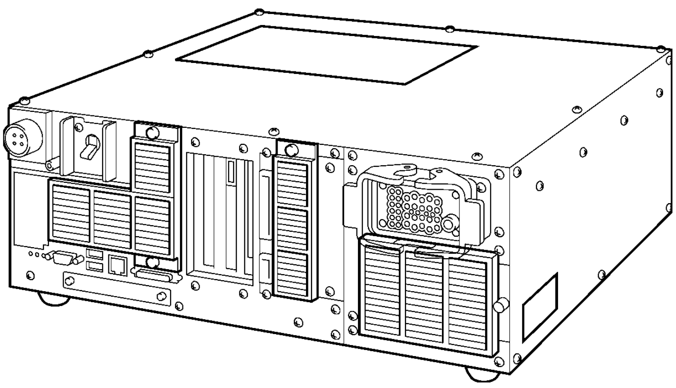
DENSO ROBOT

SMT7 CONTROLLER

INSTRUCTION MANUAL (SUPPLEMENT)



Preface

Thank you for purchasing our SMT7 controller.

The SMT7 controller controls the positioning mechanism driven by an AC servomotor, e.g., X-Y table.

This manual is a supplement to the robot instruction manuals. Read through this manual in conjunction with manuals for robot systems configured with the RC7M controller, which are given on the next page.

Products covered by this manual: SMT7 controller and options

Controller	System Configuration
SMT7	Configured with options given on pages 3 through 5.

Important

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

Cautions in handling and using the SMT7 controller

NOTES (1) If joint allocations are different between the SMT7 controller and WINCAPSIII, transferring the arm data from WINCAPSIII to the controller may cause an error. If it happens, clear the error and transfer the data again.

(2) The SMT7 controller is customized for motors specified by each customer in both hardware and software at the factory. The allowable combination of the controller's axes and motor types is printed in (2) SUBASSEMBLY 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, controller overheat, motor overheat, and other problems.

(3) This product is not evaluated for EMC directive. When you export this product to Europe, it needs to be compliant with EMC directive as a facility.

Contents

Chapter 1 Overview

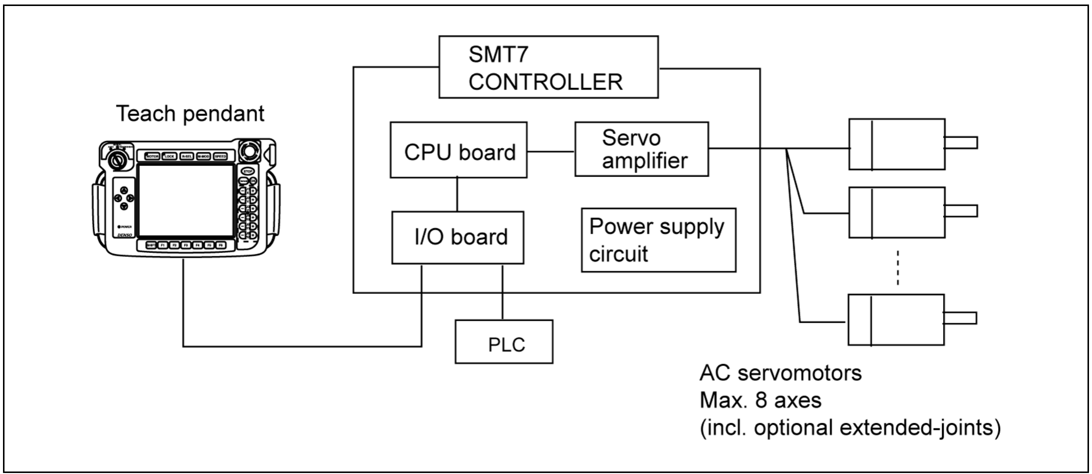
1.1 System Configuration

The SMT7 is a controller that controls the positioning mechanism driven by an AC servomotor, e.g., X-Y table.

Shown below is a system configuration sample using the SMT7 controller.

First, move the X-Y table using the teach pendant to store the position into the controller memory. At the same time, store other conditions for synchronizing with external equipment (e.g., PLC).

After that, in an automatic operation, the controller drives the X-Y table as programmed, reading out the data stored in the memory.



System Configuration

(1) Notes in operating the SMT7

The SMT7 is functionally equivalent to robot controllers except the SMT7 cannot specify arm mechanisms. Using any of the following motions and commands in the SMT7, therefore, may cause an unexpected movement. It is dangerous.

CP motion
(linear interpolation **MOVE L** or circular interpolation **MOVE C)**

TOOL movement
ROTATE command
Coordinate instruction movement (DRAW)
PALT command
APPROACH command
DEPART command

(2) Drive capacity

The motor capacity that can be driven by the SMT7 is as listed below.

SMT7 controller	Motor Capacity	Total Drive Capacity	Note
1st to 6th axes	1500 W max./axis	3000 W max.	3rd to 6th axes: Restricted to 1200 W or its equivalent

Note: Use AC servomotors specified in Chapter 3.

Note: The total drive capacity does not change even when optional extended-joints are in use.

1.2 Standard Items Contained in the Package

The items listed in the table below are contained in the product package.

Standard Items

No.	Item	Qty.
(1)	SMT7 controller (Note 1)	1
(2)	Power supply cable (5m)	1
(3)	Instruction manuals (Manual pack CD)	1 set
(4)	WINCAPSIII Install CD (Trial version)	1
(5)	Spare fuse for controller	3
(6)	Pendantless connector (Dummy connector)	1
(7)	Spare output IC for controller	1
(8)	Short socket for controller	2

Note 1: When shipped from the factory, the controller has a built-in IPM board suited for AC servomotors to be connected. When ordering the controller, therefore, also order AC servomotors.

1.3 Optional Items

The table below lists the optional items.

Optional Items (1)

No.	Item	Remarks	Part No.
1	AC servomotor (Standard type, 50W, Without brake)	SGMAH-A5A1A-DH1*	410627-0210
	AC servomotor (Standard type, 50W, With brake)	SGMAH-A5A1A-DH2*	410627-0160
	AC servomotor (Standard type, 100W, Without brake)	SGMAH-01A1A-DH1*	410627-0220
	AC servomotor (Standard type, 100W, With brake)	SGMAH-01A1A-DH2*	410627-0170
	AC servomotor (Standard type, 200W, Without brake)	SGMAH-02A1A-DH1*	410627-0230
	AC servomotor (Standard type, 200W, With brake)	SGMAH-02A1A-DH2*	410627-0180
	AC servomotor (Standard type, 400W, Without brake)	SGMAH-04A1A-DH1*	410627-0240
	AC servomotor (Standard type, 400W, With brake)	SGMAH-04A1A-DH2*	410627-0190
	AC servomotor (Standard type, 750W, Without brake)	SGMAH-08A1A-DH1*	410627-0250
	AC servomotor (Standard type, 750W, With brake)	SGMAH-08A1A-DH2*	410627-0200
	AC servomotor (Flat type, 100W, Without brake)	SGMPH-01A1A-DH1*	410627-0310
	AC servomotor (Flat type, 100W, With brake)	SGMPH-01A1A-DH2*	410627-0260
	AC servomotor (Flat type, 200W, Without brake)	SGMPH-02A1A-DH1*	410627-0320
	AC servomotor (Flat type, 200W, With brake)	SGMPH-02A1A-DH2*	410627-0270
	AC servomotor (Flat type, 400W, Without brake)	SGMPH-04A1A-DH1*	410627-0330
	AC servomotor (Flat type, 400W, With brake)	SGMPH-04A1A-DH2*	410627-0280
	AC servomotor (Flat type, 750W, Without brake)	SGMPH-08A1A-DH1*	410627-0340
	AC servomotor (Flat type, 750W, With brake)	SGMPH-08A1A-DH2*	410627-0290
	AC servomotor (Flat type, 1500W, Without brake)	SGMPH-15A1A-DH1*	410627-0350
	AC servomotor (Flat type, 1500W, With brake)	SGMPH-15A1A-DH2*	410627-0300
2	Encoder branch cable (for 4 axes)	Between controller and encoder cable	410141-4050
	Encoder branch cable (for 6 axes)		410141-4060
3	Motor branch cable (for 4 axes)	Between controller and motor cable	410141-4030
	Motor branch cable (for 6 axes)		410141-4040
4	Encoder cable (4 m)	1 cable per a motor	410141-4130
	Encoder cable (6 m)		410141-4140
	Encoder cable (12 m)		410141-4150
5	Motor cable (Connected to 750W or less motor, 4 m)	1 cable per a motor	410141-4100
	Motor cable (Connected to 750W or less motor, 6 m)		410141-4110
	Motor cable (Connected to 750W or less motor, 12 m)		410141-4120
	Motor cable (Connected to 1500w motor, 4 m)		410141-4070
	Motor cable (Connected to 1500w motor, 6 m)		410141-4080
	Motor cable (Connected to 1500w motor, 12 m)		410141-4090

Optional Items (2)

No.	Item		Remarks		Part No.
6	Encoder backup battery		1 unit per a motor		410611-0030
7	Standard I/O cable set		(8 m) Includes Nos. 7-1 and 7-2.		410149-0940
			(15 m) Includes Nos. 7-1 and 7-2		410149-0950
7-1	I/O cable for "Mini I/O" (68-pin)		(8 m)		410141-2700
			(15 m)		410141-2710
7-2	I/O cable for "HAND I/O"		(8 m)		410141-1740
			(15 m)		410141-1750
8	I/O cable for "Parallel I/O board" (96-pin)		(8 m)		410141-3050
			(15 m)		410141-3060
9	I/O cable for "SAFETY I/O" (36-pin) (Only for global type)		(8 m)		410141-3580
			(15 m)		410141-3590
10	Teach pendant		(4 m) With cable		410100-1572
			(8 m) With cable		410100-1582
			(15 m) With cable		410100-1592
11	Mini-pendant kit (Incl. cable and WINCAPSIII Light)		(4 m)	Japanese version	410109-0392
				English version	410109-0402
			(8 m)	Japanese version	410109-0412
				English version	410109-0422
			(12 m)	Japanese version	410109-0432
				English version	410109-0442
12	Pendant extension cable		(4 m)	For TP, MP	410141-3711
			(8 m)	For TP, MP	410141-3721
13	WINCAPSIII		CD-ROM (common to the languages--Japanese, English, German, Korean, and Chinese)		410090-0980
14	Parallel I/O board	Shipped as installed on the controller	NPN		410010-3320
			PNP		410010-3330
		Shipped as individual boards (supply part)	NPN		410010-3340
			PNP		410010-3350
15	DeviceNet board	Shipped as installed on the controller	For Slave station		410010-3370
			For Master station		410010-3380
			For Master & slave station		410010-3390
		Shipped as individual boards (supply part)	For Slave station		410010-3400
			For Master station		410010-3410
			For Master & slave station		410010-3480

Optional Items (3)

No.	Item	Remarks	Part No.
16	CC-Link board	Shipped as installed on the controller	410010-3430
		Shipped as individual boards (supply part)	410010-3440
17	Conveyor tracking board	Shipped as installed on the controller	410010-3460
		Shipped as individual boards (supply part)	410010-3470
18	Optional function for RS-232C board Board manufacturer: CONTEC CO., LTD. Model: COM-2P(PCI)H	Shipped after integrated in the controller	410006-0260
		Added when the board is purchased as a spare part	410006-0270
19	Optional function for S-LINK V board Board manufacturer: SUNX CO., LTD Model: SL-VPCI	Shipped after integrated in the controller	410006-0280
		Added when the board is purchased as a spare part	410006-0290
20	Optional function for PROFIBUS-DP slave board Board manufacturer: Hilscher GmbH Model: CIF50-DPS\DENSO	Shipped after integrated in the controller	410006-0300
		Added when the board is purchased as a spare part	410006-0310
21	EtherNet/IP function Board manufacturer: Hilscher GmbH Model: CIFX 50-RE\DENSO	Shipped after integrated in the controller	410006-0800
		Added when the board is purchased as a spare part	410006-0810
22	Optional function for memory extension	Extension only upon controller shipment (3.25 to 5.5 MB)	410006-0320
23	Controller protection box		410181-0091
24	I/O conversion box	For interchangeability with RC5 controller	410181-0100

For the part numbers of extended-joint options, refer to the Supplement for Extended-Joints Support.

1.4 Controller Specification

The table below lists the specifications of the SMT7 controller.

Specifications of SMT7 Controller (1)

<table>
<tr><th colspan="3">Item</th><th>Specifications</th></tr>
<tr><td colspan="3">Applicable motor</td><td>AC servomotors specified in Section 1.3. (For details, see Chapter 3.)</td></tr>
<tr><td colspan="3">Controller model</td><td>RC7M-SMT6AA :NPN I/O
RC7M-SMT6AA-P :PNP I/O
RC7M-SMT6AA-BN :NPN I/O, Global type with safety board
RC7M-SMT6AA-BP :PNP I/O, Global type with safety board
RC7M-SMT6AA-CN :NPN I/O, Global type with safety box
RC7M-SMT6AA-CP :PNP I/O, Global type with safety box</td></tr>
<tr><td colspan="3">Number of controllable axes</td><td>Max. 8 axes (incl. optional extended-joints)</td></tr>
<tr><td colspan="3">Control system</td><td>PTP, CP 3-dimensional linear, 3-dimensional circular</td></tr>
<tr><td colspan="3">Drive system</td><td>All axes: Full-digital AC servo</td></tr>
<tr><td colspan="3">Language used</td><td>DENSO robot language (conforming to SLIM)</td></tr>
<tr><td colspan="3">Memory capacity</td><td>3.25 MB (equivalent to 10,000 steps, 30,000 points)</td></tr>
<tr><td colspan="3">Teaching system</td><td>1) Remote teaching 2) Numerical input (MDI) 3) Direct teaching</td></tr>
<tr><td rowspan="10">External signals (I/O)</td><td rowspan="2">Standard I/O</td><td>Mini I/O</td><td>Input signals: 8 user open points + 11 fixed system points
Output signals: 8 user open points + 14 fixed system points
Note: In global type, some fixed system points are not used.</td></tr>
<tr><td>HAND I/O</td><td>Input signals: 8 user open points
Output signals: 8 user open points</td></tr>
<tr><td colspan="2">SAFETY I/O
(Only for Global type)</td><td>Input signals: 6 fixed system points
Output signals: 5 fixed system points</td></tr>
<tr><td rowspan="2">Parallel I/O board (Option)</td><td>2 boards</td><td>Input signals: Additional 80 user open points
Output signals: Additional 96 user open points</td></tr>
<tr><td>1 board</td><td>Input signals: Additional 40 user open points
Output signals: Additional 48 user open points</td></tr>
<tr><td rowspan="3">DeviceNet board (Option)</td><td>Master & slave</td><td>Input signals: 1024 points (Master) + 256 points (Slave)
Output signals: 1024 points (Master) + 256 points (Slave)</td></tr>
<tr><td>Master</td><td>Input signals: 1024 points
Output signals: 1024 points</td></tr>
<tr><td>Slave</td><td>Input signals: 256 points
Output signals: 256 points</td></tr>
<tr><td>CC-Link board (option)</td><td>Slave</td><td>Input signals: 384 points
Output signals: 384 points
(including remote registers RWw and RWr)</td></tr>
<tr><td colspan="3">External communication</td><td>RS-232C: 1 line
Ethernet: 1 line
USB: 2 lines</td></tr>
<tr><td colspan="3">Extension slot</td><td>3 (For an optional board)</td></tr>
<tr><td colspan="3">Self-diagnosis function</td><td>Overrun, servo error, memory error, input error, etc.</td></tr>
<tr><td colspan="3">Timer function</td><td>0.02 to 10 sec. (in units of 1/60 sec.)</td></tr>
<tr><td colspan="3">Error display</td><td>Error codes will be outputted on the external I/O.
Error messages will be displayed in English on the teach pendant (option).
Error codes will be displayed on the mini pendant (option).</td></tr>
</table>

Specifications of SMT7 Controller (2)

<table>
<tr><th colspan="2">Item</th><th colspan="2">Specifications</th></tr>
<tr><td rowspan="3">Cables</td><td>Motor cable, encoder cable (option)</td><td colspan="2">4 m, 6 m, 12 m
(Connected to the controller via the branch cable.)</td></tr>
<tr><td>I/O cable (option)</td><td colspan="2">8 m, 15 m
(For Mini I/O, HAND I/O, Optional board for parallel I/O and SAFETY I/O)</td></tr>
<tr><td>Power supply cable</td><td colspan="2">5 m</td></tr>
<tr><td colspan="2">Environmental conditions
(in operation)</td><td colspan="2">Temperature: 0 to 40°C
Humidity: 90% RH or less (no condensation allowed)</td></tr>
<tr><td colspan="2">Power source
（at full IPM boards）</td><td colspan="2">Three-phase, 200 VAC-15% to 230 VAC+10%, 50/60 Hz, 3.3KVA
Single-phase, 230 VAC-10% to 230 VAC+10%, 50/60 Hz, 3.3KVA</td></tr>
<tr><td rowspan="2">I/O power source</td><td>External power source</td><td>A 24 VDC ±10% should be supplied from external equipment.</td><td rowspan="2">Note: Refer to the RC7M CONTROLLER MANUAL, sections 4.2.1 and 5.2.1 "Setting up Mini I/O Power Supply."</td></tr>
<tr><td>Internal power source</td><td>A 24 VDC ±10% should be supplied internally in the controller.</td></tr>
<tr><td colspan="2">Safety performance (Note 1)</td><td colspan="2">-With safety board
Structure: Category 3
Performance Level: d
MTTFd: 1.87×10⁴ years
DCavg: 95.1%
-With safety box
Structure: Category 4
Performance Level: e
MTTFd: 2.03×10³ years (Emergency stop)
0.76×10³ years (Protective stop)
DCavg: 99%</td></tr>
<tr><td colspan="2">Stop category</td><td colspan="2">With safety board/with safety box: Category 1
(See IEC60204-1 for details of stop category)</td></tr>
<tr><td colspan="2">Degree of protection</td><td colspan="2">IP20</td></tr>
<tr><td colspan="2">Weight (at full IPM boards)</td><td colspan="2">Approx. 22 kg (49 lbs)</td></tr>
<tr><td colspan="4">(Note1) Safety performance of robot stopping functions (emergency stop and protective stop). Input devices to be supplied by customers such as Safety door switch are not included in the PL calculation.
Calculation conditions:
- This calculation is based on ISO 13849-1:2006 and IEC 62061:2005.
- Operating time 24 hours/day and 365 days/year
- Frequency of actuation 1 time/day (Emergency stop),10 times/day (Protective stop)</td></tr>
</table>

Controller Handling Notes

⚠WARNING

- **DO NOT touch fins. Their hot surfaces may cause severe burns.**
- **DO NOT 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 3 minutes or more. This is for protecting you from electric shock.**
- **DO NOT 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

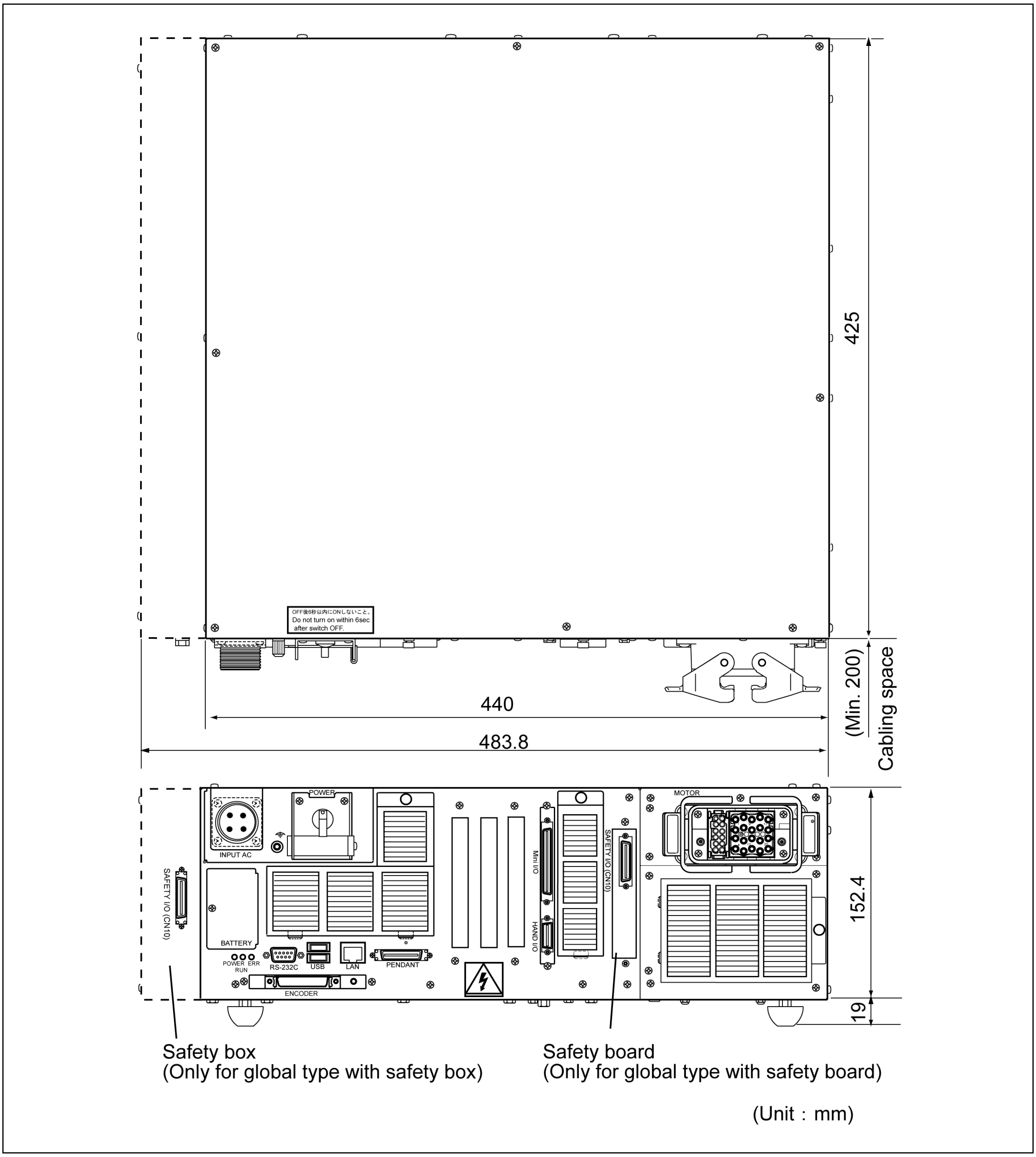
- **This controller is not designed to be dust-proof, splash-proof, or explosion-proof.**
- **Read operation manuals before installation.**
- **Do not place anything on the controller.**

⚠CAUTION

- **The 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 controller OFF before connecting/ disconnecting the power connector or motor connector. Otherwise, the internal circuits of the controller may be damaged.**

1.5 Outer Dimensions of the Controller

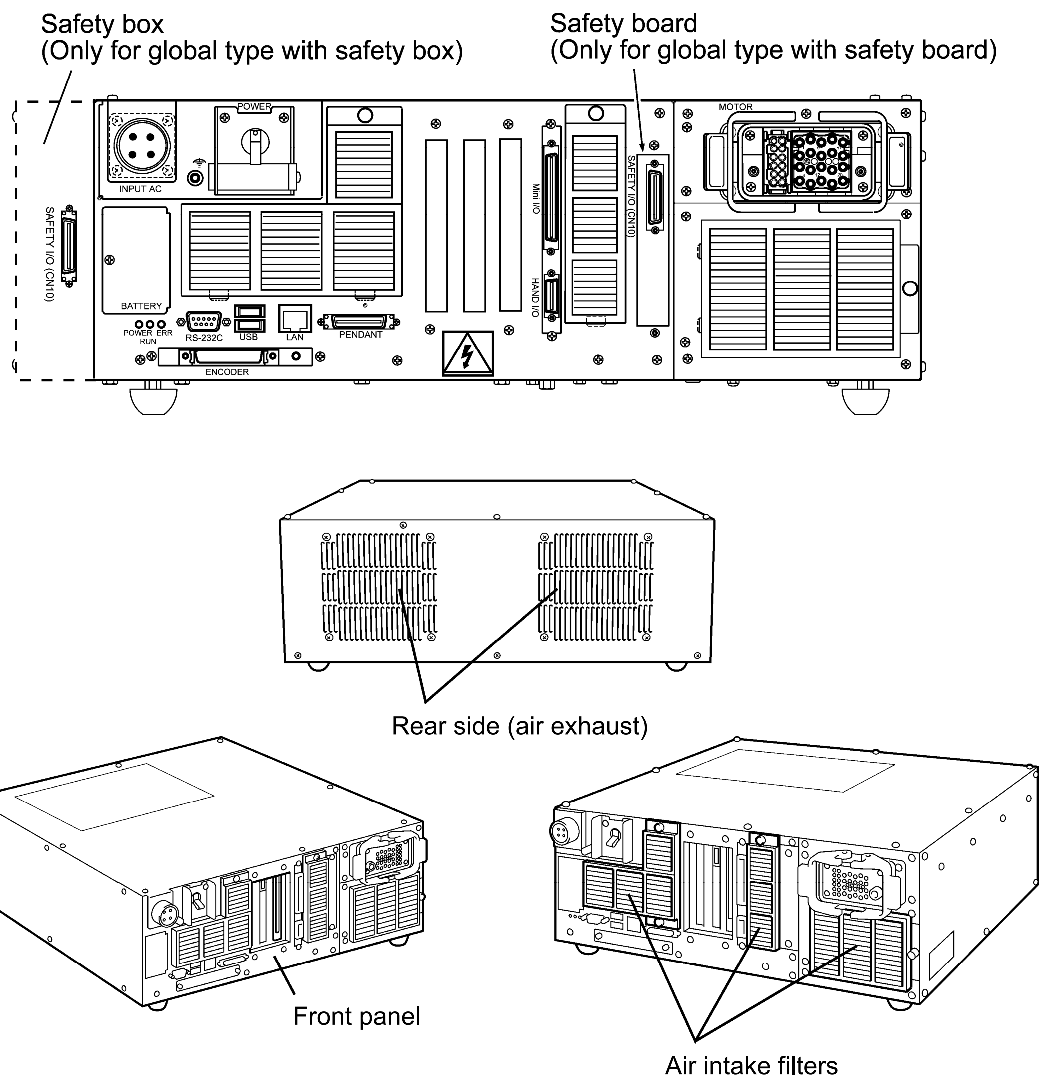
The figure below shows the outer dimensions of the SMT7.



Outer dimensions

1.6 Names of the Controller Components

The following figures show the names of the SMT7 components.



Connector No.	Marking	Name
CN1	RS-232C	Serial interface connector
CN2	USB	USB connector (2 lines)
CN3	PENDANT	Teach pendant connector
CN4	LAN	Ethernet connector
CN5	Mini I/O	User/system I/O connector
CN6	INPUT AC	Power supply connector
CN7	MOTOR	Motor connector
CN8	ENCODER	Encoder connector
CN9	HAND I/O	Hand I/O connector
CN10	SAFETY I/O	Safety I/O connector (only on the global type)

Names of SMT7 Components

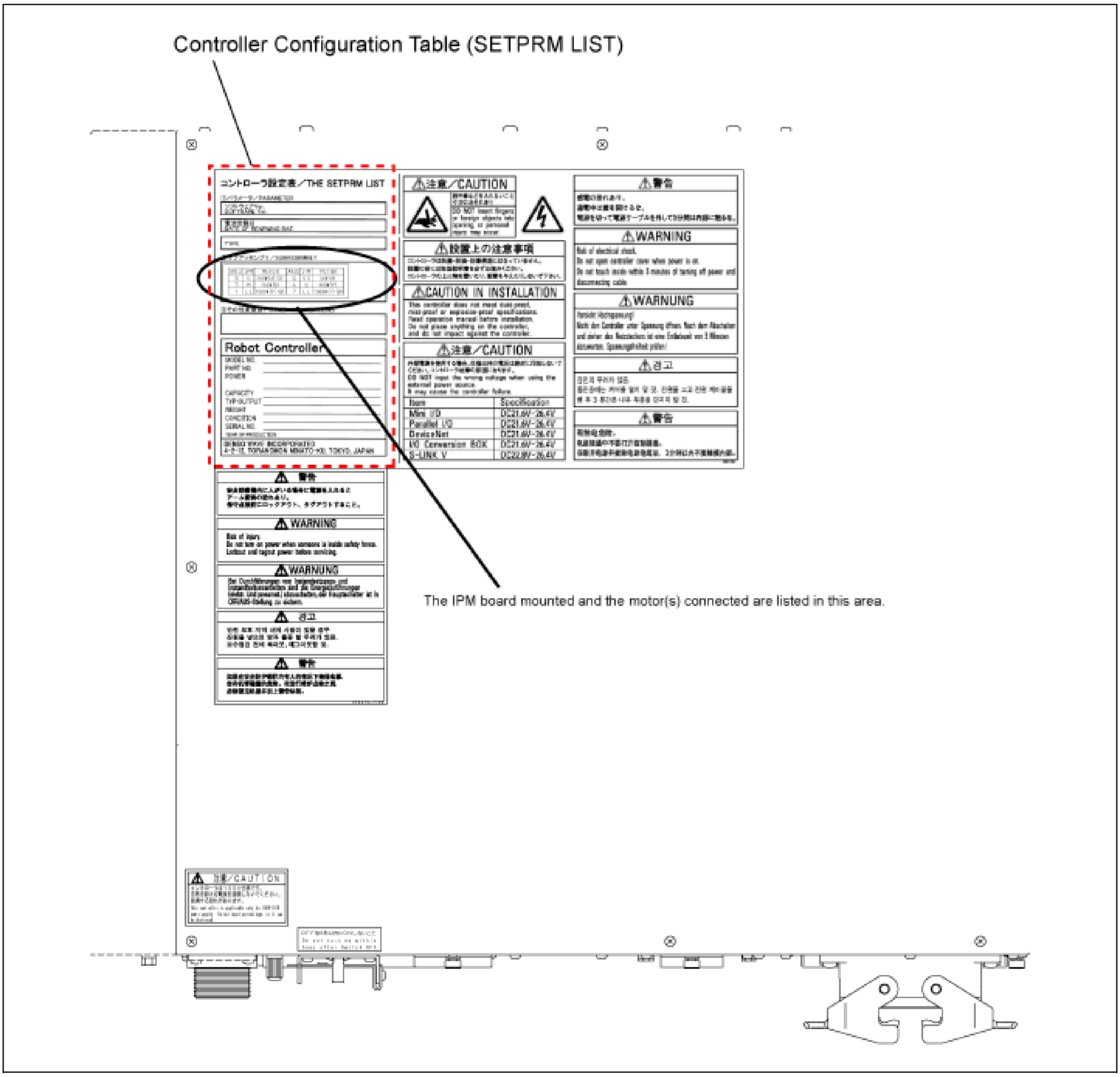
"THE SETPRM LIST" of the SMT7

The SMT7 is customized for motors specified by each customer in both hardware and software at the factory. The allowable combination of the controller's axes and motor types is printed in (2) SUBASSEMBLY 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, controller overheat, motor overheat, and other problems.

Note: When shipped from the factory, IPM boards suited to AC servomotors to be connected will be built into the controller for 1 to 6 axes.

Motor capacity	50 W	100 W	200 W	400 W	750 W	1.5 kW
IPM board type	SS	SS	S	S	M	LL



SETPRM LIST

1.7 Precautions for Safe Use of the Robot System

NOTE: This section provides safety precautions to be taken when you configure the robot system with the SMT7 controller. For details, refer to the ISO 10218-1:2006, Safety Requirements.

[1] For the mechanism to be driven

(1) If the mechanism involves a risk of bodily injury to workers, set up a safety fence to prevent danger.

(2) When the driven mechanism is the joint with the largest motion range, prepare adjustable mechanical stops with sufficient rigidity.

(3) When the joint(s) in the mechanism has the 2nd or 3rd largest motion range in all 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.

(6) Provide markings (e.g. labels) on the driven mechanisms to show which axis corresponds to which mechanism.

[2] When connecting motors

(1) When connecting the motors using cables, protect those cables from electrical noise.

[3] When mounting 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 user

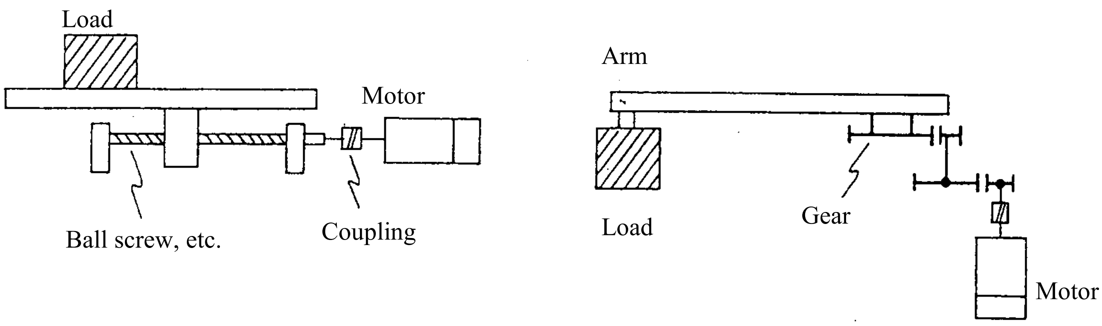
(1) When the motion range of the joint in the mechanism is 3rd largest or below in all joints, provide the user with the maximum stop time and distance of that joint, using instruction manuals, etc.

Chapter 2 Engineering Design of Servo Mechanism

2.1 Designing the Servo Mechanism

2.1.1 Example of the Mechanism

The mechanism is classified into a linear movement section and a revolving arm section as shown in Fig. 2-1.



(a) Linear movement section (b) Revolving arm

Fig. 2-1 Example of the mechanism

2.1.2 Selection of the Drive System

An appropriate control cannot be performed if a rapid torque fluctuation occurs due to stick slip or the like.
Typical appropriate and inappropriate examples of the drive system are as shown below:

• Ball screw		Grinding	Backlash small	○
		Rolling	Backlash large (Control instable)	△
• Gear	Grinding	Accuracy grade 1 or higher	Backlash small	○
	Cutting	Accuracy grade 3 or higher	Backlash medium	△
		Accuracy grade 4 or lower	Backlash large	×
• Screw shaft			Friction large	×
• Harmonic drive			Friction large (Care for selection)	△
• Slide section bearing		linear motion bearing		○
		LM guide		○
		Slide bearing	Friction large	×
• Seal, packing		Friction:	20% or less of the rated torque in conversion into the motor shaft's	△
		Friction:	More than 20% of the rated torque in conversion into the motor shaft's	×

○ denotes "Appropriate"
△ denotes "Conditionally appropriate"
× denotes "Inappropriate"

2.1.3 Design Example (High-Speed Transfer Equipment)

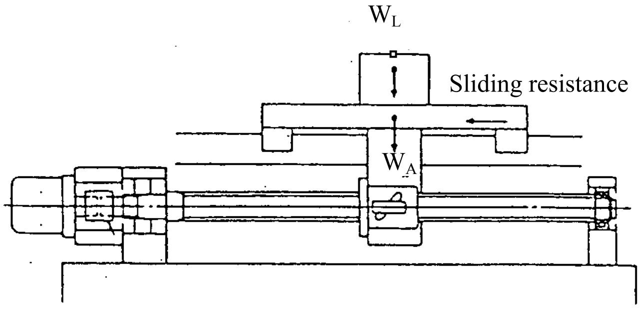


Fig. 2-2. High-speed transfer equipment

[Designing conditions]

1) Table design specification

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

2) Operation conditions

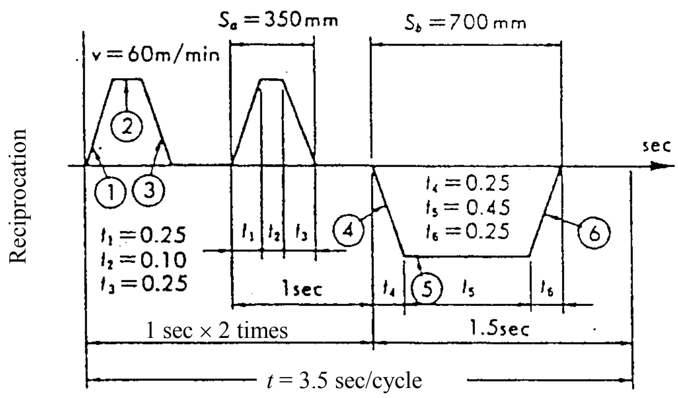


Fig. 2-3. Operation conditions

[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
Ls = max. stroke + nut length + shaft end allowance
= 700 + 100 + 100 + 900 (mm)

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

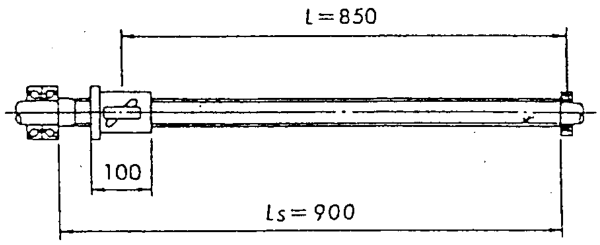


Fig. 2-4. Selection of thread length

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.

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

where

a: Safety factor (a = 0.8)
E: Modulus of longitudinal elasticity ($E = 2.06 \times 10^4$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 ($r = 7.8 \times 10^{-6}$ kg/mm^3)
A: Screw shaft cross-sectional area ($A = \pi dr^2/4$ 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	(λ =3.927)
Fixing	– fixing	f = 21.9	(λ =4.730)
Fixing	– freedom	f = 3.4	(λ =1.875)

Therefore, from equation (1)

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

where

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

f = 15.1

dr = 14.4 (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

For precision (Accuracy grade C7 or higher) $dm{\cdot}n \leq 70{,}000$
For general industry (Accuracy grade C10) $dm{\cdot}n \leq 50{,}000$ ············ Equation (2)

Therefore,

$$dm \geqq \frac{70000}{n}$$

= 23.3 (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.

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

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

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

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

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

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

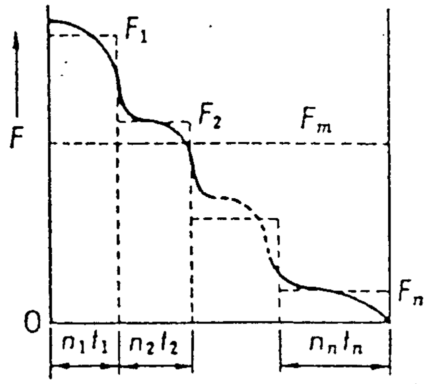


Fig. 2-5. Step-by-step fluctuation load

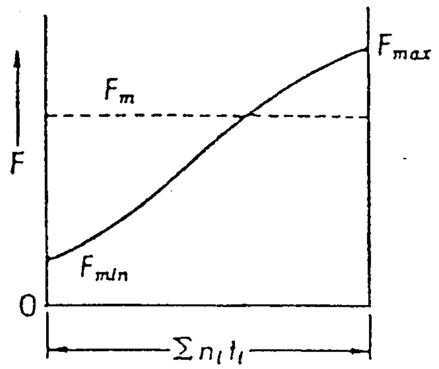


Fig. 2-6. Monotonous fluctuation load

(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) $F_m \fallingdotseq 0.65F_{max}$

In case of (b) $F_m \fallingdotseq 0.75F_{max}$ .... (6)

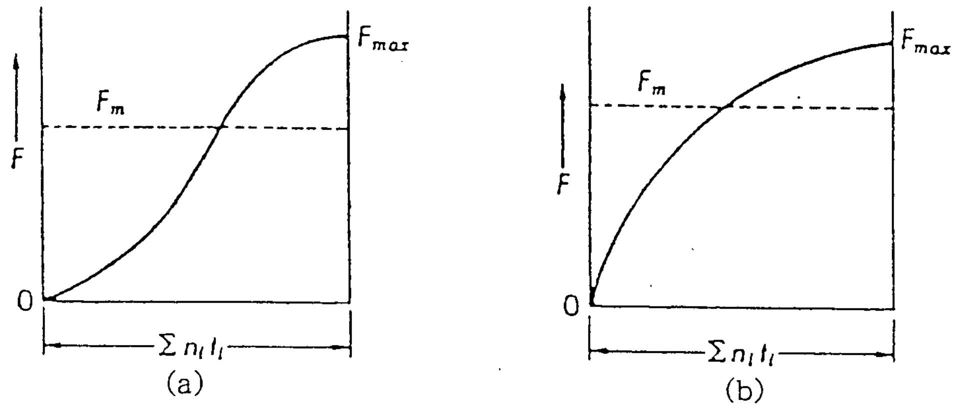


Fig. 2-7. Sine-curvedly changing load

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.

$$L = \left(\frac{Ca}{Fa \cdot f_w} \right) \cdot 10^6 \quad \cdots\cdots (7)$$

$$Lt = \frac{L}{60n} \quad \cdots\cdots (8)$$

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

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)
- f_w: 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)

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

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

[Selection of accuracy and clearance]

(a) Accuracy grade

Positioning accuracy ± 0.10/700 (mm)

From Table 2-1

Accuracy grade: C5
E = ± 0.040/1000 (mm)
e = 0.027 (mm)

Table 2-1. Allowance of accumulated main lead error (±*E*) and fluctuation (*e*)

Unit: µm

Accuracy grade			C0		C1		C2		C3		C5	
	more than	or less	±*E*	*e*	±*E*	*e*	±*E*	*e*	±*E*	*e*	±*E*	*e*
Screw part effective length (mm)	–	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

Accuracy grade \ Shaft direction clearance	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)

2.1.4 Notes for Designing

The sliding resistance of the mechanism controlled by the SMT7 should be as follows.

Sliding resistance (torque conversion) ≤ 0.2 × motor rated torque (*T*)

[1] Sliding resistance of ball screw

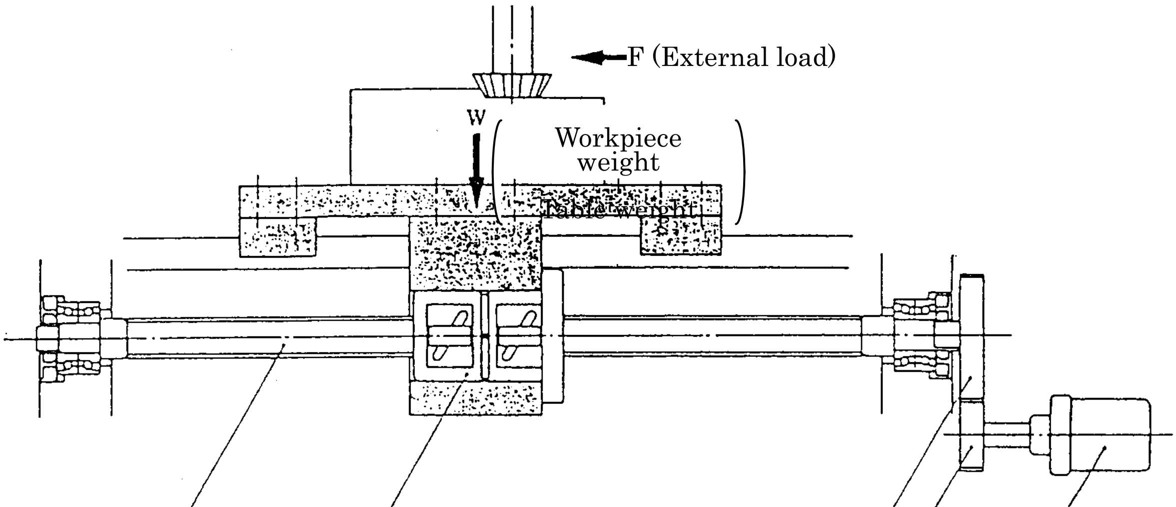


Fig. 2-8 Sliding resistance of ball screw

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

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

T_D:	Friction torque by pre-load	(Nm)
Fao:	Pre-load (5% of Ca)	(N)
l:	Lead	(N)
k:	Internal friction coefficient of pre-load nut	(0.1 - 0.3)
Ca:	Basic load rating	(N)

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

4) Evaluation

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

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	
	Double helical gear	
Intersecting axis	Straight bevel gear	98.0 - 99.0
	Spiral bevel type gear	
	Zerol bevel gear	
Skew axis	Cylindrical worm gear	30.0 - 90.0
	Crossed helical gear	70.0 - 95.0

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 (Nm) = $(I \cdot \dot{\omega}) + (N \cdot Ki + T_{FM} + T_{FD}) + (Tg + Ts)$ ······························ (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

② Calculation of motor max. occurrence torque (T_M) (conversion into the motor shaft's)

T_M (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)

·····(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.

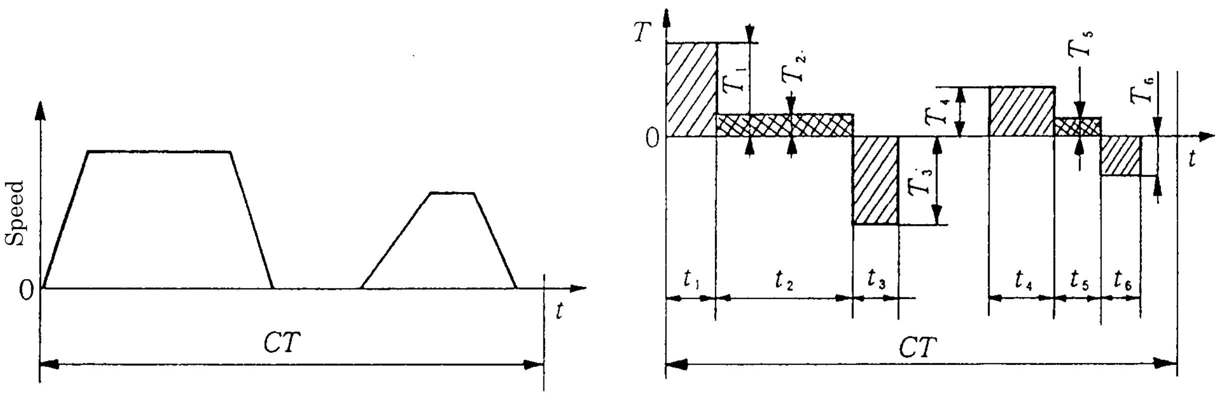
③ Calculation and evaluation of effective torque

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

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

However,

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



Speed diagram　　　　Torque diagram

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℃).

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).

$I\,(\mathrm{Nms}^2) = (I_L + I_A + I_{G4}) \times (RG1 \times RG2)^2$ ··············· (Deceleration 2 step part)
$+ (I_{G3} + I_{G2}) \times (RG1)^2$ ························ (Deceleration 1 step part)
$+ (I_{G1} + I_C + I_M + I_E + I_B)$ ····················· (No deceleration part) ················ 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)

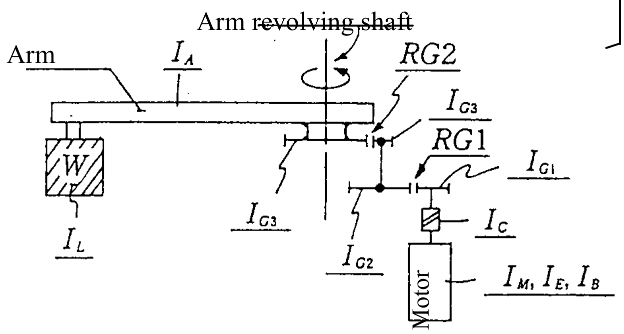


Fig. 2-11 Revolving arm

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

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

$+ (I_S + I_{G2}) \times (RG1)^2$ ··································(Deceleration 1 step part)
$+ I_{G1} + I_C + I_M + I_E + I_B$ ································(No deceleration part) ·················· 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.)

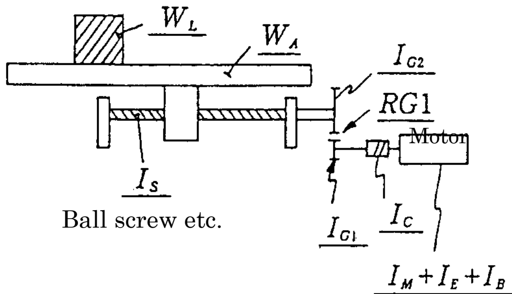


Fig. 2-12 Linear movement arm

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

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

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 × g.

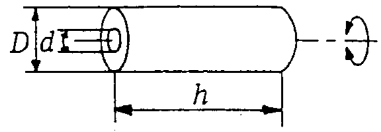


Fig. 2-13 Rotor

(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.

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

Where

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

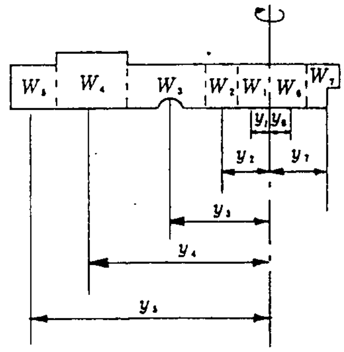


Fig. 2-14 Complex shape unit

⑤ Calculation of motor shaft angular acceleration (ω)

(a) Revolving arm

ω (rad / s^2) = $\theta \cdot 2\pi / 360 \cdot t \cdot RG$ ······ Equation (8)

(b) Linear movement

ω (rad / s^2) = $V \cdot 2\pi / l \cdot t \cdot RG$ ······ Equation (9)

Where

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

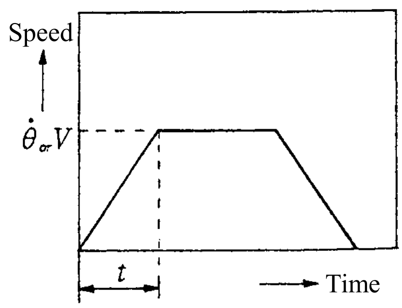


Fig. 2-15 Angular acceleration

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 (Tg)
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 (Ts)
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 (〈) of linear shaft is applied to the offset load (W) of the revolving shaft and torque (Tr) of the revolving shaft which is in proportion to the offset distance (r) occurs. (Fig. 2-17)

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

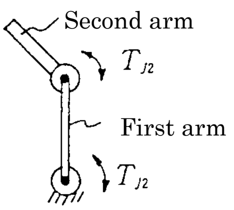


Fig. 2-16 Interference torque i

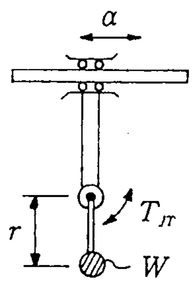


Fig. 2-17 Interference torque ii

(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 (□□) 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.

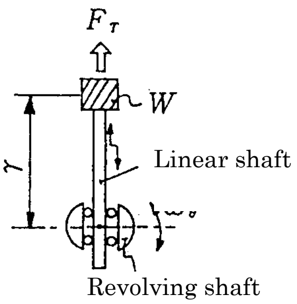


Fig. 2-18 Centrifugal force

(c) Example of Corioli's force (Fc)

When an object (W) on the revolving shaft moves at V_W speed, corioli's force (Fc) 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)

$$Fc = 2 \cdot \frac{W}{g} \cdot V_W \cdot \omega_\theta$$

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

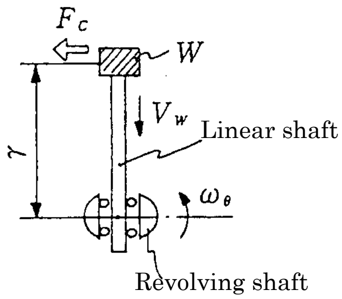


Fig. 2-19 Corioli's force

Chapter 3 Choosing AC Servomotors

There are 20 types of AC servomotors available to the SMT7 controller. This chapter provides the reference data for motor selection.

3.1 AC Servomotors

3.1.1 List of AC Servomotors

The table below lists AC servomotors available to the SMT7.

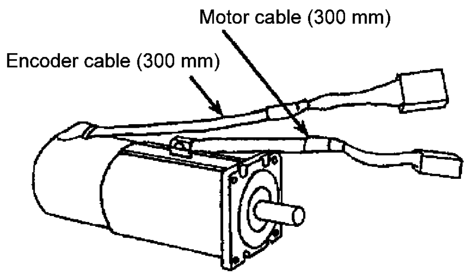
When placing an order for the SMT7, order AC servomotors selected at the same time. This is because the SMT7 is shipped from the factory with a built-in IPM board suited for AC servomotors.

List of AC Servomotors Available for the SMT7

Motor type	Motor capacity	Brake	Model	Parts No.
Standard type (For the system requiring torque with small inertia)	50 W	Without	SGMAH-A5A1A-DH1*	410627-0210
		With	SGMAH-A5A1A-DH2*	410627-0160
	100 W	Without	SGMAH-01A1A-DH1*	410627-0220
		With	SGMAH-01A1A-DH2*	410627-0170
	200 W	Without	SGMAH-02A1A-DH1*	410627-0230
		With	SGMAH-02A1A-DH2*	410627-0180
	400 W	Without	SGMAH-04A1A-DH1*	410627-0240
		With	SGMAH-04A1A-DH2*	410627-0190
	750 W	Without	SGMAH-08A1A-DH1*	410627-0250
		With	SGMAH-08A1A-DH2*	410627-0200
Flat type (For limited motor space)	100 W	Without	SGMPH-01A1A-DH1*	410627-0310
		With	SGMPH-01A1A-DH2*	410627-0260
	200 W	Without	SGMPH-02A1A-DH1*	410627-0320
		With	SGMPH-02A1A-DH2*	410627-0270
	400 W	Without	SGMPH-04A1A-DH1*	410627-0330
		With	SGMPH-04A1A-DH2*	410627-0280
	750 W	Without	SGMPH-08A1A-DH1*	410627-0340
		With	SGMPH-08A1A-DH2*	410627-0290
	1500 W	Without	SGMPH-15A1A-DH1*	410627-0350
		With	SGMPH-15A1A-DH2*	410627-0300

3.1.2 Cable End Treatment of AC Servomotors When Shipped

When shipped, the cable ends of an AC servomotor are treated with connector housings as shown below.



Cable End Treatment of AC Servomotor Shipped

3.1.3 Motor Characteristics Lists

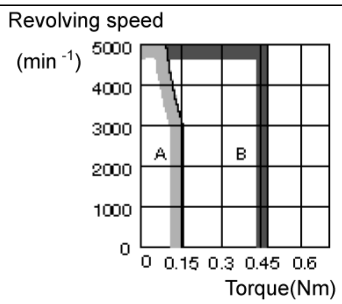
The main characteristics of each motor are listed below.

(1) Motor characteristics of standard type

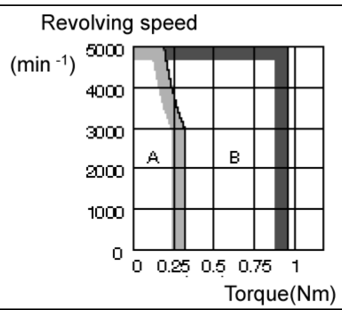
Motor model		SGMAH-A5A	SGMAH-01A	SGMAH-02A	SGMAH-04A	SGMAH-08A
Rated output W		50	100	200	400	750
Rated revolving speed r/min		3000				
Maximum revolving speed r/min		5000				
Rated torque Nm		0.159	0.318	0.637	1.27	2.39
Instantaneous max. torque Nm		0.477	0.955	1.91	3.82	7.16
Rotor inertia ($10^{-4}kgm^2$)		0.0220	0.0364	0.106	0.173	0.672
Allowable load inertia (Max. *n* times of rotor inertia)		Max. 30 times			Max. 20 times	
Rated current Arms (RMS value)		0.64	0.91	2.1	2.8	4.4
Torque constant Nm/Arms (RMS value)		0.268	0.378	0.327	0.498	0.590
Weight (without brake) kg		0.4	0.5	1.1	1.7	3.4
Weight (with brake) kg		0.7	0.8	1.6	2.2	4.3
Brake	Holding torque Nm	0.159	0.318	0.637	1.27	2.39
	Inertia at revolving part, typical ($10^{-4}kgm^2$)	0.0085		0.058		0.14
	Exiting voltage DC, V	24 ±10%				
	Exciting current DC, A (at 20°C)	0.25	0.25	0.29	0.29	0.32

Motor characteristic curve (Torque-revolving speed)

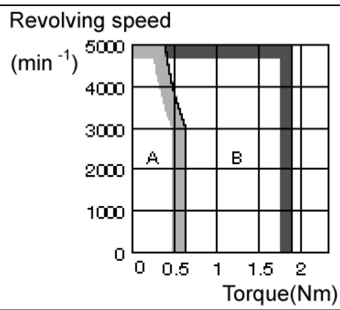
SGMAH-A5A



SGMAH-01A



SGMAH-02A

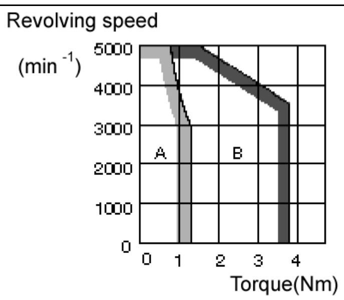


(Note)

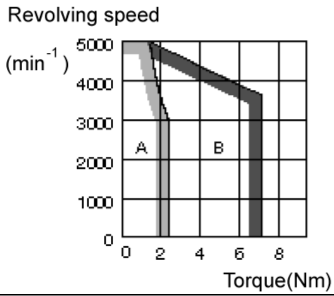
A: Continuous operating area

B: Peak loading area

SGMAH-04A



SGMAH-08A

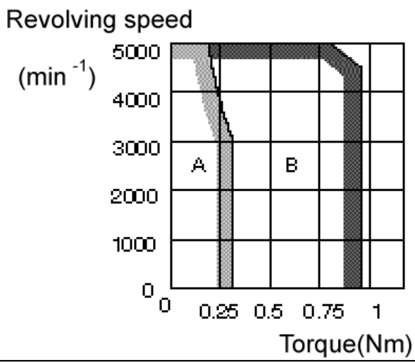


(2) Motor characteristics of flat type

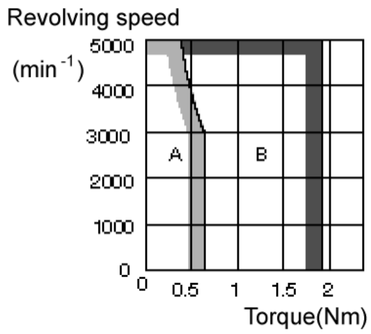
Motor model		SGMPH-01A	SGMPH-02A	SGMPH-04A	SGMPH-08A	SGMPH-15A
Rated output W		100	200	400	750	1500
Rated revolving speed r/min		3000				
Maximum revolving speed r/min		5000				
Rated torque Nm		0.318	0.637	1.27	2.39	4.77
Instantaneous max. torque Nm		0.955	1.91	3.82	7.16	14.3
Rotor inertia (10^{-4}kgm^2)		0.0491	0.193	0.331	2.10	4.02
Allowable load inertia (Max. *n* times of rotor inertia)		Max. 25 times	Max. 15 times	Max. 7 times	Max. 5 times	
Rated current Arms (RMS value)		0.89	2.0	2.6	4.1	7.5
Torque constant Nm/Arms (RMS value)		0.392	0.349	0.535	0.641	0.687
Weight (without brake) kg		0.7	1.4	2.1	4.2	6.6
Weight (with brake) kg		0.9	1.9	2.6	5.7	8.1
Brake	Holding torque Nm	0.318	0.637	1.27	2.39	4.77
	Inertia at revolving part, typical (10^{-4}kgm^2)	0.029	0.109		0.875	
	Exiting voltage DC, V	24±10%				
	Exciting current DC, A (at 20°C)	0.32	0.32	0.32	0.31	0.42

Motor characteristic curve (Torque-revolving speed)

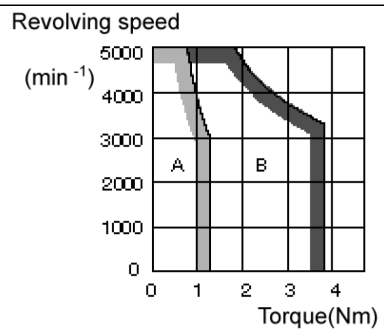
SGMPH-01A



SGMPH-02A



SGMPH-04A

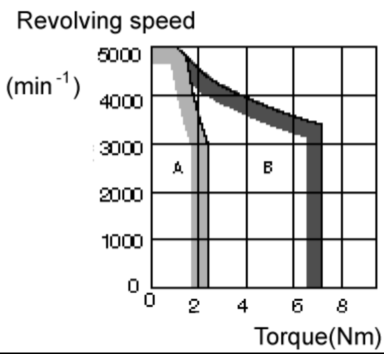


(Note)

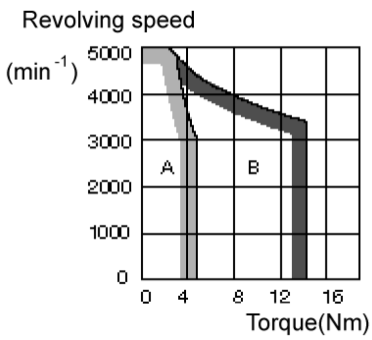
A: Continuous operating area

B: Peak loading area

SGMPH-08A



SGMPH-15A



3.1.4 Specification Details

(1) Performance

Item	Specifications
Heat resistance	Allowable ambient temperature Running: 0°C to +40°C In storage: -20°C to +80°C
Dampproof	Allowable ambient humidity 20% to 80% RH (No dew condensation allowed)
Insulation resistance	10 MΩ or more (when cooled), measured by 500 VDC megger (Motor part: Between frame and lead wire)
Withstand voltage	To resist 1500 VAC for one minute (at motor) To resist 1200 VAC for one second (at brake)
Instantaneous maximum revolving speed	100% of maximum rotation speed
Vibration resistance	49 m/s^2 max. (In each of X, Y, and Z axes)
Enclosure	Fully-enclosed, non-ventilated IP55 (except the motor shaft penetrating section)

(2) Assembly accuracy

① The assembly accuracy is specified in external dimension drawings given in Section 3.2.

- The motor shaft deviation should be measured in the lateral direction.
- The perpendicularity of the flange face to the shaft and the eccentricity of the spigot joint should be measured in the shaft upper direction.

② The end play (Shaft direction backlash) should be 0.3 mm or less.

(3) Mounting to the equipment

① When mounting the motor shaft to the equipment, use a flexible joint.

② If a rigid joint is used, even a slight runout of the center applies an excessive force to the shaft, resulting in a shaft break.

If it is not avoidable to use a rigid joint, confirm the mounting accuracy and strength of the motor shaft.

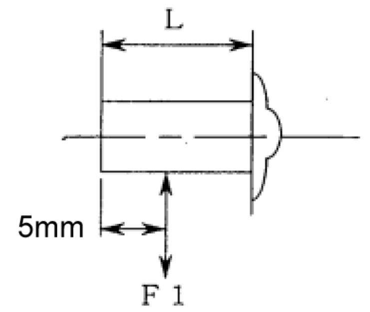
③ The motor has a built-in positioning transducer. When mounting the motor to the equipment, take special care not to apply an excessive force to the shaft; otherwise, the positioning transducer may be broken.

④ Do not pull motor lead wires. Do not allow them to be bent repeatedly.

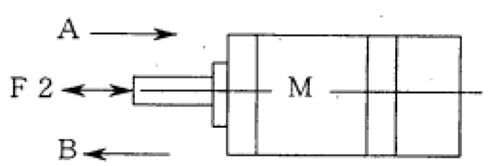
(4) Allowable shaft load

Motor			Radial load (F1)	Thrust load (F2)
Part No.	Model	Capacity		
410627-0210	SGMAH-A5A1A-DH1*	50W	68N	54N
410627-0160	SGMAH-A5A1A-DH2*	50W	68N	54N
410627-0220	SGMAH-01A1A-DH1*	100W	78N	54N
410627-0170	SGMAH-01A1A-DH2*	100W	78N	54N
410627-0230	SGMAH-02A1A-DH1*	200W	245N	74N
410627-0180	SGMAH-02A1A-DH2*	200W	245N	74N
410627-0240	SGMAH-04A1A-DH1*	400W	245N	74N
410627-0190	SGMAH-04A1A-DH2*	400W	245N	74N
410627-0250	SGMAH-08A1A-DH1*	750W	392N	147N
410627-0200	SGMAH-08A1A-DH2*	750W	392N	147N
410627-0310	SGMPH-01A1A-DH1*	100W	78N	49N
410627-0260	SGMPH-01A1A-DH2*	100W	78N	49N
410627-0320	SGMPH-02A1A-DH1*	200W	245N	68N
410627-0270	SGMPH-02A1A-DH2*	200W	245N	68N
410627-0330	SGMPH-04A1A-DH1*	400W	245N	68N
410627-0280	SGMPH-04A1A-DH2*	400W	245N	68N
410627-0340	SGMPH-08A1A-DH1*	750W	392N	147N
410627-0290	SGMPH-08A1A-DH2*	750W	392N	147N
410627-0350	SGMPH-15A1A-DH1*	1500W	490N	147N
410627-0300	SGMPH-15A1A-DH2*	1500W	490N	147N

Radial load (F1) position



Thrust load (F2) direction



(5) Lead wire colors and signals

Motor lead wires

Motor side	Name
Red	U
White	V
Blue	W
Green/Yellow	E (FG)

Brake lead wires

Brake side	Name
Black	Brake
Black	Brake

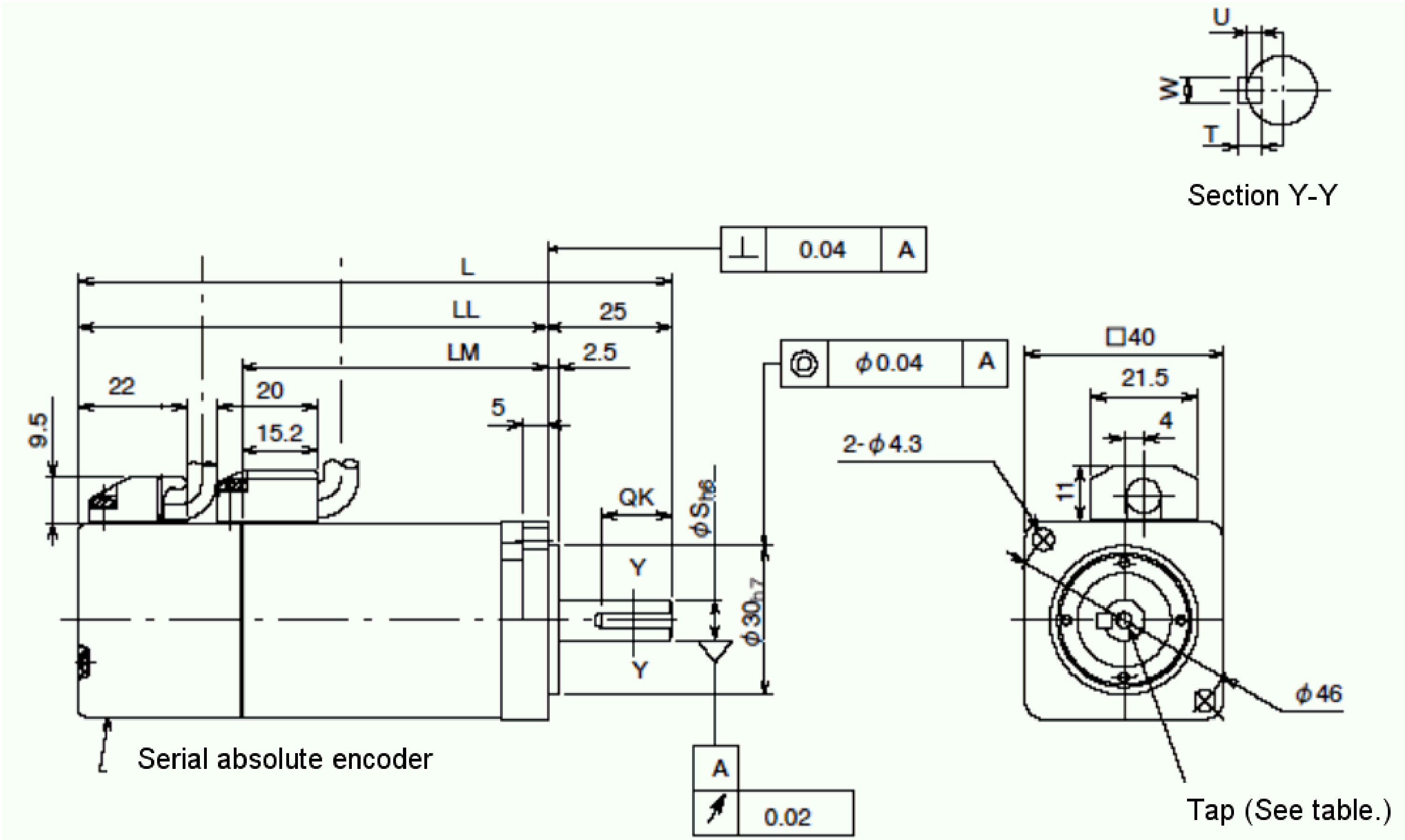
Encoder lead wires

Encoder side	Name	Remarks
Orange	BAT	Twisted pair wires
White /Orange	COMMON	
Sky blue	PS	Twisted pair wires
White /Sky blue	$\overline{PS}$	
Red	+5 V	Twisted pair wires
Black	0 V	
Shielding wire	Shield	

3.2 External Dimensions of AC Servomotors

■Standard type without brake [50W or 100W]

Part No.	Motor model SGMAH -	Rated output	L	LL	LM	S	Tap	QK	U	W	T	Approx weight
410627-0210	A5A1A - DH1*	50W	102.0	77.0	44.0	6	Dia. 2.5, Depth 5	14	1.2	2	2	0.4 kg
410627-0220	01A1A - DH1*	100W	119.5	94.5	61.5	8	Dia. 3, Depth 6	14	1.8	3	3	0.5 kg



(Unit: mm)

Remarks

(1) Assembly accuracy conforms to Japan Machine Tool Builder's Association standard (MAS402-1981). (TIR value)

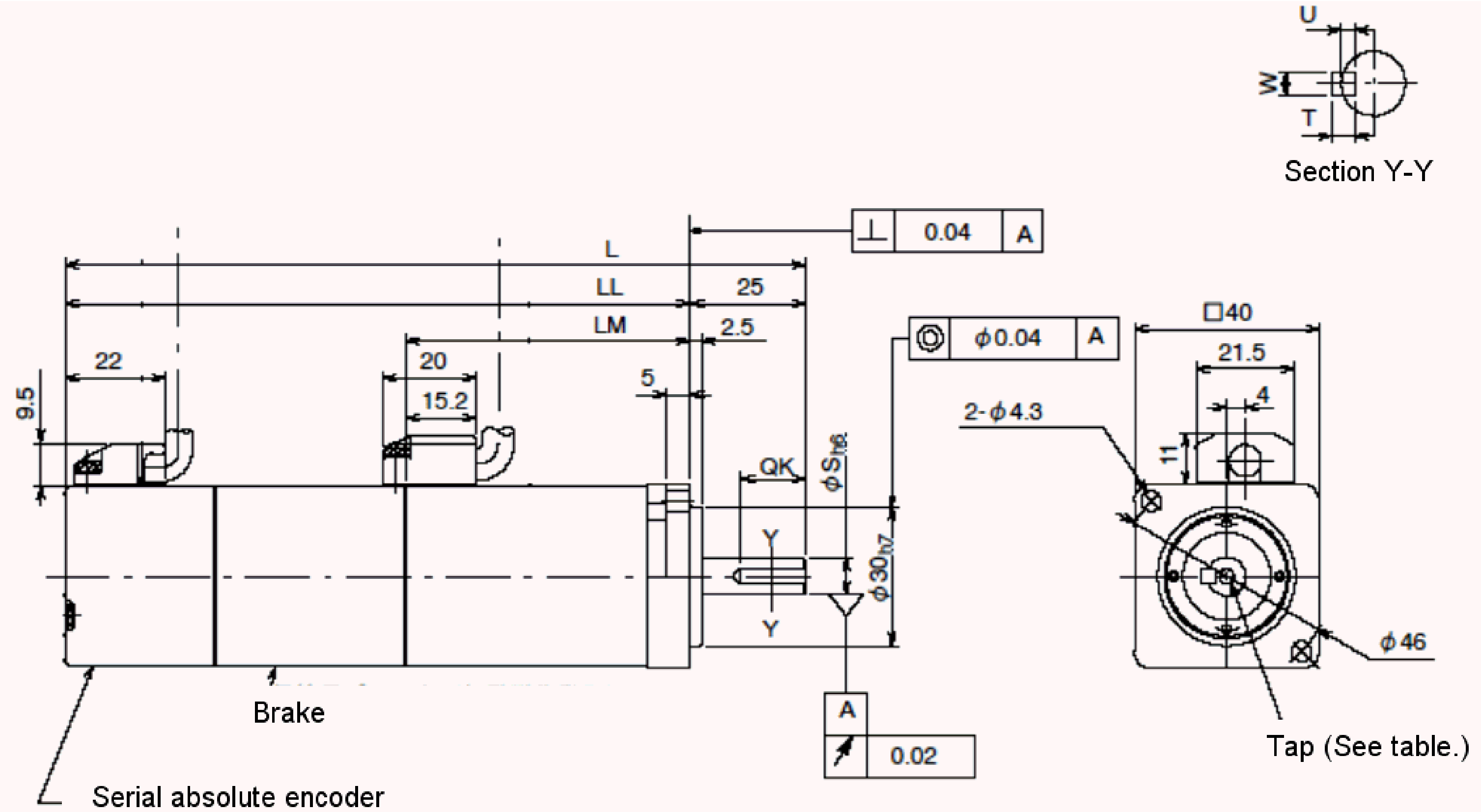
a) Shaft end deflection 0.03 (Shaft projection center)
b) Squareness of flange face against shaft 0.08 (φ45)
c) Eccentricity of flange-fitting-outside diameter against shaft (Spigot joint portion center)

(2) Flange fixing bolt: Use hexagon socket head bolt.

(3) Motor cable / Encoder cable length: 300 mm

■Standard type with brake [50W or 100W]

Part No.	Motor model SGMAH -	Rated output	L	LL	LM	S	Tap	QK	U	W	T	Approx weight
410627-0160	A5A1A - DH2*	50W	133.5	108.5	44.0	6	Dia. 2.5, Depth 5	14	1.2	2	2	0.7 kg
410627-0170	01A1A - DH2*	100W	160.0	135.0	61.5	8	Dia. 3, Depth 6	14	1.8	3	3	0.8 kg



(Unit: mm)

Remarks

(1) Assembly accuracy conforms to Japan Machine Tool Builder's Association standard (MAS402-1981). (TIR value)

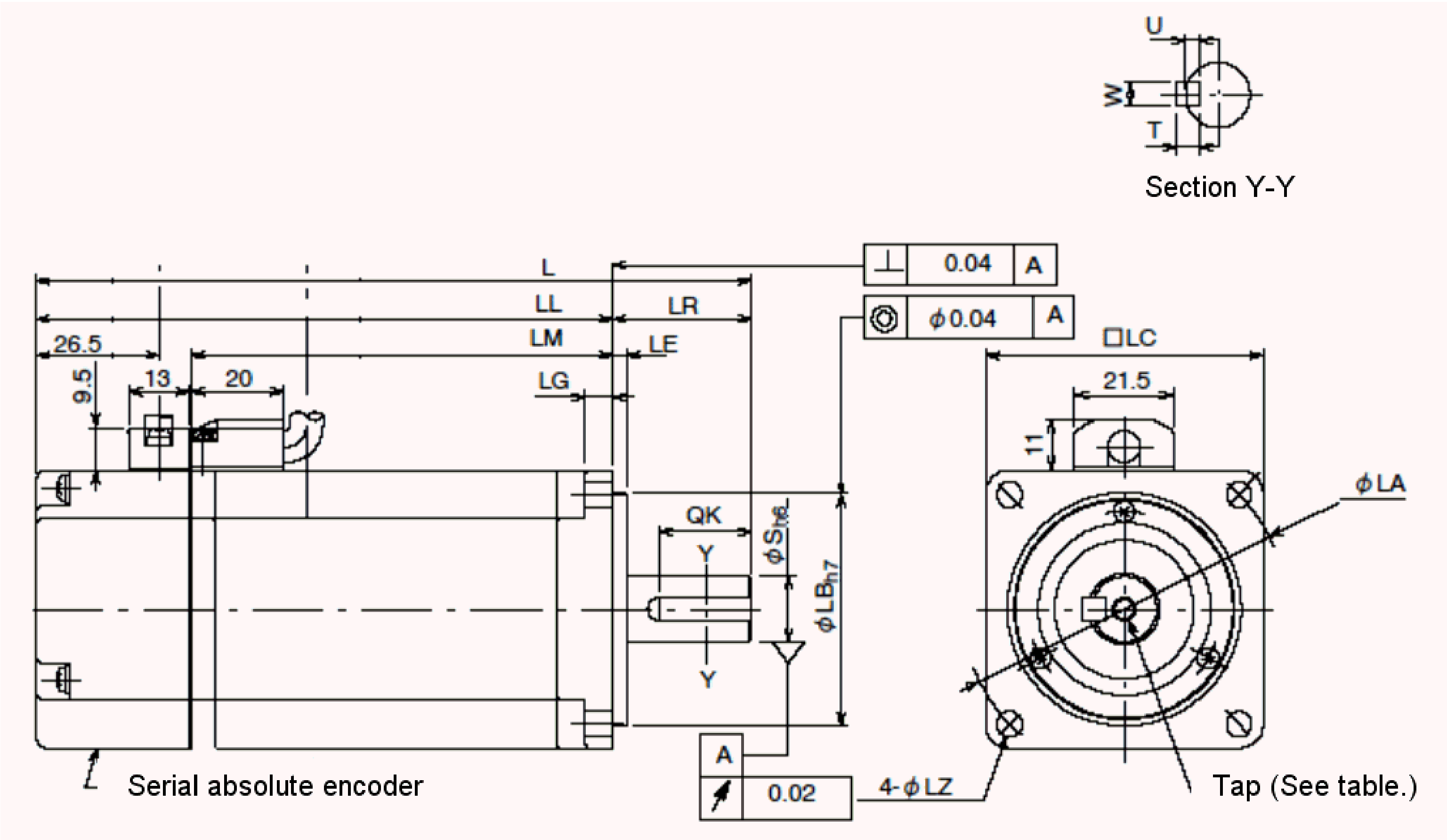
a) Shaft end deflection 0.03 (Shaft projection center)
b) Squareness of flange face against shaft 0.08 (ϕ45)
c) Eccentricity of flange-fitting-outside diameter against shaft (Spigot joint portion center)

(2) Flange fixing bolt: Use hexagon socket head bolt.

(3) Motor cable / Encoder cable length: 300 mm

■Standard type without brake [200W, 400W or 750W]

Part No.	Motor model SGMAH-	Rated output	L	LL	LM	LR	LE	LG	LC	LA	LZ	S	LB	Tap	QK	U	W	T	Approx weight
410627-0230	02A1A–DH1*	200W	126.5	96.5	62.5	30	3	6	60	70	5.5	14	50	Dia. 5, Depth 8	20	3	5	5	1.1 kg
410627-0240	04A1A–DH1*	400W	154.5	124.5	90.5	30	3	6	60	70	5.5	14	50	Dia. 5, Depth 8	20	3	5	5	1.7 kg
410627-0250	08A1A-DH1*	750W	185	145	111	40	3	8	80	90	7	16	70	Dia. 5, Depth 8	20	3	5	5	3.4kg



(Unit: mm)

Remarks

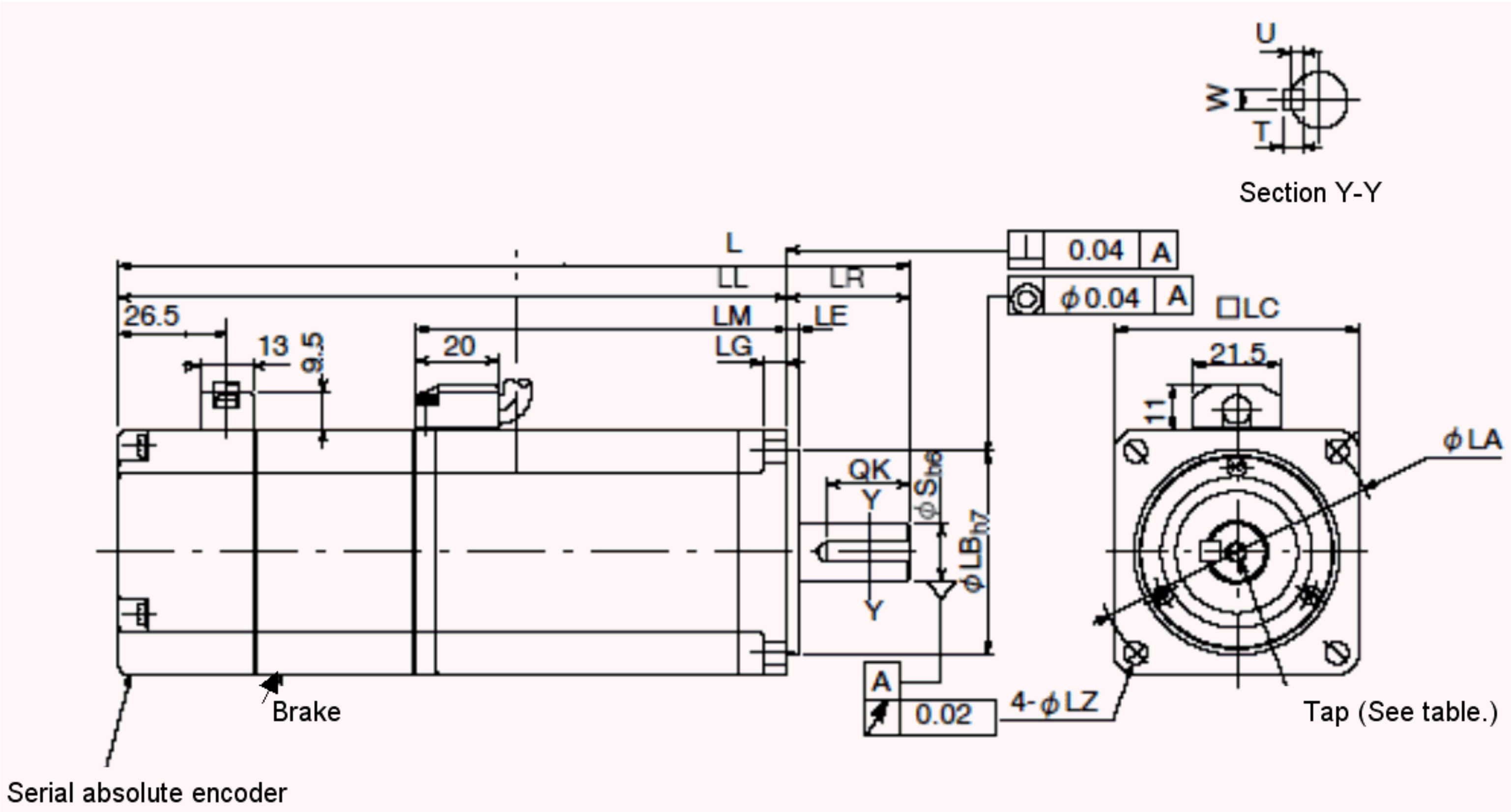
(1) Assembly accuracy conforms to Japan Machine Tool Builder's Association standard (MAS402-1981). (TIR value)
  a) Shaft end deflection 0.03 (Shaft projection center)
  b) Squareness of flange face against shaft 0.08 (ϕ45)
  c) Eccentricity of flange-fitting-outside diameter against shaft (Spigot joint portion center)

(2) Flange fixing bolt: Use hexagon socket head bolt.

(3) Motor cable / Encoder cable length: 300 mm

■Standard type with brake [200W, 400W or 750W]

Part No.	Motor model SGMAH-	Rated output	L	LL	LM	LR	LE	LG	LC	LA	LZ	S	LB	Tap	QK	U	W	T	Approx weight
410627-0180	02A1A–DH2*	200W	166.0	136.0	62.5	30	3	6	60	70	5.5	14	50	Dia. 5, Depth 8	20	3	5	5	1.6 kg
410627-0190	04A1A–DH2*	400W	194.0	164.0	90.5	30	3	6	60	70	5.5	14	50	Dia. 5, Depth 8	20	3	5	5	2.2 kg
410627-0200	08A1A-DH2*	750W	229.5	189.5	111	40	3	8	80	90	7	16	70	Dia. 5, Depth 8	20	3	5	5	4.3kg



(Unit: mm)

Remarks

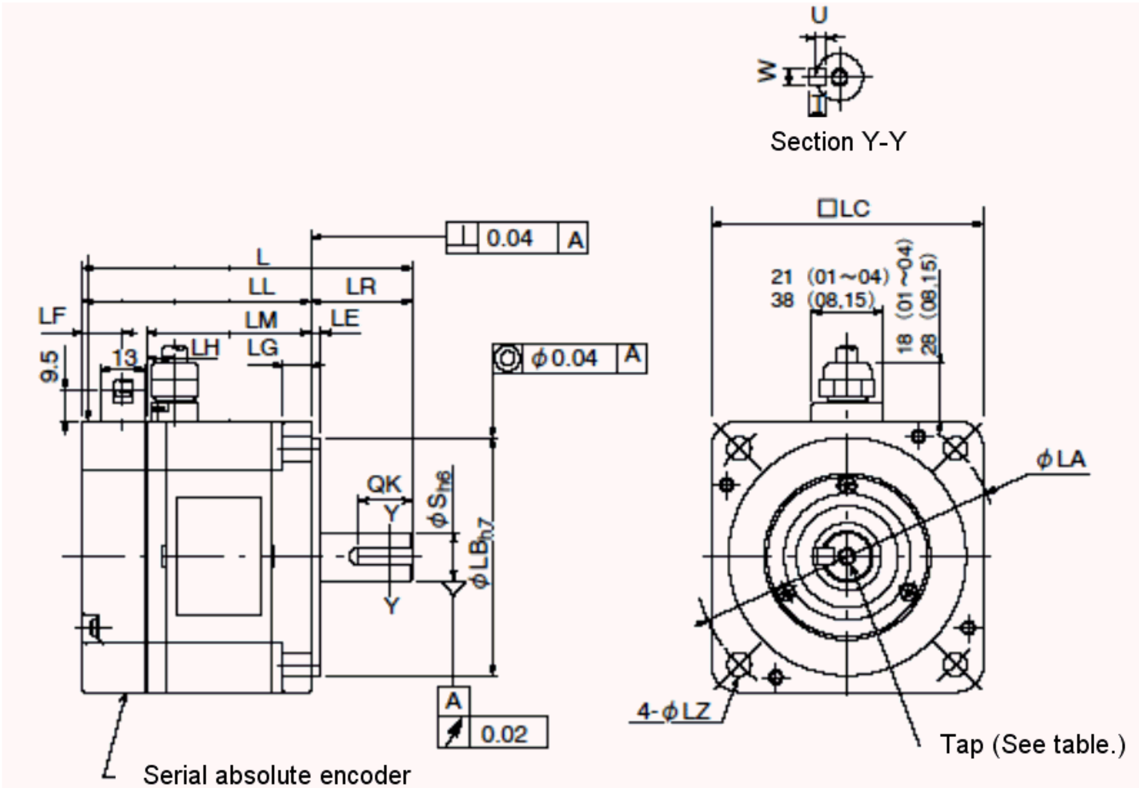
(1) Assembly accuracy conforms to Japan Machine Tool Builder's Association standard (MAS402-1981). (TIR value)
  a) Shaft end deflection 0.03 (Shaft projection center)
  b) Squareness of flange face against shaft 0.08 (ϕ45)
  c) Eccentricity of flange-fitting-outside diameter against shaft (Spigot joint portion center)

(2) Flange fixing bolt: Use hexagon socket head bolt.

(3) Motor cable / Encoder cable length: 300 mm

■Flat type without brake [100W, 200W, 400W, 750W or 1.5kW]

Part No.	Motor model SGMPH-	Rated output	L	LL	LM	LR	LE	LG	LF	LC	LA	LZ	S	LB	LH	Tap	QK	U	W	T	Approx weight
410627-0310	01A1A–DH1*	100W	87.0	62.0	42.5	25	3	6	12.5	60	70	5.5	8	50	10.55	Dia. 3, Depth 6	14	1.8	3	3	0.7 kg
410627-0320	02A1A–DH1*	200W	97.0	67.0	48.1	30	3	8	11.9	80	90	7	14	70	8.25	Dia. 5, Depth 8	16	3	5	5	1.4 kg
410627-0330	04A1A–DH1*	400W	117.0	87.0	68.1	30	3	8	11.9	80	90	7	14	70	8.25	Dia. 5, Depth 8	16	3	5	5	2.1 kg
410627-0340	08A1A-DH1*	750W	126.5	86.5	66.7	40	3.5	10	12.8	120	145	10	16	110	10.5	Dia. 5, Depth 8	22	3	5	5	4.2kg
410627-0350	15A1A-DH1*	1.5kW	154.5	114.5	94.7	40	3.5	10	12.8	120	145	10	19	110	10.5	Dia. 6, Depth 10	22	3.5	6	6	6.6kg



(Unit: mm)

Remarks

(1) Assembly accuracy conforms to Japan Machine Tool Builder's Association standard (MAS402-1981). (TIR value)

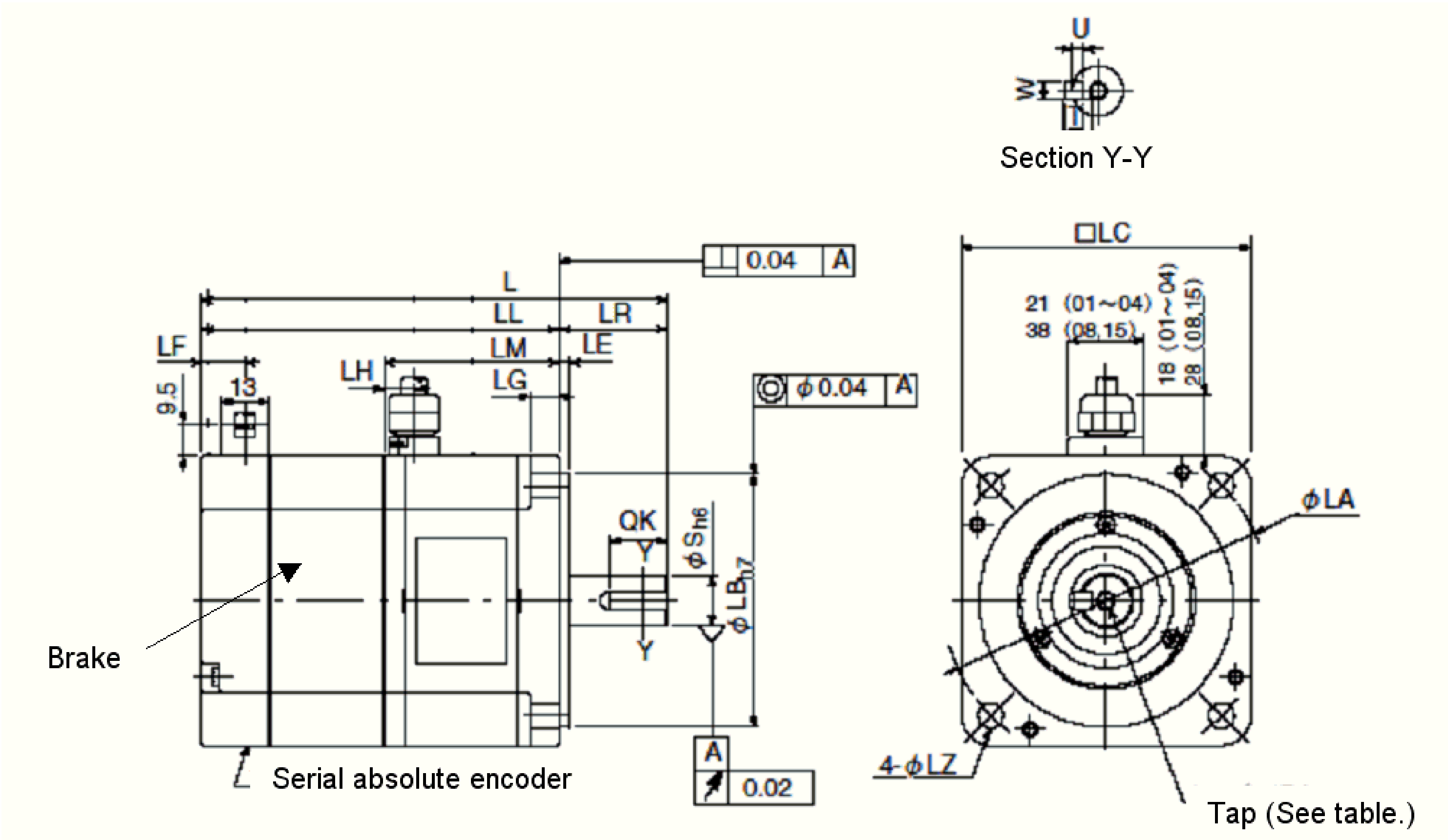
a) Shaft end deflection: 0.03 (Shaft projection center)
b) Squareness of flange face against shaft 0.08 (φ45)
c) Eccentricity of flange-fitting-outside diameter against shaft (Spigot joint portion center)

(2) Flange fixing bolt: Use hexagon socket head bolt.

(3) Motor cable / Encoder cable length: 300 mm

■Flat type with brake [100W, 200W, 400W, 750W or 1.5kW]

Part No.	Motor model SGMPH-	Rated output	L	LL	LM	LR	LE	LG	LF	LC	LA	LZ	S	LB	LH	Tap	QK	U	W	T	Approx weight
410627-0260	01A1A–DH2*	100W	116.0	91.0	42.5	25	3	6	12.5	60	70	5.5	8	50	10.55	Dia. 3, Depth 6	14	1.8	3	3	0.9 kg
410627-0270	02A1A–DH2*	200W	128.5	98.5	48.1	30	3	8	11.9	80	90	7	14	70	8.25	Dia. 5, Depth 8	16	3	5	5	1.9 kg
410627-0280	04A1A–DH2*	400W	148.5	118.5	68.1	30	3	8	11.9	80	90	7	14	70	8.25	Dia. 5, Depth 8	16	3	5	5	2.6 kg
410627-0290	08A1A–DH2*	750W	163.0	123.0	66.7	40	3.5	10	12.8	120	145	10	16	110	10.5	Dia. 5, Depth 8	22	3	5	5	5.7kg
410627-0300	15A1A–DH2*	1.5kW	188.0	148.0	94.7	40	3.5	10	12.8	120	145	10	19	110	10.5	Dia. 6, Depth 10	22	3.5	6	6	8.1kg



(Unit: mm)

Remarks

(1) Assembly accuracy conforms to Japan Machine Tool Builder's Association standard (MAS402-1981). (TIR value)

a) Shaft end deflection: 0.03 (Shaft projection center)
b) Squareness of flange face against shaft 0.08 (φ45)
c) Eccentricity of flange-fitting-outside diameter against shaft (Spigot joint portion center)

(2) Flange fixing bolt:
Use hexagon socket head bolt.

(3) Motor cable / Encoder cable length: 300 mm

Chapter 4 Configuring the Joint Parameters

To use joints, you need to configure joint parameters beforehand. There are three types of 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 joints.

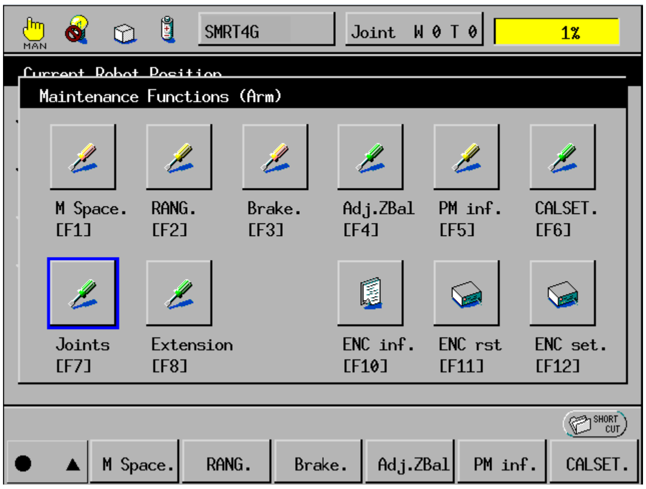
(2) Servo configuration parameters, which are provided for setting the gain and others of joint servo system.

(3) Arm configuration parameters, which are provided for performing CP motions with joints being collaborated.

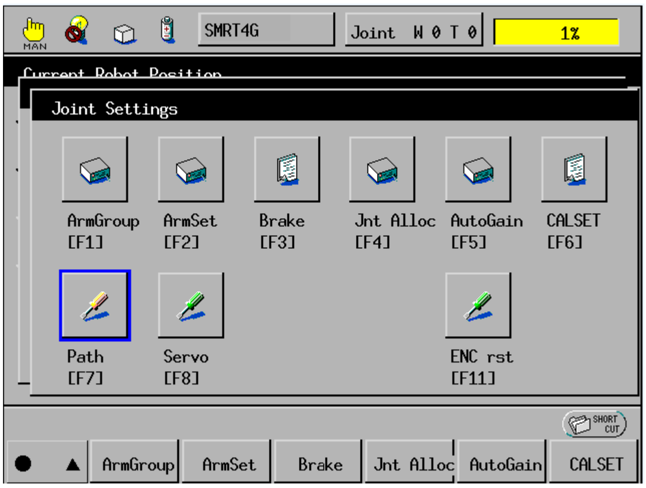
4.1 Path Configuration Parameters

(1) Call up the "Maintenance Functions (Arm)" window.

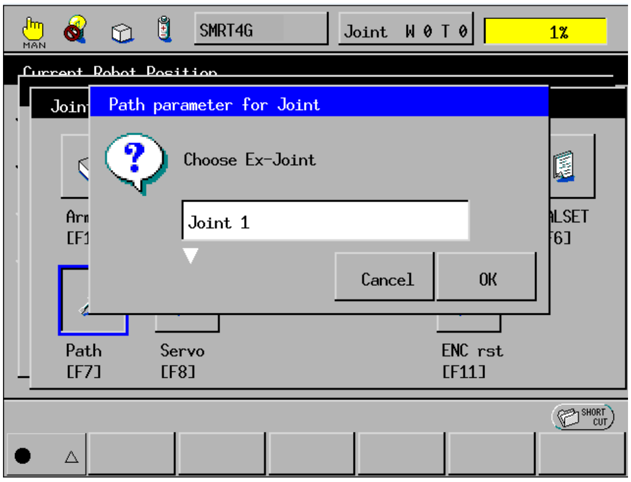
Access: Top Screen—[F2 Arm]—[F12 Maint.]



(2) Press [F7 Joints]. The Joint Settings window appears.

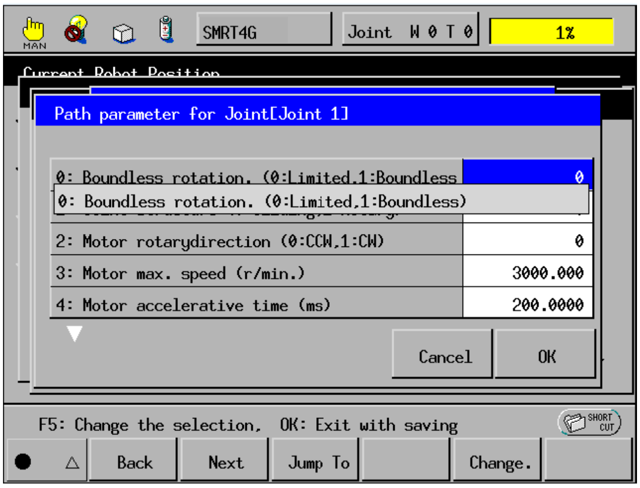


(3) Press [F7 Path]. The path configuration window appears as shown below.



(4) Select the target joint (J1 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: For the detailed procedure, refer to Section 4.5 "Detailed Description of Joint Parameter Setting."



The path configuration parameters are listed in the table on the next page.

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

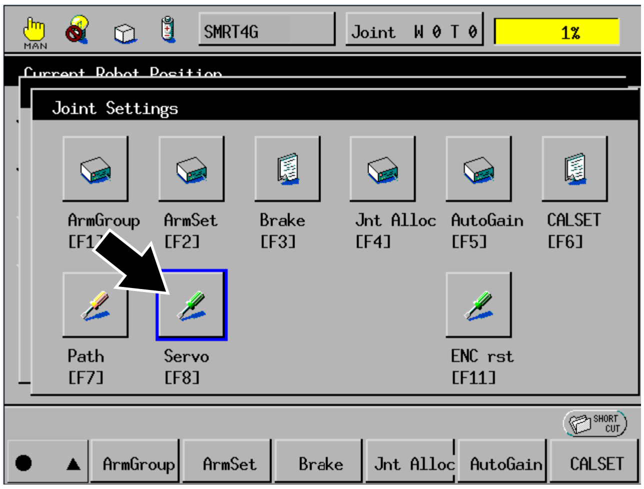
List of Path Configuration Parameters

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.	Setting this parameter to "1: Boundless" requires the Motion limit detection parameter to be set to "0: Invalid."	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 5000	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.	100	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.	Setting the Boundless rotation parameter to "1: Boundless" requires this parameter to be set to "0: Invalid."	Needed
Positive motion limit (deg.) (mm)		360	For rotary joints: degrees For sliding joints: mm	Set the positive motion limit.		Not needed
Negative motion limit (deg.) (mm)		-360	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

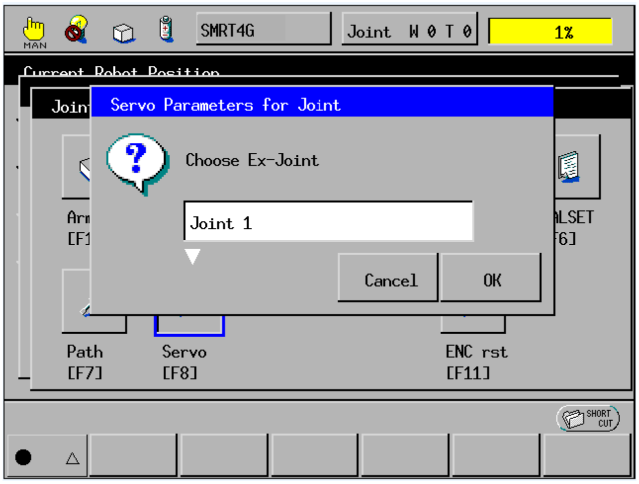
4.2 Servo Configuration Parameters

(1) Call up the Joint Settings window.

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

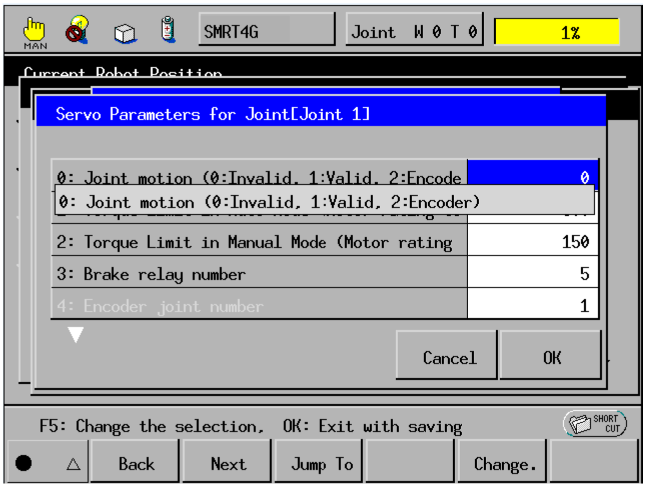


(2) On the Joint Settings window shown above, press [F8 Servo]. The servo configuration window appears as shown below. Select the target joint (J1 in this example) by using the cursor keys or jog dial.



(3) Press [OK]. The servo configuration parameters window appears as shown below. Change the servo configuration parameters and press [OK].

Note: For the detailed procedure, refer to "Detailed Description of Joint Parameter Setting."



The servo configuration parameters are listed in the table below.

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

List of Servo Configuration Parameters (1)

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 ratio %)	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.	

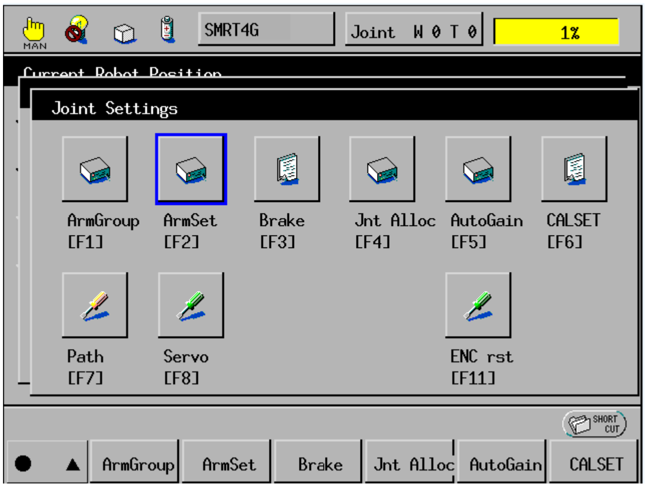
List of Servo Configuration Parameters (2)

Parameter name	Entry range	Factory default	Unit	Description	Remarks	Controller restart
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 4.7-1 given in Section 4.7.	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 4.7-2 given in Section 4.7.	Not needed
Speed loop proportional gain	1 min.	200 (for 400 W or less) 400 (for 750 W 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 4.7-3 given in Section 4.7.	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 4.7-4 given in Section 4.7.	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 (**SGMAH** 50W: 1, 100W: 2, 200W: 3, 400W: 4, 750W: 5 **SGMPH** 100W: 12, 200W: 13, 400W: 14, 750W: 15, 1500W: 16)	1 to 16			Display the connected motor capacity	No change allowed.	

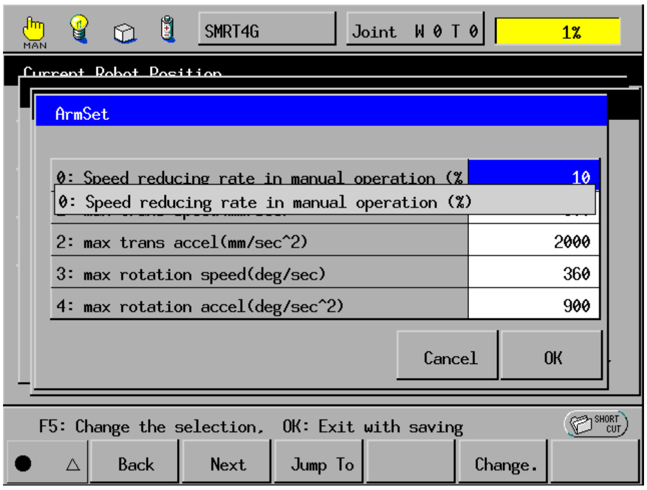
4.3 Arm Configuration Parameters

(1) Call up the Joint Settings window.

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



(2) Press [F2 ArmSet]. The ArmSet window appears as shown below.



List of Arm Configuration Parameters

Parameter name	Entry range	Factory default	Unit	Description	Remarks	Controller restart
Speed reduction rate in manual operation	1 to 10	10	%	Limit the manual operation speed to 10 % or below of the automatic operation one.		Needed
Maximum translation speed	1 min.	800	mm/s	Set the maximum translation speed in CP motion.		Needed
Maximum translation acceleration	1 min.	2000	mm/s^2	Set the maximum translation acceleration in CP motion.		Needed
Maximum rotation speed	1 min.	360	deg/s	Set the maximum rotation speed in CP motion.		Needed
Maximum rotation acceleration	1 min.	900	deg/s^2	Set the maximum rotation acceleration in CP motion.		Needed

4.3.1 Setting the Speed Reduction Rate in Manual Operation

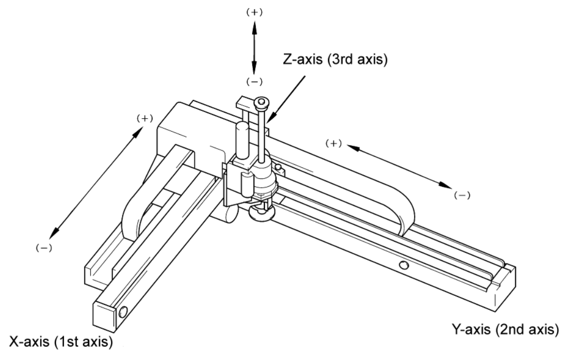
The speed reduction rate in manual operation can be limited to 10% or below of that in automatic operation.

This section provides the reduction rate calculation procedure using the maximum composite tool-end speed and the target speed in manual operation.

NOTE: For details, refer to the ISO 10218-1:2006, Safety Requirements.

The example below uses a 3-joint mechanism configured with Cartesian coordinates and limits the tool-end speed in manual operation to 250 mm/s or below.

(1) Check the specifications of the 3-joint mechanism and calculate the maximum speed of each joint.



<u>3-joint mechanism</u>
X-joint: Max. speed 2000 mm/s
Y-joint: Max. speed 2000 mm/s
Z-joint: Max. speed 1000 mm/s

<u>Calculating the maximum speed</u>
Assuming:
Lead/rev.: 40 mm
Maximum motor rotation: 3000 rpm,

Then:

$$\frac{3000[rpm]}{60} \times 40[mm/rev]$$
$$= 2000[mm/s]$$

(2) Calculate the maximum composite tool-end speed.

<u>Calculation example</u>

$$\sqrt{x^2 + y^2 + z^2} = \sqrt{(2000)^2 + (2000)^2 + (1000)^2} = 3000[mm/s]$$

(3) Calculate the speed reduction rate in manual operation to limit the tool-end speed to 250 mm/s or below.

<u>Calculation example</u>

$$250[mm/s] \Big/ 3000[mm/s] \times 100 \approx 8$$ (%) (Truncate the decimal places.)

(4) Enter the calculation result into the "Speed reducing rate in manual operation" field in the ArmSet window shown on the previous page.

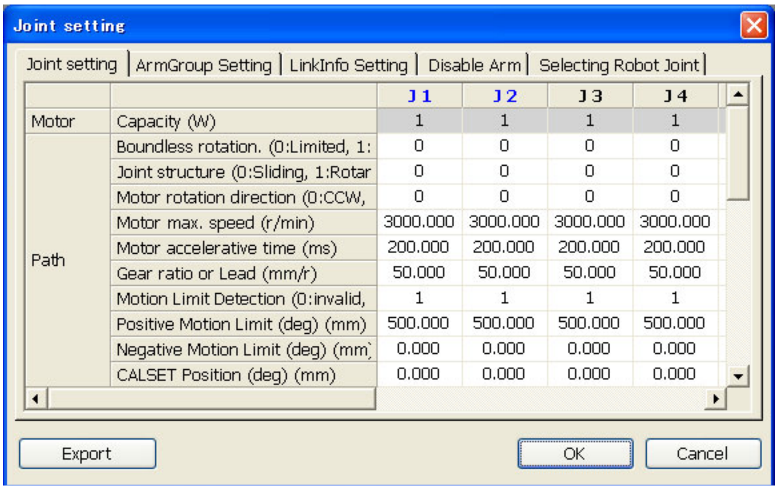
4.4 Outputting a List of Joint Parameter Settings (Using WINCAPSIII)

WINCAPSIII can display a list of joint parameter settings on the PC screen and output it in CSV format.

If you log on to WINCAPSIII as Programmer or higher level, you can configure the following parameters in the Joint Setting window.

- Joint setting table tab
  - Path settings
  - Servo settings
  - Arm settings
- Arm group tab
- Link info tab
- Disable arm tab
- Selecting Robot Joint tab

(1) Calling up the "Joint setting" window
Access: Project | Joint Setting Table



"Joint setting table" Window

(2) Outputting the joint setting table data in CSV format
Access: Export button in the Joint setting window

Pressing the [Export] button displays the file selection dialog box where you select a file to save the data in CSV format.

4.5 Detailed Description of Joint Parameter Setting

The path configuration parameters and servo configuration parameters should be configured with joints being connected to motors.

(1) Resetting the encoder

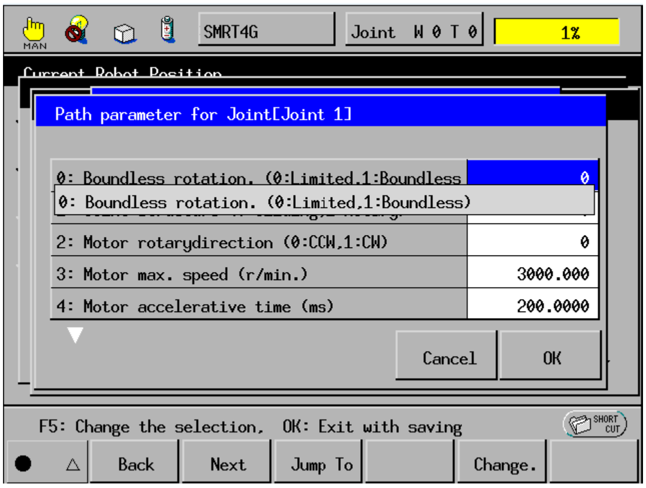
The encoder is not connected with a backup battery at the time of shipment, so the error message "J* encoder system down" or "J* encoder speed exceeded" will appear.

If this happens, reset the encoder (refer to Section 4.8.3) and restart the controller.

(2) Setting the path configuration parameters

For the calling-up procedure of the path configuration parameters window, refer to Section 4.1.

(2-1) Boundless rotation



The boundless rotation function suppresses errors that could occur if a joint keeps on rotation in the same direction. (This function applies to J5 or later.) You need to set the boundless rotation parameter to [1: Boundless] in the path configuration parameters window.

Notes for allowing boundless rotation

(1) When a joint is used as a rotary joint, an absolute motion command (DRIVEA or MOVE with EXA option) can drive it within the range of ±360°. 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 ±360° is commanded, the joint rotates the specified angle and then it automatically returns to the position within the range of ±360°. 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 a 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 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 a joint is used as a rotary joint requiring positioning, e.g., index table, observe the following instructions.

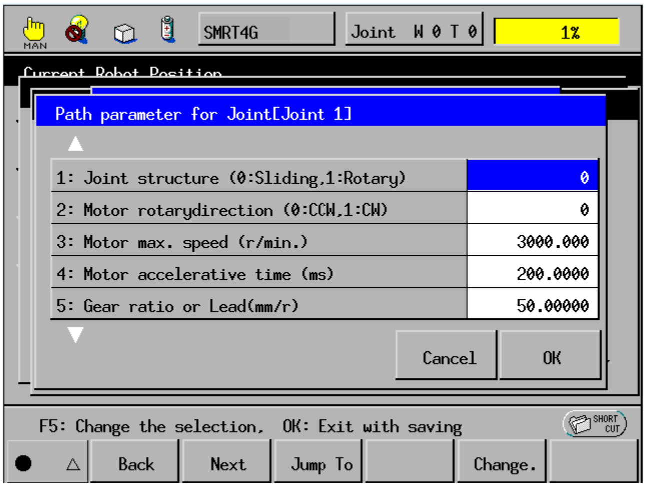
- For the reduction gear, enter an integer multiple. Entering a non-integer multiple will result in a positioning error after a lot of rotations.
- If a relative motion command specifies a motion amount using a decimal, the joint could reach the position slightly different from the specified one. Using such a relative motion command repeatedly will result in a positioning error after a lot of rotations.

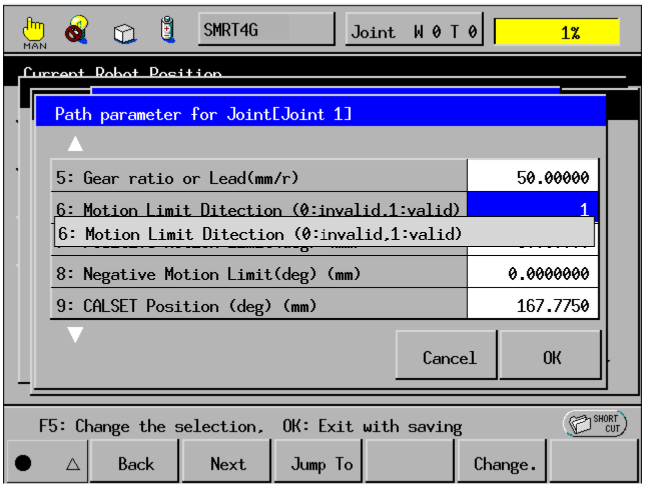
  To avoid such a positioning error, correct the difference from the specified position, for example, using an absolute motion command or MoveIndexHome library after completion of one rotation to return the joint to the home position.

(7) Rotating a 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.

(2-2) Setting the motion conditions

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.



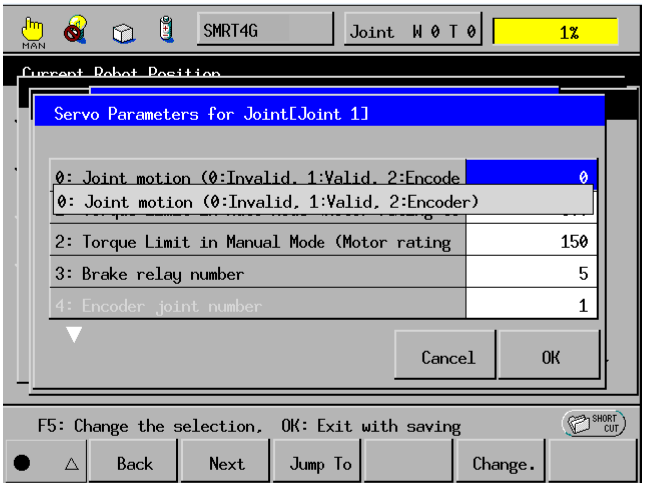


(3) Setting the servo configuration parameters

For the calling-up procedure of the servo configuration parameters window, refer to Section 4.2.

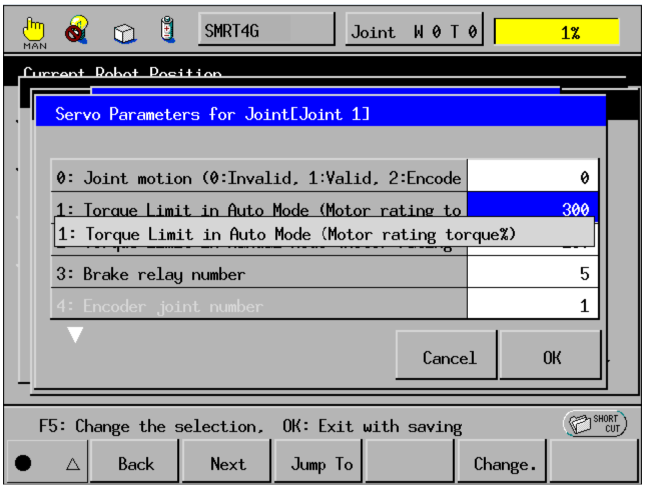
(3-1) Setting the joint motion

Set the joint motion to "1: Valid."



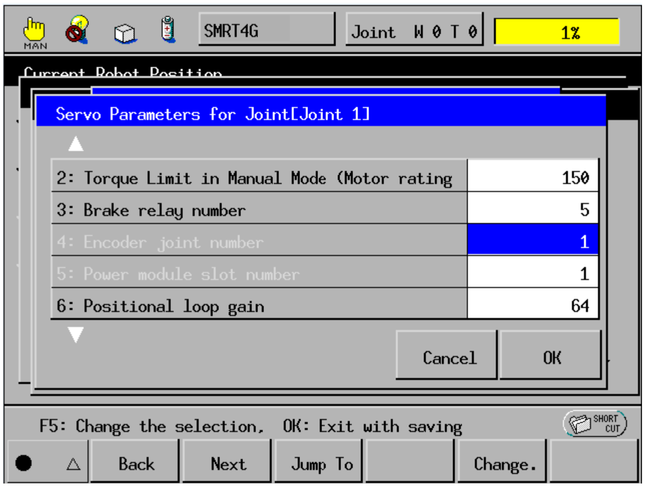
(3-2) Setting the torque limits

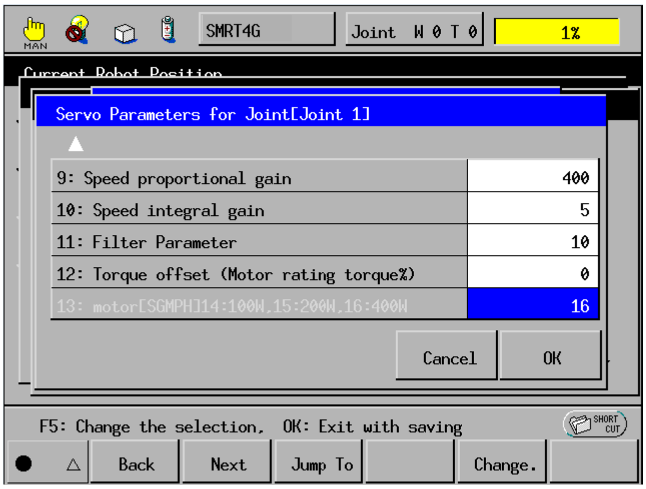
Set the torque limits in each of Auto and Manual modes.



(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.





After completion of steps (1) to (3), restart the controller.

(4) Checking the wiring

(4-1) Checking the brake wiring

If the motor has a brake, release the brake and check that the brake of all joints will be released. For the brake releasing procedure, refer to Section 4.8.2 "Releasing or locking brakes."

(4-2) Checking the encoder wiring

After releasing the brake of the 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.

(4-3) Checking the motor wiring

Turn the motor on, set the motor speed at SP10, and check that you may drive the 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.

(5) Executing CALSET

Release the brake of the motor and move the optional mechanism connected to the motor to the CALSET reference position. Then execute CALSET in the CALSET reference position, referring to Section 4.8.1 "Performing CALSET Operation on Each Joint."

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..

(6) Checking the motion of the mechanism connected to the joint motor

Run the 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.

4.6 Configuring Motors as Robot Joints or Extended-Joints

The motors connected to the controller can be configured as robot joints or extended-joints. Any or all of joints 1 to 4 can be configured as robot joints. (In version 2.7 or earlier, all of four joints J1 to J4 are fixed as robot joints.)

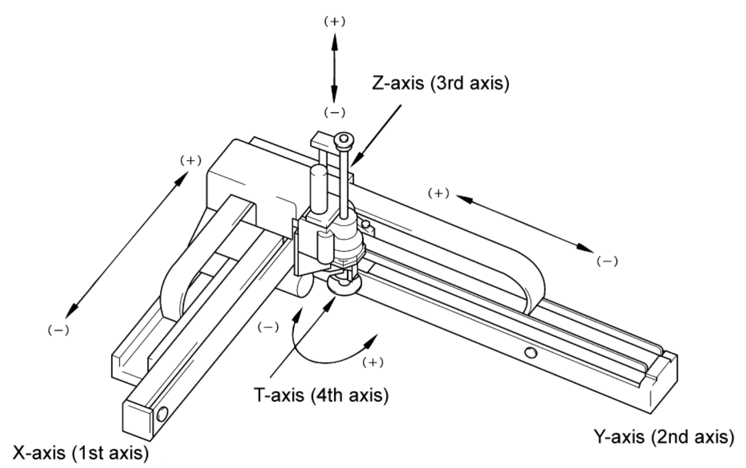
Robot joints can be driven by robot motion commands enabling CP motion (linear and circular). To enable those robot motion commands, however, joints J1 to J4 should be configured as predetermined.

All joints except robot joints are used as extended-joints.

For details about operations of robot joints and extended-joints, refer to the Supplement for Extended-Joints Support.

4.6.1 Robot Joints

Configuring robot joints J1 to J4 in Cartesian coordinates as shown below enables you to drive those joints with robot motion commands enabling CP motion (linear and circular).

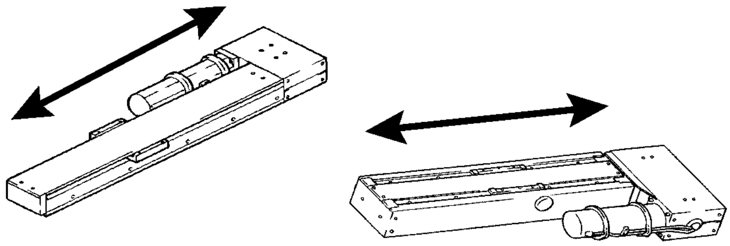


Example of joint configuration with Cartesian coordinates realized in robot motion

> **NOTE:** To drive joints correctly in a CP motion (linear or circular), the configuration and the motion directions of J1 to J4 must match the Cartesian coordinates (coordinates for RIGHTY) shown above. In a different configuration of J1 to J4, commanding a CP motion causes an unexpected motion. It is dangerous. Use a PTP motion instead of a CP motion.

4.6.2 Extended-Joints

A single extended-joint is configured as shown below. It can execute only PTP motion. A MOVE command is not available for extended-joints, so use DRIVEA and DRIVE commands to drive extended-joints.



Example of configuration realized in extended-joint motion

4.6.3 Usable Functions in Robot and Extended-Joint Motion (Examples)

	Usable functions in robot motion	Usable functions in extended-joint motion
Position variables	Joint, Position, and Double-precision variables	Floating-point variables
Motion control	All commands used in the robot, including MOVE, APPROACH, DEPART, CURJNT, and CURPOS. *	DRIVE, DRIVEA (only in PTP motion)
Manual motion mode	Joint, X-Y, and Tool modes (Cartesian coordinate type only)	Joint mode only

NOTE: The CP motion (linear or circular) of robot joints is available depending on the configuration of J1 to J4. For details, see the illustration given in "Robot Joints."

***These commands take effect only for joints configured as robot joints and they are invalid for other joints.**

4.6.4 Configuring Robot Joints

The SMT7 controller is capable of controlling a maximum of eight joints (incl. optional extended-joints) that can be configured as robot joints or extended-joints.

Up to four joints can be selectively configured as robot joints using the teach pendant or in WINCAPSIII with the following procedures.

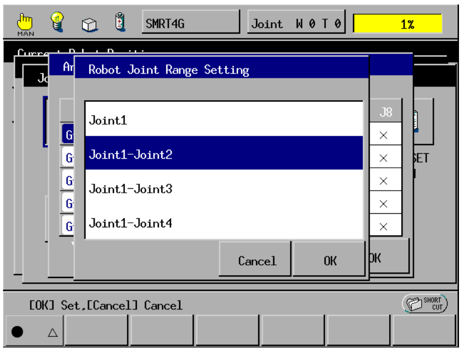
Joints not configured as robot joints are regarded as extended-joints.

Note: Modifying the robot joint configuration initializes the arm group and link information settings.

■ Configuring using the teach pendant

Access: [F2 Arm]--[F12 Maint.]--[F7 Joints]--[F1 ArmGroup]--[F6 RobotJoints]

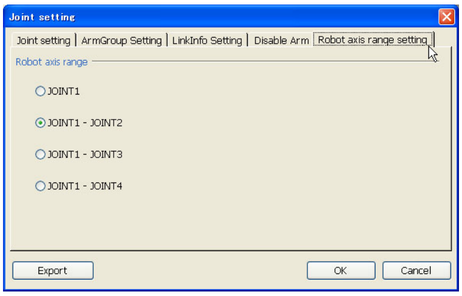
Select joints to be configured as robot joints and press OK.



■ Configuring in WINCAPSIII

Access: Project | Joint Setting Table (This displays the Joint setting window.)

Choose the Selecting Robot Joint tab. Select joints to be configured as robot joints and press OK.



Choose Connect | Transfer data to display the Transfer data window. In the WINCAPSIII pane, select Parameters | Arm parameters and then press Send to transfer the data to the robot controller.

4.7 Gain Tuning of Each Joint

In Section 4.5, you have set the motion conditions of each joint and checked the motion of the mechanism connected to each joint motor in manual 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:

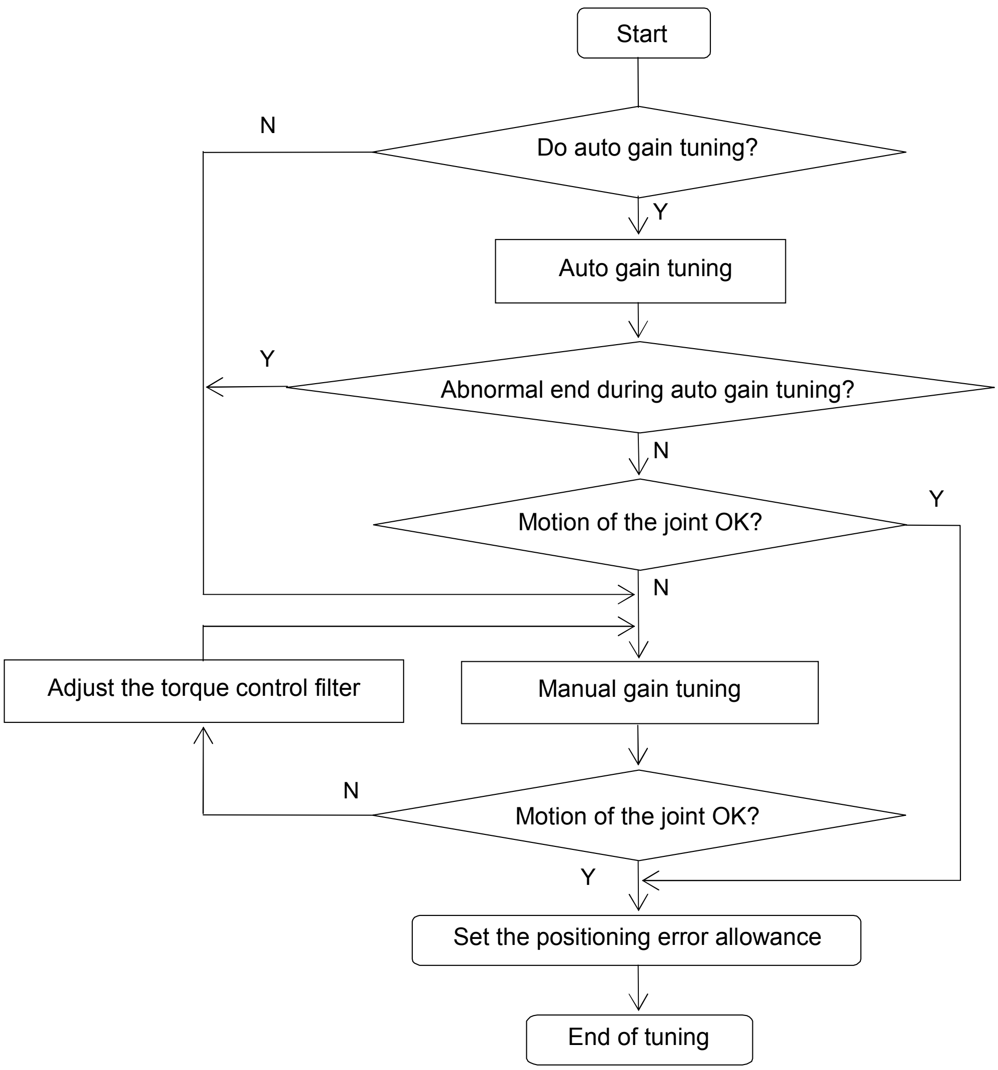
(1) Auto gain tuning

The controller performs acceleration/deceleration operation of each joint according to the default pattern preset in the controller. Based on the motion of each joint 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 can adjust the gain and torque control filter parameters for optimizing the motion of each joint.

Follow the next flowchart to tune the servo system.



4.7.1 Auto Gain Tuning

To implement auto gain tuning, the mechanism to be connected to the joint motor should satisfy the requirements given in Section 4.7.1.1 below. Otherwise, some errors may occur and the auto gain tuning process may be interrupted. If such happens, implement manual gain tuning.

4.7.1.1 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 each 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.

4.7.1.2 Auto gain tuning procedure

(1) Turn the motor power on and perform CAL.

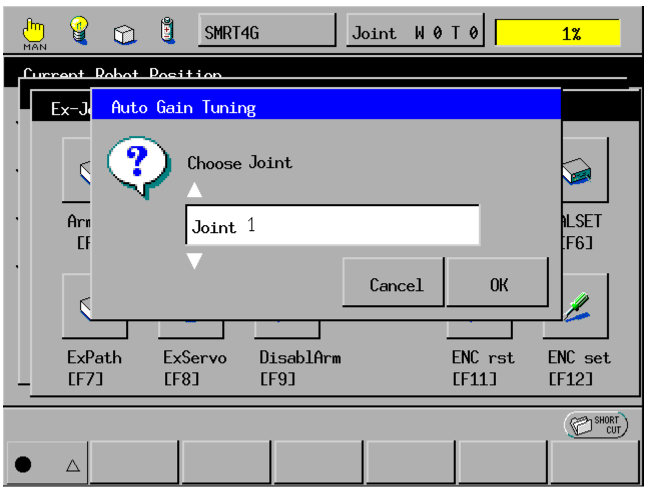
NOTE: If the controller is in Auto mode or Teach check mode, switch to Manual mode.

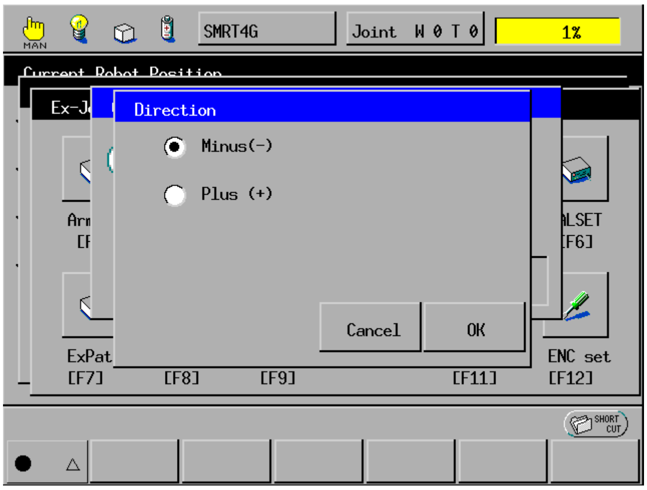
(2) Get out of the motion range so that there will be no problem even if the motor rotates in CCW and CW directions alternately two times each direction.

(3) On the teach pendant, call up the Joint Settings window.

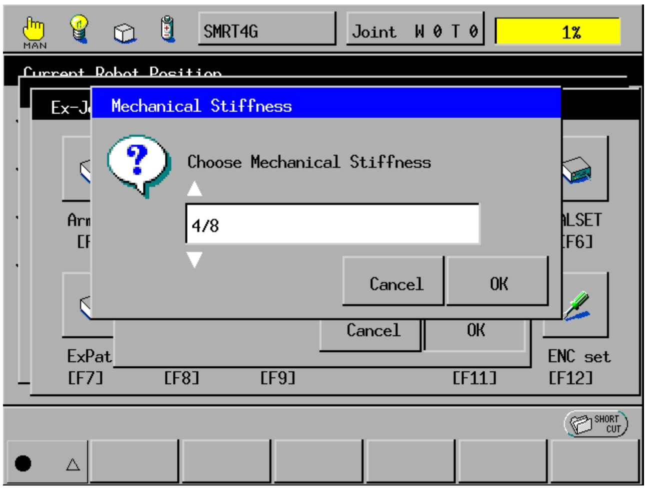
Access: Top Screen—[F2 Arm]—[F12 Maint.]—[F7 Joints]

(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.



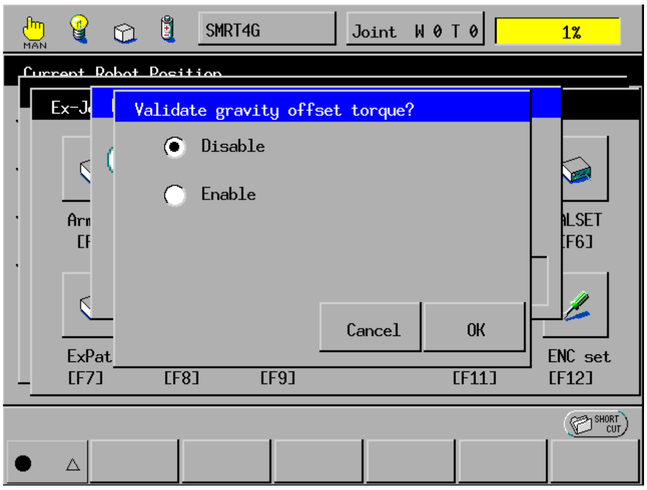


(5) Select the mechanical rigidity, referring to the rigidity reference values listed below.



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 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.

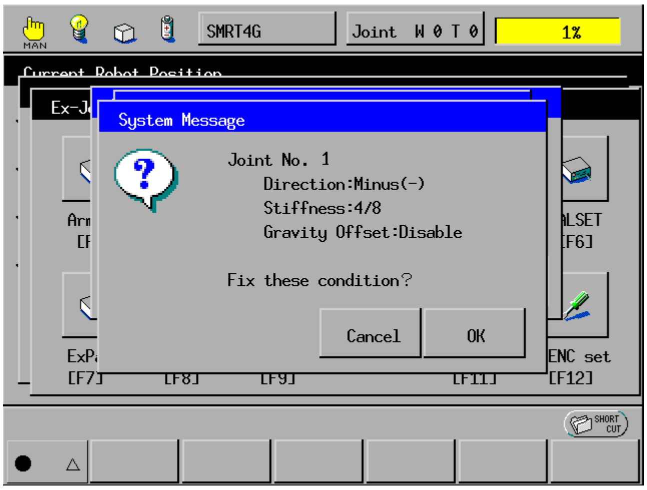
NOTE: If the joint motion has been set to [2:Encoder] on the servo configuration parameters window, then the error message "Not executable" will appear during auto gain tuning.

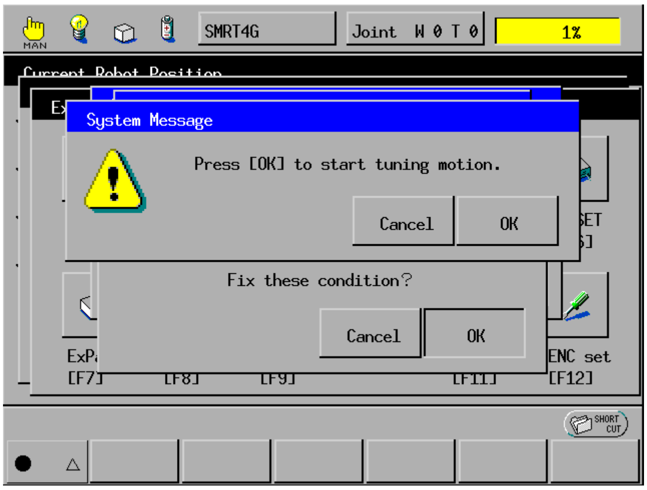
(8) In the dialog box shown below, confirm the conditions and press OK. In the confirmation window, press OK. Then auto gain tuning will start.

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 vise versa, then an error may occur during auto gain tuning. Change the mechanical rigidity setting and retry auto gain tuning.

4.7.2 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

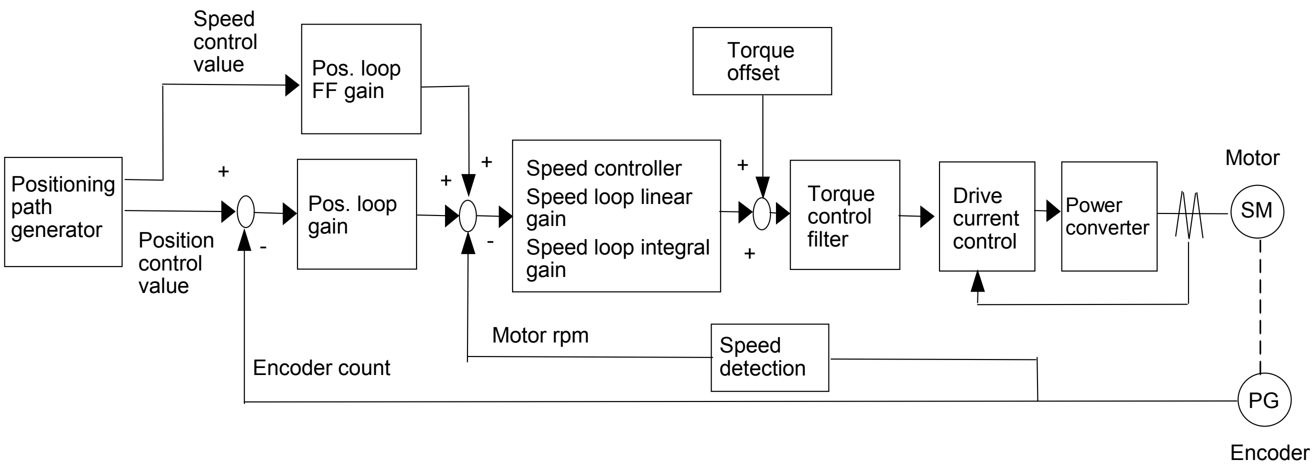
(4) Speed linear gain

(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 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 joint support system.

4.7.2.1 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:

Positioning loop gain x 125/256 (1/s) (Formula 4.7-1)

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:

[Positioning error allowance] > [Maximum motor speed (rpm)] x
(1.0-[Positioning loop forward gain (%)] x 0.01)/[Positioning loop gain] x 524288/1875

(Formula 4.7-2)

(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:

Speed response frequency (Hz) = [Speed control linear gain] / [Motor rotor inertia (kgm^2) + Load inertia converted at motor joint (kgm^2)] x [Drive current loop gain] / (2π)

(Formula 4.7-3)

The drive current system gain is as listed below.

Motor Model	Motor rated output	Drive Current System Gain
SGMAH-A5A1A	50W	1.852E-05
SGMAH-01A1A	100W	3.004E-05
SGMAH-02A1A	200W	7.144E-05
SGMAH-04A1A	400W	1.093E-04
SGMAH-08A1A	750W	1.979E-04
SGMPH-01A1A	100W	3.421E-05
SGMPH-02A1A	200W	7.845E-05
SGMPH-04A1A	400W	1.209E-04
SGMPH-08A1A	750W	2.150E-04
SGMPH-15A1A	1500W	5.819E-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:

Integral speed loop gain time constant (ms) =
0.25 x [Speed control linear gain] / [Speed loop integral gain]

(Formula 4.7-4)

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 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 "4.7.2.2 Monitor of single-joint servo data."

As described in Section 4.7.1 "Auto Gain Tuning," the torque offset value will be automatically set if you enable the gravity offset torque in auto gain tuning.

4.7.2.2 Monitor of single-joint servo data

This function allows you to monitor a specified joint servo data currently set in the 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 1ms, then you may monitor the servo data for 1.25 seconds. If 8ms, 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. For details, refer to "`SetMonitorCond`" in Section 4.9.

Once monitoring starts, the monitoring terms already defined cannot 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`. For details, refer to `StartSrvMonitor`, `StopSrvMonitor`, and `ClearSrvMonitor` in Section 4.9.

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

The single joint servo log function in WINCAPSIII can graph the monitored data on a PC screen.

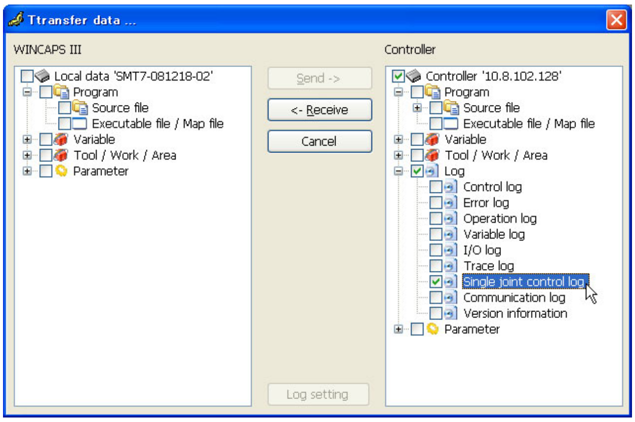
(4.1) Read monitored data

To receive single joint servo log data from the controller, use the data transfer function in WINCAPSIII as follows.

Choose Connect | Transfer data to display the Transfer data window.

In the Controller pane, select Log | Single joint control log and then press Receive.

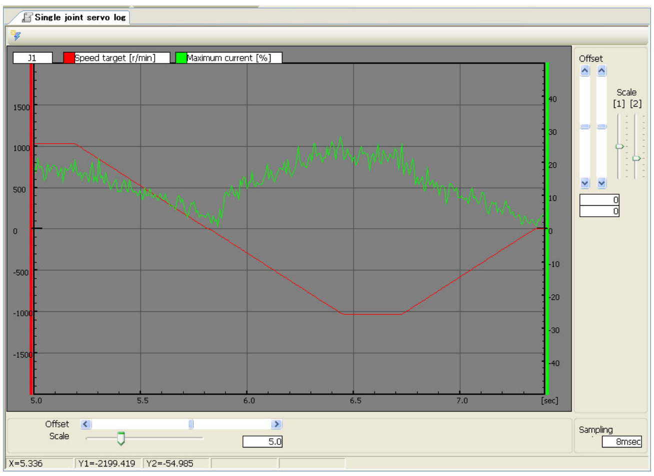
This operation transfers the single joint servo log data held in the controller to the current project in WINCAPSIII.



(4.2) Plot the graph of monitored data

Choose View | Log View | Servo data to plot the graph of the single joint servo log data of the project in WINCAPSIII.

Adjust the scale and offset of the graph and check the graphed data.



(5) Saving the monitored data into a file

WINCAPSIII can save the monitored data into a CSV file.

Choose File | Export to display the Export window.

Specify the destination folder, select Single Joint Servo Log (Log_Srv.csv) in Log, and then press Export.

This operation saves the data into the specified folder in CSV format.

4.7.2.3 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 4.7-1. 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 extend 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. (It is convenient to use the quick tuning function for the speed control system gain described in the next item [4].)

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

NOTE: Servomotors recommended earlier in this manual will issue torque ripple 4 times per rotation. The torque transmission mechanism may also issue torque ripple specific times per rotation at its output shaft.

Therefore, the frequency of the torque ripple may vary according to the speed so as to become equal to the natural frequency of the connected mechanism.

If vibrations are large in some specific speed, decrease the speed integral loop gain, positioning loop gain and/or positioning loop feed forward gain as well as stated above.

4.7.2.4 Quick tuning function for speed control system gain

As expressed in Formula 4.7-4, 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 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

4.8　Joint Exclusive Operations

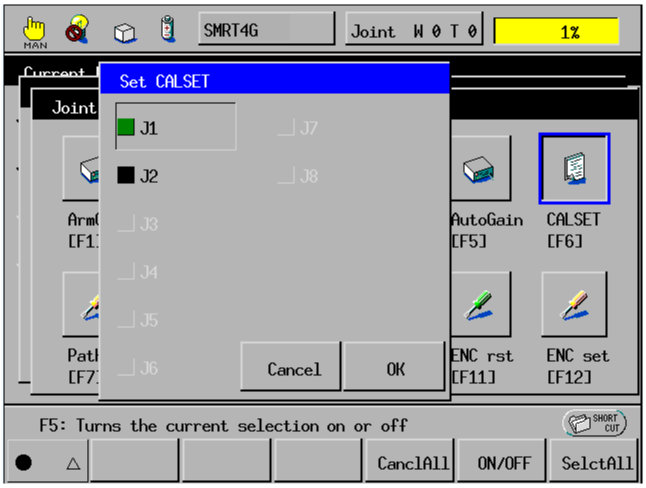
4.8.1　Performing CALSET Operation on Each Joint

■ From the teach pendant

(1) Call up the Maintenance Functions (Arm) window.

Access: Top Screen—[F2 Arm]—[F12 Maint.]—[F6 CALSET]

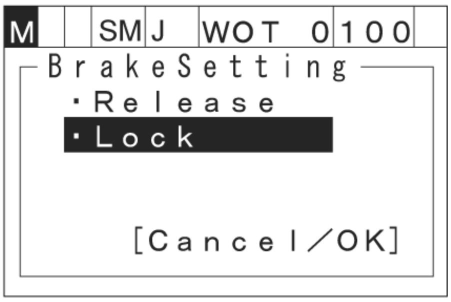
Select a joint to be CALSET and press [OK]. CALSET on the selected joint will start.



■ From the mini-pendant

Access: [AUX]—[ArmAux]—[CalSet]

(1) The CALSET joint selection window appears.



(2) Enter a joint number to be CALSET.

NOTE: Selecting 0 performs CALSET on all joints.

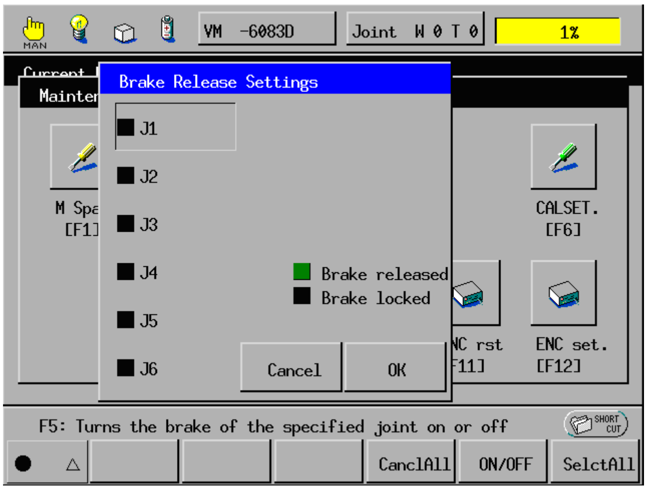
(3) Press [OK] to start CALSET on the selected joint.

4.8.2 Releasing or locking brakes

■ **From the teach pendant**

(1) Call up the Brake Release Settings window.

Access: Top Screen—[F2 Arm]—[F12 Maint.]—[F3 Brake]



(2) Select the target brake.

(3) Press [F5 ON/OFF], and the indicator color of the selected brake will change from black to green if locked or from green to black if released.

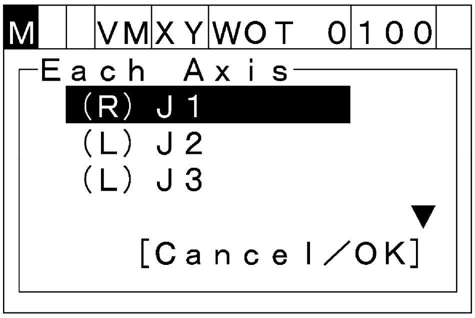
Black: Brake locked, Green: Brake released

To lock all axes' brakes, press [F4 CanclAll]; to release them, press [F6 SelctAll].

(4) Check the brake status, and then press the OK button to make the new entry take effect.

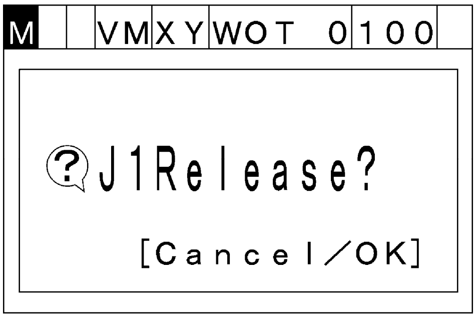
■ From the mini-pendant

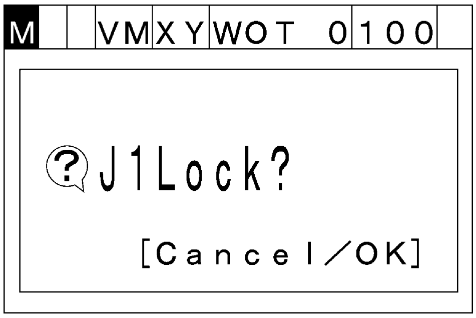
(1) Press [BRAKE] to call up the "BrakeSetting" window shown below.



(2) Choose an arbitrary joint with the up and down cursor keys. (You can vertically scroll the screen with those keys.)

Then press [OK]. Either of the following windows will appear.

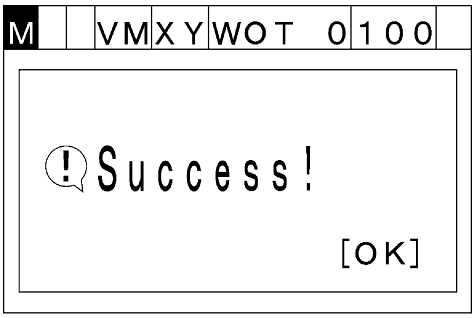




(3) To switch the selected joint brake between Release and Lock status, press [OK].

To abort brake setting and return to the previous screen, press [CANCEL].

(4) If the selected brake is released or locked successfully as specified, the following message will display.



4.8.3 Direct Teaching Mode

This section describes the direct teaching mode in the SMT7. The direct teaching mode allows you to move the joint by hand (without using the teach pendant) with the motor OFF and teach the current position to a joint variable, position variable, or homogeneous transform matrix variable. (Usual teaching requires the motor to be turned ON.)

Note 1: In the SMT7, the system has no air balance cylinder on the Z-axis, so the operation procedure for the direct teaching mode differs from that of the conventional 4-axis robots.

Note 2: In the SMT7, the brake is not released in the direct teaching mode.

■ From the teach pendant

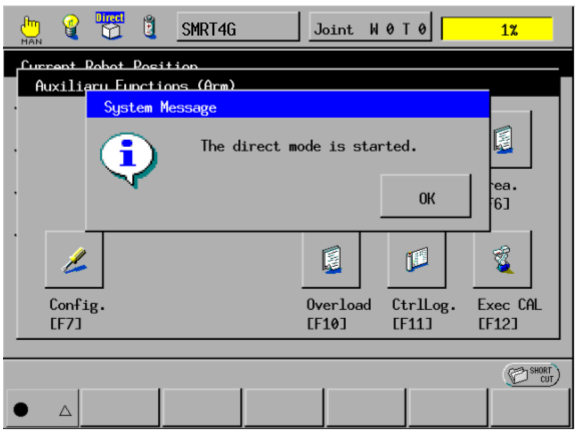
Access: Top Screen—[F2 Arm]—[F12 Maint.]—[F3 Brake]

(1) In the Auxiliary Functions (Arm) window, press [F3 Direct.].

The following message will appear. Press the OK button.

Caution:	**The system message "The specified brake(s) will be released by pressing the brake release button." appears. But the SMT7 series, the brake is not released.**

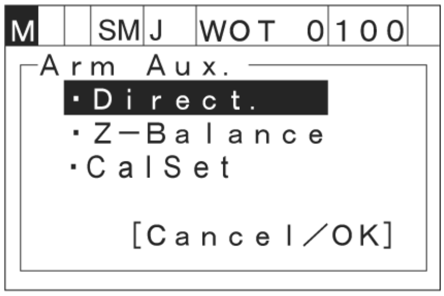
(2) The system message "The direct mode is started." appears.
If pressing the OK button, the direct teaching mode will be started.



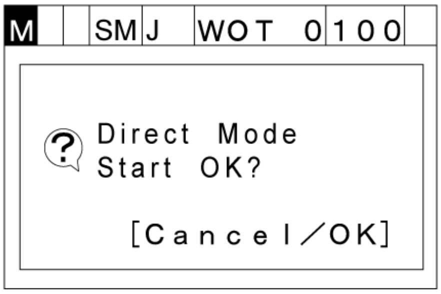
■ From the mini-pendant (Starting/ending the direct teaching mode)

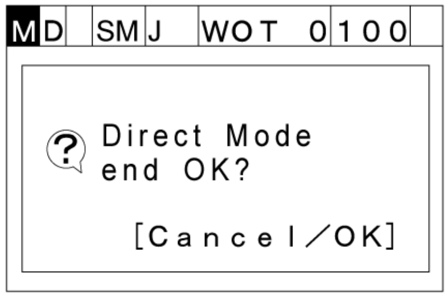
Access: [AUX]—[Arm Aux.]—[Direct.]

(1) Select [Direct] and press [OK].



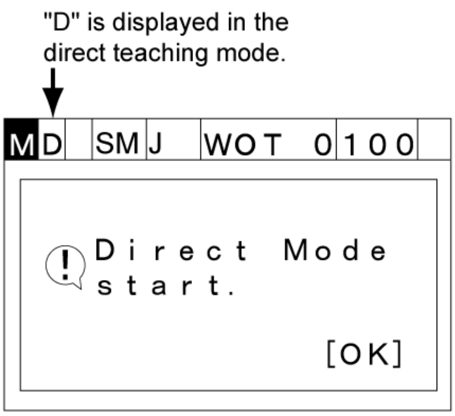
(2) A confirmation screen whether "Direct Mode Start OK?" or "Direct Mode end OK?" appears.

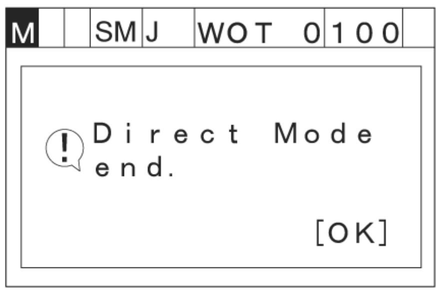




(3) Press [OK]. The direct teaching mode starts or ends.

NOTE: In the direct teaching mode, the "D" appears at the left end of the status bar.





4.8.4 Resetting Encoder

You need to reset encoders and perform CALSET if:

- Error 6411 or 6422 occurs due to first use of AC servomotors, or run-down encoder backup batteries, or
- Error 6771 or 6772 occurs due to a great impact applied to the robot when the power is off.

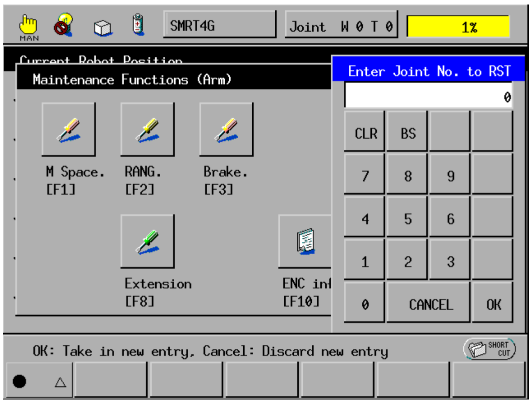
This section describes how to reset encoders using the teach pendant.

■ From the teach pendant

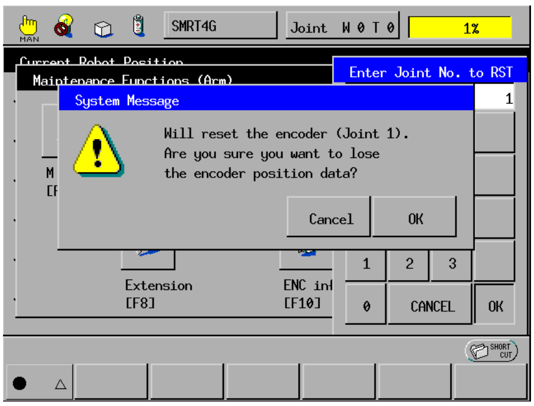
(1) Call up the Encoder reset window.

Access: Top Screen—[F2 Arm]—[F12 Maint.]—[F11 ENC rst]

Pressing [F11 ENC rst] in the Maintenance Functions (Arm) window will display the Encoder reset window as shown below.



(2) Enter the axis number whose encoder is to be reset, and press [OK].
System Message appears.

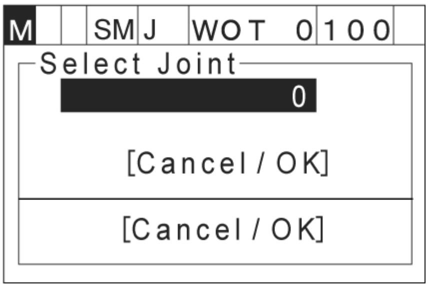


(3) Pressing [OK] resets the encoder on the selected axis.

■ From the mini-pendant

Access: [AUX]—[ArmAux]—[EncRst]

(1) The "Select Joint" screen appears, prompting you to choose the joint to reset the related encoder.



(2) Select the target joint.

(3) Press [OK] to start resetting the encoder on the target joint.

4.8.5 Operating Extended-Joints

For the operating procedures for the manual operation of extended-joints, for taking position data into variables, and for moving a joint with a variable in an extended-joint motion, refer to the Supplement for Extended-Joints Support.

4.8.6 Programmed Operation in SMT7 (Description of arm groups)

■ Concept of an arm group

An arm group is a set of semaphores for joints to be driven. Specifying an arm group using a TAKEARM command allows a task to get arm semaphores and execute motion commands. Using an arm group prevents more than one task from executing a motion command to the same joint at the same time.

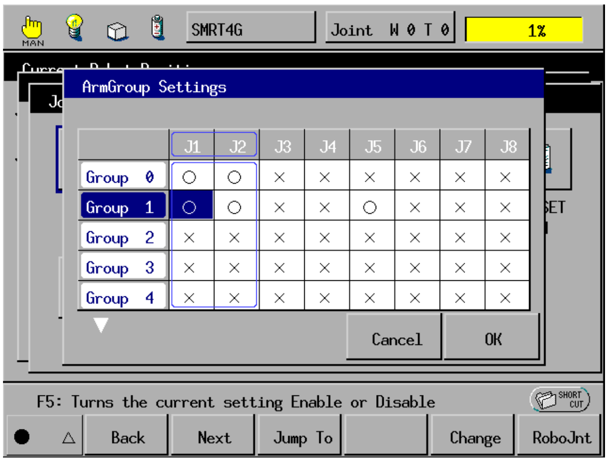
A motion command is executable only to those joints contained in the arm group held in the task.

Robot joints are regarded as a single linked joint so that they cannot individually take arm semaphores. On the contrary, extended-joints can individually take arm semaphores and the individual settings constitute an arm group.

Up to 32 arm groups are available.

Example: When an extended-joint motion is specified, a task holding Group 1 obtains permissions to drive joints 1 and 2 (robot joints) and joint 5.

Extended-joint motion setting



■ 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      ←   PRO1 gets Arm Group 1 by TAKEARM command with an
                   argument set to 1.
   .
   .
END
```

For the TAKEARM syntax and KEEP options, refer to the Programmer's Manual I, Section 14.3 "Arm Semaphore."

■ Releasing the currently held arm group

To release the currently held arm group, execute a GIVEARM command.

An occurrence of an error or program termination automatically releases the currently held arm group.

For details about the GIVEARM, refer to the Programmer's Manual I, Section 14.3 "Arm Semaphore."

Example: Halt or Step Stop does not release the currently held arm group.

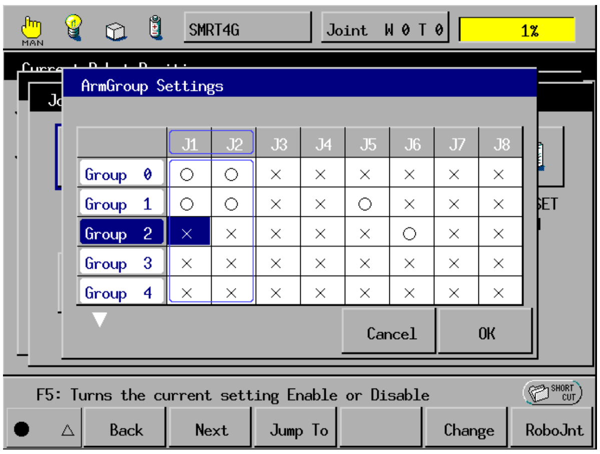
■ Restrictions on the application of arm groups

Two or more programs can run concurrently as long as their arm groups specified do not hold the same joint(s).

If their arm groups hold the same joint(s), only one program can run and arm group related lines in other programs cannot execute during execution of the currently running program.

Example: In an extended-joint motion
During execution of codes ① in PRO0, codes ② in PRO1 cannot execute, but codes ③ in PRO2 can execute concurrently.

Example: Extended-joint motion setting




```
PROGRAM PRO0
TAKEARM 1   ┐
  :         │ ①
GIVEARM     ┘
END
```

```
PROGRAM PRO1
TAKEARM 1   ┐
  :         │ ②
GIVEARM     ┘
END
```

```
PROGRAM PRO2
TAKEARM 2   ┐
  :         │ ③
GIVEARM     ┘
END
```

■ Motion commands requiring an arm group

The following commands require an arm group.

If a task holding no arm group attempts to execute any of the following motion commands, an error will occur. Before execution of those commands, get an arm group by using the TAKEARM command.

Commands
HOME, TOOL, WORK, APPROACH, DEPART, DRAW, GOHOME, MOVE, ROTATEH, ROTATE, CHANGETOOL, CHANGEWORK, DRIVE, DRIVEA, SPEED, JSPEED, ACCEL, JACCEL, DECEL, JDECEL, INTERRUPT, LETENV, POSCLR, Motion optimization library, Arm motion library

■ Defining a new configuration of an arm group

<u>To drive both J5 and J6 in an extended-joint motion</u>

Usually arm groups are configured by default as shown on the previous page; that is, Arm Group 1 contains J5, and Arm Group 2, J6.

Making a single program to hold more than one arm group (Arm Groups 1 and 2) will result in an error as shown below.

Example:
```
PROGRAM PRO2
TAKEARM 1
.
.
TAKEARM 2       'Impossible to get Arm Group 2
                'after getting Arm Group 1
                'Resulting in an error
```

To drive both J5 and J6 in a single task in an extended-joint motion, you need to define a new configuration of an arm group (e.g. Arm Group 3) to contain both joints using the procedure given on the next page. Then make the task get the newly configured arm group as shown below.

Such configuration allows only the PTP motion with DRIVE and DRIVEA commands.

Example:
```
PROGRAM PRO1
TAKEARM 3            'When changing the configuration of Arm
.                    'Group 3 to contain J5 and J6
.
.
DRIVE (5,20.5),(6,150.33) 'Drive J5 and J6 concurrently
```

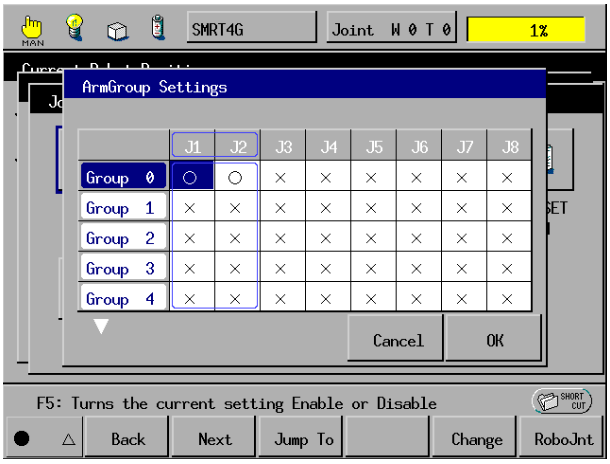
Note: A program can get the same arm group repeatedly.

Example:
```
PROGRAM PRO1
TAKEARM 1
.
.
TAKEARM 1         'Possible to get Arm Group 1
                  'even after getting it on the earlier
                  'line
```

■ From the teach pendant

(1) Call up the "ArmGroup Settings" window.

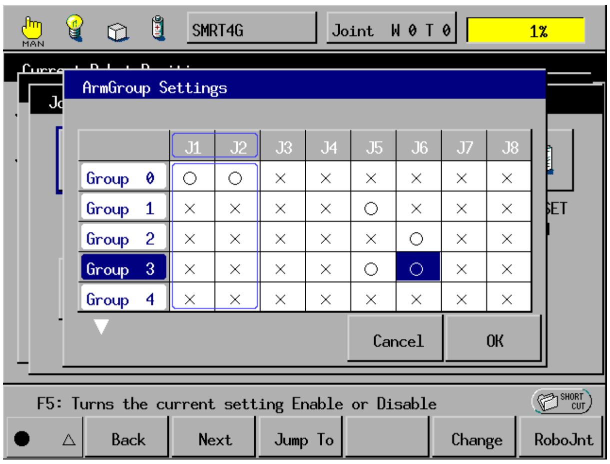
Access: Top Screen—[F2 Arm]—[F12 Maint.]—[F7 Joints]—[F1 ArmGroup]



(2) Choose the arm group to be changed and press [F5 Change].

(3) Select or deselect joints with ○ or ×, respectively, and then press [OK].

Example: Making Arm Group 3 contain J5 and J6



Note 1: New configuration settings will go into effect when the controller is turned off and then on after the change.

Note 2: Arm Group 0 cannot be accessed.

■ Notes for command execution from the specified line

The specifications about command execution from the specified line are detailed in the Setting-up Manual, Section 3.3, "Teach Check Mode (TP/MP), [4]."

(1) Making effective the arm group previously obtained by TAKEARM

If a command on the specified program line is executed, an arm group obtained by a TAKEARM command on the earlier line will automatically take effect.

Example

```
PROGRAM PRO1
TAKEARM 1       ← Get Arm Group 1
I0=3            ← Step stop at this line
MOVE P, P0
MOVE P, P1      ← If this line is specified, Arm Group 1 automatically
                  goes into effect again.
END
```

(2) Notes when using more than one arm group in a single task

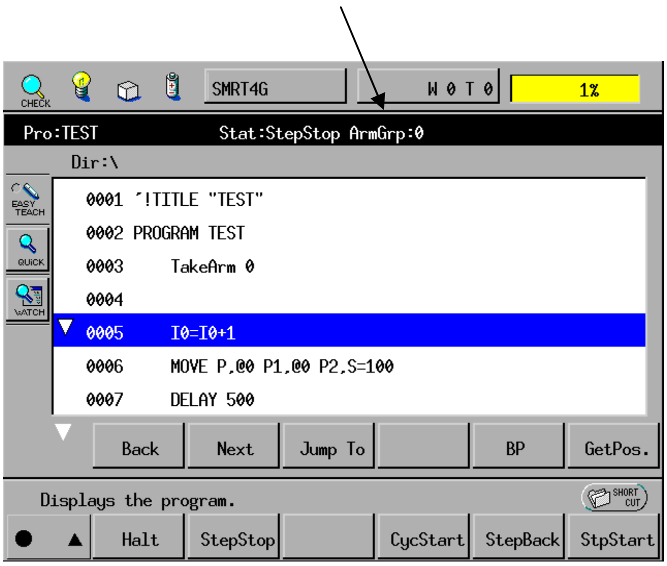
Example

```
PROGRAM PRO1
TAKEARM 1            ← Get Arm Group 1
I0=3                 ← Step stop at this line
DRIVE (7,10)
GIVEARM
TAKEARM 2
DRIVE (8,23)        ← If this line is specified, Arm Group 0
                      obtained by the earlier TAKEARM 1
                      automatically goes into effect again.
                      DRIVE command requires Arm Group 2, so an
                      error will occur.
END
```

(3) Checking an active arm group currently held by a task

You can check an active arm group by displaying the task.

Example: This program has got Arm Group 0.



4.9 Joint Parameter Configuration Commands

4.9.1 Single-Joint Servo Data Monitor Commands (Library)

SetMonitorCond

Function

Sets the monitoring conditions for single-joint servo data monitor.

Syntax

```
SetMonitorCond(<JntNumber>,<MonitorData1>,<MonitorData2>,
<SampInterval>)
```

Description

`SetMonitorCond` sets the joint number to be monitored, monitor data (up to 2 types allowed per command), and sampling interval in ms as monitoring conditions.

The following five types of data may be monitored, two types at a time, by specifying `<MonitorData1>` and `<MonitorData2>`:

`<MonitorData1>` and `<MonitorData2>`	Data to be monitored
0	Motor speed control value in rpm
1	Current motor speed (Actual speed) in rpm
2	Motor torque control value (excluding torque offset) in ratio (%) to the rated value
3	Motor rotation angle error (Motor angle control value - Actual motor angle value) in pulses
4	Motor current absolute value (Maximum value out of three absolute values detected from all 3 phases of the motor.) in ratio (%) to the rated value

`<SampInterval>` must be set in ms as an integer between 1 and 8.

Macro definition

Not needed.

Related commands

`ClearSrvMonitor`, `StartSrvMonitor`, and `StopSrvMonitor`

Notes

(1) If this library executes following the monitor start library `StartSrvMonitor`, the error "6001: Not executable" will result. Be sure to set the monitoring conditions before starting monitor.

(2) If any of the joint number, data types, and sampling interval entered is wrong, the error message "The entered value is out of the range." will result. Correct those monitoring conditions you entered.

Example

```
CALL SetMonitorCond(7,0,3,4)  'For getting speed control value and
                              'motor angle error of J7 every 4 ms.
CALL StartSrvMonitor          'Start monitoring data.
```

StartSrvMonitor

Function

Starts monitoring single-joint servo data.

Syntax

```
StartSrvMonitor
```

Description

`StartSrvMonitor` fetches a maximum of 1250 samples of single-joint servo data until `StopSrvMonitor` executes.

Macro definition

Not needed.

Related commands

`ClearSrvMonitor`, `SetMonitorCond`, and `StopSrvMonitor`

Notes

(1) 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.

(2) 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.

(3) No data may be monitored when the target motor is off. Execute this command with the motor power on.

Example

```
CALL SetMonitorCond(7,0,3,4)   'For getting speed control value and
                               'motor angle error of J7 every 4 ms.
CALL StartSrvMonitor           'Start monitoring data.
```

StopSrvMonitor

Function

Stops monitoring single-joint servo data.

Syntax

```
StopSrvMonitor
```

Description

In duration from execution of `StartSrvMonitor` to that of `StopSrvMonitor`, a maximum of 1250 samples of data may be obtained.

Macro definition

Not needed.

Related commands

`ClearSrvMonitor`, `SetMonitorCond`, and `StartSrvMonitor`

Notes

(1) 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, the last 1250 data samples before the end of the cycle may be monitored and other data will be discarded.

(2) 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.

Example

```
CALL StopSrvMonitor      'End monitoring data.
```

ClearSrvMonitor

Function

Initializes the pointer of data obtained by the single-joint servo data monitor function.

Syntax

`ClearSrvMonitor`

Description

`ClearSrvMonitor` initializes the pointer of data already obtained and starts monitoring new data up to 1250 samples.

Macro definitions

Not needed.

Related commands

`ClearSrvMonitor`, `SetMonitorCond`, and `StartSrvMonitor`

Notes

In duration from execution of `ClearSrvMonitor` to that of `StopSrvMonitor`, if the total number of data samples monitored is 1250 or less, all data may be monitored. If it exceeds 1250, the last 1250 samples before the end of the monitoring cycle may be monitored and other data will be discarded.

Example

```
CALL StartSrvMonitor     'Start monitoring data.
     .
     .
     .
CALL ClearSrvMonitor     'Clear monitored data after
                         'execution of StartSrvMonitor.
     .
     .
     .
CALL StopSrvMonitor      'Stop monitoring data.
                         '(Data between ClearSrvMonitor and
                         'StopSrvMonitor processes are monitored.)
```

4.9.2 Operation Termination Commands (Library)

MotionSkip

Function

Aborts running motion commands.

Syntax

`MotionSkip`

Description

`MotionSkip` aborts motion commands running in the task in which the `MotionSkip` executes.

Macro definition

Not needed.

Related commands

`GetJntData` and `GetSrvData`

Notes

(1) Execute this command in a TAKEARMed task that holds an arm semaphore. If not in a TAKEARMed task, the error "Not executable" will result.

(2) Executing `MotionSkip` in a robot motion task will abort robot joint motion commands. Executing it in an extended-joint motion task will abort extended-joint motion commands.

If `MotionSkip` executes in a motion task holding an arm group involving both robot joints and extended-joints, then both the robot and extended-joint motions will be aborted.

Example

```
defjnt lj1
defsng lf1
move p,P1,next
lj1=GetSrvState(2)        'Get errors of each joint rotation angle.
lf1=ABS(JOINT(2,lj1))     'Select rotation error of J2.
if lf1 > 10000 then
  CALL MotionSkip         'If the rotation error of J2 exceeds 10000
                          '(in pulses), then abort motion commands.
endif
```

MotionComp

Function

Judges whether execution of running motion commands is complete.

Syntax

`MotionComp(<MotionCommandComplete>)`

Description

If `MotionComp` judges that execution of running motion commands is complete, then it returns "1" in `<MotionCommandComplete>`.

This command checks motion commands running in the task in which the `MotionComp` executes. It is not applicable to motion commands in any other tasks.

If a motion command has an encoder value check option, then `MotionComp` will interpret the moment when the encoder count is converged within the positioning error allowance as completion of the motion command. For other operations, if motion control to the servo loop disappears, then `MotionComp` will judge that the command is complete.

Macro definition

Not needed.

Related commands

`GetJntData`, `GetSrvData`, and `MotionSkip`

Notes

(1) Execute this command in a TAKEARMed task that holds an arm semaphore. If not in a TAKEARMed task, the error "Not executable" will result.

(2) Executing `MotionComp` in a robot motion task will judge whether robot motion commands are complete. Executing it in an extended-joint motion task will judge whether extended-joint motion commands are complete.

If `MotionComp` executes in a motion task holding an arm group involving both robot joints and extended-joints, then completion of both the robot and extended-joint motions will be judged.

(3) When the motion is on Halt, `MotionComp` will interpret it as operation being in progress.

(4) If you use a local variable for `<MotionCommandComplete>`, the local variable must be reset to "0" beforehand.

Example

```
defint comp=0              'Initialize motion command completion status.
defjnt lj1
defsng lf1
move p,P1,next
DO
  lj1=GetSrvState(2)       'Get error of each joint rotation.
  lf1=ABS(JOINT(2,lj1))    'Select the rotation error of J2.
  if lf1 > 10000 then
    CALL MotionSkip        If the rotation error of J2 exceeds 10000 (in pulses),
                           'then abort motion commands and end the loop.
    EXIT DO
  endif
  CALL MotionComp(comp)
LOOP UNTIL comp=1          'Loop until the end of motion commands.
```

4.9.3 Internal Servo Data Get Commands

GetSrvData

Function

Gets the internal servo data of robot joints.

Syntax

`<InternalServoData> = GetSrvData(<DataNumber>)`

Description

`GetSrvData` gets the internal servo data specified by `<DataNumber>` into `<InternalServoData>`.

`<InternalServoData>` is a joint type data of robot. `<DataNumber` should be any of the following:

<DataNumber>	<InternalServoData>
1	Current motor speed (Actual speed) in rpm
2	Motor rotation angle error in pulses
4	Motor current absolute value in ratio (%) to the rated value
5	Motor torque control value (excluding torque offset) in ratio (%) to the rated value
8	Joint position or angle control value in mm or degrees
17	Tool-end speed (3 position elements only in the work coordinates) in mm/s
18	Tool-end positioning speed (3 position elements only in the work coordinates) in mm
19	Tool-end speed (3 position elements only in the tool coordinates) in mm/s
20	Tool-end positioning speed (3 position elements only in the tool coordinates) in mm

Macro definition

Not needed.

Related commands

`GetJntData`

Notes

(1) Data numbers other than those given above are reserved. Do not use any other number other than the above, although no error will result if you specify any number up to 30.

(2) If you attempt to fetch the servo data when the single-joint servo data monitor is running, the fetching process may become very slow. Take care when using the single-joint servo data monitor.

(3) If you change `<DataNumber>`, the modification may take time. Do not change it so frequently.

(4) Execute this command in a TAKEARMed task that holds an arm semaphore. If not in a TAKEARMed task, the error "21F7: Cannot take arm semaphore" will result.

Example

```
defjnt vel
defsng absv,xvel,yvel,zvel
vel=GetSrvData(17)                    'Get tool-end speed.
xvel=JOINT(1,vel)                     'Select X component in work coordinates.
yvel=JOINT(2,vel)                     'Select Y component in work coordinates.
zvel=JOINT(3,vel)                     'Select Z component in work coordinates.
absv = SQR(xvel*xvel+yvel*yvel+zvel*zvel) 'Calculate total tool-end speed.
```

GetJntData

Function

Gets the internal servo data of a specified joint.

Syntax

```
<JntInternalServoData> = GetJntData(<DataNumber>,<JntNumber>)
```

Description

`GetJntData` gets the internal servo data (specified by `<DataNumber>`) of a joint specified by `<JntNumber>` into `<JntInternalServoData>`.

`<JntInternalServoData>`.is a floating point type data of the specified joint. `<DataNumber>` should be any of the following:

<DataNumber>	<JntInternalServoData>
1	Current motor speed (Actual speed) in rpm
2	Motor rotation angle error in pulses
4	Motor current absolute value in ratio (%) to the rated value
5	Motor torque control value (excluding torque offset) in ratio (%) to the rated value
8	Joint position or angle control value in mm or degrees

Macro definition

Not needed

Related commands

`GetSrvData`

Notes

(1) Data numbers other than those given above are reserved. Do not use any other number other than the above, although no error will result if you specify any number up to 30.

(2) If you attempt to fetch the servo data when the single-joint servo data monitor is running, the fetching process may become very slow. Take care when using the single-joint servo data monitor.

(3) If you change `<DataNumber>`, the modification may take time. Do not change it so frequently.

(4) Execute this command in a TAKEARMed task that holds an arm semaphore. If not in a TAKEARMed task, the error "21F7: Cannot take arm semaphore" will result.

Example

```
defsng vel
vel=GetJntData(1,7)      'Get motor speed of J7.
```

Chapter 5 Installation and Wiring

5.1 Installation of Controller

5.1.1 Installation Site Conditions

Install the controller in conditions as shown in the table below.

Installation Site Condition Requirements

Item	Requirements
Ambient temperature	0 to 40℃ during operation –10 to 60℃ during storage
Humidity	90% or less during operation (Condensation not allowed) 75% or less during storage (Condensation not allowed)
Environmental safety	This controller has not been designed to withstand explosions, dust-proof, nor is it splash-proof. Therefore, it should not be installed in any environment where: (1) there are flammable gases or liquids, (2) there are any shavings from metal processing or other conductive material flying about, (3) there are any acidic, alkaline or other corrosive material, (4) there is a mist, or (5) there are any large-sized inverters, high output/high frequency transmitters, large contactors, welders, or other sources of electrical noise.
Work space	Adequate space should be allowed around the controller for inspection, overhaul and maintenance work.
Grounding resistance	The grounding resistance of the power supply should not be more than 100Ω.

5.1.2 Installing the Controller

The controller may be installed stand-alone or on the wall.

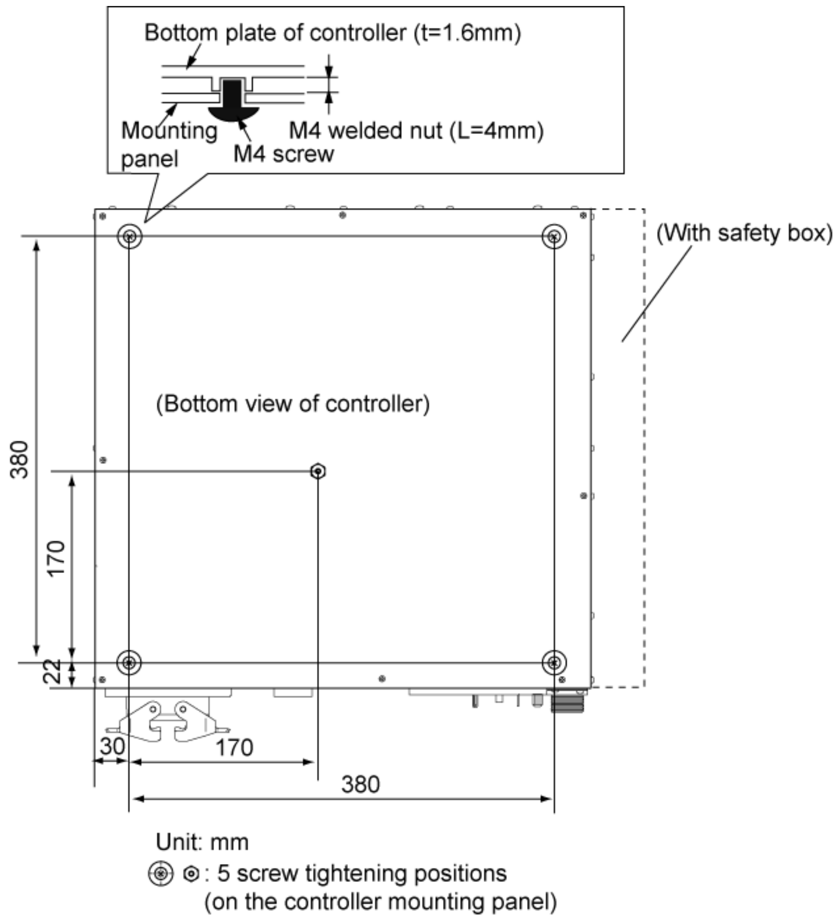
> ⚠**Caution: (1) The controller is not a dust- or splash-proof structure. Therefore, when using the controller in an environment exposed to mist, put it in an optional protective box.**
> **(2) The installation jobs should be handled by at least two persons.**

(1) Securing the controller to the controller mounting panel

1) The figure below shows the bottom view of the controller.
Five M4-nut welded holes may be used for securing the controller to the mounting panel.

2) Prepare a mounting panel large enough for mounting the controller and secure the controller onto the mounting panel using five screws.

> ⚠**Caution:** (1) The controller mounting screws must not be more than the thickness of the mounting panel plus 4 mm in length. If they exceed 4 mm, the nut-welded holes may be damaged.
> (2) Fix the controller at all of the five nut-welded holes.

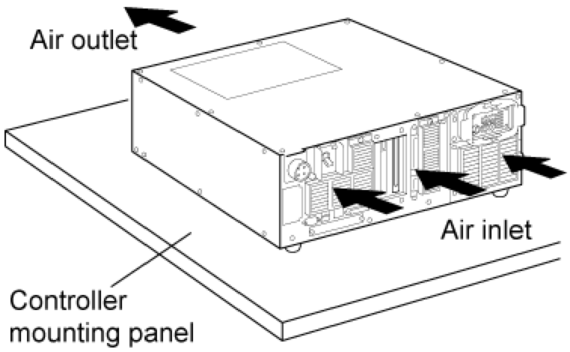


Location of Mounting Screw Holes (on the bottom of the SMT7 controller)

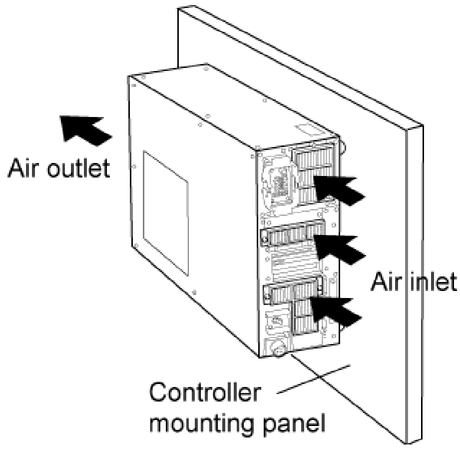
(2) Installing the controller

The controller may be installed stand-alone or on the wall.
Install the controller as shown in the figure below.

⚠**Caution:**	**Do not place anything within 200 mm from the air inlet and air outlet on the controller.**
⚠**Caution:**	**<Wall-mounted installation>** **The controller has not the air filter on the side of air outlet. Therefore, install the controller as shown in the figure below.**



<Stand-alone Installation >



<Wall-mounted Installation >

Installation of SMT7

5.2 Wiring between Controller and Motor

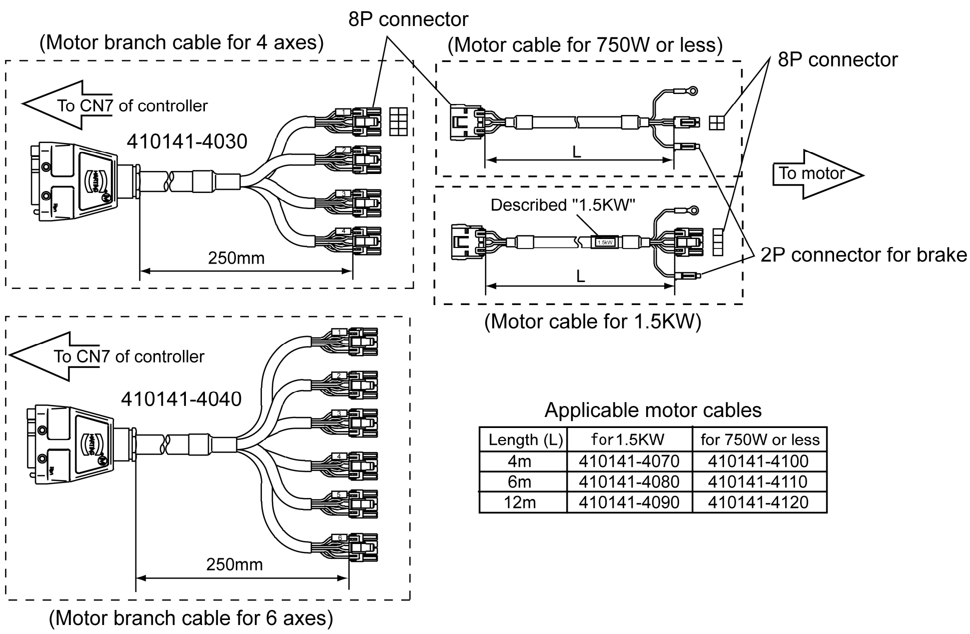
For wiring between the SMT7 controller and the motor, use optional parts listed Section 1.3 "Optional Items."

For details about wiring, refer to the Supplement for Extended-Joints Support.

5.2.1 Connecting Motor Cable

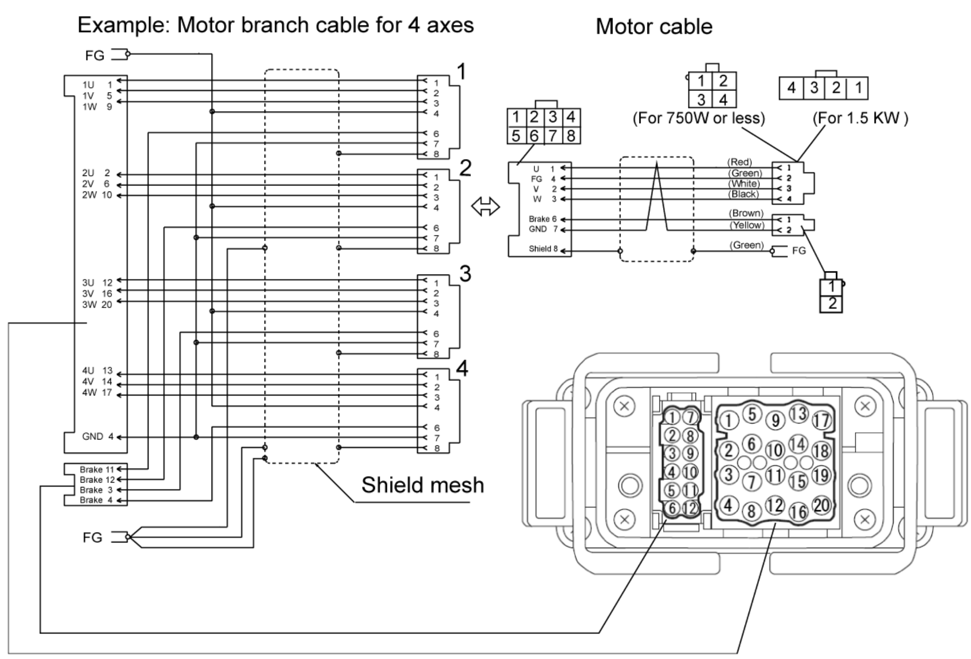
Motor cables with the length of 4, 6, and 12 m are available as options. Connect the motor cable to the SMT7 controller via the motor branch cable.

Note: Select the motor cable to be suitable for the motor power.
(1) For 750W or less (2) For 1.5kW



Applicable motor cables

Length (L)	for1.5KW	for 750W or less
4m	410141-4070	410141-4100
6m	410141-4080	410141-4110
12m	410141-4090	410141-4120

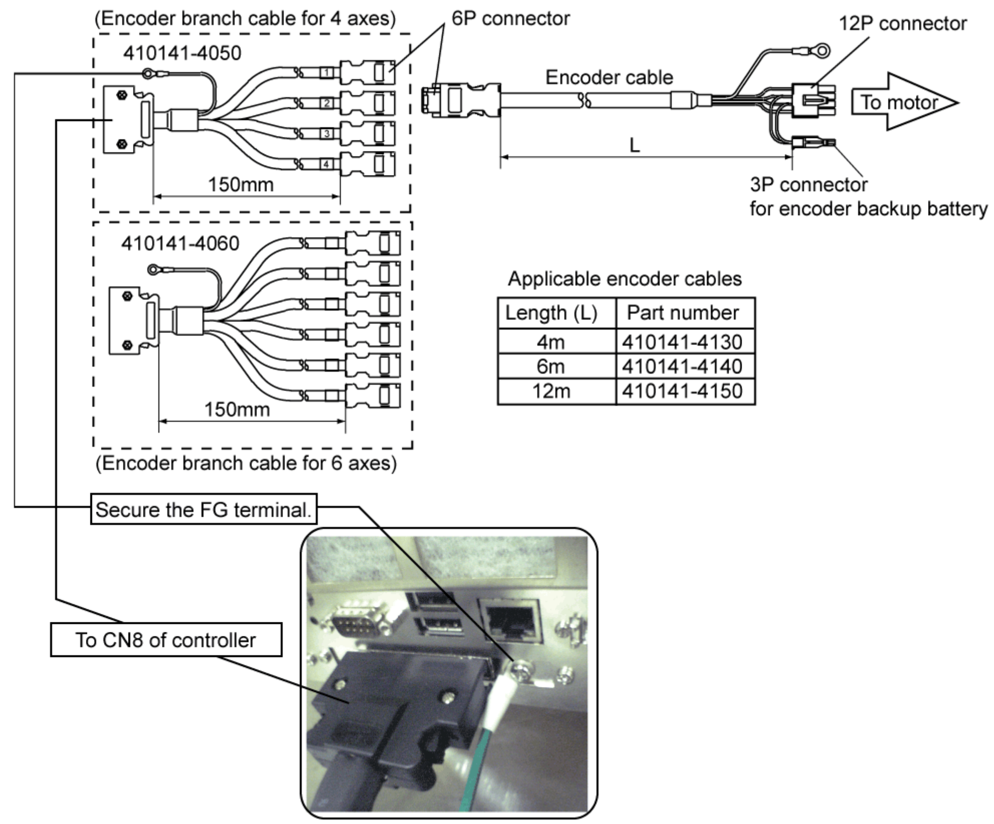


Connection of motor cable

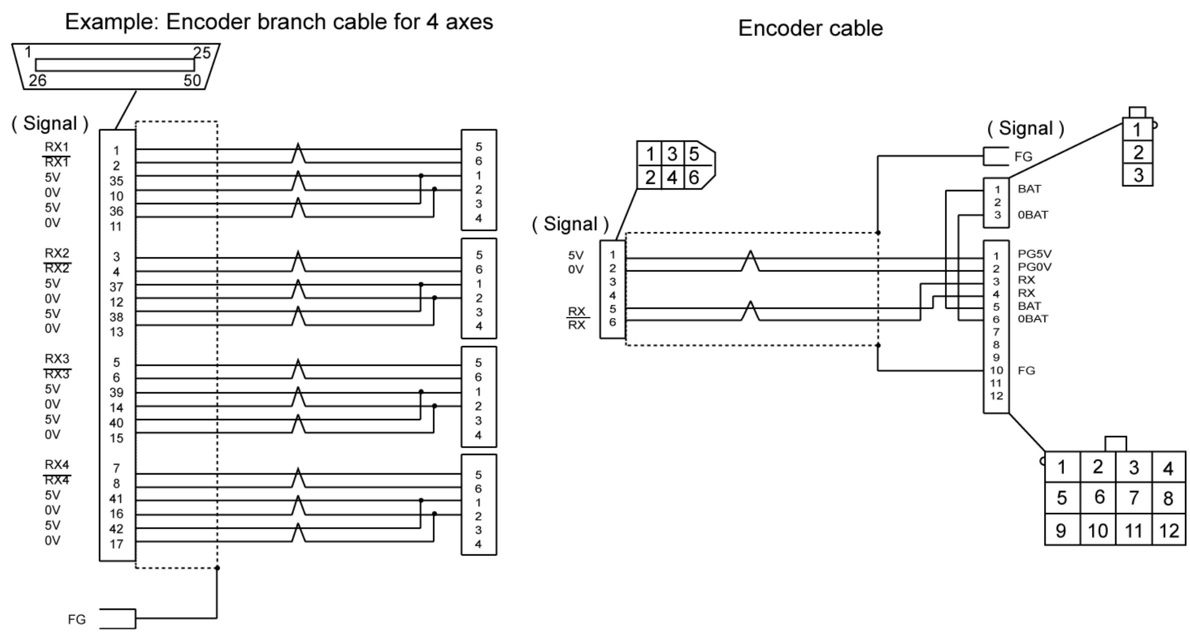
5.2.2 Connecting Encoder Cable

Encoder cables with the length of 4, 6, and 12 m are available as options. Connect the encoder cable to the SMT7 controller via the encoder branch cable.

Note: Secure the FG terminal of the encoder branch cable to the original screw on the SMT7 controller shown in the figure below.



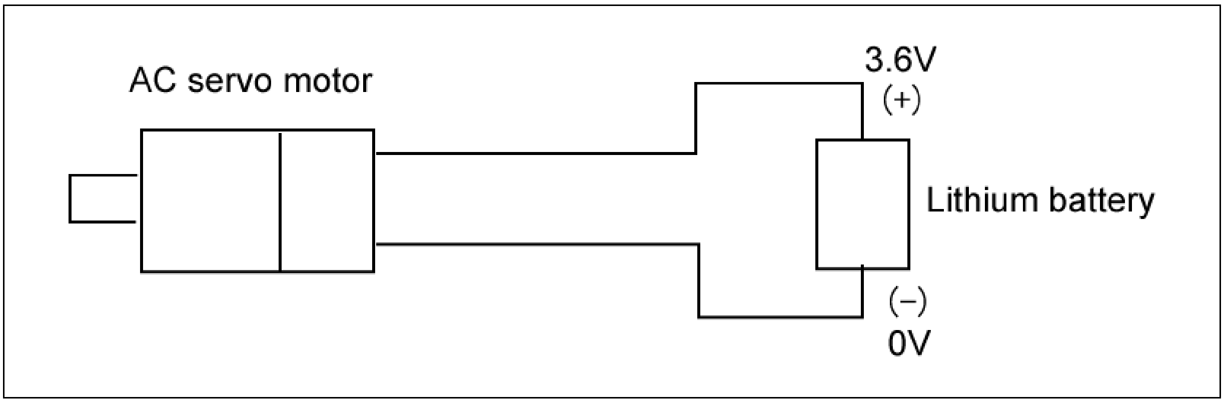
Length (L)	Part number
4m	410141-4130
6m	410141-4140
12m	410141-4150



Connection of encoder cable

5.2.3 Encoder Backup Battery

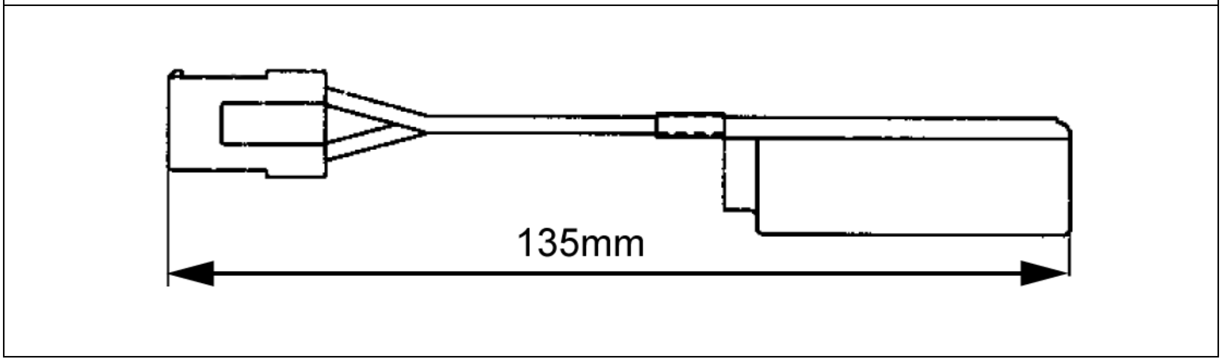
Connect a lithium battery to the encoder to memorize the position data by the absolute position encoder circuit as shown on the figure below.



Encoder backup battery circuit

The figure below shows the optional encoder backup battery.
Use one battery per single axis.
For maintenance, replace it every 2 years.

Model: MC2-BAT-ABS (Part No.: 410611-0030)



Encoder backup battery (Option)

5.2.3.1 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.**

5.2.4 Caution for Wiring

The figure below shows the wiring example when a motor is connected to the SMT7. Absolute value encoder transmits data in serial communication. So, securely connect shield or F.G.

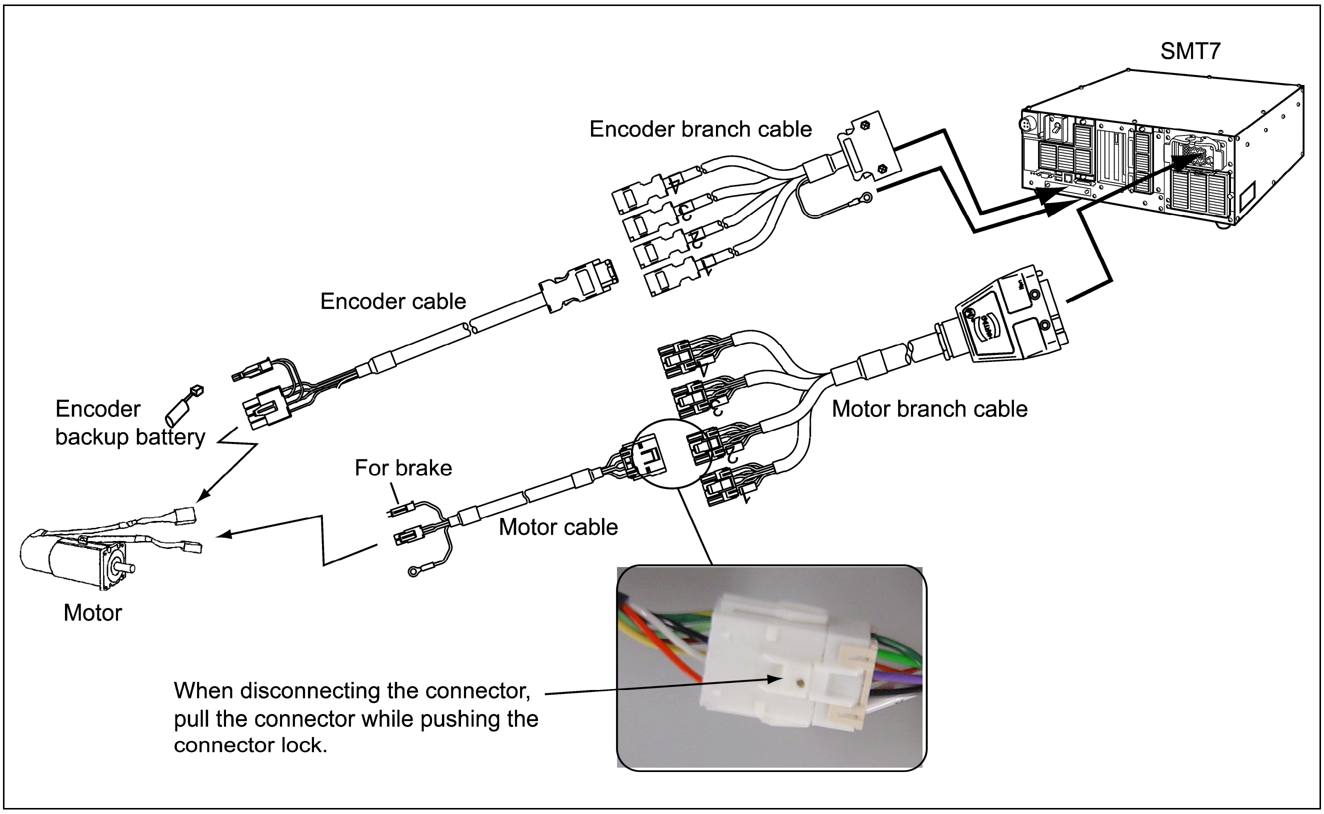
(1) Secure the FG terminal of the encoder branch cable to the original screw on the controller.

(2) Lay the wiring away from the noise occurrence source.

(3) Do not bind encoder cable and motor cable together.

(4) When disconnecting the motor cable connector from the motor branch cable, pull the connector while pushing the connector lock.

Caution: Do not bundle the teach pendant cables, I/O cables or motor cables together with high power lines such as 200 VAC lines and peripheral device cables, or route the motor cables near high power devices (motor, welder, parts feeder, etc.).



Wiring example when a motor is connected to the SMT7

5.3 Wiring of Primary Power Source

Observe the following precautions when wiring the primary power source of the controller:

(1) Connect the robot power cable to a power source separate from the welder power source.

(2) Ground the protective grounding wire (green/yellow) of the robot power cable securely.

(3) Ground the functional grounding terminal of the robot controller using a wire of 1.25 mm^2 or more in size.

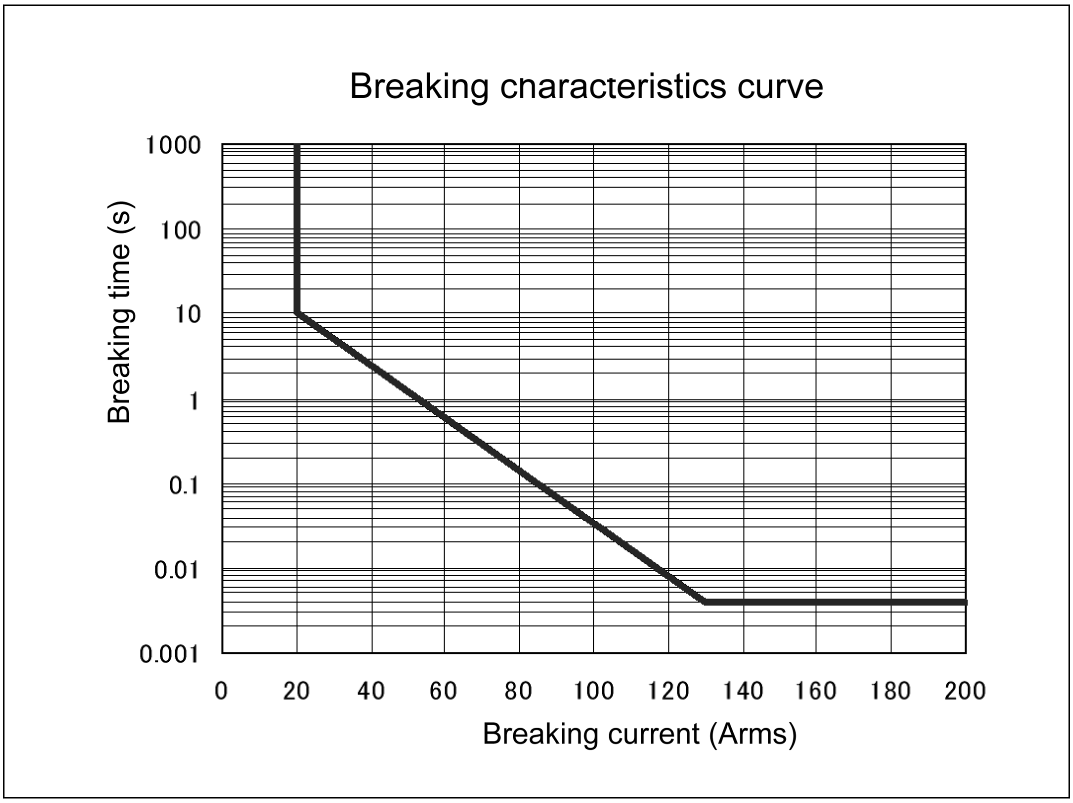
(4) For the robot power supply, use a protective grounding wire with grounding resistance of 100Ω or less.

(5) If the supply power source for the controller requires a leakage breaker, use a high frequency-proof leakage breaker for inverters.

(6) When inserting a circuit breaker between the robot and the AC input power supply, select the circuit breaker with breaking capacity higher than the following specification.

Recommended circuit breaker example:
CP33V/20 (Fuji Electric FA Components & Systems Co., Ltd.)

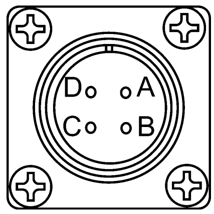
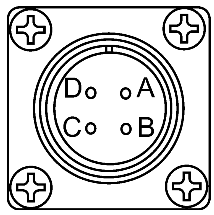
Caution:	**Using a circuit breaker with breaking capacity lower than the following specification may cause the circuit breaker to be shut down due to robot operation.**



Circuit Breaker Characteristics

(7) Prepare wires of an appropriate capacity for the 200VAC main line and other cables according to the tables given below.

Power Supply Specifications of the SMT7 Controller (at full IPM boards)

<table>
<tr><td colspan="2">Item</td><td>Specifications</td><td colspan="2">Pin assignment on power connector (CN6)
(View from the pin face of cable)</td></tr>
<tr><td rowspan="2">Power supply</td><td>Three-phase, 200 VAC</td><td>Three-phase, 200 VAC -15% to 230 VAC +10%, 50/60 Hz, 3.3 KVA</td><td>
</td><td>A: 200 VAC, phase R
B: 200 VAC, phase S
C: 200 VAC, phase T
D: Protective ground</td></tr>
<tr><td>Single-phase, 200 VAC</td><td>Single-phase, 230 VAC -10% to 230 VAC +10%, 50/60 Hz, 3.3 KVA</td><td>
</td><td>A: 200 VAC, phase R
B: 200 VAC, phase S
D: Protective ground</td></tr>
<tr><td colspan="2">Max. rush current when the power is turned ON</td><td colspan="3">40 A (for 1/50 or 1/60 second)</td></tr>
</table>

Caution: If ERROR6102 (power voltage drop) occurs when the robot is in operation, then it may be due to an insufficient capacity of the primary power source.

SMT7 CONTROLLER

INSTRUCTION MANUAL
(SUPPLEMENT)

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DENSO WAVE INCORPORATED 10N**C

The purpose of this manual is to provide accurate information in the handling and operating of the controller. 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.