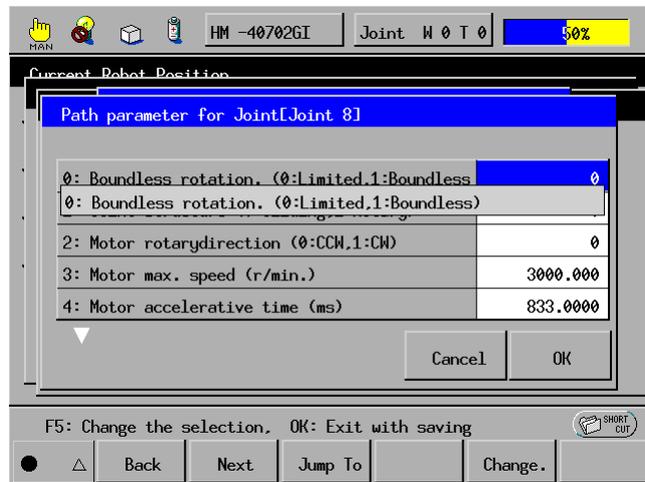
- (7) Rotating an extended-joint exceeding ± 32768 in the number of motor rotations from the reference position (CALSET position) with the controller power being off will require CALSET operation when the controller is powered on at the next time.

■ Allowing boundless rotation

From the top screen of the teach pendant, access:

[F2 Arm]—[F12 Maint.]—[F7 Joints]—[F7 Path]

In the path configuration parameters window, set the boundless rotation parameter to [1: Boundless].



[6] Setting the link info

The controller always monitors the motion speed of the robot joints being driven to limit it to a maximum of 250 mm/sec in Manual or Teach check mode.

When driving extended-joints also in Manual or Teach check mode, the controller applies the same speed limit to them.

If the link info is set up between robot joints and extended-joint(s), the controller can limit the total motion speed of the linked joints to a maximum of 250 mm/sec. Note that the total motion speed differs from the actual composite speed since the controller does not take the motion directions of individual joints into account.

■ Concept of the link info

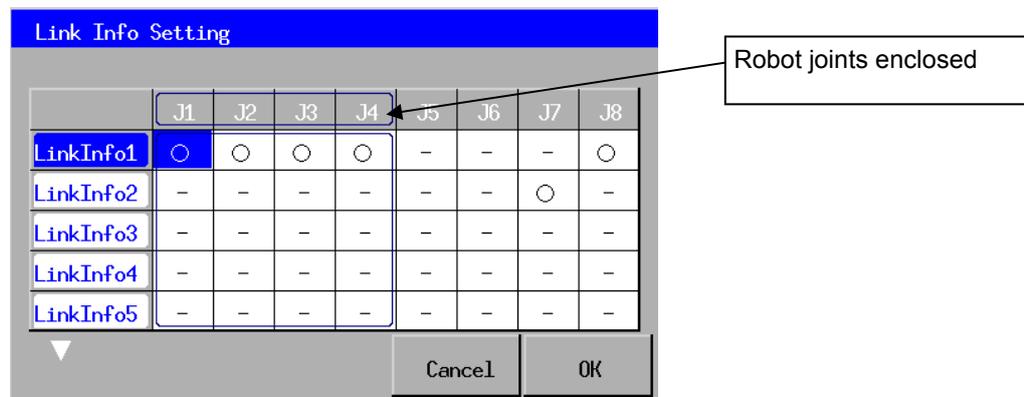
"Link info" defines whether or not robot joints and extended-joints affect with each other when they are being driven.

If the link info is set up, the linked joints are mutually affected; if not, they are driven independently.

All of robot joints are configured in a batch so that all of them are either linked or not.

An example of the link info setup window is given below.

Link info setup window (ex. 4-joint robots. J5 and J6 are invalid.)



The screenshot shows a window titled "Link Info Setting" with a table of joint linkages. The table has columns for joints J1 through J8 and rows for LinkInfo1 through LinkInfo5. A callout box labeled "Robot joints enclosed" points to the J1-J4 columns. The table content is as follows:

	J1	J2	J3	J4	J5	J6	J7	J8
LinkInfo1	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	-	-	-	<input type="radio"/>
LinkInfo2	-	-	-	-	-	-	<input type="radio"/>	-
LinkInfo3	-	-	-	-	-	-	-	-
LinkInfo4	-	-	-	-	-	-	-	-
LinkInfo5	-	-	-	-	-	-	-	-

○: Linked, -: Not linked

In the above example,

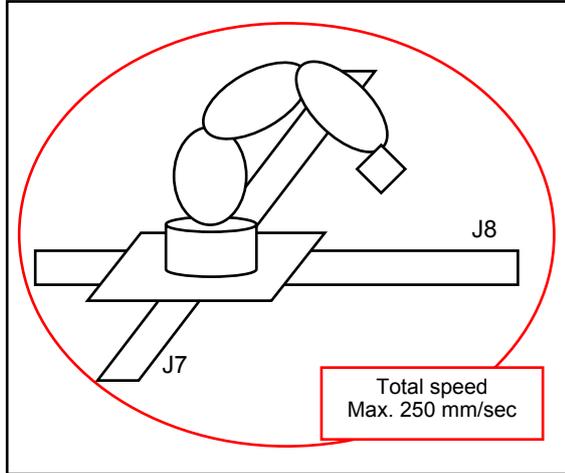
Link info 1 links robot joints J1 to J4 and extended-joint J8 together so that the robot joints and J8 are mutually affected in motion.

Link info 2 does not link extended-joint J7 with any joints so that J7 affects neither robot joints nor J8 in motion.

■ Configuration samples of robot joints and extended-joints

Given below are configuration samples and their link info to be set up.

< Configuration sample 1 > Linking robot joints and extended-joints (J7 and J8) together



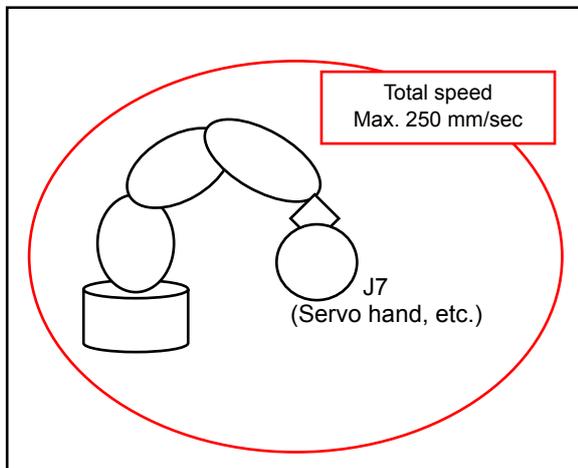
In the configuration shown at left, the motions of extended-joints J7 and J8 affect those of the robot joints, so link the robot joints and extended-joints together.

The speed limit applies to the total motion speed.

Link info setup sample (4-joint robots)

	J1	J2	J3	J4	J5	J6	J7	J8
LinkInfo1	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	-	-	<input type="radio"/>	<input type="radio"/>

< Configuration sample 2 > Linking robot joints and extended-joint (J7) together



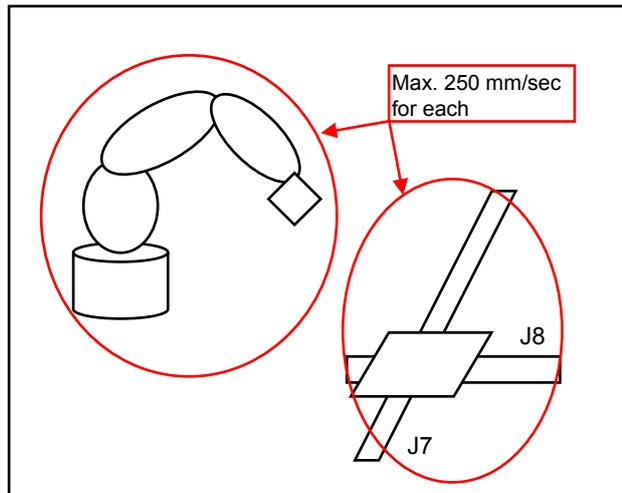
In the configuration shown at left, the motions of robot joints affect that of extended-joint J7, so link the robot joints and J7 together.

The speed limit applies to the total motion speed.

Link info setup sample (4-joint robots)

	J1	J2	J3	J4	J5	J6	J7	J8
LinkInfo1	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	-	-	<input type="radio"/>	-

< Configuration sample 3 > No link between robot joints and extended-joints, but linking extended-joints J7 and J8 together



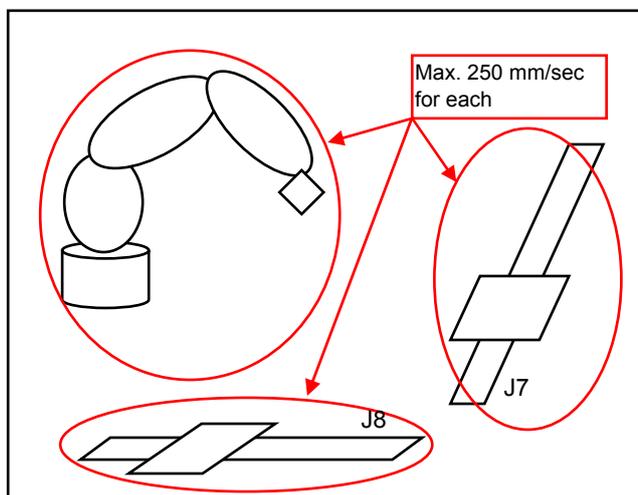
In the configuration shown at left, the motions of extended-joints J7 and J8 does not affect those of the robot joints, so do not link the robot joints and extended-joints together. But, the motions of J7 and J8 are mutually affected, so link them together.

The speed limit applies to each of the robot joints and extended-joints (J7 and J8) independently. But for J7 and J8, it applies to the total motion speed of them.

Link info setup sample (4-joint robots)

	J1	J2	J3	J4	J5	J6	J7	J8
LinkInfo1	○	○	○	○	-	-	-	-
LinkInfo2	-	-	-	-	-	-	○	○

< Configuration sample 4 > No link between robot joints and extended-joints or between extended-joints J7 and J8



In the configuration shown at left, the motions of extended-joints J7 and J8 does not affect those of the robot joints, so do not link the robot joints and extended-joints together. Neither do the motions of J7 and J8 mutually, so do not link them together.

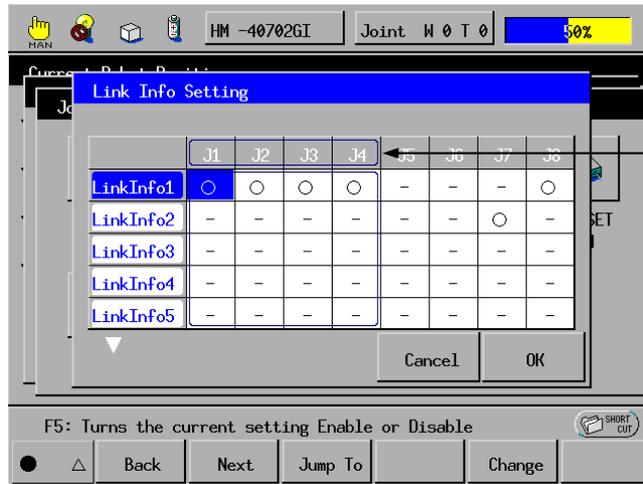
The motion speed limit applies to each of the robot joints, J7, and J8 independently.

Link info setup sample (4-joint robots)

	J1	J2	J3	J4	J5	J6	J7	J8
LinkInfo1	○	○	○	○	-	-	-	-
LinkInfo2	-	-	-	-	-	-	○	-
LinkInfo3	-	-	-	-	-	-	-	○

■ **Setting up link info**

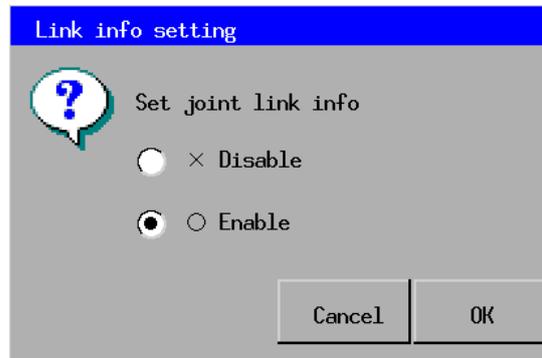
Step 1 Call up the Link Info Setting window by accessing:
[F2 Arm]—[F12 Maint.]—[F7 Joints]—[F4 LinkInfo]



Robot joints enclosed in this box

F5

Step 2 Move the cursor to a joint to be linked and then press [F5 Change].
 The setup window appears as shown below.

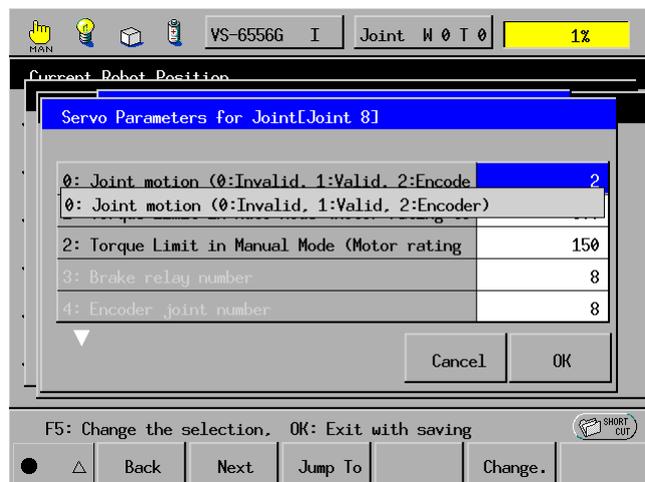


Step 3 After selecting "O" or "X," press OK.

Notes for setting up link info

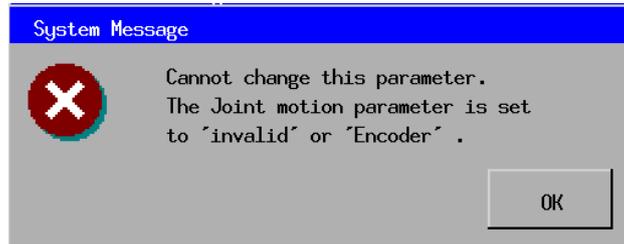
- (1) The newly configured link info goes into effect when the controller is restarted.
- (2) All of robot joints are configured in a batch so that all of them are either linked or not.
- (3) Extended-joints to be selected for linking should be set to "Valid" in the servo configuration parameters window beforehand.

If not, selecting any extended-joint for linking causes an error (see System message window 1 on the next page). If such an error occurs, access [F2 Arm]—[F12 Maint.]—[F7 Joints]—[F8 Servo] and then enable the desired extended-joint.

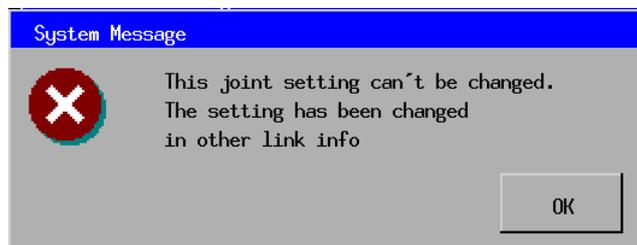


- (4) In the Link Info Setting window shown in Step 1, "-" denotes joints not specified as "Valid" or joints linked in any other joint info. Attempting to change the setting of joints marked with "-" will cause an error (see System message window 2 on the next page).
- (5) Link info should be set up for all of robot joints and extended-joints specified as "Valid." With any joint not selected for linking, pressing OK in Step 2 will cause an error (see System message window 3 on the next page).

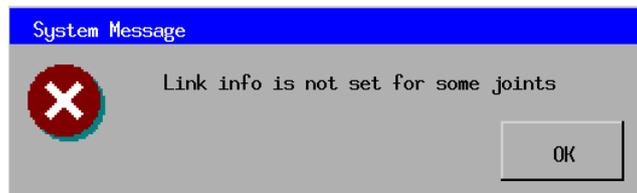
System message window 1: Joint not specified as "Valid"



System message window 2: Joint already linked



System message window 3: Any joint not selected for linking



[7] Setting the radius of gyration

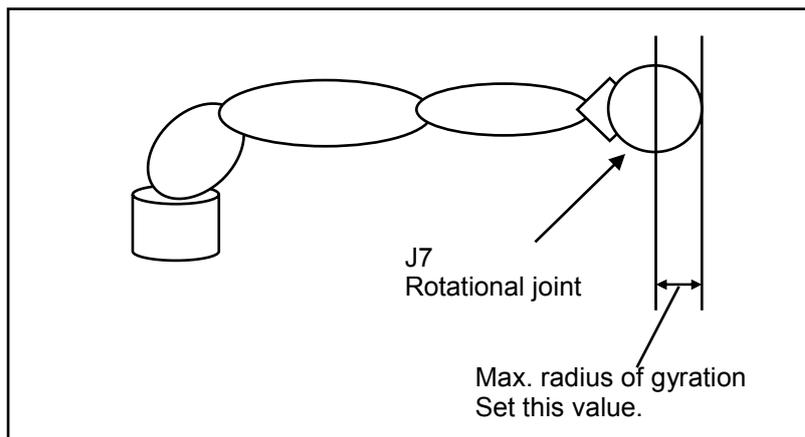
The controller limits the motion speed of both robot joints and extended-joints being driven to a maximum of 250 mm/sec in Manual or Teach check mode.

Using an extended-joint as a rotational joint requires specifying the radius of gyration of the extended-joint as a parameter.

Notes for setting up the radius of gyration

- (1) When the robot is equipped with a tool (e.g., servo hand) having rotational joint J7 as shown in Configuration sample 1, specify the radius of gyration of the rotational joint as a parameter.
- (2) When the robot is mounted on rotational joint J8 (e.g., turntable) as shown in Configuration sample 2, it is necessary to specify the total value of the "Radius of gyration of J8," "Maximum arm length of the robot (Table 3.1)," and "Maximum Z-direction length of the tool" as a parameter.
- (3) In the combination of Configuration samples 1 and 2, that is, when the robot is mounted on rotation joint J8 (e.g., turntable) and it is equipped with a tool (e.g., servo hand) having rotational joint J7, it is necessary to specify the related parameters for each joint.

< Configuration sample 1 > Robot equipped with a tool (servo hand) having rotational joint J7



< Configuration sample 2 > Robot mounted on rotation joint J8 (turntable)

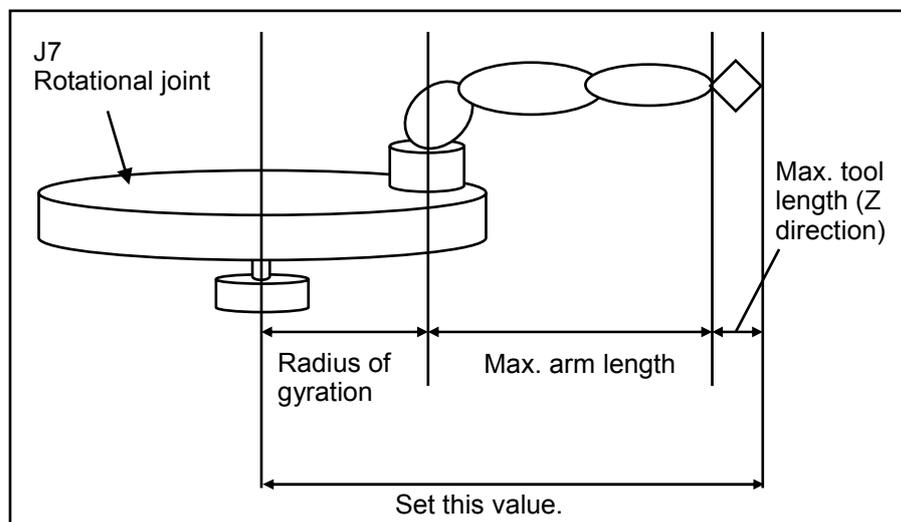


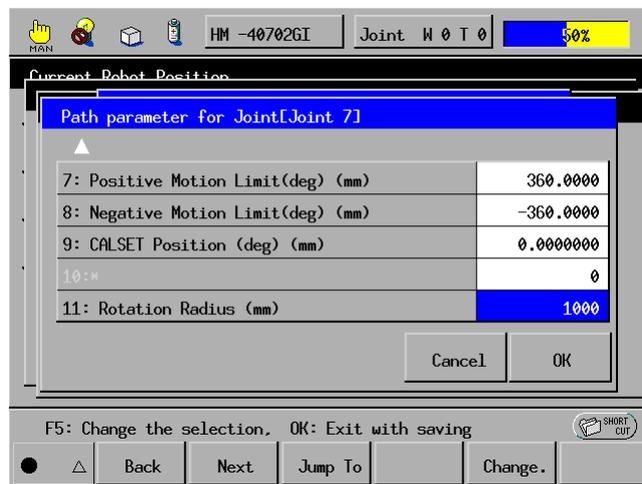
Table 3.1 Robot Models and Max. Arm Length

Robot series	Robot model	Max. arm length (mm)
VS-G-T	VS-6556G	653.42
	VS-6577G	854.88
VM-G-T	VM-6083G	1021.09
	VM-60B1G	1298.41
HS-G-T	HS-4535*G	350
	HS-4545*G	450
	HS-4555*G	550
HM-G-T	HM-4060*G	600
	HM-4A60*G	600
	HM-4070*G	700
	HM-4A70*G	700
	HM-4085*G	850
	HM-4A85*G	850
	HM-40A0*G	1000
	HM-4AA0*G	1000

■ **Specifying a "radius of gyration" parameter**

Access: Top Screen—[F2 Arm]—[F12 Maint.]—[F7 Joints]—[F7 Path]

Enter the desired value to the "Radius of gyration" in the path configuration parameters.



[8] Setting the origin points of extended-joints

The extended-joint support controller allows origin points of valid extended-joints to be configured. The origin points specify the motion range of extended joints.

Joints can be enabled or disabled individually.

3.1.2 Commands Supporting Extended-Joints

The table below lists the commands to be used for extended-joint function.

Commands	Functions	Refer to:
TAKEARM	Get an arm group. Upon execution of this statement, the programmed speed, acceleration and deceleration will be set to 100. If the gotten arm group includes any robot joint, this statement restores the tool coordinates and work coordinates to the origin.	PROGRAMMER'S MANUAL I
GIVEARM	Release the currently held arm group.	PROGRAMMER'S MANUAL I
DRIVE	Carry out the relative motion of each joint.	PROGRAMMER'S MANUAL I
DRIVEA	Carry out the absolute motion of each joint.	PROGRAMMER'S MANUAL I
MOVE	Move the robot flange to the specified coordinates. If specified with an EX option (relative motion of extended-joints) or EXA option (absolute motion of extended-joints), the MOVE can move both the robot flange and the extended-joints synchronously.	PROGRAMMER'S MANUAL I
CUREXJ	Get the current angle of an extended-joint into a floating-point variable.	PROGRAMMER'S MANUAL I
DESTEXJ	Get the target position of an extended-joint invoked by the current motion command into a floating-point variable. If the robot is on halt, this command will get the current position (commanded value).	PROGRAMMER'S MANUAL I
ARRIVE	Define the motion ratio relative to the programmed full travel distance to the target point in order to make the current program stand by to execute the next step until the robot reaches the defined motion ratio.	PROGRAMMER'S MANUAL I
SPEED	Set the monitoring conditions for single-joint servo data monitor. Specify the internal composite speed of joints included in a currently held arm group.	PROGRAMMER'S MANUAL I
JSPEED	Specify the internal speed of individual joints included in a currently held arm group.	PROGRAMMER'S MANUAL I
ACCEL	Specify the internal composite acceleration/deceleration of joints included in a currently held arm group.	PROGRAMMER'S MANUAL I
JACCEL	Specify the internal acceleration and deceleration of individual joints included in a currently held arm group.	PROGRAMMER'S MANUAL I
DECEL	Specify the internal composite deceleration of joints involved in a currently held arm group.	PROGRAMMER'S MANUAL I
JDECEL	Specify the internal deceleration ratio of individual joints included in a currently held arm group.	PROGRAMMER'S MANUAL I
CURSPD	Get the current internal composite speed of joints included in a currently held arm group.	PROGRAMMER'S MANUAL I
CURJSPD	Get the current internal speed of individual joints included in a currently held arm group.	PROGRAMMER'S MANUAL I
CURACC	Get the current internal composite acceleration of joints included in a currently held arm group.	PROGRAMMER'S MANUAL I
CURJACC	Get the current internal acceleration of individual joints included in a currently held arm group.	PROGRAMMER'S MANUAL I
CURDEC	Get the current internal composite deceleration of joints included in a currently held arm group.	PROGRAMMER'S MANUAL I
CURJDEC	Get the current internal deceleration of individual joints included in a currently held arm group.	PROGRAMMER'S MANUAL I
INTERRUPT ON/OFF	Interrupt the current robot motion.	PROGRAMMER'S MANUAL I
POSCLR	Forcibly restore the current position of a joint to 0 mm or 0 degree.	PROGRAMMER'S MANUAL I
mvSetPulseWidth Jnt	Set the encoder pulse count for an allowable positioning error for a specified extended-joint.	PROGRAMMER'S MANUAL II
mvResetPulseWidth Jnt	Reset the encoder pulse count for an allowable positioning error for a specified extended-joint to the default.	PROGRAMMER'S MANUAL II
SetCycloidJnt	Enter a specified extended-joint into the cycloid mode where the controller suppresses the peak of overshoot and residual oscillation that would occur in an end motion.	PROGRAMMER'S MANUAL II
ResetCycloidJnt	Cancel the cycloid mode set for a specified extended-joint and restore the normal mode.	PROGRAMMER'S MANUAL II
ResetCurLmt	Release the drive current limit set for a specified joint motor.	PROGRAMMER'S MANUAL II
ResetEralw	Reset the positioning error allowance of a specified joint to the initial value.	PROGRAMMER'S MANUAL II
MoveIndexHome	Rotate the index table to move a specified extended-joint to the home position.	PROGRAMMER'S MANUAL II

3.2 Configuring the Extended-Joint Parameters

To use extended-joints, you need to configure extended-joint parameters beforehand. There are two types of extended-joint parameters as described below, which can be configured by using the teach pendant.

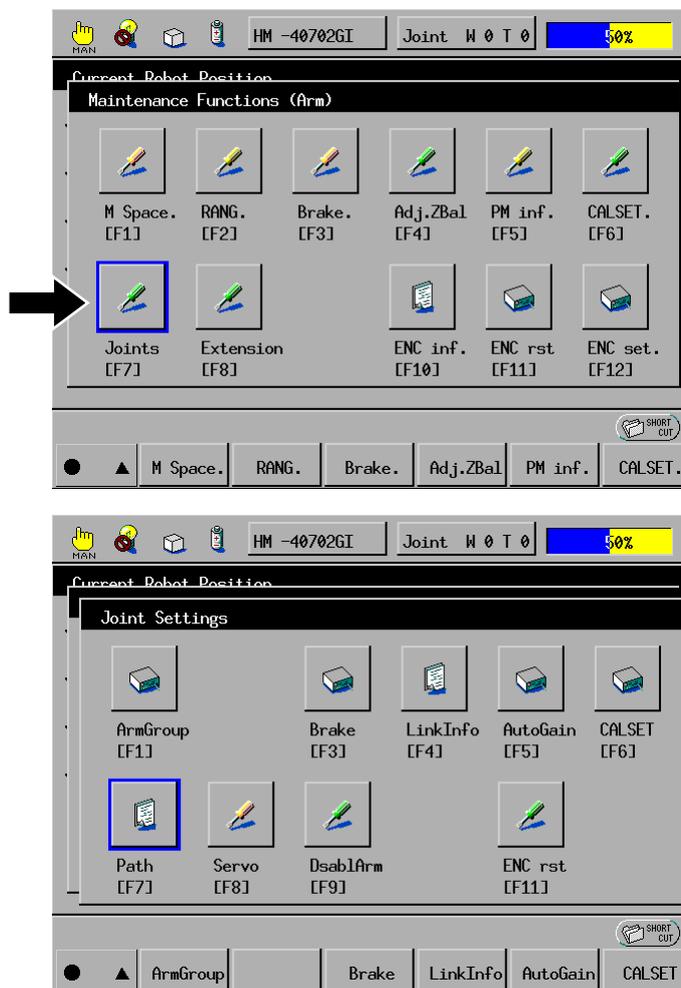
- (1) Path configuration parameters, which are provided for motion definitions (including speed, acceleration, and range of motion) of extended-joints.
- (2) Servo configuration parameters, which are provided for setting the gain and others of extended-joint servo system.

The extended-joint parameters (path configuration, servo configuration, arm group, link info, and arm disabled) can be configured also in WINCAPSIII Arm Manager. Log on as a Programmer, select Tool | Joints, and configure the related parameters. Logging on as an Operator allows you to browse the parameter values only.

3.2.1 Calling up "Path Configuration Parameters" and "Servo Configuration Parameters" Windows

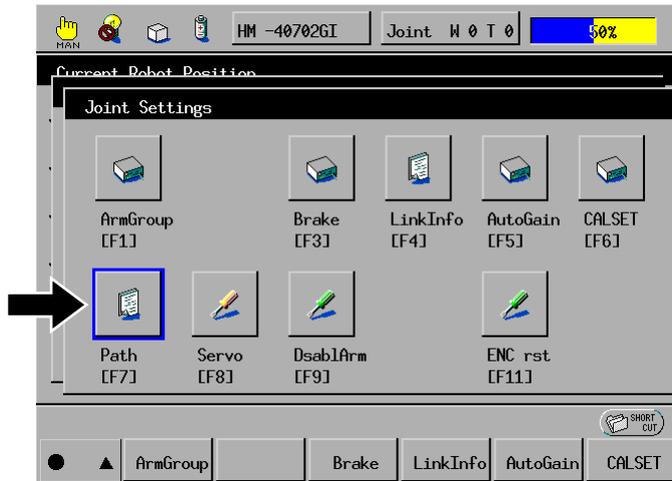
(1) Calling up the Joint Settings window

Top Screen—[F2 Arm]—[F12 Maint.]—[F7 Joints]



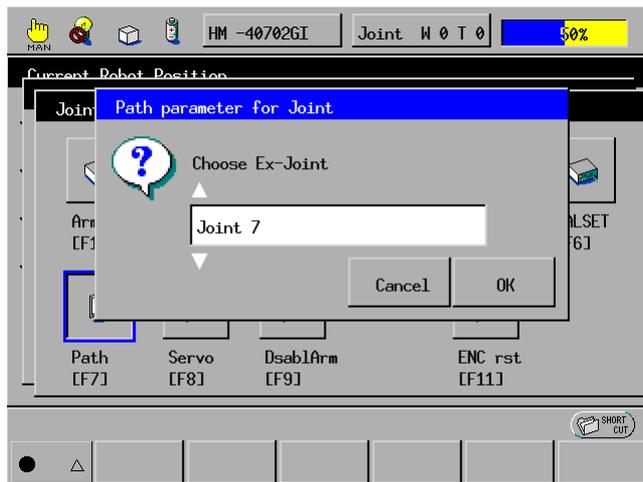
Joint Settings Window

(2) Changing the path configuration parameters

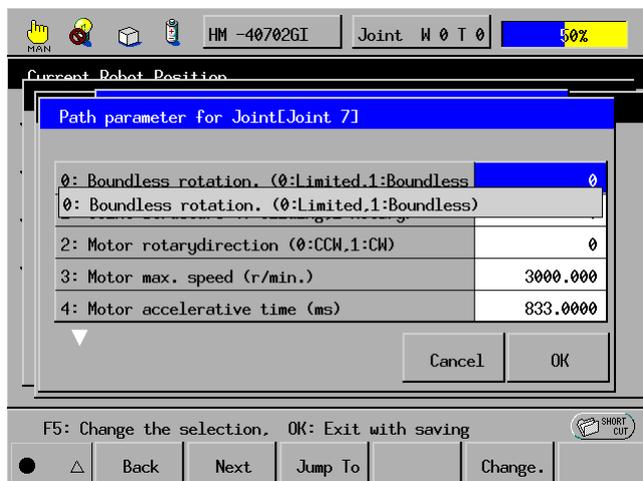


On the Joint Settings window shown above, press [F7 Path].

The path configuration window appears as shown below. Select the target joint (J7 in this example) by using the cursor keys or jog dial.



Press OK. The path configuration parameters window appears as shown below. Change the path configuration parameters and press OK.



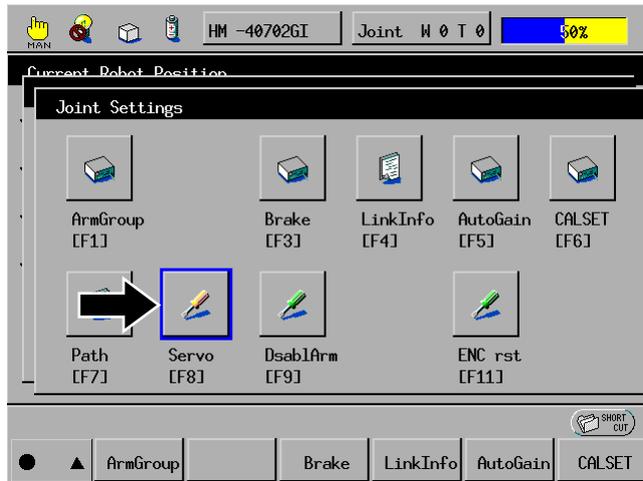
NOTE: Some parameters will take effect after the controller power is restarted.

Chapter 3 Extended-Joint Related Functions

Table 3.2 List of Path Configuration Parameters

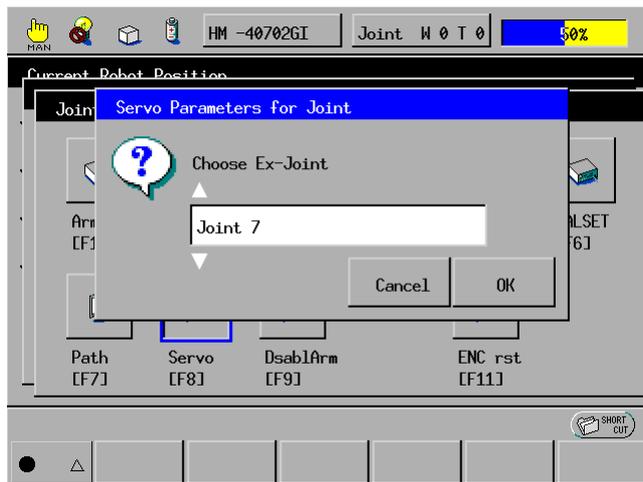
Parameter name	Entry range	Factory default	Unit	Description	Remarks	Controller restart
Boundless rotation (0: Limited, 1: Boundless)	0 or 1	0		To rotate the motor 32768 times or more in the same direction, set this parameter to 1.		Needed
Joint structure (0: Sliding, 1: Rotary)	0 or 1	1		If your optional mechanism to be connected to the specified motor has a sliding joint, then set 0; if a rotary joint, set 1.		Needed
Motor rotation direction (0: CCW, 1: CW)	0 or 1	0		To convert the CCW rotation of the specified motor (when viewed from the load side) to the positive direction movement of the connected mechanism, set 0; to convert it to the negative one, set 1.		Needed
Motor max. speed (rpm)	1 to 6000	3000	rpm	Set the maximum speed of the specified motor.		Needed
Motor acceleration time (ms)	1 min.	200	ms	Set the motor acceleration time required for the specified motor to reach the maximum speed.		Needed
Gear ratio or lead (mm/r)	0.00001 min.	50	For lead: mm/r	For rotary joints, set the deceleration ratio (motor rotation/joint rotation). For sliding joints, set the lead (movement) per motor rotation.	Up to 100,000 may be set. But if a large value is set, the entered value may be different from the displayed one due to overflow.	Needed
Motion limit detection (0: Invalid, 1: Valid)	0 or 1	1		To make the controller check the motion limit and issue an error if the specified joint is out of the range, set 1.		Needed
Positive motion limit (deg.) (mm)		500	For rotary joints: degrees For sliding joints: mm	Set the positive motion limit.		Not needed
Negative motion limit (deg.) (mm)		0	For rotary joints: degrees For sliding joints: mm	Set the negative motion limit.		Not needed
CALSET position		0	For rotary joints: degrees For sliding joints: mm	Set the CALSET reference position.		Not needed
Radius of gyration (mm)	0 to 100000	1000	mm	For rotary joints, set the maximum radius of rotation. For sliding joints, no setting is required.		Needed

(3) Changing the servo configuration parameters

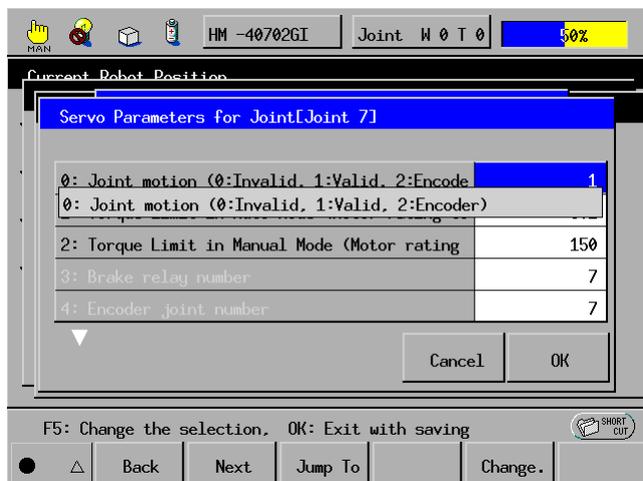


On the Joint Settings window shown above, press [F8 Servo].

The servo configuration window appears as shown below. Select the target joint (J7 in this example) by using the cursor keys or jog dial.



Press OK. The servo configuration parameters window appears as shown below. Change the servo configuration parameters and press OK.



NOTE: Some parameters will take effect after the controller power is restarted.

Table 3.3 Servo Configuration Parameters

Parameter name	Entry range	Factory default	Unit	Description	Remarks	Controller restart
Joint motion (0: Invalid, 1: Valid, 2: Encoder)	0 to 2			To connect and drive a specified motor, set 1; to use the encoder only, set 2.	If "2: Encoder" is selected, turning the motor on will release the brake. CAUTION: If any unbalanced load is applied, the joint will move towards the load.	Needed
Torque limit in auto mode (Motor rating torque %)	0 to 400	300	%	Set the torque limit value to be applied in auto mode.		Not needed
Torque limit in manual mode (Motor rating ratio %)	0 to 400	150	%	Set the torque limit value to be applied in manual mode.		Not needed
Brake relay number	0 to 8			Displays the motor brake relay number.	No change allowed.	
Encoder axis number	1 to 8			Displays the encoder axis number.	No change allowed.	
Power module slot number	1 to 8			Displays the power module slot number.	No change allowed.	
Positional loop gain	1 min.	64		Set the response of the position control system. Increasing the value will decrease the positioning time.	The positioning loop gain can be converted in unit by Formula 3.2.3-1 given in Section 3.2.3.	Not needed
Positional loop feed forward gain (%)	0 to 100	0	%	Set the loop forward gain of the position control system. Increasing the value will decrease a positioning error and increase the response, but overshoot will easily occur.		Not needed
Positioning error allowance (pulse)	1 min.	30000		Set the allowable value of positioning error. If a positioning error exceeding this allowable value occurs, an error will result.	Set the value that meets Formula 3.2.3-2 given in Section 3.2.3.	Not needed

Parameter name	Entry range	Factory default	Unit	Description	Remarks	Controller restart
Speed proportional gain	1 min.	200 (for 400W or less) 400 (for 750W or greater)		Set the response of the speed control system. Increasing the value will enable you to set a higher value of the positional loop gain.	The speed loop proportional gain can be converted to the speed response frequency in Hz by Formula 3.2.3-3 given in Section 3.2.3.	Not needed
Speed integral gain	0 min.	5		Set the integral compensation gain of the speed control system. Increasing the value will converge the speed deviation at the time of stop faster.	The speed loop integral gain can be converted to the time constant by Formula 3.2.3-4 given in Section 3.2.3.	Not needed
Filter parameter	0 to 15	10		Set the primary delay filter band in the torque instruction section. Increasing the value will decrease the time constant of the low-pass filter.		Not needed
Torque offset setting (Motor rating ratio %)	0 to 100	0	%	Set the torque offset value of the torque instruction value. If the motor undergoes any unbalanced load (movement towards the load), this offset will compensate it.	If you enable the gravity offset in auto gain tuning, the torque offset value will be automatically set.	Not needed
Motor capacity (50W : 1, 100W : 2, 200W : 3, 400W : 4, 750W : 5)	1 to 5			Display the connected motor capacity	No change allowed.	

3.2.2 Detailed Description of Extended-Joint Parameter Setting

The path configuration parameters and servo configuration parameters should be set with extended-joint motors being connected.

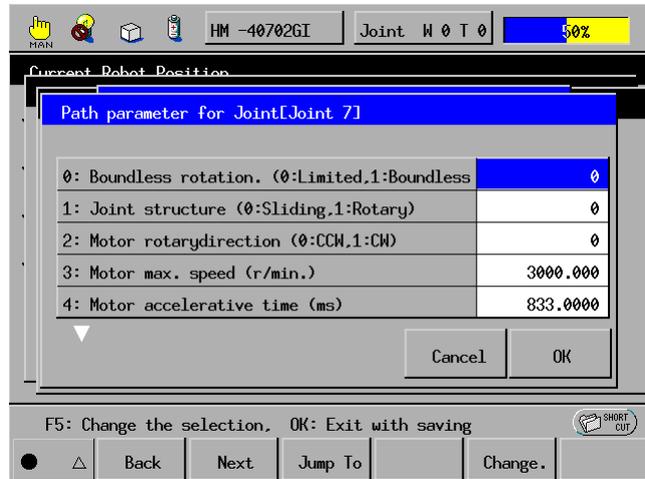
(1) Resetting the encoder of an extended-joint motor

The encoder is not connected with a backup battery at the time of shipment, so the error message "J* encoder system down" or "J* encoder speed exceeded" will appear.

NOTE: When resetting the encoder, connect only the motor cable to the extended-joint support robot controller and be sure to disconnect the robot cable from it. This is to prevent the robot motor from getting reset.

(2) Setting the path configuration parameters

(2-1) Boundless rotation



To rotate the motor 32768 times or more in the same direction, set the boundless rotation to "1: Boundless."

(2-2) Setting the motion conditions

MAN HM -40702GI Joint W 0 T 0 50%

Current Robot Position

Path parameter for Joint[Joint 7]

1: Joint structure (0:Sliding,1:Rotary)	0
2: Motor rotarydirection (0:CCW,1:CW)	0
3: Motor max. speed (r/min.)	3000.000
4: Motor accelerative time (ms)	833.0000
5: Gear ratio or Lead(mm/r)	20.00000

Cancel OK

F5: Change the selection. OK: Exit with saving

Back Next Jump To Change.

MAN HM -40702GI Joint W 0 T 0 50%

Current Robot Position

Path parameter for Joint[Joint 7]

5: Gear ratio or Lead(mm/r)	20.00000
6: Motion Limit Detection (0:invalid,1:valid)	1
7: Positive Motion Limit(deg) (mm)	360.0000
8: Negative Motion Limit(deg) (mm)	-360.0000
9: CALSET Position (deg) (mm)	0.0000000

Cancel OK

F5: Change the selection. OK: Exit with saving

Back Next Jump To Change.

MAN HM -40702GI Joint W 0 T 0 50%

Current Robot Position

Path parameter for Joint[Joint 7]

7: Positive Motion Limit(deg) (mm)	360.0000
8: Negative Motion Limit(deg) (mm)	-360.0000
9: CALSET Position (deg) (mm)	0.0000000
10:*	0
11: Rotation Radius (mm)	1000

Cancel OK

F5: Change the selection. OK: Exit with saving

Back Next Jump To Change.

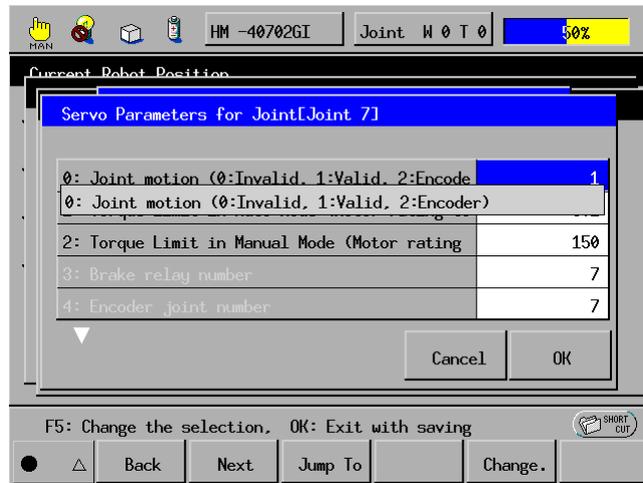
Set the motion-relation parameters--sliding/rotary joint structure, motor rotation direction, motor maximum speed, motor acceleration time, gear ratio or lead, motion limit detection, positive motion limit, negative motion limit, and CALSET reference position.

NOTE: When using an extended-joint as a rotary one with the boundless rotation selected, enter an integer multiple of the gear ratio. Entering a non-integer multiple will result in a positioning error in multiple rotation.

(3) Setting the servo configuration parameters

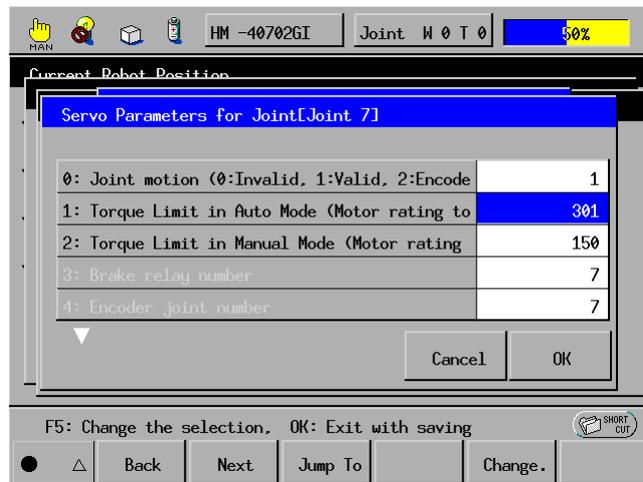
(3-1) Setting the joint motion

Set the joint motion to "1: Valid."



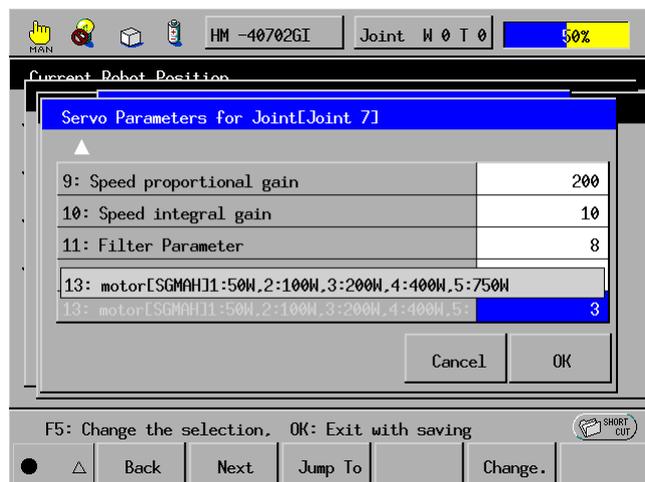
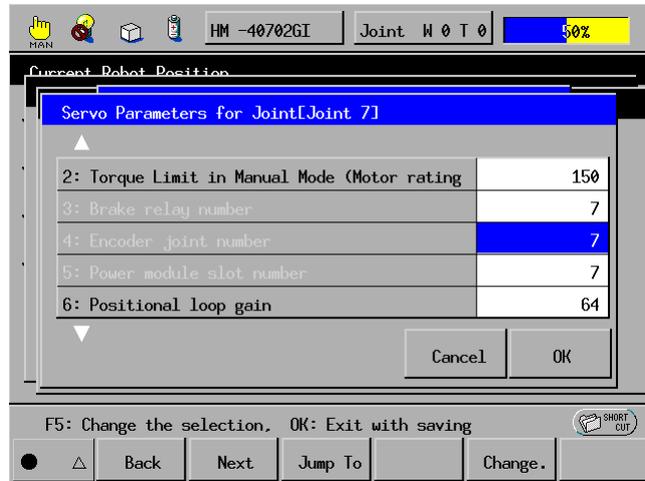
(3-2) Setting the torque limits

Set the torque limits in each of Auto and Manual modes.



(3-3) Checking the encoder axis number, power module slot number, and motor capacity

Checks that the encoder axis number and power module slot number match the joint number. Also, check that the motor capacity is selected correctly.



(4) Registering extended-joints in an arm group

Register extended-joints into an arm group.



After completion of steps (1) to (4) above, restart the robot controller.

(5) Checking the wiring

(5-1) Checking the brake wiring

If the extended-joint motor has a brake, release the brake and check that the brake of the specified joint will be released. For the brake releasing procedure, refer to Section 3.2.4.2 "Releasing and locking an extended-joint brake."

NOTE: Releasing the brake of a robot joint may drop the arm. Take care not to release the brakes of robot joints.

(5-2) Checking the encoder wiring

After releasing the brake of the extended-joint motor, apply external force to the motor and check that the data of the joint corresponding to the motor will change in the Current Robot Position window of the teach pendant.

(5-3) Checking the motor wiring

Turn the extended-joint motor on, set the motor speed at SP10, and check that you may drive the extended-joint manually in Joint mode.

If the motor vibrates abnormally or stops due to any error, check the wiring of the motor. If the wiring is correct, gradually decrease the positional loop gain and speed proportional gain of the servo configuration parameters.

(6) Executing CALSET

Release the brake of the extended-joint motor and move the optional mechanism connected to the motor to the CALSET reference position. Then execute CALSET in the CALSET reference position.

NOTE: Take care not to perform CALSET on any robot joint. Performing it on a robot joint will change the reference angle of the robot.

(7) Checking the motion of the optional mechanism connected to the extended-joint motor

Run the optional mechanism connected to the motor manually in Joint mode and check that an error will be detected if the mechanism exceeds the positive or negative motion limit.

Also check that the actual movement amount matches the values displayed in the Current Robot Position window of the teach pendant. If not, check the gear ratio and lead.

3.2.3 Gain Tuning of Extended-Joints

You have set the motion conditions of extended-joints and checked the motion of the optional mechanism connected to the extended-joint motors manually in Joint mode. After that, proceed to the gain tuning for the servo system.

Tune the servo system according to the following two types of tuning methods:

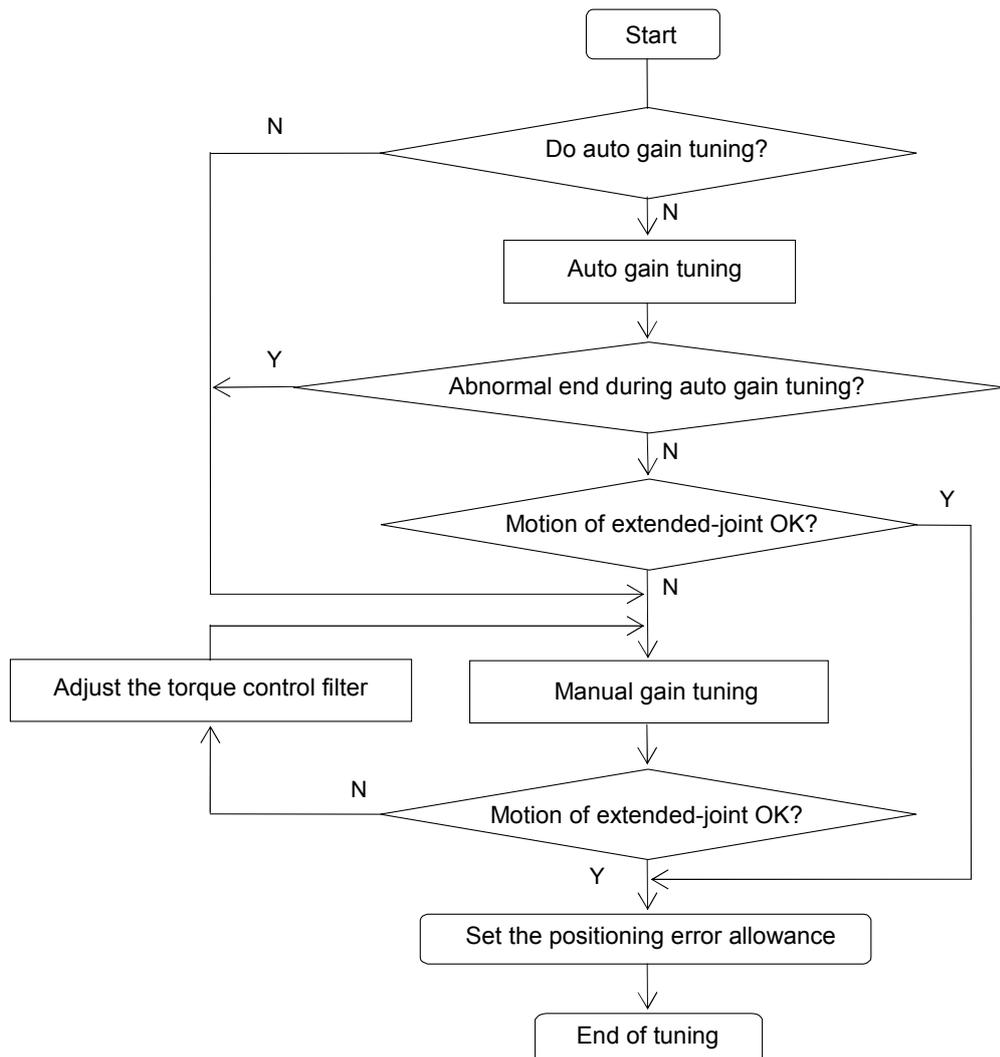
(1) Auto gain tuning

The controller performs acceleration/deceleration operation of the extended-joints according to the default pattern preset in the controller. Based on the motion of the extended-joints in that operation, the controller will estimate the inertia of payload and set the appropriate gain automatically.

(2) Manual gain tuning

The monitor function of the single-joint servo data monitors the motor speed control value, current motor speed, motor angle deviation, and torque control value. According to the monitored results, you may adjust the gain and torque control filter parameters for optimizing the motion of the extended-joints.

Follow the next flowchart to tune the servo system.



3.2.3.1 Auto gain tuning

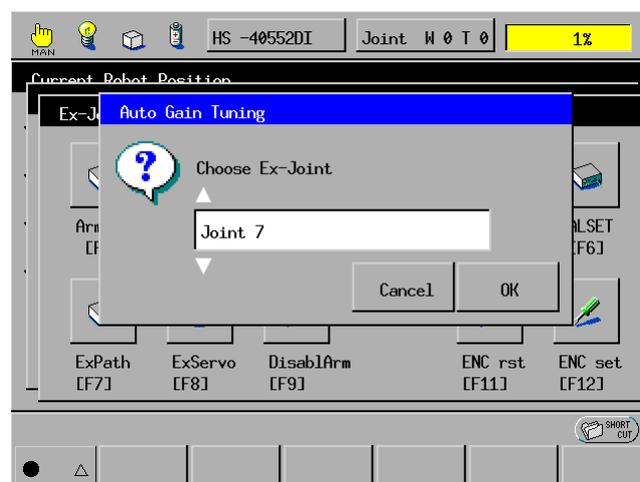
To implement auto gain tuning, your optional mechanism to be connected to the extended-joint motor should satisfy the requirements given in [1] below. Otherwise, some errors may occur and the auto gain tuning process may be interrupted. If such happens, implement manual gain tuning.

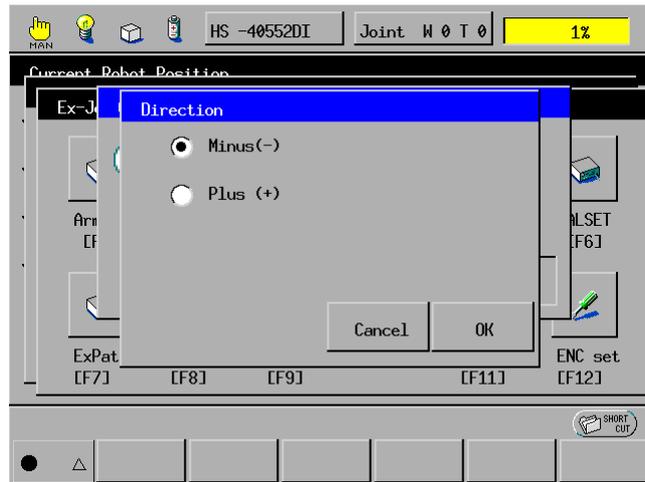
[1] Requirements for implementing auto gain tuning

- (1) The inertia of payload should be within 15 times that of the motor and should not deviate greatly.
- (2) The rigidity of the torque transmission mechanism (including motor and coupling) to be connected to the extended-joint motor should be high.
- (3) The backlash in the torque transmission mechanism should be minimized.
- (4) Rotating the motor in CCW and CW directions alternately two times each direction should result in no problem.

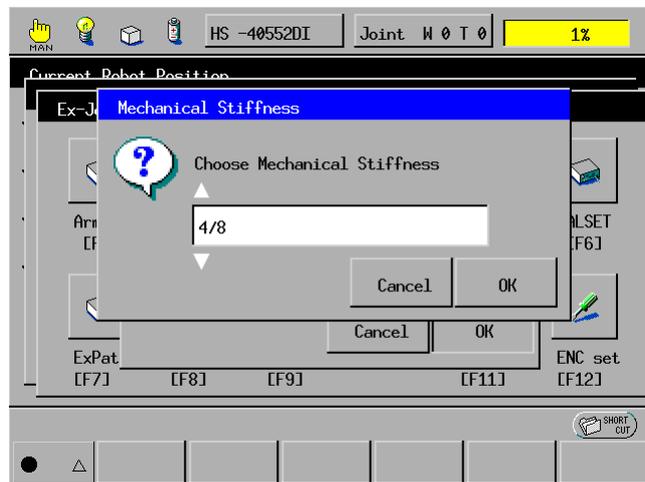
[2] Auto gain tuning procedure

- (1) Turn the motor power on and perform CAL.
NOTE: If the robot is in Auto or Teach check mode, switch to Manual mode.
- (2) Get out of the motion range so that there will be no problem even if the motor rotates in CCW and CW directions alternately two times each direction.
- (3) On the teach pendant, call up the Joint Settings window.
Access: Top Screen—[F2 Arm]—[F12 Maint.]—[F7 Joints]
- (4) Press [F5 Auto Gain] to call up the Auto Gain Tuning window as shown below.
Choose the joint number that should undergo auto gain tuning and the motor rotation direction.



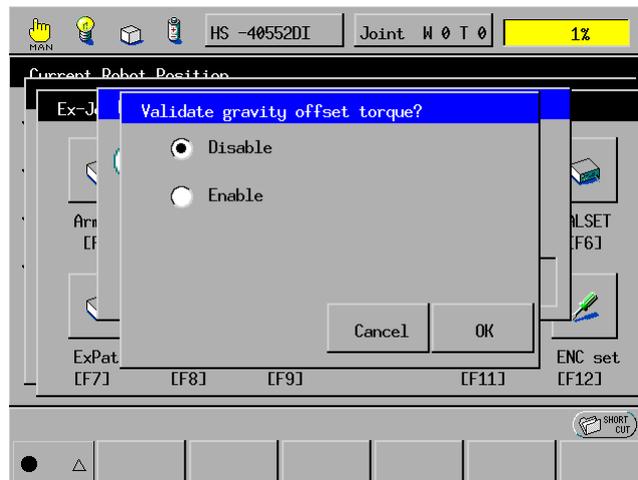


(5) Select the mechanical rigidity, referring to the rigidity reference values listed below.



Types of Torque Transmission Mechanisms	Mechanical Rigidity
Ball screw direct connection	4 to 8
Ball screw with transmission mechanism	3 to 7
Timing belt	3 to 6
Gear or rack & pinion	2 to 6
Other mechanism with low rigidity	1 to 3

- (6) Select whether the gravity offset torque should be enabled or disabled.



If an unbalanced load applies to the motor, be sure to enable the gravity offset torque.

NOTE: If you disable gravity offset torque when the motor undergoes any unbalanced load, then the extended-joint will drop in the gravity direction, causing an error. To implement auto gain tuning when an unbalanced load applies to the motor, be sure to enable the gravity offset torque.

If you enable the gravity offset torque for auto gain tuning, the controller will automatically calculate the torque offset included in servo configuration parameters. On the Joint Settings window, press [F8 Servo] to call up the servo configuration parameters window and then press OK to save the calculated torque offset value.

NOTE: If you turn the controller power off without saving the calculated torque offset value, then the value will be lost and the previous value will resume.

- (7) Hold down either one of the deadman switches through all processes of auto gain tuning. Releasing it will interrupt auto gain tuning.

NOTE: During auto gain tuning, do not press any key on the teach pendant except for the deadman switches. Doing so will interrupt auto gain tuning.

NOTE: If the joint motion has been set to [2:Encoder] on the servo configuration parameters window, then the error message "Not executable" will appear during auto gain tuning.

- (8) In the dialog box shown below, confirm the conditions and press OK. In the confirmation window, press OK. Then auto gain tuning will start. The motor rotates in CCW and CW directions alternately two times each direction in two sequences to calculate a temporary servo loop gain.

After that, the motor will repeat the sequence up to 8 times to fine-tune the gain. If the gain is fixed within the eight sequences, auto gain tuning will complete.

Caution:

For a boundless rotation joint, CALSET needs to be performed after each auto gain tuning, which deletes CALSET values.



- (9) After eight sequences of the above fine tuning operation, any of the following messages may display:

"Auto gain tuning warning 1": Overshoot found at the end of motion.

"Auto gain tuning warning 2": Slow settlement found at the end of motion.

"Auto gain tuning warning 3": Low-level oscillation found during motion.

If any of the above messages displays but there is no problem with the joint motion, then finish the gain tuning. If any abnormal noise or vibration is noted and there are some problems with the motion, then change the mechanical rigidity. After that, retry auto gain tuning or proceed to manual gain tuning.

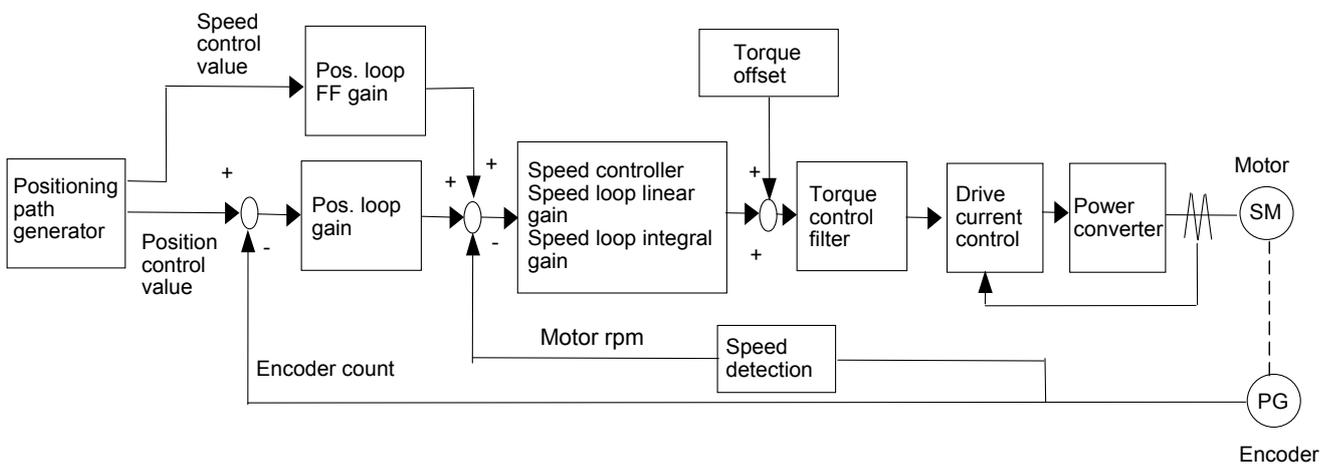
- (10) If you set higher mechanical rigidity for transmission mechanism having lower rigidity and vice versa, then an error may occur during auto gain tuning. Change the mechanical rigidity setting and retry auto gain tuning.

3.2.3.2 Manual gain tuning

You can manage the following parameters for manual gain tuning:

- (1) Positioning loop gain
- (2) Positioning loop feed forward gain
- (3) Positioning error allowance
- (4) Speed linear gain
- (5) Speed loop integral gain
- (6) Torque control filter
- (7) Torque offset

The block diagram for the servo system is shown below.



An electric servo loop system consists of the three feed back systems--positioning loop, speed control loop, and drive current loop. The inner the loop is, the quicker response required. If the response of an inner loop is not sufficiently high for an outer loop, then the overall system response degrades and vibrations or oscillations may occur in the extended-joint support system.

In this system, the innermost loop is the drive current loop and the outermost loop, the positioning loop.

You need to do gain tuning for the positioning loop and speed control loop. The drive current loop is designed to have sufficiently high response for all applications allowable to the extended-joint support system.

[1] Parameter details

(1) Positioning loop gain

Set the response of the positioning loop. The positioning loop gain is a dimensionless number, so it may be converted to the (1/s) unit according to the following formula:

$$\text{Positioning loop gain} \times 125/256 \text{ (1/s)} \quad \text{(Formula 3.2.3-1)}$$

For example, positioning loop gain 32 is equivalent to 15.625 (1/s).

Increasing the positioning loop gain will reduce the positioning time. However, increasing the gain exceeding the natural oscillation frequency of the connected mechanism will easily bring vibration or overshoot. If the natural oscillation frequency is 20 Hz, for instance, set the positioning loop gain to 20 (1/s), that is, approx. 41.

(2) Positioning loop feed forward gain

Set the speed feeding forward value of the positioning loop. Increasing the value will reduce the positioning error and increase the system response. Setting 100 may reduce the positioning error to almost 0 in constant speed operation. However, setting an excessively high value may easily cause vibration or overshoot in the system.

(3) Positioning error allowance

Set the positioning error allowance. If the actual positioning error exceeds the specified allowance, an error will occur. The positioning error allowance should satisfy the following formula:

$$\text{[Positioning error allowance]} > \frac{\text{[Maximum motor speed (rpm)]} \times (1.0 - \text{[Positioning loop forward gain (\%)]} \times 0.01)}{\text{[Positioning loop gain]} \times 524288/1875} \quad \text{(Formula 3.2.3-2)}$$

(4) Speed control linear gain

Set the response of the speed control system. Increasing the value will make it possible to set a high value to the positioning loop gain, thereby increasing the system response. The speed control linear gain to be set may be converted to the speed response frequency (in Hz) according to the following formula:

$$\text{Speed response frequency (Hz)} = \frac{\text{[Speed control linear gain]} / \text{[Motor rotor inertia (kgm}^2\text{)} + \text{Load inertia converted at motor joint (kgm}^2\text{)]} \times \text{[Drive current loop gain]} / (2\pi)}{\quad} \quad \text{(Formula 3.2.3-3)}$$

The table below shows the current control gains.

Motor model	Capacity	Current control gain
R2AA04005F	50W	1.650E-05
R2AA04010F	100W	2.804E-05
R2AA06020F	200W	5.001E-05
R2AA06040F	400W	7.894E-05
R2AA08075F	750W	1.141E-04

(5) Speed control integral gain

Set the integral compensation gain of the speed control system. You may convert the integral gain of the speed control loop into integral speed loop gain time constant (ms) according to the following formula:

$$\text{Integral speed loop gain time constant (ms)} = 0.25 \times [\text{Speed control linear gain}] / [\text{Speed loop integral gain}] \text{ (Formula 3.2.3-4)}$$

Increasing the value will decrease the integral time constant, making the speed error converge faster at the end of joint motion. However, increasing the value for the connected transmission mechanism having lower rigidity will decrease the convergence of residual oscillation at the end of joint motion.

(6) Torque control filter

This value sets the band of the linear delay component for the torque control filter. The table below lists the relationship between the value and the band.

Filter set value	3	4	5	6	7	8	9	10	11	12	13	14	15
Band (Hz)	2450	1080	843	682	559	460	377	305	241	184	133	85	41

(7) Torque offset

This value gives an offset to the torque control value of the extended-joint support system. If the motor undergoes any unbalanced load due to the force of gravity, setting this value will compensate the torque caused by the unbalanced load. The maximum offset value you can set is equal to the rated output torque of the motor.

If you set a large torque offset at once, the connected mechanism may move in the preset direction immediately after the motor power is turned on. Gradually change the torque offset while confirming the current torque value and positioning error waveform in the next item "[2] Monitor of single-joint servo data."

Selecting the gravity offset torque in auto gain tuning automatically configures the torque offset value.

[2] Monitor of single-joint servo data

This function allows you to monitor a specified joint servo data currently set in the robot controller with graphs in real-time.

(1) Monitoring capability

This function is capable of handling up to 1,250 samples of data at once. If the sampling interval is set to 1 ms, then you may monitor the servo data for 1.25 seconds; if 8 ms, you may monitor it for 10 seconds.

The following five types of data may be monitored, two types at a time:

1) Motor speed control value (rpm)

Shows the sampled control value of motor speed.

2) Current motor speed (rpm)

Shows the sampled current motor speed.

3) Motor angle deviation (pulse)

Shows the deviation between the actual motor angle and motor control angle.

4) Torque control value (%)

Shows the substantial torque control value; that is, (Torque control value – the Torque offset value). The unit is a ratio to the rated motor torque (%).

5) Motor current (%)

Shows the currently maximal motor drive current between the 3-phase driving lines. The unit is a ratio to the motor rated current.

(2) Defining the monitoring terms

To define the monitoring terms, call the single-joint servo data monitor definition library `SetMonitorCond` in your program.

Once monitoring starts, the monitoring terms already defined can not be changed until the monitoring cycle has completed. Define all necessary monitoring terms before starting a monitoring cycle.

(3) Starting and stopping the monitoring cycle

To start monitoring, run the library `StartSrvMonitor`. To end it, run the library `StopSrvMonitor`. To clear the data collected in the monitoring cycle, run the library `ClearSrvMonitor`.

If the total number of data samples monitored in a monitoring cycle is 1250 or less, all data may be monitored. If it exceeds 1250 samples, the last 1250 data samples before the end of the cycle may be monitored and other data will be discarded.

If any error occurs and the motor being monitored is turned OFF during monitoring, then a maximum of 850 samples before the OFF and 400 samples after that may be monitored.

(4) Graphing the monitored data

Log Manager in WINCAPSIII allows you to graph the monitored data on a PC screen. For details, refer to the WINCAPSIII Guide, Chapter 10, Section 10.5 "Tools Menu (Log Manager)."

4.3.8, "New Features in Log Manager."

(4.1) Read monitored data

To read the monitored data (as Servo Joint Log) into Log Manager, first establish connection between the PC and robot controller in Communications Setting Manager and choose "Import" from the File menu in Log Manger to call up the "Receive Table" dialog box. From the table, select the <Servo Joint Log> and receive it.

(4.2) Plot the graph of monitored data

In Log Manager, choose "Servo Joint Graph" from the Tools menu. Adjust the scale and offset of the graph and check the graphed data.

(5) Saving the monitored data into a file

Log Manager in WINCAPSIII allows you to save the monitored data into a CSV file. For details, refer to the WINCAPSIII Guide, Chapter 10, Section 10.5 "Tools Menu (Log Manager)."

To save the data into a CSV file, choose "Export"—"Servo Joint Data" from the File menu.

[3] Operating procedure for manual gain tuning

(1) Initializing positioning loop gain

First set the positioning loop gain to almost the same value of that calculated from natural frequency of the connected mechanism.

If the natural frequency is 20 Hz, set the positioning loop gain to 41 which equals to $20 \times 256/125$ as calculated by Formula 3.2.3-1. If the natural frequency is unknown, use the default value 64.

(2) Tuning torque

If almost constant, unbalanced load (e.g., force of gravity) applies to the motor, then set the torque offset calculated from the load.

(3) Obtaining the limit of speed linear loop gain

While increasing the speed linear loop gain gradually, find the upper limit of the loop gain at which the connected mechanism will start producing abnormal noises or oscillations.

(4) Checking the effect of the torque control filter setting

First set the torque control filter parameter to "0" and find the upper limit of speed linear loop gain again. If the speed linear loop gain obtained here is lower than the previous one obtained in step (3), reset it to 8 (default).

(5) Determining the appropriate speed linear loop gain

Apply 80% of the limit obtained in steps (3) and (4) to the speed linear loop on the connected mechanism.

(6) Tuning the speed Integral loop gain

Gradually increase the speed integral loop gain so that the positioning time and peaks of overshoot and undershoot will be minimized to optimize the connected mechanism.

(7) Tuning the positioning loop gain

If the connected mechanism is still oscillatory after carrying out the procedure in step (6), then decrease the positioning loop gain.

If you decrease the positioning time further after tuning in steps (3) through (6), then gradually increase the positioning loop gain to the extent that no noise or oscillation will be produced.

(8) Tuning the positioning loop feed forward gain

If you further decrease the positioning time of the connected mechanism, gradually increase the positioning loop feed forward gain to the extent that no oscillation will be produced.

(9) Checking operations of the connected mechanism in full motion range and in full speed range

Run the connected mechanism in the full motion range while changing the speed gradually. If any abnormal noises or vibrations occur at some particular points, then check whether the mechanism slides evenly.

If any abnormal noise occurs in some particular speed, tune the torque control filter parameter again and check whether the abnormal noise decreases.

If tuning-up of the mechanism and torque control filter parameter cannot suppress abnormal noises, then decrease the speed linear loop gain and speed integral loop gain in the same proportion.

If any vibration occurs in some particular speed, decrease the speed integral loop gain, positioning loop gain, and/or positioning loop feed forward gain.

[4] Quick tuning function for speed control system gain

As expressed in Formula 3.2.3-4, the ratio of the speed linear loop gain to speed integral loop gain makes the integral speed loop gain time constant. For fine tuning of the speed control system gain, therefore, change the speed linear loop gain and speed integral loop gain in the same proportion. This simultaneous and proportional adjustment of those gains is "Quick tuning function for speed control system gain." You may use this function with the teach pendant.

- (1) Calling up the Quick Loop Gain Tuning screen using the teach pendant

Access: Top Screen—[F2 Arm]—[F6 Aux.]—[F7 Config.]—[F3 Jump To]

Select #59.

- (2) Setting a value to "Gain Decreasing Ratio (J*)" for the joint (J*) to be tuned

The gain decreasing ratio is called Tuning Ratio. The robot controller automatically modifies the current speed linear loop gain and speed integral loop gain by the number of "Tuning Ratio" times.

The relationship between the value to be set and the tuning ratio is listed below.

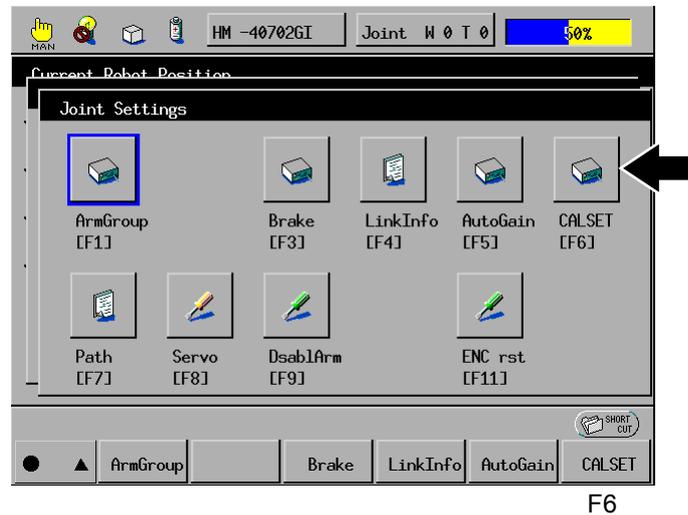
Set Value	-5	-4	-3	-2	-1	0	1	2	3	4	5
Tuning Ratio	1.5	1.4	1.3	1.2	1.1	1	0.9	0.8	0.7	0.6	0.5

3.2.4 Extended-Joints Exclusive Operations

3.2.4.1 Performing CALSET operation on an extended-joint

(1) Calling up the Joint Settings window

Access: Top Screen—[F2 Arm]—[F12 Maint.]—[F7 Joints]

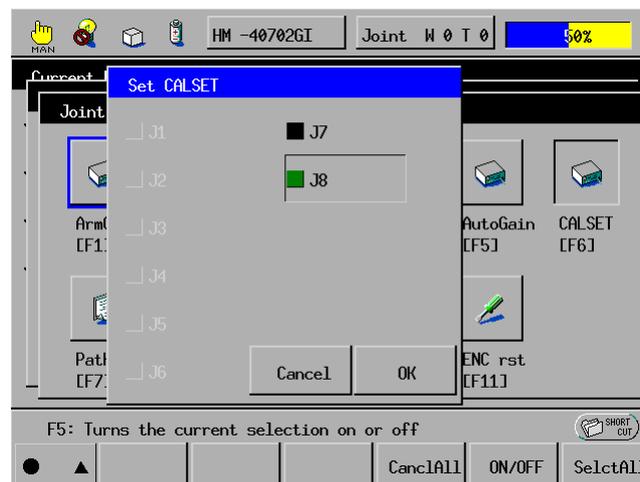


(2) Calling up the Set CALSET window

In the Joint Settings window, press [F6 CALSET] to call up the Set CALSET window.

(3) CALSETing a specified extended-joint

Select a joint to be CALSET and press OK. CALSET on the selected joint will start.



3.2.4.2 Releasing and locking an extended-joint brake

(1) Calling up the Joint Settings window

Access: Top Screen—[F2 Arm]—[F12 Maint.]—[F7 Joints]



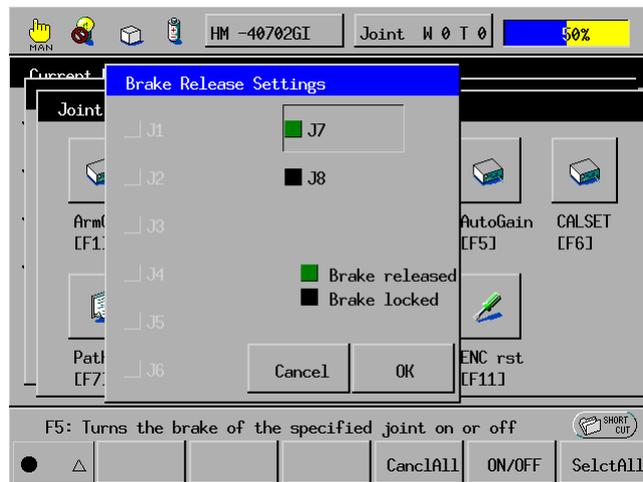
F3

(2) Calling up the Brake Release Settings window

In the Joint Settings window, press [F3 Brake.] to call up the Brake Release Settings window. When a brake is released, the joint displays in green; when locked, it displays in black.

(3) Selecting a target joint to be released or locked

Select a target joint and press [F5 ON/OFF] to change the indicator color. To release the brake, turn the indicator color green; to lock it, turn it black.

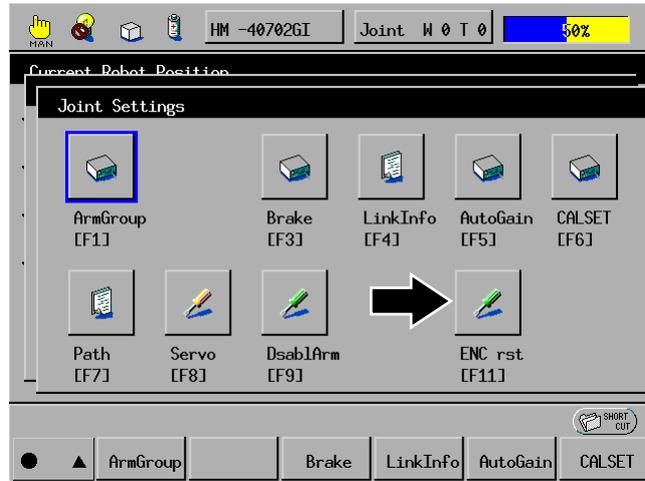


F5

3.2.4.3 Resetting an extended-joint encoder

(1) Calling up the Joint Settings window

Access: Top Screen—[F2 Arm]—[F12 Maint.]—[F7 Joints]



F11

(2) Entering the joint number of an encoder to be reset

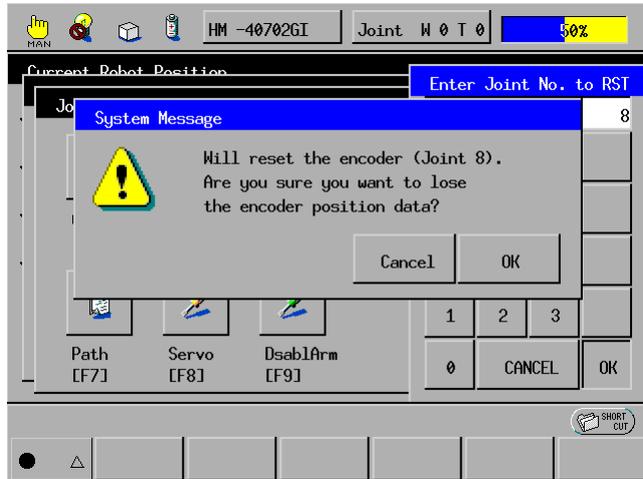
In the Joint Settings window, press [F11 ENC rst], and the numeric keypad for entering the joint number will appear as shown below.

Enter the joint number of an encoder to be reset and then press OK. Entering a robot joint number will cause an error.



(3) Confirming the specified joint number to be reset

The following confirmation message will appear. Check the specified joint number and press OK.



3.2.4.4 Enabling/disabling the robot arm

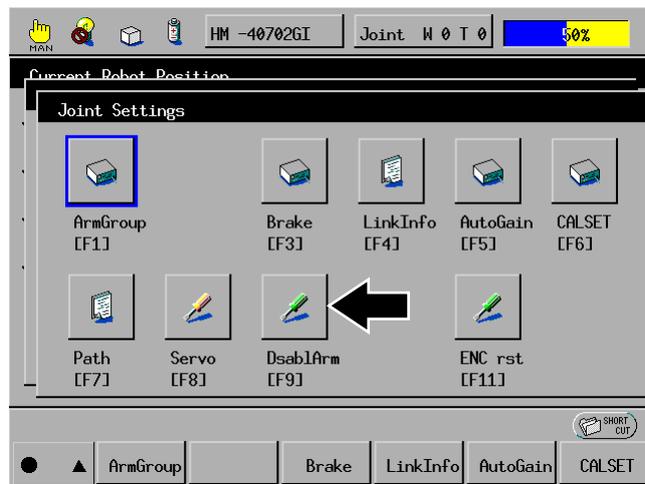
In adjustment of extended-joints, if you want to turn only extended-joint motors on for operational check without turning robot arm motor on, then disable the robot arm.

NOTE: Once you change this robot arm setting, be sure to restart the robot controller. Otherwise, an encoder-related error may occur.

NOTE: If the robot arm is disabled, turning the motor power on will not start the robot arm motors.

(1) Calling up the Joint Settings window

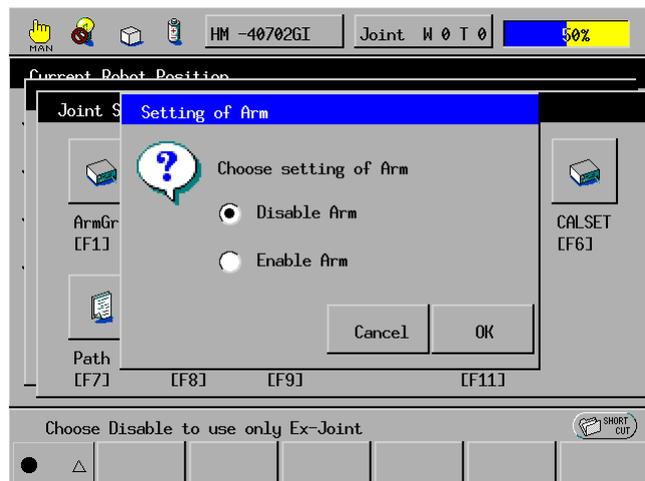
Access: Top Screen—[F2 Arm]—[F12 Maint.]—[F7 Joints]



F9

(2) Enabling/disabling the robot arm

In the Joint Settings window, press [F9 DsablArm], and the current arm setting will appear as shown below. Select the desired setting and press OK.



3.2.5 Extended-Joint Parameter Setting Commands

NOTE: Commands described in this section are used also for general robots.

[1] Single-Joint Servo Data Monitor Commands (Library)

Commands	Functions	Refer to:
SetMonitorCond	Set the monitoring conditions for single-joint servo data monitor.	PROGRAMMER'S MANUAL II
StartSrvMonitor	Start monitoring single-joint servo data.	PROGRAMMER'S MANUAL II
StopSrvMonitor	Stop monitoring single-joint servo data.	PROGRAMMER'S MANUAL II
ClearSrvMonitor	Initialize the pointer of data obtained by the single-joint servo data monitor function.	PROGRAMMER'S MANUAL II

[2] Operation Termination Commands

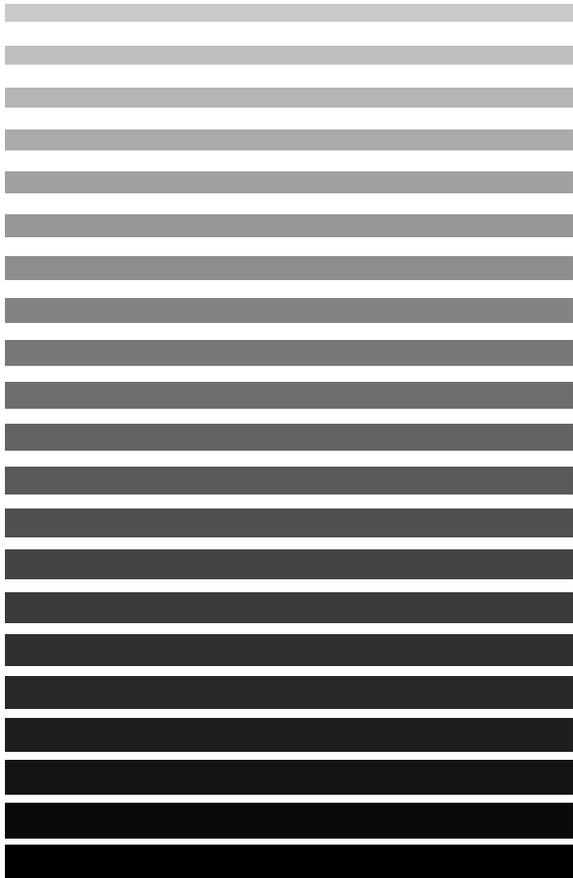
Commands	Functions	Refer to:
MotionSkip	Abort running motion commands.	PROGRAMMER'S MANUAL II
MotionComp	Judge whether execution of running motion commands is complete.	PROGRAMMER'S MANUAL II

[3] Internal Servo Data Get Commands

Commands	Functions	Refer to:
GetSrvData	Get the internal servo data of robot joints.	PROGRAMMER'S MANUAL I
GetJntData	Get the internal servo data of a specified joint.	PROGRAMMER'S MANUAL I

Chapter 4

Getting Started with Extended-Joints (Rack & Pinion)



This chapter guides you through the typical start-up procedure for driving extended-joints, taking a rack & pinion as an example.

The typical start-up procedure for driving extended-joints is given below, taking a rack & pinion as an example. Follow Sections 4.1 through 4.22. For details for each step, refer to the related items given in the previous chapters or in the related manuals.

4.1 Checking the Cable Connection

Check that the following cables are connected to the controller.

- Power cable
- Motor & encoder cable (Robot motor and encoder cables for XYC-4G series)
- Extended-joint motor cable(s) and their conversion cable(s)
- Extended-joint encoder cable(s)

4.2 Powering On the Controller

Turn the controller power switch on.

Caution: Never turn the motor power on.

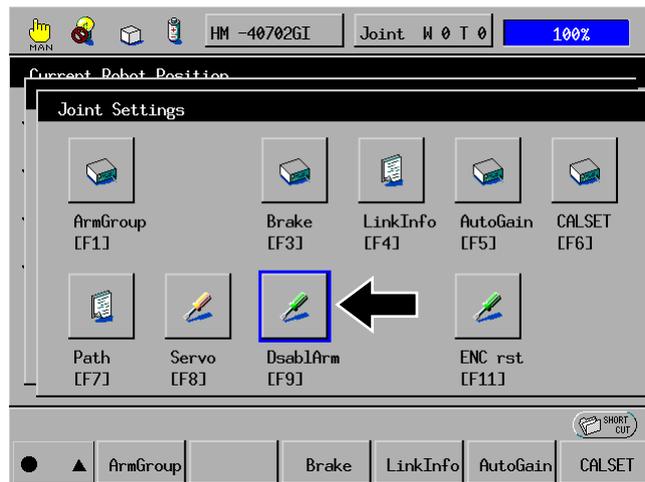
The "J7 Encoder System Down Error" message appears, so press the Cancel button on the teach pendant to clear the error.

4.3 Disabling the Robot Arm

For adjustment of extended-joints, you need to power on the extended-joint motor(s) for operational check without powering on the robot arm motor. Therefore, disable the robot arm using the following procedure.

(1) Call up the Joint Settings window.

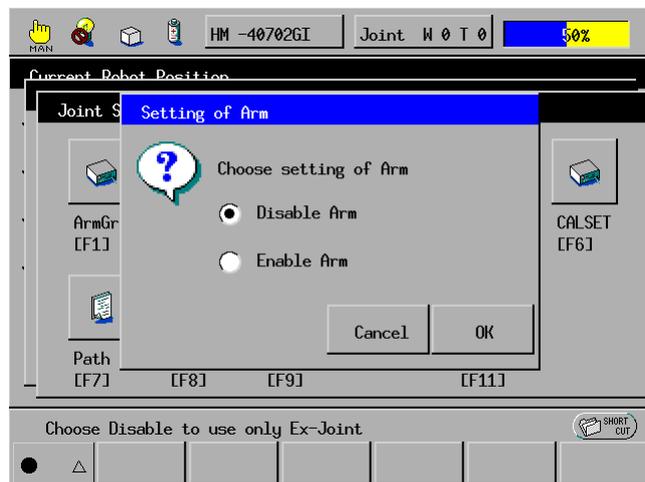
Access: Top Screen—[F2 Arm]—[F12 Maint.]—[F7 Joints]



(2) Press [F9 DsablArm] on the above window.

The current arm settings appear as shown below.

Select "Disable Arm" and press OK.



4.4 Restarting the Controller

Restart the controller.

Caution: Never turn the motor power on.

The "J7 Encoder System Down Error" message appears, so press the Cancel button on the teach pendant to clear the error.

4.5 Configuring the Extended-Joint Servo Parameters

Select an extended-joint to be used with the following procedure.

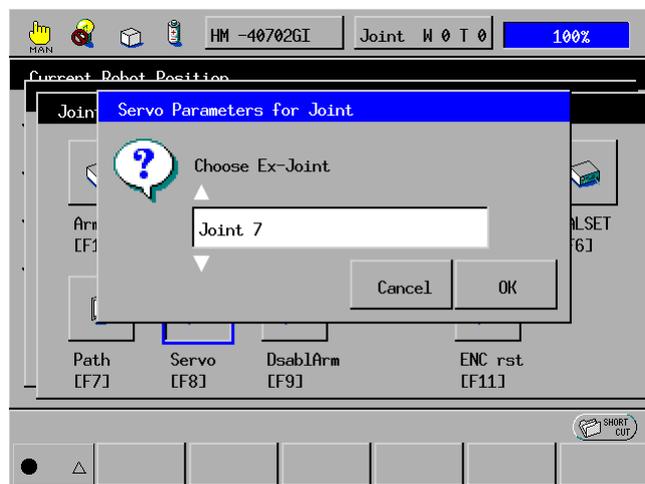
(1) Call up the Joint Settings window.

Access: Top Screen—[F2 Arm]—[F12 Maint.]—[F7 Joints]



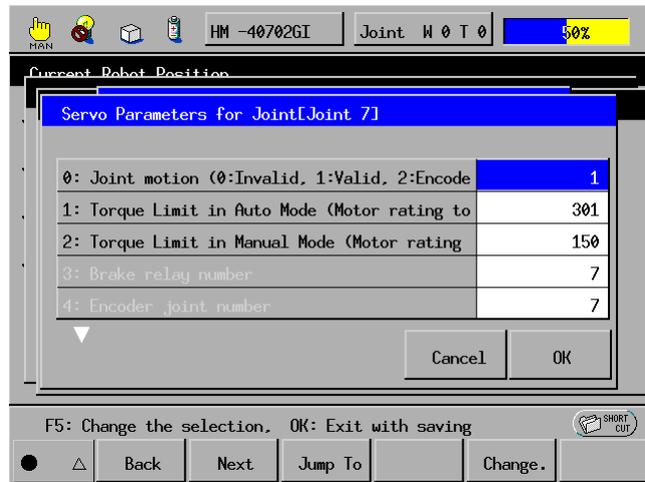
(2) Press [F8 Servo] on the above window.

The "Servo Parameters for Joint" window appear as shown below.



- (3) On the "Servo Parameters for Joint" window in step (2) above, select the target joint using the cursor keys or jog dial, and then press OK.

The servo configuration parameters window appears as shown below.



- (4) In the "Joint motion" field, select "1:Valid" and press OK.

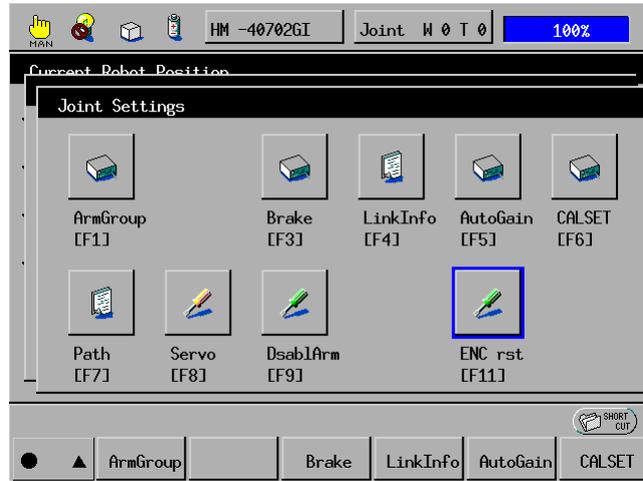
The screen returns to the Joint Settings window shown in step (1).

- (5) Repeat steps (2) through (4) for each joint to be used.

4.6 Resetting the Extended-Joint Encoder

(1) Call up the Joint Settings window.

Access: Top Screen—[F2 Arm]—[F12 Maint.]—[F7 Joints]

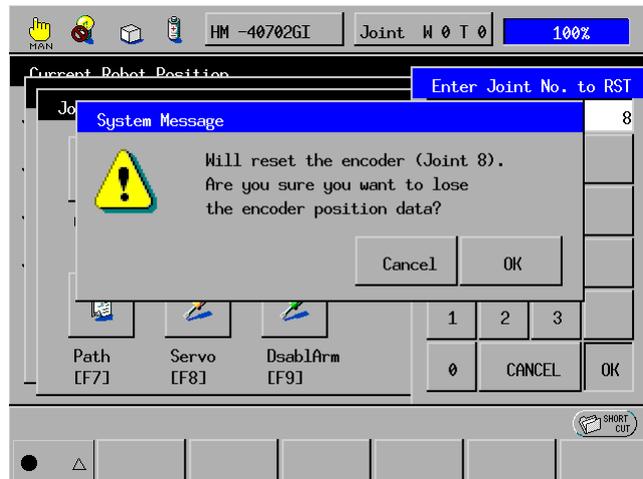


(2) In the above window, press [F11 ENC rst], and the numeric keypad for entering the joint number appears as shown below.

Enter the joint number of an encoder to be reset and then press OK.



(3) Wait for the following confirmation message to appear and then press OK.



4.7 Restarting the Controller

Restart the controller.

Caution: Never turn the motor power on.

The "J7 Encoder System Down Error" message appears, so press the Cancel button on the teach pendant to clear the error.

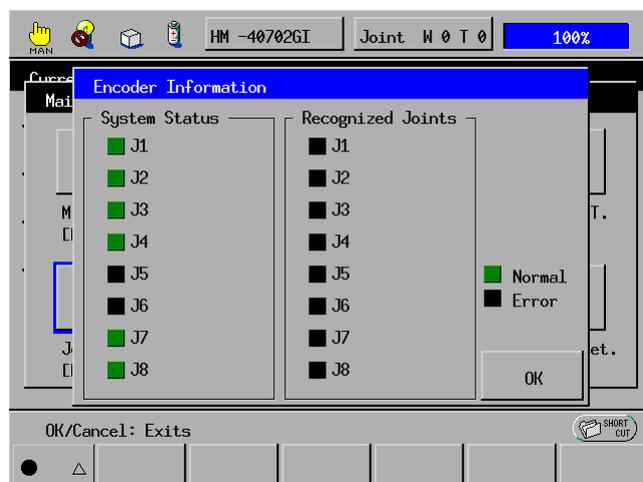
4.8 Checking the Encoder Info about Extended-Joints

Check that the extended-joint encoders are normal with the following procedure.

Call up the Encoder Information window.

Access: Top Screen—[F2 Arm]—[F12 Maint.]—[F10 ENCinfo.]

Check the boxes preceding extended-joints are green (normal).



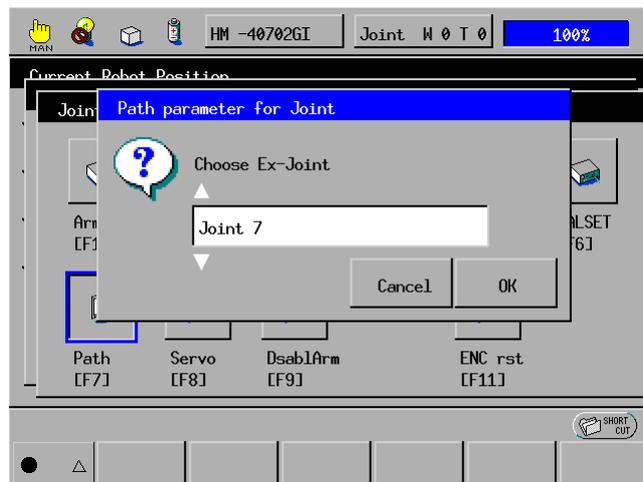
4.9 Configuring the Extended-Joint Parameters

Sections 4.9 and 4.14 instruct you to enter the minimum parameters required for manually moving extended-joints.

Select the desired axis and enter the parameters.

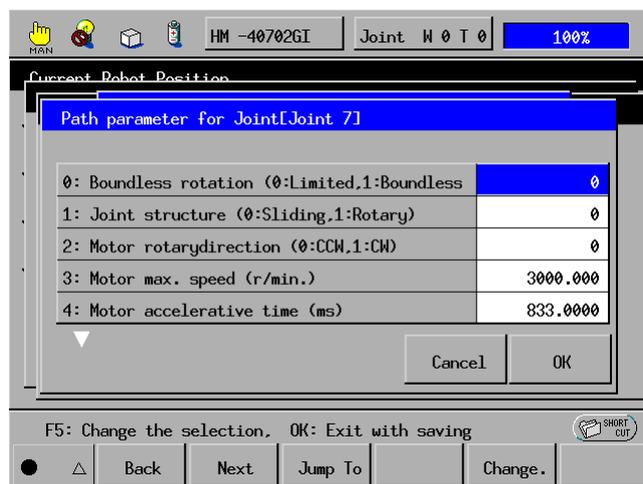
(1) Call up the "Path parameter for Joint" window.

Top Screen—[F2 Arm]—[F12 Maint.]—[F7 Joints]—[F7 Path]



(2) Select the target joint and press OK.

The path configuration parameters window appears as shown below.



(3) Configure the following parameters in the above window and then press OK.

- 0: Boundless rotation (0: Limited, 1: Boundless) (Usually enter "0.")
- 1: Joint structure (0: Sliding, 1: Rotary)
- 5: Gear ratio or lead (mm/r)

4.10 Restarting the Controller

Restart the controller.

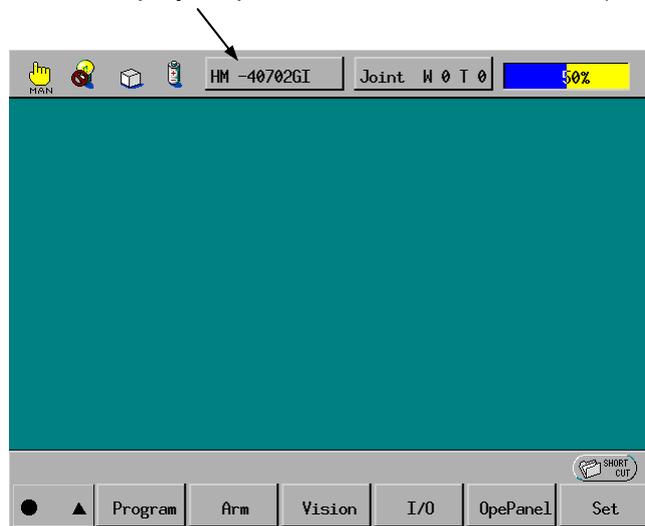
Caution: Never turn the motor power on.

The "J7 Encoder System Down Error" message appears, so press the Cancel button on the teach pendant to clear the error.

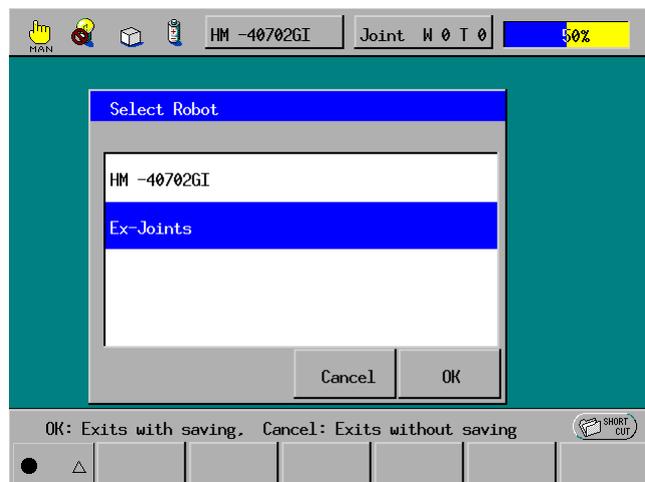
4.11 Checking the Encoder Feedback

Check that the controller receives a correct response from the extended-joint encoder.

- (1) With the top screen displayed, press the robot select button (or R-SEL key).



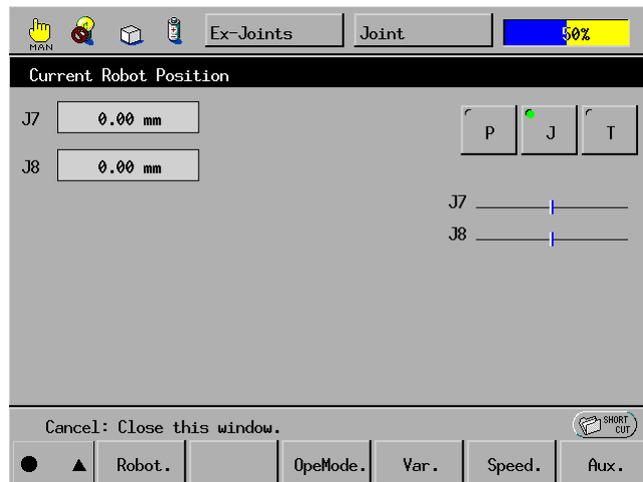
The Select Robot window appears as shown below.



- (2) Select **Ex-Joints** and then press OK.

The display returns to the top screen.

- (3) Press [F2 Arm] to call up the Current Robot Position window as shown below.



- (4) Move the extended-joint by hand to check that the encoder follows the joint movement.

Note: For an extended-joint having a brake, release the brake using the following procedure beforehand.

Releasing brakes

- 1) Access: Top Screen—[F2 Arm]—[F12 Maint.]—[F3 Brake.]
- 2) Select the joint to release the brake and then press OK.
Press OK again to lock the brake except when absolutely necessary.

4.12 Running the Extended-Joint Manually

- (1) Turn the motor ON.
- (2) Use the teach pendant to move the extended-joint in the positive (+) and negative (-) directions in Manual mode for checking for normal operation.

Note: No large movement is required in this step.

Note: Check that the movement direction specified with the arm traverse key matches the actual one of the extended-joint. If the direction is opposite, change the "2: Motor rotation direction" parameter" in Section 4.14.

4.13 Moving to the CALSET Position

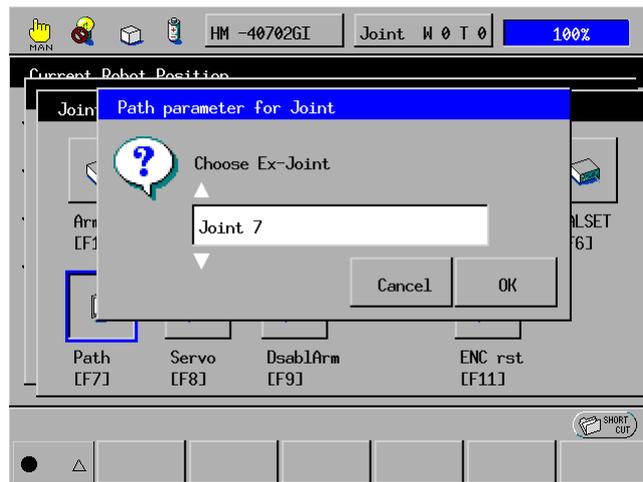
- (1) Turn the motor OFF.
- (2) Hold the joint by hand and move it to the CALSET position.

4.14 Configuring Other Extended-Joint Parameters

Enter other minimum required parameters not configured in Section 4.9.

- (1) Call up the "Path parameter for Joint" window.

Access: Top Screen—[F2 Arm]—[F12 Maint.]—[F7 Joints]—[F7 Path]

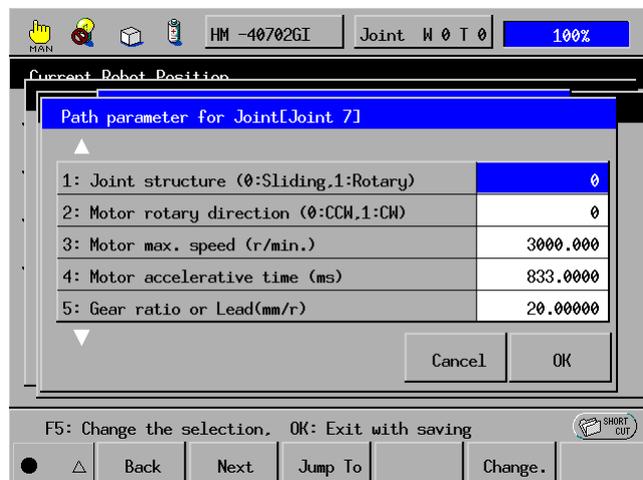


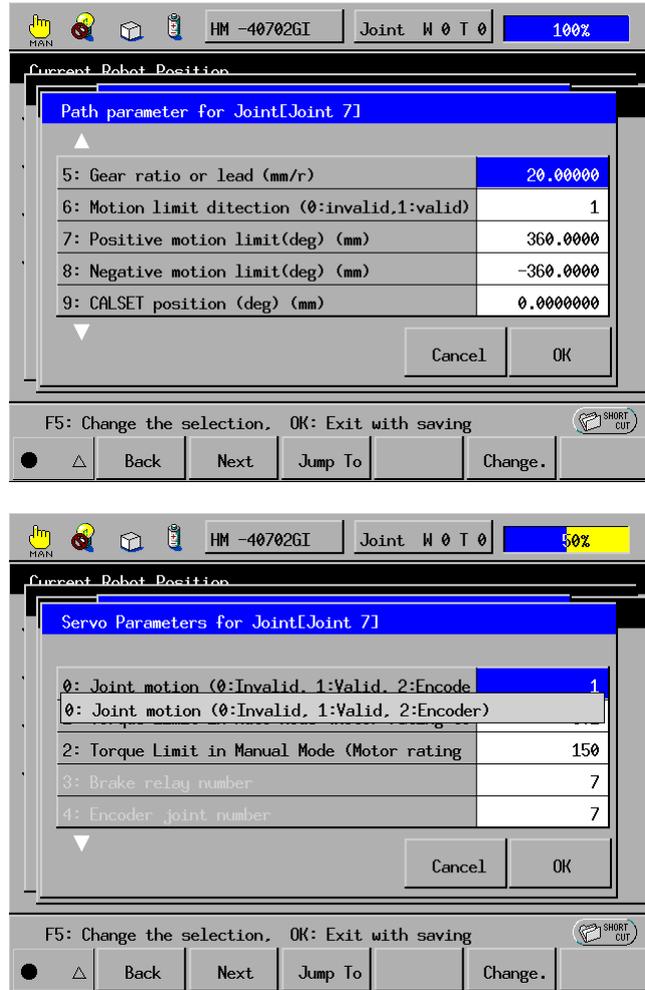
- (2) Select the target joint and press OK.

The path configuration parameters window appears as shown below and on the next page.

Configure the following parameters and then press OK.

- 2: Motor rotation direction (0: CCW, 1: CW)
- 3: Motor max. speed (r/min.)
- 4: Motor acceleration time (ms)
- 7: Positive motion limit (deg) (mm)
- 8: Negative motion limit (deg) (mm)
- 9: CALSET position (deg) (mm)
- 11: Rotation radius (mm)





4.15 Restarting the Controller

Restart the controller.

Caution: Never turn the motor power on.

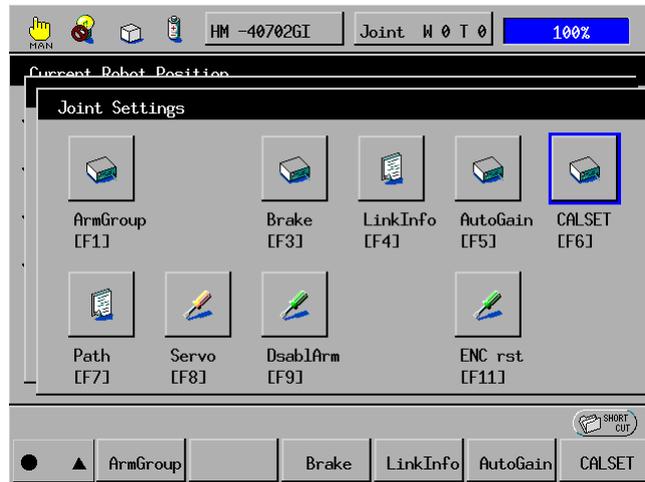
The "J7 Encoder System Down Error" message appears, so press the Cancel button on the teach pendant to clear the error.

4.16 Performing CALSET Operation

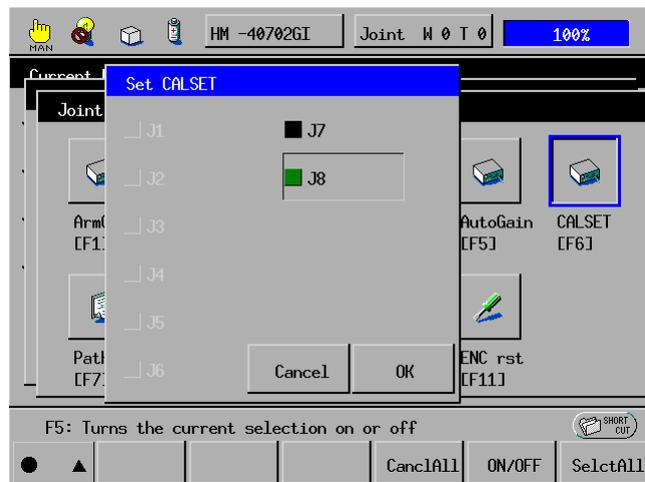
Perform CALSET operation extended-joints using the procedure given below.

- (1) Call up the Joint Settings window.

Access: Top Screen—[F2 Arm]—[F12 Maint.]—[F7 Joints]



- (2) Press [F6 CALSET] in the above window to call up the Set CALSET window as shown below.

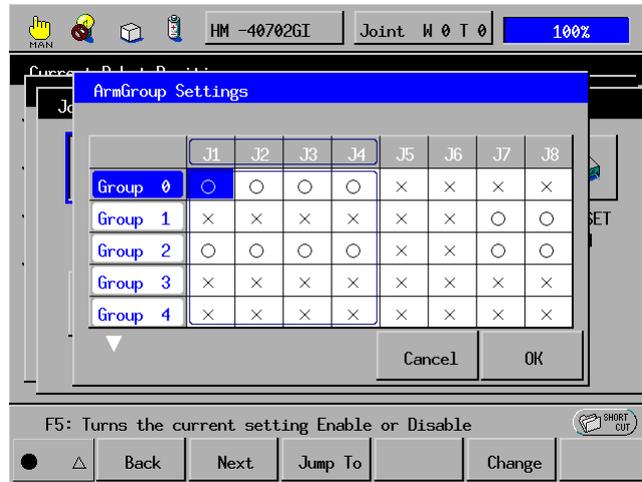


- (3) Select the extended-joint to perform CALSET and then press OK.
The controller performs CALSET operation for the specified joint.
In the same way, perform CALSET for other extended-joints.
- (4) After completion of CALSET operation, move the extended-joint(s) to the safe position by hand.

4.17 Setting up an Arm Group

(1) Call up the Arm Group Settings window.

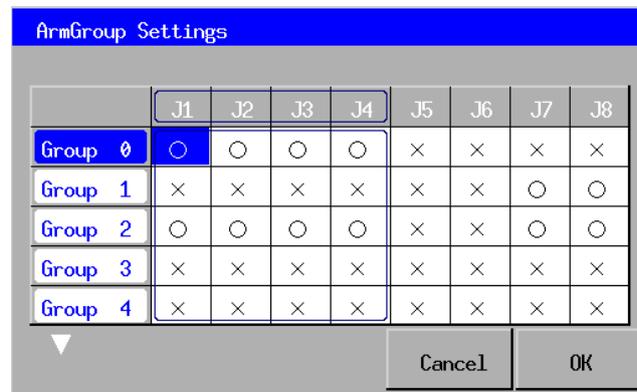
Access: Top Screen—[F2 Arm]—[F12 Maint.]—[F7 Joints]—[F1 ArmGroup]



(2) Move the cursor to a joint to be grouped and then press [F5 Change].

(3) After marking joints to be grouped or not with "O" or "X", respectively, press OK.

■ Arm Group Setup Example



This example sets up each group as shown below.

Group 0: Only robot joints involved.

TAKEARM 0

Group 1: Only extended-joints (7th and 8th) involved.

TAKEARM 1

Group 2: Robot joints and extended-joints (7th and 8th) involved.

TAKEARM 2

In programs, specify group numbers as shown below.

```

PROGRAM PRO0      PROGRAM PRO1      PROGRAM PRO2
TAKEARM 0         TAKEARM 1         TAKEARM 2
:
:
:
END              END              END
    
```

4.18 Restarting the Controller

Restart the controller.

Caution: Never turn the motor power on.

The "J7 Encoder System Down Error" message appears, so press the Cancel button on the teach pendant to clear the error.

4.19 Checking the Extended-Joint Motion

Create a sample program given below and run it to check the actual motion of extended-joints.

(1) Create the following motion program sample.

```
PROGRAM EX_TEST1
TAKEARM 1
DRIVEA @0(7,100),S=100 'Move extended-joint
DELAY 100 'Timer
DRIVEA @0(7,6000),S=100 'Move extended-joint
DELAY 100 'Timer
GIVEARM
END
```

(2) Set the external speed to about 10%, run the above program, and check the actual motion of extended-joints.

If any error occurs, investigate the sliding resistance of the extended-joint(s) or other probable causes.

4.20 Performing Auto Tuning

Perform auto tuning using the following procedure.

(1) Turn the motor power ON and perform calibration.

Note: If the controller is in Auto or Teach check mode, switch it to Manual mode.

(2) Move the extended-joint(s) to the position where rotating the extended-joints in the forward and reverse directions (in the counterclockwise and clockwise directions) each two times will not cause any problem.

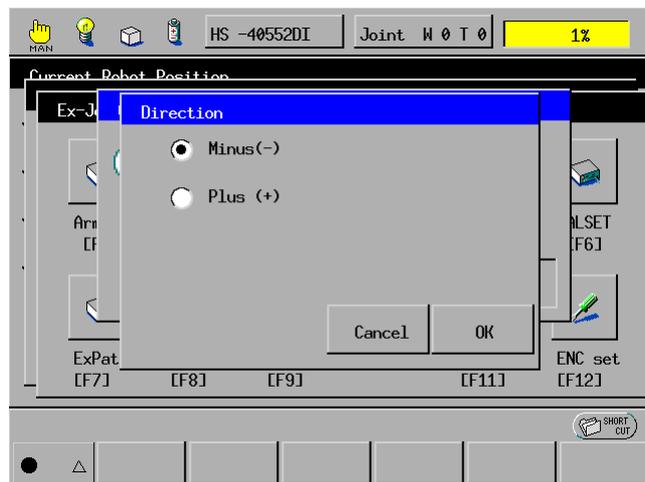
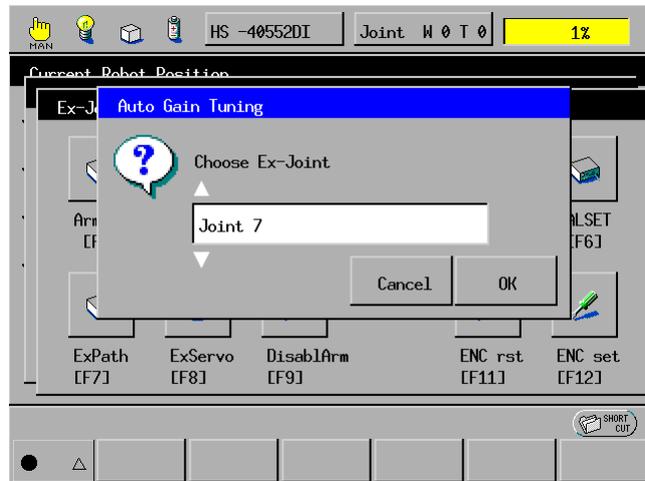
(3) Call up the Joint Settings window on the teach pendant.

Access: Top Screen—[F2 Arm]—[F12 Maint.]—[F7 Joints]

Chapter 4 Getting Started with Extended-Joints (Rack & Pinion)

- (4) Press [F5 AutoGain] to call up the Auto Gain Tuning window.

In the windows below, select the joint number to perform auto gain tuning and the movement direction.

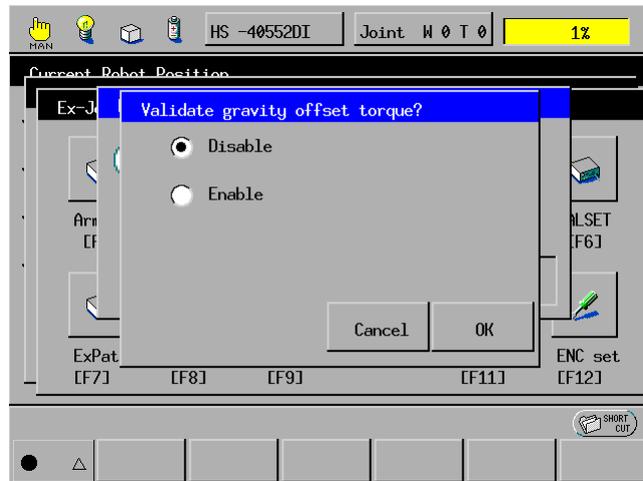


- (5) Select the machine rigidity, referring to the table below.

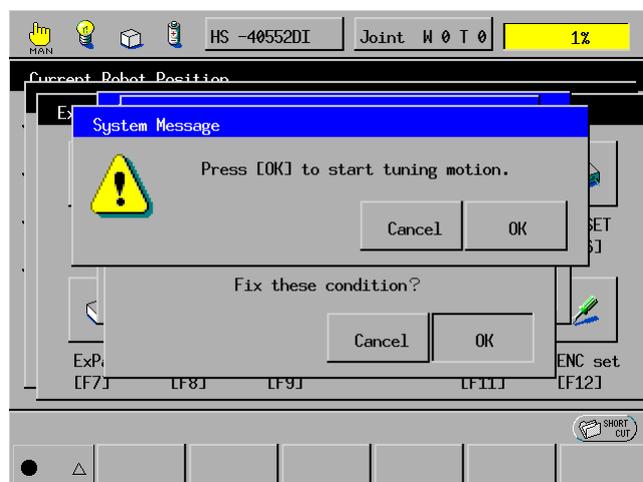
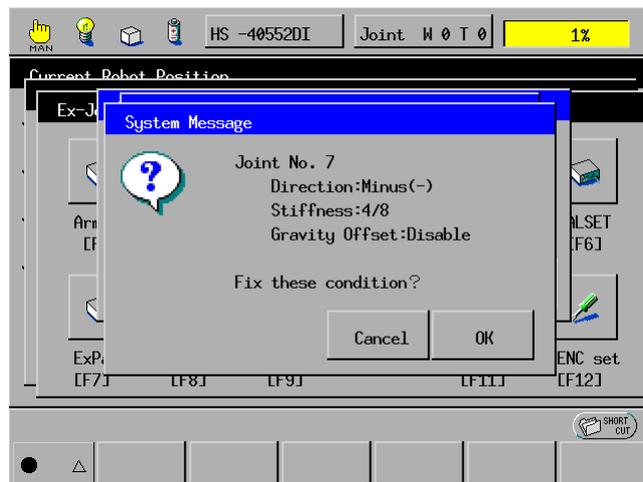
If the target machine is driven by:	Machine rigidity value
Ball-and-thread, direct-coupled	4 to 8
Reduction gear configured as a ball-and-thread drive	3 to 7
Timing belt	3 to 6
Gear, Rack & pinion	2 to 6
Other low rigidity machines	1 to 3

- (6) Select whether or not to enable the gravity offset torque.

Only for the mechanism in which the extended-joint vertically undergoes gravitational load, enable this function.



- (7) While holding down either one of the deadman switches, press OK. Auto tuning starts.



- (8) Wait for auto tuning to finish successfully.

4.21 Checking the Extended-Joint Motion in Running-in

Create a sample program for running-in and run it to check the actual motion of extended-joints while increasing the external speed.

- (1) Create the following program sample.

Read in a CALL program from the library.

```
'!TITLE "Reading in extended-joint torque and absolute current values"
PROGRAM EX_TEST2
TAKEARM 1

CALL SetMonitorCond(7,1,4,4) 'Set monitoring conditions for single-
                              'joint servo data monitor
CALL StartSrvMonitor          'Start monitoring the single-joint servo
                              'data
DRIVEA @0(7,100),S=100        'Move extended-joint
DELAY 100                     'Timer
DRIVEA @0(7,6000),S=100       'Move extended-joint
DELAY 100                     'Timer
CALL StopSrvMonitor           'End monitoring
END
```

- (2) First, set the external speed to about 10%, run the above program, and check the actual motion of extended-joints.

Gradually increase the external speed up to 100%.

If an acceleration error or any other error occurs during acceleration, decrease the "3: Motor max. speed (r/min)" out of the path configuration parameters by 500 rpm and go back to Section 4.20 "Performing Auto Tuning."

- (3) If no error occurs when the extended-joint is being driven with the external speed 100%, import the data to WINCAPSIII Log Manager and display the graph from the single-joint servo data log.

For details, refer to the WINCAPSIII Guide, Section 10.5.3 "Servo Joint Graph."



(4) Confirm the auto tuning state on the graph in step (3).

Note: The WINCAPSIII export function allows you to export the log data to the robot controller and save it as the desired name in CSV format.

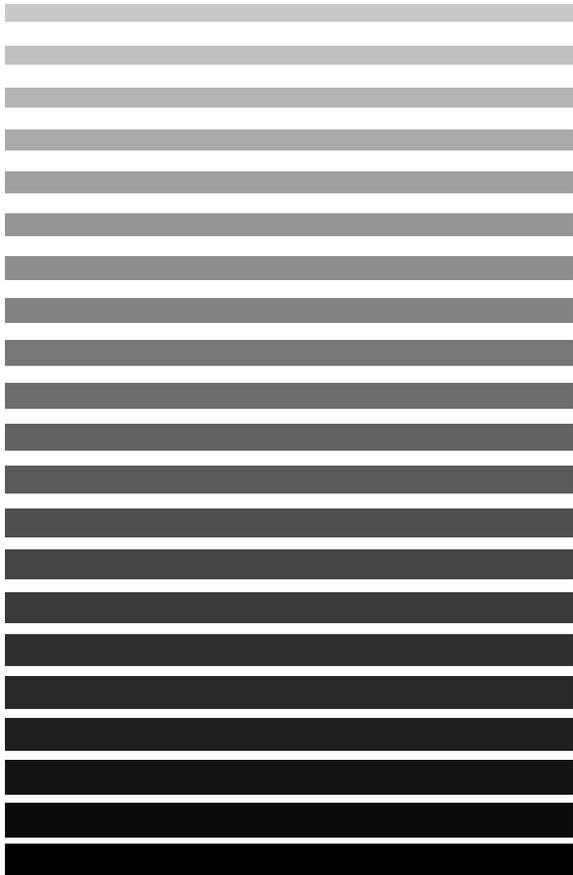
4.22 Enabling the Robot Arm

Enable the robot arm that has been disabled in Section 4.3.

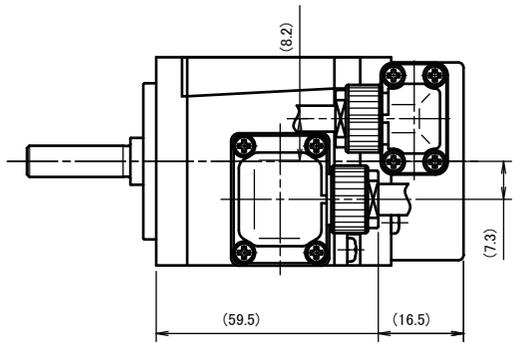
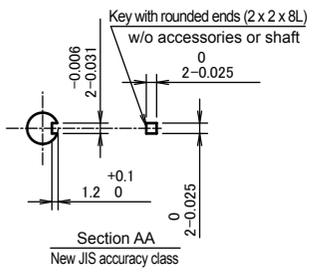
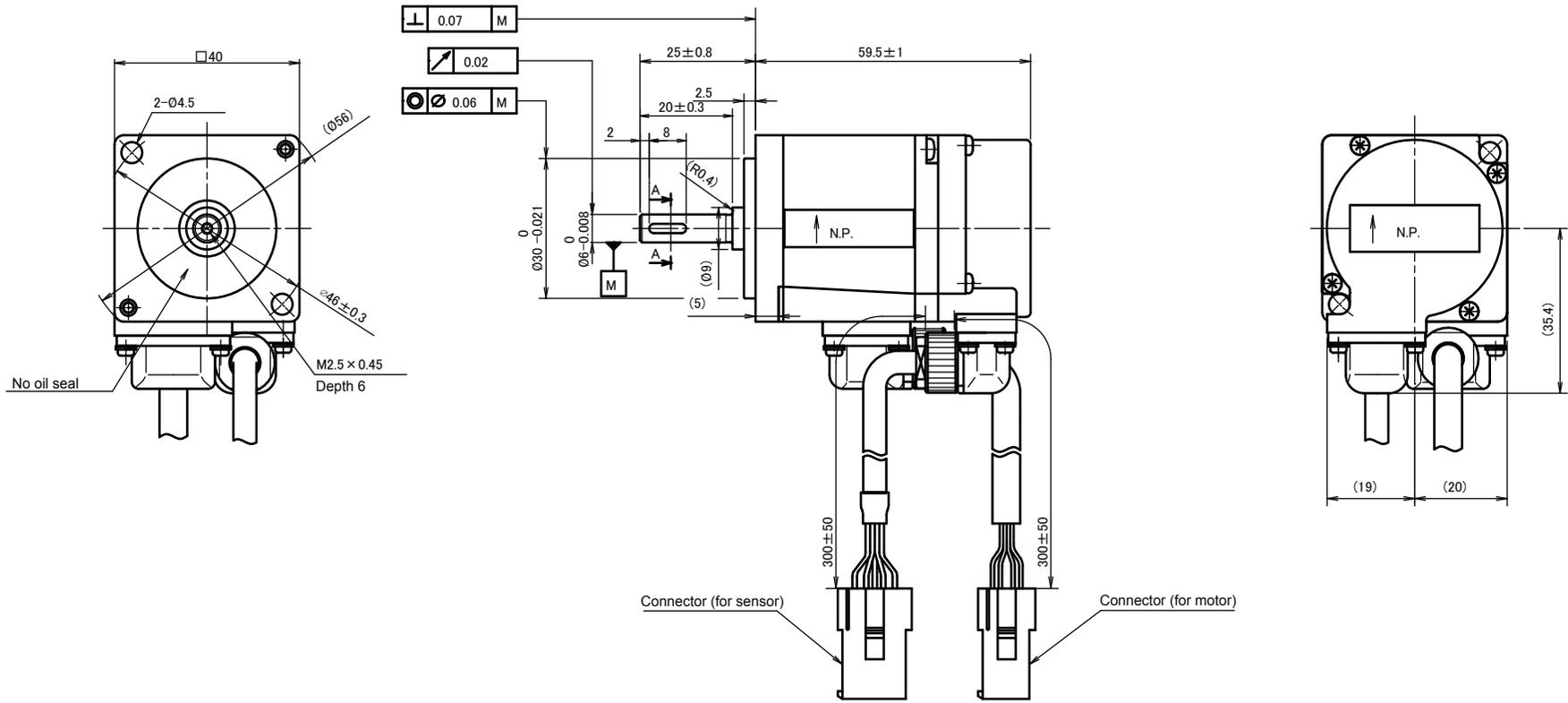
Chapter 5



Appendix

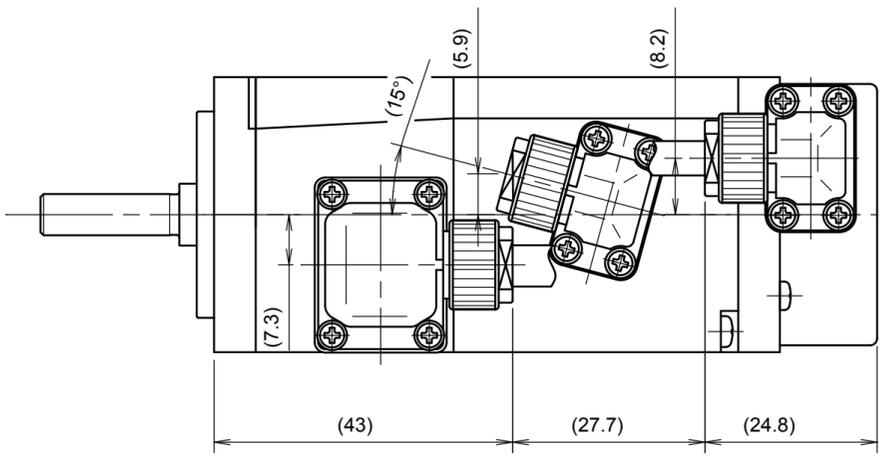
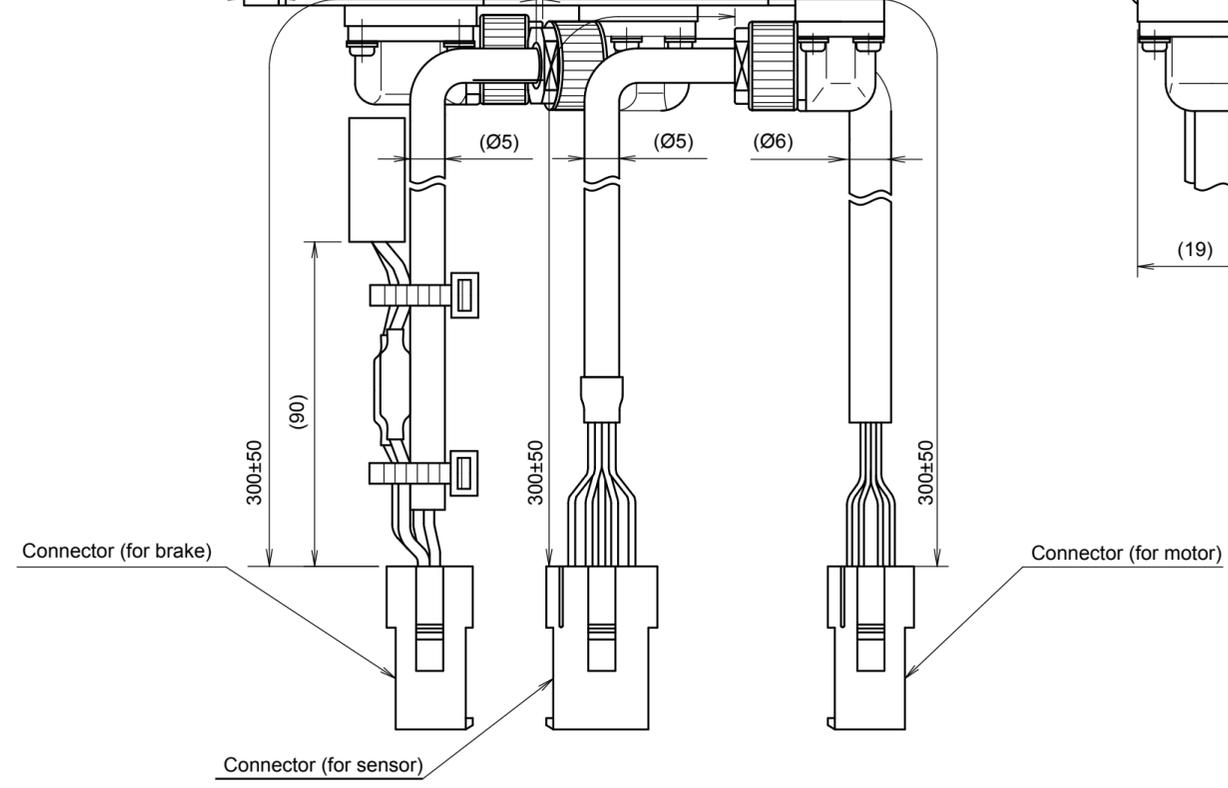
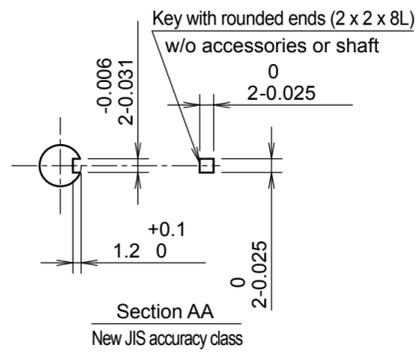
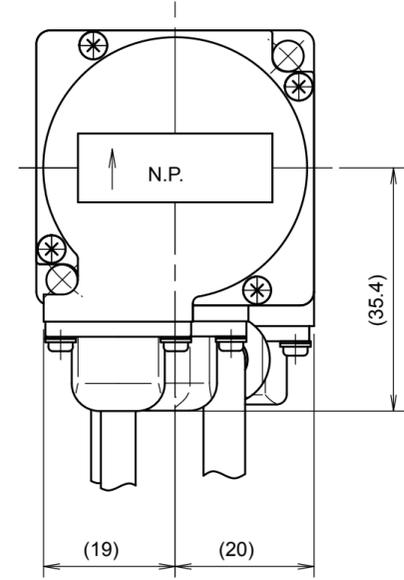
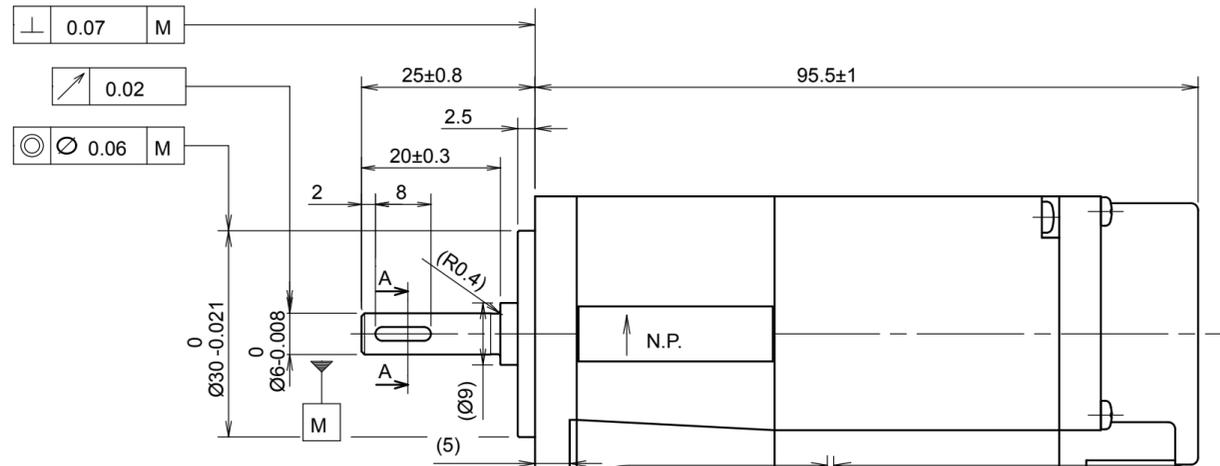
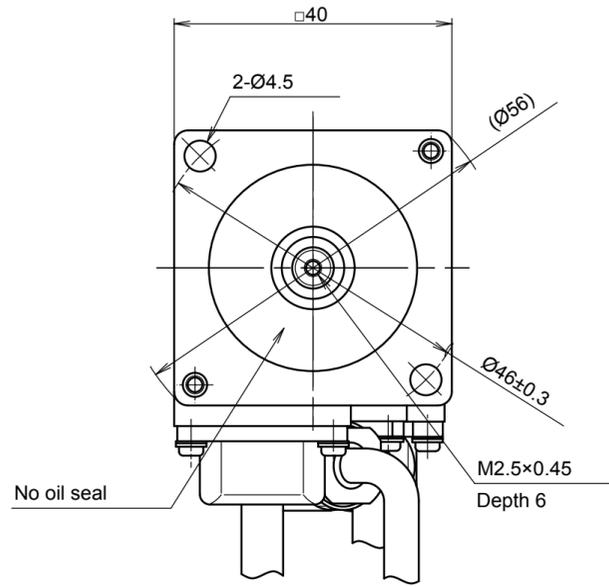


5.1 External Dimensions of Motors



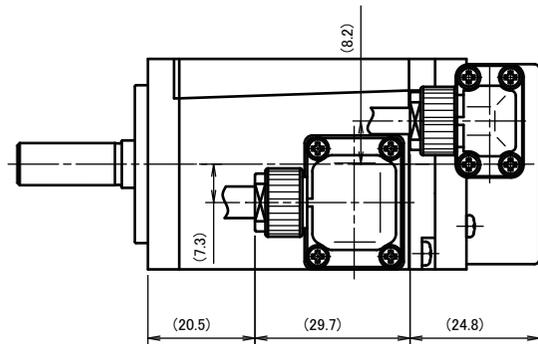
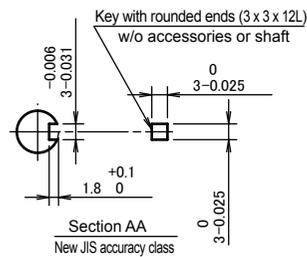
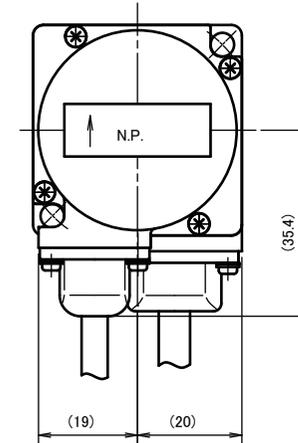
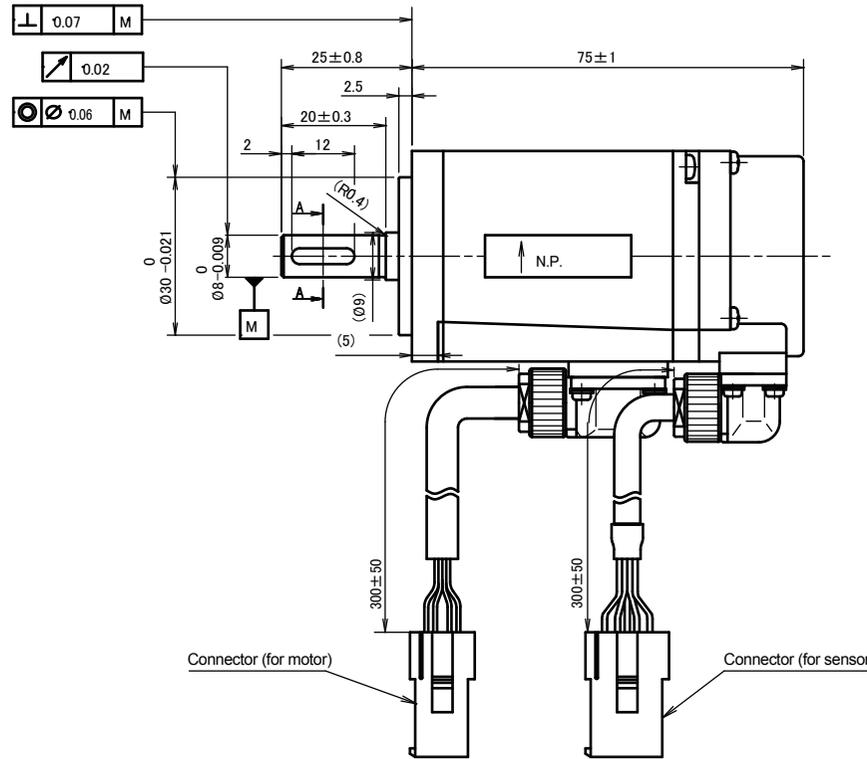
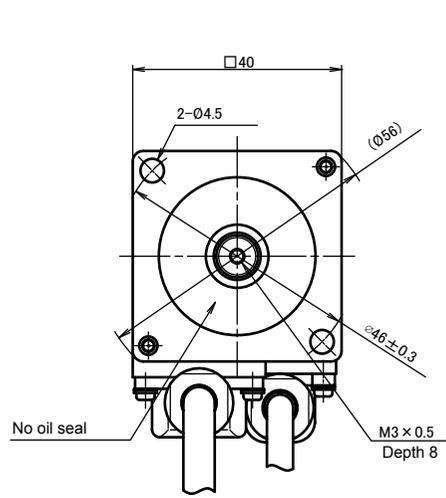
Allowable Shaft Load

In assembling		In running		
Radial load (N)	Thrust load (N)	Radial load (N)	Thrust load (N)	
FR	F direction	FR	F direction	
150	98	80	29	



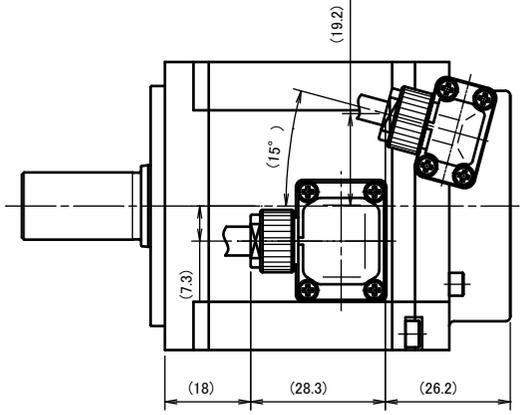
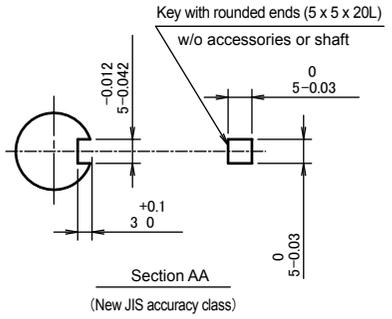
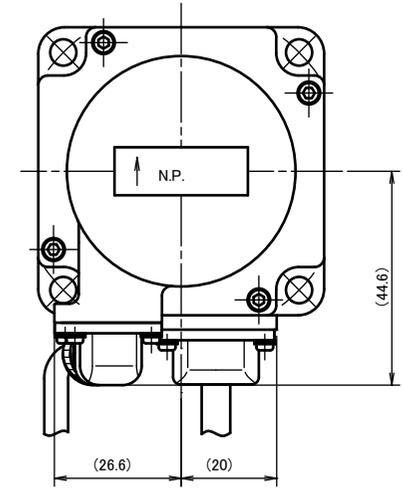
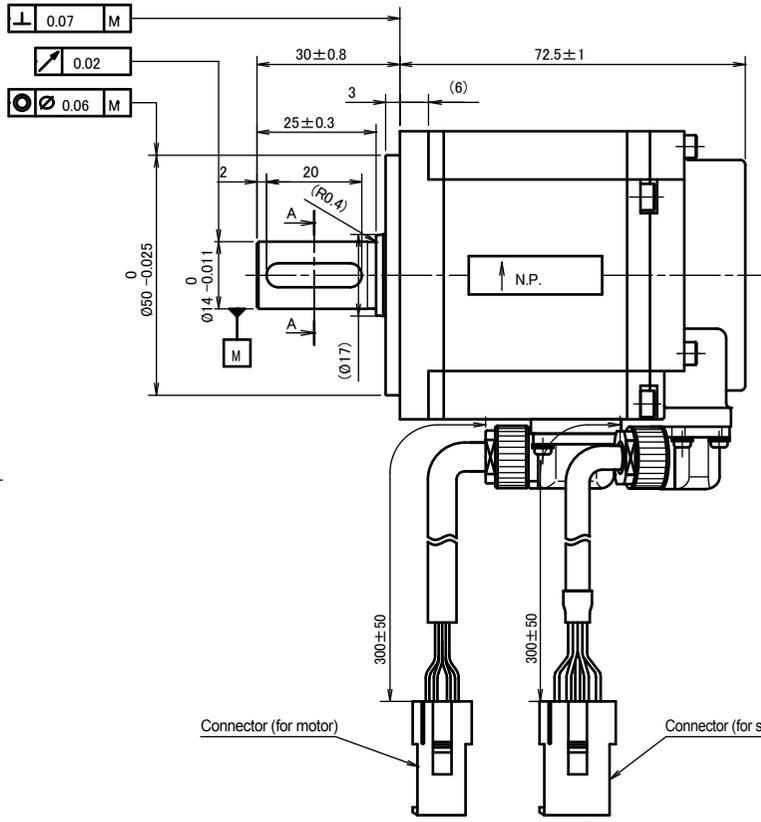
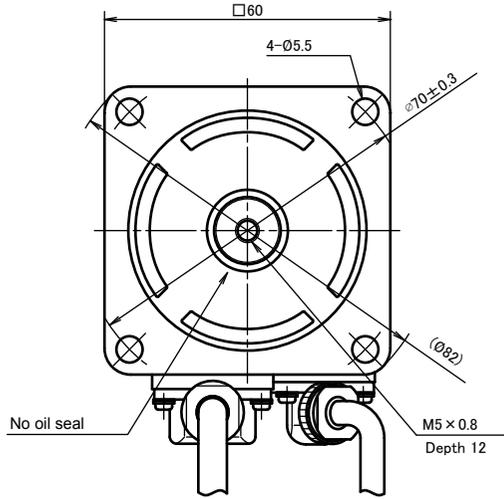
Allowable Shaft Load

In assembling			In running			
Radial load (N)	Thrust load (N)		Radial load (N)	Thrust load (N)		
FR	F direction	F1 direction	FR	F direction	F1 direction	
150	98	98	80	29	29	



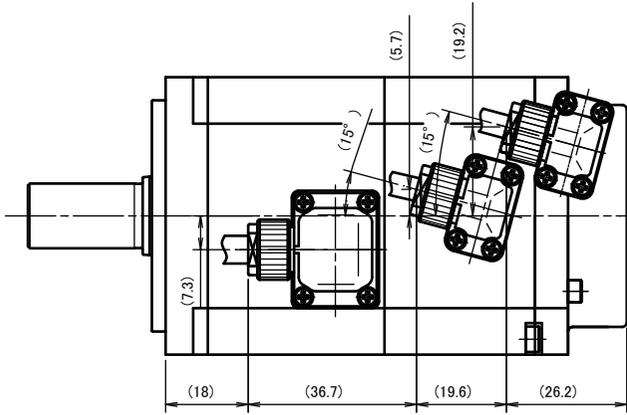
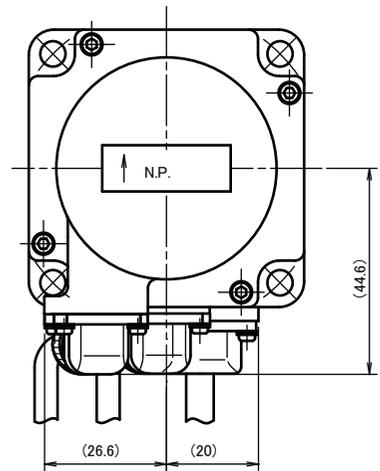
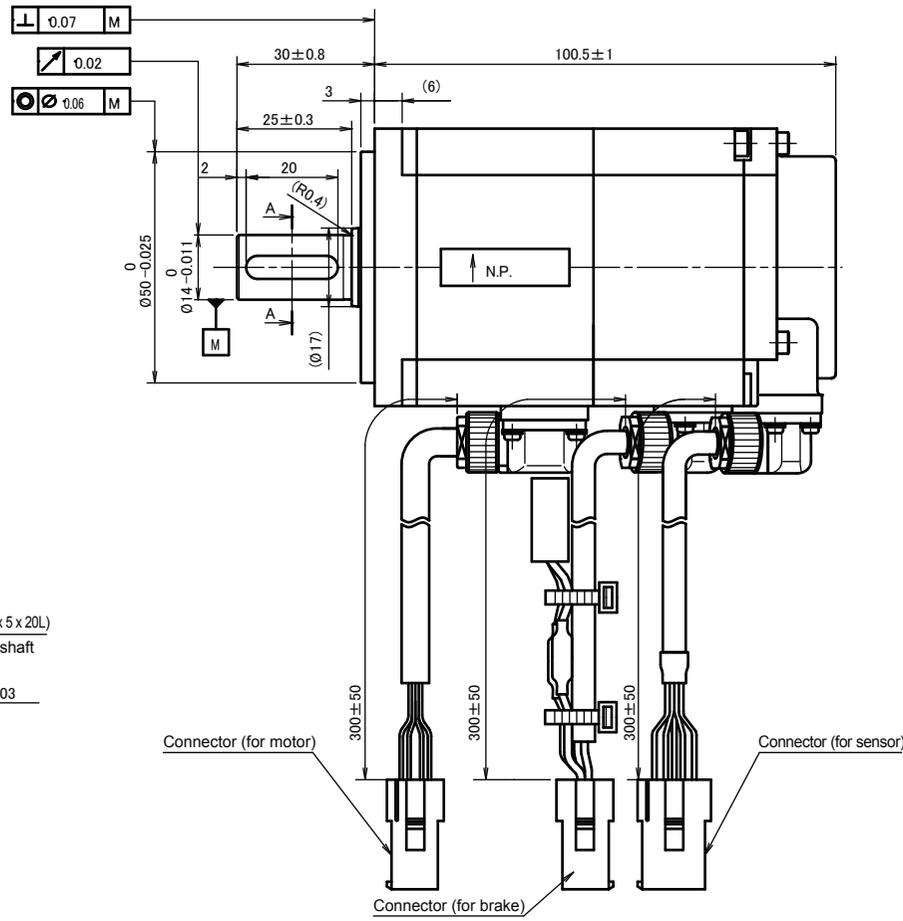
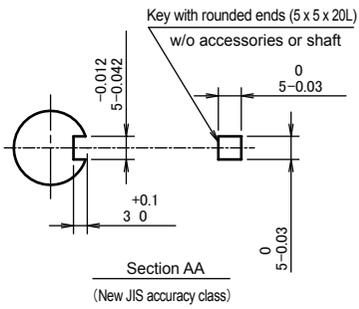
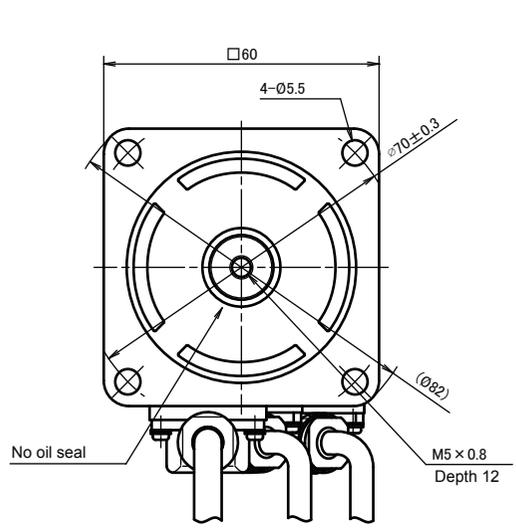
Allowable Shaft Load

In assembling			In running			
Radial load (N)	Thrust load (N)		Radial load (N)	Thrust load (N)		
FR	F direction	F1 direction	FR	F direction	F1 direction	
150	98	98	98	29	29	



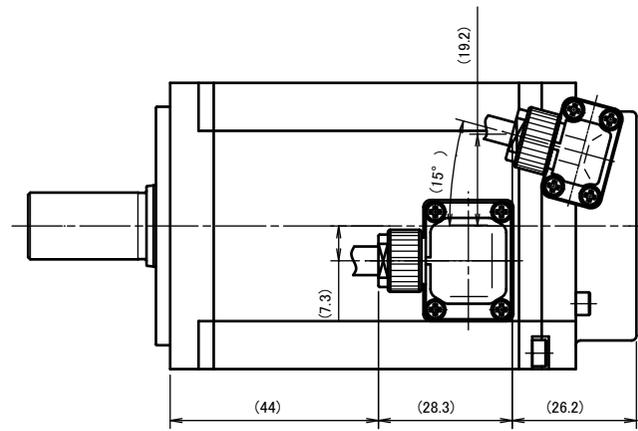
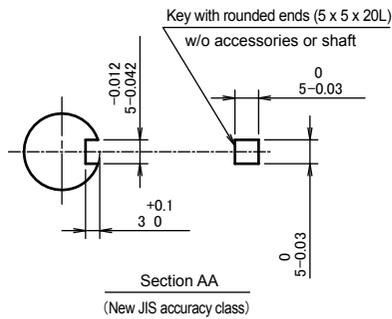
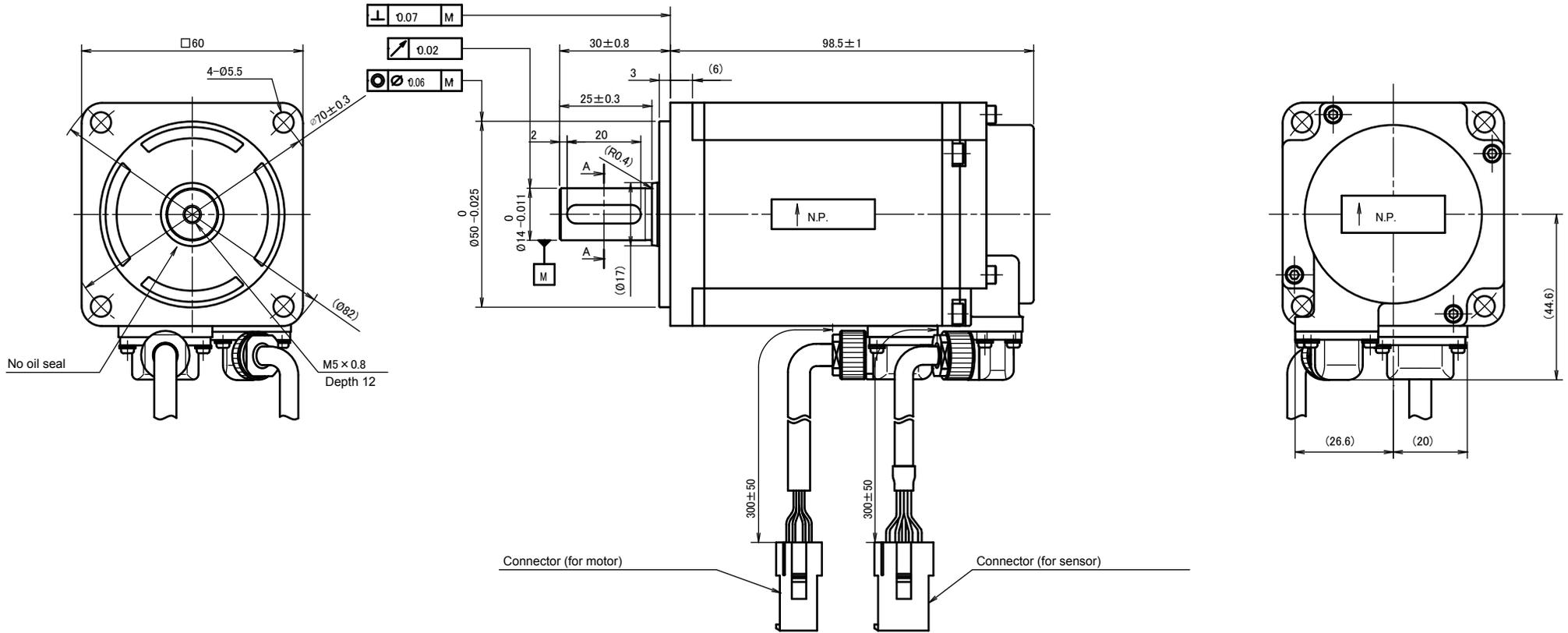
Allowable Shaft Load

In assembling			In running			
Radial load (N)	Thrust load (N)		Radial load (N)	Thrust load (N)		
FR	F direction	F1 direction	FR	F direction	F1 direction	
390	200	200	200	68	68	



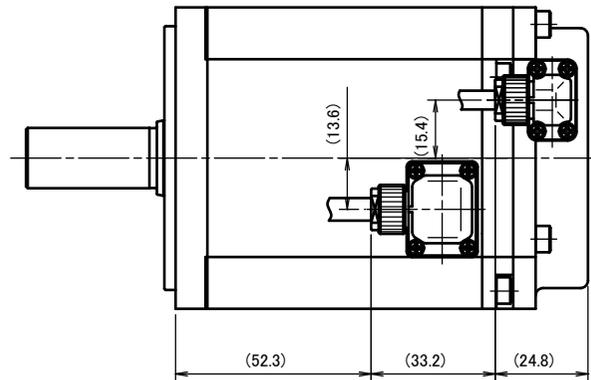
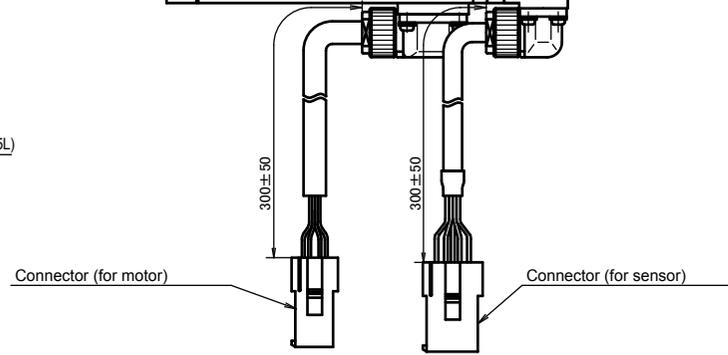
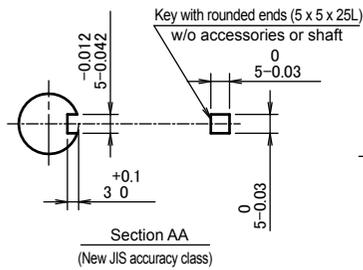
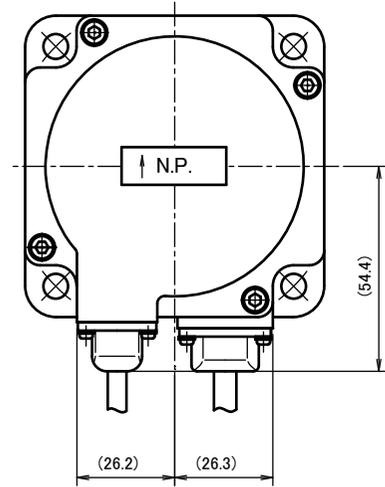
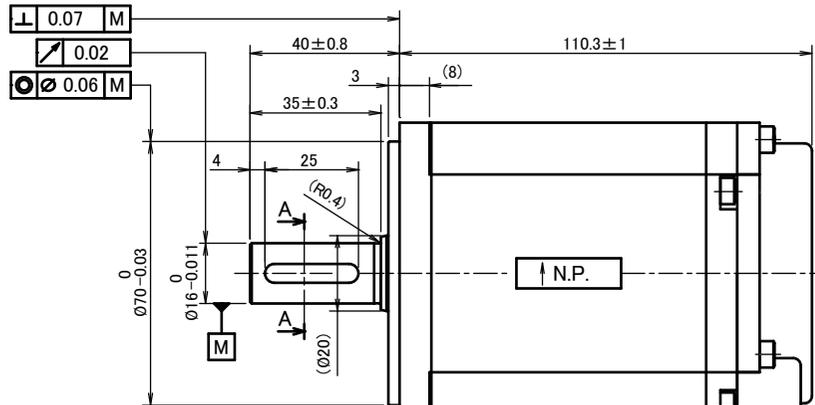
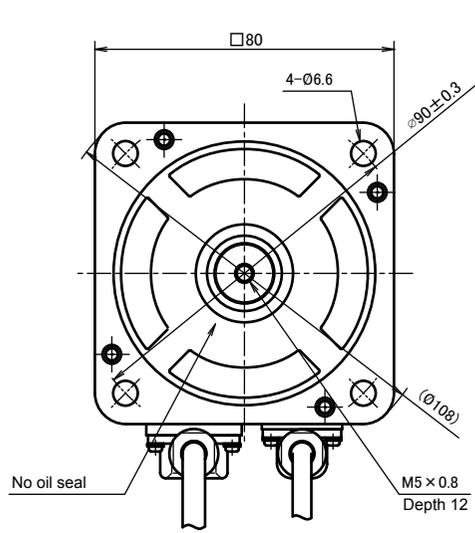
Allowable Shaft Load

In assembling		In running		FR → LR ↓ 2LR/3
Radial load (N)	Thrust load (N)	Radial load (N)	Thrust load (N)	
FR	F direction	FR	F direction	F1 ←
390	200	200	68	
	F1 direction		F1 direction	
	200		68	



Allowable Shaft Load

In assembling			In running		
Radial load (N)	Thrust load (N)		Radial load (N)	Thrust load (N)	
FR	F direction	F1 direction	FR	F direction	F1 direction
390	200	200	250	68	68



Allowable Shaft Load

In assembling			In running			
Radial load (N)	Thrust load (N)		Radial load (N)	Thrust load (N)		
FR	F direction	F1 direction	FR	F direction	F1 direction	
590	390	390	340	200	200	

5.2.1.3 Design Example (High-Speed Transfer Equipment)

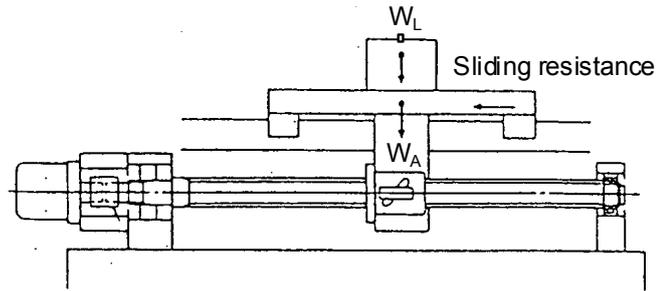


Fig. 2-2. High-speed transfer equipment

[Designing conditions]

1) Table design specification

Table weight	:	$W_A = 40 \text{ kg}$
Transferred object weight	:	$W_L = 20 \text{ kg (Max)}$
Max. stroke	:	$S_{max} = 700 \text{ mm}$
Fast feed speed	:	$S_{max} = 1000 \text{ mm/sec (60 m/min)}$
Positioning accuracy	:	$\pm 0.10/700 \text{ mm (0.01 mm/pulse)}$
Repeat accuracy	:	$\pm 0.010 \text{ mm}$
Required life	:	$L_t = 25000 \text{ hr (5 years)}$
Slide surface (rolling)	:	$\mu = 0.01 \text{ (Friction factor)}$
Drive motor	:	AC motor ($N_{max} = 3000 \text{ rpm}$)

2) Operation conditions

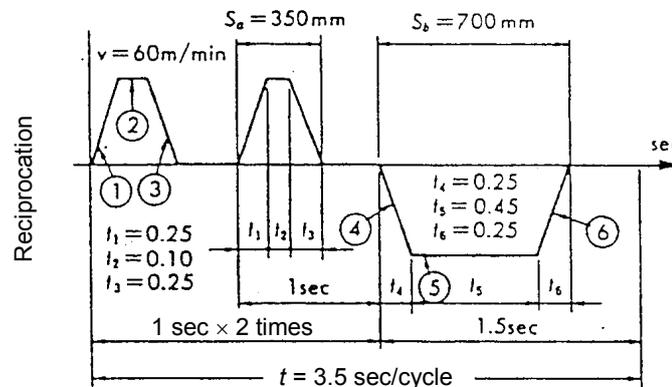


Fig. 2-3. Operation conditions

[Items to be decided]

- 1) Selection of screw shaft dia., lead and nut
- 2) Selection of accuracy and clearance

An explanation is given to these items as follows.

[Selection of screw shaft dia., lead and nut]

1) Selection of lead (l)

From the max. speed of DC motor

$$l \geq \frac{V_{\max}}{N_{\max}} = \frac{1000 \times 60}{3000} = 20 \text{ (mm)}$$

Select from among accuracy large lead products of 20 mm or longer lead.

2) Temporary selection of thread length

$$\begin{aligned} L_s &= \text{max. stroke} + \text{nut length} + \text{shaft end allowance} \\ &= 700 + 100 + 100 + 900 \text{ (mm)} \end{aligned}$$

3) Selection of screw shaft dia.

Select the shaft dia. by checking the allowable speed with a high speed feed. The bearing support construction shall be of the most general fixing-support one.

① Dangerous speed

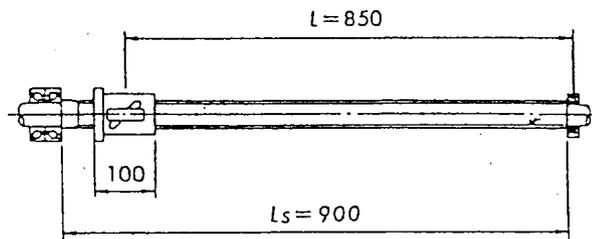


Fig. 2-4. Selection of thread length

An examination is required for the ball screw speed not to resonate with the intrinsic number of vibrations of the screw shaft. The allowable speed shall be 80% or less of this dangerous speed.

$$n = a \times \frac{60\lambda^2}{2\pi L^2} \sqrt{\frac{EI}{\gamma A}} = f \frac{dr}{L^2} \times 10^7 \text{ (rpm)} \dots\dots\dots \text{Equation (1)}$$

where

- a : Safety factor ($a = 0.8$)
- E : Modulus of longitudinal elasticity ($E = 2.06 \times 10^4 \text{ kPa}$)
- I : Minimum secondary moment of the screw shaft cross section

$$I = \frac{\pi}{64} dr^4 \text{ (mm}^4\text{)}$$

- dr : Screw shaft minor dia (mm) <See Dimension Table>
- r : Specific weight of the material ($r = 7.8 \times 10^{-6} \text{ kg/mm}^3$)
- A : Screw shaft cross-sectional area ($A = \pi dr^2/4 \text{ mm}^2$)
- L : Distance between mounting points (mm)
- f, λ : Factor fixed by the mounting method of the ball screw

Support – support	$f = 9.7$	$(\lambda = \pi)$
Fixing – support	$f = 15.1$	$(\lambda = 3.927)$
Fixing – fixing	$f = 21.9$	$(\lambda = 4.730)$
Fixing – freedom	$f = 3.4$	$(\lambda = 1.875)$

Therefore, from equation (1)

$$dr \geq \frac{n \cdot L^2}{f} \times 10^{-7} \text{ (mm)}$$

where

$$L = \text{Max. stroke} + \text{Nut length}/2 + \text{Shaft end allowance} \\ = 700 + 50 + 100 = 850 \text{ (mm)}$$

$$f = 15.1$$

$$dr = 14.4 \text{ (mm)}$$

② $dm \cdot n$ value

Allowable speed is also regulated by $dm \cdot n$ value which shows peripheral speed (dm : center circle dia. of steel ball mm n : speed rpm).

Generally

$$\left. \begin{array}{l} \text{For precision (Accuracy grade C7 or higher) } dm \cdot n \leq 70,000 \\ \text{For general industry (Accuracy grade C10) } dm \cdot n \leq 50,000 \end{array} \right\} \dots\dots\dots \text{Equation (2)}$$

Therefore,

$$dm \leq \frac{70000}{n} \\ = 23.3 \text{ (mm)}$$

Primary selection: Shaft dia. 20 (mm)
Lead 20 (mm)

4) Life forecast

(When accelerating ①④)

$$a_1 = \frac{V_{mas}}{t_1} = \frac{1}{0.25} = 4 \text{ (m / sec}^2\text{)}$$

$$F_1 = \mu(W_A + W_L)g + (W_A + W_L)a_1 \\ = 0.01 \times 60 \times 9.8 + 60 \times 4 = 245.9 \text{ (N)}$$

$$N_1 = \frac{n}{2} = \frac{3000}{2} = 1500 \text{ (rpm)}$$

$$t_a = 2 \times t_1 + t_4 = 0.75 \text{ (sec)}$$

(At constant speed ②⑤)

$$F_2 = \mu(W_1 + W_2)g = 0.01 \times 60 \times 9.8 = 5.9 \text{ (N)}$$

$$N_2 = 3000 \text{ (rpm)}$$

$$t_b = 2 \times t_2 + t_5 = 0.65 \text{ (sec)}$$

(When decelerating ③⑥)

$$F_3 = -\mu(W_1 + W_2)g + (W_1 + W_2)a_3 = 234 \text{ (N)}$$

$$N_3 = 1500 \text{ (rpm)}$$

$$t_c = 2 \times t_3 + t_5 = 0.75 \text{ (sec)}$$

4-1) Average load F_m , Average rpm N_m

When shaft direction load is changed, find the average load which may give the life equal to the fatigue life under changing load conditions, and calculate the life.

(a) When load and rpm are divided step-by-step (Fig. 2-5)

Shaft direction load (kgf)	Speed (rpm)	Time in use or rate of time in use
F_1	n_1	t_1
F_2	n_2	t_2
·	·	·
·	·	·
·	·	·
F_n	n_n	t_n

Average load F_m can be achieved by the following equation.

$$\text{Average load } F_m = \left(\frac{F_1^3 \cdot n_1 \cdot t_1 + F_2^3 \cdot n_2 \cdot t_2 + \dots + F_n^3 \cdot n_n \cdot t_n}{n_1 \cdot t_1 + n_2 \cdot t_2 + \dots + n_n \cdot t_n} \right)^{1/3} \dots \text{Equation (3)}$$

And the average rpm can be achieved by the following equation.

$$N_m = \frac{n_1 \cdot t_1 + n_2 \cdot t_2 + \dots + n_n \cdot t_n}{t_1 + t_2 + \dots + t_n} \dots \text{Equation (4)}$$

(b) When load is changed almost linearly (Fig. 2-6)

Average load F_m can be approximately achieved by the following equation.

$$F_m = \frac{1}{3}(F_{min} + 2F_{max}) \dots \text{Equation (5)}$$

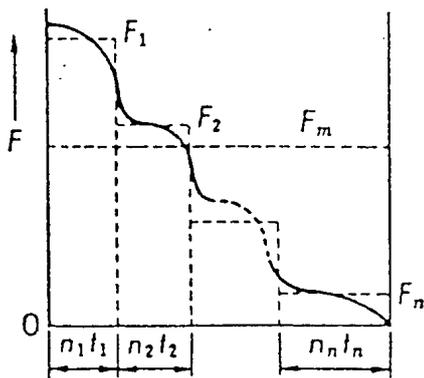


Fig. 2-5. Step-by-step fluctuation load

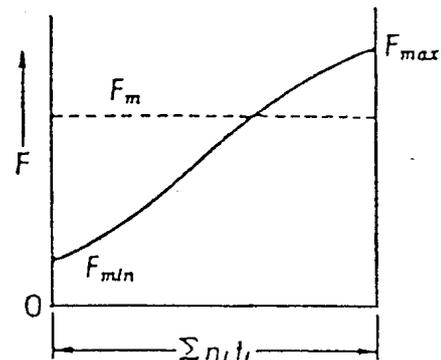


Fig. 2-6. Monotonous fluctuation load

(c) When load is changed like a sine curve (Fig. 2-7)

Average load F_m can be approximately achieved by the following equation.

Fig. 6 In case of (a) $F_m \doteq 0.65F_{max}$ } Equation (6)
 In case of (b) $F_m \doteq 0.75F_{max}$ }

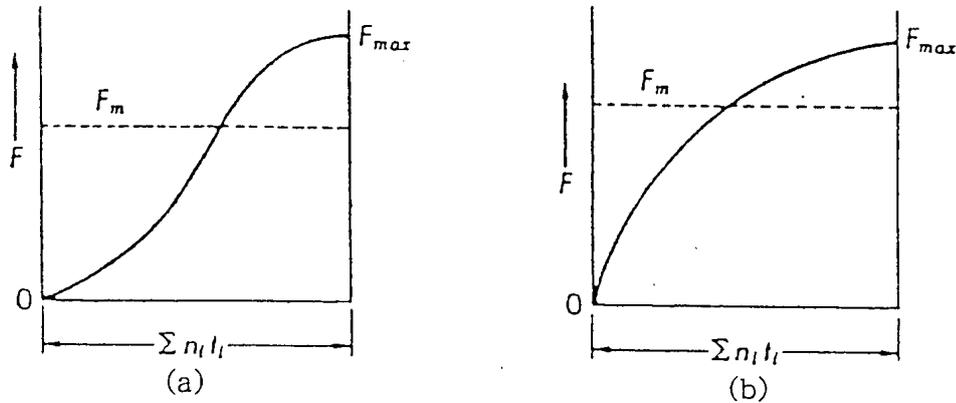


Fig. 2-7. Sine-curvedly changing load

Therefore, from equation (3), (4)

$$F_m = \left(\frac{F_1^3 \cdot N_1 \cdot t_a + F_2^3 \cdot N_2 \cdot t_b + F_3^3 \cdot N_3 \cdot t_c}{N_1 \cdot t_a + N_2 \cdot t_b + N_3 \cdot t_c} \right)^{1/3} \times g = 195 \text{ (N)}$$

$$N_m = \frac{N_1 \cdot t_a + N_2 \cdot t_b + N_3 \cdot t_c}{t} = 1200 \text{ (rpm)}$$

4-2) Life calculation

Fatigue life is generally shown by total rpm. Sometimes it is shown by total rotation time or total running distance. Fatigue life can be achieved by the following equation.

$$L = \left(\frac{Ca}{Fa \cdot fw} \right) \cdot 10^6 \text{ Equation (7)}$$

$$Lt = \frac{L}{60n} \text{ Equation (8)}$$

$$Ls = \frac{L \cdot l}{10^6} \text{ Equation (9)}$$

- Where L : Rated fatigue life (rev)
 Lt : Life time (hr)
 Ls : Running distance life (km)
 Ca : Basic dynamic load rating (N)
 Fa : Shaft direction load (N)
 n : Speed (rpm)
 l : Lead (mm)
 fw : Load coefficient (coefficient by operating condition)

Smooth running without shock	1.0 - 1.2
Normal running	1.2 - 1.5
Running with shock/vibration	1.5 - 3.0

When selecting a ball screw, it is not economical to make its fatigue life uselessly long because the ball screw must be so much big. For reference, general target value of fatigue life is shown bellow.

Machine tool	20,000 hours
Industrial machine	10,000 hours
Automatic controller	15,000 hours
Measuring instrument	15,000 hours

Therefore, from equation (7), (8) (T clearance $Ca = 7056$ kgf)

$$L_t = \left(\frac{Ca}{F_m \cdot f_w} \right)^3 \times \frac{1}{60N_m} \times 10^6$$

$$\approx 380000 \geq 25000 \text{ (hr)}$$

[Selection of accuracy and clearance]

(a) Accuracy grade

Positioning accuracy $\pm 0.10/700$ (mm)

From Table 2-1

Accuracy grade: C5
$E = \pm 0.040/1000$ (mm)
$e = 0.027$ (mm)

Table 2-1. Allowance of accumulated main lead error ($\pm E$) and fluctuation (e)

Unit: μm

Accuracy grade		C0		C1		C2		C3		C5	
more than	or less	$\pm E$	e								
–	100	3	3	3.5	5	5	7	8	8	18	18
100	200	3.5	3	4.5	5	7	7	10	8	20	18
200	315	4	3.5	6	5	8	7	12	8	23	18
315	400	5	3.5	7	5	9	7	13	10	25	20
400	500	6	4	8	5	10	7	15	10	27	20
500	630	6	4	9	6	11	8	16	12	30	23
630	800	7	5	10	7	13	9	18	13	35	25
800	1000	8	6	11	8	15	10	21	15	40	27
1000	1250	9	6	13	9	18	11	24	16	46	30
1250	1600	11	7	15	10	21	13	29	18	54	35
1600	2000	–	–	18	11	25	15	35	21	65	40
2000	2500	–	–	22	13	30	18	41	24	77	46
2500	3150	–	–	26	15	36	21	50	29	93	54
3150	4000	–	–	30	18	44	25	60	35	115	65
4000	5000	–	–	–	–	52	30	72	41	140	77
5000	6300	–	–	–	–	65	36	90	50	170	93
6300	8000	–	–	–	–	–	–	110	60	210	115
8000	10000	–	–	–	–	–	–	–	–	260	140
10000	12500	–	–	–	–	–	–	–	–	320	170

Source : NSK catalog

(b) Shaft direction clearance

Repeat positioning accuracy: ± 0.010 (mm)

Min. resolution: 0.01 mm/pulse

From the above,

Shaft direction clearance: *T* clearance 0.005 (mm) or less

Table 2-2. Combination of accuracy grade and shaft direction clearance

Unit: mm

Shaft direction clearance Accuracy grade	Z	T	S	N	L
	0 (Pre-load)	0.005 or less	0.020 or less	0.050 or less	0.3 or less
C0	C0Z	C0T	–	–	–
C1	C1Z	C1T	–	–	–
C2	C2Z	C2T	–	–	–
C3	C3Z	C3T	C3S	–	–
C5	C5Z	C5T	C5S	C5N	–
C7	–	–	C7S	C7N	C7L

[Results]

Use the following spec. ball screw.

Shaft dia. 20 (mm), lead 20 (mm)

Screw length (temporary) 800 mm

Accuracy grade C5 shaft direction clearance *T* (0.005 mm or less)

5.2.1.4 Notes for Designing

The sliding resistance of the mechanism controlled by the SMT7 should be as follows.
 Sliding resistance (torque conversion) $\leq 0.2 \times$ motor rated torque (T)

[1] Sliding resistance of ball screw

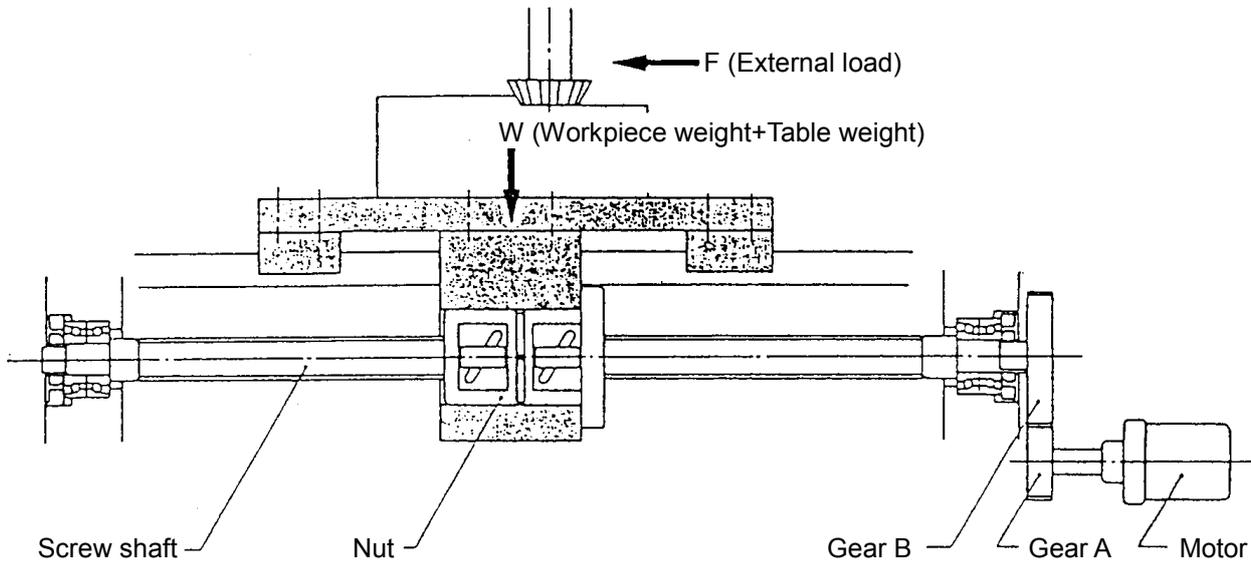


Fig. 2-8 Sliding resistance of ball screw

1) Friction torque by external load

$$T_p = \frac{Fa \cdot l}{2\pi \cdot \eta}$$

T_p :	Friction torque by external load	(Nm)
Fa :	Shaft direction load	(N)
$Fa = F + \mu W$		
F :	External load	(N)
W :	Workpiece weight + Table weight	(N)
μ :	Friction coefficient of slide surface	(0.003 - 0.004)
l :	Lead (m)	
η :	Effectiveness (0.9)...Ball screw (1.0)...LM guide	

2) Friction torque by pre-load

$$T_D = k \times \frac{F_{a0} \cdot l}{2\pi}$$

T_D :	Friction torque by pre-load	(Nm)
F_{a0} :	Pre-load (5% of C_a)	(N)
l :	Lead	(N)
k :	Internal friction coefficient of pre-load nut	(0.1 - 0.3)
C_a :	Basic load rating	(N)

3) Motor rated torque (T_R)
Refer to motor catalog.

4) Evaluation

$$(T_P + T_D) \times \left(\frac{N_1}{N_2} \right) \leq 0.2 \times T_R$$

- T_P : Friction torque by external load (Nm)
- T_D : Friction torque by pre-load (Nm)
- T_R : Motor rated torque (Nm)
- N_1 : The number of gear A teeth
- N_2 : The number of gear B teeth

5) Others

It is recommended to use the grinding ball screw. Rolling ball screw has so large backlash that it may not move properly.

[2] Gear sliding resistance

Table 2-3 shows gear transmission efficiency.

Use gear of which transmission efficiency is 98% or more except for skew gears. In this case, sliding resistance of gear (friction torque) can be disregarded.

Table 2-3. Classification and type of gear

Classification of gear	Type of gear	Efficiency (%)
Parallel axis	Spur gear	98.0 - 99.5
	Rack	
	Internal gear	
	Helical gear	
	Helical rack	
Intersecting axis	Double helical gear	98.0 - 99.0
	Straight bevel gear	
	Spiral bevel type gear	
Skew axis	Zerol bevel gear	30.0 - 90.0
	Cylindrical worm gear	
	Crossed helical gear	70.0 - 95.0

5.2.2 Knowledge Required for Selection of Servomotors

This section describes basic knowledge required for selecting an optimal servomotor output and reduction gear ratio in designing of servo mechanism drive including robots.

① Calculation of load drive torque (T) (conversion into the motor shaft's)

Drive torque = Inertia + Friction + Particular $T \text{ (Nm)} = (I \cdot \dot{\omega}) + (N \cdot Ki + T_{FM} + T_{FD}) + (Tg + Ts) \dots\dots\dots (1)$
--

Where	I = Total inertia moment in conversion into the motor shaft's (Nms ²) ④ $\dot{\omega}$ = Motor shaft angle acceleration (rad/s ²) ⑤ N = Motor usage rpm (rpm) Ki = Braking constant (see motor catalog) (Nm/rpm) T_{FM} = Motor static friction torque (see motor catalog) (Nm) T_{FD} = Friction torque of transmission system, etc. (conversion into the motor shaft's) (Nm) ⑥ Tg = Gravity holding torque (conversion into the motor shaft's) (Nm) ⑦ Ts = Interference torque, centrifugal force, coriolis force, etc. (conversion into the motor shaft's) (Nm) ⑧	}
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② Calculation of motor max. occurrence torque (T_M) (conversion into the motor shaft's)

$T_M \text{ (kgcm)} = I_R \cdot Kt$

Where	I_R = Max. current value which can be applied to motor (Ao·p) Kt = Torque constant (See motor catalog) (Nm/Ao·p)	} \dots\dots(2)
-------	---	-----------------

Or this is shown by the "Instantaneous max. torque" in the motor catalog.

[Note]
 $T_M > T$ shall be formed.

However, drive torque T shall be designed within 2.5 times of motor rated torque as SMT7.

③ Calculation and evaluation of effective torque

When the servomotor moves like fig. 2-10 pattern, the effective torque (T_t) of 1 cycle is achieved by the following equation.

$$T_t(\text{Nm}) = \sqrt{\frac{\sum_{i=1}^{i=n} (T_i^2 \times t_i)}{CT}} \dots\dots\dots \text{Equation (3)}$$

However,

- T_1 } Drive torque (T in equation (1)) (Nm)
- T_4 }
- T_3 } Deceleration torque (subtract friction torque from T in equation (1)) (Nm)
- T_6 }
- T_2 } Friction torque + particular torque (Nm)
- T_5 }
- t_i Time of $T_1 - T_6$ (sec)
- CT Cycle time (sec)

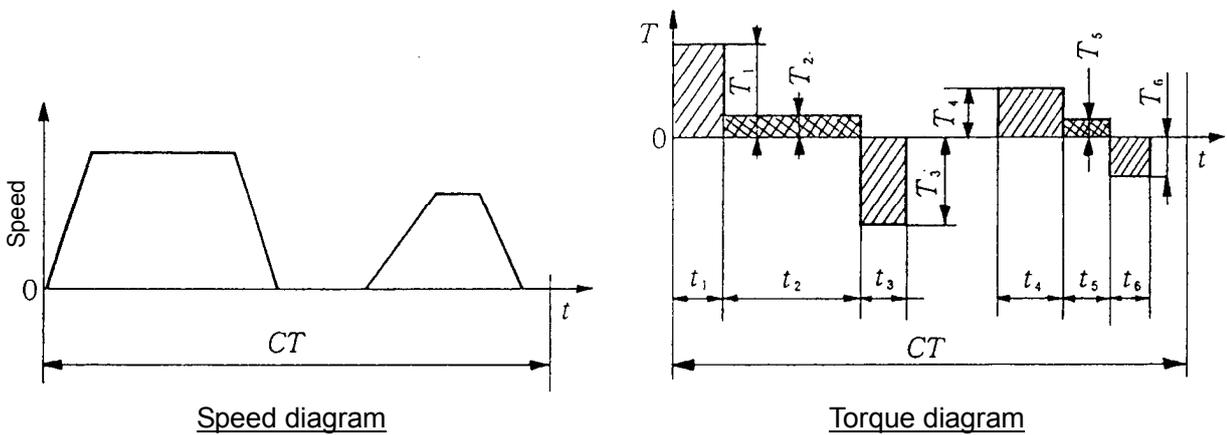


Fig. 2-10 Evaluation of effective torque

(a) Evaluation of motor unit

$T_t < T_R$ (Rated torque in the motor catalog) shall be formed.

Use the motor within 80% of motor rated torque because of encoder circuit thermal limit (70°C).

When the effective torque is 80% or more of motor rated torque, measure the temperature of encoder circuit to check it is within the limit.

④ Calculation of total inertia moment (I) (conversion into the motor shaft's)

(a) Revolving arm (Fig. 2-11).

$$I(\text{Nms}^2) = (I_L + I_A + I_{G4}) \times (RG1 \times RG2)^2 \dots\dots\dots (\text{Deceleration 2 step part})$$

$$+ (I_{G3} + I_{G2}) \times (RG1)^2 \dots\dots\dots (\text{Deceleration 1 step part})$$

$$+ (I_{G1} + I_C + I_M + I_E + I_B) \dots\dots\dots (\text{No deceleration part}) \dots\dots\dots \text{Equation (4)}$$

Where

I_L	: Inertia moment of load W arm revolution shaft	(Nms^2)
I_A	: Inertia moment of arm revolution shaft	(Nms^2)
I_{G1}	: 1st step pinion inertia moment	(Nms^2)
I_{G2}	: 1st step gear inertia moment	(Nms^2)
I_{G3}	: 2nd step pinion inertia moment	(Nms^2)
I_{G4}	: 2nd step gear inertia moment	(Nms^2)
I_C	: Coupling inertia moment	(Nms^2)
I_M	: Motor armature inertia moment	(Nms^2)
I_E	: Encoder inertia moment	(Nms^2)
I_B	: Built-in brake inertia moment	(Nms^2)
$RG1$: First step gear ratio	($1/n$)
$RG2$: Second step gear ratio	($1/n$)

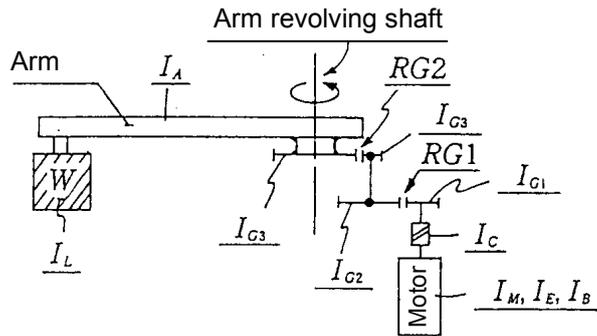


Fig. 2-11 Revolving arm

(b) Linear movement arm (Fig. 2-12)

$$I(\text{Nms}^2) = W_L + W_A \times \left(\frac{l}{2\pi}\right)^2 \times (RG1)^2 \dots\dots\dots (\text{Deceleration 2 step part})$$

$$+ (I_S + I_{G2}) \times (RG1)^2 \dots\dots\dots (\text{Deceleration 1 step part})$$

$$+ I_{G1} + I_C + I_M + I_E + I_B \dots\dots\dots (\text{No deceleration part}) \dots\dots\dots \text{Equation (5)}$$

Where

W_L	: Load weight	(kg)
W_A	: Arm weight	(kg)
I_S	: Inertia moment of ball screw	(Nms^2)
l	: Lead of ball screw	(m/rev.)

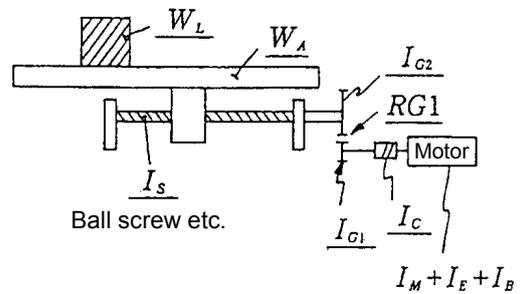


Fig. 2-12 Linear movement arm

(c) Calculation of rotor inertia moment (I_1) (Fig. 2-13)

$$I_1(\text{Nms}^2) = \frac{\pi}{32}(D^4 - d^4) \times h \times \rho \times \frac{1}{9.8} \dots\dots\dots \text{Equation (6)}$$

Where

- D : Outer diameter (m)
- d : Inner diameter (m)
- h : Thickness (m)
- ρ : Specific gravity (kg/m^3)

* When inertia is expressed by GD^2 ,
divide it by $4 \times g$.

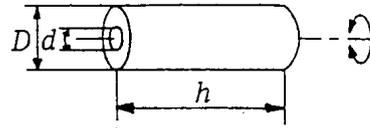


Fig. 2-13 Rotor

(d) Calculation of complex shape unit inertia moment (I_2) (Fig. 2-14)

Inertia moment of complex shape unit can not be achieved by the equation. Therefore, divide the unit into parts and achieve the inertia moment by each part and add such moments.

$$I_2(\text{Nms}^2) = \sum_{i=1}^{i=n} (W_i \times y_i^2) \dots\dots\dots \text{Equation (7)}$$

Where

- $W_i =$ Divided part weight (kg)
- $y_i =$ Distance from center of revolution to center of divided part (m)

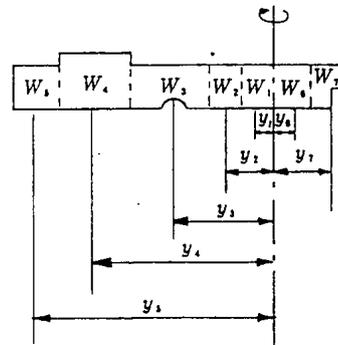


Fig. 2-14 Complex shape unit

⑤ Calculation of motor shaft angular acceleration (ω)

(a) Revolving arm

$$\omega (\text{rad} / \text{s}^2) = \theta \cdot 2\pi / 360 \cdot t \cdot RG \dots\dots\dots \text{Equation (8)}$$

(b) Linear movement

$$\omega (\text{rad} / \text{s}^2) = V \cdot 2\pi / l \cdot t \cdot RG \dots\dots\dots \text{Equation (9)}$$

Where

- t = Acceleration time (sec.)
- θ = Arm revolving speed ($^\circ/\text{s}$)
- V = Linear speed (m/s)
- RG = Total deceleration ratio ($\frac{1}{n}$)
- l = Ball screw, Rack & Pinion } Lead (m/rev.)

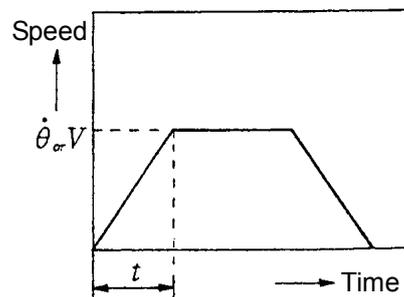


Fig. 2-15 Angular acceleration

⑥ Friction torque of transmission system, etc. (T_{FD})

Divide the friction torque of the slide part, seal, speed reducer, etc. by deceleration ratio to make the quotient as the friction torque in conversion into the motor shaft. Especially be sure to know that the transmission mechanism friction torque before deceleration is directly applied to the motor.

⑦ Gravity holding torque (T_g)

When the gravity needs to be held, divide the holding unit weight by gear ratio to make the quotient as the gravity torque in conversion into the motor shaft's. When taking gravity balance by air cylinder or counter weight, the gravity holding torque is "0". Be sure to check, however, the slide resistance of air cylinder and the addition of inertia moment.

⑧ Particular load torque (T_s)

When the degree of freedom is 2 or more, sometimes interference torque or centrifugal force or corioli's force is applied by other shaft movement. Achieve the sum of these forces by mechanism construction or motion speed and divide it by gear ratio to make the quotient as the torque in conversion into the motor shaft's.

(a) Example of interference torque

- (i) On two joint arm, second arm drive torque (T_{J2}) is applied to first arm. (Fig. 2-16)
- (ii) Also in combination of linear movement and revolving shaft movement, acceleration (α) of linear shaft is applied to the offset load (W) of the revolving shaft and torque (T_r) of the revolving shaft which is in proportion to the offset distance (r) occurs. (Fig. 2-17)

$$T_{JT} = \frac{W \cdot \alpha \cdot r}{g} \quad (g: \text{Gravitational acceleration } 9.8 \text{ m/s}^2)$$

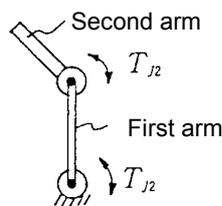


Fig. 2-16 Interference torque i

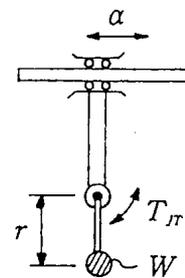


Fig. 2-17 Interference torque ii

(b) Example of centrifugal force (F_T)

On an object (W) on the revolving shaft, centrifugal force (F_T) occurs from center to outside in proportion to the square of revolving shaft angular speed (ω_θ) and the revolving radius (r) (Fig. 2-18)

$$F_T = \frac{W}{g} \cdot \gamma \cdot \omega_\theta^2$$

* On fig. 2-18, linear shaft supports centrifugal force.

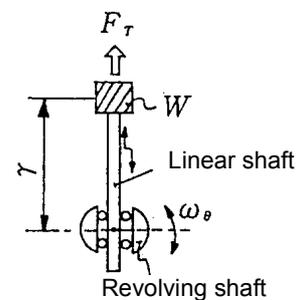


Fig. 2-18 Centrifugal force

(c) Example of Coriolis's force (F_c)

When an object (W) on the revolving shaft moves at V_w speed, coriolis's force (F_c) which is in proportion to the double of the product of W , revolving shaft angular speed (ω_θ) and speed (V_w) occurs in the vertical direction to V_w on the object (W). (Fig. 2-19)

$$F_c = 2 \cdot \frac{W}{g} \cdot V_w \cdot \omega_\theta$$

On Fig. 2-19, a torque which is the multiplication of coriolis's force (F_c) by radius (r) occurs on the revolving shaft, and a friction resistance which is the multiplication of coriolis's force (F_c) by slide part friction coefficient occurs on the linear shaft.

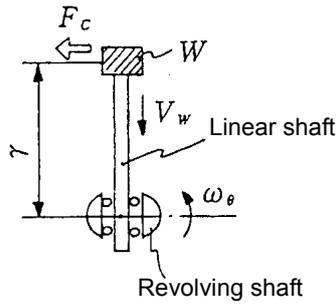


Fig. 2-19 Coriolis's force

5.3 Configuring Encoder Axis Numbers for Extended-joint Motors

An extended-joint motor holds an axis number in its encoder. Based on the axis number, the robot controller identifies the connected extended-joint motor to control it.

Axis number "7" or "8" is regarded as an extended-joint by the robot controller. When an extended-joint motor is shipped from the factory, the axis number is set to "1." It is therefore necessary to configure the axis number correctly before use.

⚠ CAUTION: Be sure to configure an encoder axis number correctly for each extended-joint motor before connecting motors to the robot controller. Connecting motors configured with the same axis number and turning on the power to them may break all motors being connected.

5.3.1 Encoder axis number configuration tools (option)

Given below are optional tools required for configuring encoder axis numbers.

Configuration tool for motor & encoder cable connector (required for robots except X Y robots)

Part number: 410141-5110

This tool is required for robots except XY robots.

Connect this tool to the motor & encoder cable connector on the controller instead of the motor & encoder cable.



Configuration tool for encoder connector

Part number: 410141-5280

Connect this tool to each of the encoder connectors on the controller instead of the encoder cables, except the encoder connector used by the encoder whose axis number is to be configured.

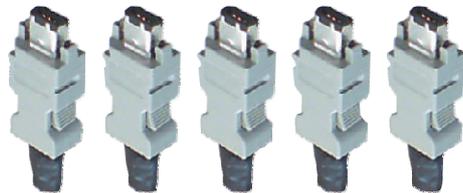


Configuration tool set (incl. 5 tools) for encoder connectors

Part number: 410141-5290

This is a set of five configuration tools (410141-5280).

Use this set for XY robots having an extended-joint(s).



5.3.2 Encoder axis number configuration procedure

Configure an encoder axis number using the following procedure.

STEP 1

Check the configuration of the internal IPM board and the motor axis number of the extended-joint unit in "③ OTHER MODIFICATIONS" on the controller configuration table (SETPRM LIST) labeled on the top of the robot controller. (For the XY robots, check SLOT 5/SLOT 6.)

STEP 2

Make sure that the controller power is OFF.

STEP 3

Connect only an extended-joint motor whose encoder axis number is to be configured. Make sure any other motors are disconnected from the controller.

The connection of the motor and encoder axis number configuration tool(s) differs depending upon the robot type and the number of extended-joints used. Refer to "Connecting the extended-joint motor and encoder axis number configuration tool(s)."

STEP 4

Turn the controller power ON.

STEP 5

Immediately after the start of the controller, an error "Jx encoder system down failure" may occur. If it happens, reset the motor encoder data of the joint that has caused the error.

Encoder reset procedure: [ExtScrn]–[F2 Arm]–[F12 Maint.]–[F11 ENC rst]

Restart the controller.

TIP: An extended-joint motor is shipped with axis number being set to "1," so an error "J1 encoder system down failure" occurs. Reset the motor encoder data of joint 1. An error "encoder system down failure" is caused by loss of CALSET data or other data when the power for preserving data is not supplied to the motor.

STEP 6

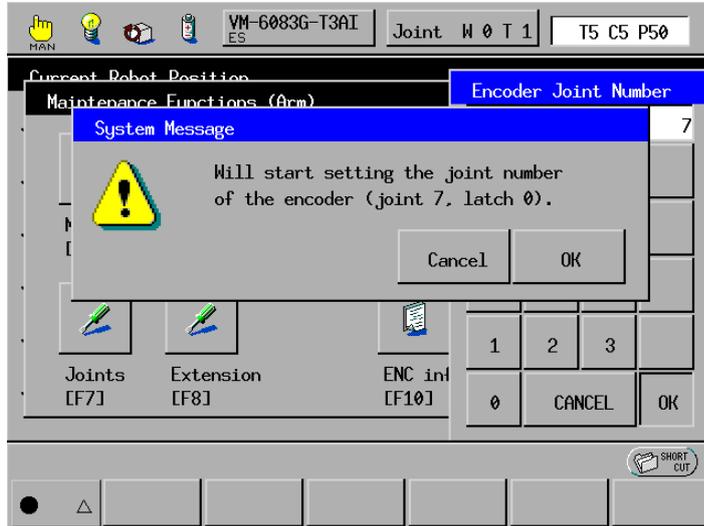
If an error "Jx encoder data not received" occurs immediately after the start of the controller, press the AUX, RESET, and Down arrow keys simultaneously to lock the machine.

STEP 7

Use the teach pendant to switch to the extended screen and press [F2 Arm]–[F12 Maint.]–[F12 ENC set.].

Enter password "1111."

Enter the desired axis number ("7" or "8") of the motor to be configured.



STEP 8

Turn the controller power OFF.

STEP 9

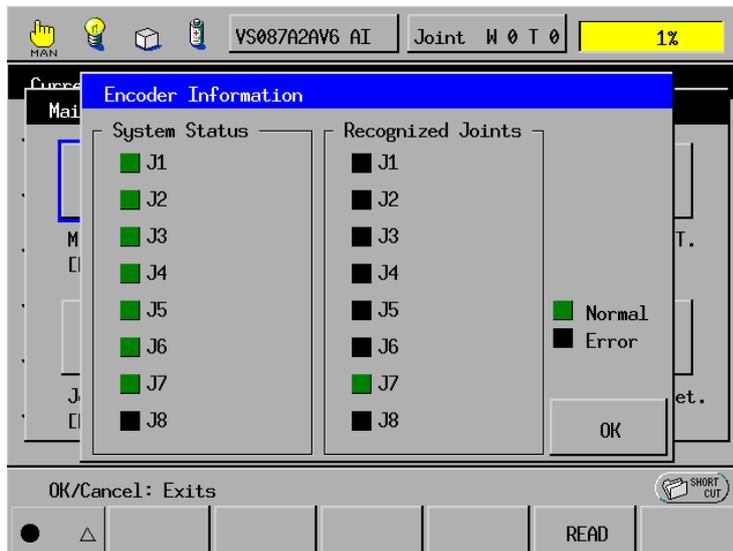
Check that the encoder axis number is selected.

Turn the controller power ON.

An error occurs, so lock the machine by pressing the AUX, RESET, and Down arrow keys simultaneously.

Use the teach pendant to switch back to the extended screen and press [F2 Arm]–[F12 Maint.]–[F10 ENC inf.].

After checking that the setting is correct, turn the controller power OFF.



STEP 10

Configure the encoder axis number for each of the extended-joint motors, using STEP 1 to STEP 8.

STEP 11

After completion of configuration of encoder axis numbers for all motors, connect all motors including the robot motors and turn the controller power ON.

STEP 12

Check the error log. If an error "Jx encoder system down failure" has occurred on extended-joints, reset the motor encoder data of the joint by pressing [ExtScrn]–[F2 Arm]–[F12 Maint.]–[F11 ENC rst].

STEP 13

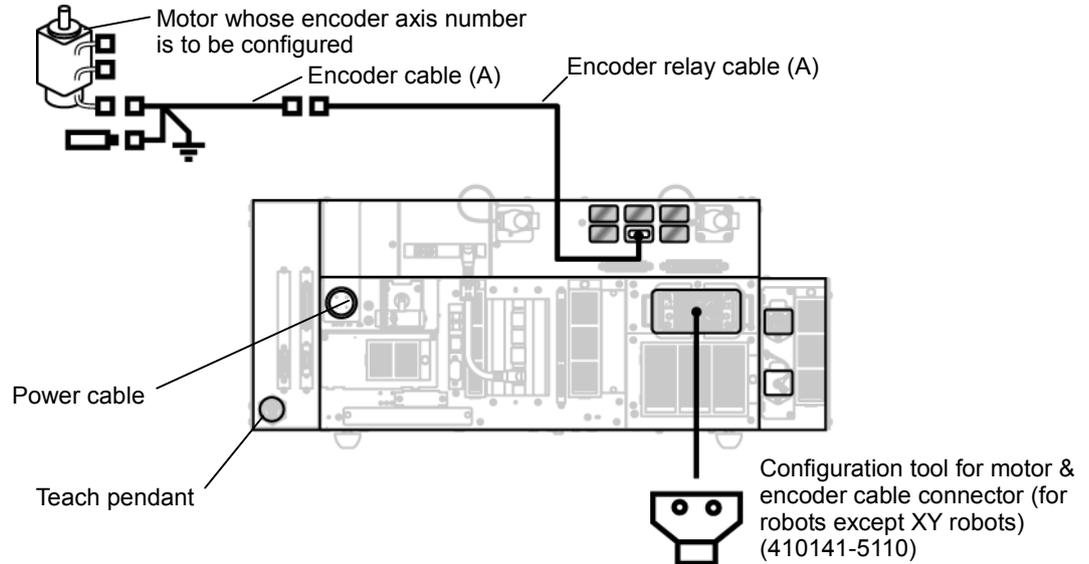
Make CALSET and other joint settings for extended-joints.

5.3.3 Connecting the extended-joint motor and encoder axis number configuration tools

Connect the extended-joint motor and encoder axis number configuration tools that match the robot type and the number of extended-joints.

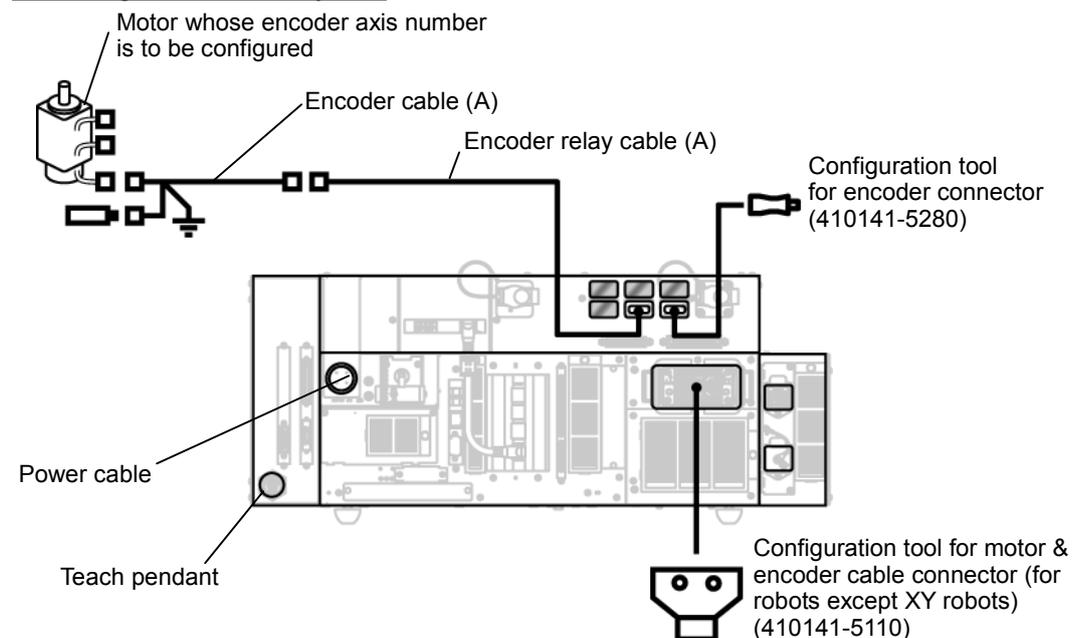
■ Robots except XY robots

For using a single extended-joint



TIP: If you do not have the configuration tool for motor & encoder cable connector (410141-5110) at hand, use jumper pins instead, referring to "Using jumper pins instead of the configuration tool for motor & encoder cable connector (410141-5110)."

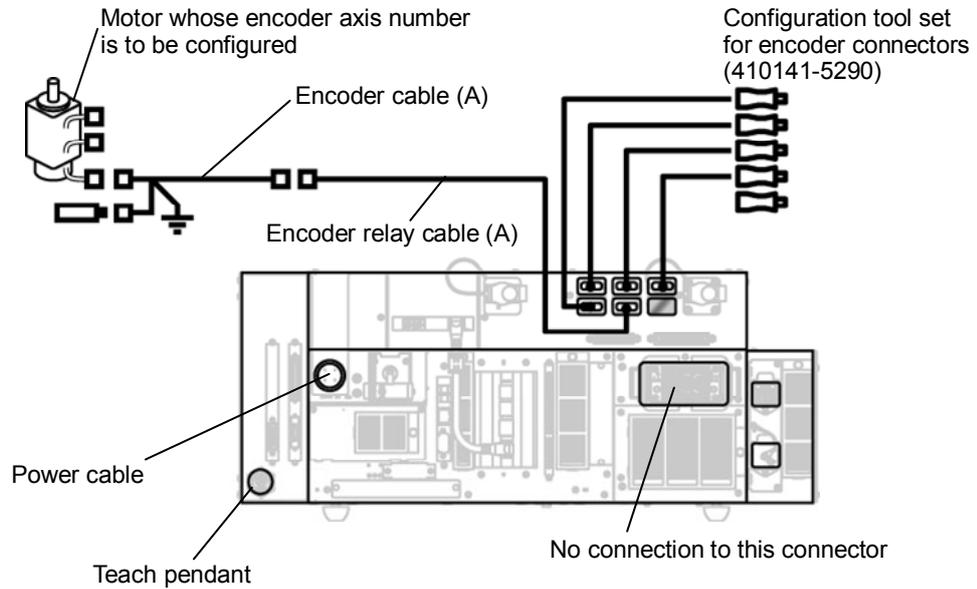
For using two extended-joints



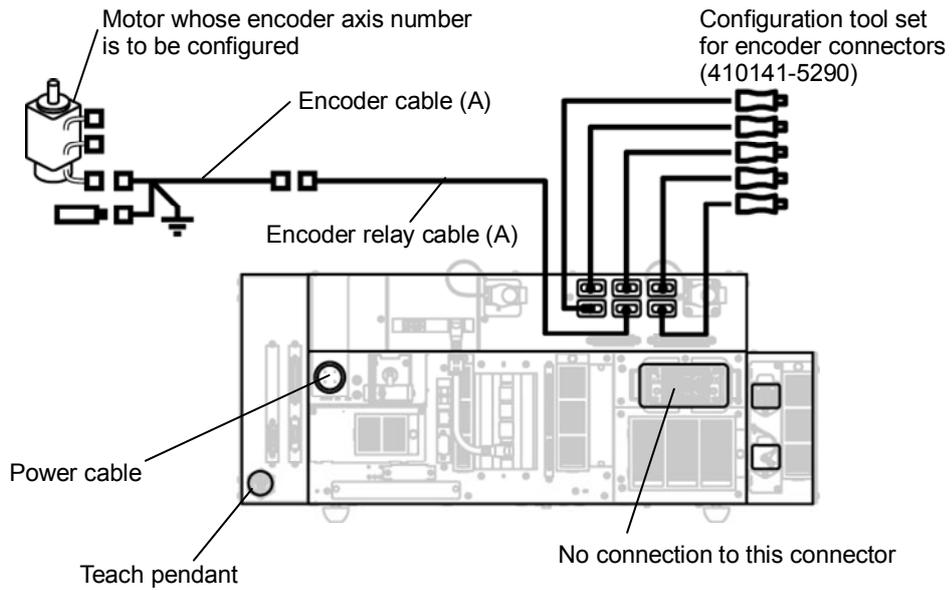
TIP: If you do not have the configuration tool for motor & encoder cable connector (410141-5110) at hand, use jumper pins instead, referring to "Using jumper pins instead of the configuration tool for motor & encoder cable connector (410141-5110)."

■ XY robots

For using a single extended-joint



For using two extended-joints

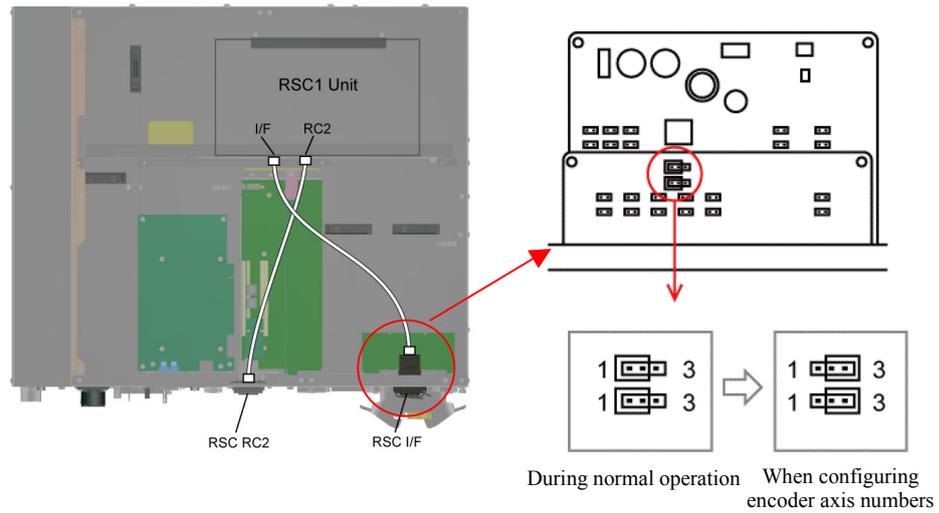


5.3.4 Using jumper pins instead of the configuration tool for motor & encoder cable connector (410141-5110)

If you do not have the configuration tool for motor & encoder cable connector (410141-5110) at hand, use the jumper pins in the controller instead.

Open the top cover of the controller and configure the following switches with jumper pins as shown below.

After configuring encoder axis numbers, be sure to return the jumper pins to the original position.



NOTE: Do not change the configuration of the jumper pins on XY robots.

DENSO ROBOT

V*-G-T / H*-G-T SERIES

Extended-Joints Support (T03)

SUPPLEMENT

First Edition March 2011
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DENSO WAVE INCORPORATED

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The purpose of this manual is to provide accurate information in the handling and operating of the robot. Please feel free to send your comments regarding any errors or omissions you may have found, or any suggestions you may have for generally improving the manual.

In no event will DENSO WAVE INCORPORATED be liable for any direct or indirect damages resulting from the application of the information in this manual.

