PORTABLE GENERAL PURPOSE INTELLIGENT ARM

Operating Manual
(CE Marking)

(91-00411)

Rev. 1

MITSUBISHI HEAVY INDUSTRIES, LTD.

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Introduction

Thank you for your purchasing this Portable General Purpose Intelligent Arm. This Operating Manual describes the handling, setting procedure and instructions for "Portable General Purpose Intelligent Arm PA-10". Please read this Operating Manual before use.

For Safe Operation

1. General Precautions

General Precautions
● Read this Operating Manual carefully, and operate the machine properly. Keep this manual with care so that it can be referred to as required. ● Before starting work or operation, check if the functions and performance of this product are properly available. ● Please note we are not responsible for the functions and performance of any product used, or modified in manners other than the standards shown in the specifications. ● In case our product is used in combination with other system, the functions and/or performance may not be realized due to operating conditions and environment. Pay enough attention to possible problems before such use. ● To prevent various damages possibly caused by unexpected failure or malfunction, establish sufficient safety measures. ● Please note we are not responsible for any damage caused directly, or indirectly by the use of this product or its failure.

2. Notes for safe operation

2.1 Introduction

PA-10 arm moves based on software prepared by the customer. For work application, in addition to the arm, various other equipment will be required, for example; transfer equipment, endeffector tools, sensors, etc. PA-10 including these peripheral devices belongs to the manipulator controlled by labor safety & health rules, and must meet the regulations specified in related ordinances. For the teaching and inspection carried out in the robot's motion range without cutting off the drive power (power supply) above all must meet the regulations specified in related ordinances .

The followings are the related ordinances for robot. Please ensure that you will respect these regulations, and work safely.

(a) EN775(ISO 10218) :Manipulating industrial robots, safety
(b) ISO 11161 :Industrial automation systems—
Safety of integrated manufacturing systems
(c) EN60204-1(IEC60204-1) :Electrical equipment of industrial machines

To configure an original system by integrating the portable general purpose intelligent arm PA-10, prepare an operating manual reflecting the contents of this document, and pay enough attention to safety measures.

2.2 Safety Measures

Please ensure safe operation, by employing appropriate safety measures for the work site, based on the following recommendations.

(1) General

(a) Do not approach arm while in motion.

For safe operation, install interlocks to protect against arm motion caused by unexpected malfunction. Do not take unnecessary risks. While in operation, take care not to enter within manipulator motion limits.

(b) Matters for special attention during stoppage

Confirm what condition the arm has been stopped in. If the arm is stopped in automatic operation, etc., sudden movement can occur, which could be very dangerous. Please indicate work conditions, and consider the safety of others working around you. It is important for an observer to keep watch at all times, indicating what the manipulator is presently doing, and preventing the other worker from unintentionally entering within the arm motion limits.

(c) Put into effect two fold safety measures

Accidents occur due to some sort of carelessness, or lack of checking. To ensure safe working, it is recommended to apply two fold safety measures on the work site.

(d) Know the work

Before beginning work, thoroughly understand what the arm is made to do, what it does, what it can do, contents of work, arm specifications, etc. Studying first can prevent accidents later.

(e) Decide procedures and signals

Please decide upon procedures for teaching, operation, inspection, work in case of abnormality, etc. For good work safety, work carefully step by step through procedures, following signals when 2 or more people are working.

(f) Two people for teaching work, test work, etc.

When carrying out work within arm motion limits (teaching, inspection, etc.), it is recommended to work in groups of two to ensure the safety of the worker within the motion limits, so that one person can observe the work circumstances at all times.

(g) Carry out inspection before starting work

Carelessness is a powerful enemy. Even with familiar work, always carry out inspection before starting work to avoid malfunction.

(2) Unpacking/Transportation

Portable general purpose intelligent arm PA-10 is light in weight, so it can be handled without special lifting equipment. During unpacking/transportation, however, take sufficient care to avoid dropping on feet, crushing hands, back injury, etc.

Also, take care not to allow the arm to fall down when setting it.

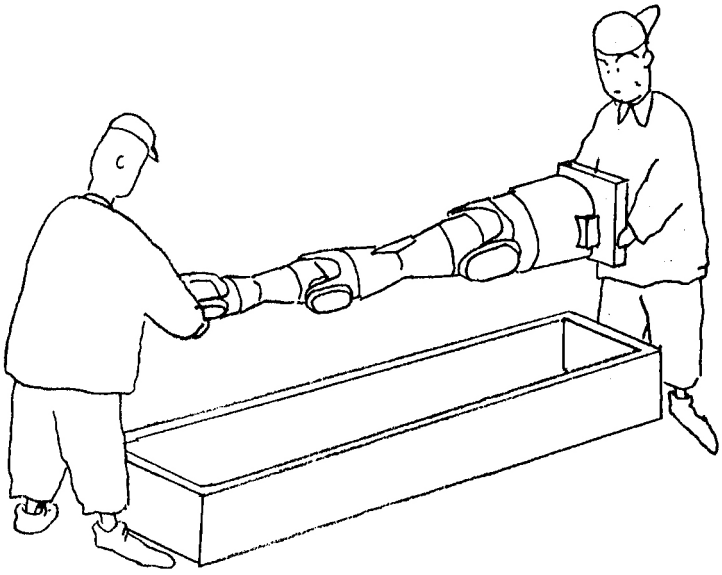
-MIND YOUR FEET

-LIFT WITH CORRECT POSTURE

-USE LIFTING AIDS

-KEEP GOOD BALANCE

-SIGNAL



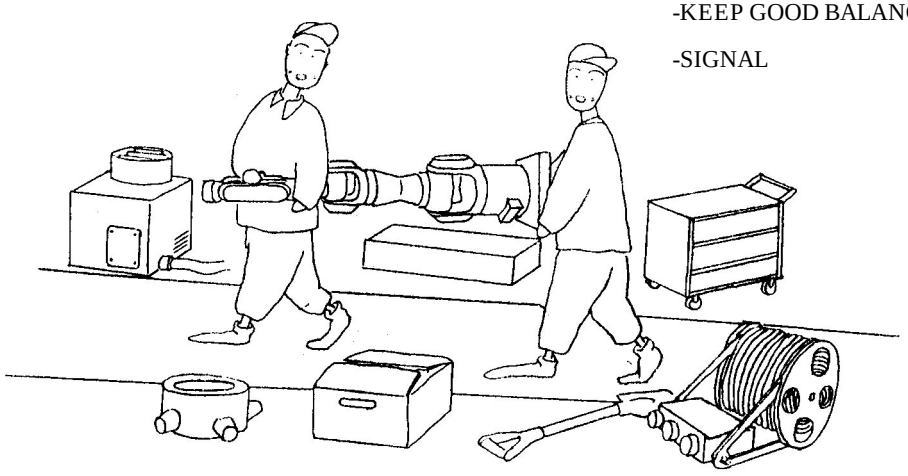
-MIND YOUR FEET

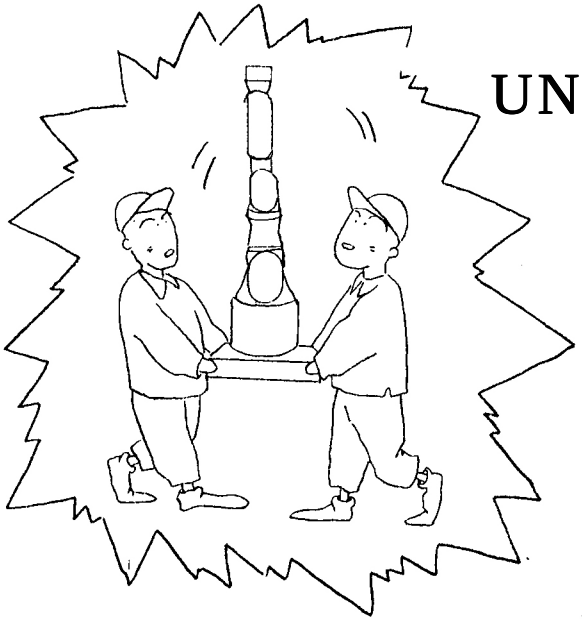
-LIFT WITH CORRECT POSTURE

-USE LIFTING AIDS

-KEEP GOOD BALANCE

-SIGNAL



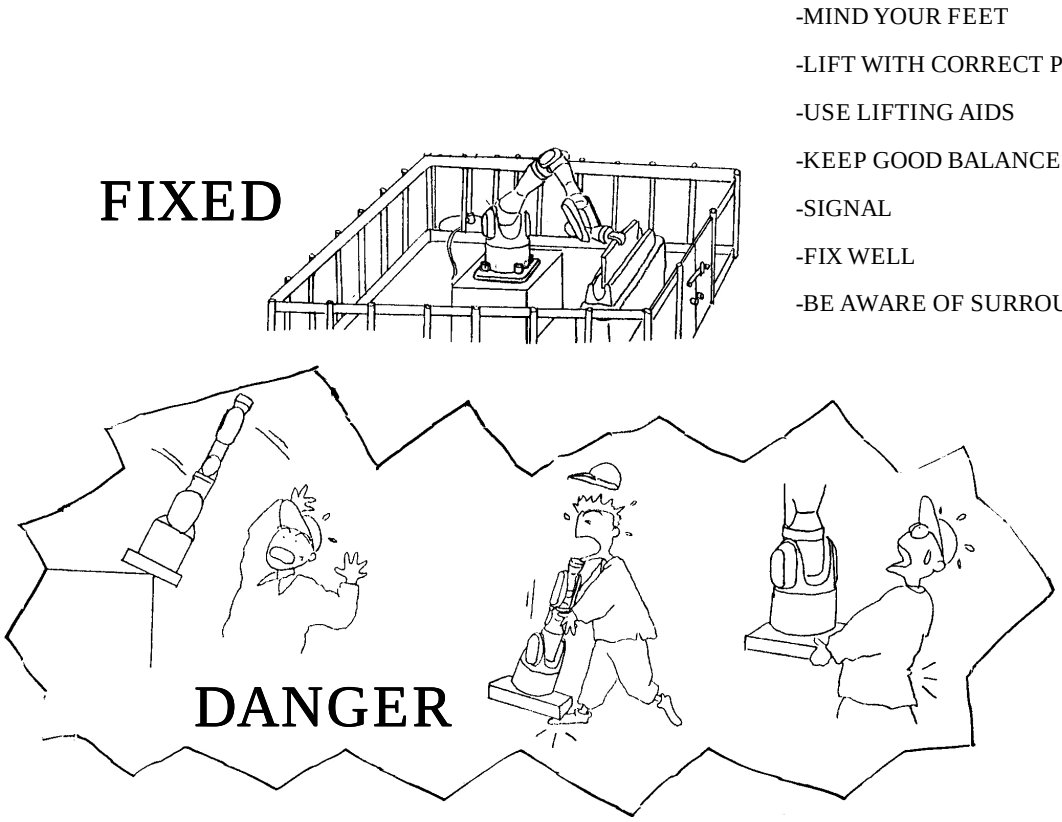


UNSTABLE

(3) Setting Up

When setting up the PA-10 please take the following precaution:

(a) Consider arrangements for work and maintenance.
(b) Attach arm to mounting of sufficient strength and hardness taking into account arm weight, work-tool weight, payload weight, handling speed, etc.
(c) If using two or more robots working together, take sufficient precautions to avoid mutual interference by providing the required mutual interlock function. As a safety measure for work, please add emergency stop function, etc.
(d) Please take sufficient precautions to ensure that operating devices, such as the operating box, are mounted/held securely to avoid drops which could result in unexpected arm movement. Also, usually the stop switch, so during work (teaching automatic operation, etc) ensure the operation device can be approached easily.
(e) Noise may cause unexpected arm motion, so ensure all equipment is earthed.
(f) Take sufficient measures to protect cables.
(g) It is recommended to position operation state indicators (rotating lamps, sign board, etc) in easily visible places.
(h) When working in high places, take measures to ensure workers and objects are prevented from falling.



(4) Power Supply ON, Control ON and Servo ON

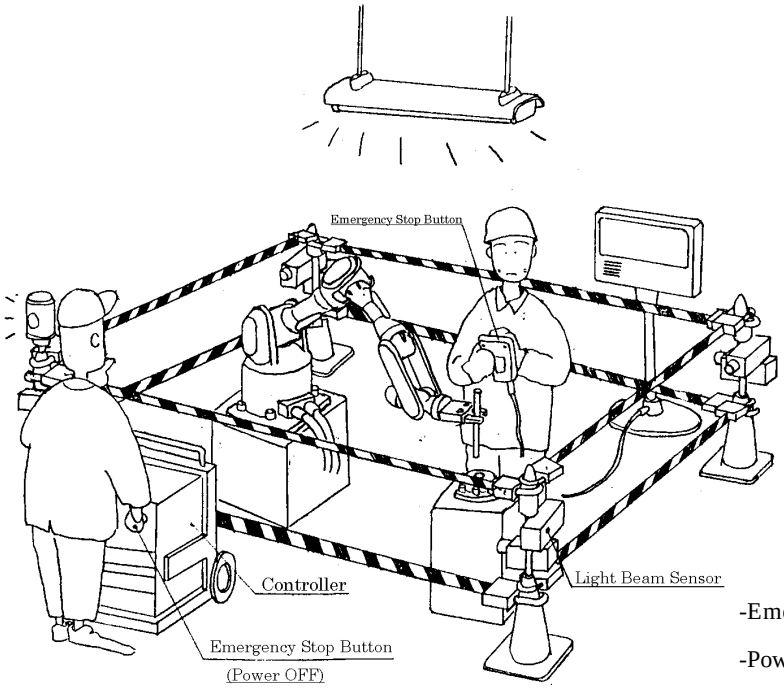
Before switching ON the power, control and servos, please check the followings:

(a) No one is within arm motion limits.
(b) Controller door is closed.
(c) Daily inspection has been carried out, and there are no abnormalities.
(d) Connected equipment will not move dangerously when manipulator is started.
(e) Tools, etc. have not been left within arm motion limits.
(f) Emergency switch can be operated quickly and easily.
(g) Workers are not at dangers from flying objects caused by unexpected arm motion.
(h) Workers are not at dangers when the arm drops in emergency stop, or any object held by the hand is ejected.
(i) Operation device is not indicating any abnormality.

(5) Teaching Work

When carrying out the teaching work, please observe the followings:

(a) If any teaching work is carried out in the robot motion limits without cutting off the power for robot, ensure that such work be performed by operators who have been trained specially as specified by Labor Ministry.
(b) Before starting work, confirm the followings from outside of the arm motion limits. If any abnormality is detected, please correct it immediately.
-No abnormal movement of surrounding equipment.
-Emergency stop function is working normally.
-No leak of air or oil from any pipes/tubes.
-Sign indicating teaching in progress.
-Teaching mode key switch of the controller is teach mode.
-Teaching speed is slow.
(c) Avoid working within arm motion limits. Please work from outside of arm motion limits if possible.
(d) Ensure that an escape route is prepared in case of mishap.
(e) Work is often carried out with arm power ON, and the worker tends to concentrate only on the end of arm. So, it is recommended during work that an observer should stand outside of arm motion limits in a position where whole arm can be seen easily, so that arm can be stopped immediately if any malfunction occurs.
(f) Please ensure adequate lighting is provided for the work environment.
(g) Please ensure the workers wear appropriate protective gears.
(h) During teaching, please operate the arm as slowly as possible.



-Emergency Stop Button

-Power Supply Check

-Safety Training

-Status Check

-Status Indication

-Ensure Escape Route

-Ensure Good Lighting

-Safety Protection

(6) Program Motion

When moving robot to check prepared program, please observe the following precautions:

(a) Please check the contents of program before attempting automatic operation.

(b) Please check the teaching mode key switch of the controller at run mode before attempting automatic operation.

(c) When the contents of program has been checked, please confirm for each step if arm moves correctly in accordance with the program.

(d) When checks have been completed, please run the actual program at low speed.

(e) If there is no problem in the movement check, check the safety measures, and start automatic operation.

NOTE : Pay sufficient attention to safety, and do not place too much confidence on the written program. Robot is faithful, and moves faithfully as programmed. "YOU" the programmer must ensure safety. Please pay great attention to safety when programming.

(7) Automatic Operation

During automatic operation, please pay attention to the following precautions:

(a) Before starting automatic operation, please check the followings:
-There is no one within the arm motion limits.
-The contents of work agrees with the program to be executed.
-Connected devices have no sign of abnormality, and are ready for starting automatic operation.
-The teaching mode key switch of the controller is at run mode.

(b) Establish a system to trigger emergency stop immediately in case abnormality occurs.

(c) Check movement for at least 1 cycle.

(d) If the machine is suspected to move "strangely", or any abnormality occurs actually, stop the robot quickly (as a fundamental rule, switch off the power), and inspect. (If there appears to be an abnormality in the specifications, then please inform MHI of the case.)

(e) Please check if sign is indicating automatic operation.

(f) During automatic operation, please take measures to prevent personnel from entering within arm motion limits, no matter what the conditions may be (even non-moving condition).
eg observer, or safety barrier (Japan Green Cross, etc.), safety plug, beam-type switch, etc.
(KEYENCE http://www.keyence.co.jp / OMRON http://www.omron.co.jp/, etc.)

-Check Program

-Check Movement

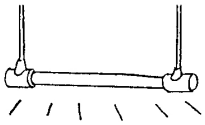
-Check Indication

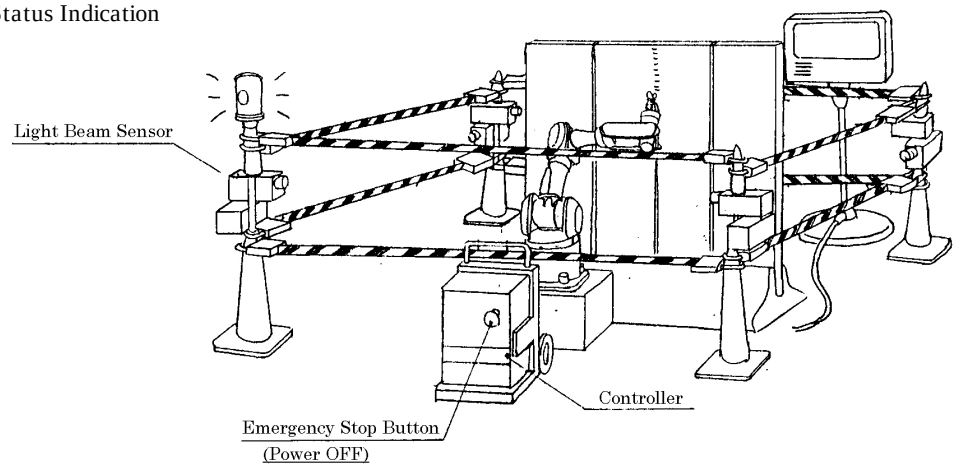
-Check Within Arm Motion Limits

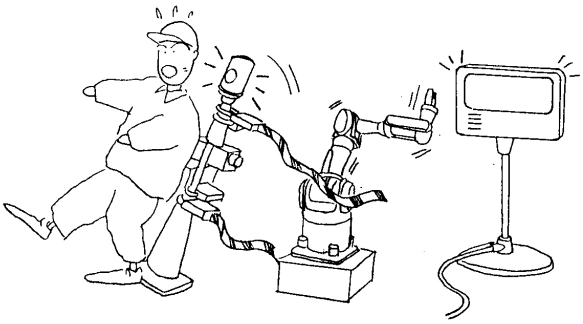
-Check Entry Prevention

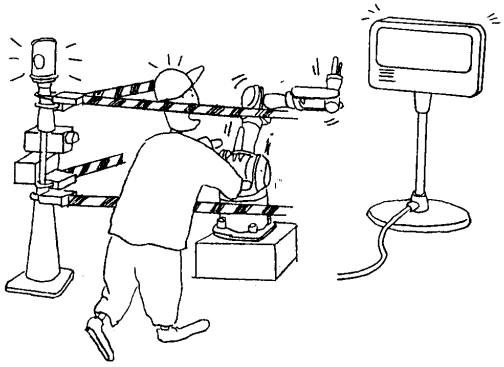
-Emergency Stop Button

-Status Indication









(8) Abnormality

If any abnormality occurs, take the following steps:

(a) As a fundamental rule, turn OFF the power supply before inspection.

(b) Indicate that inspection is in progress.

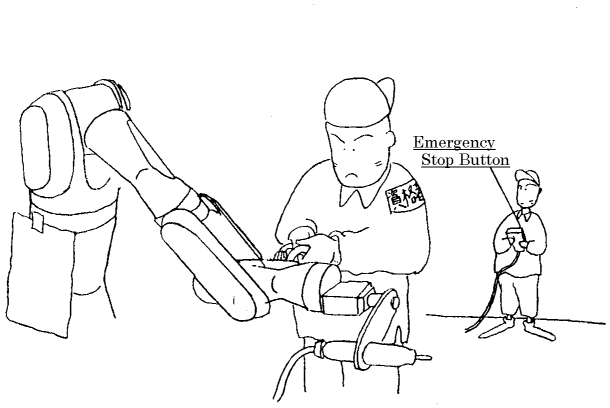
(c) Take measures so that other people can not operate the machine, and assign an observer to guard.

(d) Observer should always be ready to push emergency stop button.

(e) If inspection is carried out without cutting off the power, specially trained workers should perform such inspection.

(f) Re-check what is abnormal.

(g) If you have any doubt, please inform MHI, before entering arm motion limits, of the "process to failure", "failure" and "present condition" in details as far as possible.



-Emergency Stop Button

-Check Power Supply

-Safety Training

-Check State

-Status Indication

-Ensure Escape Route

-Ensure Good Lighting

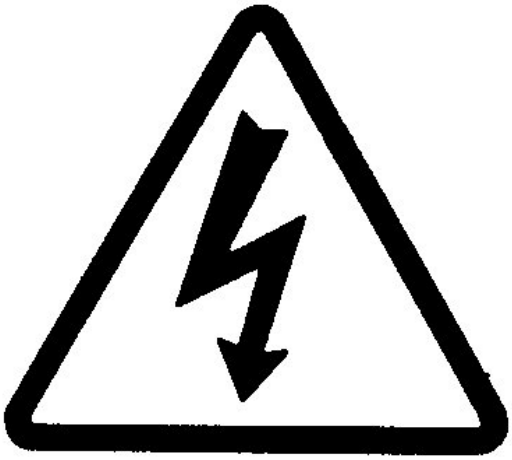
-Safety Protection

(9) Motion Recovery

For motion recovery, carry out the checks for each step as in starting the machine initially. If abnormalities occur, please check not only the section affected in such case but also the whole system.

3. Warning Label

Establish measures to prevent human approach to the machine in operation.



Operating the machine with the cover opened could lead to electric shock. Be sure to close the cover.
To prevent electric shock, also be sure to operate the machine properly earthed (type 3 earthing).

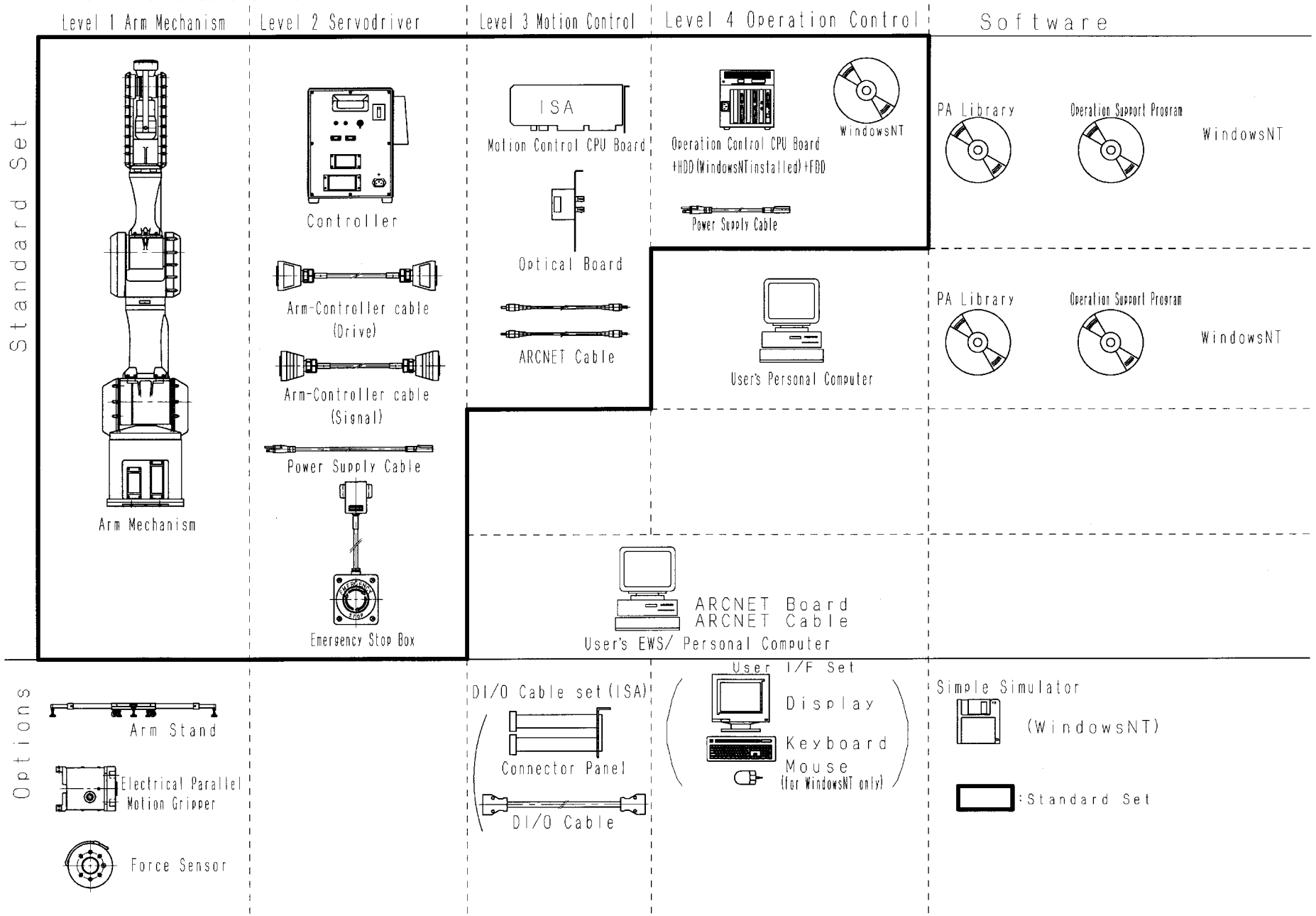
Chapter1 Overview

Portable General Purpose Intelligent Arm has the following features:

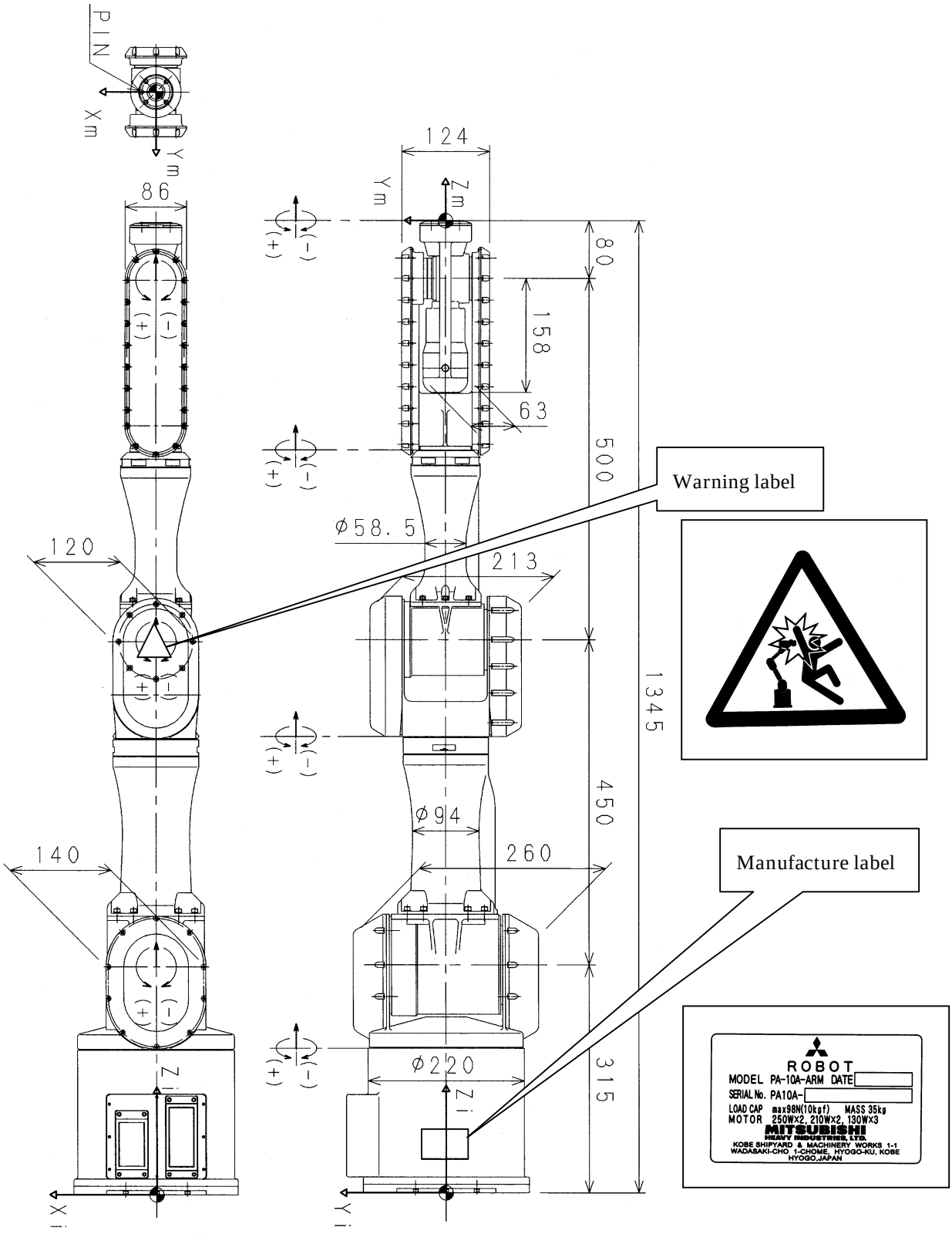
1. Employing epoch-making open system
   Arm can be assembled in the existing work system freely, and various types of work can be performed by utilizing the user's know-how.
   For the controller, the internal PC or any PC available in the market can be used.
2. As dexterous as human hand even under adverse environment
   With the arm length of 950mm the same as human hand, the 7-joint specification allows the work to be performed while avoiding obstacles. The machine (arm only) can be operated even under an environment requiring dust-proof/drip proof (standard spec.), explosion-proof/water proof/ cleanness (optional).
3. Dead weight is only 35kg. The controller is also compact, light in weight, and portable.
   Yet, 10kg can be lifted up. The machine can be brought in, and used at a construction site or a factory where system lines are not established.

The following page shows the system configuration of Portable General Purpose Intelligent Arm.

PA-10 Portable General Purpose Intelligent Arm System

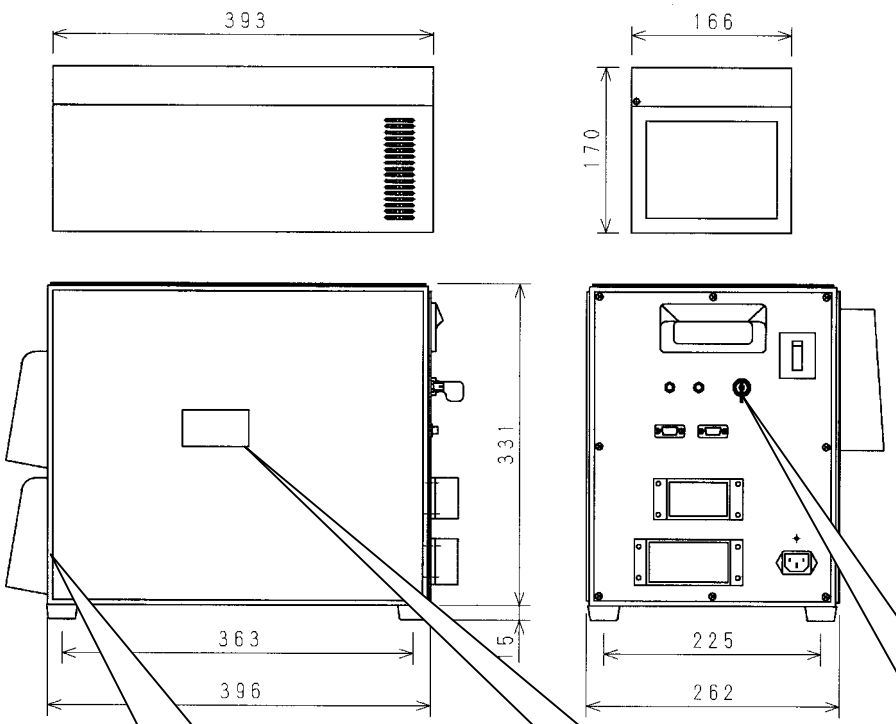


1.1 Appearance of Arm

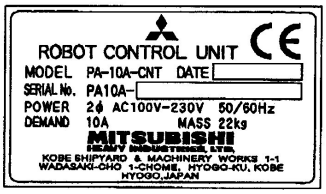


1.2

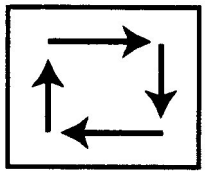
1.2 Appearance of controller



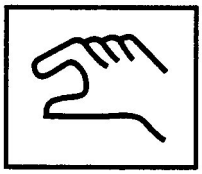
Level4



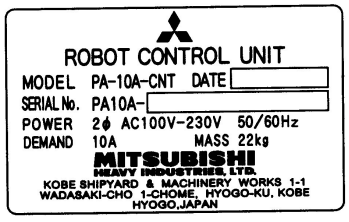
-Run mode



-Teach mode



Level2,3



No CEmake label

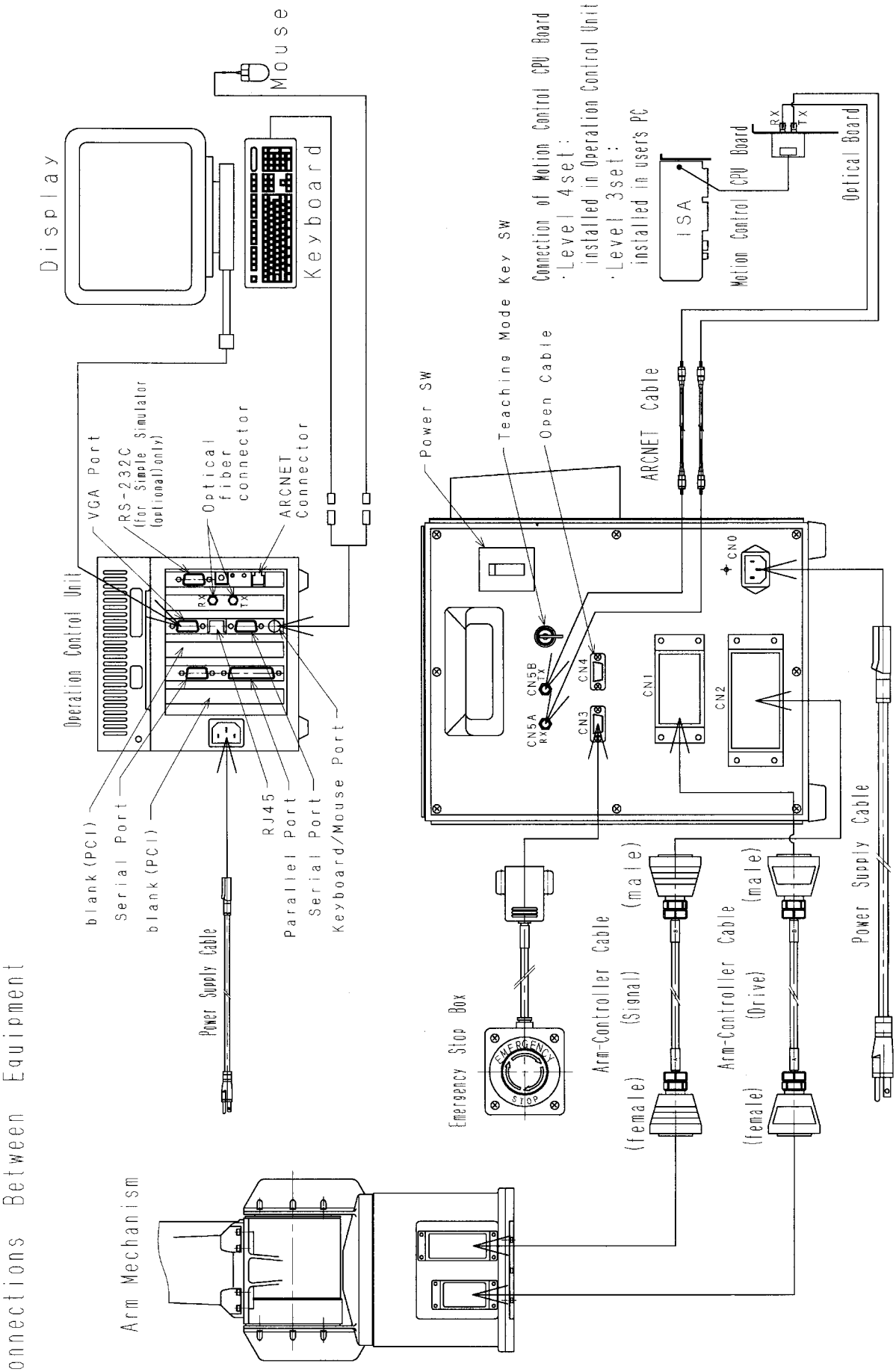
Chapter 2 Specifications

This chapter describes the specifications of Portable General Purpose Intelligent Arm.

2.1 Inter-Unit Connections

Before starting operation, connect the units as shown in the drawing on the next page.

Connections Between Equipment



If purchasing the level2 system, connect between your ARCNET board and optical board as shown in the drawing on the next page.

（1）CONNECTION BETWEEN YOUR ARCNET BOARD AND Optical BOARD

①Remove HYC2485S from YOUR ARCNET BOARD.
②Install an 8pins socket on YOUR ARCNET BOARD.
③Connect an 8pins plug of Optical BOARD to the 8pins socket.
(Refer to Fig-1 and 2)

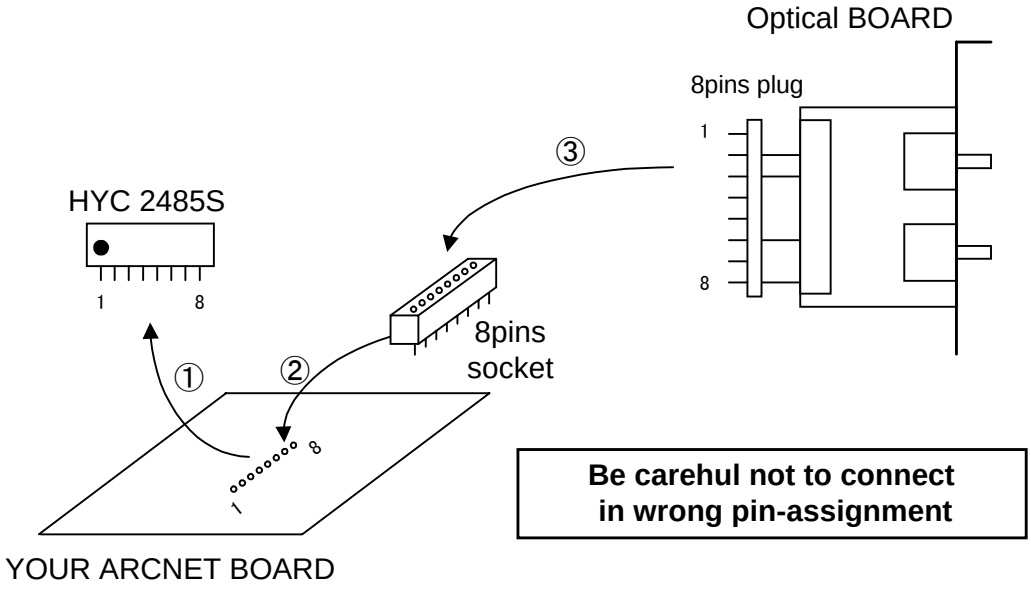


Fig-1. Installation of 8pins socket

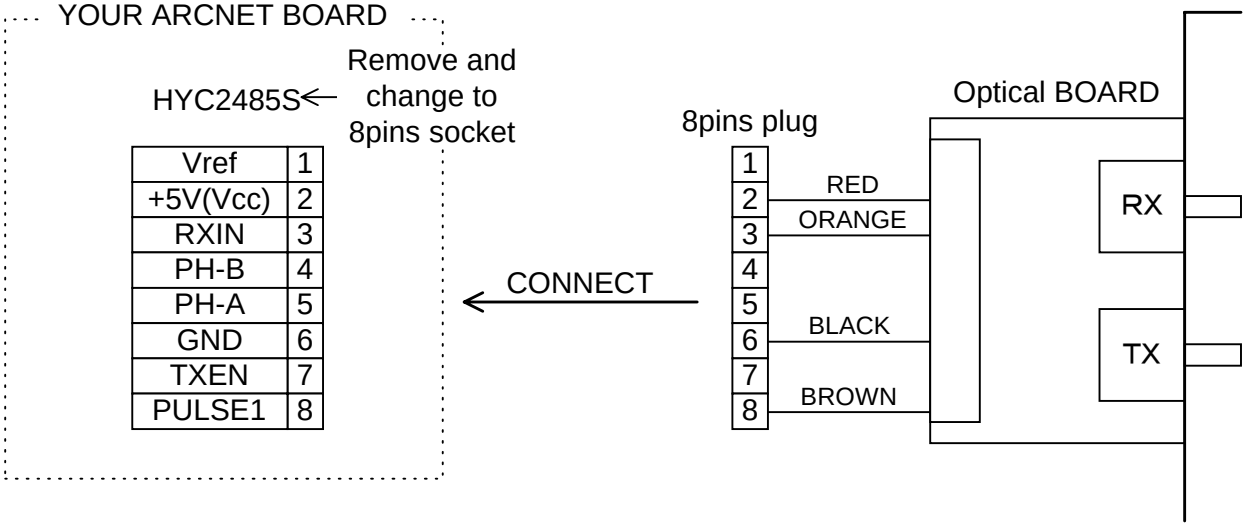


Fig-2. Connection between YOUR ARCNET BOARD and Optical BOARD

（2）CONNECTION BETWEEN Optical BOARD AND CONTROLLER

Concerning the connection between Optial BOARD and CONTROLLER , refer to Fig-3.

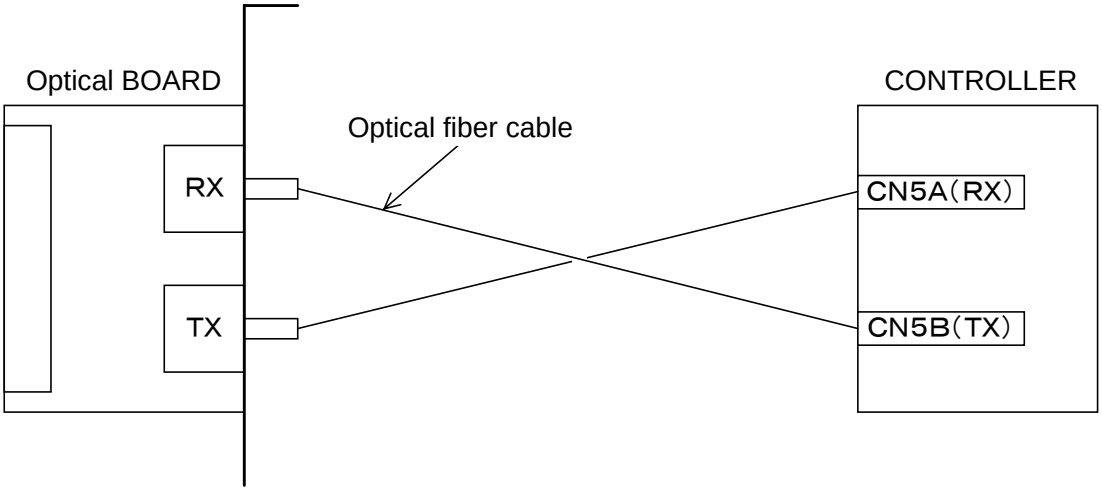


Fig-3. Connection between ARCNET BOARD and Optical BOARD with Optical fiber cable

2.2 Arm

Portable General Purpose Intelligent Arm employs an "Open Architecture" dividing the system into levels, and arm itself comprises the 1st level.

(1) Specifications

Item	Specifications				
Name	Main body of portable general purpose intelligent arm				
Model	PA-10A-ARM				
Type	Vertical multi-joint type				
Configuration	Dust-proof/drip-proof construction (explosion-proof/water-proof as optional)				
Number of joints	7				
Joint configuration	R-P-R-P-R-P-R from robot-mounting side (R : rotation , P : pivot)				
Joint names	S1-S2-S3-E1-E2-W1-W2 from robot-mounting side (S: shoulder joint, E: elbow joint, W: wrist joint)				
Arm length	Shoulder reach : 315mm (base surface to S2) Upper arm : 450mm (S2 to E1 axes) Lower arm : 500mm (E1 to W1 axes) Wrist reach : 80mm (W1 to mechanical interface side)				
Movable range	See 2.2.(4).				
Joint operating range & max. operating speed *1	Axis name	Limit (angle)			Max. operating speed (rad/sec)
		Mechanical limit	Servo limit	Software limit	
	S1 (rotation)	+-180	+-178	+-177	+-1
	S2 (swing)	+- 94	+- 92	+- 91	+-1
	S3 (rotation)	+-180	+-175	+-174	+-2
	E1 (swing)	+-143	+-138	+-137	+-2
	E2 (rotation)	+-270	+-256	+-255	+-2π
	W1 (swing)	+-180	+-166	+-165	+-2π
	W2 (rotation)	+-limitless rotation	+-361	+-360	+-2π
Max. integrated speed	1550mm/sec				
Load capacity	10kgf				
Drive method	AC servo motor with non-excitation brake/brushless resolver				
Sensor	Output axis brushless resolver *2				
Ambient temp.	0 to 5℃				
Humidity	30 to 90% RH (no condensation)				
Din	65.9dB				
Altitude	Below 1000m				
Storage temp.	-10 to 60 ℃				
Mass of main body	36kg				
External appearance	Finished by aluminium alloy painting				
Paint color	Body : pastel white (Japan Paint Industry Association S10-733) Cover : pastel green (Japan Paint Industry Association S38-552)				

*1 The software limit of W2 axis is +-360 degrees. Please note: If power is re-supplied when it is lost at a

position exceeding +-180 degrees, initial angle is not recovered, but an angle displaced by 180 degrees is given.

*2 The zero point of the output axis resolver does not correspond to the zero point of manipulator.

(a) Installation

This arm can be installed in any position (floor, wall and suspended). When installing the arm, check if the flatness of the place is 0.05 or less, and tighten the 4 bolts on the base surface. When installing this arm, please use the attached bolts.

(Spec of the attached bolts)

Size	ISO M screw M16
Material	SUSXM7
Intension	A2-70
bind torque	122Nm

The surface of arm base shall come in contact with the installation place by more than an area of radius 50mm around the installing bolts.

(b) Mechanical operating range of joint

Each joint shall be used within the movable range. The rotary joints (S1, S3 and E2) and W1 joint above all can move across the movable range, but should not be used in such way, because such movement could damage the internal cables.

If the customer prepares the servo driver or control software, set the electrical, or software limit to a range narrower than this mechanical movable range, and make sure that such mechanical range is not exceeded.

(c) Motor output

Set the torque duty and speed duty of each arm joint to 50% or less.

(d) Brake

Internal electromagnetic brake is not for controlling but for maintenance. Never try to operate the machine in a way that joints are activated when brake is applied.

(e) Maintenance

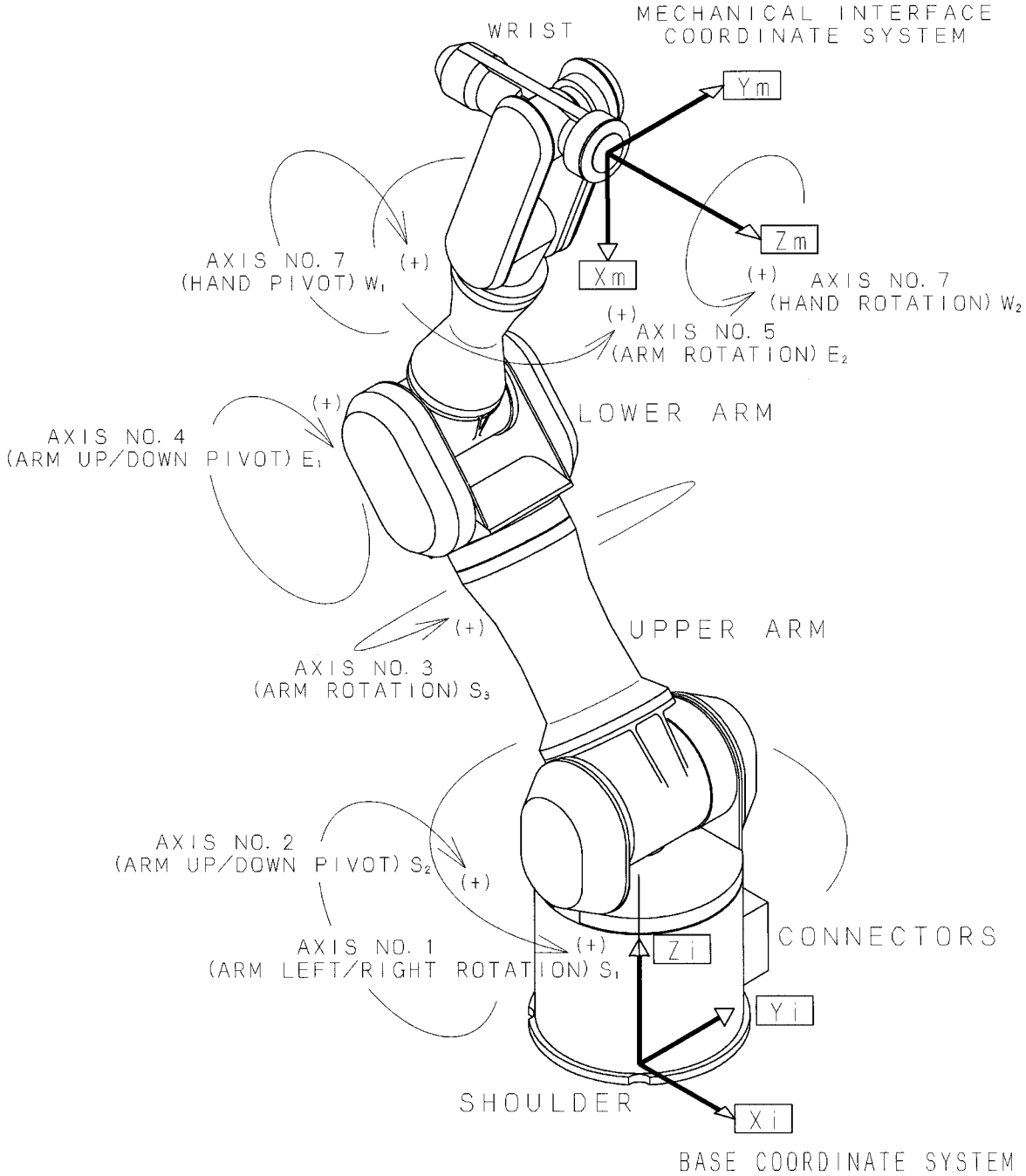
The inside of arm is of extremely complicated construction. Customer shall never try to disassemble or repair anything. Please contact MHI instead.

(f) Earthing

The body of this arm is connected to the F.GND terminal of the motor cable connector. The main body of arm is earthed by connecting the arm and controller by using an arm-board cable. Therefore, be sure to earth the main body of controller.

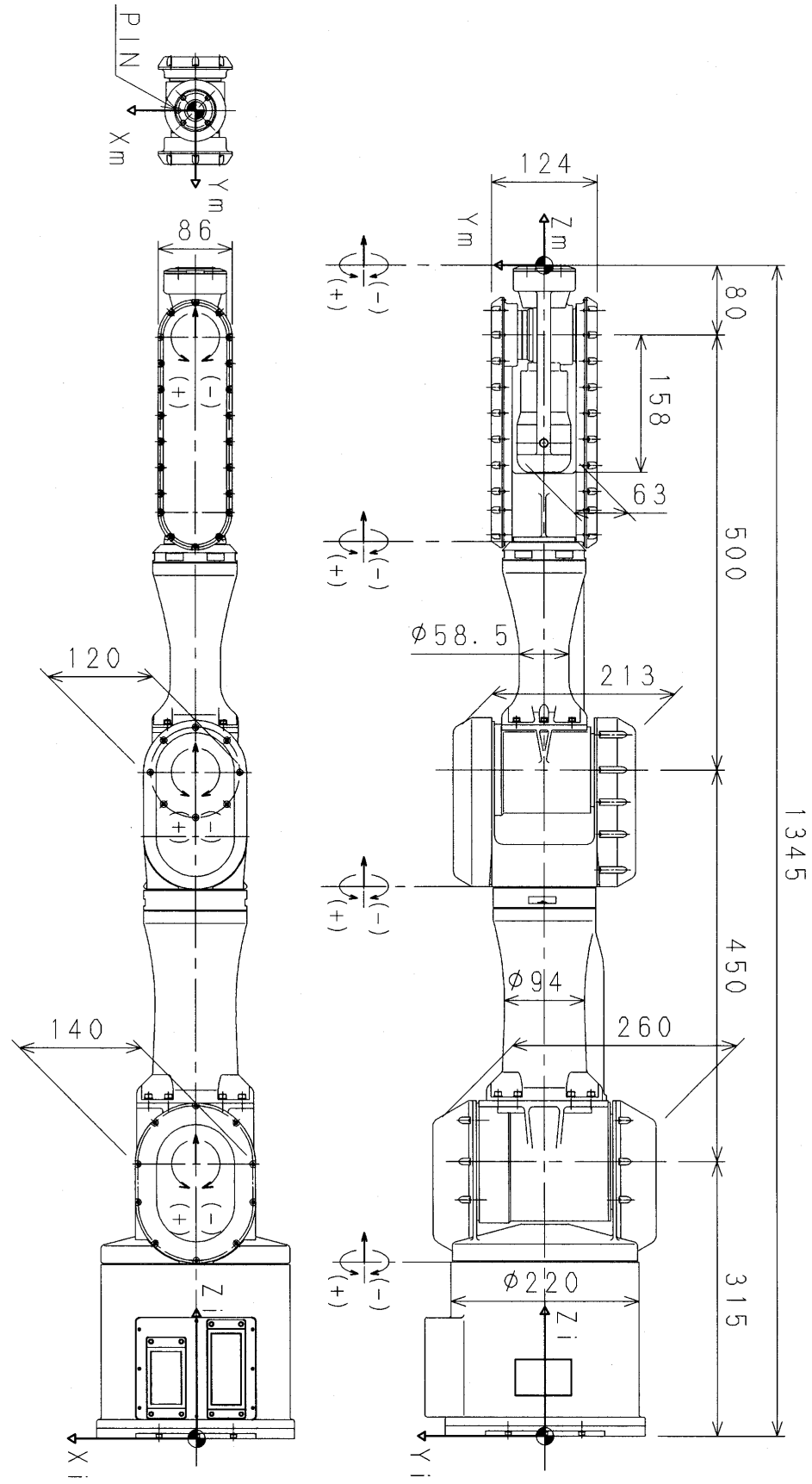
(2) Definition of Coordinate System

The definition of coordinate system for the portable general purpose intelligent arm is shown below:



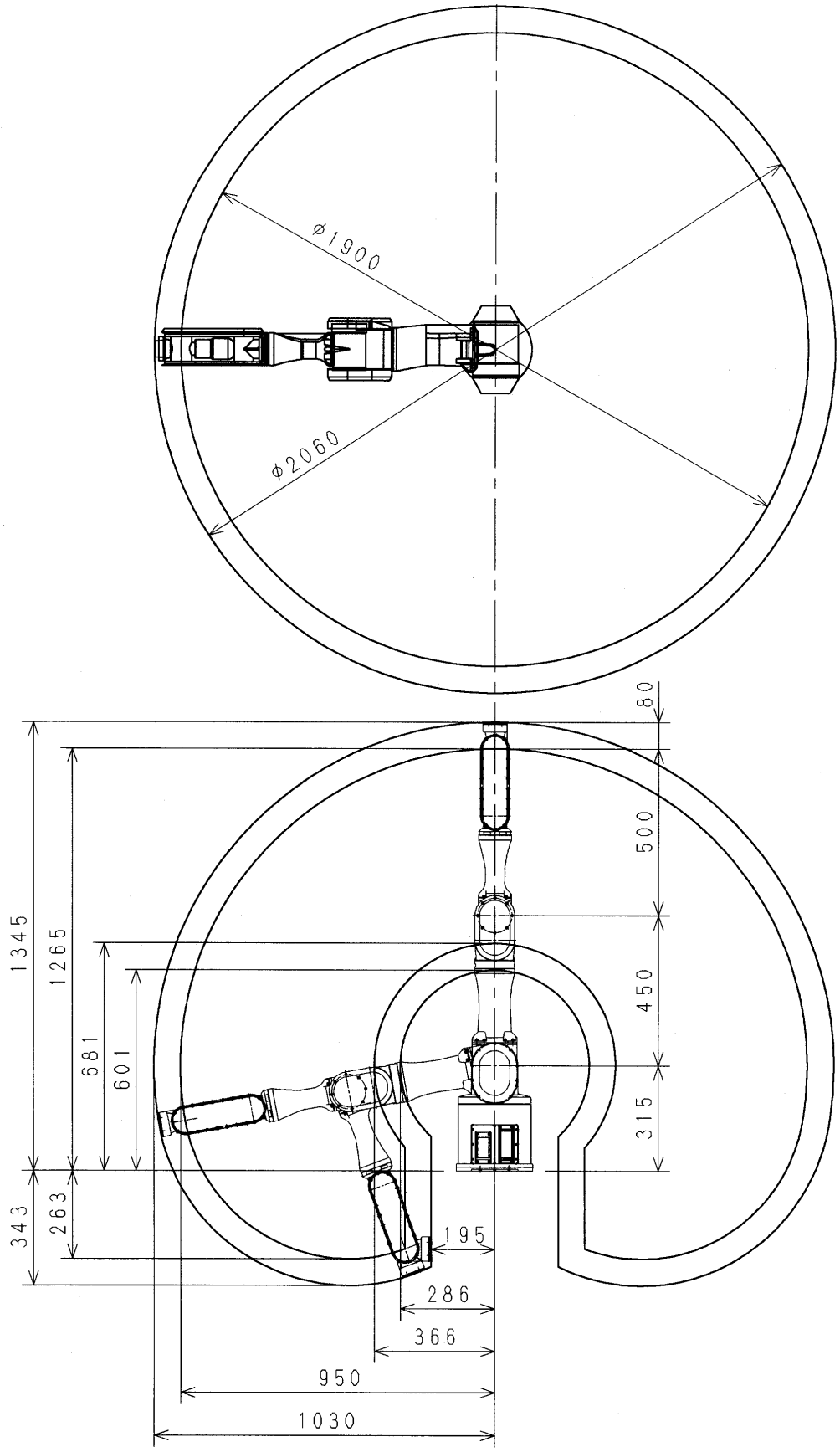
(3) Outline Drawing

The outline drawing of the portable general purpose intelligent arm is shown below:



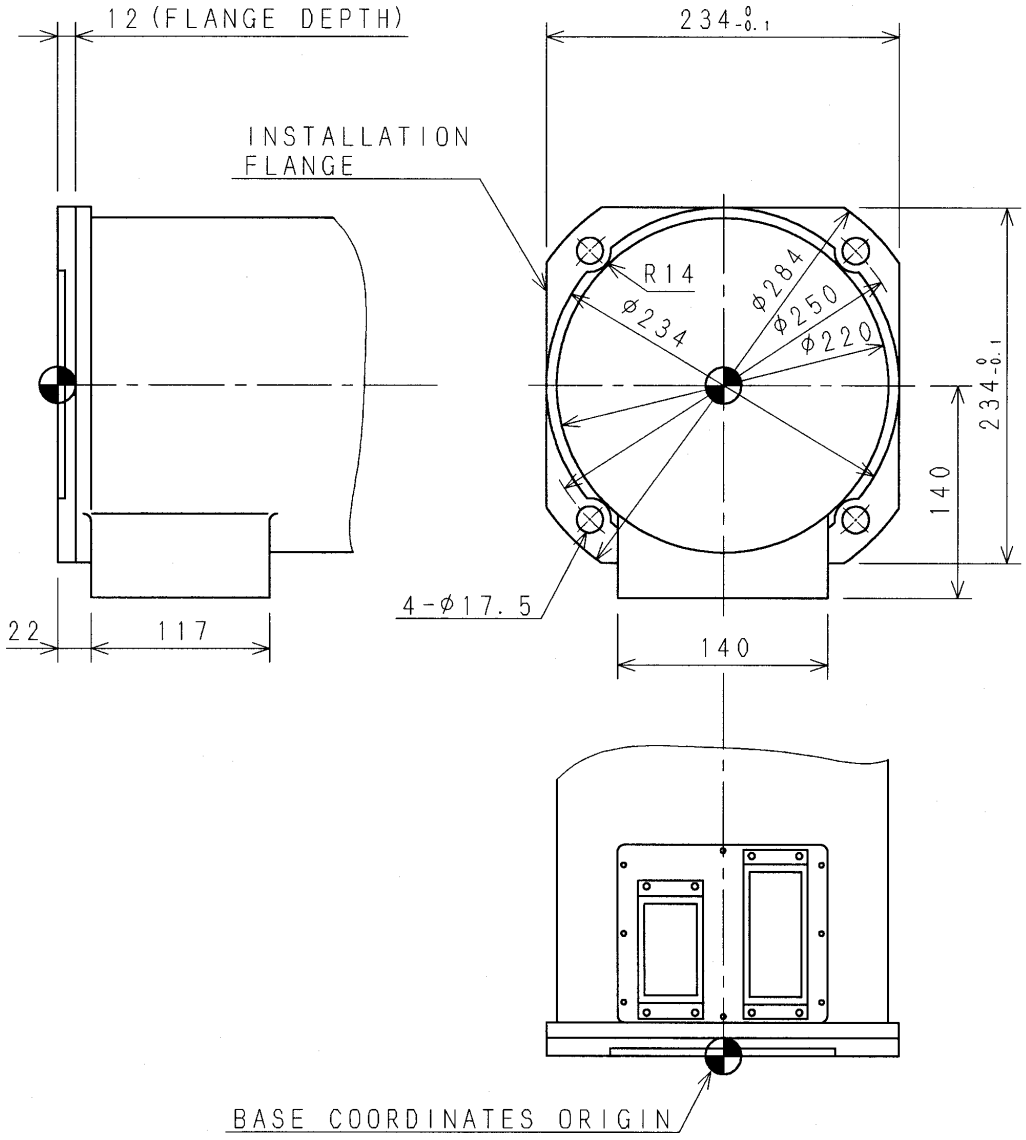
(4) Range of Operation

The range of operation for the portable general purpose intelligent arm is shown below:



(5) Base Flange Dimensions

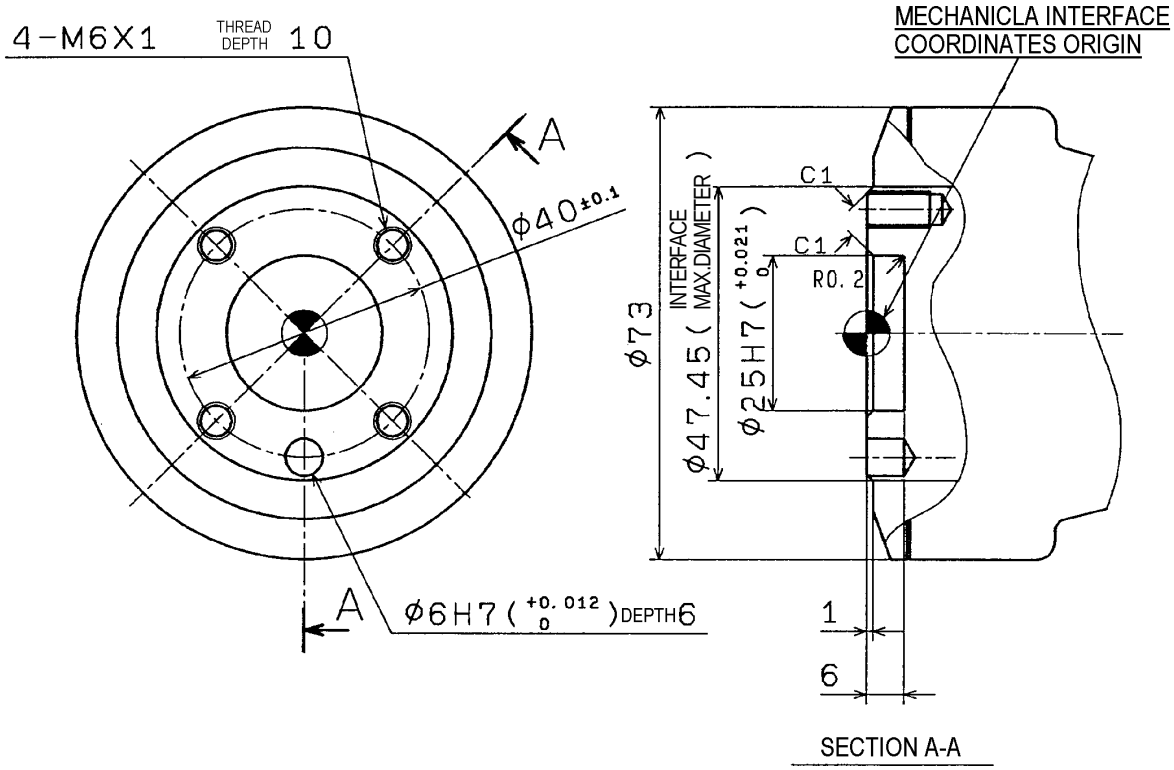
The flange dimensions the base-mounting surface for the portable general purpose intelligent arm is shown below:



INSTALLATION FLANGE MATERIAL : ALUMINIUM ALLOY (A7075-T6)

(6) Mechanical Interface Flange Dimensions

The flange dimensions mechanical interface surface for the portable general purpose intelligent arm is shown below:



INTERFACE SURFACE MATERIAL : STAINLESS STEEL (SUS304)

The requirements for installing the load on top of the manipulator (mechanical interface flange) is shown.

(a) The portable mass of a robot is generally an indication of mass. However, even with the same tool and work mass, the load may be restricted when widely decentered. The portable weight shown in the specifications means the total mass including the tool unit under the following conditions:

(b) Allowable load values are shown below:

Table Allowable load values

Torque	9.8 N·m
Inertia moment	0.1 Kg·m^2

If the volume of load is small, and can be regarded as a mass point, the torque/inertia moment is given by the following formula:

Torque = 9.8GL N·m

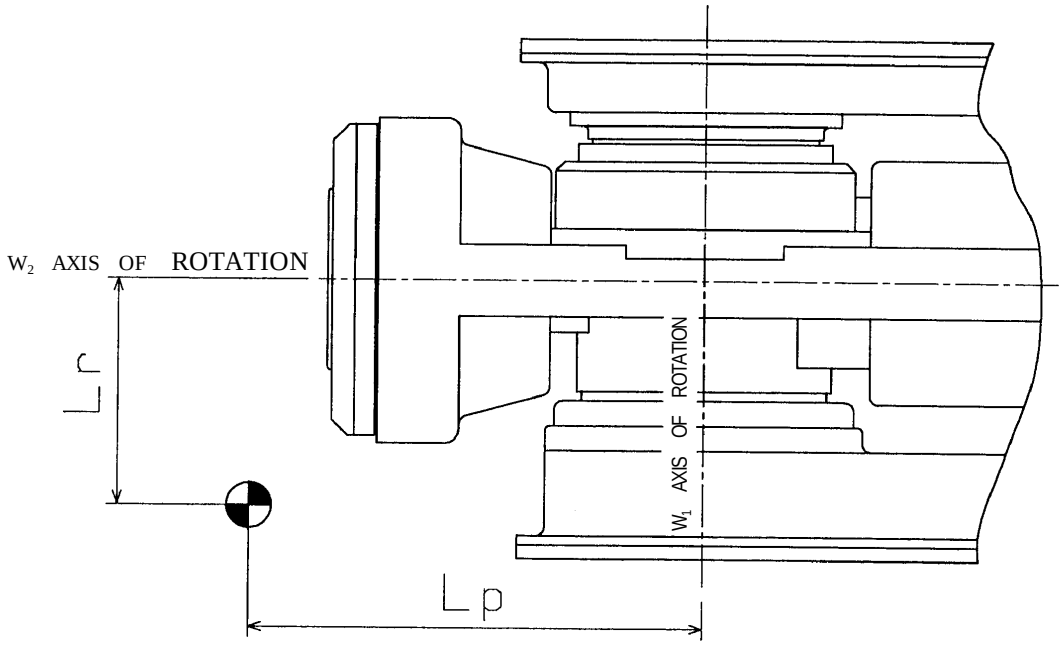
Inertia moment = GL^2 Kg·m^2

Where, G: mass of load (unit: Kg)

L: moment arm length (unit: m)

Note L is the larger of Lp (distance from W1 joint to load) and Lr (distance from W2 joint to load).

Regard a force as the load the same way as for mass.



(7) Setting and canceling of the mechanical limit switch

The mechanical limit switch is installed on the S1 axes because preventing the overrun. The setting and cancellation for the mechanical limit switch are shown the following.

(A) Setting for shipping

The mechanical limit switch of S1 axis is set to “on” at about +-177 deg dor shipping to stop the S1 axis operation.

(B) Modification of limit angle

To change the operating range of the S1 axis, modify the striker installation position of the limit switch to the optional position. Make sure to check and see the operation for safety after modifying the striker installation position.

(C) Cancel of limit switch

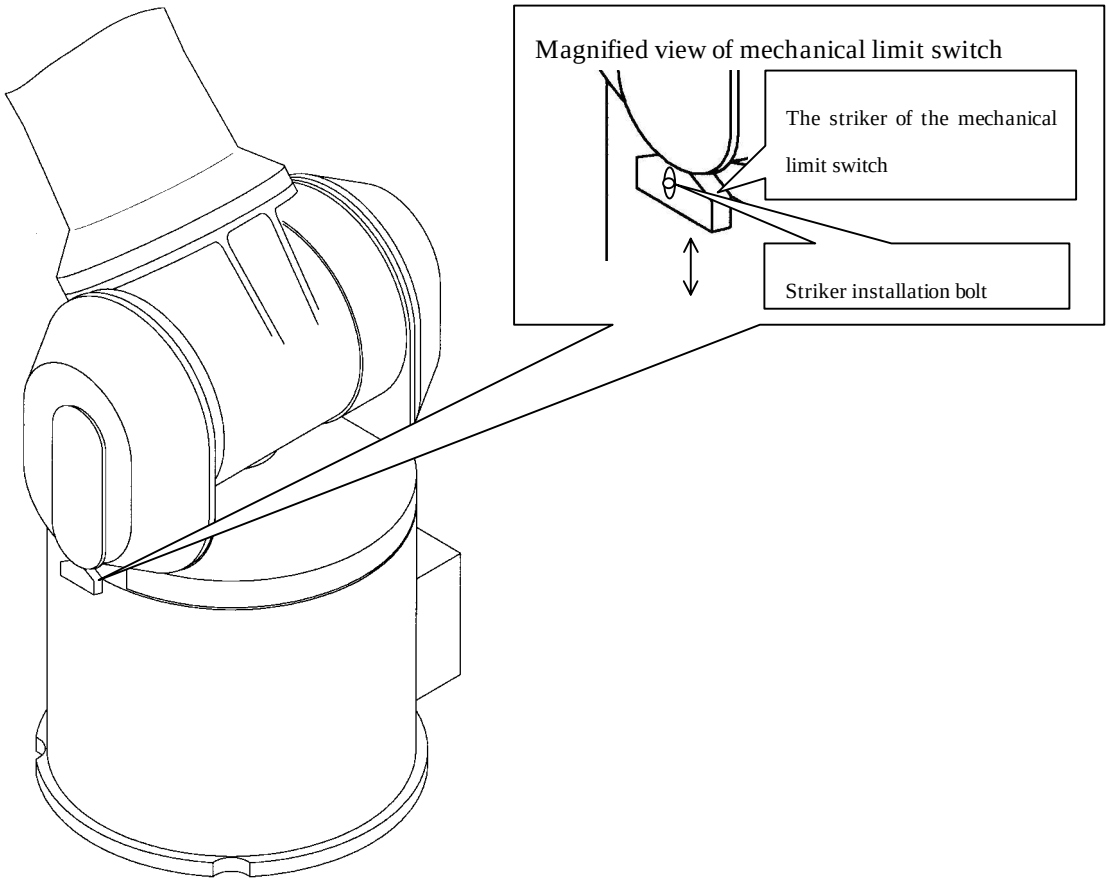
In case that the limit switch was turned to “on” to stop the arm, cancel the limit switch as follows:

(a) Power off the controller.

(b) Release the striker installation bolt of the limit switch to slide the striker until the limit switch is turned to “off”.

(c) Start up the controller to operate the S1.

(d) Power off the controller again to reinstall the striker of the limit switch.



2.3 Controller

(1) Specifications

Controller comprises the 2nd level of the portable general purpose intelligent arm, along with the servo driver in the section 2.4. Servo driver has IPM and PS in it. The arm-board cable, power supply cable and emergency stop box are attached additionally.

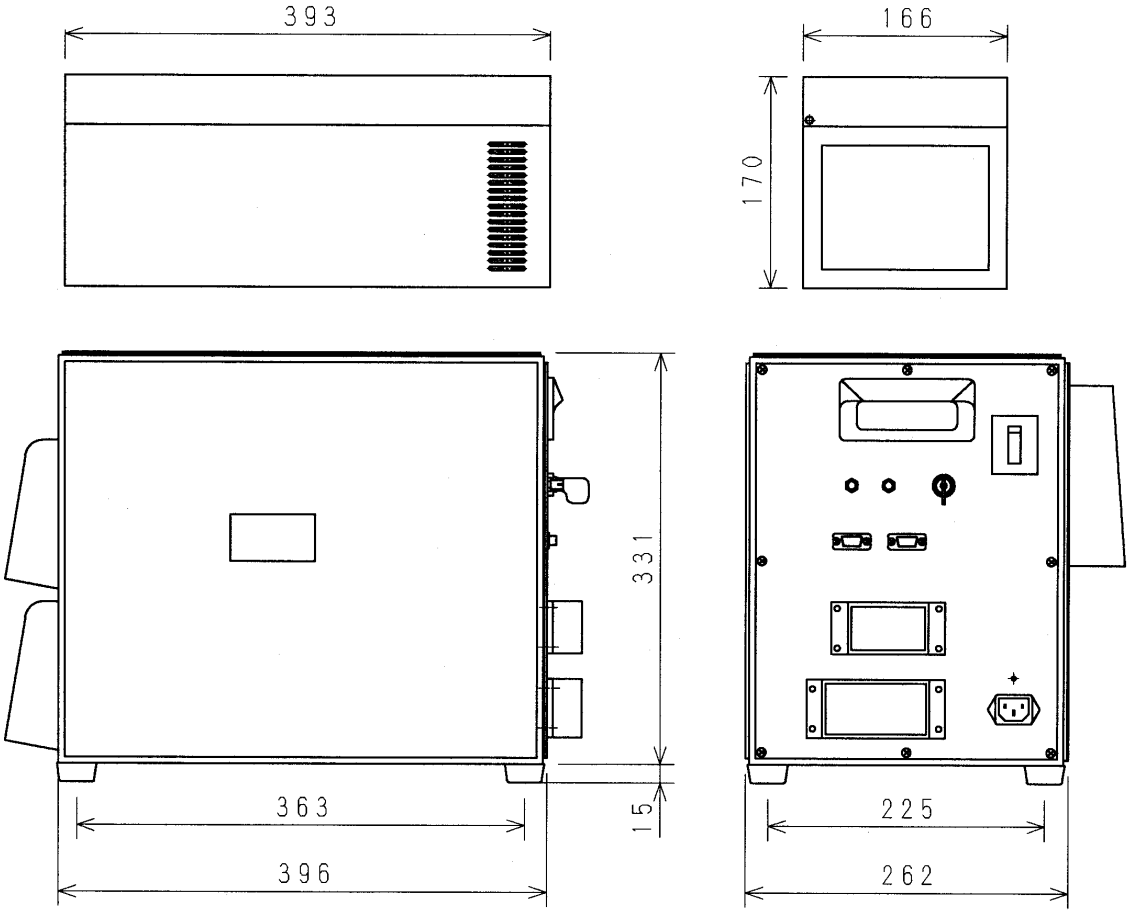
The specifications of the controller are shown as follows:

Item	Specifications	
Model	PA-10A-CNT	
External dimensions [mm]	2nd, 3rd levels : 262Wx346Hx396D 4th level only : 166Wx170Hx393D	
Mass	2nd, 3rd levels : 22kg 4th level : 29kg(only 4th level:7kg)	
Drive method	Internal servo driver described later	
Emergency stop	Emergency stop box attached	
Environment	Ambient temp	From 0 to 40 ℃ (When operated outdoors, use this in the shade.)
	Humidity	80% RH or less (no condensation)
Power supply	AC85-264V+-10%, 50/60Hz 2nd, 3rd levels : 1kVAx1 4th level : 1kVAx1 + 0.15kVAx1	
Protection circuit	Internal leak breaker	
Altitude	Below 1000m	
Storage temp.	From -10 to 60 ℃	
Painting	Main body: Munsell 5Y7/1	

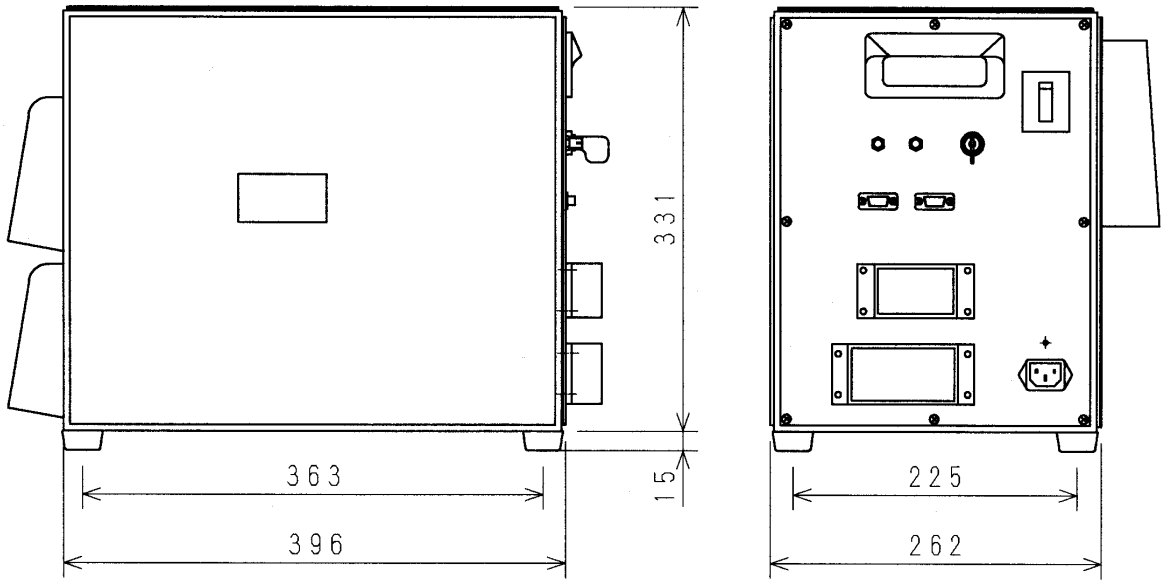
(2) Outline Drawing

The outline of the controller is shown below:

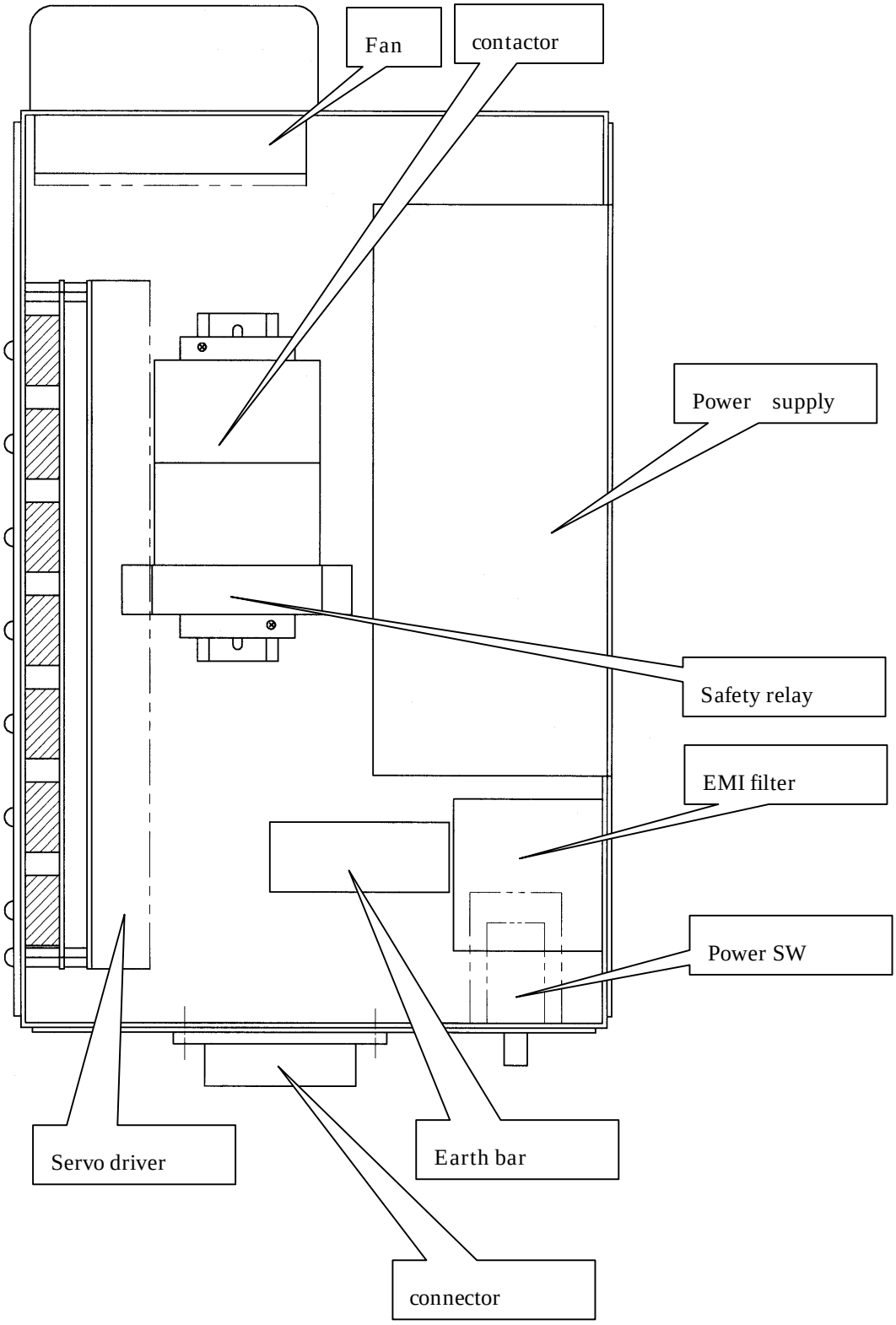
Outline of controller (4th level)



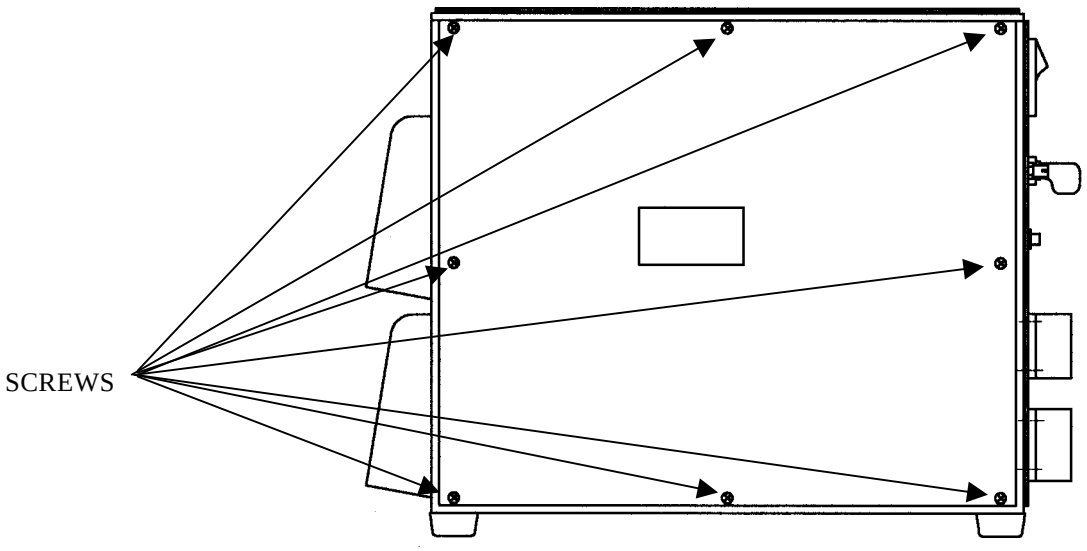
Outline of controller (2nd level/3rd level)



Inside view of the controller(2nd level)



By removing the screws shown below, the state-indicating LED of the servo driver can be checked.



(3) Setting method of selector key switch of operate mode

Operate the key switch on the front of the control panel to set the operate mode of the arm.

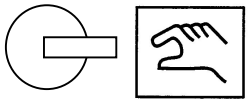
Run mode: Normal operate mode. Every axis of the arm can be operated till the rated speed.

Teach mode: In teach mode, the operating speed of every axis is limited the arm tip operating speed so as to be less than 250mm/sec.

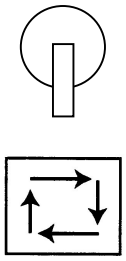
> Caution:
> To teach the arm, set the selector key switch of the operate mode “Teach mode”.

Key switch condition

-Teach mode

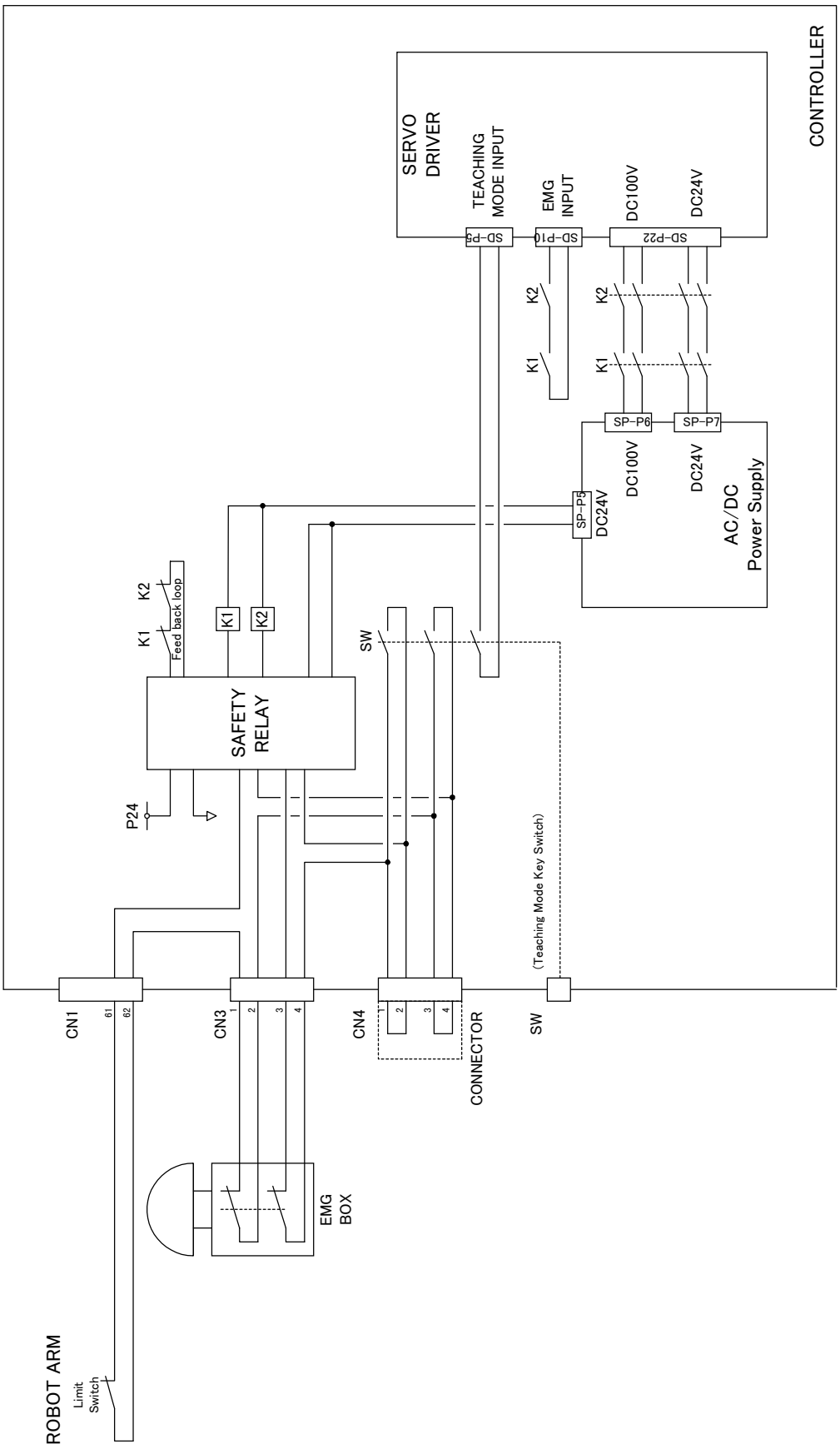


-Run mode

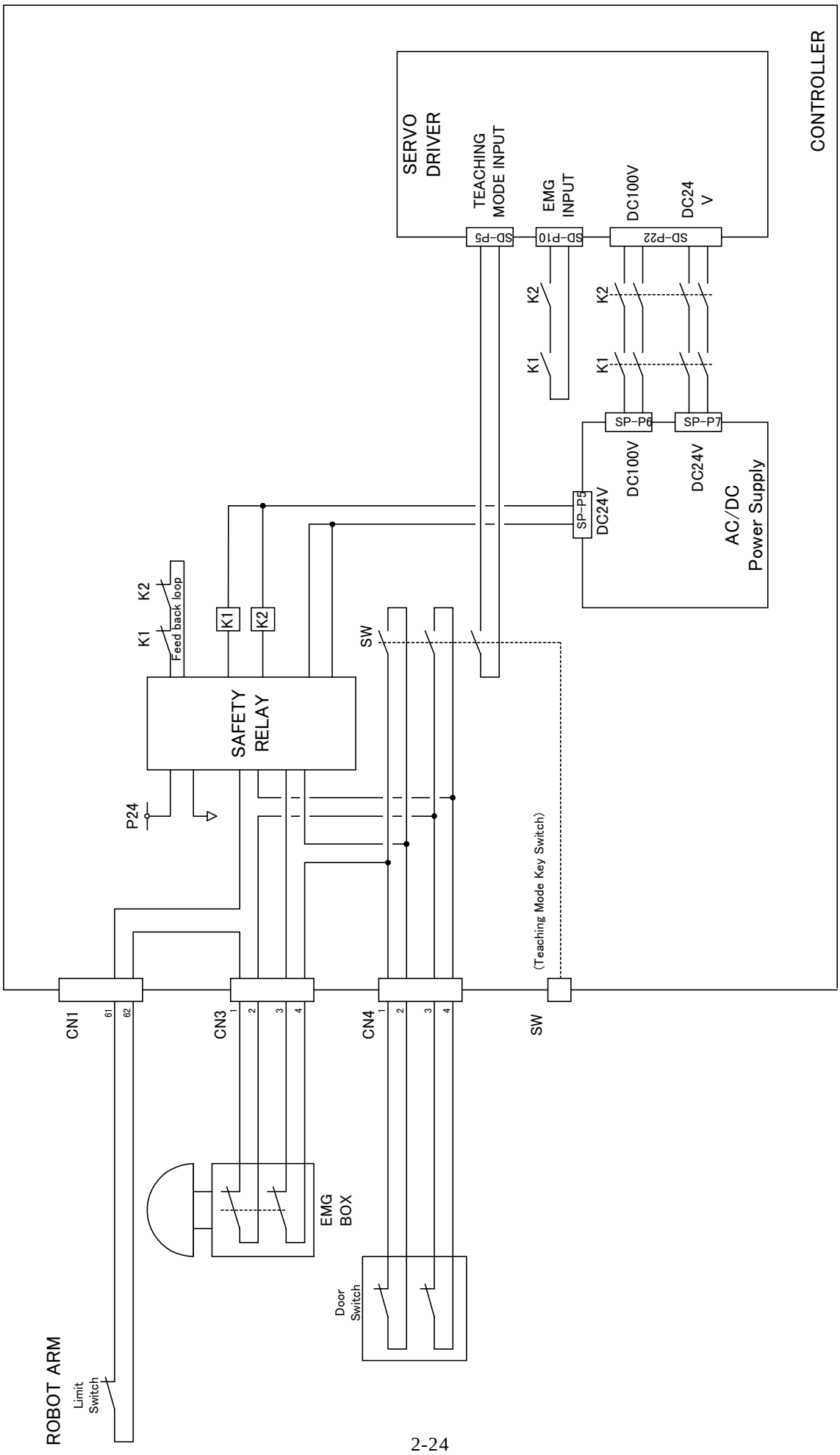


(4) Interlock

The controller interlock diagram is shown in the following page.


CONTROLLER
SERVO DRIVER
TEACHING MODE INPUT
EMG INPUT
DC100V
DC24V
SD-P5
SD-P10
SD-P22
K2
K1
SP-P6
SP-P7
SP-P5
DC24V
AC/DC Power Supply
Feed back loop
SAFETY RELAY
SW
P24
(Teaching Mode Key Switch)
CN1
CN3
CN4
CONNECTOR
SW
EMG BOX
ROBOT ARM
Limit Switch

The close cable is connected to CN4 in the normal shipment. See the connection diagram in the following page to connect the external emergency stop switch or the door switch.


CONTROLLER
SERVO DRIVER
TEACHING MODE INPUT
EMG INPUT
DC100V
DC24 V
SD-P5
SD-P10
SD-P22
K2
K1
SP-P6
SP-P7
DC100V
DC24V
SP-P5
DC24V
AC/DC Power Supply
SW
K1
K2
K2
K1
Feed back loop
SAFETY RELAY
P24
(Teaching Mode Key Switch)
CN1
61
62
CN3
1
2
3
4
CN4
1
2
3
4
SW
EMG BOX
Door Switch
ROBOT ARM
Limit Switch

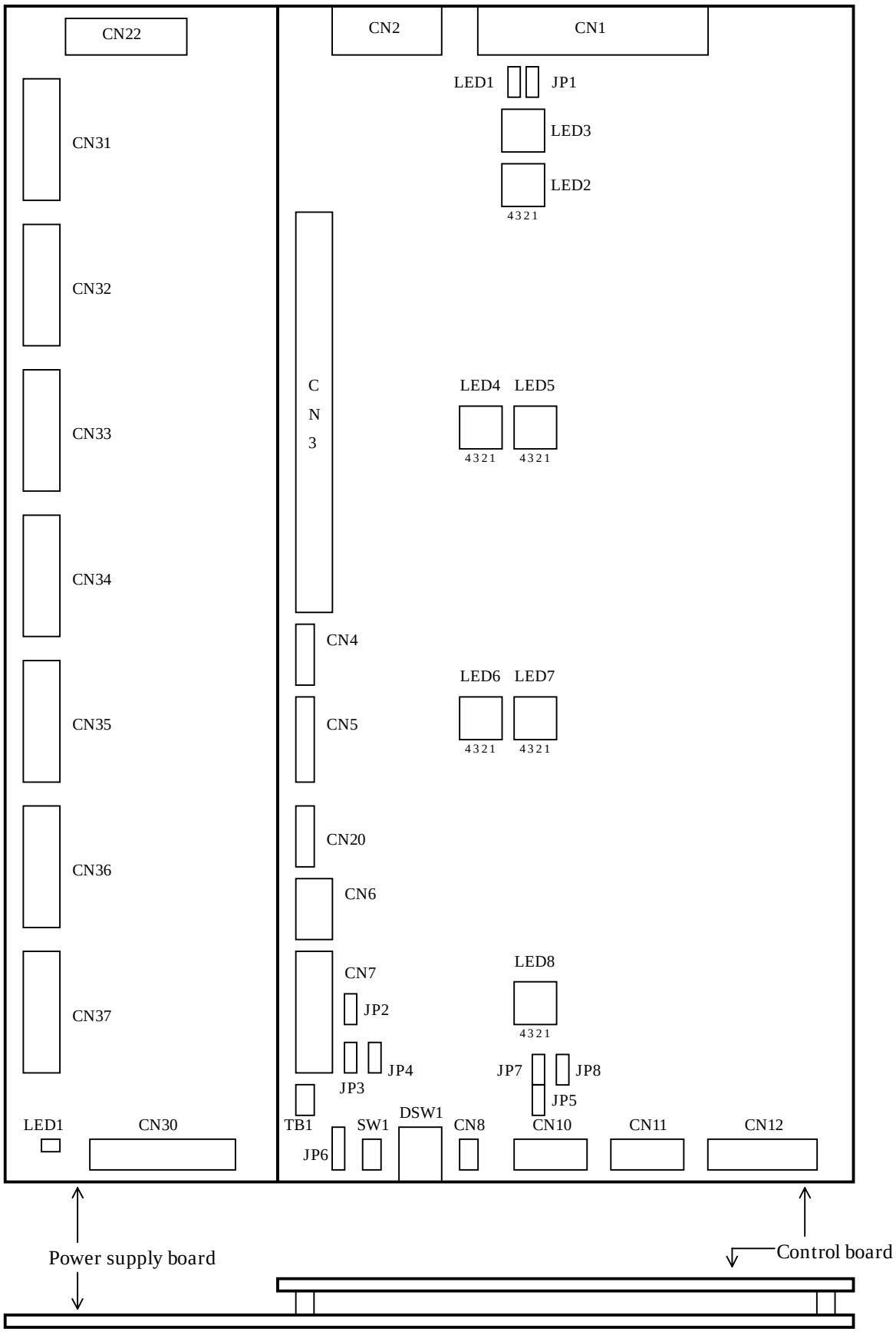
2.4 Servo Driver

Servo driver comprises the 2nd level of the portable general purpose intelligent arm, and is integrated in the controller of the section 2.3. For details, see the operating manual for the servo driver.

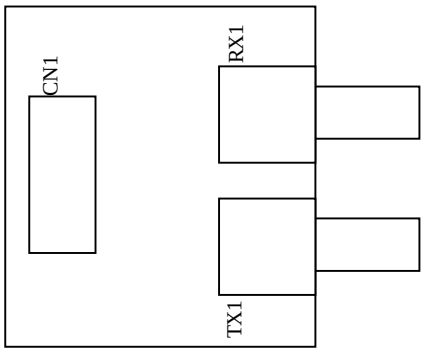
(1) Outline of Basic Specifications

Item	Specifications
Type & configuration	Semi-digital servo 7 axes/board
Command values	Speed command / Motor-torque command Input via ARCNET
Control capacity	Speed control : 1000:1 for full-scale range Within 1% of speed deviation (actuator loaded as rated) Control function : Speed control: 665μs digital PI Current loop: analog P
Communication I/F	Optic/Electric-Electric/Optic + ARCNET controller (5 Mbps)
Displays functions (by LEDs)	Mechanical brake ON/OFF, control power ON/OFF Speed control/torque control, motor power ON/OFF Error display, position limit ON/OFF

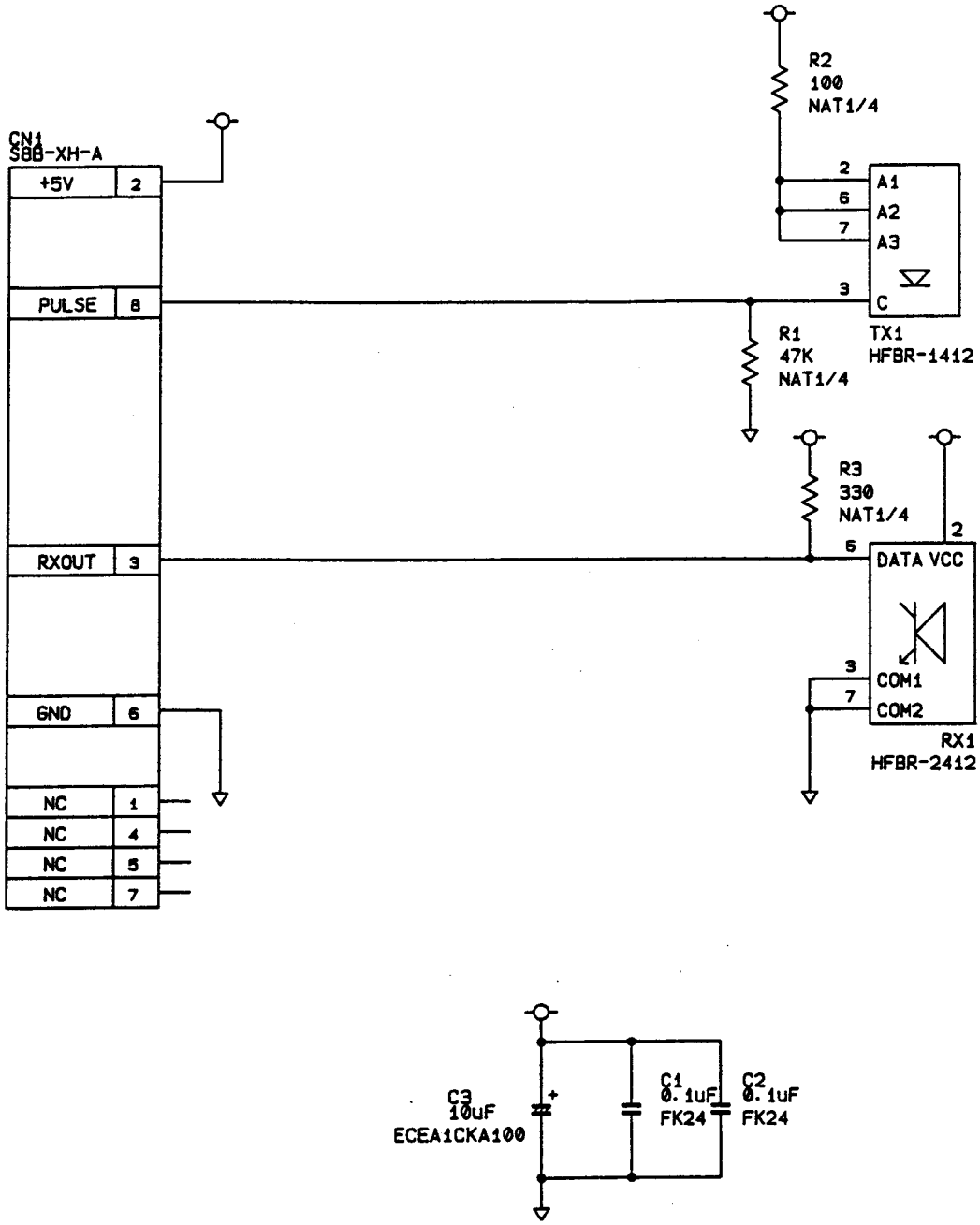
Sketch Drawing of Servo Driver



Sketch Drawing of Optical Board



Circuit diagram of the optical board

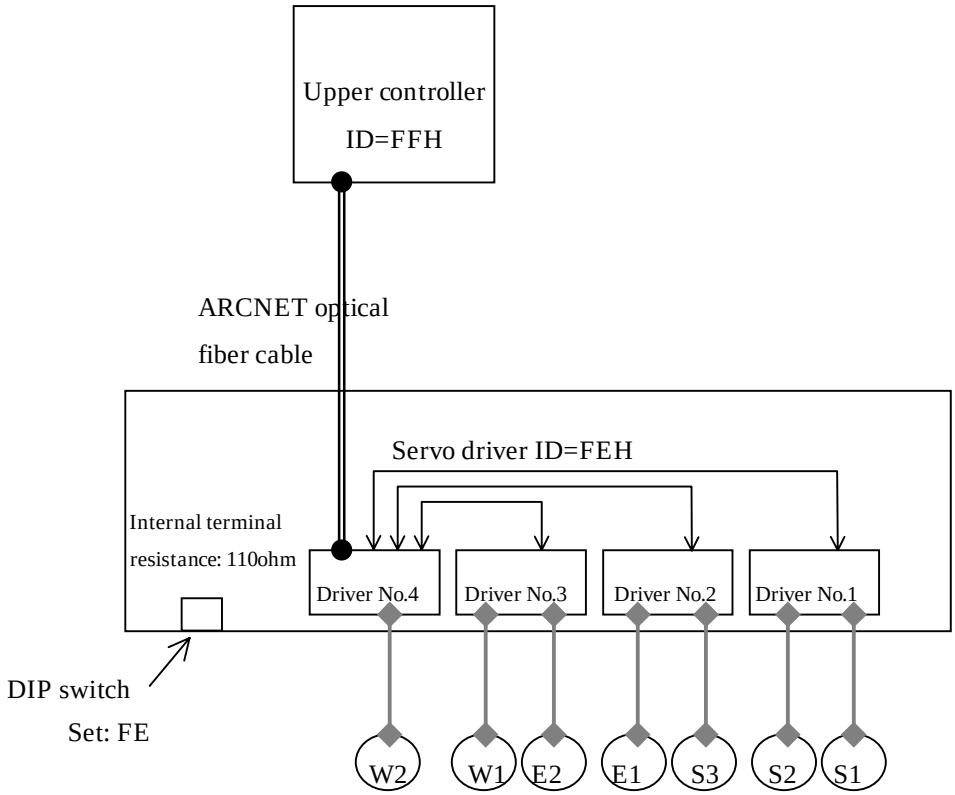


(2) How to use the servo driver (outline)

All the command to the servo driver, all the information from the servo driver is via ARCNET. The motion controller in the standard system is the MHI's motion controller (MHID6780). Here, general purpose CPU will be mainly described, where the motion controller side is called <upper controller>.

(a) Connection and ARCNET_ID

Set the ARCNET_ID addresses for the upper controller and servo driver as follows:
Servo driver consists of 4 driver units. The driver numbers are as shown below:



	1st axis	2nd axis
Driver No. 1	S1 axis	S2 axis
Driver No. 2	S3 axis	E1 axis
Driver No. 3	E2 axis	W1 axis
Driver No. 4	W2 axis	

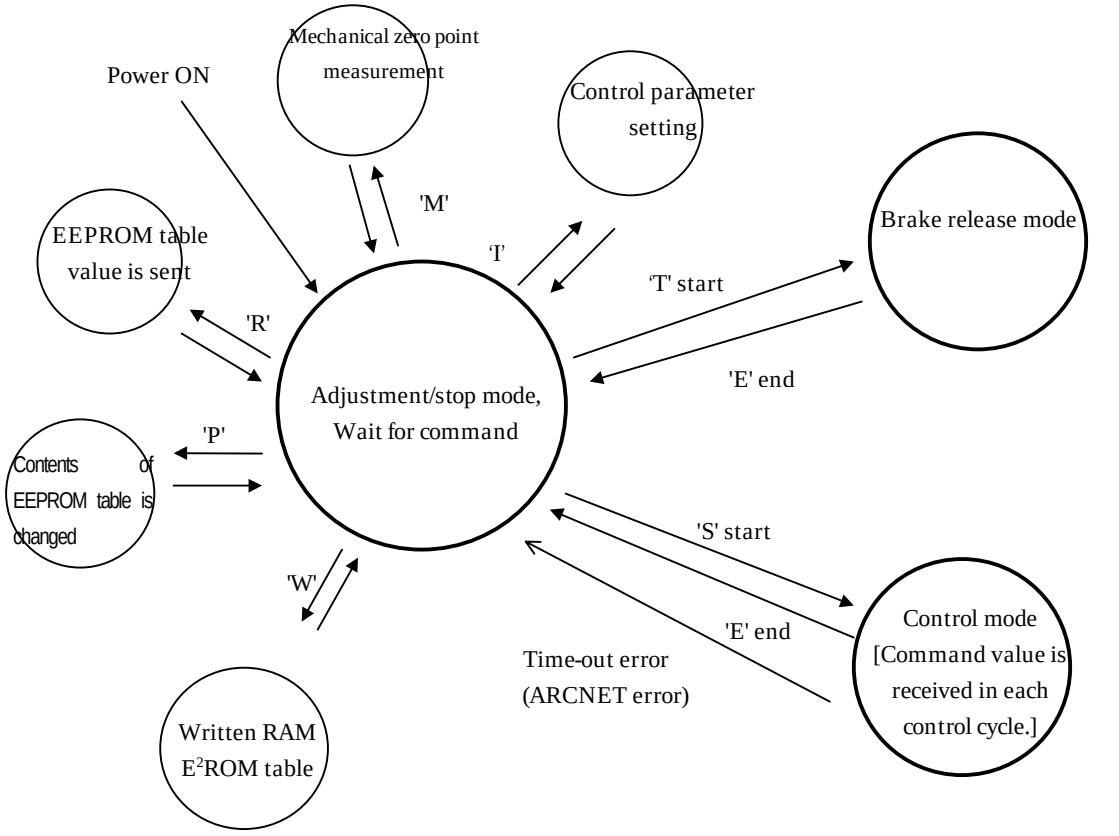
The ARCNET address of the destination shall be set by the DIP switch on the servo driver front panel. When using MHI's motion controller, set this to **FE**.

(b) State Transition Diagram of The Servo Driver

During the communication between the servo driver and upper controller, the following 3 states are available:

- Control mode
- Brake release mode
- Adjustment/stop mode (wait for command)←Power startup

The servo driver shows the following state transition according to the command sent from the upper controller.



(c) Type of Communication Commands

The commands sent from the upper controller to the servo driver can be classified as follows:

-Commands used in the control mode

-Commands required in adjustment

-Commands used when error occurs, or used in exceptional processing

(1) Commands used in control mode

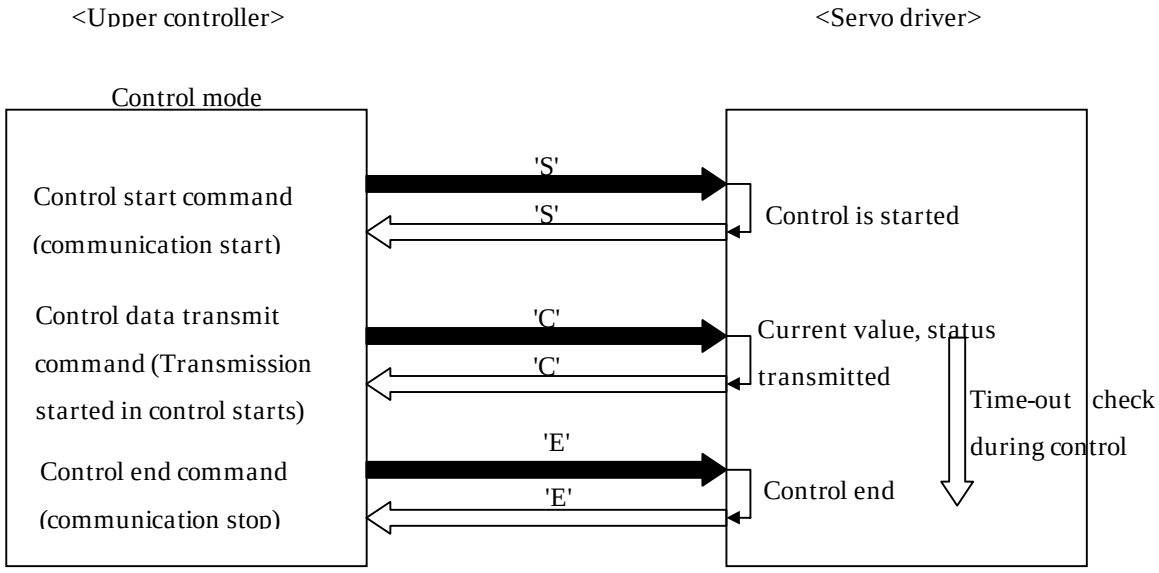
The commands used in the normal control are the control command ('S')/control data transmit command ('C') and control end command ('E'). They are sent at once to all the servo drivers.

They are transmitted normally in the order of 'S' → 'C' → ----- 'C' → 'E'.

After the 'S' command is transmitted, the 'C' command is recognized also in the servo driver side if such command is transmitted from upper controller in each specified cycle.

Time-out check is then performed.

In the MHI's motion control CPU, the control 'C' command is transmitted in each control cycle (10ms) in the control mode.



(d) Command specifications(outline)

Control Data Transmit Command 'C'

Control data transmit command 'C' is transmits at a time the command values for the drivers No.1-No.4.

In the normal control, the 'C' command shall be used with the 'S' and 'E' commands.

If the deadman switch of the 'C' command is turned Enable, the state of servo lock is given when the deadman switch is OFF. Note however that MHI's motion control CPU is always used under the setting of Disable.

If used by 'T'->'C', only brake ON/OFF of the 'C' command is effective on the servo ON condition.

(1) Upper controller → servo driver

In the control mode, the control command value (control data transmit command) is transmitted to the servo driver from the upper controller in each control cycle.

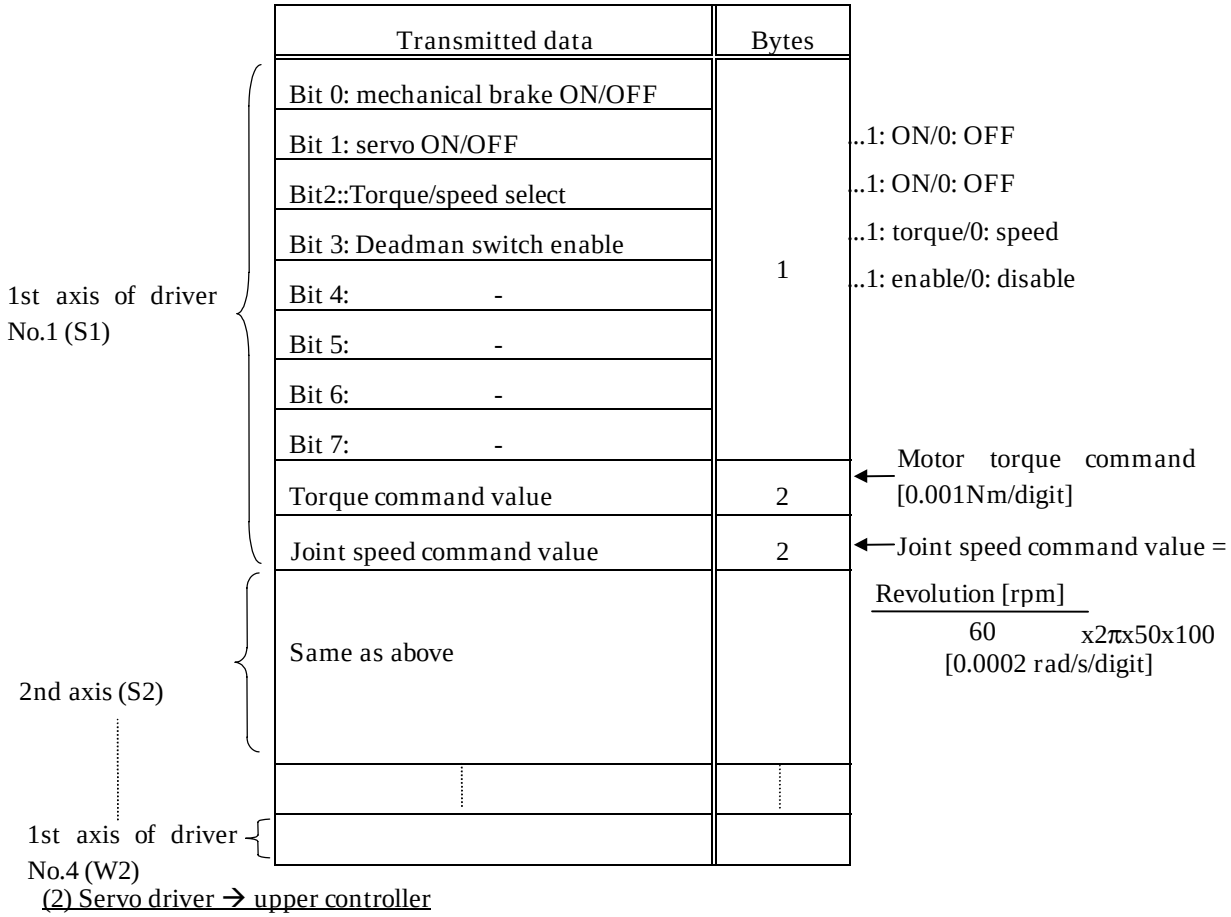
<Data format>

Sender ID: FFH

Receiver ID: FEH

Data type: 'C'

Number of transmitted data: 35



(2) Servo driver → upper controller

After transmitting the control data transmit command from the upper controller, the current value and status of each axis shall be transmitted (returned) to the upper controller.

<Data format>

Sender ID: FEH

Receiver ID: FFH

Data type: 'C'

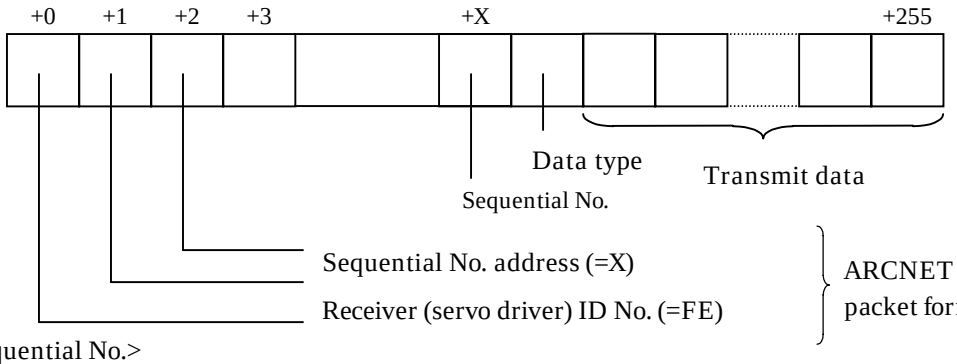
Number of transmitted data: 58

	Transmitted data	Bytes	
1st axis of driver No.1 (S1)	Servo status_1	2	
	Joint angle_1	4	...RV format
	Motor torque command value_1	2	...0.001Nm/digit
2nd axis (S2)	Servo status_2	2	
	Joint angle_2	4	
	Motor torque command value_2	2	
Driver No.2	Same as above		
			*) RV format RV= $\frac{deg \times 2^{14} \times 50}{360}$
1st axis of driver No.4 (W2)	Servo status_1	2	
	Joint angle_1	4	
	Motor torque command value_1	2	
	Master servo status	2	

(e) Format of Communication Command

The format of ARCNET communication command is shown below:

(1) Upper controller -> servo driver transmit format (short packet)



<Sequential No.>

The upper controller side attaches some ID (sequential No.) when sending. (Servo driver side returns the value as it is.)

<Data type>

-Normal control

- 'S' = control start command
- 'C' = control data transmit command
- 'E' = control end command

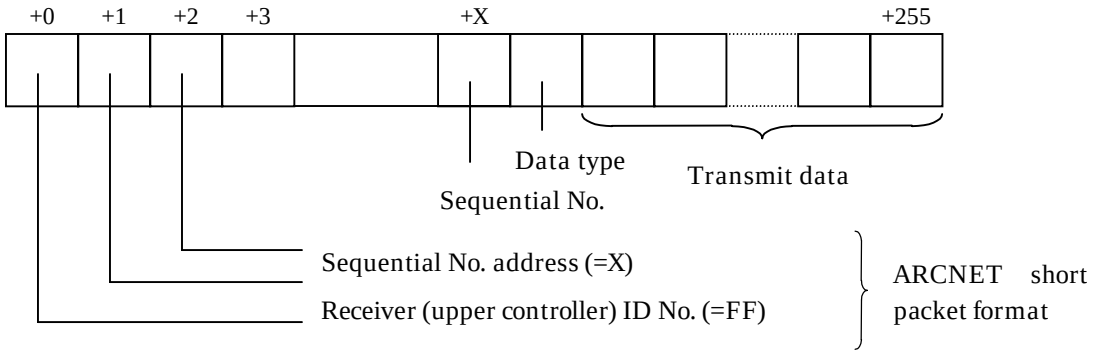
-Adjustment

- 'I' = parameter setting request command
- 'M' = mechanical zero point measurement instruction command
- 'R' = transmit request command for current EEPROM table
- 'W' = command for writing RAM in EEPROM table
- 'P' = command for changing EEPROM table

-Brake released

- 'T' = brake release start command
- 'C' = control data transmit command
- 'E' = control end command

(2) Servo driver→ upper controller transmit format (short packet)



<Sequential No.>

The ID (sequential No.) transmitted from the upper controller side shall be returned as it is.

<Data type>

-Normal control

'S' = Complete command for control start command
'C' = Current value transmit command for control data transmitted (including error status)
'E' = Complete command for control end command

-Adjustment

'I' = Complete command for initial setting request
'M' = Complete command for mechanical zero point measurement (including mechanical zero point measurement value)
'R' = Command to transmit the current contents of EEPROM table to the upper controller
'W' = Complete command for writing into EEPROM table
'P' = Complete command for changing EEPROM table

-Brake release

'T' = Complete command for brake release start command
'C' = Current value transmit command for control data transmitted (including error status)
'E' = Complete command for control end command

Transmit data differs for each data type (command).

2.4 Arm-Board Cable and Power Supply Cable

-Arm-board cable

This is the cable to connect the main body of arm and controller, comprising the signal cable to transmit the sensor information and the drive cable to supply power to motor.

-Power supply cable

This is the cable to supply power to the controller.

(1) Specifications

The specifications for the arm-board cable power supply cable and optical fiber cable are shown below:

Arm-board cable

Item	Specifications	
Wire type	For signal	For drive
Model	PA-10A-CBL1	PA-10A-CBL2
External dimensions	Approx. ϕ23.5mm x 5m (max 25mm)	Approx. ϕ19.5mm x 5m (max 25mm)
Weight	0.52kgf/m	0.53kgf/m
Bending radius	250mm or less prohibited	200mm or less prohibited

Power supply cable

Item	Specifications
Model	PA-10A-CBL0
Connector type	Ordinary earthing type 2P
Cable length	3m

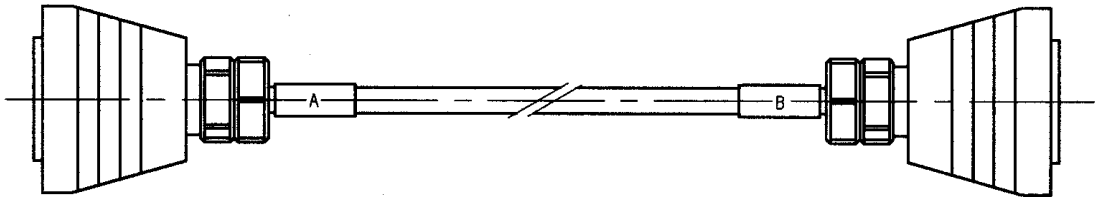
Optical fiber cable

Item	Specifications
Fiber type	e.g. FVST2 62G-P
Cable length	1m

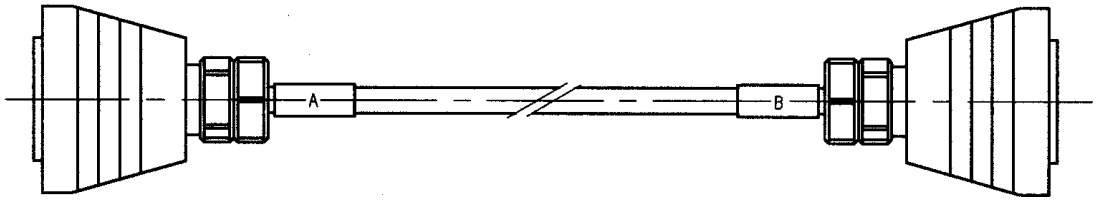
(2) Outline Drawing

The outline of the arm-board cable is shown below:

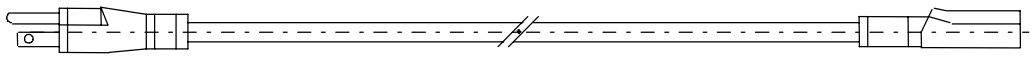
Arm-board cable (for signal)



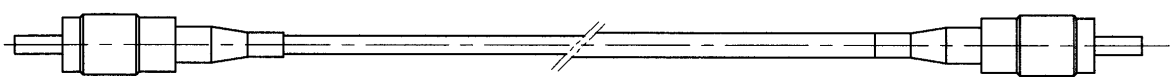
Arm-board cable (for drive)



The outline of the power supply cable is shown below:



The outline of the optical fiber cable is shown below:



2.5 Emergency Stop Box

This is used to stop the operation of the arm in emergency.

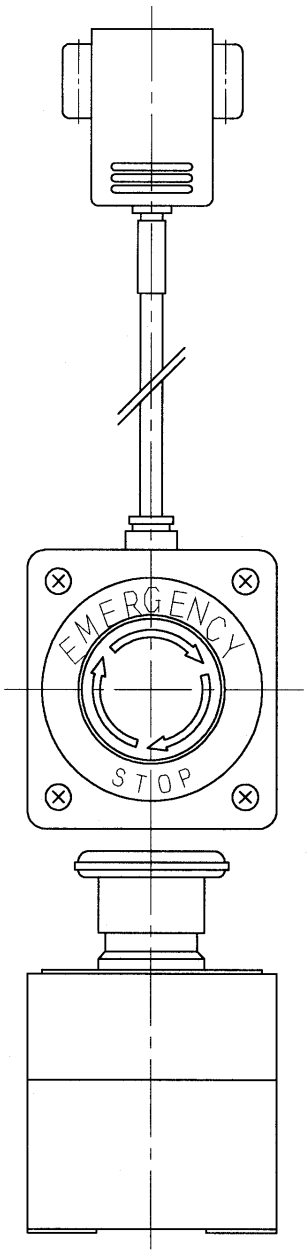
(1) Specifications

The specifications of the emergency stop box are shown below:

Item	Specifications
Model	PA-10A-CBL3
Operational function	Push-lock/turn reset
Contact	2b
Cable length	5m

(2) Outline Drawing

The outline drawing of the emergency stop box is shown as follows:



2.6 Motion Control CPU Board

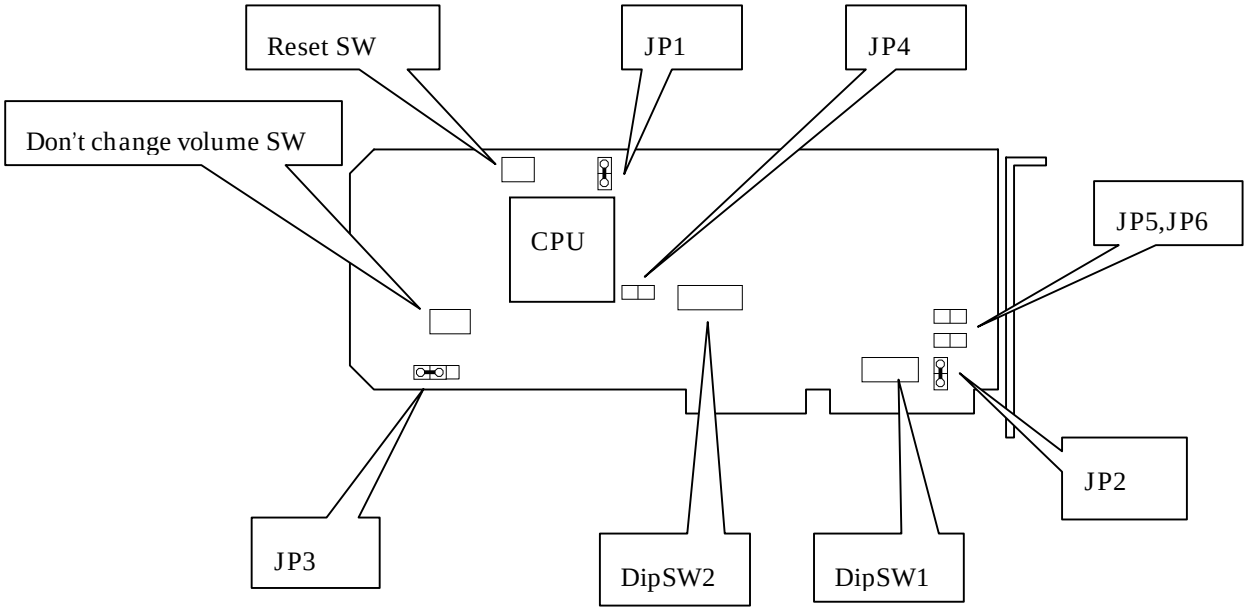
Motion control CPU Board (3rd level) consists of 1 sheet of CPU board. This unit calculates the speed command value for each axis from the hand position, attitude command and axis angle command sent from upper operation controller or external PC.

ISA Bus Specification is available.

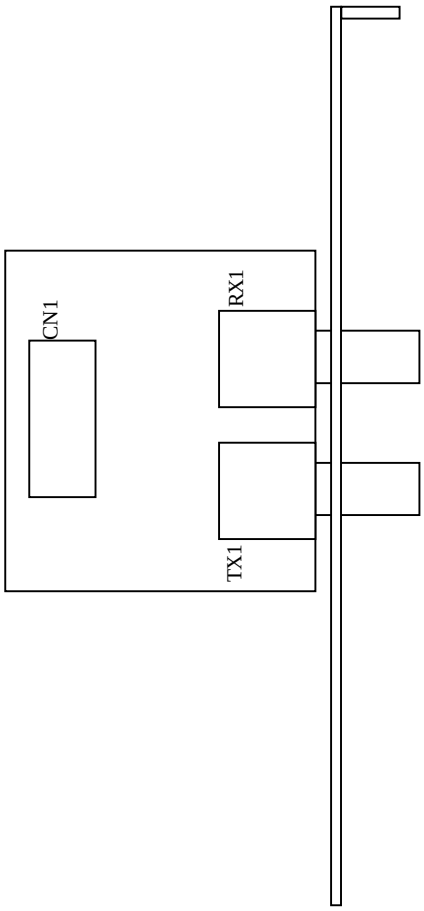
The specifications of the motion controller are shown below.

Item	Specifications
Model	MHI-D6780
Control method	Control by each axis Hand control/attitude control by 7 axes at once
Input	Command issuance by PA library (via bus)
Output	Speed command of each axis (via ARCNET)
Play-back function	PTP: arc-circle compensation, linear compensation, CP for each axis
Teaching data memory capacity	1 Mbyte
Number of teaching data	PTP: 2000 points CP: approx. 60 sec
Teaching data storage	Hard disk, floppy disk (4th level)
External I/O signal	RS-232C 1ch (appropriated for each axis output for monitor to simple simulator)
	DI/O 32 points each

Sketch Drawing of Motion Control CPU Board



Sketch Drawing of Optical Board



2.7 Operation Controller

Operation controller (4th level) is a PC. Under standard settings, a PC for industrial use is built in the controller. Any PC at your hand may be used. Operation controller is a user interface unit to generate the hand position and attitude commands. Generated commands are handed to the operation controller by using PA library.

The specifications of the operation controller under standard settings are shown below:

Item		Specifications
Standard		based on PICMG Standard
CPU		Intel® Celeron™ (433 MHz)
Memory	1st cash memory	32 KB (built in CPU)
	2nd cash memory	128 KB (built in CPU)
	Main RAM	64 MB (SDRAM/EDO 64 MB x1) [168Pin DIMM slot x3] [MAX:768MB]
	Video RAM	4 MB (SGRAM)
Display	Video chip	ATI 3D Rage Pro
	Display resolution	1,600x1,200 (max 64k colors)
FDD		3.5 inch floppy disk drive
HDD		10 GB (E-IDE)
Interface		Enhanced IDE x2 (1ch used) FDD connector x1 (used) Parallel x1 Serial x2 Key board/mouse connect PS/2 connector x1 VGA connector x1 RJ-45 connector x1
Free slot (MHI motion control CPU mounted)		PCI: 1 (half size loadable) ISA: 1 (full size loadable)
OS		Windows ® NT Workstation 4.0 Service Pack4(pre installed)

In case any customer tries to prepare a motion controller (PC), the specifications of such PC shall be as follows:

Item	Specifications
Applicable type	PC/AT compatible
OS	Windows® NT Workstation 4.0 (Service Pack4 or more recommended)
CPU	i80486DX(25 MHz) or more (Pentium® or more recommended)
Memory	32 MB or more
HDD	The amount available on the partition more than 165MB is necessary to store the system file.
FDD	2-mode floppy disk drive
Display resolution & number of display colors	640 x 480 256 colors (1024 x 768 256 colors or more recommended)
Required free slot	ISA bus x2 (full size) *1
Mouse	Required

*1 : This is required when our motion controller is loaded.

CAUTION:

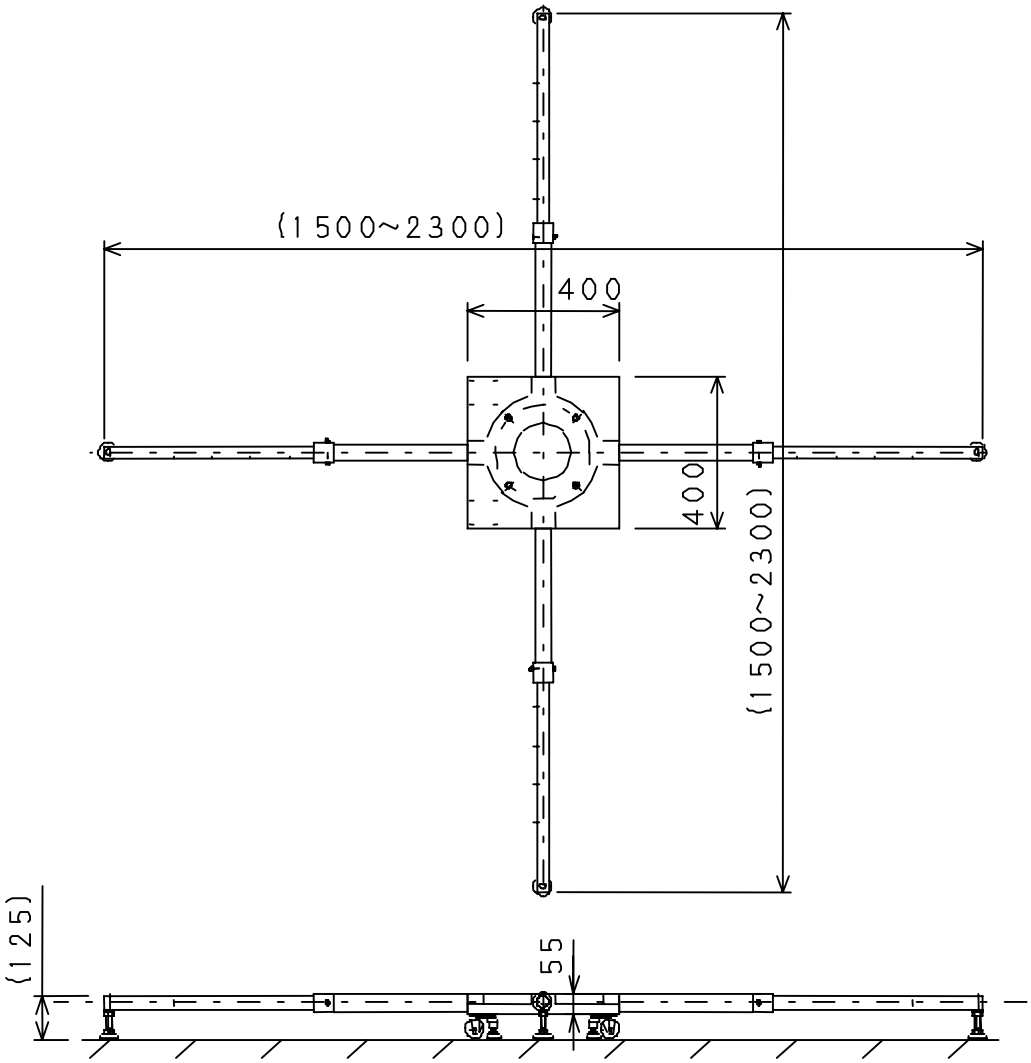
Prepare the CE marking-ready operation controller to do it by yourself.

Chapter 3 Specifications of Optional Products

This chapter describes the specifications of the optional products for portable general purpose intelligent arm.

3.1 Arm-support Stand

This is a support stand for portable general purpose intelligent arm. Its outline is shown below:



3.2 PA Library

This is a library required to execute/develop the operation-assist programs and application software for portable general purpose intelligent arm. DLL type library prepared by Visual C++® is used for this. Sample software is attached so that the PA libraries prepared by Visual C++® or Visual Basic® compilers can be used.

When developing applications, Visual C++® or Visual Basic® compiler is required additionally.

(All the source programs are attached.)

(Operation checked by Visual Basic® Ver. 5.0 or Visual C++® Ver. 5.0)

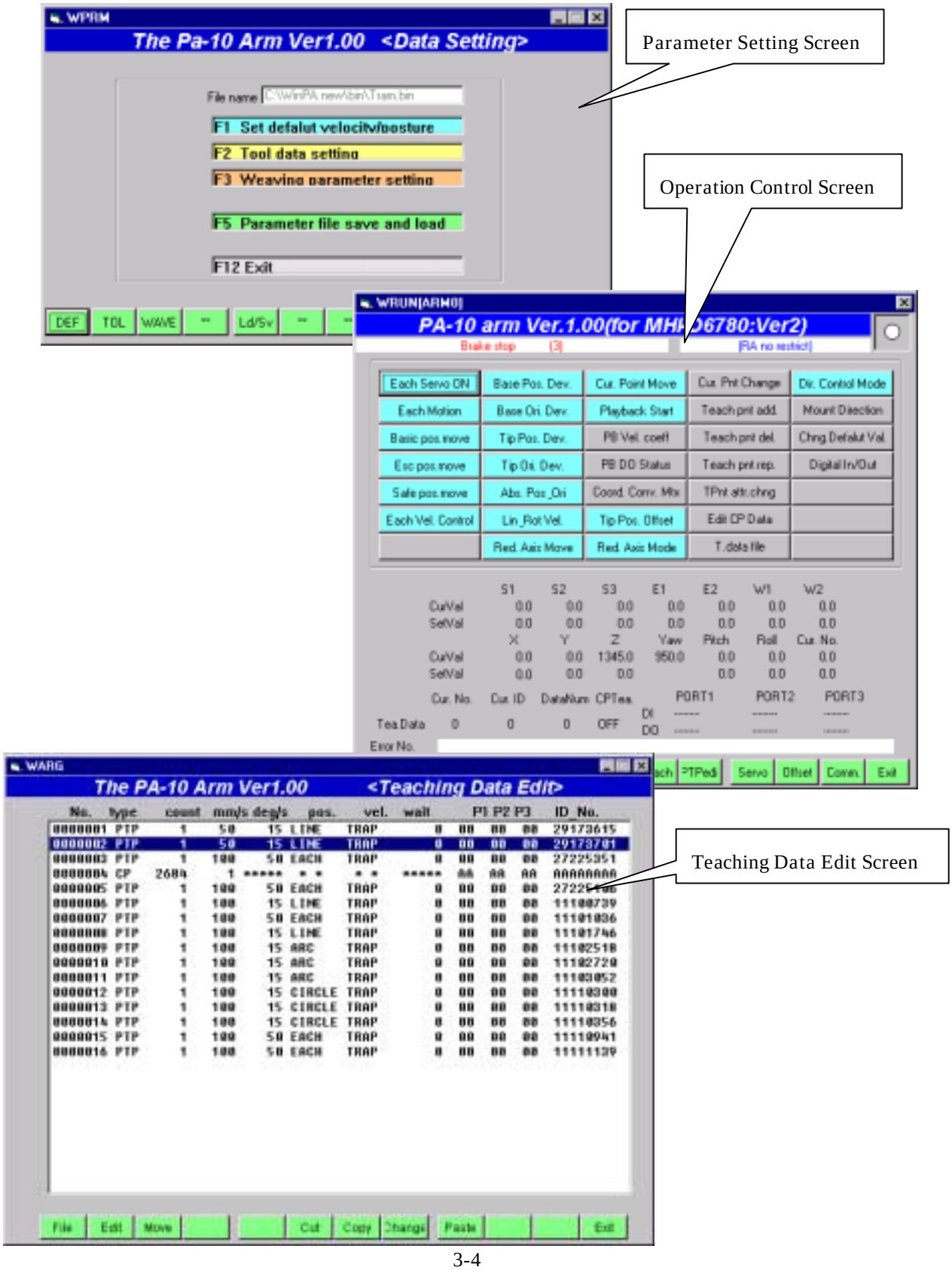
-List of PA library functions (excerpt)

pa_ini_sys	Initializes PA library.
pa_ter_sys	Ends PA library.
pa_opn_arm	Opens arm (control arm select)
pa_cls_arm	Closes arm (control arm cut off)
pa_sta_arm	Controller start (servo driver communication start)
pa_ext_arm	Controller end (servo driver communication end)
pa_stp_arm	Arm brake stopped
pa_sus_arm	Arm stopped temporarily
pa_rsm_arm	Arm's temporary stop released
pa_exe_axs	Angle control of each axis
pa_mov_XYZ	Positon deviation control at base coordinate
pa_mov_YPR	Attitude deviation control at base coordinate
pa_mov_mat	Absolute position control of top position/attitude
pa_ply_pnt	Play-back control
pa_add_pnt	Adds the teaching points.
pa_set_pnt	Sets the attributes of teaching points.
pa_mod_vel	Sets the speed control mode.
pa_odr_jou	Sets the redundant axis control data.
pa_mod_dpd	Sets the target position/attitude real control.
pa_set_mat	Sets the coordinate space conversion matrix.
pa_get_mod	Reads the control status of arm.
pa_inp_dio	Digital input (by unit of 32 ch)
pa_oup_dio	Digital output (by unit of 32 ch)
pa_set_tol	Sets the tool information.

3.3 Operation Support Program

This is a program allowing the operator to operate the arm interactively on the display by using the keyboard or mouse. It is also possible to edit the operation/teaching data. (If purchased with PA library, all the source files are attached.)

Examples of screen message are shown below:

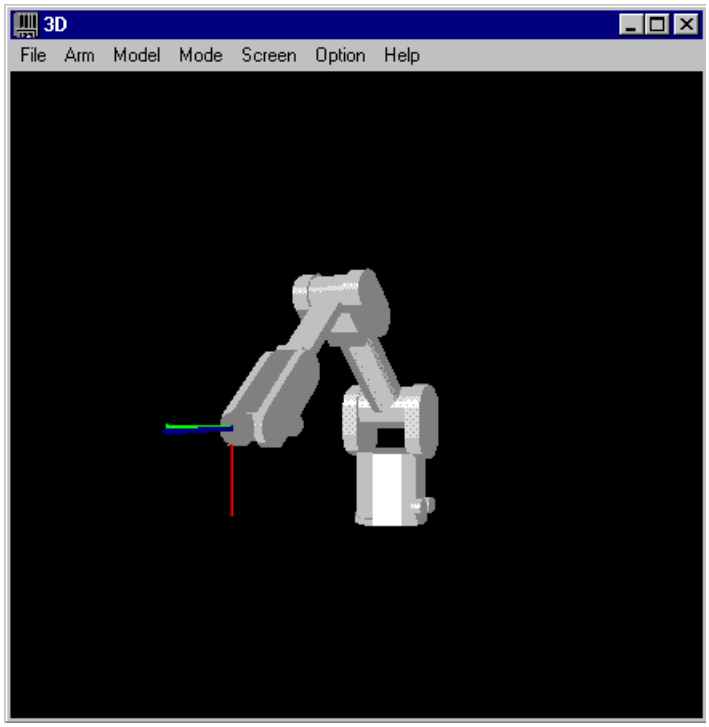


3.4 Simple Simulator

This is a simulator allowing a screen check of arm actions, and is used for debugging in developing application programs.

In the simulator , no additional PC is necessary, because the computer for operation control receives the data.

Examples of screen message is shown below:



3.5 User Interface Set

(1) Key board

This is a key board for PC/AT compatible machines, and is used to enter data by connecting to the operation controller of standard specifications. A key board is 104key key board.

CAUTION:

Prepare the CE making-ready keyboard to do it by yourself. Select the connecting cable of 3m or less to the keyboard. The keyboard is not assured its operation when it is connected to the cable of 3m or more.

(2) Mouse

This is a mouse of PS2 specifications for PC/AT compatible machines, and is used in GUI operations by connecting to the operation controller of standard specifications.

CAUTION:

Prepare the CE making-ready Mouse to do it by yourself. Select the connecting cable of 3m or less to the mouse. The mouse is not assured its operation when it is connected to the cable of 3m or more.

(3) Display

This is a 15-inch display of multi-scan type adapted for various frequencies, and is used to display pictures by connecting to the operation controller of standard specifications.

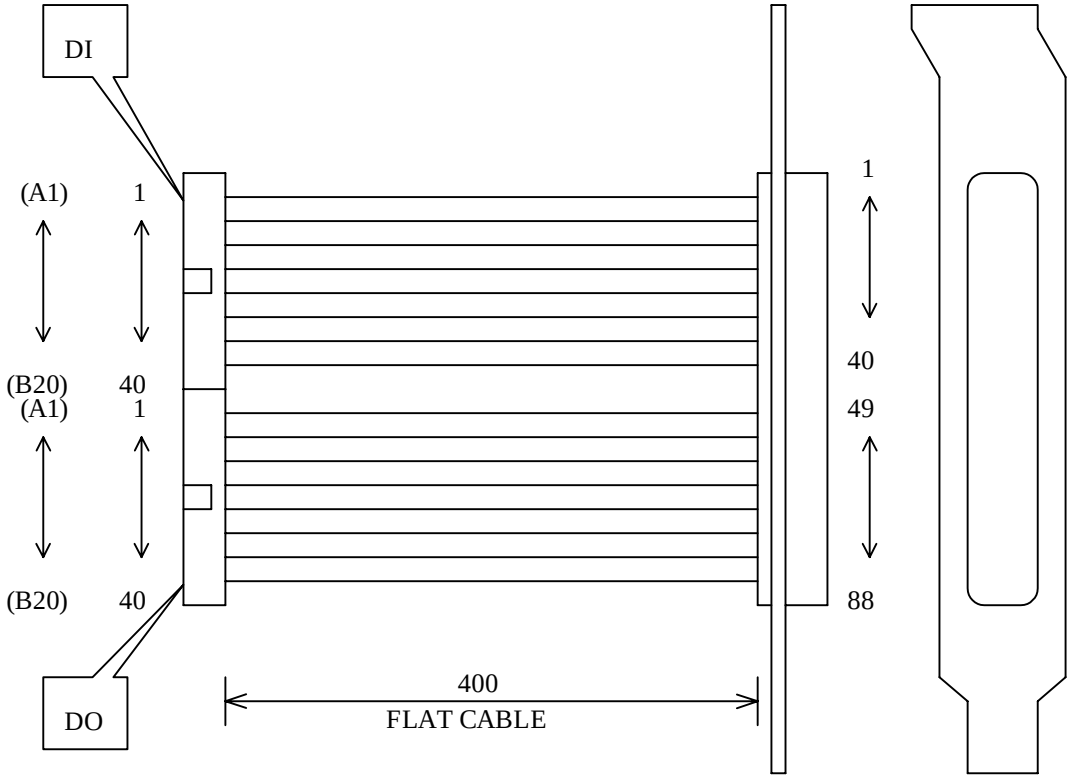
3.6 External DI/O Connection Set

This is a kit for connection with external devices by connecting to the DI/O connector on the operation control CPU board, and drawing the DI/O connector out of the casing, and consists of external DI/O panel and external DI/O cable.

(1) External DI/O Panel

This is a panel to draw the connectors out onto the PC's expansion slots; connectors to exchange information between the portable general purpose intelligent arm and external devices by using DI/O signals.

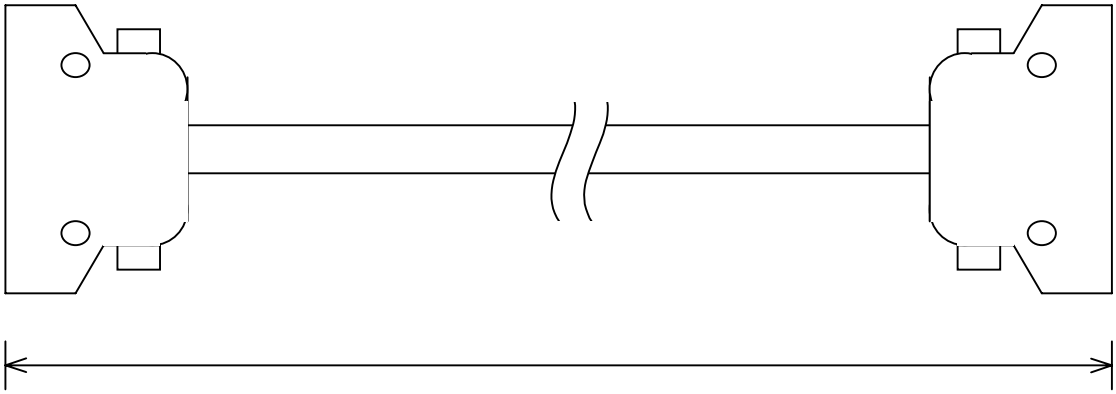
Its outline is shown below:



:41-48,89-96 : Not used

(2) External DI/O Cable

This is a shielded cable of 96 pins to be connected between the external DI/O panel and external devices. Its outline is shown below:



3.7 Force Sensor

This is a force sensor of 6 degrees-of-freedom.

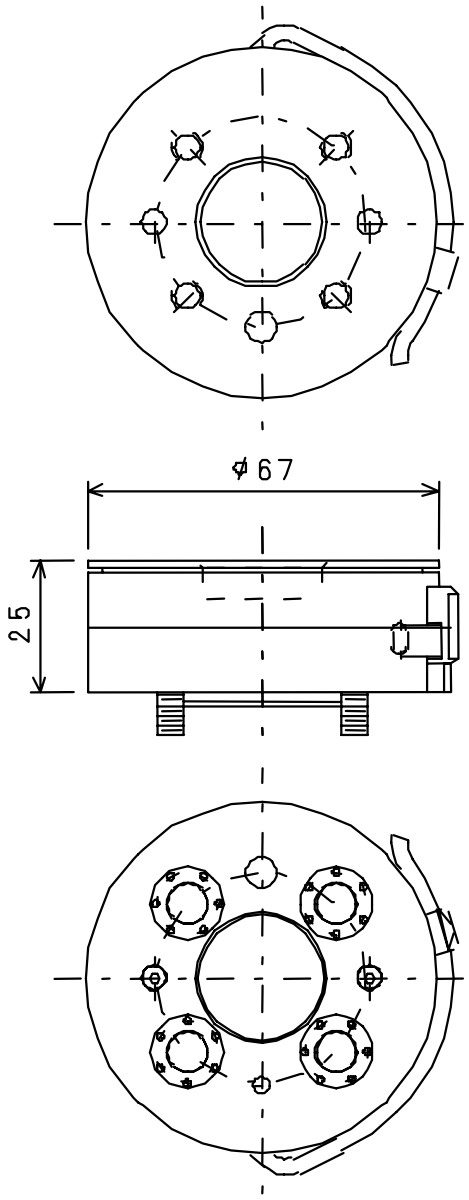
(1) Specifications

The specifications of force sensor are shown below:

Item	Specifications
Rated load	Fx,Fy : 200N
	Fz : 400N
	Mx, My, Mz: 12.5 Nm
	(Coordinate corresponds to the mechanical interface coordinate of PA-10 which is moved in parallel by the sensor width in the direction Z.)
Sampling time	125 μsec (max.)
Machine I/F	Sensor can be installed on PA-10 directly. Sensor flange is of the same shape as PA-10.
System configuration	Sensor unit, receiver board, sensor-receiver cable (5m)
External dimensions	ϕ67x25 (excl. protrusions)
Mass	180g
Power supply	Supplied from receiver board.
Environmental requirements	Temp. 0 to 50 ℃, not drip proof/ not dust proof
BUS specification of receiver board	ISA bus

(2) Outline Drawing

The outline drawing of force sensor is shown below:



3.8 Electric Parallel Hand Set

This is an electric parallel hand installed on the hand top of the arm. By using the attached hand-mount bracket, this is installed on the hand top of the arm. To control this from the motion controller, an external DI/O cable is necessary.

(1) Specifications

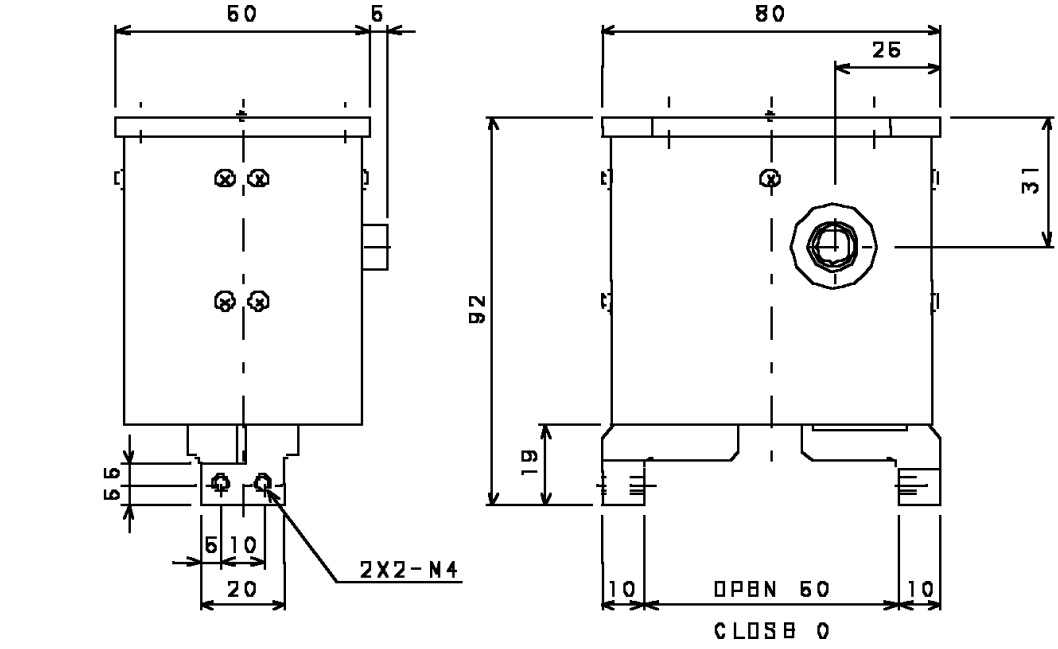
The specifications of electric parallel hand are shown below:

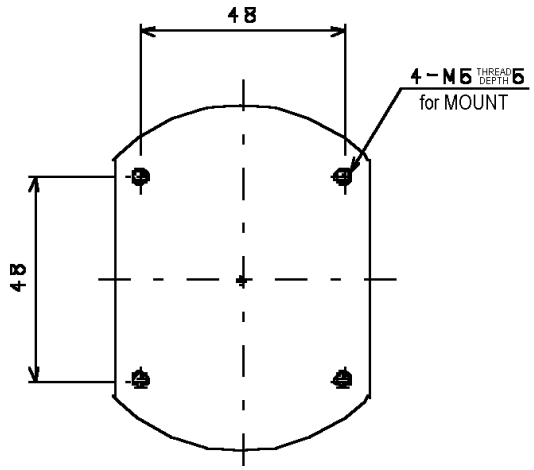
Item		Specifications
Hand	Drive method	DC motor
	Number of axes	Open/close 1 axis
	Holding force	0.5 kgf-7.0 kgf (manual volume adjustment)
	Stroke	60mm (one side 30mm)
Controller	Input	Open command/close command/speed slow command (non-voltage contact or transistor input)
	Output	Open status/close status (open collector output)
	Power	AC100V
Common	Environmental requirements	Temp. from 0 to 40 °C., non-drip proof
	Cable length	5m

* This can be controlled directly from the digital output of external DI/O board. (Cables shall be prepared by the user, or the external DI/O cable of PA-10 option shall be purchased.)

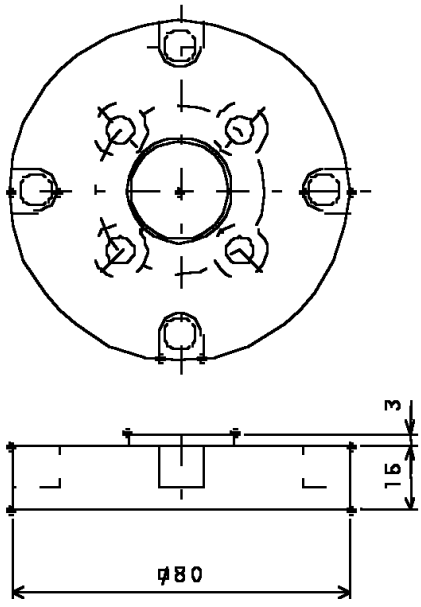
(2) Outline Drawing

The outlines of the electric parallel hand and hand mounting bracket are shown below:





HANDMOUNT BRACKET



Chapter 4 Setup

This chapter describes the method for setting up the portable general purpose intelligent arm. Please read this chapter carefully before use.

4.1 Preparations by Customer

Please prepare the followings before use.

(1) Power supply

In using by the 2nd level or 3rd level, AC85V-AC264V of a capacity 1kVA is necessary as the power for the controller. Connector type should be ordinary earthing type of 2P. In using by the 4th level, AC90V-AC132V/AC180-AC264V of a capacity 0.15kVA is additionally required as the power for the operation controller. Connector type shall be ordinary earthing type of 2P. Please prepare these power supplies. Also in addition to these power supplies, the power sources should be prepared for any other peripheral devices then used (electric hand, display, etc.).

(2) Safety Measures

Before using the machine, carry out the safety trainings specified in the applicable laws and regulations, and take safety measures according to the application. (Be sure to read Chapter 1 "Safety Manual".)

4.2 Instructions for Installation

To install the machine, take the following precautions:

(1) Instructions for Power Supply

(a) Before pulling off/plugging in the power supply cable, be sure to turn OFF the power switch.

(b) When pulling off/plugging in the power supply cable, be sure to hold the plug, and not to pull the cable.

(c) Once the power switch is turned OFF, wait for 5 seconds or more, and then turn it ON again. If the power plug is pulled off while the power switch is ON, first turn OFF the power switch, wait for 5 seconds or more, and then turn it ON again.

(d) For improving the noise resistance, and for safety reasons (preventing electric shock), be sure to provide proper earthing. In earthing, use wire of a cross section area of $2mm^2$ or more according to the type 3 earthing (earth resistance 100Ω or less).

(e) Receiving plug is not of water-proof type.

(2) Instructions for Maintenance and Operating Environment

(a) Don't store, or use this system in a highly humid or dusty place

(b) Arm controller has ventilation holes in the back and left side to prevent temp. rise. Install the system in a way that the ventilation hole in the left side is 5cm or more apart from other unit or walls, and the ventilation hole in the back is 10cm or more apart from other unit or walls. Also take care so that heat may not be accumulated and raise the ambient temp. up to a level exceeding the range specified in 4.2. (3) "Requirements for Installation Environment".
Avoid storing, or using the controller in a place other than specified by environmental specifications, such as the place of extremely high or low temp., or place subject to frequent temp. change.

(c) Don't store, or use the controller in a place exposed to direct sunlight, or place near heat source.

(d) Don't use the controller in the rain.

(e) Don't apply any shock to the controller, because it is made of delicate electronic parts. Don't store, or use either the controller in a place subject to shock or vibration. If any shock or vibration is applied, internal HDD could be crushed.

(f) If this system is operated with water, any other liquid or metals trapped in it, dangerous situations could be brought about. Take sufficient care not to trap any foreign matter.

(g) Avoid storing, or using this system in the air including chemical fumes or steam emitted around, or in a place exposed to chemicals.

(h) Don't try to store, or use this system as it is disassembled, because it could cause failure or electric shock.

(i) Don't store, or use this system with anything heavy placed on the controller.

(j) Since the controller has heat-radiating units in both sides, neither side of the controller should be contacted directly by hand(s) when power is ON.

(k) Be sure to connect, or disconnect cables of this system when power is OFF.

(l) Be sure to operate the controller as it stands upright. If laid horizontal, or upside down, heat is radiated insufficiently, ending in a malfunction or failure.

(m) To guarantee a continuous operation or data, external uninterruptive power supply should be provided, and power should be supplied via such source.

(n) If any noise comes from the power supply, provide a noise cutting transformer in the input line of the power supply, or noise filter, etc. out of the main body of controller. Noise resistance may be improved by such means.

(o) To use this system under adverse environment, be sure to meet 4.2 (3) "Requirements for Installation Environment".

(p) When installing the arm, be sure to prepare the arm support stand (PA-10A-AF) or anything equivalent to, or exceeding it.

(q) Be sure to take safety measures such as providing safety barriers around the place where the arm is installed. (For details, see Chapter 1 "Safety Manual") .

(3) Requirements for Installation Environment

"PA-10" is a manipulator designed for use in a work place identified by 3K (Japanese phrase meaning "Dangerous", "Dirty" and "Hard"). The units shown in the following table can be used under such adverse conditions. Note, however, that any other unit could malfunction, or fail if used under such adverse conditions. Therefore, pay enough attention to the requirements for installation environment before starting work.

Units that can be used under adverse conditions

Name of unit	Model
Arm	PA-10A-ARM
Arm-board cable (for signal)	PA-10A-CBL1
Arm-board cable (for drive)	PA-10A-CBL2
Arm-support stand	PA-10A-AF

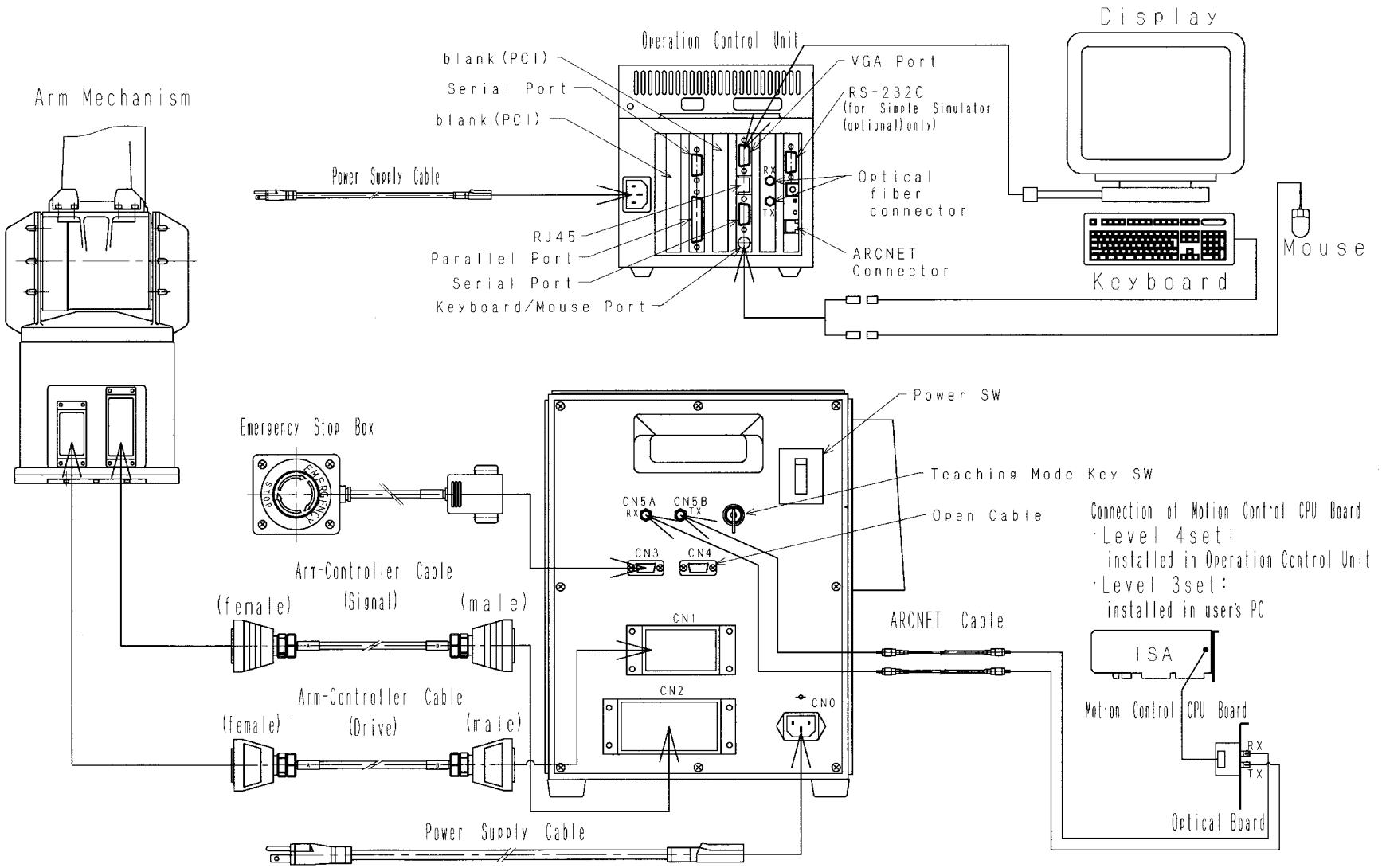
Operating environment of arm and controller

Item	Arm	Arm controller
Ambient temp.	From 0 to 50 ℃	From 0 to 40 ℃
Storage temp.	From -10 to 60 ℃	From -10 to 60 ℃
Humidity	30-90% RH (no condensation)	80% RH or less (no condensation)
Altitude	Below 1000m	Below 1000m
Direct sunlight	Can be used (Surface temp. should not rise.)	Cannot be used (Use this in a shade.)
Rain	Should not be extremely heavy.	Not permitted
Drifting dust	Should not be extremely dense.	Not permitted
Corrosive gases	Not permitted	Not permitted
Explosive gases	Not permitted (Arm separately specified may be used.)	Not permitted
Oil mist	Should not be extremely dense.	Not permitted
Vibration	3G	----------
Power voltage	----------	Single-phase AC85-264V
Power frequency	----------	50/60 Hz
Insulation resistance	----------	50 Mohm
Withstand voltage	----------	AC500V 1 min
Earthing	Controller is earthed by connecting a special cable. Therefore, no earthing is necessary.	Type 3 earthing

4.3 Inter-Unit Connections

Before starting operation, connect the units as shown in the drawing on the next page.

Connections Between Equipment



If purchasing the level2 system, connect between your ARCNET board and optical board as shown in the drawing on the next page.

(1) CONNECTION BETWEEN YOUR ARCNET BOARD AND O/E-E/O BOARD

①Remove HYC2485S from YOUR ARCNET BOARD.
②Install an 8pins socket on YOUR ARCNET BOARD.
③Connect an 8pins plug of O/E-E/O BOARD to the 8pins socket.
(Refer to Fig-1 and 2)

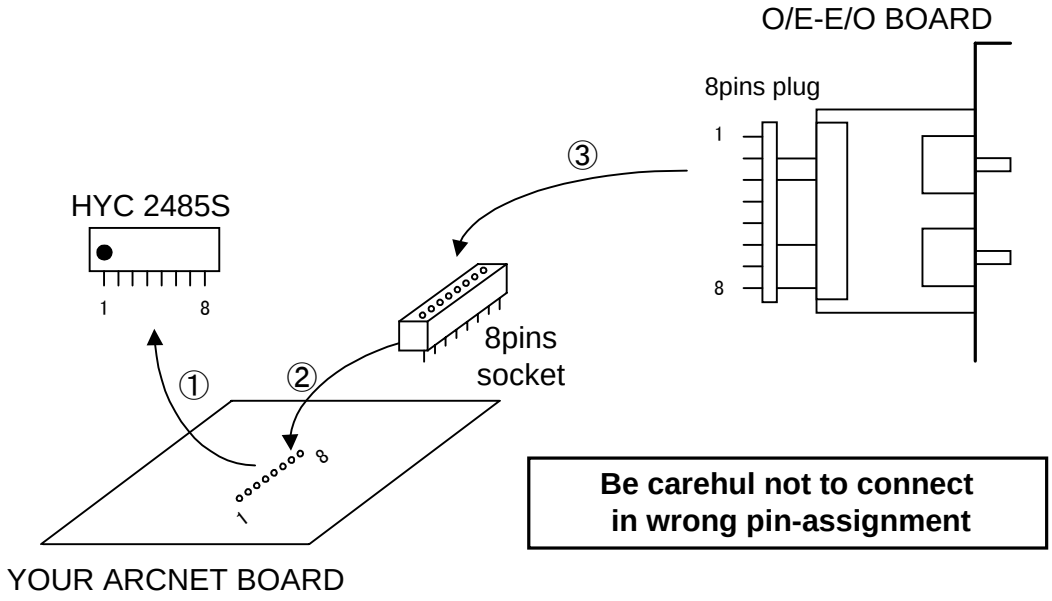


Fig-1. Installation of 8pins socket

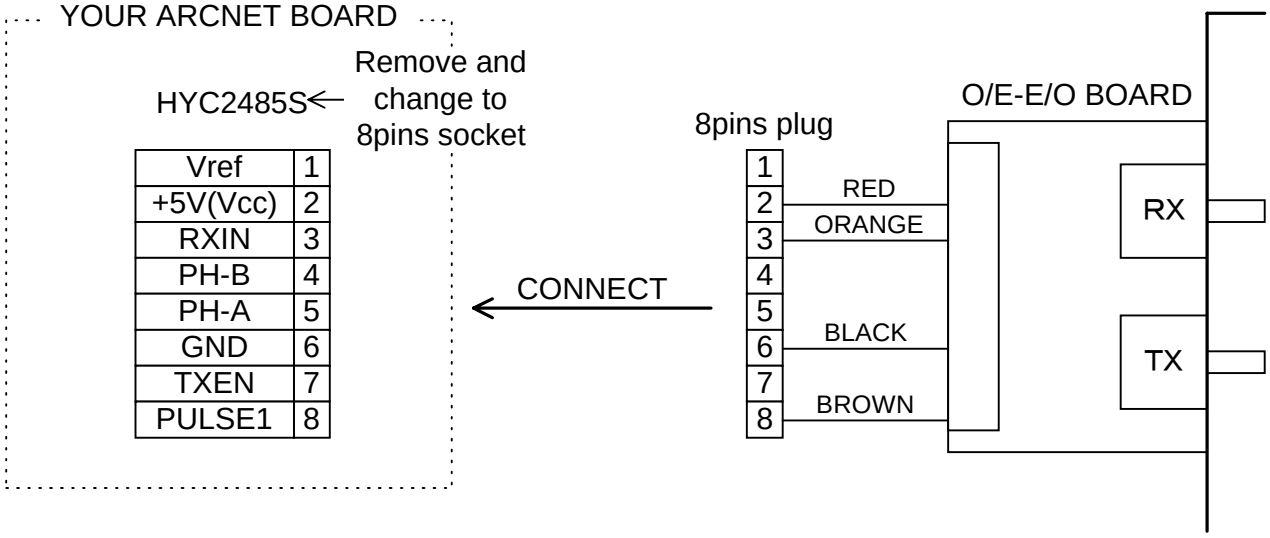


Fig-2. Connection between YOUR ARCNET BOARD and O/E-E/O BOARD

（2）CONNECTION BETWEEN O/E-E/O BOARD AND CONTROLLER

Concerning the connection between O/E-E/O BOARD and CONTROLLER , refer to Fig-3.

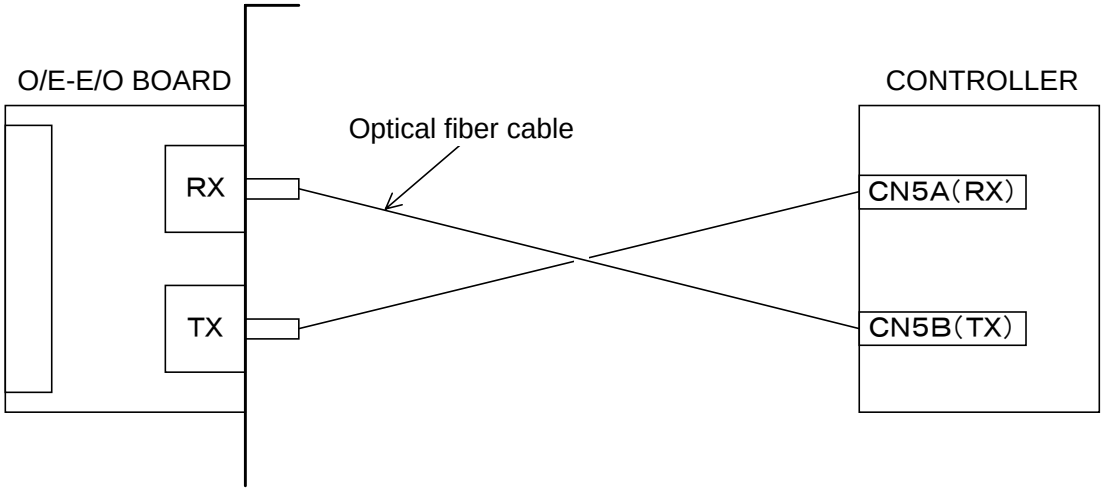


Fig-3. Connection between ARCNET BOARD and O/E-E/O BOARD with Optical fiber cable

This is the connector pin assignment for arm-board cables.

Arm-board cable (for signal)

No.	Signal Name	Use
1	RMS1-SIN(+)	S1 Axis Motor Resolver SIN(+)
2	RMS1-SIN(-)	S1 Axis Motor Resolver SIN(-)
3	RMS1-COS(+)	S1 Axis Motor Resolver COS(+)
4	RMS1-COS(-)	S1 Axis Motor Resolver COS(-)
5	RGS1-SIN(+)	S1 Axis Gear Resolver SIN(+)
6	RGS1-SIN(-)	S1 Axis Gear Resolver SIN(-)
7	RGS1-COS(+)	S1 Axis Gear Resolver COS(+)
8	RGS1-COS(-)	S1 Axis Gear Resolver COS(-)
9	RMS2-SIN(+)	S2 Axis Motor Resolver SIN(+)
10	RMS2-SIN(-)	S2 Axis Motor Resolver SIN(-)
11	RMS2-COS(+)	S2 Axis Motor Resolver COS(+)
12	RMS2-COS(-)	S2 Axis Motor Resolver COS(-)
13	RGS2-SIN(+)	S2 Axis Gear Resolver SIN(+)
14	RGS2-SIN(-)	S2 Axis Gear Resolver SIN(-)
15	RGS2-COS(+)	S2 Axis Gear Resolver COS(+)
16	RGS2-COS(-)	S2 Axis Gear Resolver COS(-)
17	RMS3-SIN(+)	S3 Axis Motor Resolver SIN(+)
18	RMS3-SIN(-)	S3 Axis Motor Resolver SIN(-)
19	RMS3-COS(+)	S3 Axis Motor Resolver COS(+)
20	RMS3-COS(-)	S3 Axis Motor Resolver COS(-)
21	RGS3-SIN(+)	S3 Axis Gear Resolver SIN(+)
22	RGS3-SIN(-)	S3 Axis Gear Resolver SIN(-)
23	RGS3-COS(+)	S3 Axis Gear Resolver COS(+)
24	RGS3-COS(-)	S3 Axis Gear Resolver COS(-)
25	RME1-SIN(+)	E1 Axis Motor Resolver SIN(+)
26	RME1-SIN(-)	E1 Axis Motor Resolver SIN(-)
27	RME1-COS(+)	E1 Axis Motor Resolver COS(+)
28	RME1-COS(-)	E1 Axis Motor Resolver COS(-)
29	RGE1-SIN(+)	E1 Axis Gear Resolver SIN(+)
30	RGE1-SIN(-)	E1 Axis Gear Resolver SIN(-)
31	RGE1-COS(+)	E1 Axis Gear Resolver COS(+)
32	RGE1-COS(-)	E1 Axis Gear Resolver COS(-)
33	RME2-SIN(+)	E2 Axis Motor Resolver SIN(+)
34	RME2-SIN(-)	E2 Axis Motor Resolver SIN(-)
35	RME2-COS(+)	E2 Axis Motor Resolver COS(+)
36	RME2-COS(-)	E2 Axis Motor Resolver COS(-)
37	RGE2-SIN(+)	E2 Axis Gear Resolver SIN(+)
38	RGE2-SIN(-)	E2 Axis Gear Resolver SIN(-)
39	RGE2-COS(+)	E2 Axis Gear Resolver COS(+)
40	RGE2-COS(-)	E2 Axis Gear Resolver COS(-)
41	RMW1-SIN(+)	W1 Axis Motor Resolver SIN(+)
42	RMW1-SIN(-)	W1 Axis Motor Resolver SIN(-)
43	RMW1-COS(+)	W1 Axis Motor Resolver COS(+)
44	RMW1-COS(-)	W1 Axis Motor Resolver COS(-)
45	RGW1-SIN(+)	W1 Axis Gear Resolver SIN(+)
46	RGW1-SIN(-)	W1 Axis Gear Resolver SIN(-)
47	RGW1-COS(+)	W1 Axis Gear Resolver COS(+)
48	RGW1-COS(-)	W1 Axis Gear Resolver COS(-)
49	RMW2-SIN(+)	W2 Axis Motor Resolver SIN(+)
50	RMW2-SIN(-)	W2 Axis Motor Resolver SIN(-)
51	RMW2-COS(+)	W2 Axis Motor Resolver COS(+)
52	RMW2-COS(-)	W2 Axis Motor Resolver COS(-)
53	RGW2-SIN(+)	W2 Axis Gear Resolver SIN(+)
54	RGW2-SIN(-)	W2 Axis Gear Resolver SIN(-)
55	RGW2-COS(+)	W2 Axis Gear Resolver COS(+)
56	RGW2-COS(-)	W2 Axis Gear Resolver COS(-)
57	REF1(+)	Resolver Reference 1 (+)
58	REF1(-)	Resolver Reference 1 (-)
59	REF2(+)	Resolver Reference 2 (+)
60	REF2(-)	Resolver Reference 2 (-)
61	MLSW(+)	Mechanical Limit Switch(+)
62	MLSW(-)	Mechanical Limit Switch(-)
63	N.C	
64	N.C	
65	N.C	
66	N.C	
67	N.C	
68	N.C	
69	N.C	
70	N.C	
71	N.C	
72	N.C	
	N.C	

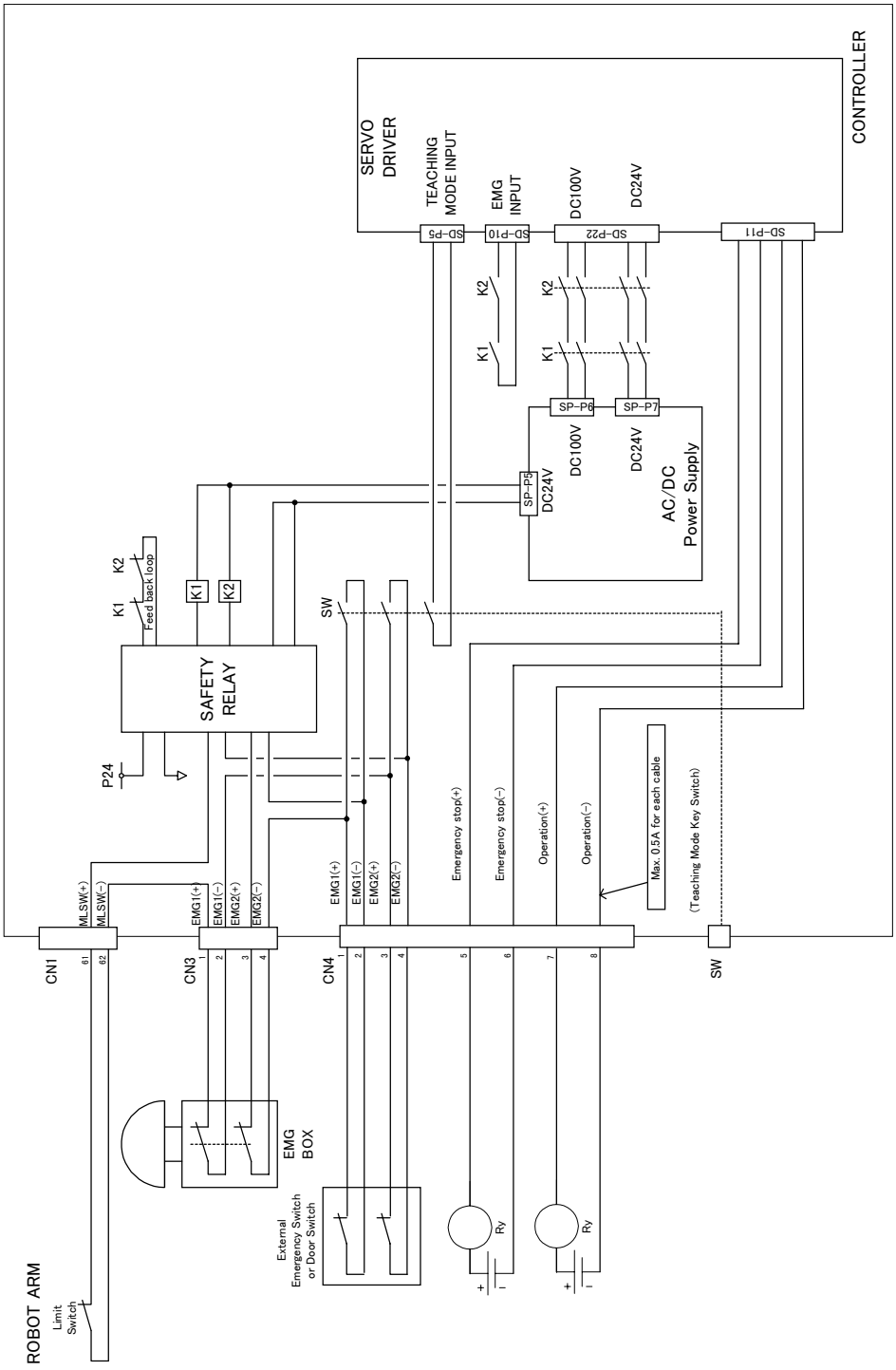
Arm-board cable (for drive)

No.	Signal Name	Use
1	S1-U	S1 Axis Motor Phase U
2	S1-V	S1 Axis Motor Phase V
3	S1-W	S1 Axis Motor Phase W
4	S2-U	S2 Axis Motor Phase U
5	S2-V	S2 Axis Motor Phase V
6	S2-W	S2 Axis Motor Phase W
7	N.C	
8	S3-U	S3 Axis Motor Phase U
9	S3-V	S3 Axis Motor Phase V
10	S3-W	S3 Axis Motor Phase W
11	E1-U	E1 Axis Motor Phase U
12	E1-V	E1 Axis Motor Phase V
13	E1-W	E1 Axis Motor Phase W
14	N.C	
15	E2-U	E2 Axis Motor Phase U
16	E2-V	E2 Axis Motor Phase V
17	E2-W	E2 Axis Motor Phase W
18	W1-U	W1 Axis Motor Phase U
19	W1-V	W1 Axis Motor Phase V
20	W1-W	W1 Axis Motor Phase W
21	N.C	
22	W2-U	W2 Axis Motor Phase U
23	W2-V	W2 Axis Motor Phase V
24	W2-W	W2 Axis Motor Phase W
25	N.C	
26	N.C	
27	N.C	
28	N.C	
29	S1 Brake	S1 Axis Brake
30	S2 Brake	S2 Axis Brake
31	S3 Brake	S3 Axis Brake
32	E1 Brake	E1 Axis Brake
33	E2 Brake	E2 Axis Brake
34	W1 Brake	W1 Axis Brake
35	W2 Brake	W2 Axis Brake
36	Brake Common	Brake Common
37	S1-LSW	S1 Axis Limit Switch
38	S3-LSW	S3 Axis Limit Switch
39	E2-LSW	E2 Axis Limit Switch
40	LSW-GND	Limit Switch Common (GND)
41	N.C	
42	N.C	
	FG	Frame Ground

4.4 Connection to External Units

(1) Connection by connector

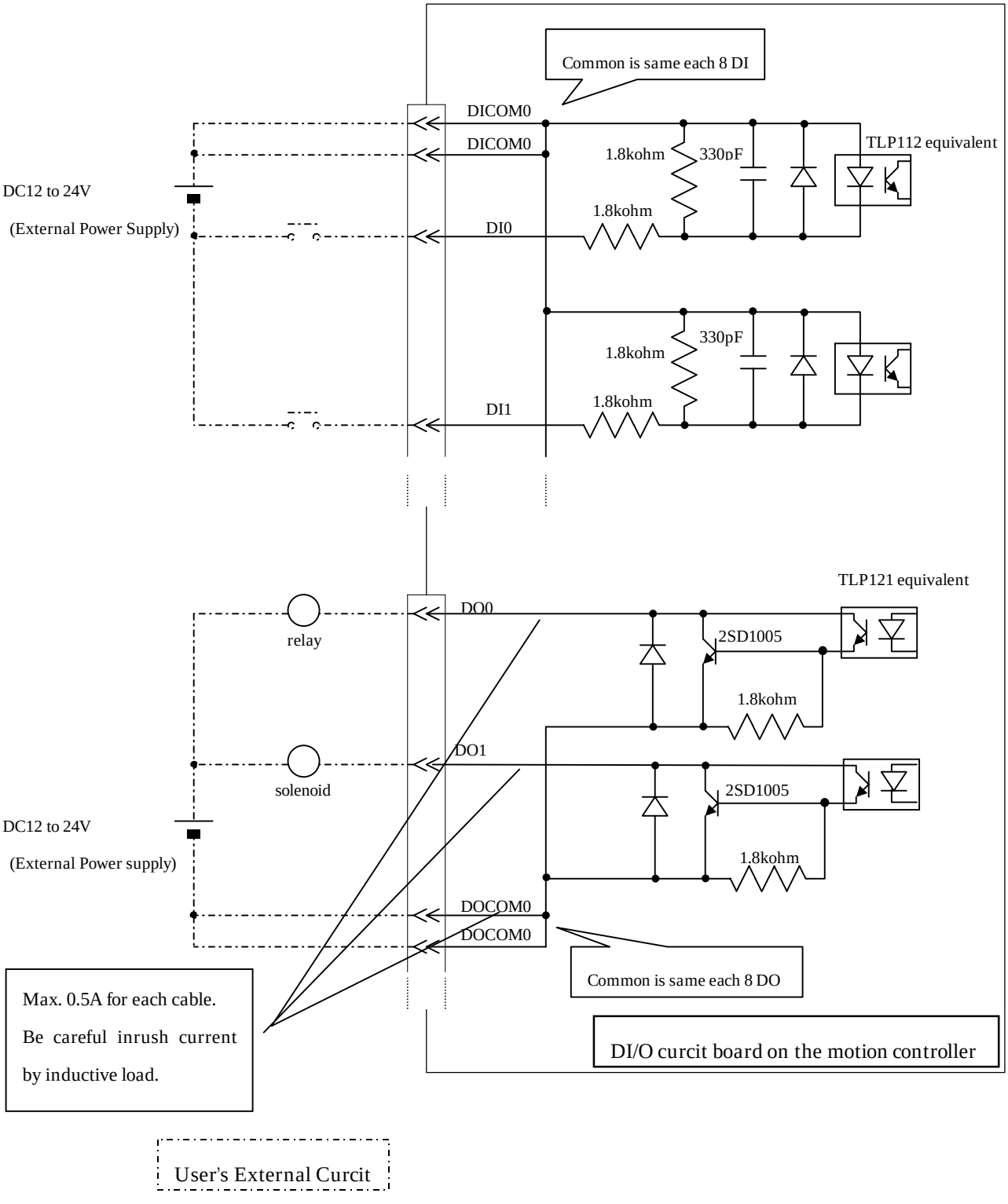
The connection to the emergency stop box will be described below as an example.



(2) Connection by DI/O Board

The following drawing shows an example of the connection to external units via DI/O board.

To operate the externally-connected units (relay, etc.) by the DI/O signal, it is necessary to supply from outside the power (from +12V to +24V) to the DI/O circuit board on the controller. Please prepare a power source in the side of externally-connected unit.



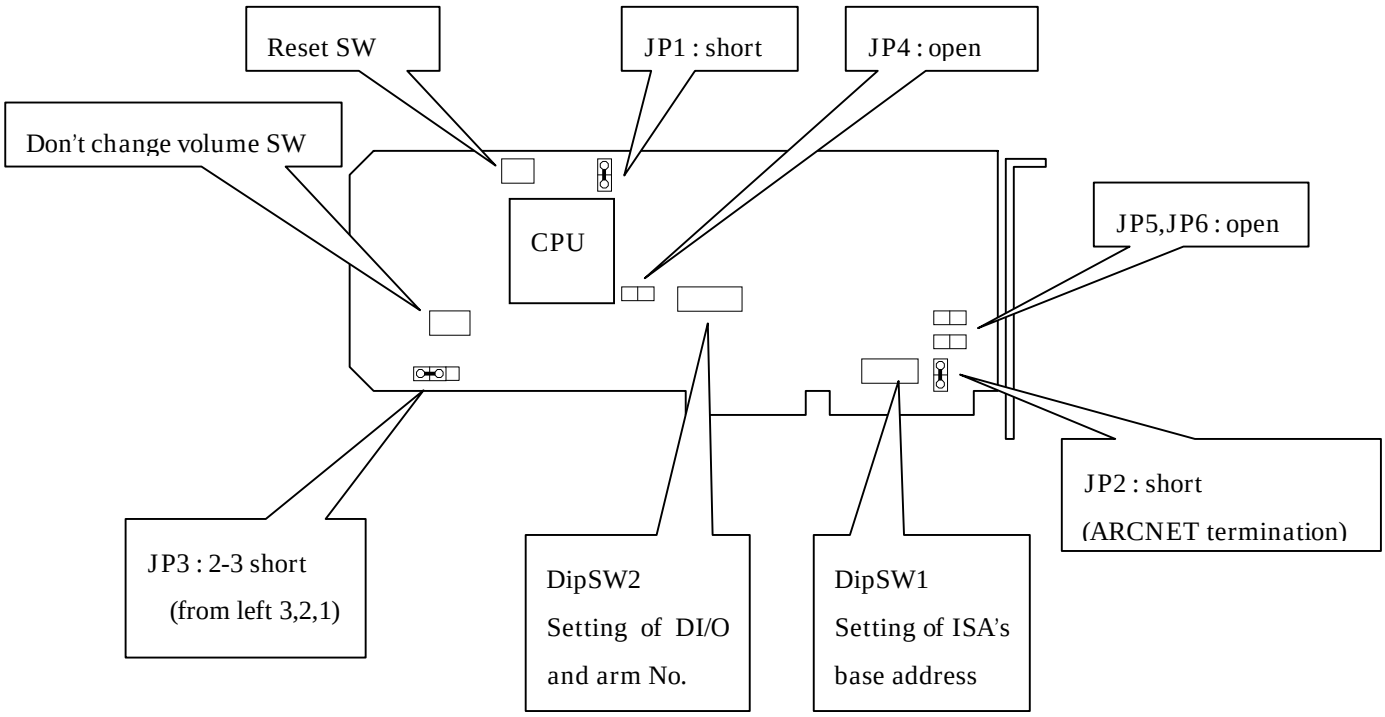
The connector pin assignment for external DI/O board is shown below:

	3rd level			External DI/O Connection Set (option)									
	Motion Controller Board			External DI/O connector panel			External DI/O cable						
	Signal name	Connector pin No.			Pin No.		Connector pin No.		Color of cable		Mark of cable	Connector pin No.	
Digital INPUT	DI0	Connector JAE: PS-40PE-D4LT1-B1	1	40 pin flat cable	Receptacle connector HONDA tsushin kogyo, Inc. : PCR-E96PMA	1	Socket connector HONDA tsushin kogyo, Inc. : PCR-E96PFA	1	96 pin AWG#28 twisted pair cable	Orange	Black point 1	Socket connector HONDA tsushin kogyo, Inc. : PCR-E96PFA	1
	DI1		2			2		2		Orange	Red point 1		2
	DI2		3			3		3		Gray	Black point 1		3
	DI3		4			4		4		Gray	Red point 1		4
	DI4		5			5		5		White	Black point 1		5
	DI5		6			6		6		White	Red point 1		6
	DI6		7			7		7		Yellow	Black point 1		7
	DI7		8			8		8		Yellow	Red point 1		8
	DICOM0		9			9		9		Pink	Black point 1		9
	DICOM0		10			10		10		Pink	Red point 1		10
	DI8		11			11		11		Orange	Black point 2		11
	DI9		12			12		12		Orange	Red point 2		12
	DI10		13			13		13		Gray	Black point 2		13
	DI11		14			14		14		Gray	Red point 2		14
	DI12		15			15		15		White	Black point 2		15
	DI13		16			16		16		White	Red point 2		16
	DI14		17			17		17		Yellow	Black point 2		17
	DI15		18			18		18		Yellow	Red point 2		18
	DICOM1		19			19		19		Pink	Black point 2		19
	DICOM1		20			20		20		Pink	Red point 2		20
	DI16		21			21		21		Orange	Black point 3		21
	DI17		22			22		22		Orange	Red point 3		22
	DI18		23			23		23		Gray	Black point 3		23
	DI19		24			24		24		Gray	Red point 3		24
	DI20		25			25		25		White	Black point 3		25
	DI21		26			26		26		White	Red point 3		26
	DI22		27			27		27		Yellow	Black point 3		27
	DI23		28			28		28		Yellow	Red point 3		28
	DICOM2		29			29		29		Pink	Black point 3		29
	DICOM2		30			30		30		Pink	Red point 3		30
	DI24		31			31		31		Orange	Black point 4		31
	DI25		32			32		32		Orange	Red point 4		32
	DI26		33			33		33		Gray	Black point 4		33
	DI27		34			34		34		Gray	Red point 4		34
	DI28		35			35		35		White	Black point 4		35
	DI29		36			36		36		White	Red point 4		36
	DI30		37			37		37		Yellow	Black point 4		37
	DI31		38			38		38		Yellow	Red point 4		38
	DICOM3		39			39		39		Pink	Black point 4		39
	DICOM4		40			40		40		Pink	Red point 4		40
	41-48(NC)					41-48		41-48		41-48 : straight connection			41-48
Digital OUTPUT	DO0	Connector JAE: PS-40PE-D4LT1-B1	1	40 pin flat cable	Receptacle connector HONDA tsushin kogyo, Inc. : PCR-E96PMA	49	Socket connector HONDA tsushin kogyo, Inc. : PCR-E96PFA	49	96 pin AWG#28 twisted pair cable	Pink	Black all	Socket connector HONDA tsushin kogyo, Inc. : PCR-E96PFA	49
	DO1		2			50		50		Pink	Red all		50
	DO2		3			51		51		Orange	Black long 1		51
	DO3		4			52		52		Orange	Red long 1		52
	DO4		5			53		53		Gray	Black long 1		53
	DO5		6			54		54		Gray	Red long 1		54
	DO6		7			55		55		White	Black long 1		55
	DO7		8			56		56		White	Red long 1		56
	DOCOM0		9			57		57		Yellow	Black long 1		57
	DOCOM0		10			58		58		Yellow	Red long 1		58
	DO8		11			59		59		Pink	Black long 1		59
	DO9		12			60		60		Pink	Red long 1		60
	DO10		13			61		61		Orange	Black long 2		61
	DO11		14			62		62		Orange	Red long 2		62
	DO12		15			63		63		Gray	Black long 2		63
	DO13		16			64		64		Gray	Red long 2		64
	DO14		17			65		65		White	Black long 2		65
	DO15		18			66		66		White	Red long 2		66
	DOCOM1		19			67		67		Yellow	Black long 2		67
	DOCOM1		20			68		68		Yellow	Red long 2		68
	DO16		21			69		69		Pink	Black long 2		69
	DO17		22			70		70		Pink	Red long 2		70
	DO18		23			71		71		Orange	Black long 3		71
	DO19		24			72		72		Orange	Red long 3		72
	DO20		25			73		73		Gray	Black long 3		73
	DO21		26			74		74		Gray	Red long 3		74
	DO22		27			75		75		White	Black long 3		75
	DO23		28			76		76		White	Red long 3		76
	DOCOM2		29			77		77		Yellow	Black long 3		77
	DOCOM2		30			78		78		Yellow	Red long 3		78
	DO24		31			79		79		Pink	Black long 3		79
	DO25		32			80		80		Pink	Red long 3		80
	DO26		33			81		81		Orange	Black long 4		81
	DO27		34			82		82		Orange	Red long 4		82
	DO28		35			83		83		Gray	Black long 4		83
	DO29		36			84		84		Gray	Red long 4		84
	DO30		37			85		85		White	Black long 4		85
	DO31		38			86		86		White	Red long 4		86
	DOCOM3		39			87		87		Yellow	Black long 4		87
	DOCOM3		40			88		88		Yellow	Red long 4		88
	89-96(NC)					89-96		89-96		89-96 : straight connection			89-96

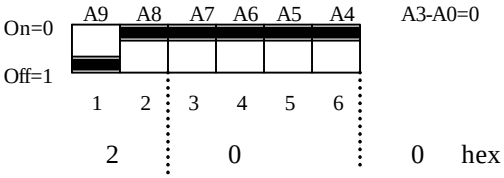
Chapter 5 How to Change Settings

5.1 Setting of Motion Control CPU Board

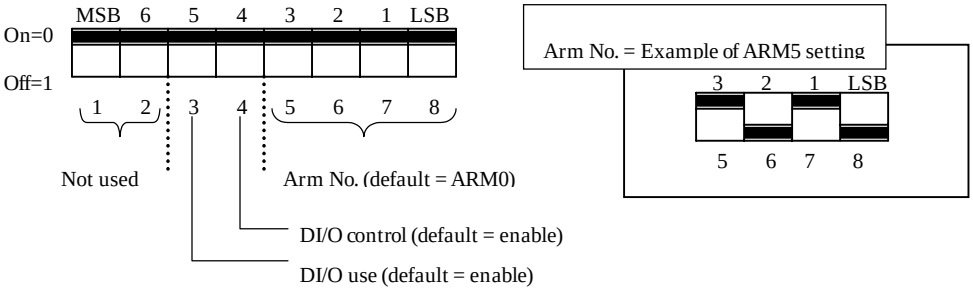
The setting of the motion control CPU board is shown as follows:



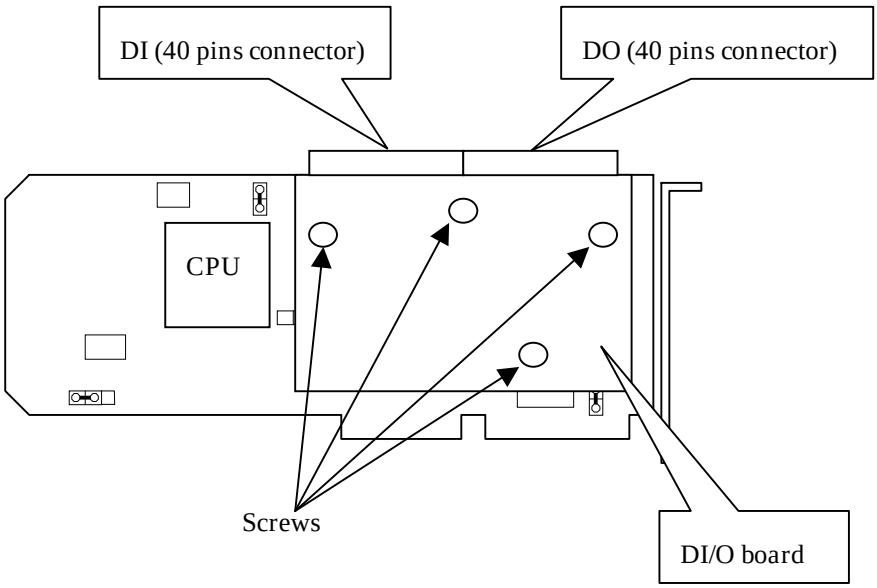
Setting of DipSW1---Setting of ISA's base address



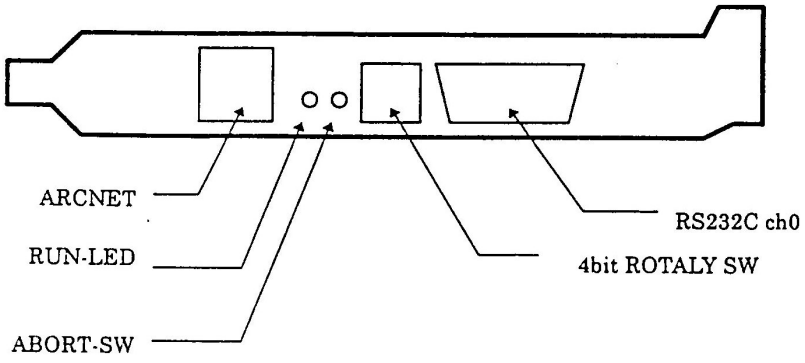
Setting of DipSW2



The following drawing shows the DI/O board as it is mounted. This can be removed by loosening 4 screws. External unit can be connected to the DI and DO connectors. By connecting the optional DI/O connect kit to the DI and DO connectors, the connectors can be taken out of the case, and connected to external units by shielded cable.



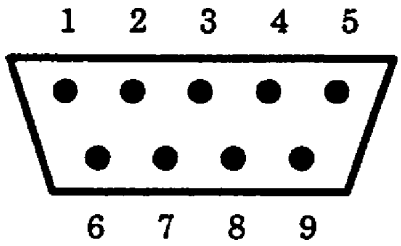
The panel unit of the motion control CPU board is shown below:



RS232C ch0 (D-sub 9 pin male)

No.	Signal name
1	Not used
2	RXD
3	TXD
4	DTR
5	GND
6	DSR
7	RTS
8	CTS
9	Not used

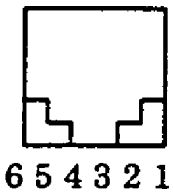
Front view



ARCNET (6 pin moduler)

No.	Signal name
1	Not used
2	Not used
3	PH-A
4	PH-B
5	Not used
6	Not used

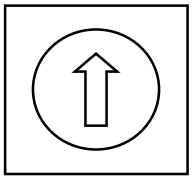
Front view



4bit ROTARY SW

No.	Requirements to start
0	Not used
1	Starts motion control program.
2	Not used
3	Not used
4	Not used
5	Not used
6	Not used
7	Not used
8	Not used
9	Not used
A	Not used
B	Not used
C	Not used
D	Not used
E	Not used
F	Starts motion control program, and outputs the value of each monitor axis.

Front view

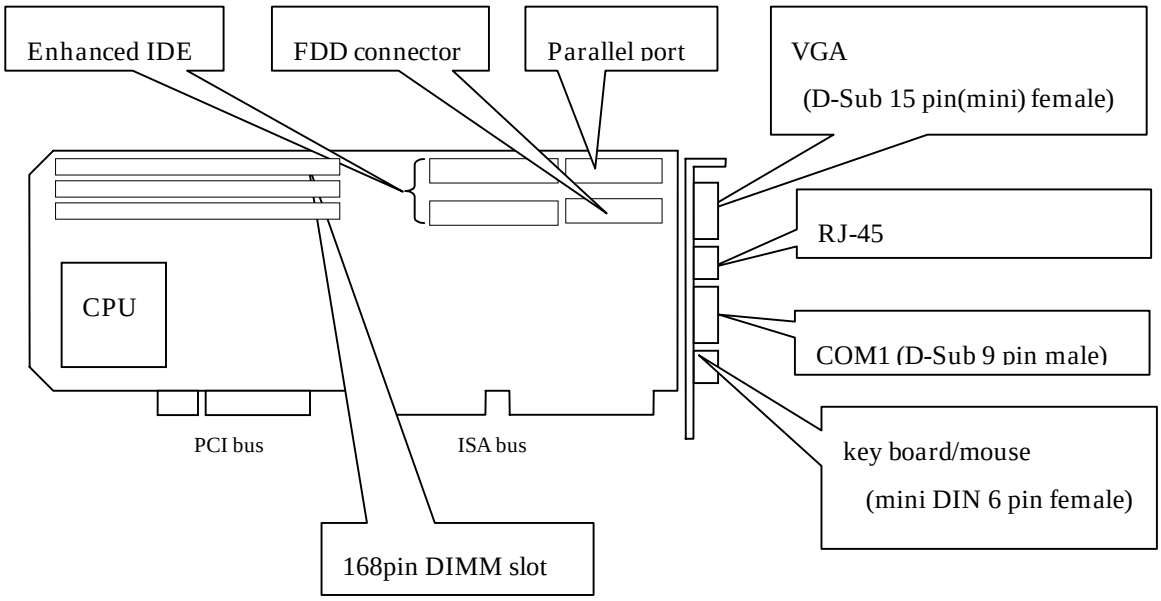


ROTARY SW is used to select the starting conditions for motion control program. Set this to “1” or “F”.

5.2 Setting of Operation Control CPU Board

Establish connections by referring to the following drawing:

Operation control CPU board



Chapter 6 Maintenance & Inspection Manual

Introduction

Thank-you very much for patronage of the PA-10 Portable General Purpose Intelligent Arm.

The PA-10 is a precision device, so to keep it in good working order, regular maintenance and inspection are necessary. This document, the "Maintenance and Inspection Manual", is a compilation of matters to note about maintenance and inspection. For peace of mind and safety please study this document carefully before using the PA-10.

6.1 General

(1) Inspection Frequency

There are two types of maintenance and inspection work; "Daily Inspection" carried out by user, and "Periodic Inspection" which must be carried out by MHI since arm disassembly is required.

The "Daily Inspection" should be carried out at the beginning of each day before the robot is used.

The "Periodic Inspection" interval is set as written below. If using the MHI controller, the accumulated operating time is indicated by the "time counter" inside the controller box. If using a controller of your own design, please ensure that a record of accumulated operating time is kept. If by any chance trouble should occur and a record of the accumulated operating time is not available, the guarantee will become invalid.

Especially if considering application in severe conditions (if payload duty is large, or if used in bad environment, powder dust, etc) it is recommended to shorten the interval between periodic inspections being carried out.

Periodic inspection interval:

(a) 1000 hours or 1 year, which ever is shortest.
(b) Every 1000 hours, after first inspection.

Periodic inspection is necessary even within the guarantee period (1 year from delivery of goods, or 3000 hours of use, which ever comes first). If the PA-10 is used without periodic inspection, the guarantee will become invalid.

(2) Other Matters to Note

(a) In compliance with labor health and safety regulations as well as related notices, maintenance and inspection work must be carried out according to a set schedule, in a set procedure, by appropriately qualified workers. Please read carefully and observe the related rules, etc, which appear in the "Safety Manual".

(b) Please leave all maintenance and inspection work requiring disassembly to MHI. Please note that trouble resulting from disassembly work not authorized by MHI is exempt from the guarantee, even if occuring within the guarantee period.

(c) During daily inspections if abnormality is recognized, please stop using immediately, and consult MHI.

(d) Please note that "Periodic Inspection" is at customers expense, and that the guarantee period can not be extended.

6.2 Daily Inspection

When using PA-10, before starting work every day, please inspect the following items. While carrying out in-operation inspection, please ensure that all personnel remain outside the manipulator motion limits.

Inspection Items	Date & time	Inspector
Manipulator		
-Manipulator remains in the same position as in the last use.		Good / Not good
-Screws not loose		Good / Not good
-No abnormal noise, smell or vibration detected during operation		Good / Not good
-When emergency stop button is pressed, manipulator motion is stopped, and when button is released, the motion does not resume.		Good / Not good
Cables		
-Not damaged		Good / Not good
-No abnormal generation of heat at connections		Good / Not good
-Connectors not loose		Good / Not good
Controller		
-Connectors not loose		Good / Not good
-Supply voltage is as specified, and earth connection (type 3) connected.		Good / Not good
-Floppy disk drive cleaned regularly		Good / Not good
-System works normally when power is switched ON.		Good / Not good
-When emergency stop button is pressed, manipulator stops, and when the button is released, the motion does not resume.		Good / Not good
-Cooling fans work.		Good / Not good
-No abnormal noise, smell, etc. detected during operation		Good / Not good
Peripheral Equipment		
-No abnormality detected with interlocks between safety equipment and PA-10		Good / Not good
-No abnormality detected with safety barrier or other safety related devices		Good / Not good
** Anything else that should be considered **		

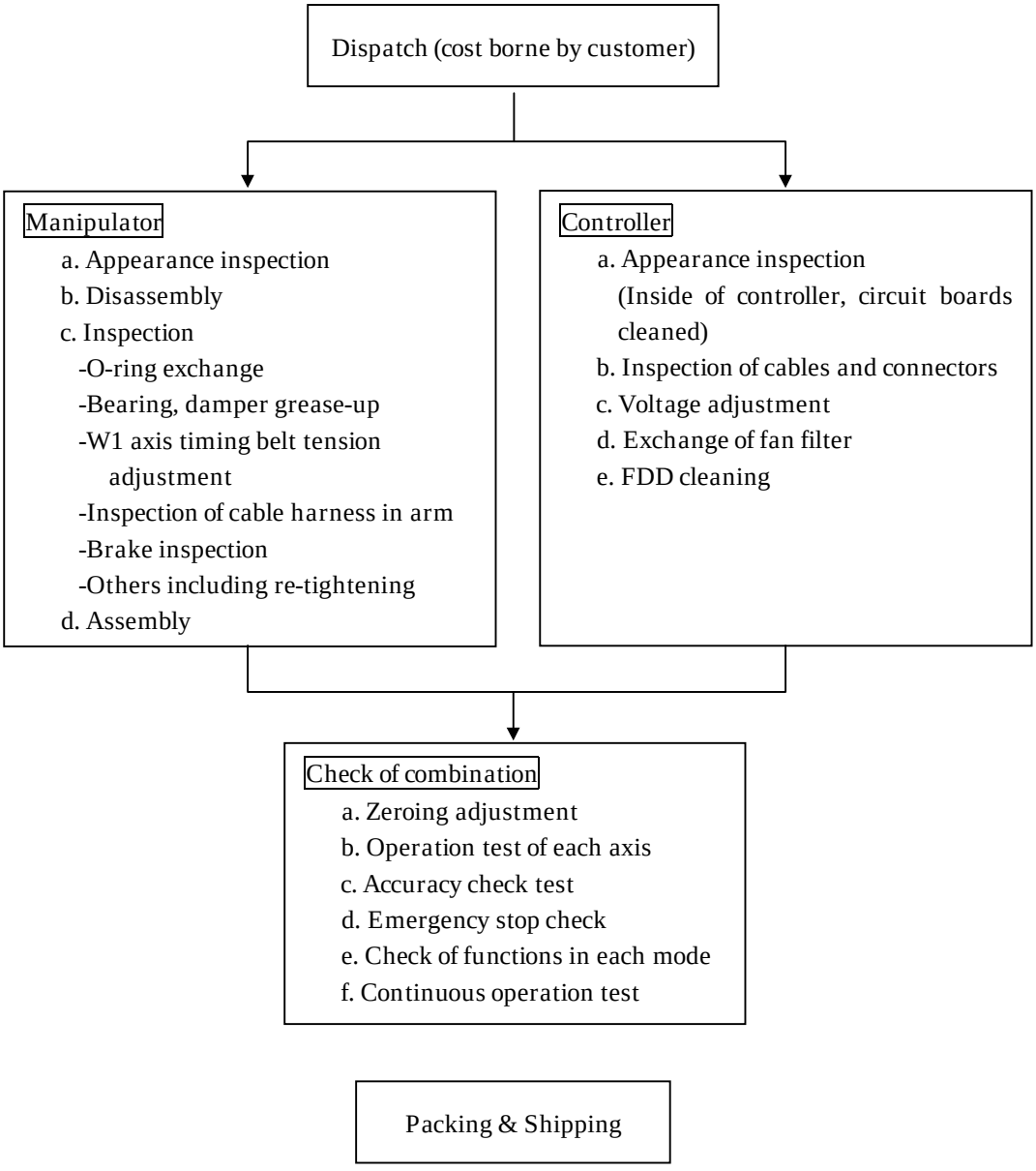
6.3 Periodic Inspection

Periodic inspection involves disassembly, and is to be carried out at MHI's factory.

Periodic inspection fee includes; the inspection fee (including fee for exchange of consumable goods*[1]), packing fee, and return fee.

Expense for dispatch to MHI's factory should be borne by customer. The periodic inspection items are as shown below. Standard time for the complete process is one (1) week (However, time for transportation is excluded. If exchange of component is required, it may take more time).

If it is necessary to exchange any component other than consumables as a result of inspection, MHI will contact the customer each time, and get approval before carrying out the work. Component exchange within the guarantee period will not be charged. However, fees will be charged, even within the guarantee period, if goods are deemed to have been handled inadvertently, or used by customer in any way other than specified *[2].



*1: Consumable parts & O-ring:

Grease for gear, bearing and O-ring

W1 axis timing belt

Controller fan filter

*2: Damages and failure caused by external reasons such as natural disasters including earthquake, storm and flood, or fire and abnormal voltage.

Failure due to misuse

Failure due to other devices then connected

Damages/failure caused during transfer/transportation

Failure as a result of repair/modification carried out in a place other than MHI

Others similar to the above items

Chapter 7 Before Purchasing Product

Before purchasing the product, please consider the followings:

7.1 Delivery Term

Delivery term is 3 months from accepting order.

Such term will get longer or shorter according to the options taken or the conditions of production. Please consult MHI in advance.

7.2 Delivery

F.O.B

Please note that any other requirement for delivery (set-up, adjustment, dispatch of instructors, etc.) will be charged.

7.3 Acceptance

The delivery of the product shall be regarded as acceptance of products.

If delivery test records are required in delivery, consult MHI. Unless requested additionally, such document will not be attached.

7.4 Guarantee

(1) Period of Guarantee

The period of guarantee shall be one (1) year from delivery of arm (main body), or 3000 hours of use whichever comes first. The period of guarantee for the products exchanged or repaired shall be the rest of the initial guarantee period, or 30 days from delivery of exchanged/repaired product whichever comes later.

(2) Scope of Guarantee

Any nonconformance of portable general purpose intelligent arm, caused by any fault of MHI during the period of guarantee, will be corrected free of charge. The substitute product(s) leased during such repair work will be charged.

Please note there may be no substitute products available according to the case.

Repair of any fault detected after expiration of guarantee shall be charged. Also note that the repair of the troubles shown below, and consumables will be charged, even within the guarantee period, if goods are deemed to have been handled inadvertently, or used by customer in any way other than specified:

- -Damages and failure caused by external reasons such as natural disasters including earthquake, storm and flood, or fire and abnormal voltage.
- -Failure due to mis-use
- -Failure due to other devices then connected
- -Damages/failure caused by shock from transfer/transportation/drop
- -Failure as a result of repair/modification carried out in a place other than MHI

(3) Contents of Guarantee

In discretion of MHI, the guarantee will be performed in either the repair, exchange or refund for portable general purpose intelligent arm.

In any case, MHI will be responsible for up to the amount actually paid by the customer.

7.5 Maintenance Contract

To operate this portable general purpose intelligent arm comfortably, customer is requested to conclude a maintenance contract. Maintenance contract is effective for one (1) year.

(1) Contents of Maintenance Contract

-Superiority Services

If any unexpected fault occurs, the product will be repaired and dispatched within 1 week from acceptance at the factory. Therefore, downtime will be minimized. Of course, the repair of any fault attributable to MHI within the period of guarantee will not be charged.

-Half-charge Service for Initial Periodic Inspection

If maintenance contract is concluded by the time the arm is purchased, the customer can have its arm checked in the periodic inspection for the first year at half cost (normal: 600,000 yen) when such contract is updated after 1 year of use.

-Free Technical Consulting

Concerning the operation of the machine, questions will be answered by telephone and facsimile. However, any question concerning the programming techniques (use of PA library, use of internal variables, etc.) for preparing application programs will be charged.

-Free Version-up of Software

In time for version-up of the purchased software, updated versions will be provided free of charge. (Change of hardware will be charged separately for actual costs.)

(2) Instruction for Maintenance Contract

-This contract relates to arm, and is not applied to the maintenance of applications (excluding version-ups).

You can choose to contract, or not contract. If however, such contract is concluded by the time the arm is purchased, chores of proceedings are settled at a time. You are then eligible for the half-charge service mentioned above for periodic inspection. This is a more convenient, and costsaving way.

7.6 Operating Conditions for Programs Supplied by Other Companies

Programs Supplied by Other Companies shall be approved for use by the suppliers directly. Therefore, customer will not be guaranteed by MHI for such things, and MHI will not be responsible for anything about them. The customer is requested to use these programs according to the conditions provided by the suppliers.

Programs Supplied by Other Companies include the followings:

-Blue Water Systems WinRT™

-Microsoft® Visual C++®

-Microsoft ® Visual Basic®

7.7 Contact Address

For anything about Portable General Purpose Intelligent Arm, please contact the following address. Also please feel free to contact the same way for a system configuration using the arm.

100-8315
5-1, Marunouchi 2-chome, Chiyoda-ku, Tokyo 100-8315, JAPAN
Mitsubishi Heavy Industries, Ltd. Laser & Electronics Team. General Machinery Dept. Machinery Headquarters.
TEL: +81-3-3212-9675
FAX: +81-3-3212-9859

Also by way of the home page (http://www.robot-arm.com/), programs using applications and PA library are introduced, and a free download service for sample programs and arm CAD data is available. Please feel free to access the home page.

-Visual Basic and Visual C++ are the registered trade marks of U.S. Microsoft Corporation.
-WinRT is the trade mark of Blue Water Systems, Inc.
-The company names and trade names shown in this document are the trade marks or registered trade marks of the companies.

The specifications shown in this document may be subject to changes for improvement without prior notice.